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INPUT-OUTPUT MANUALS FOR LINEAR DYNAMIC PROGRAMS FOR COMPLIANT RISERS

by

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ABSTRACT

The objective of this report is to present input-output manuals, sample runs and outputs of programs RCNATOUT, RCLINDYN, RCNATIN, RCLINDY1, RCFORC1, RCLINDY3, RCFORCE, RCLINDY2, ORTHOG and ORTHOG1 which are used in the

- o estimation of the out-of-plane natural frequencies and corresponding mode numbers
- o solution of the out-of-plane linear dynamic eigenproblem
- o estimation of the in-plane natural frequencies and corresponding mode numbers
- o solution of the in-plane linear dynamic eigenproblem
- o solution of the out-of-plane linear dynamic problem for a given frequency and amplitude of excitation at the top
- o alternate solution of the out-of-plane linear dynamic eigenproblem
- o solution of the in-plane linear dynamic problem for a given frequency and amplitude of excitation at the top
- o alternate solution of the in-plane linear dynamic eigenproblem
- o evaluation of the orthogonality condition of out-of-plane natural modes, and
- o evaluation of the orthogonality condition of in-plane natural modes

of a compliant riser with a planar static configuration without torsion, respectively.

The initial approximations and the theory implemented in these programs can be found in M.I.T. Sea Grant Report 85-19.

ACKNOWLEDGMENTS

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RELATED SEA GRANT AND DESIGN LABORATORY REPORTS

1. A Mathematical Model for Compliant Risers, by N. M. Patrikalakis and C. Chryssostomidis, MIT Sea Grant Report, No. 85-17, 1985.
2. Non-Linear Statics of Non-Rotationally Uniform Rods with Torsion, by N. M. Patrikalakis and C. Chryssostomidis, MIT Sea Grant Report, No. 85-18, 1985.
3. Input-Output Manuals for Non-Linear 2-D and 3-D Static Programs for Compliant Risers, by N. M. Patrikalakis and C. Chryssostomidis, MIT Design Laboratory Report, No. 85-1, September, 1985.
4. Linear Dynamics of Compliant Risers, by N. M. Patrikalakis and C. Chryssostomidis, MIT Sea Grant Report, No. 85-19, 1985.

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Chapter I

INTRODUCTION

The programs presented in this report solve the three-dimensional linear dynamic problem of a compliant riser with a planar static configuration without torsion. The sequence of steps the prospective user is supposed to follow are described next.

- Initially the user should use program RCINPUT for the preparation of geometrical, structural and hydrodynamic characteristics of compliant risers. This program is described in [3].
- Next the 2-D static compliant riser problem should be solved for the required excitation. Program RCSTAT2D is used for this step, as described in [3].
- Next it is suggested that the user employs programs RCNATOUT and RCNATIN to obtain an estimate of the natural frequencies and mode numbers for out-of-plane and in-plane motion of a compliant riser with a planar static configuration without torsion. The above step is not appropriate in a case of zero current velocity since the asymptotic theory used in RCNATOUT and RCNATIN is no longer valid [4]. This special case is treated below.
- Using the natural frequency estimates, the out-of-plane linear dynamic eigenproblem is solved using RCLINDYN and the in-plane linear dynamic eigenproblem is solved using RCLINDYI.
- For the case of zero current velocity the out-of-plane linear dynamic problem is solved as follows:

The program RCFORC1 is used to obtain the out-of-plane linear forced dynamic response for a certain frequency and amplitude of excitation at the top without damping. The output from this program is then used as an input to program RCLINDY3, which solves the out-of-plane linear dynamic eigenproblem. The above method for zero current can be also used for arbitrary currents.

o For the case of zero current velocity the in-plane linear dynamic problem is solved as follows:

The program RCFORCE is used to obtain the in-plane linear forced dynamic response for a certain frequency and amplitude of excitation at the top without damping. The output from this program is then used as an input to program RCLINDY2, which solves the in-plane linear dynamic eigenproblem. The above method for zero current can be also used for arbitrary currents.

o Finally, Programs ORTHOG and ORTHOG1 can be used to evaluate the orthogonality of out-of-plane and in-plane natural modes. This provides a check of the accuracy of numerical results.

A flowchart of the above procedures can be found in Table 1 below.

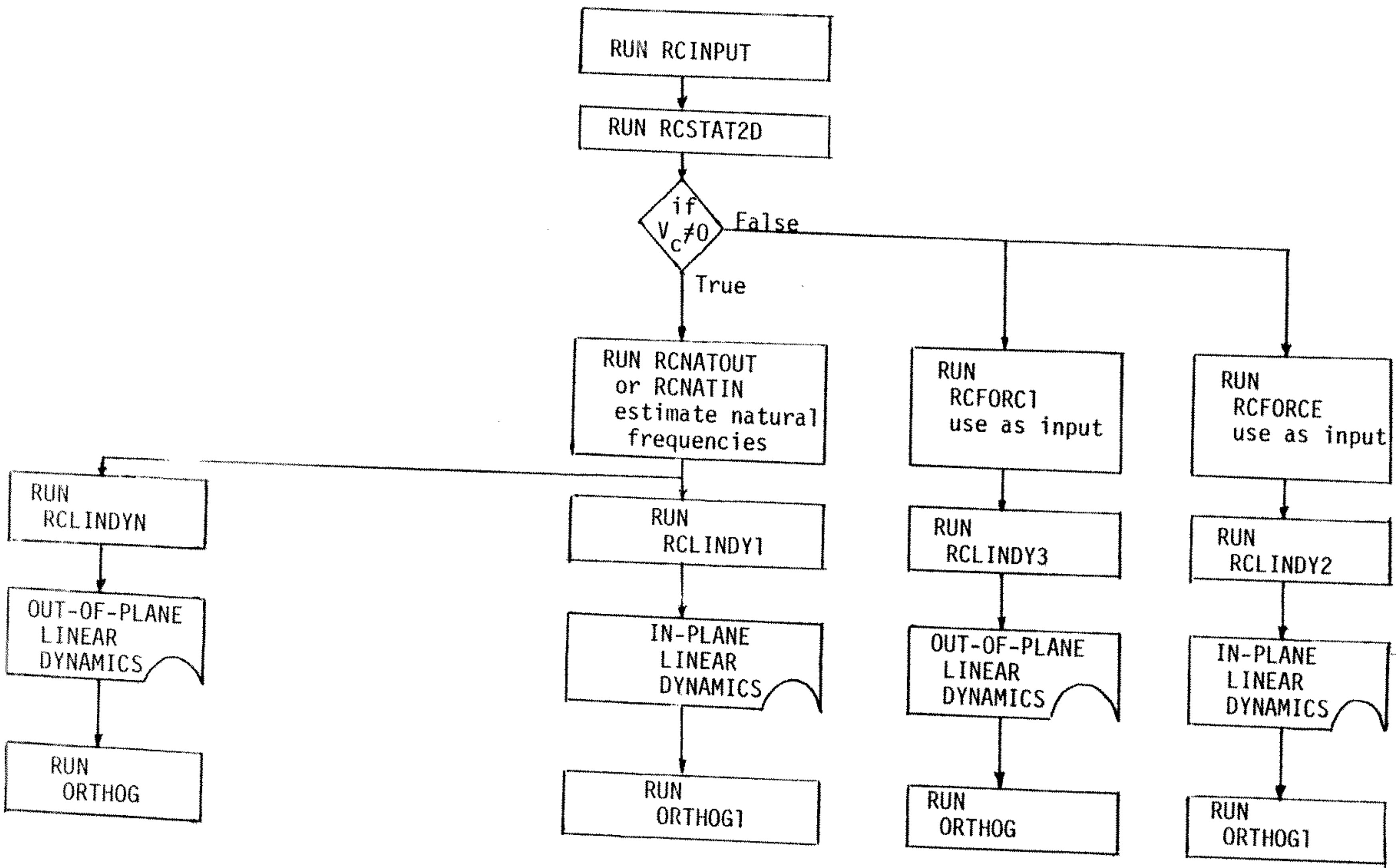

Table 1. Flowchart for the Solution of the Three-dimensional Linear Eigenproblem of a Compliant Riser with a Planar Static Configuration

Chapter II

II.1 Input-Output Manual for Out-of-Plane Natural Frequency and Mode Number Estimation Program, RCNATOUT

This program is written in FORTRAN 77 and allows the interactive estimation of the out-of-plane natural frequencies and the corresponding mode numbers of compliant risers using an asymptotic method described in [4].

Before executing the program the user must make sure that

- o Devices five and six correspond to input/output from the terminal.
- o Device eight must be associated with the data file containing geometric, structural and hydrodynamic characteristics of the compliant riser created by a previous execution of the data preprocessing program RCINPUT. This file has a logical record length of 80 characters.
- o Device ten must be associated with the input data file containing the non-dimensional static planar solution created by RCSTAT2D. This file has a logical record length of 132 characters.
- o Device eleven must be associated with an output file with logical record length of 80 characters. This file contains the converged natural frequencies and mode numbers as well as the characteristic equation values at a series of frequency points. These natural frequency estimates can be used as inputs for a run of RCLINDYN.

<u>Input Variables</u> [Free Format]

At the beginning of the program the static 2-D solution created from RCSTAT2D is read from device ten. The user is informed about the mean current velocity in the x direction and the maximum non-dimensional static effective tension. If the number of static division points is less than four or greater than the value of MNP (Maximum Number of Allowable Points) the program halts execution. If the mean velocity is zero, the program halts execution because the asymptotic theory is no longer valid.

Then the geometric, structural and hydrodynamic characteristics of the compliant riser are read from the file associated with device eight. The user has the opportunity to review this data on his terminal and decide either to continue with the program or stop (see [3]).

The user is then asked to input the upper limit of the frequency range and frequency spacing (in rad/s) for which he wishes to evaluate the characteristic equation for the eigenfrequencies. The default lower limit of the frequency range is 0.01 rad/s. The maximum permissible number of frequency points is also displayed. The frequency spacing should be such, so that the frequency points are less than the maximum allowable points. Then the user is asked if he wants to change the value of

$$\nu = (EI^{\eta\eta}(0)/TL^2)^{1/2}$$

(for definition of variables see [4]) to be used to determine the approximate natural frequencies for the out-of-plane problem. If he decides to change ν, he is asked the new value for ν.

Next the program evaluates the characteristic equation at all points in the frequency range. Then the natural frequencies in the specified range are determined. This is done by checking the change of sign in the characteristic equation. Finally, the program prints the following results in the file connected with device 11:

- o Number of natural frequencies in the specified frequency range.
- o Mode number and corresponding natural frequency estimate.
- o Two columns of real numbers, the first of which is the frequency (in rad/s) and the second, the corresponding value of the characteristic determinant at this frequency.

II.2 Sample Run, Input and Output

II.2.1 Linear Current Excitation

II.2.1.1 Interactive Session

INPUT

Device 5 = TERMINAL

Device 8 = RCJOA01 DATA A

Device 10 = RCCL2DRR DATA A

OUTPUT

Device 6 = TERMINAL

Device 11 = FREQOUT DATA A

```
R; T=0.01/0.01 20:53:35
rcnatout rcjoao1 rccl2drr freqout
FI 8 DISK RCJOA01 DATA A ( RECFM FB LRECL 80 BLKSIZE 800
FI 10 DISK RCCL2DRR DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 11 DISK FREQOUT DATA A ( RECFM F LRECL 80
GLOBAL TXTLIB VFORTLIB CMSLIB NAG1 NAG2
LOAD RCNATOUT ( START
EXECUTION BEGINS...
MNP=151
2-D STATIC SOLUTION FROM DEVICE 10
NP = 76
MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =0.129000D+01
2-D STATIC SOLUTION SUCCESFULLY READ
MAXIMUM STATIC EFFECTIVE TENSION/WA*L = 0.3089D+02

INPUT
THE MAXIMUM FREQUENCY AND FREQUENCY SPACING (IN RAD/S)
FOR WHICH YOU WISH TO EVALUATE THE FREQUENCY FUNCTION
MAXIMUM PERMISSIBLE NUMBER OF FREQUENCY POINTS IS = 300
?
2.,.01
THE VALUE OF NU TO BE USED IS = 0.1979D-01
IF YOU WANT TO CHANGE NU INPUT 1
?
2
R; T=0.47/0.60 20:54:14
cp spool console stop close
```

II.2.1.2 RCJOA01 DATA A

```
CHINESE LANTERN FROM JOAO,   APRIL 1985
  9 0.883920D+02 0.292000D+01
0.820000D+03 0.115434D-01 0.000000D+00 0.345000D+07
0.250000D+01 0.499300D+02 0.404700D+02 0.824400D+02 0.292000D+01
0.310000D+00 0.930000D+00 0.267000D+09 0.660000D+04 0.237400D-01 -.330000D+03
0.250000D+01 0.499300D+02 0.404700D+02 0.824400D+02 0.292000D+01
0.310000D+00 0.930000D+00 0.267000D+09 0.577500D+04 0.237400D-01 -.330000D+03
0.250000D+01 0.499300D+02 0.404700D+02 0.824400D+02 0.292000D+01
0.310000D+00 0.930000D+00 0.267000D+09 0.495000D+04 0.237400D-01 -.330000D+03
0.250000D+01 0.499300D+02 0.404700D+02 0.824400D+02 0.292000D+01
0.310000D+00 0.930000D+00 0.267000D+09 0.412500D+04 0.237400D-01 -.330000D+03
0.683920D+02 0.499300D+02 0.404700D+02 0.824400D+02 0.292000D+01
0.310000D+00 0.930000D+00 0.267000D+09 0.330000D+04 0.237400D-01 0.000000D+00
0.250000D+01 0.499300D+02 0.404700D+02 0.824400D+02 0.292000D+01
0.310000D+00 0.930000D+00 0.267000D+09 0.412500D+04 0.237400D-01 0.330000D+03
0.250000D+01 0.499300D+02 0.404700D+02 0.824400D+02 0.292000D+01
0.310000D+00 0.930000D+00 0.267000D+09 0.495000D+04 0.237400D-01 0.330000D+03
0.250000D+01 0.499300D+02 0.404700D+02 0.824400D+02 0.292000D+01
0.310000D+00 0.930000D+00 0.267000D+09 0.577500D+04 0.237400D-01 0.330000D+03
0.250000D+01 0.499300D+02 0.404700D+02 0.824400D+02 0.292000D+01
0.310000D+00 0.930000D+00 0.267000D+09 0.660000D+04 0.237400D-01 0.330000D+03
0.503200D+02 0.200000D+00 0.244000D+05 -.122000D+04 0.116400D+07 -.582000D+05
0.000000D+00 0.493200D+00 0.780600D-01
0.503200D+02 0.200000D+00 0.213500D+05 -.122000D+04 0.101850D+07 -.582000D+05
0.000000D+00 0.493200D+00 0.780600D-01
0.503200D+02 0.200000D+00 0.183000D+05 -.122000D+04 0.873000D+06 -.582000D+05
0.000000D+00 0.493200D+00 0.780600D-01
0.503200D+02 0.200000D+00 0.152500D+05 -.122000D+04 0.727500D+06 -.582000D+05
0.000000D+00 0.493200D+00 0.780600D-01
0.503200D+02 0.200000D+00 0.122000D+05 0.000000D+00 0.582000D+06 0.000000D+00
0.000000D+00 0.493200D+00 0.780600D-01
0.503200D+02 0.200000D+00 0.152500D+05 0.122000D+04 0.727500D+06 0.582000D+05
0.000000D+00 0.493200D+00 0.780600D-01
0.503200D+02 0.200000D+00 0.183000D+05 0.122000D+04 0.873000D+06 0.582000D+05
0.000000D+00 0.493200D+00 0.780600D-01
0.503200D+02 0.200000D+00 0.213500D+05 0.122000D+04 0.101850D+07 0.582000D+05
0.000000D+00 0.493200D+00 0.780600D-01
0.503200D+02 0.200000D+00 0.244000D+05 0.122000D+04 0.116400D+07 0.582000D+05
0.000000D+00 0.493200D+00 0.780600D-01
```

II.2.1.3 RCCL2DRR DATA A

76 0.129000D+01

0.000000D+00	0.170039D+02	-.238894D+02	-.831943D+02	0.157080D+01	0.000000D+00	0.000000D+00	0.000000D+00	0.129964D+03	0.103000D+01
0.986636D-03	0.188299D+02	-.224204D+02	-.765616D+02	0.149202D+01	0.393819D-04	0.985601D-03	0.170885D-07	0.131839D+03	0.103062D+01
0.246464D-02	0.210989D+02	-.202124D+02	-.674058D+02	0.138574D+01	0.235331D-03	0.244990D-02	0.456129D-07	0.134181D+03	0.103154D+01
0.394265D-02	0.228898D+02	-.180743D+02	-.591772D+02	0.129231D+01	0.576161D-03	0.388758D-02	0.770377D-07	0.136044D+03	0.103244D+01
0.558056D-02	0.244206D+02	-.158539D+02	-.510930D+02	0.120214D+01	0.109848D-02	0.543945D-02	0.114492D-06	0.137652D+03	0.103342D+01
0.721847D-02	0.255745D+02	-.138280D+02	-.440177D+02	0.112438D+01	0.174897D-02	0.694227D-02	0.154072D-06	0.138881D+03	0.103436D+01
0.885637D-02	0.264380D+02	-.120108D+02	-.378565D+02	0.105745D+01	0.250625D-02	0.839433D-02	0.195248D-06	0.139817D+03	0.103527D+01
0.111404D-01	0.272851D+02	-.981897D+01	-.306058D+02	0.979541D+00	0.370698D-02	0.103367D-01	0.254557D-06	0.140761D+03	0.103650D+01
0.134244D-01	0.278406D+02	-.799468D+01	-.246880D+02	0.916627D+00	0.504106D-02	0.121903D-01	0.315413D-06	0.141409D+03	0.103766D+01
0.157084D-01	0.282016D+02	-.649122D+01	-.198747D+02	0.865928D+00	0.647792D-02	0.139655D-01	0.377282D-06	0.141859D+03	0.103878D+01
0.178993D-01	0.284264D+02	-.530522D+01	-.161128D+02	0.826647D+00	0.793103D-02	0.156050D-01	0.437246D-06	0.142166D+03	0.103981D+01
0.200901D-01	0.285721D+02	-.432907D+01	-.130396D+02	0.794827D+00	0.944131D-02	0.171920D-01	0.497603D-06	0.142391D+03	0.104080D+01
0.222809D-01	0.286649D+02	-.352706D+01	-.105327D+02	0.769100D+00	0.109965D-01	0.187352D-01	0.558212D-06	0.142561D+03	0.104177D+01
0.244717D-01	0.287225D+02	-.286846D+01	-.849115D+01	0.748339D+00	0.125870D-01	0.202419D-01	0.618981D-06	0.142694D+03	0.104272D+01
0.280184D-01	0.287699D+02	-.204078D+01	-.597489D+01	0.722927D+00	0.152183D-01	0.226199D-01	0.717538D-06	0.142860D+03	0.104421D+01
0.315651D-01	0.287848D+02	-.143952D+01	-.407588D+01	0.705264D+00	0.178999D-01	0.249412D-01	0.816201D-06	0.142991D+03	0.104567D+01
0.351118D-01	0.287829D+02	-.101126D+01	-.261797D+01	0.693520D+00	0.206150D-01	0.272233D-01	0.914887D-06	0.143103D+03	0.104711D+01
0.413491D-01	0.287618D+02	-.543656D+00	-.103372D+01	0.682654D+00	0.254366D-01	0.311804D-01	0.108837D-05	0.143279D+03	0.104959D+01
0.475865D-01	0.287331D+02	-.290851D+00	-.173341D+00	0.679189D+00	0.302851D-01	0.351046D-01	0.126171D-05	0.143447D+03	0.105206D+01
0.547166D-01	0.286983D+02	-.139066D+00	0.341387D+00	0.680014D+00	0.358327D-01	0.395840D-01	0.145963D-05	0.143636D+03	0.105487D+01
0.618467D-01	0.286633D+02	-.624267D-01	0.611680D+00	0.683525D+00	0.413699D-01	0.440763D-01	0.165731D-05	0.143825D+03	0.105770D+01
0.778360D-01	0.285857D+02	-.512844D-02	0.864156D+00	0.695791D+00	0.537091D-01	0.542456D-01	0.209975D-05	0.144255D+03	0.106409D+01
0.954915D-01	0.285016D+02	0.188175D-02	0.961707D+00	0.712081D+00	0.671701D-01	0.656704D-01	0.258692D-05	0.144742D+03	0.107126D+01
0.114743D+00	0.284120D+02	-.284039D-02	0.103436D+01	0.731328D+00	0.816236D-01	0.783880D-01	0.311651D-05	0.145287D+03	0.107926D+01
0.135516D+00	0.283178D+02	-.625201D-02	0.108843D+01	0.753368D+00	0.969321D-01	0.924290D-01	0.368608D-05	0.145895D+03	0.108808D+01
0.157726D+00	0.282205D+02	-.592275D-02	0.117302D+01	0.778454D+00	0.112943D+00	0.107823D+00	0.429305D-05	0.146566D+03	0.109775D+01
0.181288D+00	0.281218D+02	-.692341D-02	0.126509D+01	0.807162D+00	0.129482D+00	0.124603D+00	0.493469D-05	0.147306D+03	0.110829D+01
0.206107D+00	0.280237D+02	-.751215D-02	0.137457D+01	0.839896D+00	0.146354D+00	0.142805D+00	0.560822D-05	0.148117D+03	0.111973D+01
0.232087D+00	0.279282D+02	-.834319D-02	0.150035D+01	0.877213D+00	0.163338D+00	0.162464D+00	0.631080D-05	0.149003D+03	0.113208D+01
0.259123D+00	0.278379D+02	-.919832D-02	0.164522D+01	0.919704D+00	0.180182D+00	0.183610D+00	0.703955D-05	0.149969D+03	0.114537D+01
0.287110D+00	0.277556D+02	-.101068D-01	0.181034D+01	0.968024D+00	0.196609D+00	0.206267D+00	0.779158D-05	0.151019D+03	0.115961D+01
0.315938D+00	0.276841D+02	-.109844D-01	0.199626D+01	0.102285D+01	0.212304D+00	0.230444D+00	0.856405D-05	0.152155D+03	0.117480D+01
0.345492D+00	0.276265D+02	-.117289D-01	0.220170D+01	0.108486D+01	0.226922D+00	0.256125D+00	0.935414D-05	0.153380D+03	0.119094D+01
0.375655D+00	0.275853D+02	-.121762D-01	0.242265D+01	0.115458D+01	0.240084D+00	0.283260D+00	0.101591D-04	0.154694D+03	0.120799D+01
0.406309D+00	0.275624D+02	-.121133D-01	0.265113D+01	0.123235D+01	0.251392D+00	0.311745D+00	0.109762D-04	0.156094D+03	0.122589D+01
0.437333D+00	0.275580D+02	-.113052D-01	0.287445D+01	0.131811D+01	0.260442D+00	0.341410D+00	0.118027D-04	0.157571D+03	0.124453D+01
0.468605D+00	0.275705D+02	-.955897D-02	0.307533D+01	0.141122D+01	0.266856D+00	0.372006D+00	0.126360D-04	0.159112D+03	0.126375D+01
0.500000D+00	0.275954D+02	-.683061D-02	0.323401D+01	0.151040D+01	0.270313D+00	0.403198D+00	0.134731D-04	0.160695D+03	0.128335D+01
0.531395D+00	0.276259D+02	-.327400D-02	0.333203D+01	0.161365D+01	0.270596D+00	0.434578D+00	0.143111D-04	0.162293D+03	0.130307D+01
0.562667D+00	0.276614D+02	0.775502D-03	0.335631D+01	0.171842D+01	0.267626D+00	0.465694D+00	0.151467D-04	0.163883D+03	0.132262D+01
0.593691D+00	0.277102D+02	0.479997D-02	0.330304D+01	0.182191D+01	0.261480D+00	0.496089D+00	0.159770D-04	0.165450D+03	0.134172D+01
0.624345D+00	0.277807D+02	0.826120D-02	0.317961D+01	0.192143D+01	0.252391D+00	0.525352D+00	0.167992D-04	0.166982D+03	0.136011D+01
0.654508D+00	0.278789D+02	0.108104D-01	0.300241D+01	0.201479D+01	0.240711D+00	0.553151D+00	0.176107D-04	0.168469D+03	0.137757D+01
0.684062D+00	0.280078D+02	0.123485D-01	0.279189D+01	0.210048D+01	0.226876D+00	0.579257D+00	0.184090D-04	0.169902D+03	0.139398D+01
0.712890D+00	0.281673D+02	0.129901D-01	0.256757D+01	0.217776D+01	0.211351D+00	0.603539D+00	0.191917D-04	0.171274D+03	0.140923D+01
0.740877D+00	0.283549D+02	0.129430D-01	0.234500D+01	0.224650D+01	0.194599D+00	0.625953D+00	0.199563D-04	0.172581D+03	0.142332D+01
0.767913D+00	0.285664D+02	0.124729D-01	0.213454D+01	0.230704D+01	0.177051D+00	0.646517D+00	0.207002D-04	0.173820D+03	0.143624D+01
0.793893D+00	0.287966D+02	0.116809D-01	0.194257D+01	0.235997D+01	0.159096D+00	0.665290D+00	0.214205D-04	0.174988D+03	0.144804D+01
0.818712D+00	0.290397D+02	0.110135D-01	0.177024D+01	0.240602D+01	0.141077D+00	0.682356D+00	0.221143D-04	0.176083D+03	0.145876D+01
0.842274D+00	0.292904D+02	0.963498D-02	0.162204D+01	0.244597D+01	0.123291D+00	0.697808D+00	0.227786D-04	0.177106D+03	0.146847D+01
0.864484D+00	0.295431D+02	0.100213D-01	0.148606D+01	0.248044D+01	0.105995D+00	0.711742D+00	0.234102D-04	0.178055D+03	0.147722D+01
0.885257D+00	0.297930D+02	0.537268D-02	0.139297D+01	0.251033D+01	0.894087D-01	0.724247D+00	0.240059D-04	0.178929D+03	0.148508D+01
0.904508D+00	0.300354D+02	-.191615D-02	0.128280D+01	0.253612D+01	0.737199D-01	0.735405D+00	0.245626D-04	0.179729D+03	0.149209D+01
0.922164D+00	0.302664D+02	0.366355D-02	0.115457D+01	0.255779D+01	0.590927D-01	0.745292D+00	0.250772D-04	0.180454D+03	0.149830D+01

0.938153D+00	0.304825D+02	0.598605D-01	0.889706D+00	0.257459D+01	0.456745D-01	0.753988D+00	0.255467D-04	0.181104D+03	0.150377D+01
0.945283D+00	0.305810D+02	0.137684D+00	0.614876D+00	0.258007D+01	0.396488D-01	0.757800D+00	0.257571D-04	0.181393D+03	0.150616D+01
0.952414D+00	0.306803D+02	0.296225D+00	0.877526D-01	0.258281D+01	0.336069D-01	0.761587D+00	0.259683D-04	0.181682D+03	0.150854D+01
0.958651D+00	0.307662D+02	0.567726D+00	-.808400D+00	0.258089D+01	0.283196D-01	0.764896D+00	0.261535D-04	0.181933D+03	0.151062D+01
0.964888D+00	0.308447D+02	0.108411D+01	-.249525D+01	0.257116D+01	0.230502D-01	0.768234D+00	0.263393D-04	0.182178D+03	0.151272D+01
0.968435D+00	0.308780D+02	0.156743D+01	-.407742D+01	0.255965D+01	0.200752D-01	0.770165D+00	0.264451D-04	0.182308D+03	0.151393D+01
0.971982D+00	0.308915D+02	0.225704D+01	-.616800D+01	0.254167D+01	0.171287D-01	0.772139D+00	0.265510D-04	0.182420D+03	0.151517D+01
0.975528D+00	0.308653D+02	0.322160D+01	-.898149D+01	0.251509D+01	0.142264D-01	0.774178D+00	0.266568D-04	0.182496D+03	0.151645D+01
0.977719D+00	0.308134D+02	0.399900D+01	-.112915D+02	0.249297D+01	0.124654D-01	0.775481D+00	0.267221D-04	0.182509D+03	0.151727D+01
0.979910D+00	0.307161D+02	0.495518D+01	-.141546D+02	0.246521D+01	0.107373D-01	0.776828D+00	0.267873D-04	0.182479D+03	0.151812D+01
0.982101D+00	0.305493D+02	0.613047D+01	-.176978D+02	0.243046D+01	0.905203D-02	0.778228D+00	0.268522D-04	0.182382D+03	0.151900D+01
0.984292D+00	0.302762D+02	0.757202D+01	-.220760D+02	0.238706D+01	0.742251D-02	0.779692D+00	0.269166D-04	0.182182D+03	0.151992D+01
0.986005D+00	0.299538D+02	0.891875D+01	-.262003D+02	0.234581D+01	0.619823D-02	0.780890D+00	0.269664D-04	0.181919D+03	0.152067D+01
0.987718D+00	0.294953D+02	0.104874D+02	-.310524D+02	0.229688D+01	0.502909D-02	0.782142D+00	0.270157D-04	0.181523D+03	0.152146D+01
0.989431D+00	0.288495D+02	0.123040D+02	-.367497D+02	0.223894D+01	0.392837D-02	0.783454D+00	0.270640D-04	0.180943D+03	0.152228D+01
0.991144D+00	0.279474D+02	0.143899D+02	-.434209D+02	0.217042D+01	0.291264D-02	0.784833D+00	0.271110D-04	0.180110D+03	0.152315D+01
0.992782D+00	0.267614D+02	0.166460D+02	-.508361D+02	0.209337D+01	0.203985D-02	0.786219D+00	0.271543D-04	0.178993D+03	0.152402D+01
0.994419D+00	0.251556D+02	0.191493D+02	-.593855D+02	0.200327D+01	0.128564D-02	0.787672D+00	0.271954D-04	0.177460D+03	0.152493D+01
0.996057D+00	0.230037D+02	0.218611D+02	-.691762D+02	0.189816D+01	0.676474D-03	0.789192D+00	0.272335D-04	0.175384D+03	0.152589D+01
0.997535D+00	0.204712D+02	0.244166D+02	-.791404D+02	0.178868D+01	0.276975D-03	0.790614D+00	0.272646D-04	0.172922D+03	0.152678D+01
0.999013D+00	0.172574D+02	0.269606D+02	-.901925D+02	0.166367D+01	0.464375D-04	0.792073D+00	0.272915D-04	0.169782D+03	0.152770D+01
0.100000D+01	0.146780D+02	0.285696D+02	-.981546D+02	0.157080D+01	0.214481D-18	0.793058D+00	0.273068D-04	0.167251D+03	0.152832D+01

II.2.1.4 FREQOUT DATA A

```
CHINESE LANTERN FROM JOAO,   APRIL 1985

ESTIMATES OF OUT-OF PLANE NATURAL FREQUENCIES FOR A 2-D STATIC CONFIGURATION

NUMBER OF NATURAL FREQUENCIES IN SPECIFIED RANGE:   6
MODE =    1
NATURAL FREQUENCY BETWEEN
0.330000D+00 AND 0.340000D+00 RAD/SEC
****************************************
MODE =    2
NATURAL FREQUENCY BETWEEN
0.650000D+00 AND 0.660000D+00 RAD/SEC
****************************************
MODE =    3
NATURAL FREQUENCY BETWEEN
0.980000D+00 AND 0.990000D+00 RAD/SEC
****************************************
MODE =    4
NATURAL FREQUENCY BETWEEN
0.131000D+01 AND 0.132000D+01 RAD/SEC
****************************************
MODE =    5
NATURAL FREQUENCY BETWEEN
0.164000D+01 AND 0.165000D+01 RAD/SEC
****************************************
MODE =    6
NATURAL FREQUENCY BETWEEN
0.197000D+01 AND 0.198000D+01 RAD/SEC
****************************************

FREQUENCY (RAD/SEC)  EQUATION VALUE
     0.100000D-01     0.950482D-01
     0.200000D-01     0.189238D+00
     0.300000D-01     0.281719D+00
     0.400000D-01     0.371655D+00
     0.500000D-01     0.458234D+00
     0.600000D-01     0.540675D+00
     0.700000D-01     0.618231D+00
     0.800000D-01     0.690203D+00
     0.900000D-01     0.755939D+00
     0.100000D+00     0.814844D+00
     0.110000D+00     0.866386D+00
     0.120000D+00     0.910098D+00
     0.130000D+00     0.945584D+00
     0.140000D+00     0.972520D+00
     0.150000D+00     0.990663D+00
     0.160000D+00     0.999846D+00
     0.170000D+00     0.999984D+00
     0.180000D+00     0.991072D+00
     0.190000D+00     0.973190D+00
     0.200000D+00     0.946496D+00
     0.210000D+00     0.911228D+00
     0.220000D+00     0.867703D+00
     0.230000D+00     0.816309D+00
     0.240000D+00     0.757509D+00
     0.250000D+00     0.691832D+00
```

0.260000D+00	0.619867D+00
0.270000D+00	0.542262D+00
0.280000D+00	0.459717D+00
0.290000D+00	0.372975D+00
0.300000D+00	0.282817D+00
0.310000D+00	0.190057D+00
0.320000D+00	0.955309D-01
0.330000D+00	0.931794D-04
0.340000D+00	-.953947D-01
0.350000D+00	-.190070D+00
0.360000D+00	-.283076D+00
0.370000D+00	-.373571D+00
0.380000D+00	-.460737D+00
0.390000D+00	-.543783D+00
0.400000D+00	-.621956D+00
0.410000D+00	-.694547D+00
0.420000D+00	-.760895D+00
0.430000D+00	-.820396D+00
0.440000D+00	-.872508D+00
0.450000D+00	-.916755D+00
0.460000D+00	-.952730D+00
0.470000D+00	-.980103D+00
0.480000D+00	-.998619D+00
0.490000D+00	-.100810D+01
0.500000D+00	-.100847D+01
0.510000D+00	-.999693D+00
0.520000D+00	-.981858D+00
0.530000D+00	-.955114D+00
0.540000D+00	-.919695D+00
0.550000D+00	-.875915D+00
0.560000D+00	-.824162D+00
0.570000D+00	-.764897D+00
0.580000D+00	-.698649D+00
0.590000D+00	-.626011D+00
0.600000D+00	-.547634D+00
0.610000D+00	-.464221D+00
0.620000D+00	-.376523D+00
0.630000D+00	-.285328D+00
0.640000D+00	-.191459D+00
0.650000D+00	-.957612D-01
0.660000D+00	0.900745D-03
0.670000D+00	0.976531D-01
0.680000D+00	0.193620D+00
0.690000D+00	0.287933D+00
0.700000D+00	0.379736D+00
0.710000D+00	0.468195D+00
0.720000D+00	0.552505D+00
0.730000D+00	0.631900D+00
0.740000D+00	0.705654D+00
0.750000D+00	0.773092D+00
0.760000D+00	0.833598D+00
0.770000D+00	0.886614D+00
0.780000D+00	0.931651D+00
0.790000D+00	0.968292D+00
0.800000D+00	0.996194D+00
0.810000D+00	0.101509D+01

0.820000D+00	0.102481D+01
0.830000D+00	0.102524D+01
0.840000D+00	0.101636D+01
0.850000D+00	0.998259D+00
0.860000D+00	0.971072D+00
0.870000D+00	0.935036D+00
0.880000D+00	0.890468D+00
0.890000D+00	0.837757D+00
0.900000D+00	0.777372D+00
0.910000D+00	0.709848D+00
0.920000D+00	0.635786D+00
0.930000D+00	0.555850D+00
0.940000D+00	0.470754D+00
0.950000D+00	0.381262D+00
0.960000D+00	0.288180D+00
0.970000D+00	0.192345D+00
0.980000D+00	0.946224D-01
0.990000D+00	-.410434D-02
0.100000D+01	-.102942D+00
0.101000D+01	-.200994D+00
0.102000D+01	-.297370D+00
0.103000D+01	-.391192D+00
0.104000D+01	-.481607D+00
0.105000D+01	-.567789D+00
0.106000D+01	-.648947D+00
0.107000D+01	-.724338D+00
0.108000D+01	-.793269D+00
0.109000D+01	-.855102D+00
0.110000D+01	-.909264D+00
0.111000D+01	-.955252D+00
0.112000D+01	-.992633D+00
0.113000D+01	-.102105D+01
0.114000D+01	-.104024D+01
0.115000D+01	-.105000D+01
0.116000D+01	-.105023D+01
0.117000D+01	-.104091D+01
0.118000D+01	-.102210D+01
0.119000D+01	-.993973D+00
0.120000D+01	-.956751D+00
0.121000D+01	-.910760D+00
0.122000D+01	-.856401D+00
0.123000D+01	-.794152D+00
0.124000D+01	-.724565D+00
0.125000D+01	-.648256D+00
0.126000D+01	-.565907D+00
0.127000D+01	-.478255D+00
0.128000D+01	-.386085D+00
0.129000D+01	-.290227D+00
0.130000D+01	-.191544D+00
0.131000D+01	-.909289D-01
0.132000D+01	0.107084D-01
0.133000D+01	0.112446D+00
0.134000D+01	0.213358D+00
0.135000D+01	0.312526D+00
0.136000D+01	0.409044D+00
0.137000D+01	0.502029D+00

0.138000D+01	0.590627D+00
0.139000D+01	0.674024D+00
0.140000D+01	0.751450D+00
0.141000D+01	0.822188D+00
0.142000D+01	0.885579D+00
0.143000D+01	0.941031D+00
0.144000D+01	0.988023D+00
0.145000D+01	0.102611D+01
0.146000D+01	0.105492D+01
0.147000D+01	0.107418D+01
0.148000D+01	0.108368D+01
0.149000D+01	0.108332D+01
0.150000D+01	0.107309D+01
0.151000D+01	0.105305D+01
0.152000D+01	0.102336D+01
0.153000D+01	0.984267D+00
0.154000D+01	0.936114D+00
0.155000D+01	0.879314D+00
0.156000D+01	0.814365D+00
0.157000D+01	0.741841D+00
0.158000D+01	0.662384D+00
0.159000D+01	0.576702D+00
0.160000D+01	0.485562D+00
0.161000D+01	0.389782D+00
0.162000D+01	0.290224D+00
0.163000D+01	0.187786D+00
0.164000D+01	0.833955D-01
0.165000D+01	-.219996D-01
0.166000D+01	-.127441D+00
0.167000D+01	-.231967D+00
0.168000D+01	-.334621D+00
0.169000D+01	-.434463D+00
0.170000D+01	-.530575D+00
0.171000D+01	-.622070D+00
0.172000D+01	-.708101D+00
0.173000D+01	-.787871D+00
0.174000D+01	-.860634D+00
0.175000D+01	-.925710D+00
0.176000D+01	-.982483D+00
0.177000D+01	-.103042D+01
0.178000D+01	-.106905D+01
0.179000D+01	-.109800D+01
0.180000D+01	-.111698D+01
0.181000D+01	-.112580D+01
0.182000D+01	-.112434D+01
0.183000D+01	-.111260D+01
0.184000D+01	-.109064D+01
0.185000D+01	-.105865D+01
0.186000D+01	-.101690D+01
0.187000D+01	-.965730D+00
0.188000D+01	-.905591D+00
0.189000D+01	-.837007D+00
0.190000D+01	-.760583D+00
0.191000D+01	-.676997D+00
0.192000D+01	-.586992D+00
0.193000D+01	-.491376D+00

0.194000D+01	-.391007D+00
0.195000D+01	-.286790D+00
0.196000D+01	-.179668D+00
0.197000D+01	-.706141D-01
0.198000D+01	0.393802D-01
0.199000D+01	0.149311D+00
0.200000D+01	0.258171D+00
0.201000D+01	0.364961D+00

Chapter III

III.1 Input-Output Manual for the Out-of-Plane Linear Eigenproblem Solution Program, RCLINDYN

This program is written in FORTRAN 77 and allows the interactive solution of the out-of-plane linear eigenproblem for a compliant riser with a planar static configuration without torsion, as described in [4].

Before executing the program the user must make sure that

- Devices five and six correspond to input/output from the terminal
- Device eight must be associated with the data file containing geometric, structural and hydrodynamic characteristics of the compliant riser created by a previous execution of the data preprocessing program RCINPUT. This file has a logical record length of 80 characters.
- Device nine must be associated with an output data file with logical record length of 132 characters which upon completion of the program contains a complete list of the inputs, initial approximation and the converged solution of the problem.
- Device ten must be associated with the input data file containing the non-dimensional static planar solution created by RCSTAT2D. This file has a logical record length of 132 characters.
- Device eleven must be associated with an output file with logical record length of 117 characters. This file contains the converged solution of the problem in a concise form appropriate for use in the preparation of illustrations and/or as an input to RCLINDYN from device twelve in a subsequent execution of this program.

- Device twelve may be associated with an input file containing an initial approximate solution of an out-of-plane linear dynamic problem, resulting from a previous execution of RCLINDYN. This option can be used if greater accuracy is needed for the solution of the problem. Device twelve may be associated with a dummy file name if this option is not used.

Input Variables [Free Format]

At the beginning of the program the static 2-D solution created from RCSTAT2D is read from device ten. The user is informed about the mean current velocity in the X direction and the maximum non-dimensional static effective tension. If the number of static discretization points is less than four or greater than the value of MNP (maximum number of allowable points) the program halts execution. If the mean velocity is zero, the program halts execution because the asymptotic theory is no longer valid.

Then the geometric, structural and hydrodynamic characteristics of the compliant riser are read from the file associated with device eight. The user has the opportunity to review this data on his terminal and decide either to continue with the program or stop, see [3].

Next the user is asked whether he wants the initial approximation to be calculated using asymptotics (input IEXIST = 0) or whether he wants to use the option to read an initial approximation from device twelve created by a previous run of the same program (input IEXIST = 1).

Case 1 (IEXIST = 0)

The user is asked whether he wants to change the value of $\nu=(EI^{\eta\eta}(0)/T\cdot L^2)^{1/2}$ to be used to determine the natural frequency for the out-of-plane solution. If he wants to change it, he is asked the new value for ν.

Next the user is asked to supply an initial guess for the natural frequency in rad/s. The information for the approximate natural frequencies is obtained by running RCNATOUT program which provides an estimate of the natural frequencies and their corresponding mode-number.

The program calculates the approximate natural frequency using the asymptotic theory and displays its value. Then the user is given the alternatives:

- o Input 1 if he wants to redo the calculation. This can be used in case the converged frequency doesn't correspond to the mode which the user wants to evaluate.
- o Input 2 if he chooses to stop the program.
- o Input any other integer to continue with the program.

Next the user is asked to input the mode number corresponding to the approximate natural frequency, as determined from RCNATOUT program. The initial asymptotic approximation is evaluated and the orthonormalizing constant used for r and ψ, as well as the fourth boundary condition at s = 0 are printed. The user is then asked if he wants to review the initial approximation by displaying it in his terminal. If he chooses to do so, he should input 1. Subsequently the approximate solution is printed in the file associated with the device nine. The following quantities are printed:

- o Number of discretization points NP
- o Natural frequency (rad/s)
- o Order of point (starting from the lower end)
- o Non-dimensional arc length
- o Non-dimensional shear force in the η direction, Q_1^η

- Non-dimensional component of rate of rotation about $\vec{\zeta}$, Ω_1^{ζ}
- Non-dimensional component of rate of rotation about $\vec{\xi}$, Ω_1^{ξ}
- Euler angle θ_1
- Euler angle β_1 or ψ_1
- Non-dimensional displacement r
- Non-dimensional natural frequency

Subsequently the program prints the maximum of the absolute value of the initial ($\varepsilon=0$) non-dimensional component of $\vec{\Omega}_1$ in the $\vec{\xi}$ direction. This number is used to estimate a reasonable tolerance for convergence of iterations. The user is requested to input a tolerance as a fraction of this number; e.g., 0.01 for 1% tolerance or better for all quantities of interest. Typically Ω_1^{ξ} will be determined with an accuracy a little better than the above fraction and all other variables will be even more accurate.

The user is given the opportunity to stop the program at this point if he wishes. He should input 0 if he wants to stop.

If he chooses to continue he is asked to input the initial increment of the continuation parameter $\delta\varepsilon$ (condition $0<\delta\varepsilon\leq 1$). If no continuation is required, then use $\delta\varepsilon=1$. If continuation is required, then $\delta\varepsilon=0.1$ will usually suffice. For large changes between initial and final problem a smaller value of $\delta\varepsilon$, e.g., 0.05 or 0.025 might be necessary.

Case 2 (IEXIST = 1)

In this case an initial approximation to the solution for $\varepsilon=1$ is available from a previous run of RCLINDYN. The program reads the information from the previous run concerning the number of division points, NP, the mode number and the corresponding natural frequency. If the number of division points is greater than MNP, the program stops execution.

Then the user has the option to review the initial approximation by displaying it in his terminal. The assumed boundary condition for the curvature at the lower end of the riser is also printed.

Subsequently, the program prints the maximum of the absolute values of the initial component of $\vec{\Omega}_1$ in the $\vec{\xi}$ direction. This number is used to estimate a reasonable tolerance for the convergence of iterations. The user is requested to input a tolerance as a fraction of this number; e.g., 0.01 for 1% tolerance or better for all quantities of interest. Typically, Ω_1^{ξ} will be determined with an accuracy a little better than the above fraction and all other variables will be even more accurate. Subsequently the user is given the opportunity to halt the execution of the program.

After the initial approximation is fully defined the program enters NAG subroutine D02RAF which provides the iterative numerical solution to the problem. The manual of this subroutine is included in Chapter X. The input value of IFAIL is 111, indicating that the soft failure option with error message and monitoring information printing has been selected. Error messages are directed to device six.

Once the execution of D02RAF is completed, the current value of IFAIL is printed on the terminal. For an explanation of this parameter, see NAG manual for D02RAF, Chapter X. Only if IFAIL=0 or IFAIL=4, the execution of the program continues with printout of the riser characteristics and the final solution of the problem. Otherwise, the program stops. When IFAIL≠0, the user should consult the manual quoted above for interpretation of the results and a possible course of action.

If IFAIL=0 or 4, the riser characteristics and the final solution of the problem are printed in the file associated with device nine. For the riser characteristics the same format is used as in program RCSTAT2D. This is described in [3] (pp. 23-25).

Following, the non-dimensional out-of-plane solution is written in the file associated with device nine. The mode number, natural frequency and final number of points NP at which the solution is available is printed first. Then the following data is printed for I=1 to NP:

s, Q_1^{η}, Ω_1^{ζ}, Ω_1^{ξ}, θ_1, β, r, Σ

with

FORMAT (8(1X, D10.4)).

Next, the maximum (non-dimensional) estimated errors of Q_1^{η}, Ω_1^{ζ}, Ω_1^{ξ}, θ_1, β, r, Σ provided by the NAG subroutine D02RAF are printed. Subsequently, the following data is written in the file associated with device eleven:

MODE, NP, SIGMAD: Mode number, number of points at which converged solution is available and dimensional natural frequency (in rad/s) with

FORMAT (1X, I2, 1X, I3, 1X, D10.4) and

For I=1 to NP the non-dimensional

s, Q_1^{η}, Ω_1^{ζ}, Ω_1^{ξ}, θ_1, β, r, Σ, and dimensional current velocity $V_c(s)$

with

FORMAT (9(1X, D12.6)).

The data written in the file associated with device eleven, due to their simple form, can be used very easily as input to plotting programs. In addition, this data is useful in subsequent runs of RCLINDYN, if such an option is selected.

III.2 Sample Run, Input and Output

III.2.1 Linear Current Excitation

III.2.1.1 Interactive Session

INPUT

Device 5 = TERMINAL

Device 8 = RCJOA01 DATA A*

Device 10 = RCCL2DRR DATA A*

Device 12 = DUMMY DATA A

OUTPUT

Device 6 = TERMINAL

Device 9 = JOA01 DATA A

Device 11 = JOA01A DATA A

*Files included in Chapter II.

```
R; T=0.01/0.01 15:48:42
rclindyn rcjoao1 joao1 rccl2drr joao1a dummy
FI 8 DISK RCJOAO1 DATA A ( RECFM FB LRECL 80 BLKSIZE 800
FI 9 DISK JOAO1 DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 10 DISK RCCL2DRR DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 11 DISK JOAO1A DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
FI 12 DISK DUMMY DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
GLOBAL TXTLIB VFORTLIB CMSLIB NAG1 NAG2
LOAD RCLINDYN ( START
EXECUTION BEGINS...
MNP=151
2-D STATIC SOLUTION FROM DEVICE 10
NP = 76
MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S , VM =0.129000D+01
2-D STATIC SOLUTION SUCCESFULLY READ
MAXIMUM STATIC TENSION/WAL = 0.3089D+02
DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS
IF YES INPUT 1 , IF NO INPUT 0
?
0
INPUT 1 IF YOU WISH TO READ INITIAL APPROXIMATION.
         CREATED BY A PREVIOUS RUN OF THIS PROGRAM
ELSE INPUT 0 (AN INITIAL APPROXIMATION WILL BE CALCULATED LOCALLY)
?
0
THE VALUE OF NU TO BE USED IS = 0.1979D-01
IF YOU WANT TO CHANGE NU INPUT 1
?
2
INPUT INITIAL GUESS FOR SIGMA IN RAD/SEC
?
.33
 IFAIL FOR APPROXIMATE EVALUATION OF SIGMA IS           0
THE FUNCTION IS F = 0.9714D-16
THE CONVERGED SIGMA IS 0.3300D+00
INPUT 1 IF YOU WANT TO REDO THE CALCULATION
INPUT 2 IF YOU WANT TO STOP
?
3
 INPUT MODE NUMBER CORRESPONDING TO ABOVE APPROXIMATE SIGMA
?
1
THE ORTHONORMALIZING CONSTANT FOR THE APPROXIMATE
SOLUTION IS SQRT(A) = 0.9334D+01
THE BOUNDARY CONDITION AT S=0    OMEGAXI(0) = 0.2747D+03
DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION
IF YES INPUT 1
?
2
MAXIMUM ABSOLUTE VALUE OF N-D OMEGA XI IS =0.274676D+03
THIS NUMBER CAN BE USED TO ESTIMATE
A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS
INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE
E.G. INPUT 0.01 FOR 1% ACCURACY
?
.01
 IF YOU WANT TO STOP INPUT 0
?
1
INPUT INITIAL INCREMENT OF CONTINUATION PARAMETER DELEPS
```

```
IF NO CONTINUATION IS REQUIRED INPUT DELEPS = 1.DO
IF CONTINUATION IS REQUIRED THEN O.DO < DELEPS < 1.DO
RECOMMENDATION :
USUALLY DELEPS = O.1DO WILL SUFFICE
FOR LARGE CHANGES BETWEEN INITIAL AND FINAL PROBLEM
A SMALLER VALUE OF DELEPS, E.G. O.05DO OR O.025DO MIGHT BE
.1
NECESSARY
?

DO2RAF MONITORING INFORMATION

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =    76
  CORRECTION NUMBER     O    RESIDUAL SHOULD BE .LE.  1.OOD+OO
   ITERATION NUMBER     O    RESIDUAL =  7.32D-O1
    SQUARED NORM OF CORRECTION =  8.48D+O2
    SQUARED NORM OF GRADIENT    =  1.16D+O3
    SCALAR PRODUCT OF CORRECTION AND GRADIENT =  5.36D-O1
   ITERATION NUMBER     1    RESIDUAL =  3.74D-O4

 CONTINUATION PARAMETER EPSILON =  2.OOD-O1   DELEPS =  2.OOD-O1

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =    76
  CORRECTION NUMBER     O    RESIDUAL SHOULD BE .LE.  1.OOD+OO
   ITERATION NUMBER     O    RESIDUAL =  2.37D-O1

 CONTINUATION PARAMETER EPSILON =  6.OOD-O1   DELEPS =  4.OOD-O1

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =    76
  CORRECTION NUMBER     O    RESIDUAL SHOULD BE .LE.  1.OOD+OO
   ITERATION NUMBER     O    RESIDUAL =  1.71D+OO
    SQUARED NORM OF CORRECTION =  1.17D+O2
    SQUARED NORM OF GRADIENT    =  1.53D+O4
    SCALAR PRODUCT OF CORRECTION AND GRADIENT =  2.94D+OO
   ITERATION NUMBER     1    RESIDUAL =  9.87D-O5

 CONTINUATION PARAMETER EPSILON =  1.OOD+OO   DELEPS =  8.OOD-O1

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =    76
  CORRECTION NUMBER     O    RESIDUAL SHOULD BE .LE.  2.75D-O4
   ITERATION NUMBER     O    RESIDUAL =  1.19D+O1
    SQUARED NORM OF CORRECTION =  5.9OD+O3
    SQUARED NORM OF GRADIENT    =  4.6OD+O5
    SCALAR PRODUCT OF CORRECTION AND GRADIENT =  1.42D+O2
   ITERATION NUMBER     1    RESIDUAL =  3.55D-O3
    SQUARED NORM OF CORRECTION =  2.O6D-O3
    SQUARED NORM OF GRADIENT    =  2.56D-O6
    SCALAR PRODUCT OF CORRECTION AND GRADIENT =  1.26D-O5
   ITERATION NUMBER     2    RESIDUAL =  1.19D-O6

 MESH SELECTION
  NUMBER OF NEW POINTS    8

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =    84
  CORREC''ON NUMBER     O    RESIDUAL SHOULD BE .LE.  2.75D-O4
```

```
  ITERATION NUMBER     0    RESIDUAL =  2.68D-01
   SQUARED NORM OF CORRECTION =  4.31D-01
   SQUARED NORM OF GRADIENT    =  4.36D-01
   SCALAR PRODUCT OF CORRECTION AND GRADIENT =  7.20D-02
  ITERATION NUMBER     1    RESIDUAL =  2.78D-08

 MESH SELECTION
  NUMBER OF NEW POINTS    1

 CORRECTION NUMBER     0    ESTIMATED MAXIMUM ERROR =  5.10D-01
 ESTIMATED ERROR BY COMPONENTS
   1.20D-02  1.54D-02  5.10D-01  1.86D-02  1.28D-02  2.01D-03  2.71D-03
IFAIL =  0
R; T=3.24/3.60 15:50:22
cp spool console stop close
```

III.2.1.2 JOA01 DATA A

INITIAL CONDITION FOR EPS=0. AND NP = 76 POINTS, NATURAL FREQUENCY = 0.3300D+00 RAD/SEC

I	ARC	SHEAR ETA	OMEGA ZETA	OMEGA XI	THETA	BETA	R	SIGMA
1	0.000000D+00	-.591156D+01	0.290842D+01	0.274676D+03	0.000000D+00	0.000000D+00	-.120808D-22	0.375852D+01
2	0.986636D-03	-.562518D+01	0.258510D+01	0.261317D+03	0.264361D+00	-.727465D-02	-.131498D-03	0.375852D+01
3	0.246464D-02	-.522202D+01	0.217428D+01	0.242505D+03	0.636515D+00	-.504215D-01	-.800670D-03	0.375852D+01
4	0.394265D-02	-.484785D+01	0.183905D+01	0.225041D+03	0.981874D+00	-.122102D+00	-.199985D-02	0.375852D+01
5	0.558056D-02	-.446456D+01	0.153973D+01	0.207144D+03	0.133561D+01	-.222806D+00	-.390176D-02	0.375852D+01
6	0.721847D-02	-.411171D+01	0.130208D+01	0.190661D+03	0.166121D+01	-.336249D+00	-.635972D-02	0.375852D+01
7	0.885637D-02	-.378686D+01	0.111378D+01	0.175480D+03	0.196089D+01	-.454947D+00	-.932943D-02	0.375852D+01
8	0.111404D-01	-.337648D+01	0.914234D+00	0.156290D+03	0.233936D+01	-.619172D+00	-.142487D-01	0.375852D+01
9	0.134244D-01	-.301080D+01	0.770695D+00	0.139177D+03	0.267641D+01	-.774470D+00	-.199842D-01	0.375852D+01
10	0.157084D-01	-.268495D+01	0.667681D+00	0.123915D+03	0.297653D+01	-.915844D+00	-.264465D-01	0.375852D+01
11	0.178993D-01	-.240579D+01	0.596512D+00	0.110826D+03	0.323342D+01	-.103634D+01	-.332544D-01	0.375852D+01
12	0.200901D-01	-.215587D+01	0.544954D+00	0.990971D+02	0.346313D+01	-.114162D+01	-.405945D-01	0.375852D+01
13	0.222809D-01	-.193211D+01	0.507679D+00	0.885835D+02	0.366851D+01	-.123226D+01	-.484107D-01	0.375852D+01
14	0.244717D-01	-.173178D+01	0.480791D+00	0.791584D+02	0.385206D+01	-.130933D+01	-.566525D-01	0.375852D+01
15	0.280184D-01	-.145094D+01	0.451883D+00	0.659203D+02	0.410865D+01	-.140921D+01	-.707835D-01	0.375852D+01
16	0.315651D-01	-.107596D+01	0.498171D+00	0.548205D+02	0.432219D+01	-.148230D+01	-.857459D-01	0.375852D+01
17	0.351118D-01	-.902127D+00	0.488881D+00	0.455082D+02	0.449962D+01	-.153268D+01	-.101400D+00	0.375852D+01
18	0.413491D-01	-.662560D+00	0.481592D+00	0.326040D+02	0.474118D+01	-.158168D+01	-.130260D+00	0.375852D+01
19	0.475865D-01	-.487569D+00	0.479794D+00	0.230909D+02	0.491338D+01	-.159662D+01	-.160401D+00	0.375852D+01
20	0.547166D-01	-.344461D+00	0.479858D+00	0.152061D+02	0.504831D+01	-.159009D+01	-.195948D+00	0.375852D+01
21	0.618467D-01	-.211860D+00	0.560485D+00	0.958321D+01	0.513557D+01	-.156904D+01	-.232278D+00	0.375852D+01
22	0.778360D-01	-.997381D-01	0.561413D+00	0.200728D+01	0.522113D+01	-.149889D+01	-.315236D+00	0.375852D+01
23	0.954915D-01	-.371997D-01	0.673697D+00	-.215482D+01	0.521571D+01	-.140387D+01	-.407477D+00	0.375852D+01
24	0.114743D+00	-.190348D-01	0.841041D+00	-.459415D+01	0.514862D+01	-.128975D+01	-.507316D+00	0.375852D+01
25	0.135516D+00	-.134361D-01	0.839202D+00	-.626807D+01	0.503479D+01	-.116006D+01	-.613146D+00	0.375852D+01
26	0.157726D+00	-.111642D-01	0.836521D+00	-.764339D+01	0.487983D+01	-.101703D+01	-.723304D+00	0.375852D+01
27	0.181288D+00	-.101008D-01	0.832874D+00	-.891562D+01	0.468450D+01	-.860113D+00	-.836040D+00	0.375852D+01
28	0.206107D+00	-.940049D-02	0.828086D+00	-.101494D+02	0.444773D+01	-.690090D+00	-.949430D+00	0.375852D+01
29	0.232087D+00	-.875526D-02	0.821931D+00	-.113535D+02	0.416823D+01	-.508002D+00	-.106142D+01	0.375852D+01
30	0.259123D+00	-.806244D-02	0.814153D+00	-.125149D+02	0.384536D+01	-.315826D+00	-.116982D+01	0.375852D+01
31	0.287110D+00	-.729162D-02	0.804474D+00	-.136127D+02	0.347948D+01	-.116501D+00	-.127239D+01	0.375852D+01
32	0.315938D+00	-.643718D-02	0.792607D+00	-.146239D+02	0.307218D+01	0.857134D-01	-.136689D+01	0.375852D+01
33	0.345492D+00	-.550276D-02	0.778286D+00	-.155255D+02	0.262631D+01	0.284998D+00	-.145117D+01	0.375852D+01
34	0.375655D+00	-.449635D-02	0.761298D+00	-.162962D+02	0.214600D+01	0.473832D+00	-.152320D+01	0.375852D+01
35	0.406309D+00	-.342886D-02	0.741532D+00	-.169169D+02	0.163652D+01	0.643050D+00	-.158122D+01	0.375852D+01
36	0.437333D+00	-.231347D-02	0.719048D+00	-.173722D+02	0.110417D+01	0.782240D+00	-.162377D+01	0.375852D+01
37	0.468605D+00	-.116511D-02	0.694130D+00	-.176502D+02	0.556083D+00	0.880703D+00	-.164976D+01	0.375852D+01
38	0.500000D+00	-.240888D-12	0.667325D+00	-.177436D+02	-.481011D-12	0.928920D+00	-.165849D+01	0.375852D+01
39	0.531395D+00	0.116511D-02	0.639433D+00	-.176502D+02	-.556083D+00	0.920347D+00	-.164976D+01	0.375852D+01
40	0.562667D+00	0.231347D-02	0.611430D+00	-.173722D+02	-.110417D+01	0.852988D+00	-.162377D+01	0.375852D+01
41	0.593691D+00	0.342886D-02	0.584344D+00	-.169169D+02	-.163652D+01	0.730200D+00	-.158122D+01	0.375852D+01
42	0.624345D+00	0.449635D-02	0.559103D+00	-.162962D+02	-.214600D+01	0.560293D+00	-.152320D+01	0.375852D+01
43	0.654508D+00	0.550275D-02	0.536402D+00	-.155255D+02	-.262631D+01	0.354985D+00	-.145117D+01	0.375852D+01
44	0.684062D+00	0.643718D-02	0.516643D+00	-.146239D+02	-.307218D+01	0.127280D+00	-.136689D+01	0.375852D+01
45	0.712890D+00	0.729161D-02	0.499939D+00	-.136127D+02	-.347948D+01	-.110471D+00	-.127239D+01	0.375852D+01
46	0.740877D+00	0.806239D-02	0.486180D+00	-.125149D+02	-.384536D+01	-.347871D+00	-.116982D+01	0.375852D+01
47	0.767913D+00	0.875508D-02	0.475104D+00	-.113536D+02	-.416823D+01	-.577046D+00	-.106142D+01	0.375852D+01
48	0.793893D+00	0.939982D-02	0.466373D+00	-.101494D+02	-.444773D+01	-.792626D+00	-.949430D+00	0.375852D+01
49	0.818712D+00	0.100984D-01	0.459636D+00	-.891586D+01	-.468451D+01	-.991261D+00	-.836040D+00	0.375852D+01
50	0.842274D+00	0.111564D-01	0.454559D+00	-.764418D+01	-.487985D+01	-.117144D+01	-.723304D+00	0.375852D+01
51	0.864484D+00	0.134121D-01	0.450871D+00	-.627049D+01	-.503484D+01	-.133237D+01	-.613145D+00	0.375852D+01
52	0.885257D+00	0.189662D-01	0.448373D+00	-.460108D+01	-.514876D+01	-.147524D+01	-.507313D+00	0.375852D+01
53	0.904508D+00	0.369405D-01	0.357533D+00	-.217322D+01	-.521607D+01	-.160092D+01	-.407472D+00	0.375852D+01

54	0.922164D+00	0.989970D-01	0.297937D+00	0.196257D+01	-.522201D+01	-.170743D+01	-.315219D+00	0.375852D+01
55	0.938153D+00	0.210195D+00	0.299245D+00	0.948271D+01	-.513756D+01	-.178740D+01	-.232240D+00	0.375852D+01
56	0.945283D+00	0.341715D+00	0.257395D+00	0.150620D+02	-.505116D+01	-.181278D+01	-.195894D+00	0.375852D+01
57	0.952414D+00	0.483654D+00	0.258010D+00	0.228854D+02	-.491744D+01	-.182355D+01	-.160318D+00	0.375852D+01
58	0.958651D+00	0.657181D+00	0.256859D+00	0.323216D+02	-.474677D+01	-.181133D+01	-.130149D+00	0.375852D+01
59	0.964888D+00	0.894742D+00	0.250244D+00	0.451205D+02	-.450730D+01	-.176271D+01	-.101249D+00	0.375852D+01
60	0.968435D+00	0.106714D+01	0.241180D+00	0.543576D+02	-.433135D+01	-.171057D+01	-.855641D-01	0.375852D+01
61	0.971982D+00	0.143904D+01	0.194838D+00	0.653675D+02	-.411959D+01	-.163341D+01	-.705648D-01	0.375852D+01
62	0.975528D+00	0.171748D+01	0.164792D+00	0.784942D+02	-.386521D+01	-.152617D+01	-.563940D-01	0.375852D+01
63	0.977719D+00	0.191616D+01	0.136365D+00	0.878426D+02	-.368317D+01	-.144225D+01	-.481210D-01	0.375852D+01
64	0.979910D+00	0.213807D+01	0.964465D-01	0.982704D+02	-.347949D+01	-.134248D+01	-.402701D-01	0.375852D+01
65	0.982101D+00	0.238594D+01	0.405596D-01	0.109904D+03	-.325167D+01	-.122533D+01	-.328915D-01	0.375852D+01
66	0.984292D+00	0.266279D+01	-.374713D-01	0.122885D+03	-.299691D+01	-.108981D+01	-.260410D-01	0.375852D+01
67	0.986005D+00	0.290162D+01	-.119012D+00	0.134073D+03	-.277696D+01	-.970959D+00	-.210929D-01	0.375852D+01
68	0.987718D+00	0.316202D+01	-.224509D+00	0.146264D+03	-.253700D+01	-.841461D+00	-.165385D-01	0.375852D+01
69	0.989431D+00	0.344595D+01	-.360793D+00	0.159548D+03	-.227524D+01	-.702872D+00	-.124136D-01	0.375852D+01
70	0.991144D+00	0.375553D+01	-.536559D+00	0.174024D+03	-.198971D+01	-.558027D+00	-.875714D-02	0.375852D+01
71	0.992782D+00	0.407769D+01	-.751580D+00	0.189081D+03	-.169250D+01	-.417858D+00	-.573805D-02	0.375852D+01
72	0.994419D+00	0.442741D+01	-.102458D+01	0.205418D+03	-.136978D+01	-.282307D+00	-.322792D-02	0.375852D+01
73	0.996057D+00	0.480751D+01	-.137071D+01	0.223167D+03	-.101897D+01	-.159917D+00	-.126757D-02	0.375852D+01
74	0.997535D+00	0.517855D+01	-.176025D+01	0.240486D+03	-.676490D+00	-.705756D-01	-.114690D-04	0.375852D+01
75	0.999013D+00	0.557834D+01	-.223946D+01	0.259141D+03	-.307438D+00	-.134755D-01	0.719049D-03	0.375852D+01
76	0.100000D+01	0.586243D+01	-.261761D+01	0.272394D+03	-.451795D-01	-.761245D-15	0.894142D-03	0.375852D+01

CHINESE LANTERN FROM JOAO, APRIL 1985

```
 9           = NUMBER OF RISER SEGMENTS
0.883920D+02 = UNSTRETCHED RISER LENGTH IN M
0.292000D+01 = APPROXIMATE AVERAGE EFFECTIVE WEIGHT PER UNIT LENGTH IN N/M
0.820000D+03 = INNER FLUID DENSITY IN KG/M3
0.102500D+04 = SALT WATER DENSITY IN KG/M3
0.115434D-01 = INNER CROSS SECTIONAL AREA IN M2
0.000000D+00 = INNER FLUID SPEED IN M/S
0.345000D+07 = INNER FLUID OVERPRESSURE IN N/M2
0.258105D+03 = APPROXIMATE TOTAL EFFECTIVE WEIGHT IN WATER IN N
0.797324D+04 = MAXIMUM STATIC TENSION IN N
0.129000D+01 = MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S
```

D A T A   P E R   R I S E R   S E G M E N T   F O R   NSEG =   9   S E G M E N T S

D I M E N S I O N A L   Q U A N T I T I E S   I N   T H E   S . I .   S Y S T E M

RLENG	DXI	PXIETA	AO	WEIGHT	MASS	TMASS	AMAXI	AMAETA	AMAZI	TMAXI	TMAETA
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.6839D+02	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03

```
0.2500D+01 0.3100D+00 0.9300D+00 0.2374D-01 0.2920D+01 0.4993D+02 0.4047D+02 0.8244D+02 0.5032D+02 0.0000D+00 0.1324D+03 0.1003D+03
```

EA	EIETA	EIETAS	EIXI	EIXIS	GIP	GIPS	DETA	JZI	AJZI	TJZI
0.2670D+09	0.6600D+04	-.3300D+03	0.2440D+05	-.1220D+04	0.1164D+07	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.5775D+04	-.3300D+03	0.2135D+05	-.1220D+04	0.1019D+07	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4950D+04	-.3300D+03	0.1830D+05	-.1220D+04	0.8730D+06	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4125D+04	-.3300D+03	0.1525D+05	-.1220D+04	0.7275D+06	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.3300D+04	0.0000D+00	0.1220D+05	0.0000D+00	0.5820D+06	0.0000D+00	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4125D+04	0.3300D+03	0.1525D+05	0.1220D+04	0.7275D+06	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4950D+04	0.3300D+03	0.1830D+05	0.1220D+04	0.8730D+06	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.5775D+04	0.3300D+03	0.2135D+05	0.1220D+04	0.1019D+07	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.6600D+04	0.3300D+03	0.2440D+05	0.1220D+04	0.1164D+07	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00

```
*******************************************************
 M O D E   N U M B E R =  1
 N A T U R A L   F R E Q U E N C Y = 0.3200D+00 RAD/S
*******************************************************
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ORTHONORMALIZED NONDIMENSIONAL RESULTS AT NP = 84 POINTS

S	QETA	OMEGAZETA	OMEGAXI	THETA	BETA	R	SIGMA
0.0000D+00	-.5055D+01	0.2797D+01	0.2205D+03	0.0000D+00	0.0000D+00	0.0000D+00	0.3645D+01
0.9866D-03	-.4928D+01	0.2544D+01	0.2188D+03	0.2165D+00	-.5542D-02	-.1068D-03	0.3645D+01
0.1726D-02	-.4825D+01	0.2369D+01	0.2168D+03	0.3768D+00	-.1987D-01	-.3260D-03	0.3645D+01
0.2465D-02	-.4718D+01	0.2207D+01	0.2140D+03	0.5344D+00	-.4151D-01	-.6627D-03	0.3645D+01
0.3204D-02	-.4607D+01	0.2057D+01	0.2108D+03	0.6887D+00	-.6935D-01	-.1115D-02	0.3645D+01
0.3943D-02	-.4494D+01	0.1919D+01	0.2072D+03	0.8393D+00	-.1023D+00	-.1679D-02	0.3645D+01
0.4762D-02	-.4366D+01	0.1779D+01	0.2028D+03	0.1001D+01	-.1438D+00	-.2433D-02	0.3645D+01
0.5581D-02	-.4237D+01	0.1651D+01	0.1981D+03	0.1158D+01	-.1892D+00	-.3317D-02	0.3645D+01
0.7218D-02	-.3979D+01	0.1432D+01	0.1880D+03	0.1456D+01	-.2877D+00	-.5459D-02	0.3645D+01
0.8856D-02	-.3725D+01	0.1254D+01	0.1775D+03	0.1733D+01	-.3917D+00	-.8071D-02	0.3645D+01
0.1114D-01	-.3383D+01	0.1061D+01	0.1628D+03	0.2086D+01	-.5369D+00	-.1243D-01	0.3645D+01
0.1342D-01	-.3062D+01	0.9204D+00	0.1486D+03	0.2404D+01	-.6753D+00	-.1756D-01	0.3645D+01
0.1571D-01	-.2765D+01	0.8182D+00	0.1352D+03	0.2691D+01	-.8022D+00	-.2338D-01	0.3645D+01
0.1790D-01	-.2503D+01	0.7475D+00	0.1232D+03	0.2940D+01	-.9110D+00	-.2955D-01	0.3645D+01
0.2009D-01	-.2262D+01	0.6968D+00	0.1121D+03	0.3167D+01	-.1007D+01	-.3624D-01	0.3645D+01
0.2228D-01	-.2042D+01	0.6609D+00	0.1019D+03	0.3375D+01	-.1089D+01	-.4340D-01	0.3645D+01
0.2447D-01	-.1841D+01	0.6360D+00	0.9262D+02	0.3565D+01	-.1160D+01	-.5101D-01	0.3645D+01
0.2802D-01	-.1552D+01	0.6116D+00	0.7937D+02	0.3839D+01	-.1252D+01	-.6414D-01	0.3645D+01
0.3157D-01	-.1305D+01	0.6015D+00	0.6733D+02	0.4076D+01	-.1320D+01	-.7817D-01	0.3645D+01
0.3511D-01	-.1095D+01	0.6008D+00	0.5636D+02	0.4280D+01	-.1367D+01	-.9299D-01	0.3645D+01
0.4135D-01	-.8012D+00	0.6109D+00	0.4097D+02	0.4568D+01	-.1413D+01	-.1206D+00	0.3645D+01
0.4759D-01	-.5845D+00	0.6281D+00	0.2958D+02	0.4782D+01	-.1427D+01	-.1497D+00	0.3645D+01
0.5472D-01	-.4045D+00	0.6513D+00	0.2017D+02	0.4960D+01	-.1419D+01	-.1845D+00	0.3645D+01
0.6185D-01	-.2769D+00	0.6781D+00	0.1313D+02	0.5084D+01	-.1397D+01	-.2203D+00	0.3645D+01
0.7784D-01	-.1098D+00	0.7465D+00	0.2960D+01	0.5228D+01	-.1325D+01	-.3027D+00	0.3645D+01
0.9549D-01	-.3647D-01	0.8377D+00	-.2250D+01	0.5255D+01	-.1226D+01	-.3953D+00	0.3645D+01

0.1147D+00	-.1003D-01	0.8936D+00	-.5120D+01	0.5207D+01	-.1109D+01	-.4960D+00	0.3645D+01
0.1355D+00	-.2992D-02	0.8916D+00	-.6744D+01	0.5106D+01	-.9768D+00	-.6031D+00	0.3645D+01
0.1577D+00	-.9404D-03	0.8888D+00	-.8027D+01	0.4965D+01	-.8307D+00	-.7149D+00	0.3645D+01
0.1813D+00	0.4724D-03	0.8850D+00	-.9264D+01	0.4783D+01	-.6699D+00	-.8298D+00	0.3645D+01
0.2061D+00	0.1999D-02	0.8800D+00	-.1048D+02	0.4557D+01	-.4951D+00	-.9457D+00	0.3645D+01
0.2321D+00	0.3807D-02	0.8737D+00	-.1165D+02	0.4284D+01	-.3075D+00	-.1061D+01	0.3645D+01
0.2591D+00	0.5920D-02	0.8658D+00	-.1273D+02	0.3963D+01	-.1089D+00	-.1172D+01	0.3645D+01
0.2871D+00	0.8339D-02	0.8560D+00	-.1368D+02	0.3594D+01	0.9743D-01	-.1278D+01	0.3645D+01
0.3159D+00	0.1102D-01	0.8442D+00	-.1447D+02	0.3177D+01	0.3071D+00	-.1375D+01	0.3645D+01
0.3455D+00	0.1389D-01	0.8301D+00	-.1505D+02	0.2715D+01	0.5139D+00	-.1462D+01	0.3645D+01
0.3757D+00	0.1678D-01	0.8139D+00	-.1541D+02	0.2212D+01	0.7096D+00	-.1537D+01	0.3645D+01
0.4063D+00	0.1945D-01	0.7954D+00	-.1554D+02	0.1676D+01	0.8845D+00	-.1596D+01	0.3645D+01
0.4373D+00	0.2163D-01	0.7751D+00	-.1548D+02	0.1112D+01	0.1027D+01	-.1640D+01	0.3645D+01
0.4686D+00	0.2301D-01	0.7532D+00	-.1528D+02	0.5309D+00	0.1127D+01	-.1665D+01	0.3645D+01
0.5000D+00	0.2344D-01	0.7302D+00	-.1504D+02	-.5915D-01	0.1173D+01	-.1673D+01	0.3645D+01
0.5314D+00	0.2300D-01	0.7066D+00	-.1483D+02	-.6483D+00	0.1158D+01	-.1662D+01	0.3645D+01
0.5627D+00	0.2205D-01	0.6830D+00	-.1468D+02	-.1227D+01	0.1082D+01	-.1632D+01	0.3645D+01
0.5937D+00	0.2101D-01	0.6599D+00	-.1456D+02	-.1785D+01	0.9474D+00	-.1585D+01	0.3645D+01
0.6243D+00	0.2017D-01	0.6378D+00	-.1440D+02	-.2315D+01	0.7641D+00	-.1523D+01	0.3645D+01
0.6545D+00	0.1966D-01	0.6175D+00	-.1411D+02	-.2806D+01	0.5450D+00	-.1445D+01	0.3645D+01
0.6841D+00	0.1947D-01	0.5993D+00	-.1363D+02	-.3252D+01	0.3043D+00	-.1356D+01	0.3645D+01
0.7129D+00	0.1948D-01	0.5836D+00	-.1293D+02	-.3649D+01	0.5542D-01	-.1256D+01	0.3645D+01
0.7409D+00	0.1954D-01	0.5705D+00	-.1202D+02	-.3994D+01	-.1906D+00	-.1149D+01	0.3645D+01
0.7679D+00	0.1957D-01	0.5598D+00	-.1095D+02	-.4287D+01	-.4257D+00	-.1038D+01	0.3645D+01
0.7939D+00	0.1949D-01	0.5514D+00	-.9754D+01	-.4528D+01	-.6443D+00	-.9230D+00	0.3645D+01
0.8187D+00	0.1930D-01	0.5450D+00	-.8494D+01	-.4720D+01	-.8436D+00	-.8083D+00	0.3645D+01
0.8423D+00	0.1913D-01	0.5402D+00	-.7211D+01	-.4868D+01	-.1022D+01	-.6953D+00	0.3645D+01
0.8645D+00	0.1957D-01	0.5367D+00	-.5898D+01	-.4975D+01	-.1180D+01	-.5860D+00	0.3645D+01
0.8853D+00	0.2449D-01	0.5344D+00	-.4321D+01	-.5044D+01	-.1319D+01	-.4819D+00	0.3645D+01
0.9045D+00	0.4574D-01	0.4992D+00	-.1827D+01	-.5068D+01	-.1439D+01	-.3846D+00	0.3645D+01
0.9222D+00	0.1067D+00	0.4450D+00	0.2527D+01	-.5030D+01	-.1539D+01	-.2954D+00	0.3645D+01
0.9382D+00	0.2517D+00	0.4065D+00	0.1130D+02	-.4894D+01	-.1614D+01	-.2161D+00	0.3645D+01
0.9453D+00	0.3655D+00	0.3920D+00	0.1750D+02	-.4782D+01	-.1637D+01	-.1816D+00	0.3645D+01
0.9524D+00	0.5297D+00	0.3789D+00	0.2599D+02	-.4623D+01	-.1646D+01	-.1481D+00	0.3645D+01
0.9587D+00	0.7318D+00	0.3658D+00	0.3652D+02	-.4432D+01	-.1634D+01	-.1198D+00	0.3645D+01
0.9649D+00	0.1012D+01	0.3471D+00	0.5118D+02	-.4175D+01	-.1588D+01	-.9300D-01	0.3645D+01
0.9684D+00	0.1217D+01	0.3307D+00	0.6189D+02	-.3993D+01	-.1539D+01	-.7851D-01	0.3645D+01
0.9720D+00	0.1461D+01	0.3062D+00	0.7394D+02	-.3779D+01	-.1468D+01	-.6473D-01	0.3645D+01
0.9755D+00	0.1752D+01	0.2680D+00	0.8758D+02	-.3530D+01	-.1370D+01	-.5177D-01	0.3645D+01
0.9777D+00	0.1957D+01	0.2340D+00	0.9732D+02	-.3357D+01	-.1293D+01	-.4423D-01	0.3645D+01
0.9799D+00	0.2184D+01	0.1879D+00	0.1082D+03	-.3167D+01	-.1202D+01	-.3708D-01	0.3645D+01
0.9821D+00	0.2435D+01	0.1250D+00	0.1202D+03	-.2956D+01	-.1095D+01	-.3037D-01	0.3645D+01
0.9843D+00	0.2712D+01	0.3921D-01	0.1336D+03	-.2723D+01	-.9715D+00	-.2415D-01	0.3645D+01
0.9860D+00	0.2947D+01	-.4909D-01	0.1449D+03	-.2522D+01	-.8634D+00	-.1966D-01	0.3645D+01
0.9877D+00	0.3198D+01	-.1618D+00	0.1569D+03	-.2303D+01	-.7457D+00	-.1552D-01	0.3645D+01
0.9894D+00	0.3465D+01	-.3055D+00	0.1696D+03	-.2063D+01	-.6199D+00	-.1178D-01	0.3645D+01
0.9911D+00	0.3746D+01	-.4880D+00	0.1827D+03	-.1799D+01	-.4888D+00	-.8477D-02	0.3645D+01
0.9928D+00	0.4023D+01	-.7074D+00	0.1954D+03	-.1522D+01	-.3625D+00	-.5758D-02	0.3645D+01
0.9936D+00	0.4163D+01	-.8363D+00	0.2016D+03	-.1373D+01	-.3005D+00	-.4573D-02	0.3645D+01
0.9944D+00	0.4303D+01	-.9798D+00	0.2077D+03	-.1219D+01	-.2406D+00	-.3512D-02	0.3645D+01
0.9952D+00	0.4442D+01	-.1139D+01	0.2135D+03	-.1057D+01	-.1840D+00	-.2580D-02	0.3645D+01
0.9961D+00	0.4578D+01	-.1315D+01	0.2190D+03	-.8882D+00	-.1320D+00	-.1784D-02	0.3645D+01
0.9968D+00	0.4698D+01	-.1490D+01	0.2235D+03	-.7306D+00	-.9036D-01	-.1186D-02	0.3645D+01
0.9975D+00	0.4813D+01	-.1680D+01	0.2274D+03	-.5681D+00	-.5490D-01	-.7059D-03	0.3645D+01
0.9983D+00	0.4922D+01	-.1887D+01	0.2307D+03	-.4013D+00	-.2705D-01	-.3477D-03	0.3645D+01

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0.9990D+00 0.5023D+01 -.2109D+01 0.2332D+03 -.2309D+00 -.8281D-02 -.1141D-03 0.3645D+01
0.9995D+00 0.5086D+01 -.2267D+01 0.2344D+03 -.1158D+00 -.1531D-02 -.2857D-04 0.3645D+01
0.1000D+01 0.5145D+01 -.2432D+01 0.2350D+03 0.0000D+00 0.0000D+00 -.4753D-19 0.3645D+01
MAXIMUM ESTIMATED ERROR BY COMPONENTS
          0.9617D-02 0.1233D-01 0.4091D+00 0.1491D-01 0.1025D-01 0.1616D-02 0.2714D-02
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III.2.1.3 JOA01A DATA A

1 84 0.3200D+00

0.000000D+00	-.505530D+01	0.279705D+01	0.220451D+03	0.000000D+00	0.000000D+00	0.000000D+00	0.364493D+01	0.103000D+01
0.986636D-03	-.492762D+01	0.254395D+01	0.218838D+03	0.216500D+00	-.554221D-02	-.106803D-03	0.364493D+01	0.103062D+01
0.172564D-02	-.482520D+01	0.236914D+01	0.216751D+03	0.376765D+00	-.198727D-01	-.326015D-03	0.364493D+01	0.103108D+01
0.246464D-02	-.471814D+01	0.220693D+01	0.214048D+03	0.534383D+00	-.415127D-01	-.662685D-03	0.364493D+01	0.103154D+01
0.320364D-02	-.460742D+01	0.205696D+01	0.210834D+03	0.688722D+00	-.693535D-01	-.111463D-02	0.364493D+01	0.103199D+01
0.394265D-02	-.449403D+01	0.191877D+01	0.207202D+03	0.839328D+00	-.102344D+00	-.167924D-02	0.364493D+01	0.103244D+01
0.476160D-02	-.436628D+01	0.177867D+01	0.202791D+03	0.100148D+01	-.143778D+00	-.243301D-02	0.364493D+01	0.103293D+01
0.558056D-02	-.423732D+01	0.165150D+01	0.198066D+03	0.115842D+01	-.189220D+00	-.331745D-02	0.364493D+01	0.103342D+01
0.721847D-02	-.397915D+01	0.143228D+01	0.188011D+03	0.145631D+01	-.287664D+00	-.545880D-02	0.364493D+01	0.103436D+01
0.885637D-02	-.372477D+01	0.125421D+01	0.177519D+03	0.173315D+01	-.391694D+00	-.807081D-02	0.364493D+01	0.103527D+01
0.111404D-01	-.338333D+01	0.106149D+01	0.162844D+03	0.208615D+01	-.536894D+00	-.124325D-01	0.364493D+01	0.103650D+01
0.134244D-01	-.306241D+01	0.920385D+00	0.148613D+03	0.240403D+01	-.675324D+00	-.175603D-01	0.364493D+01	0.103766D+01
0.157084D-01	-.276508D+01	0.818174D+00	0.135166D+03	0.269086D+01	-.802191D+00	-.233787D-01	0.364493D+01	0.103878D+01
0.178993D-01	-.250265D+01	0.747511D+00	0.123155D+03	0.294029D+01	-.910959D+00	-.295473D-01	0.364493D+01	0.103981D+01
0.200901D-01	-.226199D+01	0.696786D+00	0.112066D+03	0.316750D+01	-.100652D+01	-.362378D-01	0.364493D+01	0.104080D+01
0.222809D-01	-.204197D+01	0.660904D+00	0.101899D+03	0.337493D+01	-.108921D+01	-.434044D-01	0.364493D+01	0.104177D+01
0.244717D-01	-.184110D+01	0.636031D+00	0.926234D+02	0.356466D+01	-.115988D+01	-.510060D-01	0.364493D+01	0.104272D+01
0.280184D-01	-.155224D+01	0.611623D+00	0.793695D+02	0.383893D+01	-.125202D+01	-.641352D-01	0.364493D+01	0.104421D+01
0.315651D-01	-.130470D+01	0.601504D+00	0.673294D+02	0.407627D+01	-.132001D+01	-.781716D-01	0.364493D+01	0.104567D+01
0.351118D-01	-.109479D+01	0.600832D+00	0.563600D+02	0.427973D+01	-.136721D+01	-.929897D-01	0.364493D+01	0.104711D+01
0.413491D-01	-.801226D+00	0.610867D+00	0.409659D+02	0.456754D+01	-.141310D+01	-.120581D+00	0.364493D+01	0.104959D+01
0.475865D-01	-.584529D+00	0.628124D+00	0.295764D+02	0.478221D+01	-.142654D+01	-.149740D+00	0.364493D+01	0.105206D+01
0.547166D-01	-.404462D+00	0.651262D+00	0.201651D+02	0.496039D+01	-.141890D+01	-.184473D+00	0.364493D+01	0.105487D+01
0.618467D-01	-.276906D+00	0.678052D+00	0.131285D+02	0.508385D+01	-.139704D+01	-.220281D+00	0.364493D+01	0.105770D+01
0.778360D-01	-.109827D+00	0.746468D+00	0.295953D+01	0.522845D+01	-.132467D+01	-.302725D+00	0.364493D+01	0.106409D+01
0.954915D-01	-.364650D-01	0.837656D+00	-.224979D+01	0.525523D+01	-.122618D+01	-.395272D+00	0.364493D+01	0.107126D+01
0.114743D+00	-.100300D-01	0.893590D+00	-.511960D+01	0.520669D+01	-.110903D+01	-.495976D+00	0.364493D+01	0.107926D+01
0.135516D+00	-.299230D-02	0.891600D+00	-.674374D+01	0.510643D+01	-.976822D+00	-.603093D+00	0.364493D+01	0.108808D+01
0.157726D+00	-.940403D-03	0.888771D+00	-.802711D+01	0.496503D+01	-.830654D+00	-.714937D+00	0.364493D+01	0.109775D+01
0.181288D+00	0.472374D-03	0.884977D+00	-.926351D+01	0.478279D+01	-.669861D+00	-.829776D+00	0.364493D+01	0.110829D+01
0.206107D+00	0.199939D-02	0.880031D+00	-.104780D+02	0.455677D+01	-.495144D+00	-.945675D+00	0.364493D+01	0.111973D+01
0.232087D+00	0.380747D-02	0.873707D+00	-.116459D+02	0.428422D+01	-.307502D+00	-.106052D+01	0.364493D+01	0.113208D+01
0.259123D+00	0.591990D-02	0.865771D+00	-.127283D+02	0.396338D+01	-.108950D+00	-.117201D+01	0.364493D+01	0.114537D+01
0.287110D+00	0.833876D-02	0.855989D+00	-.136836D+02	0.359383D+01	0.974325D-01	-.127776D+01	0.364493D+01	0.115961D+01
0.315938D+00	0.110242D-01	0.844157D+00	-.144701D+02	0.317664D+01	0.307122D+00	-.137535D+01	0.364493D+01	0.117480D+01
0.345492D+00	0.138891D-01	0.830131D+00	-.150526D+02	0.271461D+01	0.513888D+00	-.146241D+01	0.364493D+01	0.119094D+01
0.375655D+00	0.167762D-01	0.813864D+00	-.154091D+02	0.221221D+01	0.709648D+00	-.153671D+01	0.364493D+01	0.120799D+01
0.406309D+00	0.194515D-01	0.795439D+00	-.155404D+02	0.167555D+01	0.884542D+00	-.159630D+01	0.364493D+01	0.122589D+01
0.437333D+00	0.216252D-01	0.775089D+00	-.154778D+02	0.111221D+01	0.102740D+01	-.163954D+01	0.364493D+01	0.124453D+01
0.468605D+00	0.230130D-01	0.753185D+00	-.152843D+02	0.530855D+00	0.112681D+01	-.166523D+01	0.364493D+01	0.126375D+01
0.500000D+00	0.234398D-01	0.730195D+00	-.150439D+02	-.591519D-01	0.117272D+01	-.167264D+01	0.364493D+01	0.128335D+01
0.531395D+00	0.229972D-01	0.706623D+00	-.148332D+02	-.648270D+00	0.115837D+01	-.166153D+01	0.364493D+01	0.130307D+01
0.562667D+00	0.220505D-01	0.682994D+00	-.146830D+02	-.122692D+01	0.108193D+01	-.163221D+01	0.364493D+01	0.132262D+01
0.593691D+00	0.210102D-01	0.659870D+00	-.145627D+02	-.178545D+01	0.947405D+00	-.158548D+01	0.364493D+01	0.134172D+01
0.624345D+00	0.201692D-01	0.637844D+00	-.143990D+02	-.231454D+01	0.764109D+00	-.152264D+01	0.364493D+01	0.136011D+01
0.654508D+00	0.196641D-01	0.617500D+00	-.141086D+02	-.280580D+01	0.545002D+00	-.144542D+01	0.364493D+01	0.137757D+01
0.684062D+00	0.194727D-01	0.599321D+00	-.136279D+02	-.325240D+01	0.304319D+00	-.135590D+01	0.364493D+01	0.139398D+01
0.712890D+00	0.194781D-01	0.583613D+00	-.129297D+02	-.364950D+01	0.554220D-01	-.125642D+01	0.364493D+01	0.140923D+01
0.740877D+00	0.195447D-01	0.570476D+00	-.120239D+02	-.399442D+01	-.190628D+00	-.114945D+01	0.364493D+01	0.142332D+01
0.767913D+00	0.195654D-01	0.559823D+00	-.109484D+02	-.428664D+01	-.425660D+00	-.103751D+01	0.364493D+01	0.143624D+01
0.793893D+00	0.194903D-01	0.551428D+00	-.975413D+01	-.452750D+01	-.644331D+00	-.923012D+00	0.364493D+01	0.144804D+01
0.818712D+00	0.193019D-01	0.544993D+00	-.849447D+01	-.471989D+01	-.843552D+00	-.808256D+00	0.364493D+01	0.145876D+01
0.842274D+00	0.191324D-01	0.540194D+00	-.721119D+01	-.486780D+01	-.102222D+01	-.695304D+00	0.364493D+01	0.146847D+01
0.864484D+00	0.195728D-01	0.536739D+00	-.589813D+01	-.497549D+01	-.118005D+01	-.585994D+00	0.364493D+01	0.147722D+01
0.885257D+00	0.244860D-01	0.534411D+00	-.432116D+01	-.504434D+01	-.131871D+01	-.481923D+00	0.364493D+01	0.148508D+01

0.904508D+00	0.457403D-01	0.499219D+00	-.182708D+01	-.506807D+01	-.143897D+01	-.384586D+00	0.364493D+01	0.149209D+01
0.922164D+00	0.106669D+00	0.444998D+00	0.252729D+01	-.502990D+01	-.153930D+01	-.295441D+00	0.364493D+01	0.149830D+01
0.938153D+00	0.251748D+00	0.406483D+00	0.112981D+02	-.489369D+01	-.161372D+01	-.216107D+00	0.364493D+01	0.150377D+01
0.945283D+00	0.365527D+00	0.392025D+00	0.175012D+02	-.478231D+01	-.163688D+01	-.181612D+00	0.364493D+01	0.150616D+01
0.952414D+00	0.529722D+00	0.378859D+00	0.259854D+02	-.462316D+01	-.164606D+01	-.148077D+00	0.364493D+01	0.150854D+01
0.958651D+00	0.731793D+00	0.365834D+00	0.365186D+02	-.443191D+01	-.163383D+01	-.119839D+00	0.364493D+01	0.151062D+01
0.964888D+00	0.101222D+01	0.347111D+00	0.511785D+02	-.417490D+01	-.158795D+01	-.929984D-01	0.364493D+01	0.151272D+01
0.968435D+00	0.121653D+01	0.330735D+00	0.618853D+02	-.399254D+01	-.153940D+01	-.785134D-01	0.364493D+01	0.151393D+01
0.971982D+00	0.146132D+01	0.306163D+00	0.739359D+02	-.377885D+01	-.146806D+01	-.647309D-01	0.364493D+01	0.151517D+01
0.975528D+00	0.175180D+01	0.267976D+00	0.875763D+02	-.353035D+01	-.136950D+01	-.517717D-01	0.364493D+01	0.151645D+01
0.977719D+00	0.195665D+01	0.233961D+00	0.973157D+02	-.335727D+01	-.129269D+01	-.442263D-01	0.364493D+01	0.151727D+01
0.979910D+00	0.218361D+01	0.187860D+00	0.108176D+03	-.316677D+01	-.120159D+01	-.370792D-01	0.364493D+01	0.151812D+01
0.982101D+00	0.243483D+01	0.125046D+00	0.120241D+03	-.295640D+01	-.109483D+01	-.303712D-01	0.364493D+01	0.151900D+01
0.984292D+00	0.271187D+01	0.392051D-01	0.133567D+03	-.272308D+01	-.971472D+00	-.241494D-01	0.364493D+01	0.151992D+01
0.986005D+00	0.294701D+01	-.490914D-01	0.144871D+03	-.252234D+01	-.863390D+00	-.196567D-01	0.364493D+01	0.152067D+01
0.987718D+00	0.319847D+01	-.161824D+00	0.156911D+03	-.230307D+01	-.745715D+00	-.155237D-01	0.364493D+01	0.152146D+01
0.989431D+00	0.346544D+01	-.305501D+00	0.169587D+03	-.206277D+01	-.619934D+00	-.117844D-01	0.364493D+01	0.152228D+01
0.991144D+00	0.374577D+01	-.488032D+00	0.182705D+03	-.179872D+01	-.488791D+00	-.847701D-02	0.364493D+01	0.152315D+01
0.992782D+00	0.402276D+01	-.707444D+00	0.195360D+03	-.152156D+01	-.362454D+00	-.575769D-02	0.364493D+01	0.152402D+01
0.993600D+00	0.416285D+01	-.836337D+00	0.201602D+03	-.137342D+01	-.300454D+00	-.457292D-02	0.364493D+01	0.152447D+01
0.994419D+00	0.430288D+01	-.979771D+00	0.207683D+03	-.121855D+01	-.240606D+00	-.351215D-02	0.364493D+01	0.152493D+01
0.995238D+00	0.444175D+01	-.113911D+01	0.213511D+03	-.105676D+01	-.184023D+00	-.258042D-02	0.364493D+01	0.152541D+01
0.996057D+00	0.457810D+01	-.131547D+01	0.218969D+03	-.888247D+00	-.132049D+00	-.178393D-02	0.364493D+01	0.152589D+01
0.996796D+00	0.469772D+01	-.149012D+01	0.223465D+03	-.730619D+00	-.903619D-01	-.118576D-02	0.364493D+01	0.152633D+01
0.997535D+00	0.481278D+01	-.168028D+01	0.227433D+03	-.568094D+00	-.549009D-01	-.705889D-03	0.364493D+01	0.152678D+01
0.998274D+00	0.492183D+01	-.188654D+01	0.230738D+03	-.401251D+00	-.270536D-01	-.347715D-03	0.364493D+01	0.152724D+01
0.999013D+00	0.502341D+01	-.210926D+01	0.233229D+03	-.230938D+00	-.828089D-02	-.114121D-03	0.364493D+01	0.152770D+01
0.999506D+00	0.508634D+01	-.226714D+01	0.234362D+03	-.115780D+00	-.153082D-02	-.285687D-04	0.364493D+01	0.152801D+01
0.100000D+01	0.514476D+01	-.243234D+01	0.235002D+03	0.000000D+00	0.000000D+00	-.475305D-19	0.364493D+01	0.152832D+01

Chapter IV

IV.1 Input-Output Manual for In-Plane Natural Frequency and Mode Number Estimation Program, RCNATIN

This program is written in FORTRAN 77 and allows the interactive estimation of the in-plane natural frequencies and corresponding mode numbers of compliant risers with a planar static configuration without torsion using an asymptotic method described in [4].

Before executing the program the user must make sure that:

- o Devices five and six correspond to input/output from the terminal.
- o Device eight must be associated with the data file containing geometric, structural and hydrodynamic characteristics of the compliant riser created by a previous execution of the data preprocessing program, RCINPUT. This file has a logical record length of 80 characters.
- o Device ten must be associated with the input data file containing the non-dimensional static planar solution created by RCSTAT2D. This file has a logical record length of 132 characters.
- o Device eleven must be associated with an output file with logical record length of 80 characters. This file contains the converged natural frequencies and mode numbers as well as the determinant of the characteristic matrix at a series of frequency points. These natural frequency estimates can be used as inputs for a run of RCLINDY1.

Input Variables [Free Format]

At the beginning of the program the static 2-D solution created from RCSTAT2D is read from device ten. The user is informed about the mean current velocity in the x direction and the maximum non-dimensional static effective tension. If the number of static division points is less than four or greater than the value of MNP (maximum number of allowable points), the program halts execution. If the mean velocity is zero, the program halts execution because the asymptotic theory is no longer valid. Then the geometric, structural and hydrodynamic characteristics of the compliant riser are read from the file associated with device eight. The user has the opportunity to review this data on his terminal and decide either to continue with the program or stop (see [3]).

The user is then asked to input the upper limit of the frequency range and frequency spacing (in rad/s) for which he wishes to evaluate the characteristic determinant. The default lower limit of the frequency range is 0.01 rad/s. The maximum permissible number of frequency points is also displayed. The frequency spacing should be such so that the frequency points are less than the maximum allowable points.

The user is asked to input the normal drag coefficient used in the static solution. Its value together with the mean current speed is then displayed. The program then asks the user to input estimates for λ and c, see [2,3]. These values will be used for the cable approximation of the planar static solution. λ must have the sign of the mean current speed which is also displayed and for small top x (static) displacements, a good estimate for c is $-1/2\lambda$, [3].

The program calculates λ and c using NAG subroutine C05NBF and displays the solution as well as the values of the functions used to determine the solution. These functions should, ideally, be zero. The user is given the opportunity to redo the calculation of λ and c by trying a different initial estimate (input IPP=1), [3]. Then the program evaluates the characteristic frequency determinant at all points in the interval requested. The determinant includes contributions from the fast and slow in-plane dynamic solutions, see [4].

Then the natural frequencies in the specified range are determined. This is done by checking the change of sign in the characteristic frequency determinant. The program then outputs the results.

In the file connected with device eleven the following are printed:

- o Number of natural frequencies in the specified frequency range.
- o Mode numbers and corresponding natural frequency estimate.
- o Two columns of real numbers, the first of which is the frequency (in rad/s) and the second, the corresponding value of the characteristic determinant at this frequency.

IV.2 Sample Run, Input and Output

IV.2.1 Linear Current Excitation

IV.2.1.1 Interactive Session

INPUT

Device 5 = TERMINAL

Device 8 = RCJOA01 DATA A*

Device 10 = RCCL2DRR DATA A*

*Files included in Chapter II.

OUTPUT

Device 6 = TERMINAL

Device 11 = FREQIN DATA A

```
 . T=0.01/0.01 20:54:39
rcnatin rcjoao1 rccl2drr freqin
FI 8 DISK RCJOA01 DATA A ( RECFM FB LRECL 80 BLKSIZE 800
FI 10 DISK RCCL2DRR DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 11 DISK FREQIN DATA A ( RECFM F LRECL 80
GLOBAL TXTLIB VFORTLIB CMSLIB NAG1 NAG2
LOAD RCNATIN ( START
EXECUTION BEGINS...
MNP=151
2-D STATIC SOLUTION FROM DEVICE 10
NP = 76
MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =0.129000D+01
2-D STATIC SOLUTION SUCCESFULLY READ
MAXIMUM STATIC EFFECTIVE TENSION/WA*L = 0.3089D+02

INPUT
THE MAXIMUM FREQUENCY AND FREQUENCY SPACING (IN RAD/S) FOR
WHICH YOU WISH TO EVALUATE THE DETERMINANT OF MATRIX P
MAXIMUM PERMISSIBLE NUMBER OF FREQUENCY POINTS IS = 300
?
2.,.01
INPUT NORMAL DRAG COEFFICIENT USED IN STATIC SOLUTION
?
1.
MEAN CURRENT SPEED =0.129000D+01
NORMAL DRAG COEFFICIENT =0.100000D+01
INPUT ESTIMATES OF LAMBDA AND C
LAMBDA MUST HAVE THE SIGN OF MEAN CURRENT SPEED
 FOR SMALL XTOP A GOOD ESTIMATE OF C IS -0.5*LAMBDA
?
3.,-1.5
SOLUTION FOR CABLE ...
IFAIL = 0
LAMBDA =0.304294D+01
C      =-.152147D+01
VALUE OF FUNCTION FOR HORIZONTAL DISPLACEMENT =0.145726D-15
VALUE OF FUNCTION FOR VERTICAL DISPLACEMENT =-.693889D-16
DO YOU WISH TO TRY A DIFFERENT INITIAL LAMDA, OR C,
IF YES INPUT 1
?
2
CABLE APPROXIMATION
LAMBDA =0.304294D+01 C =-.152147D+01 TENSION =0.767988D+04
R; T=0.95/1.13 20:55:31
cp spool console stop close
```

IV.2.1.2 FREQIN DATA A

```
CHINESE LANTERN FROM JOAO,   APRIL 1985

ESTIMATES OF IN-PLANE NATURAL FREQUENCIES FOR A 2-D STATIC CONFIGURATION

NUMBER OF NATURAL FREQUENCIES IN SPECIFIED RANGE:   6
MODE =    1
NATURAL FREQUENCY BETWEEN
0.470000D+00 AND 0.480000D+00 RAD/SEC
****************************************
MODE =    2
NATURAL FREQUENCY BETWEEN
0.780000D+00 AND 0.790000D+00 RAD/SEC
****************************************
MODE =    3
NATURAL FREQUENCY BETWEEN
0.108000D+01 AND 0.109000D+01 RAD/SEC
****************************************
MODE =    4
NATURAL FREQUENCY BETWEEN
0.137000D+01 AND 0.138000D+01 RAD/SEC
****************************************
MODE =    5
NATURAL FREQUENCY BETWEEN
0.166000D+01 AND 0.167000D+01 RAD/SEC
****************************************
MODE =    6
NATURAL FREQUENCY BETWEEN
0.194000D+01 AND 0.195000D+01 RAD/SEC
****************************************

FREQUENCY (RAD/SEC)  DETERMINANT
     0.100000D-01     -.845239D+07
     0.200000D-01     -.169912D+08
     0.300000D-01     -.257024D+08
     0.400000D-01     -.346708D+08
     0.500000D-01     -.439798D+08
     0.600000D-01     -.537102D+08
     0.700000D-01     -.639399D+08
     0.800000D-01     -.747423D+08
     0.900000D-01     -.861858D+08
     0.100000D+00     -.983321D+08
     0.110000D+00     -.111234D+09
     0.120000D+00     -.124936D+09
     0.130000D+00     -.139470D+09
     0.140000D+00     -.154853D+09
     0.150000D+00     -.171088D+09
     0.160000D+00     -.188160D+09
     0.170000D+00     -.206032D+09
     0.180000D+00     -.224648D+09
     0.190000D+00     -.243926D+09
     0.200000D+00     -.263758D+09
     0.210000D+00     -.284010D+09
     0.220000D+00     -.304517D+09
     0.230000D+00     -.325088D+09
     0.240000D+00     -.345500D+09
     0.250000D+00     -.365501D+09
```

0.260000D+00	-.384809D+09
0.270000D+00	-.403118D+09
0.280000D+00	-.420093D+09
0.290000D+00	-.435379D+09
0.300000D+00	-.448600D+09
0.310000D+00	-.459367D+09
0.320000D+00	-.467281D+09
0.330000D+00	-.471937D+09
0.340000D+00	-.472933D+09
0.350000D+00	-.469878D+09
0.360000D+00	-.462394D+09
0.370000D+00	-.450128D+09
0.380000D+00	-.432761D+09
0.390000D+00	-.410013D+09
0.400000D+00	-.381652D+09
0.410000D+00	-.347504D+09
0.420000D+00	-.307459D+09
0.430000D+00	-.261481D+09
0.440000D+00	-.209611D+09
0.450000D+00	-.151979D+09
0.460000D+00	-.888032D+08
0.470000D+00	-.203980D+08
0.480000D+00	0.528234D+08
0.490000D+00	0.130348D+09
0.500000D+00	0.211562D+09
0.510000D+00	0.295753D+09
0.520000D+00	0.382112D+09
0.530000D+00	0.469739D+09
0.540000D+00	0.557647D+09
0.550000D+00	0.644776D+09
0.560000D+00	0.729994D+09
0.570000D+00	0.812118D+09
0.580000D+00	0.889921D+09
0.590000D+00	0.962148D+09
0.600000D+00	0.102753D+10
0.610000D+00	0.108482D+10
0.620000D+00	0.113277D+10
0.630000D+00	0.117020D+10
0.640000D+00	0.119598D+10
0.650000D+00	0.120906D+10
0.660000D+00	0.120849D+10
0.670000D+00	0.119347D+10
0.680000D+00	0.116332D+10
0.690000D+00	0.111750D+10
0.700000D+00	0.105569D+10
0.710000D+00	0.977720D+09
0.720000D+00	0.883648D+09
0.730000D+00	0.773736D+09
0.740000D+00	0.648469D+09
0.750000D+00	0.508562D+09
0.760000D+00	0.354957D+09
0.770000D+00	0.188828D+09
0.780000D+00	0.115740D+08
0.790000D+00	-.175189D+09
0.800000D+00	-.369637D+09
0.810000D+00	-.569752D+09

0.820000D+00	-.773342D+09
0.830000D+00	-.978059D+09
0.840000D+00	-.118143D+10
0.850000D+00	-.138087D+10
0.860000D+00	-.157372D+10
0.870000D+00	-.175730D+10
0.880000D+00	-.192891D+10
0.890000D+00	-.208586D+10
0.900000D+00	-.222556D+10
0.910000D+00	-.234550D+10
0.920000D+00	-.244334D+10
0.930000D+00	-.251688D+10
0.940000D+00	-.256418D+10
0.950000D+00	-.258352D+10
0.960000D+00	-.257348D+10
0.970000D+00	-.253296D+10
0.980000D+00	-.246121D+10
0.990000D+00	-.235784D+10
0.100000D+01	-.222285D+10
0.101000D+01	-.205665D+10
0.102000D+01	-.186008D+10
0.103000D+01	-.163438D+10
0.104000D+01	-.138123D+10
0.105000D+01	-.110274D+10
0.106000D+01	-.801388D+09
0.107000D+01	-.480084D+09
0.108000D+01	-.142086D+09
0.109000D+01	0.209007D+09
0.110000D+01	0.569294D+09
0.111000D+01	0.934606D+09
0.112000D+01	0.130056D+10
0.113000D+01	0.166259D+10
0.114000D+01	0.201604D+10
0.115000D+01	0.235616D+10
0.116000D+01	0.267824D+10
0.117000D+01	0.297759D+10
0.118000D+01	0.324968D+10
0.119000D+01	0.349014D+10
0.120000D+01	0.369489D+10
0.121000D+01	0.386013D+10
0.122000D+01	0.398245D+10
0.123000D+01	0.405886D+10
0.124000D+01	0.408688D+10
0.125000D+01	0.406454D+10
0.126000D+01	0.399046D+10
0.127000D+01	0.386387D+10
0.128000D+01	0.368464D+10
0.129000D+01	0.345332D+10
0.130000D+01	0.317112D+10
0.131000D+01	0.283995D+10
0.132000D+01	0.246241D+10
0.133000D+01	0.204177D+10
0.134000D+01	0.158193D+10
0.135000D+01	0.108744D+10
0.136000D+01	0.563414D+09
0.137000D+01	0.154948D+08

0.138000D+01	-.550190D+09
0.139000D+01	-.112711D+10
0.140000D+01	-.170838D+10
0.141000D+01	-.228688D+10
0.142000D+01	-.285529D+10
0.143000D+01	-.340623D+10
0.144000D+01	-.393230D+10
0.145000D+01	-.442622D+10
0.146000D+01	-.488090D+10
0.147000D+01	-.528954D+10
0.148000D+01	-.564576D+10
0.149000D+01	-.594362D+10
0.150000D+01	-.617780D+10
0.151000D+01	-.634361D+10
0.152000D+01	-.643711D+10
0.153000D+01	-.645517D+10
0.154000D+01	-.639552D+10
0.155000D+01	-.625682D+10
0.156000D+01	-.603871D+10
0.157000D+01	-.574180D+10
0.158000D+01	-.536775D+10
0.159000D+01	-.491920D+10
0.160000D+01	-.439985D+10
0.161000D+01	-.381435D+10
0.162000D+01	-.316834D+10
0.163000D+01	-.246837D+10
0.164000D+01	-.172183D+10
0.165000D+01	-.936886D+09
0.166000D+01	-.122420D+09
0.167000D+01	0.712103D+09
0.168000D+01	0.155672D+10
0.169000D+01	0.240110D+10
0.170000D+01	0.323465D+10
0.171000D+01	0.404664D+10
0.172000D+01	0.482637D+10
0.173000D+01	0.556328D+10
0.174000D+01	0.624709D+10
0.175000D+01	0.686794D+10
0.176000D+01	0.741653D+10
0.177000D+01	0.788426D+10
0.178000D+01	0.826335D+10
0.179000D+01	0.854693D+10
0.180000D+01	0.872921D+10
0.181000D+01	0.880553D+10
0.182000D+01	0.877245D+10
0.183000D+01	0.862786D+10
0.184000D+01	0.837098D+10
0.185000D+01	0.800246D+10
0.186000D+01	0.752436D+10
0.187000D+01	0.694017D+10
0.188000D+01	0.625482D+10
0.189000D+01	0.547460D+10
0.190000D+01	0.460717D+10
0.191000D+01	0.366145D+10
0.192000D+01	0.264754D+10
0.193000D+01	0.157664D+10

0.194000D+01	0.460907D+09
0.195000D+01	-.686665D+09
0.196000D+01	-.185240D+10
0.197000D+01	-.302208D+10
0.198000D+01	-.418116D+10
0.199000D+01	-.531488D+10
0.200000D+01	-.640852D+10
0.201000D+01	-.744752D+10

Chapter V

V.1 Input-Output Manual for the In-Plane Linear Eigenproblem Solution Program, RCLINDY1

This program is written in FORTRAN 77 and allows the interactive solution of the in-plane linear eigenproblem for a compliant riser with a planar static configuration without torsion as described in [4].

Before executing the program the user must make sure that:

- o Devices five and six correspond to input/output from the terminal.
- o Device eight must be associated with the data file containing geometric, structural and hydrodynamic characteristics of the compliant riser created by a previous execution of the data preprocessing program RCINPUT. This file has a logical record length of 80 characters.
- o Device nine must be associated with an output data file with logical record length of 132 characters which upon completion of the program contains a complete list of the input, initial approximation and the converged solution of the problem.
- o Device ten must be associated with the input data file containing the non-dimensional static planar solution created by RCSTAT2D. This file has a logical record length of 132 characters.
- o Device eleven must be associated with an output file with logical record length of 117 characters. This file contains the converged solution of the problem in a concise form appropriate for use in the preparation of illustrations and/or as an input to RCLINDY1 from device twelve in a subsequent execution of this program.

o Device twelve may be associated with an input file containing an initial approximate solution of an in-plane linear eigenproblem, resulting from a previous execution of RCLINDY1. This option can be used if greater accuracy is needed for the solution of the problem. Device twelve may be associated with a dummy file name if this option is not used.

Input Variables [Free Format]

At the beginning of the program the static 2-D solution created from RCSTAT2D is read from device ten. The user is informed about the mean current velocity in the x direction and the maximum non-dimensional static effective tension. If the number of static discretization points is less than four or greater than the value of MNP (maximum number of allowable points), the program halts execution. If the mean velocity is zero, the program halts execution because the asymptotic theory is not valid for this case. Then the geometric, structural and hydrodynamic characteristics of the compliant riser are read from the file associated with device eight. The user has the opportunity to review this data on his terminal and decide either to continue with the program or stop, see [3].

Next, the user is asked whether he wants the initial approximation to be calculated using asymptotics (input IEXIST=0) or whether he wants to use the option to read an initial approximation from device twelve created by a previous run of RCLINDY1 (input IEXIST=1).

Case 1 (IEXIST = 0)

The user is asked to input the initial increment of the continuation parameter $\delta\varepsilon$ (condition $0<\delta\varepsilon\leq 1$). If no continuation is required, then use $\delta\varepsilon=1$.

If continuation is required, then $\delta\varepsilon=0.1$ will usually suffice. For large changes between initial and final problem, a smaller value of $\delta\varepsilon$, e.g. 0.05 or 0.025 might be necessary. The user is asked to input the normal drag coefficient used in the static solution. Its value, together with the mean current speed, is subsequently displayed. The program asks the user to input estimates for λ and c [2,3]. These values will be used for the cable approximation of the planar static solution. λ must have the sign of the mean current speed, which is also displayed and for small top x displacement, a good estimate for c is $-(1/2)\lambda$, [3]. The program calculates λ and c and displays the solution as well as the values of the functions used to determine the solution. These functions should, ideally, be zero. The user is given the opportunity to redo the calculation of λ and c by trying a different initial estimate (input IPP=1), [3]. Next, the user is asked to supply an initial guess for the natural frequency in rad/s. The information for the approximate natural frequencies is obtained by running RCNATIN program which provides an estimate of the natural frequencies and their corresponding mode number.

During the calculation of the approximate natural frequency the user is supplied with information about the determinant of the characteristic matrix. Ideally this should become zero. The user may ignore the value of IFAIL printed in this case. Vanishing of the determinant of the characteristic matrix allows the program to calculate the approximate natural frequency and display its value. Then the user is given the following alternatives:

- Input 1 if he wants to redo the calculation. This may be used when the converged frequency does not correspond to the mode which the user wants to evaluate.

- o Input 2 if he chooses to stop.
- o Input any other integer to continue with the program.

Subsequently, the user is asked to input the mode number corresponding to the approximate natural frequency, as determined from the RCNATIN program.

Next a linear system of five equations is solved to determine the constant coefficients multiplying the various terms composing the overall solution allowing us to obtain the initial approximation [4]. The values of the above constant coefficients are displayed on the screen. In addition, the sixth equation is also evaluated for the values of the coefficients determined above. Ideally it should be zero.

The initial approximation is then evaluated and the orthonormalizing constant used for p and q as well as the fourth boundary condition at s=0 are printed. The user is then asked if he wants to review the initial approximation by displaying it in his terminal. If he chooses to do so, he should input 1. Subsequently the approximate solution is printed in the file associated with the device nine. The following quantities are printed:

- o Number of discretization points NP
- o Natural frequency
- o Order of point (starting from the lower end)
- o Non-dimensional arc length
- o Non-dimensional dynamic effective tension, T_1
- o Non-dimensional shear force in the $\vec{\xi}$ direction, Q_1^{ξ}
- o Non-dimensional component of rate of rotation about $\vec{\eta}$,Ω_1^{η}
- o Euler angle ϕ_1

- o Non-dimensional displacement p
- o Non-dimensional displacement q
- o Non-dimensional natural frequency.

Subsequently, the program prints the maximum of the absolute value of the initial (ε=0) non-dimensional component of $\vec{\Omega}_1$ in the $\vec{\eta}$ direction. This number is used to estimate a reasonable tolerance for convergence of iterations. The user is requested to input a tolerance as a fraction of this number; e.g., 0.01 for 1% tolerance or better for all quantities of interest. Typically Ω_1^η will be determined with an accuracy a little better than the above fraction and all other quantities will be even more accurate.

The user is given the opportunity to stop the program at this point if he wishes. He should input zero if he wants to stop.

Case 2 (IEXIST = 1)

In this case an initial approximation to the solution for ε=1 is available from a previous run of RCLINDY1. The program reads the information from the previous run concerning the number of subdivision points, NP, the mode number and the corresponding natural frequency. If the number of subdivision points is greater than MNP, the program stops execution.

Then the user has the option to review the initial approximation by displaying it in his terminal. The assumed boundary condition for Ω_1^η at the lower end of the riser [4] is also printed.

Subsequently, the program prints the maximum of the absolute value of the initial component of $\vec{\Omega}_1$ in the $\vec{\eta}$ direction. This number is used to estimate a reasonable tolerance for the convergence of iterations. The user is requested to input a tolerance as a fraction of this number e.g. 0.01 for 1% tolerance or better for all quantities of interest. Typically Ω_1^η will be determined with an accuracy a little better than the above fraction and all other quantities will be even more accurate. Subsequently the user is given the opportunity to halt the execution of the program.

After the initial approximation is fully defined the program enters NAG subroutine DO2RAF, which provides the iterative numerical solution to the problem. The manual of this subroutine is included in Chapter 10. The input value of IFAIL is 111, indicating that the soft failure option with error message and monitoring information printing has been selected. Error messages are directed to device six.

Once the execution of DO2RAF is completed, the current value of IFAIL is printed on the terminal. For an explanation of this parameter, see NAG manual for DO2RAF, Chapter 10. Only if IFAIL=0 or IFAIL=4, the execution of the program continues with printout of the riser characteristics and the final solution of the problem. Otherwise the program stops. When IFAIL≠0, the user should consult the manual quoted above for interpretation of the results and a possible course of action. If IFAIL=0 or 4, the riser characteristics and the final solution of the problem are printed in the file associated with device nine. For the riser characteristics the format used in the program RCSTAT2D is also used here. This is described in [3] (pp. 23-25).

Following, the non-dimensional in-plane solution is written in the file associated with device nine. The mode number, natural frequency and final number of points NP at which the solution is available is printed first.

Then the following data is printed for I=1 to NP: s, T_1, Q_1^{ξ}, Ω_1^{η}, ϕ_1, p, q, σ with

FORMAT (8(1X,D10.4)).

Next the maximum (non-dimensional) estimated errors of T_1, Q_1^{ξ}, Ω_1^{η}, ϕ_1, p, q, σ provided by the NAG subroutine D02RAF are printed. Subsequently, the following data is written in the file associated with device eleven:

MODE, NP, SIGMAD, XTOP, YTOP = Mode number, number of points at which converged solution is available, dimensional natural frequency (in rad/s) and x and y static displacements at the top with

FORMAT (1X,I2,1X,I3,3 (1X,D10.4))

and for I=1 to NP: the non-dimensional

s, T_1, Q_1^{ξ}, Ω_1^{η}, ϕ_1, p, q, σ and the dimensional current velocity $V_c(s)$ with

FORMAT (9(1X,D12.6)).

The data written in the file associated with device eleven, due to their simple form, can be used very easily as input to plotting programs. In addition, this data is useful in subsequent runs of RCLINDY1, if such an option is selected, as explained before.

V.2 Sample Run, Input and Output

V.2.1 Linear Current Excitation

V.2.1.1 Interactive Session

INPUT

Device 5 = TERMINAL

Device 8 = RCJOA01 DATA A*

Device 10 = RCCL2DRR DATA A*

Device 12 = DUMMY DATA A

*Files included in Chapter II.

OUTPUT

Device 6 = TERMINAL

Device 9 = INPLA1 DATA A

Device 11 = INPLA1A DATA A

```
R; T=0.01/0.01 20:26:33
rclindy1 rcjoao1 inpla1 rccl2drr inpla1a dummy
FI 8 DISK RCJOAO1 DATA A ( RECFM FB LRECL 80 BLKSIZE 800
FI 9 DISK INPLA1 DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 10 DISK RCCL2DRR DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 11 DISK INPLA1A DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
FI 12 DISK DUMMY DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
GLOBAL TXTLIB VFORTLIB CMSLIB NAG1 NAG2
LOAD RCLINDY1 ( START
EXECUTION BEGINS...
MNP=151
2-D STATIC SOLUTION FROM DEVICE 10
NP = 76
MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S .VM =0.129000D+01
2-D STATIC SOLUTION SUCCESFULLY READ
MAXIMUM STATIC EFFECTIVE TENSION/WA*L = 0.3089D+02
DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS
IF YES INPUT 1 , IF NO INPUT 0
?
0
INPUT 1 IF YOU WISH TO READ INITIAL APPROXIMATION,
        CREATED BY A PREVIOUS RUN OF THIS PROGRAM
ELSE INPUT 0 (AN INITIAL APPROXIMATION WILL BE CALCULATED LOCALLY)
?
0
INPUT INITIAL INCREMENT OF CONTINUATION PARAMETER DELEPS
IF NO CONTINUATION IS REQUIRED INPUT DELEPS = 1.D0
IF CONTINUATION IS REQUIRED THEN 0.D0 < DELEPS < 1.D0
RECOMMENDATION :
USUALLY DELEPS = 0.1D0 WILL SUFFICE
FOR LARGE CHANGES BETWEEN INITIAL AND FINAL PROBLEM
A SMALLER VALUE OF DELEPS, E.G. 0.05D0 OR 0.025D0 MIGHT BE
NECESSARY
?
.1
INPUT NORMAL DRAG COEFFICIENT USED IN STATIC SOLUTION
?
1.
MEAN CURRENT SPEED =0.129000D+01
NORMAL DRAG COEFFICIENT =0.100000D+01
INPUT ESTIMATES OF LAMBDA AND C
LAMBDA MUST HAVE THE SIGN OF MEAN CURRENT SPEED
 FOR SMALL XTOP A GOOD ESTIMATE OF C IS -0.5*LAMBDA
?
3.,-1.5
SOLUTION FOR CABLE ...
IFAIL = 0
LAMBDA =0.304294D+01
C      =-.152147D+01
VALUE OF FUNCTION FOR HORIZONTAL DISPLACEMENT =0.145726D-15
VALUE OF FUNCTION FOR VERTICAL DISPLACEMENT =-.693889D-16
DO YOU WISH TO TRY A DIFFERENT INITIAL LAMDA, C, OR TOLERANCE
IF YES INPUT 1
?
2
CABLE APPROXIMATION
LAMBDA =0.304294D+01 C =-.152147D+01 TENSION =0.767988D+04
 INPUT INITIAL GUESS FOR SIGMA IN RAD/S
?
.49
```

```
IFAIL FOR THE DETERMINANT OF P = 0
DET =0.130348D+09
IFAIL FOR THE DETERMINANT OF P = 0
DET =0.130348D+09
IFAIL FOR THE DETERMINANT OF P = 0
DET =0.543073D+07
IFAIL FOR THE DETERMINANT OF P = 0
DET =0.266538D+06
IFAIL FOR THE DETERMINANT OF P = 0
DET =0.645052D+03
IFAIL FOR THE DETERMINANT OF P = 0
DET =0.771932D-01
IFAIL FOR THE DETERMINANT OF P = 1
DET =0.000000D+00
 IFAIL FOR APPROXIMATE EVALUATION OF SIGMA IS          0
THE DETERMINANT IS = 0.0000D+00
THE CONVERGED SIGMA IS 0.4729D+00
INPUT 1 IF YOU WANT TO REDO THE CALCULATION
INPUT 2 IF YOU WANT TO STOP
?
3
 INPUT MODE NUMBER CORRESPONDING TO ABOVE APPROXIMATE SIGMA
?
1
 IFAIL FOR THE EVALUATION OF CONSTANT COEFFICIENTS IS          0
CONSTANT COEFFICIENTS ARE:
A1 = 1.00          B1 =-.2076D+01
G1 =-.2251D-02  D1 =-.2251D-02
C1 =-.1516D-15  C2 =0.5535D+00
SIXTH EQUATION = -.1102D-13
THE ORTHONORMALIZING CONSTANT FOR THE APPROXIMATE
SOLUTION IS SQRT(A) = 0.3265D+01
THE BOUNDARY CONDITION AT S=0 IS OMEGAETA(0) = 0.6791D+03
DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION
IF YES INPUT 1
?
2
MAXIMUM ABSOLUTE VALUE OF N-D OMEGA ETA IS =0.679078D+03
THIS NUMBER CAN BE USED TO ESTIMATE
A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS
INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE
E.G. INPUT 0.01 FOR 1% ACCURACY
?
.01
 IF YOU WANT TO STOP INPUT 0
?
1

DO2RAF MONITORING INFORMATION

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =    76
  CORRECTION NUMBER     0   RESIDUAL SHOULD BE .LE.  1.00D+00
   ITERATION NUMBER     0   RESIDUAL =  2.33D+01
    SQUARED NORM OF CORRECTION =  1.10D+05
    SQUARED NORM OF GRADIENT   =  6.84D+05
    SCALAR PRODUCT OF CORRECTION AND GRADIENT =  5.43D+02
   ITERATION NUMBER     1   RESIDUAL =  1.28D-02

 CONTINUATION PARAMETER EPSILON =  2.00D-01   DELEPS =  2.00D-01
```

```
MONITORING NEWTON ITERATION
 NUMBER OF POINTS IN CURRENT MESH =    76
 CORRECTION NUMBER     O   RESIDUAL SHOULD BE .LE.  1.00D+00
  ITERATION NUMBER     O   RESIDUAL =  2.17D-03

CONTINUATION PARAMETER EPSILON =  6.000D-01   DELEPS =  4.00D-01

MONITORING NEWTON ITERATION
 NUMBER OF POINTS IN CURRENT MESH =    76
 CORRECTION NUMBER     O   RESIDUAL SHOULD BE .LE.  1.00D+00
  ITERATION NUMBER     O   RESIDUAL =  3.18D-02

CONTINUATION PARAMETER EPSILON =  1.00D+00   DELEPS =  8.00D-01

MONITORING NEWTON ITERATION
 NUMBER OF POINTS IN CURRENT MESH =    76
 CORRECTION NUMBER     O   RESIDUAL SHOULD BE .LE.  6.79D-04
  ITERATION NUMBER     O   RESIDUAL =  3.71D-01
   SQUARED NORM OF CORRECTION =  5.71D+02
   SQUARED NORM OF GRADIENT    =  6.85D-02
   SCALAR PRODUCT OF CORRECTION AND GRADIENT =  1.37D-01
  ITERATION NUMBER     1   RESIDUAL =  2.79D-04

MESH SELECTION
 NUMBER OF NEW POINTS   9

MONITORING NEWTON ITERATION
 NUMBER OF POINTS IN CURRENT MESH =    85
 CORRECTION NUMBER     O   RESIDUAL SHOULD BE .LE.  6.79D-04
  ITERATION NUMBER     O   RESIDUAL =  7.03D-01
   SQUARED NORM OF CORRECTION =  5.35D+00
   SQUARED NORM OF GRADIENT    =  1.02D+01
   SCALAR PRODUCT OF CORRECTION AND GRADIENT =  4.95D-01
  ITERATION NUMBER     1   RESIDUAL =  3.61D-07

MESH SELECTION
 NUMBER OF NEW POINTS   O

CORRECTION NUMBER     O   ESTIMATED MAXIMUM ERROR =  1.64D+00
ESTIMATED ERROR BY COMPONENTS
  4.87D-02  4.25D-02  1.64D+00  3.75D-02  4.72D-03  3.10D-03  1.92D-02
IFAIL =  O
R; T=2.88/3.38 20:29:45
cp spool console stop close
```

V.2.1.2 INPLA1 DATA A

INITIAL CONDITION FOR EPS=0. AND NP = 76 POINTS, NATURAL FREQUENCY = 0.4729D+00 RAD/SEC

I	ARC	TENSION	SHEAR XI	OMEGA ETA	PHI1	P	Q	SIGMA
1	0.000000D+00	0.816109D+01	0.367700D+01	0.679078D+03	-.256387D-14	0.425061D-17	0.637592D-16	0.538535D+01
2	0.986636D-03	0.733677D+01	0.484345D+01	0.647797D+03	0.670003D+00	0.141105D-07	0.144334D-03	0.538535D+01
3	0.246464D-02	0.614038D+01	0.615942D+01	0.559777D+03	0.155819D+01	0.101846D-05	0.155302D-02	0.538535D+01
4	0.394265D-02	0.512495D+01	0.533924D+01	0.483255D+03	0.232471D+01	0.483647D-05	0.421723D-02	0.538535D+01
5	0.558056D-02	0.427882D+01	0.454522D+01	0.410586D+03	0.305205D+01	0.143182D-04	0.842924D-02	0.538535D+01
6	0.721847D-02	0.365796D+01	0.385141D+01	0.348662D+03	0.366972D+01	0.311810D-04	0.137725D-01	0.538535D+01
7	0.885637D-02	0.320548D+01	0.326220D+01	0.296549D+03	0.419420D+01	0.570979D-04	0.200768D-01	0.538535D+01
8	0.111404D-01	0.277024D+01	0.262022D+01	0.236655D+03	0.479614D+01	0.111065D-03	0.302035D-01	0.538535D+01
9	0.134244D-01	0.249366D+01	0.210211D+01	0.188351D+03	0.527525D+01	0.188785D-03	0.415974D-01	0.538535D+01
10	0.157084D-01	0.232074D+01	0.167533D+01	0.149822D+03	0.565653D+01	0.293039D-03	0.540004D-01	0.538535D+01
11	0.178993D-01	0.221849D+01	0.134627D+01	0.120239D+03	0.594881D+01	0.420136D-03	0.666549D-01	0.538535D+01
12	0.200901D-01	0.215659D+01	0.108287D+01	0.964709D+02	0.618338D+01	0.575518D-03	0.799020D-01	0.538535D+01
13	0.222809D-01	0.212103D+01	0.865964D+00	0.773226D+02	0.637150D+01	0.760675D-03	0.936249D-01	0.538535D+01
14	0.244717D-01	0.210284D+01	0.695431D+00	0.621546D+02	0.652218D+01	0.976891D-03	0.107729D+00	0.538535D+01
15	0.280184D-01	0.209467D+01	0.502107D+00	0.434895D+02	0.670460D+01	0.139558D-02	0.131181D+00	0.538535D+01
16	0.315651D-01	0.210172D+01	0.314968D+00	0.299003D+02	0.683067D+01	0.190264D-02	0.155189D+00	0.538535D+01
17	0.351118D-01	0.211700D+01	0.225477D+00	0.204601D+02	0.691670D+01	0.250150D-02	0.179578D+00	0.538535D+01
18	0.413491D-01	0.215181D+01	0.134957D+00	0.958401D+01	0.700267D+01	0.378616D-02	0.223028D+00	0.538535D+01
19	0.475865D-01	0.218909D+01	0.822325D-01	0.290324D+01	0.703625D+01	0.537778D-02	0.266832D+00	0.538535D+01
20	0.547166D-01	0.223106D+01	0.476954D-01	-.169761D+01	0.703674D+01	0.758883D-02	0.317008D+00	0.538535D+01
21	0.618467D-01	0.227260D+01	0.263699D-01	-.455590D+01	0.701205D+01	0.102338D-01	0.367070D+00	0.538535D+01
22	0.778360D-01	0.236559D+01	0.147524D-01	-.877965D+01	0.690001D+01	0.178239D-01	0.478208D+00	0.538535D+01
23	0.954915D-01	0.246676D+01	0.752016D-02	-.124492D+02	0.671044D+01	0.290400D-01	0.598075D+00	0.538535D+01
24	0.114743D+00	0.257517D+01	0.103262D-01	-.161994D+02	0.643483D+01	0.449142D-01	0.724019D+00	0.538535D+01
25	0.135516D+00	0.268852D+01	0.104318D-01	-.202518D+02	0.605611D+01	0.666107D-01	0.852684D+00	0.538535D+01
26	0.157726D+00	0.280226D+01	0.106993D-01	-.246694D+02	0.555834D+01	0.953877D-01	0.979823D+00	0.538535D+01
27	0.181288D+00	0.291017D+01	0.109702D-01	-.295053D+02	0.492065D+01	0.132543D+00	0.110024D+01	0.538535D+01
28	0.206107D+00	0.300242D+01	0.110852D-01	-.346935D+02	0.412455D+01	0.179289D+00	0.120767D+01	0.538535D+01
29	0.232087D+00	0.306624D+01	0.108783D-01	-.401361D+02	0.315204D+01	0.236589D+00	0.129475D+01	0.538535D+01
30	0.259123D+00	0.308457D+01	0.100223D-01	-.455718D+02	0.199087D+01	0.304879D+00	0.135311D+01	0.538535D+01
31	0.287110D+00	0.303583D+01	0.808126D-02	-.505233D+02	0.639462D+00	0.383734D+00	0.137362D+01	0.538535D+01
32	0.315938D+00	0.289406D+01	0.454131D-02	-.541976D+02	-.883430D+00	0.471432D+00	0.134691D+01	0.538535D+01
33	0.345492D+00	0.263045D+01	-.994640D-03	-.554670D+02	-.252672D+01	0.564527D+00	0.126447D+01	0.538535D+01
34	0.375655D+00	0.221723D+01	-.849673D-02	-.530004D+02	-.419559D+01	0.657584D+00	0.112023D+01	0.538535D+01
35	0.406309D+00	0.163440D+01	-.171634D-01	-.456343D+02	-.574774D+01	0.743296D+00	0.912648D+00	0.538535D+01
36	0.437333D+00	0.879118D+00	-.253162D-01	-.329542D+02	-.700649D+01	0.813218D+00	0.646842D+00	0.538535D+01
37	0.468605D+00	-.252697D-01	-.308184D-01	-.158280D+02	-.779686D+01	0.859206D+00	0.335834D+00	0.538535D+01
38	0.500000D+00	-.102540D+01	-.319792D-01	0.351253D+01	-.799606D+01	0.875272D+00	-.405040D-15	0.538535D+01
39	0.531395D+00	-.204428D+01	-.284498D-01	0.220777D+02	-.757630D+01	0.859206D+00	-.335834D+00	0.538535D+01
40	0.562667D+00	-.299771D+01	-.214453D-01	0.371820D+02	-.661465D+01	0.813218D+00	-.646842D+00	0.538535D+01
41	0.593691D+00	-.381452D+01	-.130617D-01	0.473360D+02	-.526319D+01	0.743296D+00	-.912648D+00	0.538535D+01
42	0.624345D+00	-.445157D+01	-.522549D-02	0.524496D+02	-.369784D+01	0.657584D+00	-.112023D+01	0.538535D+01
43	0.654508D+00	-.489741D+01	0.959160D-03	0.534017D+02	-.207471D+01	0.564527D+00	-.126447D+01	0.538535D+01
44	0.684062D+00	-.516620D+01	0.523392D-02	0.514282D+02	-.508355D+00	0.471432D+00	-.134691D+01	0.538535D+01
45	0.712890D+00	-.528712D+01	0.786335D-02	0.476792D+02	0.930028D+00	0.383734D+00	-.137362D+01	0.538535D+01
46	0.740877D+00	-.529456D+01	0.929419D-02	0.430250D+02	0.220421D+01	0.304879D+00	-.135311D+01	0.538535D+01
47	0.767913D+00	-.522140D+01	0.995628D-02	0.380425D+02	0.330207D+01	0.236589D+00	-.129475D+01	0.538535D+01
48	0.793893D+00	-.509561D+01	0.101649D-01	0.330682D+02	0.422638D+01	0.179289D+00	-.120767D+01	0.538535D+01
49	0.818712D+00	-.493935D+01	0.101529D-01	0.282956D+02	0.498760D+01	0.132543D+00	-.110024D+01	0.538535D+01
50	0.842274D+00	-.476898D+01	0.100135D-01	0.237939D+02	0.560117D+01	0.953877D-01	-.979823D+00	0.538535D+01
51	0.864484D+00	-.459677D+01	0.987890D-02	0.196380D+02	0.608260D+01	0.666107D-01	-.852684D+00	0.538535D+01
52	0.885257D+00	-.443013D+01	0.990369D-02	0.157762D+02	0.645094D+01	0.449142D-01	-.724019D+00	0.538535D+01
53	0.904508D+00	-.427423D+01	0.723769D-02	0.121583D+02	0.671976D+01	0.290403D-01	-.598078D+00	0.538535D+01

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54 0.922164D+00 -.413167D+01 0.144417D-01 0.859149D+01 0.690519D+01 0.178239D-01 -.478208D+00 0.538535D+01
55 0.938153D+00 -.400281D+01 0.261773D-01 0.443638D+01 0.701489D+01 0.102339D-01 -.367072D+00 0.538535D+01
56 0.945283D+00 -.394559D+01 0.475559D-01 0.159674D+01 0.703881D+01 0.758897D-02 -.317011D+00 0.538535D+01
57 0.952414D+00 -.388782D+01 0.821929D-01 -.299471D+01 0.703766D+01 0.537764D-02 -.266829D+00 0.538535D+01
58 0.958651D+00 -.383625D+01 0.134972D+00 -.967204D+01 0.700353D+01 0.378614D-02 -.223027D+00 0.538535D+01
59 0.964888D+00 -.378642D+01 0.225410D+00 -.205471D+02 0.691701D+01 0.250153D-02 -.179579D+00 0.538535D+01
60 0.968435D+00 -.376244D+01 0.314744D+00 -.299819D+02 0.683066D+01 0.190263D-02 -.155189D+00 0.538535D+01
61 0.971982D+00 -.374671D+01 0.501690D+00 -.435584D+02 0.670432D+01 0.139553D-02 -.131178D+00 0.538535D+01
62 0.975528D+00 -.374682D+01 0.694851D+00 -.622029D+02 0.652172D+01 0.976923D-03 -.107731D+00 0.538535D+01
63 0.977719D+00 -.376105D+01 0.865252D+00 -.773590D+02 0.637093D+01 0.760684D-03 -.936256D-01 0.538535D+01
64 0.979910D+00 -.379438D+01 0.108201D+01 -.964922D+02 0.618273D+01 0.575510D-03 -.799014D-01 0.538535D+01
65 0.982101D+00 -.385695D+01 0.133751D+01 -.120243D+03 0.594811D+01 0.420117D-03 -.666531D-01 0.538535D+01
66 0.984292D+00 -.396487D+01 0.165235D+01 -.149484D+03 0.565583D+01 0.293018D-03 -.539982D-01 0.538535D+01
67 0.986005D+00 -.409586D+01 0.196344D+01 -.177198D+03 0.537822D+01 0.212246D-03 -.446103D-01 0.538535D+01
68 0.987718D+00 -.428705D+01 0.233600D+01 -.210294D+03 0.504875D+01 0.146756D-03 -.357576D-01 0.538535D+01
69 0.989431D+00 -.456233D+01 0.276922D+01 -.249554D+03 0.465775D+01 0.954559D-04 -.275398D-01 0.538535D+01
70 0.991144D+00 -.495466D+01 0.328231D+01 -.296064D+03 0.419377D+01 0.570909D-04 -.200753D-01 0.538535D+01
71 0.992782D+00 -.548057D+01 0.386595D+01 -.348616D+03 0.366934D+01 0.311749D-04 -.137708D-01 0.538535D+01
72 0.994419D+00 -.620745D+01 0.454591D+01 -.410517D+03 0.305211D+01 0.143216D-04 -.843054D-02 0.538535D+01
73 0.996057D+00 -.720526D+01 0.534022D+01 -.483205D+03 0.232483D+01 0.483784D-05 -.421800D-02 0.538535D+01
74 0.997535D+00 -.840856D+01 0.616029D+01 -.559740D+03 0.155838D+01 0.101897D-05 -.155352D-02 0.538535D+01
75 0.999013D+00 -.983077D+01 0.484415D+01 -.647771D+03 0.670238D+00 0.141589D-07 -.144511D-03 0.538535D+01
76 0.100000D+01 -.108123D+02 0.367725D+01 -.679066D+03 -.567637D-14 0.127518D-16 0.850122D-17 0.538535D+01
CHINESE LANTERN FROM JOAO,  LINEAR DYNAMICS PROGRAMS, MARCH 1985
   9          = NUMBER OF RISER SEGMENTS
0.883920D+02 = UNSTRETCHED RISER LENGTH IN M
0.292000D+01 = APPROXIMATE AVERAGE EFFECTIVE WEIGHT PER UNIT LENGTH IN N/M
0.820000D+03 = INNER FLUID DENSITY IN KG/M3
0.102500D+04 = SALT WATER DENSITY IN KG/M3
0.115434D-01 = INNER CROSS SECTIONAL AREA IN M2
0.000000D+00 = INNER FLUID SPEED IN M/S
0.345000D+07 = INNER FLUID OVERPRESSURE IN N/M2
0.258105D+03 = APPROXIMATE TOTAL EFFECTIVE WEIGHT IN WATER IN N
0.797324D+04 = AVERAGE STATIC TENSION IN N
0.129000D+01 = MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S
0.189584D-16 = X COORDINATE AT TOP IN M
0.701000D+02 = Y COORDINATE AT TOP IN M


D A T A   P E R   R I S E R   S E G M E N T   F O R   NSEG =   9   S E G M E N T S
D I M E N S I O N A L   Q U A N T I T I E S   I N   T H E   S . I .   S Y S T E M
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RLENG	DXI	PXIETA	AO	WEIGHT	MASS	TMASS	AMAXI	AMAETA	AMAZI	TMAXI	TMAZI
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.6839D+02	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02

0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02

EA	EIETA	EIETAS	EIXI	EIXIS	GIP	GIPS	DETA	JZI	AJZI	TJZI
0.2670D+09	0.6600D+04	-.3300D+03	0.2440D+05	-.1220D+04	0.1164D+07	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.5775D+04	-.3300D+03	0.2135D+05	-.1220D+04	0.1019D+07	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4950D+04	-.3300D+03	0.1830D+05	-.1220D+04	0.8730D+06	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4125D+04	-.3300D+03	0.1525D+05	-.1220D+04	0.7275D+06	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.3300D+04	0.0000D+00	0.1220D+05	0.0000D+00	0.5820D+06	0.0000D+00	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4125D+04	0.3300D+03	0.1525D+05	0.1220D+04	0.7275D+06	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4950D+04	0.3300D+03	0.1830D+05	0.1220D+04	0.8730D+06	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.5775D+04	0.3300D+03	0.2135D+05	0.1220D+04	0.1019D+07	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.6600D+04	0.3300D+03	0.2440D+05	0.1220D+04	0.1164D+07	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00

****

M O D E N U M B E R = 1

N A T U R A L F R E Q U E N C Y = 0.4530D+00 RAD/S

****

ORTHONORMALIZED NONDIMENSIONAL RESULTS AT NP = 85 POINTS

S	TENSION	QXI	OMEGAETA	PHI	P	Q	SIGMA
0.0000D+00	0.7288D+01	0.3388D+01	0.6129D+03	0.0000D+00	0.0000D+00	0.0000D+00	0.5159D+01
0.4933D-03	0.6922D+01	0.3505D+01	0.5981D+03	0.2987D+00	-.1347D-05	0.7365D-04	0.5159D+01
0.9866D-03	0.6570D+01	0.3593D+01	0.5829D+03	0.5900D+00	-.8226D-05	0.2927D-03	0.5159D+01
0.1726D-02	0.6073D+01	0.3675D+01	0.5594D+03	0.1012D+01	-.3986D-04	0.8834D-03	0.5159D+01
0.2465D-02	0.5612D+01	0.3707D+01	0.5355D+03	0.1417D+01	-.1075D-03	0.1777D-02	0.5159D+01
0.3204D-02	0.5188D+01	0.3698D+01	0.5113D+03	0.1803D+01	-.2208D-03	0.2959D-02	0.5159D+01
0.3943D-02	0.4802D+01	0.3656D+01	0.4873D+03	0.2172D+01	-.3865D-03	0.4415D-02	0.5159D+01
0.4762D-02	0.4415D+01	0.3579D+01	0.4611D+03	0.2561D+01	-.6362D-03	0.6329D-02	0.5159D+01
0.5581D-02	0.4070D+01	0.3477D+01	0.4354D+03	0.2928D+01	-.9577D-03	0.8542D-02	0.5159D+01
0.7218D-02	0.3492D+01	0.3228D+01	0.3866D+03	0.3601D+01	-.1812D-02	0.1378D-01	0.5159D+01
0.8856D-02	0.3043D+01	0.2944D+01	0.3415D+03	0.4197D+01	-.2929D-02	0.2001D-01	0.5159D+01
0.1114D-01	0.2587D+01	0.2540D+01	0.2856D+03	0.4914D+01	-.4847D-02	0.3012D-01	0.5159D+01
0.1342D-01	0.2280D+01	0.2159D+01	0.2375D+03	0.5511D+01	-.7074D-02	0.4166D-01	0.5159D+01
0.1571D-01	0.2078D+01	0.1817D+01	0.1969D+03	0.6007D+01	-.9483D-02	0.5440D-01	0.5159D+01
0.1790D-01	0.1951D+01	0.1531D+01	0.1640D+03	0.6402D+01	-.1186D-01	0.6758D-01	0.5159D+01
0.2009D-01	0.1870D+01	0.1285D+01	0.1364D+03	0.6731D+01	-.1422D-01	0.8155D-01	0.5159D+01
0.2228D-01	0.1821D+01	0.1075D+01	0.1132D+03	0.7005D+01	-.1649D-01	0.9621D-01	0.5159D+01
0.2447D-01	0.1792D+01	0.8976D+00	0.9378D+02	0.7231D+01	-.1864D-01	0.1114D+00	0.5159D+01
0.2802D-01	0.1775D+01	0.6660D+00	0.6889D+02	0.7520D+01	-.2177D-01	0.1371D+00	0.5159D+01
0.3157D-01	0.1778D+01	0.4915D+00	0.4932D+02	0.7730D+01	-.2440D-01	0.1637D+00	0.5159D+01
0.3511D-01	0.1793D+01	0.3624D+00	0.3373D+02	0.7877D+01	-.2648D-01	0.1911D+00	0.5159D+01
0.4135D-01	0.1832D+01	0.2121D+00	0.1517D+02	0.8029D+01	-.2881D-01	0.2404D+00	0.5159D+01
0.4759D-01	0.1877D+01	0.1266D+00	0.4082D+01	0.8089D+01	-.2974D-01	0.2906D+00	0.5159D+01
0.5472D-01	0.1928D+01	0.7200D-01	-.3546D+01	0.8091D+01	-.2950D-01	0.3483D+00	0.5159D+01

0.6185D-01	0.1978D+01	0.4254D-01	-.8465D+01	0.8048D+01	-.2819D-01	0.4059D+00	0.5159D+01
0.7784D-01	0.2092D+01	0.1483D-01	-.1536D+02	0.7858D+01	-.2252D-01	0.5334D+00	0.5159D+01
0.9549D-01	0.2214D+01	0.9624D-02	-.2036D+02	0.7543D+01	-.1276D-01	0.6696D+00	0.5159D+01
0.1147D+00	0.2345D+01	0.1079D-01	-.2511D+02	0.7105D+01	0.1509D-02	0.8107D+00	0.5159D+01
0.1355D+00	0.2480D+01	0.1165D-01	-.2950D+02	0.6538D+01	0.2098D-01	0.9522D+00	0.5159D+01
0.1577D+00	0.2615D+01	0.1048D-01	-.3414D+02	0.5831D+01	0.4668D-01	0.1089D+01	0.5159D+01
0.1813D+00	0.2741D+01	0.9240D-02	-.3853D+02	0.4975D+01	0.7982D-01	0.1214D+01	0.5159D+01
0.2061D+00	0.2849D+01	0.7657D-02	-.4249D+02	0.3969D+01	0.1214D+00	0.1322D+01	0.5159D+01
0.2321D+00	0.2925D+01	0.5718D-02	-.4577D+02	0.2823D+01	0.1724D+00	0.1404D+01	0.5159D+01
0.2591D+00	0.2954D+01	0.3410D-02	-.4810D+02	0.1554D+01	0.2333D+00	0.1455D+01	0.5159D+01
0.2871D+00	0.2915D+01	0.7153D-03	-.4919D+02	0.1927D+00	0.3039D+00	0.1466D+01	0.5159D+01
0.3159D+00	0.2789D+01	-.2358D-02	-.4874D+02	-.1219D+01	0.3834D+00	0.1433D+01	0.5159D+01
0.3455D+00	0.2555D+01	-.5774D-02	-.4647D+02	-.2626D+01	0.4695D+00	0.1349D+01	0.5159D+01
0.3757D+00	0.2192D+01	-.9436D-02	-.4214D+02	-.3962D+01	0.5587D+00	0.1214D+01	0.5159D+01
0.4063D+00	0.1688D+01	-.1316D-01	-.3560D+02	-.5154D+01	0.6455D+00	0.1027D+01	0.5159D+01
0.4373D+00	0.1041D+01	-.1664D-01	-.2688D+02	-.6123D+01	0.7231D+00	0.7934D+00	0.5159D+01
0.4686D+00	0.2650D+00	-.1945D-01	-.1622D+02	-.6797D+01	0.7839D+00	0.5212D+00	0.5159D+01
0.5000D+00	-.6060D+00	-.2114D-01	-.4191D+01	-.7117D+01	0.8203D+00	0.2233D+00	0.5159D+01
0.5314D+00	-.1521D+01	-.2143D-01	0.8424D+01	-.7051D+01	0.8273D+00	-.8402D-01	0.5159D+01
0.5627D+00	-.2419D+01	-.2012D-01	0.2069D+02	-.6596D+01	0.8028D+00	-.3826D+00	0.5159D+01
0.5937D+00	-.3236D+01	-.1722D-01	0.3162D+02	-.5784D+01	0.7494D+00	-.6549D+00	0.5159D+01
0.6243D+00	-.3925D+01	-.1313D-01	0.4040D+02	-.4680D+01	0.6730D+00	-.8860D+00	0.5159D+01
0.6545D+00	-.4455D+01	-.8458D-02	0.4655D+02	-.3369D+01	0.5823D+00	-.1066D+01	0.5159D+01
0.6841D+00	-.4822D+01	-.3815D-02	0.4997D+02	-.1943D+01	0.4858D+00	-.1190D+01	0.5159D+01
0.7129D+00	-.5036D+01	0.3789D-03	0.5091D+02	-.4887D+00	0.3913D+00	-.1259D+01	0.5159D+01
0.7409D+00	-.5121D+01	0.3917D-02	0.4977D+02	0.9201D+00	0.3041D+00	-.1277D+01	0.5159D+01
0.7679D+00	-.5106D+01	0.6736D-02	0.4705D+02	0.2229D+01	0.2275D+00	-.1251D+01	0.5159D+01
0.7939D+00	-.5019D+01	0.8910D-02	0.4322D+02	0.3402D+01	0.1629D+00	-.1188D+01	0.5159D+01
0.8187D+00	-.4885D+01	0.1047D-01	0.3868D+02	0.4418D+01	0.1101D+00	-.1098D+01	0.5159D+01
0.8423D+00	-.4723D+01	0.1160D-01	0.3377D+02	0.5271D+01	0.6833D-01	-.9872D+00	0.5159D+01
0.8645D+00	-.4550D+01	0.1242D-01	0.2873D+02	0.5965D+01	0.3629D-01	-.8642D+00	0.5159D+01
0.8853D+00	-.4377D+01	0.1142D-01	0.2406D+02	0.6514D+01	0.1231D-01	-.7353D+00	0.5159D+01
0.9045D+00	-.4210D+01	0.1046D-01	0.1916D+02	0.6930D+01	-.5039D-02	-.6060D+00	0.5159D+01
0.9222D+00	-.4055D+01	0.1604D-01	0.1405D+02	0.7223D+01	-.1681D-01	-.4809D+00	0.5159D+01
0.9382D+00	-.3914D+01	0.4656D-01	0.6772D+01	0.7389D+01	-.2383D-01	-.3637D+00	0.5159D+01
0.9453D+00	-.3851D+01	0.7894D-01	0.1478D+01	0.7419D+01	-.2567D-01	-.3108D+00	0.5159D+01
0.9524D+00	-.3788D+01	0.1377D+00	-.6757D+01	0.7400D+01	-.2643D-01	-.2579D+00	0.5159D+01
0.9587D+00	-.3733D+01	0.2266D+00	-.1861D+02	0.7321D+01	-.2597D-01	-.2121D+00	0.5159D+01
0.9649D+00	-.3683D+01	0.3766D+00	-.3801D+02	0.7144D+01	-.2413D-01	-.1672D+00	0.5159D+01
0.9684D+00	-.3662D+01	0.5007D+00	-.5397D+02	0.6981D+01	-.2236D-01	-.1424D+00	0.5159D+01
0.9720D+00	-.3655D+01	0.6629D+00	-.7359D+02	0.6755D+01	-.2004D-01	-.1184D+00	0.5159D+01
0.9755D+00	-.3669D+01	0.8695D+00	-.9789D+02	0.6451D+01	-.1722D-01	-.9552D-01	0.5159D+01
0.9777D+00	-.3697D+01	0.1022D+01	-.1164D+03	0.6216D+01	-.1527D-01	-.8200D-01	0.5159D+01
0.9799D+00	-.3747D+01	0.1196D+01	-.1381D+03	0.5937D+01	-.1318D-01	-.6908D-01	0.5159D+01
0.9821D+00	-.3830D+01	0.1391D+01	-.1634D+03	0.5607D+01	-.1101D-01	-.5685D-01	0.5159D+01
0.9843D+00	-.3960D+01	0.1605D+01	-.1927D+03	0.5217D+01	-.8811D-02	-.4542D-01	0.5159D+01
0.9860D+00	-.4107D+01	0.1781D+01	-.2185D+03	0.4865D+01	-.7120D-02	-.3711D-01	0.5159D+01
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0.9894D+00	-.4574D+01	0.2125D+01	-.2780D+03	0.4016D+01	-.4016D-02	-.2243D-01	0.5159D+01
0.9911D+00	-.4927D+01	0.2262D+01	-.3112D+03	0.3512D+01	-.2708D-02	-.1621D-01	0.5159D+01
0.9928D+00	-.5360D+01	0.2340D+01	-.3444D+03	0.2975D+01	-.1671D-02	-.1106D-01	0.5159D+01
0.9936D+00	-.5617D+01	0.2349D+01	-.3612D+03	0.2686D+01	-.1242D-02	-.8810D-02	0.5159D+01
0.9944D+00	-.5901D+01	0.2330D+01	-.3780D+03	0.2384D+01	-.8785D-03	-.6784D-02	0.5159D+01
0.9952D+00	-.6215D+01	0.2275D+01	-.3944D+03	0.2067D+01	-.5821D-03	-.4998D-02	0.5159D+01
0.9961D+00	-.6557D+01	0.2177D+01	-.4101D+03	0.1738D+01	-.3525D-03	-.3465D-02	0.5159D+01

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0.9975D+00 -.7241D+01 0.1861D+01 -.4357D+03 0.1112D+01 -.9738D-04 -.1378D-02 0.5159D+01
0.9983D+00 -.7608D+01 0.1619D+01 -.4464D+03 0.7865D+00 -.3594D-04 -.6808D-03 0.5159D+01
0.9990D+00 -.7985D+01 0.1310D+01 -.4551D+03 0.4534D+00 -.7352D-05 -.2240D-03 0.5159D+01
0.9995D+00 -.8238D+01 0.1062D+01 -.4597D+03 0.2276D+00 -.1181D-05 -.5615D-04 0.5159D+01
0.1000D+01 -.8489D+01 0.7774D+00 -.4629D+03 0.0000D+00 0.0000D+00 0.4239D-19 0.5159D+01
MAXIMUM ESTIMATED ERROR BY COMPONENTS
           0.4394D-01 0.3839D-01 0.1479D+01 0.3383D-01 0.4257D-02 0.2797D-02 0.1922D-01
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V.2.1.3 INPLA1A DATA A

1 85 0.4530D+00 0.2145D-18 0.7931D+00

0.000000D+00	0.728757D+01	0.338805D+01	0.612872D+03	0.000000D+00	0.000000D+00	0.000000D+00	0.515949D+01	0.103000D+01
0.493318D-03	0.692164D+01	0.350534D+01	0.598143D+03	0.298708D+00	-.134651D-05	0.736537D-04	0.515949D+01	0.103031D+01
0.986636D-03	0.657017D+01	0.359269D+01	0.582905D+03	0.590024D+00	-.822562D-05	0.292689D-03	0.515949D+01	0.103062D+01
0.172564D-02	0.607276D+01	0.367503D+01	0.559423D+03	0.101211D+01	-.398629D-04	0.883399D-03	0.515949D+01	0.103108D+01
0.246464D-02	0.561199D+01	0.370727D+01	0.535464D+03	0.141668D+01	-.107493D-03	0.177712D-02	0.515949D+01	0.103154D+01
0.320364D-02	0.518848D+01	0.369826D+01	0.511346D+03	0.180348D+01	-.220839D-03	0.295916D-02	0.515949D+01	0.103199D+01
0.394265D-02	0.480193D+01	0.365607D+01	0.487327D+03	0.217249D+01	-.386466D-03	0.441470D-02	0.515949D+01	0.103244D+01
0.476160D-02	0.441516D+01	0.357890D+01	0.461081D+03	0.256084D+01	-.636221D-03	0.632921D-02	0.515949D+01	0.103293D+01
0.558056D-02	0.406997D+01	0.347733D+01	0.435431D+03	0.292794D+01	-.957728D-03	0.854239D-02	0.515949D+01	0.103342D+01
0.721847D-02	0.349171D+01	0.322759D+01	0.386577D+03	0.360113D+01	-.181188D-02	0.137841D-01	0.515949D+01	0.103436D+01
0.885637D-02	0.304333D+01	0.294413D+01	0.341506D+03	0.419739D+01	-.292912D-02	0.200148D-01	0.515949D+01	0.103527D+01
0.111404D-01	0.258720D+01	0.254049D+01	0.285551D+03	0.491350D+01	-.484712D-02	0.301238D-01	0.515949D+01	0.103650D+01
0.134244D-01	0.228022D+01	0.215866D+01	0.237538D+03	0.551087D+01	-.707438D-02	0.416599D-01	0.515949D+01	0.103766D+01
0.157084D-01	0.207772D+01	0.181662D+01	0.196881D+03	0.600698D+01	-.948346D-02	0.543989D-01	0.515949D+01	0.103878D+01
0.178993D-01	0.195136D+01	0.153056D+01	0.164019D+03	0.640232D+01	-.118605D-01	0.675772D-01	0.515949D+01	0.103981D+01
0.200901D-01	0.187047D+01	0.128457D+01	0.136367D+03	0.673137D+01	-.142179D-01	0.815518D-01	0.515949D+01	0.104080D+01
0.222809D-01	0.182072D+01	0.107510D+01	0.113178D+03	0.700472D+01	-.164926D-01	0.962054D-01	0.515949D+01	0.104177D+01
0.244717D-01	0.179243D+01	0.897635D+00	0.937832D+02	0.723142D+01	-.186390D-01	0.111436D+00	0.515949D+01	0.104272D+01
0.280184D-01	0.177471D+01	0.666014D+00	0.688853D+02	0.751989D+01	-.217693D-01	0.137085D+00	0.515949D+01	0.104421D+01
0.315651D-01	0.177787D+01	0.491470D+00	0.493174D+02	0.772951D+01	-.244050D-01	0.163721D+00	0.515949D+01	0.104567D+01
0.351118D-01	0.179287D+01	0.362369D+00	0.337278D+02	0.787677D+01	-.264753D-01	0.191098D+00	0.515949D+01	0.104711D+01
0.413491D-01	0.183230D+01	0.212072D+00	0.151730D+02	0.802928D+01	-.288102D-01	0.240396D+00	0.515949D+01	0.104959D+01
0.475865D-01	0.187684D+01	0.126611D+00	0.408233D+01	0.808933D+01	-.297419D-01	0.290557D+00	0.515949D+01	0.105206D+01
0.547166D-01	0.192780D+01	0.719961D-01	-.354582D+01	0.809124D+01	-.294972D-01	0.348261D+00	0.515949D+01	0.105487D+01
0.618467D-01	0.197849D+01	0.425426D-01	-.846499D+01	0.804842D+01	-.281878D-01	0.405899D+00	0.515949D+01	0.105770D+01
0.778360D-01	0.209178D+01	0.148274D-01	-.153596D+02	0.785795D+01	-.225172D-01	0.533362D+00	0.515949D+01	0.106409D+01
0.954915D-01	0.221450D+01	0.962450D-02	-.203599D+02	0.754263D+01	-.127626D-01	0.669598D+00	0.515949D+01	0.107126D+01
0.114743D+00	0.234503D+01	0.107887D-01	-.251053D+02	0.710500D+01	0.150905D-02	0.810699D+00	0.515949D+01	0.107926D+01
0.135516D+00	0.248031D+01	0.116481D-01	-.295045D+02	0.653779D+01	0.209842D-01	0.952151D+00	0.515949D+01	0.108808D+01
0.157726D+00	0.261480D+01	0.104831D-01	-.341440D+02	0.583097D+01	0.466757D-01	0.108865D+01	0.515949D+01	0.109775D+01
0.181288D+00	0.274132D+01	0.923975D-02	-.385303D+02	0.497480D+01	0.798173D-01	0.121412D+01	0.515949D+01	0.110829D+01
0.206107D+00	0.284916D+01	0.765683D-02	-.424885D+02	0.396939D+01	0.121427D+00	0.132179D+01	0.515949D+01	0.111973D+01
0.232087D+00	0.292533D+01	0.571770D-02	-.457683D+02	0.282294D+01	0.172403D+00	0.140450D+01	0.515949D+01	0.113208D+01
0.259123D+00	0.295367D+01	0.341046D-02	-.480976D+02	0.155406D+01	0.233250D+00	0.145498D+01	0.515949D+01	0.114537D+01
0.287110D+00	0.291532D+01	0.715310D-03	-.491875D+02	0.192697D+00	0.303897D+00	0.146636D+01	0.515949D+01	0.115961D+01
0.315938D+00	0.278938D+01	-.235841D-02	-.487404D+02	-.121884D+01	0.383385D+00	0.143261D+01	0.515949D+01	0.117480D+01
0.345492D+00	0.255450D+01	-.577424D-02	-.464718D+02	-.262579D+01	0.469543D+00	0.134921D+01	0.515949D+01	0.119094D+01
0.375655D+00	0.219156D+01	-.943648D-02	-.421413D+02	-.396220D+01	0.558696D+00	0.121384D+01	0.515949D+01	0.120799D+01
0.406309D+00	0.168756D+01	-.131601D-01	-.356032D+02	-.515379D+01	0.645507D+00	0.102714D+01	0.515949D+01	0.122589D+01
0.437333D+00	0.104065D+01	-.166429D-01	-.268760D+02	-.612297D+01	0.723127D+00	0.793424D+00	0.515949D+01	0.124453D+01
0.468605D+00	0.265030D+00	-.194541D-01	-.162213D+02	-.679684D+01	0.783851D+00	0.521212D+00	0.515949D+01	0.126375D+01
0.500000D+00	-.605959D+00	-.211442D-01	-.419072D+01	-.711726D+01	0.820348D+00	0.223303D+00	0.515949D+01	0.128335D+01
0.531395D+00	-.152122D+01	-.214257D-01	0.842409D+01	-.705081D+01	0.827288D+00	-.840228D-01	0.515949D+01	0.130307D+01
0.562667D+00	-.241865D+01	-.201187D-01	0.206868D+02	-.659563D+01	0.802829D+00	-.382637D+00	0.515949D+01	0.132262D+01
0.593691D+00	-.323637D+01	-.172222D-01	0.316213D+02	-.578423D+01	0.749351D+00	-.654871D+00	0.515949D+01	0.134172D+01
0.624345D+00	-.392492D+01	-.131258D-01	0.404021D+02	-.468033D+01	0.673016D+00	-.886001D+00	0.515949D+01	0.136011D+01
0.654508D+00	-.445547D+01	-.845816D-02	0.465471D+02	-.336900D+01	0.582255D+00	-.106604D+01	0.515949D+01	0.137757D+01
0.684062D+00	-.482165D+01	-.381532D-02	0.499708D+02	-.194276D+01	0.485843D+00	-.119041D+01	0.515949D+01	0.139398D+01
0.712890D+00	-.503556D+01	0.378865D-03	0.509059D+02	-.488721D+00	0.391321D+00	-.125949D+01	0.515949D+01	0.140923D+01
0.740877D+00	-.512085D+01	0.391695D-02	0.497711D+02	0.920101D+00	0.304144D+00	-.127749D+01	0.515949D+01	0.142332D+01
0.767913D+00	-.510595D+01	0.673648D-02	0.470525D+02	0.222896D+01	0.227543D+00	-.125113D+01	0.515949D+01	0.143624D+01
0.793893D+00	-.501889D+01	0.890961D-02	0.432157D+02	0.340155D+01	0.162859D+00	-.118841D+01	0.515949D+01	0.144804D+01
0.818712D+00	-.488453D+01	0.104710D-01	0.386756D+02	0.441778D+01	0.110093D+00	-.109772D+01	0.515949D+01	0.145876D+01
0.842274D+00	-.472291D+01	0.115974D-01	0.337676D+02	0.527123D+01	0.683328D-01	-.987168D+00	0.515949D+01	0.146847D+01
0.864484D+00	-.455003D+01	0.124228D-01	0.287321D+02	0.596529D+01	0.362862D-01	-.864213D+00	0.515949D+01	0.147722D+01

0.885257D+00	-.437654D+01	0.114241D-01	0.240564D+02	0.651358D+01	0.123055D-01	-.735335D+00	0.515949D+01	0.148508D+01
0.904508D+00	-.421016D+01	0.104649D-01	0.191555D+02	0.692951D+01	-.503949D-02	-.606038D+00	0.515949D+01	0.149209D+01
0.922164D+00	-.405543D+01	0.160397D-01	0.140515D+02	0.722267D+01	-.168061D-01	-.480870D+00	0.515949D+01	0.149830D+01
0.938153D+00	-.391415D+01	0.465641D-01	0.677188D+01	0.738914D+01	-.238336D-01	-.363728D+00	0.515949D+01	0.150377D+01
0.945283D+00	-.385122D+01	0.789381D-01	0.147820D+01	0.741855D+01	-.256694D-01	-.310805D+00	0.515949D+01	0.150616D+01
0.952414D+00	-.378806D+01	0.137651D+00	-.675711D+01	0.739973D+01	-.264323D-01	-.257905D+00	0.515949D+01	0.150854D+01
0.958651D+00	-.373282D+01	0.226623D+00	-.186116D+02	0.732062D+01	-.259690D-01	-.212056D+00	0.515949D+01	0.151062D+01
0.964888D+00	-.368289D+01	0.376564D+00	-.380109D+02	0.714404D+01	-.241340D-01	-.167200D+00	0.515949D+01	0.151272D+01
0.968435D+00	-.366240D+01	0.500744D+00	-.539708D+02	0.698091D+01	-.223647D-01	-.142417D+00	0.515949D+01	0.151393D+01
0.971982D+00	-.365455D+01	0.662871D+00	-.735866D+02	0.675469D+01	-.200396D-01	-.118437D+00	0.515949D+01	0.151517D+01
0.975528D+00	-.366904D+01	0.869504D+00	-.978872D+02	0.645066D+01	-.172237D-01	-.955170D-01	0.515949D+01	0.151645D+01
0.977719D+00	-.369655D+01	0.102213D+01	-.116410D+03	0.621590D+01	-.152699D-01	-.819987D-01	0.515949D+01	0.151727D+01
0.979910D+00	-.374682D+01	0.119583D+01	-.138111D+03	0.593707D+01	-.131846D-01	-.690781D-01	0.515949D+01	0.151812D+01
0.982101D+00	-.382974D+01	0.139093D+01	-.163399D+03	0.560677D+01	-.110115D-01	-.568494D-01	0.515949D+01	0.151900D+01
0.984292D+00	-.395994D+01	0.160488D+01	-.192653D+03	0.521671D+01	-.881120D-02	-.454185D-01	0.515949D+01	0.151992D+01
0.986005D+00	-.410676D+01	0.178112D+01	-.218470D+03	0.486459D+01	-.711986D-02	-.371100D-01	0.515949D+01	0.152067D+01
0.987718D+00	-.430666D+01	0.195814D+01	-.246938D+03	0.446596D+01	-.550473D-02	-.294243D-01	0.515949D+01	0.152146D+01
0.989431D+00	-.457444D+01	0.212462D+01	-.277957D+03	0.401639D+01	-.401631D-02	-.224318D-01	0.515949D+01	0.152228D+01
0.991144D+00	-.492722D+01	0.226196D+01	-.311189D+03	0.351179D+01	-.270761D-02	-.162108D-01	0.515949D+01	0.152315D+01
0.992782D+00	-.536044D+01	0.233982D+01	-.344390D+03	0.297487D+01	-.167073D-02	-.110640D-01	0.515949D+01	0.152402D+01
0.993600D+00	-.561661D+01	0.234871D+01	-.361225D+03	0.268610D+01	-.124198D-02	-.880992D-02	0.515949D+01	0.152447D+01
0.994419D+00	-.590121D+01	0.232957D+01	-.377959D+03	0.238359D+01	-.878538D-03	-.678446D-02	0.515949D+01	0.152493D+01
0.995238D+00	-.621501D+01	0.227513D+01	-.394359D+03	0.206732D+01	-.582125D-03	-.499846D-02	0.515949D+01	0.152541D+01
0.996057D+00	-.655749D+01	0.217737D+01	-.410113D+03	0.173789D+01	-.352537D-03	-.346550D-02	0.515949D+01	0.152589D+01
0.996796D+00	-.688969D+01	0.204441D+01	-.423476D+03	0.142988D+01	-.200821D-03	-.230950D-02	0.515949D+01	0.152633D+01
0.997535D+00	-.724140D+01	0.186105D+01	-.435694D+03	0.111242D+01	-.973845D-04	-.137845D-02	0.515949D+01	0.152678D+01
0.998274D+00	-.760847D+01	0.161893D+01	-.446390D+03	0.786485D+00	-.359419D-04	-.680766D-03	0.515949D+01	0.152724D+01
0.999013D+00	-.798508D+01	0.130959D+01	-.455131D+03	0.453373D+00	-.735168D-05	-.224000D-03	0.515949D+01	0.152770D+01
0.999506D+00	-.823818D+01	0.106167D+01	-.459657D+03	0.227649D+00	-.118142D-05	-.561458D-04	0.515949D+01	0.152801D+01
0.100000D+01	-.848899D+01	0.777371D+00	-.462934D+03	0.000000D+00	0.000000D+00	0.423855D-19	0.515949D+01	0.152832D+01

Chapter VI

VI.1 Input-Output Manual for the Out-of-Plane Forced Linear Dynamic Problem Solution Program, RCFORC1

This program is written in FORTRAN 77 and allows the interactive solution of the out-of-plane forced undamped linear dynamic problem for a compliant riser with a planar static configuration without torsion for given frequency and excitation at the top as described in [4]. Excitation at the top is allowed. The output of this program can be used as input to RCLINDY3 to solve the out-of-plane linear dynamic problem with homogeneous boundary conditions (out-of-plane eigenproblem).

Before executing the program the user must make sure that

- o Devices five and six correspond to input/output from the terminal
- o Device eight must be associated with the data file containing geometric, structural and hydrodynamic characteristics of the compliant riser created by a previous execution of the data preprocessing program RCINPUT. This file has a logical record length of 80 characters.
- o Device ten must be associated with the input data file containing the non-dimensional static planar solution created by RCSTAT2D. This file has a logical record length of 132 characters.
- o Device eleven must be associated with an output file with logical record length of 117 characters. This file contains the converged solution of the problem in a concise form appropriate for use in the preparation of illustrations and/or as an input to RCLINDY3 from device twelve in a subsequent execution of this program.

Input Variables [Free Format]

At the beginning of the program the static 2-D solution created from RCSTAT2D is read from device ten. The values of the mean current velocity in the x direction and the maximum non-dimensional static effective tension are printed on the terminal. If the number of static discretization points is less than four or greater than the value of MNP (maximum number of allowable points), the program halts execution.

Then the geometric, structural and hydrodynamic characteristics of the compliant riser are read from the file associated with device eight. The user has the opportunity to review this data on his terminal and decide either to continue with the program or stop, see [3]. Then the user is asked for the excitation frequency in (rad/s). In order to get meaningful results, this frequency should be close to one of the out-of-plane natural frequencies of the compliant riser. Next he is asked for the r and β amplitudes of excitation at the top of the riser. Appropriate values for these amplitudes range from one to zero. Then the user is asked to supply the tolerance for convergence of iterations. Suggested values are the excitation amplitudes or 1/10 of these values. However, at the end of the run the results should be checked, since the maximum of the resulting variables will be evaluated within this tolerance. Then the user is asked to input the mode number corresponding to the frequency of excitation.

Subsequently, the program enters NAG subroutine D02GBF, which provides the numerical solution to the problem. The manual of this subroutine is included in Chapter X. The input value of IFAIL is 111, indicating that the soft failure option with error message and monitoring information printing has been selected. Error messages are directed to device six. Once the execution of D02GBF is completed, the current value of IFAIL is printed on the terminal. For an explanation of this parameter, see NAG manual for D02GBF, Chapter X.

Only if IFAIL=0 or IFAIL=4, the execution of the program continues with printout of the final solution of the problem. Otherwise, the program stops. When IFAIL≠0, the user should consult the manual quoted above for interpretation of the results and a possible course of action. If IFAIL=0 or 4, the solution is printed in the file associated with device eleven. The following quantities are printed:

MODE, NP, SIGMAD = Mode number, number of points at which converged solution is available and dimensional natural frequency (in rad/s)

with FORMAT (1X, I2, 1X, I3, 1X, D10.4) and

for I=1, NP: The non-dimensional

s, Q_1^η, Ω_1^ζ, Ω_1^ξ, $\dot{\theta}_1$, β, r, Σ

with FORMAT (8(1X, D12.6))

The data written in the file associated with device eleven can be used as input to program RCLINDY3.

VI.2 Sample Run, Input and Output

VI.2.1 Zero Current Excitation

VI.2.1.1 Interactive Session

INPUT

Device 5 = TERMINAL

Device 8 = RCJOA01 DATA A*

Device 10 = RC2DZERR DATA A

OUTPUT

Device 6 = TERMINAL

Device 11 = OUTZER1E

---

* File included in Chapter II

```
R; T=0.01/0.01 17:12:15
rcforc1 rcjoao1 rc2dzerr outzer1e
FI 8 DISK RCJOAO1 DATA A ( RECFM FB LRECL 80 BLKSIZE 800
FI 10 DISK RC2DZERR DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 11 DISK OUTZER1E DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
GLOBAL TXTLIB VFORTLIB CMSLIB NAG1 NAG2
LOAD RCFORC1 ( START
EXECUTION BEGINS...
MNP=151
2-D STATIC SOLUTION FROM DEVICE 10
NP = 54
MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S .VM =0.000000D+00
2-D STATIC SOLUTION SUCCESFULLY READ
MAXIMUM STATIC EFFECTIVE TENSION/WA*L = 0.5547D+00
DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS
IF YES INPUT 1 , IF NO INPUT 0
?
0
 INPUT EXCITATION FREQUENCY IN RAD/S
?
.049
 INPUT AMPLITUDE OF EXCITATION AT TOP OF RISER FOR R
?
.1
 INPUT AMPLITUDE OF EXCITATION AT TOP OF RISER FOR B
?
0.
 INPUT TOLERANCE FOR CONVERGENCE OF ITERATIONS
 SUGGESTED VALUE IS THE EXCITATION AMPLITUDE OR 1/10 OF THE EXCITATION AMPLITUDE
?
.1
 INPUT MODE NUMBER CORRESPONDING TO FREQUENCY OF EXCITATION
?
1

DO2GBF MONITORING INFORMATION
 NUMBER OF POINTS IN CURRENT MESH =    54

 CORRECTION NUMBER     0    ESTIMATED MAXIMUM ERROR =  5.99D-01
 ESTIMATED ERROR BY COMPONENTS
   7.76D-02  1.28D-02  5.99D-01  4.95D-02  4.92D-02  1.20D-02
 NUMBER OF POINTS IN CURRENT MESH =    54

 CORRECTION NUMBER     1    ESTIMATED MAXIMUM ERROR =  4.72D-02
 ESTIMATED ERROR BY COMPONENTS
   3.84D-03  1.61D-03  4.72D-02  4.11D-03  2.75D-03  7.24D-04
IFAIL =  0
R; T=1.04/1.27 17:13:50
cp spool console stop close
```

VI.2.1.2 RC2DZERR DATA A

54 0.000000D+00

0.000000D+00	-.445340D+00	0.106243D+00	-.898201D+01	0.157080D+01	0.000000D+00	0.000000D+00	0.000000D+00	0.112515D+03	0.000000D+00
0.102730D-02	-.445279D+00	0.102122D+00	-.905566D+01	0.156153D+01	0.475259D-05	0.102729D-02	-.442227D-09	0.112566D+03	0.000000D+00
0.410499D-02	-.444907D+00	0.896417D-01	-.927049D+01	0.153333D+01	0.764910D-04	0.410403D-02	-.176645D-08	0.112720D+03	0.000000D+00
0.922042D-02	-.443620D+00	0.684993D-01	-.960758D+01	0.148503D+01	0.390724D-03	0.920927D-02	-.396333D-08	0.112976D+03	0.000000D+00
0.163526D-01	-.440285D+00	0.383815D-01	-.100338D+02	0.141496D+01	0.124823D-02	0.162881D-01	-.701039D-08	0.113333D+03	0.000000D+00
0.254721D-01	-.433114D+00	-.718041D-03	-.104993D+02	0.132127D+01	0.308006D-02	0.252182D-01	-.108602D-07	0.113787D+03	0.000000D+00
0.365416D-01	-.419653D+00	-.481038D-01	-.109686D+02	0.120235D+01	0.643956D-02	0.357584D-01	-.154228D-07	0.114326D+03	0.000000D+00
0.495156D-01	-.397006D+00	-.101884D+00	-.113652D+02	0.105728D+01	0.119671D-01	0.474827D-01	-.205440D-07	0.114935D+03	0.000000D+00
0.643406D-01	-.362547D+00	-.158296D+00	-.115540D+02	0.887047D+00	0.203075D-01	0.597165D-01	-.259866D-07	0.115580D+03	0.000000D+00
0.809559D-01	-.315173D+00	-.211669D+00	-.114373D+02	0.695505D+00	0.319699D-01	0.715146D-01	-.314293D-07	0.116217D+03	0.000000D+00
0.901246D-01	-.286440D+00	-.235583D+00	-.111845D+02	0.591700D+00	0.393026D-01	0.770135D-01	-.340954D-07	0.116520D+03	0.000000D+00
0.992932D-01	-.256920D+00	-.255167D+00	-.108028D+02	0.490731D+00	0.471599D-01	0.817327D-01	-.365033D-07	0.116786D+03	0.000000D+00
0.119277D+00	-.196409D+00	-.281394D+00	-.855577D+01	0.294217D+00	0.656215D-01	0.893007D-01	-.408821D-07	0.117224D+03	0.000000D+00
0.126460D+00	-.178360D+00	-.285146D+00	-.730761D+01	0.237196D+00	0.725542D-01	0.911824D-01	-.421831D-07	0.117336D+03	0.000000D+00
0.133643D+00	-.163117D+00	-.286304D+00	-.605258D+01	0.189209D+00	0.795765D-01	0.926973D-01	-.433687D-07	0.117427D+03	0.000000D+00
0.140825D+00	-.150757D+00	-.285327D+00	-.479730D+01	0.150245D+00	0.866580D-01	0.939056D-01	-.444584D-07	0.117500D+03	0.000000D+00
0.163850D+00	-.129931D+00	-.271479D+00	-.862496D+00	0.854406D-01	0.109549D+00	0.964452D-01	-.475820D-07	0.117647D+03	0.000000D+00
0.188255D+00	-.134370D+00	-.243485D+00	0.299488D+01	0.112282D+00	0.133864D+00	0.986696D-01	-.506998D-07	0.117754D+03	0.000000D+00
0.213942D+00	-.157212D+00	-.199967D+00	0.649446D+01	0.235603D+00	0.159181D+00	0.102931D+00	-.543199D-07	0.117944D+03	0.000000D+00
0.240804D+00	-.184274D+00	-.137770D+00	0.928561D+01	0.449737D+00	0.184474D+00	0.111789D+00	-.587536D-07	0.118360D+03	0.000000D+00
0.268731D+00	-.196841D+00	-.597189D-01	0.109797D+02	0.735583D+00	0.207596D+00	0.127235D+00	-.638980D-07	0.119119D+03	0.000000D+00
0.297608D+00	-.180649D+00	0.201477D-01	0.113163D+02	0.106063D+01	0.225519D+00	0.149679D+00	-.691669D-07	0.120256D+03	0.000000D+00
0.327317D+00	-.135870D+00	0.822770D-01	0.103507D+02	0.138524D+01	0.235559D+00	0.177495D+00	-.737120D-07	0.121690D+03	0.000000D+00
0.342527D+00	-.106736D+00	0.102333D+00	0.948685D+01	0.153635D+01	0.237215D+00	0.192607D+00	-.754955D-07	0.122474D+03	0.000000D+00
0.357736D+00	-.766422D-01	0.114381D+00	0.847410D+01	0.167310D+01	0.236682D+00	0.207804D+00	-.768435D-07	0.123263D+03	0.000000D+00
0.388740D+00	-.193358D-01	0.118774D+00	0.622887D+01	0.190139D+01	0.229877D+00	0.238008D+00	-.782818D-07	0.124829D+03	0.000000D+00
0.420200D+00	0.278492D-01	0.105463D+00	0.405135D+01	0.206267D+01	0.217154D+00	0.266769D+00	-.781523D-07	0.126313D+03	0.000000D+00
0.451988D+00	0.645340D-01	0.844457D-01	0.219813D+01	0.216105D+01	0.200649D+00	0.293940D+00	-.767329D-07	0.127707D+03	0.000000D+00
0.483974D+00	0.940844D-01	0.622911D-01	0.763983D+00	0.220733D+01	0.182131D+00	0.320025D+00	-.742807D-07	0.129039D+03	0.000000D+00
0.516026D+00	0.120137D+00	0.423481D-01	-.256516D+00	0.221442D+01	0.162913D+00	0.345679D+00	-.709620D-07	0.130347D+03	0.000000D+00
0.548012D+00	0.145217D+00	0.259911D-01	-.918540D+00	0.219475D+01	0.143921D+00	0.371416D+00	-.668596D-07	0.131657D+03	0.000000D+00
0.579800D+00	0.170626D+00	0.135323D-01	-.129645D+01	0.215888D+01	0.125785D+00	0.397522D+00	-.620068D-07	0.132987D+03	0.000000D+00
0.611260D+00	0.196778D+00	0.471553D-02	-.146653D+01	0.211495D+01	0.108896D+00	0.424065D+00	-.564199D-07	0.134339D+03	0.000000D+00
0.642264D+00	0.223588D+00	-.100583D-02	-.149732D+01	0.206870D+01	0.934600D-01	0.450951D+00	-.501207D-07	0.135709D+03	0.000000D+00
0.672683D+00	0.250759D+00	-.428081D-02	-.144486D+01	0.202378D+01	0.795388D-01	0.477997D+00	-.431465D-07	0.137087D+03	0.000000D+00
0.702392D+00	0.277953D+00	-.572477D-02	-.135159D+01	0.198216D+01	0.671008D-01	0.504977D+00	-.355544D-07	0.138462D+03	0.000000D+00
0.731269D+00	0.304857D+00	-.583246D-02	-.124781D+01	0.194461D+01	0.560589D-01	0.531660D+00	-.274197D-07	0.139821D+03	0.000000D+00
0.759196D+00	0.331208D+00	-.493473D-02	-.115449D+01	0.191110D+01	0.463031D-01	0.557828D+00	-.188339D-07	0.141155D+03	0.000000D+00
0.786058D+00	0.356788D+00	-.318643D-02	-.108648D+01	0.188107D+01	0.377221D-01	0.583283D+00	-.990122D-08	0.142452D+03	0.000000D+00
0.811745D+00	0.381408D+00	-.571539D-03	-.105548D+01	0.185365D+01	0.302170D-01	0.607849D+00	-.736223D-09	0.143703D+03	0.000000D+00
0.836150D+00	0.404901D+00	0.308388D-02	-.107236D+01	0.182780D+01	0.237078D-01	0.631370D+00	0.853925D-08	0.144902D+03	0.000000D+00
0.859175D+00	0.427102D+00	0.809238D-02	-.114861D+01	0.180238D+01	0.181351D-01	0.653710D+00	0.177983D-07	0.146040D+03	0.000000D+00
0.880723D+00	0.447834D+00	0.150176D-01	-.131206D+01	0.177590D+01	0.134628D-01	0.674745D+00	0.269109D-07	0.147111D+03	0.000000D+00
0.900707D+00	0.466925D+00	0.237247D-01	-.141792D+01	0.174855D+01	0.965720D-02	0.694363D+00	0.357466D-07	0.148110D+03	0.000000D+00
0.919044D+00	0.484265D+00	0.332994D-01	-.146961D+01	0.172211D+01	0.665140D-02	0.712452D+00	0.441771D-07	0.149031D+03	0.000000D+00
0.935659D+00	0.499753D+00	0.434396D-01	-.158082D+01	0.169683D+01	0.435224D-02	0.728907D+00	0.520797D-07	0.149869D+03	0.000000D+00
0.950484D+00	0.513293D+00	0.541206D-01	-.171822D+01	0.167243D+01	0.266578D-02	0.743636D+00	0.593387D-07	0.150618D+03	0.000000D+00
0.963458D+00	0.524831D+00	0.650264D-01	-.187112D+01	0.164918D+01	0.149751D-02	0.756557D+00	0.658486D-07	0.151275D+03	0.000000D+00
0.974528D+00	0.534362D+00	0.756837D-01	-.202252D+01	0.162764D+01	0.748086D-03	0.767600D+00	0.715157D-07	0.151836D+03	0.000000D+00
0.983647D+00	0.541936D+00	0.855149D-01	-.216219D+01	0.160858D+01	0.315773D-03	0.776710D+00	0.762599D-07	0.152299D+03	0.000000D+00
0.990780D+00	0.547642D+00	0.939435D-01	-.228751D+01	0.159272D+01	0.102367D-03	0.783839D+00	0.800159D-07	0.152660D+03	0.000000D+00
0.995895D+00	0.551596D+00	0.100432D+00	-.238654D+01	0.158077D+01	0.205836D-04	0.788953D+00	0.827338D-07	0.152920D+03	0.000000D+00
0.998973D+00	0.553911D+00	0.104527D+00	-.245001D+01	0.157332D+01	0.130050D-05	0.792031D+00	0.843783D-07	0.153076D+03	0.000000D+00
0.100000D+01	0.554673D+00	0.105927D+00	-.247187D+01	0.157080D+01	0.000000D+00	0.793058D+00	0.849288D-07	0.153128D+03	0.000000D+00

D I M E N S I O N A L R E S U L T S A T NP= 54 P O I N T S

S(M)	S*-S(M)	X(M)	Y(M)	V(M/S)	T(KN)	QXI(KN)	RETA(M)	META(KN.M)	PHI(DEG)	P(KN)
0.0000D+00	0.0000D+00	0.0000D+00	0.0000D+00	0.0000D+00	-.1149D+00	0.2742D-01	-.9841D+01	-.6707D+00	0.9000D+02	0.2904D+02
0.9081D-01	-.3909D-07	0.4201D-03	0.9080D-01	0.0000D+00	-.1149D+00	0.2636D-01	-.9761D+01	-.6762D+00	0.8947D+02	0.2905D+02
0.3628D+00	-.1561D-06	0.6761D-02	0.3628D+00	0.0000D+00	-.1148D+00	0.2314D-01	-.9535D+01	-.6922D+00	0.8785D+02	0.2909D+02
0.8150D+00	-.3503D-06	0.3454D-01	0.8140D+00	0.0000D+00	-.1145D+00	0.1768D-01	-.9200D+01	-.7174D+00	0.8509D+02	0.2916D+02
0.1445D+01	-.6197D-06	0.1103D+00	0.1440D+01	0.0000D+00	-.1136D+00	0.9906D-02	-.8809D+01	-.7492D+00	0.8107D+02	0.2925D+02
0.2252D+01	-.9600D-06	0.2723D+00	0.2229D+01	0.0000D+00	-.1118D+00	-.1853D-03	-.8419D+01	-.7840D+00	0.7570D+02	0.2937D+02
0.3230D+01	-.1363D-05	0.5692D+00	0.3161D+01	0.0000D+00	-.1083D+00	-.1242D-01	-.8059D+01	-.7166D+00	0.6889D+02	0.2951D+02
0.4377D+01	-.1816D-05	0.1058D+01	0.4197D+01	0.0000D+00	-.1025D+00	-.2630D-01	-.7777D+01	-.7425D+00	0.6058D+02	0.2967D+02
0.5687D+01	-.2297D-05	0.1795D+01	0.5278D+01	0.0000D+00	-.9357D-01	-.4086D-01	-.7650D+01	-.6470D+00	0.5082D+02	0.2983D+02
0.7156D+01	-.2778D-05	0.2826D+01	0.6321D+01	0.0000D+00	-.8135D-01	-.5463D-01	-.7728D+01	-.6405D+00	0.3985D+02	0.3000D+02
0.7966D+01	-.3014D-05	0.3474D+01	0.6807D+01	0.0000D+00	-.7393D-01	-.6080D-01	-.7903D+01	-.5219D+00	0.3390D+02	0.3007D+02
0.8777D+01	-.3227D-05	0.4169D+01	0.7225D+01	0.0000D+00	-.6631D-01	-.6586D-01	-.8182D+01	-.5041D+00	0.2812D+02	0.3014D+02
0.1054D+02	-.3614D-05	0.5800D+01	0.7893D+01	0.0000D+00	-.5069D-01	-.7263D-01	-.1033D+02	-.3194D+00	0.1686D+02	0.3026D+02
0.1118D+02	-.3729D-05	0.6413D+01	0.8060D+01	0.0000D+00	-.4604D-01	-.7360D-01	-.1210D+02	-.2728D+00	0.1359D+02	0.3029D+02
0.1181D+02	-.3833D-05	0.7034D+01	0.8194D+01	0.0000D+00	-.4210D-01	-.7390D-01	-.1460D+02	-.2260D+00	0.1084D+02	0.3031D+02
0.1245D+02	-.3930D-05	0.7660D+01	0.8301D+01	0.0000D+00	-.3891D-01	-.7364D-01	-.1843D+02	-.1791D+00	0.8608D+01	0.3033D+02
0.1448D+02	-.4206D-05	0.9683D+01	0.8525D+01	0.0000D+00	-.3354D-01	-.7007D-01	-.1025D+03	-.3220D-01	0.4895D+01	0.3037D+02
0.1664D+02	-.4481D-05	0.1183D+02	0.8722D+01	0.0000D+00	-.3468D-01	-.6284D-01	0.2951D+02	0.1118D+00	0.6433D+01	0.3039D+02
0.1891D+02	-.4801D-05	0.1407D+02	0.9098D+01	0.0000D+00	-.4058D-01	-.5161D-01	0.1361D+02	0.2425D+00	0.1350D+02	0.3044D+02
0.2129D+02	-.5193D-05	0.1631D+02	0.9881D+01	0.0000D+00	-.4756D-01	-.3556D-01	0.9519D+01	0.3467D+00	0.2577D+02	0.3055D+02
0.2375D+02	-.5648D-05	0.1835D+02	0.1125D+02	0.0000D+00	-.5081D-01	-.1541D-01	0.8050D+01	0.4099D+00	0.4215D+02	0.3075D+02
0.2631D+02	-.6114D-05	0.1993D+02	0.1323D+02	0.0000D+00	-.4663D-01	0.5200D-02	0.7811D+01	0.4225D+00	0.6077D+02	0.3104D+02
0.2893D+02	-.6516D-05	0.2082D+02	0.1569D+02	0.0000D+00	-.3507D-01	0.2124D-01	0.8540D+01	0.3864D+00	0.7937D+02	0.3141D+02
0.3028D+02	-.6673D-05	0.2097D+02	0.1702D+02	0.0000D+00	-.2755D-01	0.2641D-01	0.9317D+01	0.3542D+00	0.8803D+02	0.3161D+02
0.3162D+02	-.6792D-05	0.2092D+02	0.1837D+02	0.0000D+00	-.1978D-01	0.2952D-01	0.1043D+02	0.3164D+00	0.9586D+02	0.3181D+02
0.3436D+02	-.6919D-05	0.2032D+02	0.2104D+02	0.0000D+00	-.4991D-02	0.3066D-01	0.1419D+02	0.2325D+00	0.1089D+03	0.3222D+02
0.3714D+02	-.6908D-05	0.1919D+02	0.2358D+02	0.0000D+00	0.7188D-02	0.2722D-01	0.2182D+02	0.1513D+00	0.1182D+03	0.3260D+02
0.3995D+02	-.6783D-05	0.1774D+02	0.2598D+02	0.0000D+00	0.1666D-01	0.2180D-01	0.4021D+02	0.8206D-01	0.1238D+03	0.3296D+02
0.4278D+02	-.6566D-05	0.1610D+02	0.2829D+02	0.0000D+00	0.2428D-01	0.1608D-01	0.1157D+03	0.2852D-01	0.1265D+03	0.3331D+02
0.4561D+02	-.6272D-05	0.1440D+02	0.3056D+02	0.0000D+00	0.3101D-01	0.1093D-01	-.3446D+03	-.9577D-02	0.1269D+03	0.3364D+02
0.4844D+02	-.5910D-05	0.1272D+02	0.3283D+02	0.0000D+00	0.3748D-01	0.6708D-02	-.9623D+02	-.3429D-01	0.1258D+03	0.3398D+02
0.5125D+02	-.5481D-05	0.1112D+02	0.3514D+02	0.0000D+00	0.4404D-01	0.3493D-02	-.6818D+02	-.4840D-01	0.1237D+03	0.3432D+02
0.5403D+02	-.4987D-05	0.9626D+01	0.3748D+02	0.0000D+00	0.5079D-01	0.1217D-02	-.6027D+02	-.5475D-01	0.1212D+03	0.3467D+02
0.5677D+02	-.4430D-05	0.8261D+01	0.3986D+02	0.0000D+00	0.5771D-01	-.2596D-03	-.5903D+02	-.5590D-01	0.1185D+03	0.3503D+02
0.5946D+02	-.3814D-05	0.7031D+01	0.4225D+02	0.0000D+00	0.6472D-01	-.1105D-02	-.6118D+02	-.5394D-01	0.1160D+03	0.3538D+02
0.6209D+02	-.3143D-05	0.5931D+01	0.4464D+02	0.0000D+00	0.7174D-01	-.1478D-02	-.6540D+02	-.5046D-01	0.1136D+03	0.3574D+02
0.6464D+02	-.2424D-05	0.4955D+01	0.4699D+02	0.0000D+00	0.7869D-01	-.1505D-02	-.7084D+02	-.4659D-01	0.1114D+03	0.3609D+02
0.6711D+02	-.1665D-05	0.4093D+01	0.4931D+02	0.0000D+00	0.8549D-01	-.1274D-02	-.7656D+02	-.4310D-01	0.1095D+03	0.3643D+02
0.6948D+02	-.8752D-06	0.3334D+01	0.5156D+02	0.0000D+00	0.9209D-01	-.8224D-03	-.8136D+02	-.4056D-01	0.1078D+03	0.3677D+02
0.7175D+02	-.6508D-07	0.2671D+01	0.5373D+02	0.0000D+00	0.9844D-01	-.1475D-03	-.8375D+02	-.3941D-01	0.1062D+03	0.3709D+02
0.7391D+02	0.7548D-06	0.2096D+01	0.5581D+02	0.0000D+00	0.1045D+00	0.7960D-03	-.8243D+02	-.4003D-01	0.1047D+03	0.3740D+02
0.7594D+02	0.1573D-05	0.1603D+01	0.5778D+02	0.0000D+00	0.1102D+00	0.2089D-02	-.7696D+02	-.4288D-01	0.1033D+03	0.3769D+02
0.7785D+02	0.2379D-05	0.1190D+01	0.5964D+02	0.0000D+00	0.1156D+00	0.3876D-02	-.6737D+02	-.4898D-01	0.1018D+03	0.3797D+02
0.7962D+02	0.3160D-05	0.8536D+00	0.6138D+02	0.0000D+00	0.1205D+00	0.6123D-02	-.6234D+02	-.6617D-01	0.1002D+03	0.3823D+02
0.8124D+02	0.3905D-05	0.5879D+00	0.6298D+02	0.0000D+00	0.1250D+00	0.8595D-02	-.6015D+02	-.8230D-01	0.9867D+02	0.3847D+02
0.8270D+02	0.4603D-05	0.3847D+00	0.6443D+02	0.0000D+00	0.1290D+00	0.1121D-01	-.5592D+02	-.8853D-01	0.9722D+02	0.3868D+02
0.8402D+02	0.5245D-05	0.2356D+00	0.6573D+02	0.0000D+00	0.1325D+00	0.1397D-01	-.5144D+02	-.1123D+00	0.9582D+02	0.3888D+02
0.8516D+02	0.5820D-05	0.1324D+00	0.6687D+02	0.0000D+00	0.1355D+00	0.1678D-01	-.4724D+02	-.1222D+00	0.9449D+02	0.3904D+02
0.8614D+02	0.6321D-05	0.6612D-01	0.6785D+02	0.0000D+00	0.1379D+00	0.1953D-01	-.4370D+02	-.1510D+00	0.9326D+02	0.3919D+02
0.8695D+02	0.6741D-05	0.2791D-01	0.6865D+02	0.0000D+00	0.1399D+00	0.2207D-01	-.4088D+02	-.1614D+00	0.9216D+02	0.3931D+02

0.8758D+02	0.7073D-05	0.9048D-02	0.6929D+02	0.0000D+00	0.1413D+00	0.2425D-01	-.3864D+02	-.1708D+00	0.9126D+02	0.3940D+02
0.8803D+02	0.7313D-05	0.1819D-02	0.6974D+02	0.0000D+00	0.1424D+00	0.2592D-01	-.3704D+02	-.1782D+00	0.9057D+02	0.3947D+02
0.8830D+02	0.7458D-05	0.1150D-03	0.7001D+02	0.0000D+00	0.1430D+00	0.2698D-01	-.3608D+02	-.1829D+00	0.9014D+02	0.3951D+02
0.8839D+02	0.7507D-05	0.0000D+00	0.7010D+02	0.0000D+00	0.1432D+00	0.2734D-01	-.3576D+02	-.1846D+00	0.9000D+02	0.3952D+02

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0.000000D+00	0.142261D+01	-.160160D+00	-.136137D+02	0.000000D+00	0.000000D+00	0.000000D+00	0.416474D+01
0.102730D-02	0.143388D+01	-.158951D+00	-.136785D+02	-.140192D-01	-.989260D-04	0.719546D-05	0.416474D+01
0.410499D-02	0.146779D+01	-.155146D+00	-.138713D+02	-.564130D-01	0.412048D-03	0.115440D-03	0.416474D+01
0.922042D-02	0.152451D+01	-.148215D+00	-.141852D+02	-.128083D+00	0.409655D-02	0.586765D-03	0.416474D+01
0.163526D-01	0.160403D+01	-.137290D+00	-.146022D+02	-.230108D+00	0.156439D-01	0.186297D-02	0.416474D+01
0.254721D-01	0.170548D+01	-.121216D+00	-.150843D+02	-.362907D+00	0.422806D-01	0.456594D-02	0.416474D+01
0.365416D-01	0.182610D+01	-.990766D-01	-.155488D+02	-.524672D+00	0.939300D-01	0.948019D-02	0.416474D+01
0.495156D-01	0.195975D+01	-.697622D-01	-.158754D+02	-.709046D+00	0.182533D+00	0.174938D-01	0.416474D+01
0.643406D-01	0.209552D+01	-.324159D-01	-.158693D+02	-.902589D+00	0.319317D+00	0.294693D-01	0.416474D+01
0.809559D-01	0.221724D+01	0.122805D-01	-.153177D+02	-.108365D+01	0.510020D+00	0.460299D-01	0.416474D+01
0.901246D-01	0.226758D+01	0.376869D-01	-.147001D+02	-.116249D+01	0.626943D+00	0.563391D-01	0.416474D+01
0.992932D-01	0.230540D+01	0.631098D-01	-.138517D+02	-.122424D+01	0.748020D+00	0.672933D-01	0.416474D+01
0.119277D+00	0.234194D+01	0.104680D+00	-.101547D+02	-.129677D+01	0.998210D+00	0.926107D-01	0.416474D+01
0.126460D+00	0.233875D+01	0.112748D+00	-.831385D+01	-.130412D+01	0.107317D+01	0.101956D+00	0.416474D+01
0.133643D+00	0.232805D+01	0.118208D+00	-.651370D+01	-.130433D+01	0.113661D+01	0.111328D+00	0.416474D+01
0.140825D+00	0.231144D+01	0.121586D+00	-.476414D+01	-.129952D+01	0.118821D+01	0.120681D+00	0.416474D+01
0.163850D+00	0.222674D+01	0.124336D+00	0.414776D+00	-.126850D+01	0.127468D+01	0.150274D+00	0.416474D+01
0.188255D+00	0.209381D+01	0.126117D+00	0.510010D+01	-.123300D+01	0.124444D+01	0.180809D+00	0.416474D+01
0.213942D+00	0.191025D+01	0.140132D+00	0.904649D+01	-.119276D+01	0.109829D+01	0.211999D+00	0.416474D+01
0.240804D+00	0.167423D+01	0.175048D+00	0.118668D+02	-.111668D+01	0.854944D+00	0.243118D+00	0.416474D+01
0.268731D+00	0.139904D+01	0.230143D+00	0.130540D+02	-.965909D+00	0.562293D+00	0.272348D+00	0.416474D+01
0.297608D+00	0.111881D+01	0.293823D+00	0.123397D+02	-.732974D+00	0.292751D+00	0.296997D+00	0.416474D+01
0.327317D+00	0.870460D+00	0.349961D+00	0.100768D+02	-.460693D+00	0.107613D+00	0.314739D+00	0.416474D+01
0.342527D+00	0.764172D+00	0.371618D+00	0.862793D+01	-.330271D+00	0.532867D-01	0.320742D+00	0.416474D+01
0.357736D+00	0.671285D+00	0.388156D+00	0.716236D+01	-.215183D+00	0.217680D-01	0.324871D+00	0.416474D+01
0.388740D+00	0.512863D+00	0.408660D+00	0.451765D+01	-.376947D-01	0.540248D-02	0.328616D+00	0.416474D+01
0.420200D+00	0.376396D+00	0.417498D+00	0.263385D+01	0.711936D-01	0.213141D-01	0.327944D+00	0.416474D+01
0.451988D+00	0.249377D+00	0.420642D+00	0.158724D+01	0.133315D+00	0.448206D-01	0.324604D+00	0.416474D+01
0.483974D+00	0.127684D+00	0.421602D+00	0.121382D+01	0.174196D+00	0.653977D-01	0.319653D+00	0.416474D+01
0.516026D+00	0.122720D-01	0.421719D+00	0.127507D+01	0.212745D+00	0.802249D-01	0.313456D+00	0.416474D+01
0.548012D+00	-.940520D-01	0.421286D+00	0.154510D+01	0.259198D+00	0.890200D-01	0.305931D+00	0.416474D+01
0.579800D+00	-.188488D+00	0.420350D+00	0.184583D+01	0.316411D+00	0.920601D-01	0.296808D+00	0.416474D+01
0.611260D+00	-.269212D+00	0.419033D+00	0.205670D+01	0.382108D+00	0.899324D-01	0.285837D+00	0.416474D+01
0.642264D+00	-.335845D+00	0.417551D+00	0.211104D+01	0.451161D+00	0.836515D-01	0.272924D+00	0.416474D+01
0.672683D+00	-.389535D+00	0.416135D+00	0.198500D+01	0.517470D+00	0.745852D-01	0.258181D+00	0.416474D+01
0.702392D+00	-.432774D+00	0.414957D+00	0.168349D+01	0.575278D+00	0.641851D-01	0.241926D+00	0.416474D+01
0.731269D+00	-.469005D+00	0.414113D+00	0.122698D+01	0.619887D+00	0.536959D-01	0.224638D+00	0.416474D+01
0.759196D+00	-.502184D+00	0.413626D+00	0.641515D+00	0.647932D+00	0.439722D-01	0.206897D+00	0.416474D+01
0.786058D+00	-.536351D+00	0.413483D+00	-.473038D-01	0.657372D+00	0.354323D-01	0.189325D+00	0.416474D+01
0.811745D+00	-.575283D+00	0.413659D+00	-.816762D+00	0.647373D+00	0.281172D-01	0.172526D+00	0.416474D+01
0.836150D+00	-.622176D+00	0.414143D+00	-.164672D+01	0.618150D+00	0.218123D-01	0.157043D+00	0.416474D+01
0.859175D+00	-.679403D+00	0.414950D+00	-.251827D+01	0.570840D+00	0.162046D-01	0.143316D+00	0.416474D+01
0.880723D+00	-.748880D+00	0.419004D+00	-.344466D+01	0.506676D+00	0.109437D-01	0.131678D+00	0.416474D+01
0.900707D+00	-.827039D+00	0.391765D+00	-.393140D+01	0.432650D+00	0.622988D-02	0.122276D+00	0.416474D+01
0.919044D+00	-.905753D+00	0.347458D+00	-.403295D+01	0.359561D+00	0.252546D-02	0.115006D+00	0.416474D+01
0.935659D+00	-.981565D+00	0.316623D+00	-.419302D+01	0.291287D+00	-.183078D-03	0.109595D+00	0.416474D+01
0.950484D+00	-.105384D+01	0.293482D+00	-.434758D+01	0.227959D+00	-.199611D-02	0.105744D+00	0.416474D+01
0.963458D+00	-.112102D+01	0.276377D+00	-.448478D+01	0.170601D+00	-.292964D-02	0.103156D+00	0.416474D+01
0.974528D+00	-.118138D+01	0.263737D+00	-.459535D+01	0.120270D+00	-.306826D-02	0.101545D+00	0.416474D+01
0.983647D+00	-.123323D+01	0.254686D+00	-.467773D+01	0.779364D-01	-.259136D-02	0.100641D+00	0.416474D+01
0.990780D+00	-.127516D+01	0.247908D+00	-.475019D+01	0.442801D-01	-.176633D-02	0.100205D+00	0.416474D+01
0.995895D+00	-.130603D+01	0.243230D+00	-.480561D+01	0.198262D-01	-.892554D-03	0.100041D+00	0.416474D+01
0.998973D+00	-.132494D+01	0.240489D+00	-.484024D+01	0.497726D-02	-.240236D-03	0.100003D+00	0.416474D+01
0.100000D+01	-.133130D+01	0.239586D+00	-.485199D+01	0.000000D+00	0.000000D+00	0.100000D+00	0.416474D+01

Chapter VII

VII.1 Input-Output Manual for the Out-of-Plane Linear Eigenproblem Solution Program, RCLINDY3

This program is written in FORTRAN 77 and allows the interactive solution of the out-of-plane linear dynamic eigenproblem for a compliant riser with a planar static configuration, as described in [4]. The initial (ε=0) approximation is prepared by RCFORC1. This program is particularly useful in the case of zero current velocity where the asymptotic theory is not valid.

Before executing the program the user must make sure that:

- o Devices five and six correspond to input/output from the terminal
- o Device eight must be associated with the data file containing geometric, structural and hydrodynamic characteristics of the compliant riser created by a previous execution of the data preprocessing program RCINPUT. This file has a logical record length of 80 characters.
- o Device nine must be associated with an output data file with logical record length of 132 characters which upon completion of the program contains a complete list of the input, initial approximation and the converged solution of the problem.
- o Device ten must be associated with the input data file containing the non-dimensional static planar solution created by RCSTAT2D. This file has a logical record length of 132 characters.

- Device eleven must be associated with an output file with logical record length of 117 characters. This file contains the converged solution of the problem in a concise form appropriate for use in the preparation of illustrations and/or as an input to RCLINDYN from device twelve.
- Device twelve must be associated with an input file containing the initial approximate solution of the undamped forced out-of-plane linear dynamic problem resulting from a previous execution of RCFORC1.

Input Variables [Free Format]

At the beginning of the program the static 2-D solution created from RCSTAT2D is read from device ten. The values of the mean current velocity in the x direction and the maximum non-dimensional static effective tension are printed on the terminal. If the number of static discretization points is less than four or greater than the value of MNP (maximum number of allowable points) the program halts execution.

Then the geometric, structural and hydrodynamic characteristics of the compliant riser are read from the file associated with device eight. The user has the opportunity to review this data on his terminal and decide either to continue with the program or stop, see [3].

In this case an initial ($\varepsilon=0$) approximation to the solution is available from a previous run of RCFORC1. The program reads the information from the previous run concerning the number of discretization points NP, the mode number and the corresponding frequency of excitation. If the number of discretization points is greater than MNP, the program stops execution. The same happens if NP is less than the number of static discretization points. Then the user has the option to review the initial approximation by displaying in his terminal. The assumed boundary condition for the curvature at the lower ball point of the riser is printed at the terminal. Subsequently, the initial solution provided by RCFORC1 is printed in the file associated with the device nine. The following quantities are printed:

- o Number of discretization points NP
- o Natural frequency (rad/s)
- o Order of point (starting from the lower end)
- o Non-dimensional arc length
- o Non-dimensional shear force in the $\vec{\eta}$ direction, Q_1^η
- o Non-dimensional component of rate of rotation about $\vec{\zeta}, \Omega_1^\zeta$
- o Non-dimensional component of rate of rotation about $\vec{\xi}, \Omega_1^\xi$
- o Euler angle θ_1
- o Euler angle β or ψ_1
- o Non-dimensional displacement r
- o Non-dimensional natural frequency

Subsequently, the program prints the maximum of the absolute value of the initial rate of rotation about $\vec{\xi}$ direction. This number is used to estimate a reasonable tolerance for convergence of iterations. The user is requested to input a tolerance as a fraction of this number; e.g. 0.01 for 1% tolerance or better for all quantities of interest. Typically,

Ω_1^ξ will be determined with an accuracy a little better than the above fraction and all other variables will be even more accurate. After the run the accuracy of the results should be checked. The user is given the opportunity to stop the program at this point if he wishes.

If he chooses to continue, he is asked to input the initial increment of the continuation parameter $\delta\varepsilon$ (condition $0<\delta\varepsilon\leq 1$). If no continuation is required, then use $\delta\varepsilon=1$. If continuation is required, then $\delta\varepsilon=0.1$ will usually suffice. For large changes between initial and final problem, a smaller value of $\delta\varepsilon$, e.g. 0.05 or 0.25 might be necessary.

After the initial approximation is fully defined, the program enters NAG subroutine DO2RAF, which provides the iterative numerical solution of the problem. The manual of this subroutine is included in Chapter X. The input value of IFAIL is 111, indicating that the soft failure option with error message and monitoring information printing has been selected. Error messages are directed to device six. Once the execution of DO2RAF is completed, the current value of IFAIL is printed on the terminal. For an explanation of this parameter, see NAG manual for DO2RAF, Chapter X. Only if IFAIL = 0 or IFAIL = 4, the execution of the program continues with printout of the riser characteristics and the final solution of the problem. Otherwise the program stops. When IFAIL≠0, the user should consult the manual quoted above for interpretation of the results and a possible course of action. If IFAIL = 0 or 4, the riser characteristics and the final solution of the problem are printed in the file associated with device nine. For the riser characteristics the format used in the static program RCSTAT2D is also used here. This is described in [3] (pp. 23-25).

Next the non-dimensional out-of-plane solution is written in the file associated with device nine.

The mode number, natural frequency and final number of points NP at which the solution is available is printed first. Then the following data is printed for I=1 to NP:

$s, Q_1^\eta, \Omega_1^\zeta, \Omega_1^\xi, \theta_1, \beta, r, \Sigma$ with

FORMAT (8(1X,D10.4)). Next the maximum (non-dimensional) estimated errors of $Q_1^\eta, \Omega_1^\zeta, \Omega_1^\xi, \theta_1, \beta, r, \Sigma$ provided by the NAG subroutine D02RAF are printed. Subsequently, the following data is written in the file associated with device eleven:

MODE, NP, SIGMAD: Mode number, number of points at which converged solution is available and dimensional natural frequency (in rad/s) with

FORMAT (1X,I2,1X,I3,1X,D10.4) and

for I=1 to NP the non-dimensional

$s, Q_1^\eta, \Omega_1^\zeta, \Omega_1^\xi, \theta_1, \beta, r, \Sigma$ and the dimensional current velocity $V_c(s)$ with

FORMAT (9(1X,D12.6))

The data written in the file associated with device eleven due to their simple form can be easily used as input to plotting programs. In addition, this data is useful in subsequent runs of RCLINDYN, if such an option is selected.

VII.2 Sample Run, Input and Output

VII.2.1 Zero Current Excitation

VII.2.1.1 Interactive Session

INPUT

Device 5 = TERMINAL

Device 8 = RCJOA01 DATA A*

Device 10 = RC2DZERR DATA A**

Device 12 = OUTZER1E DATA A**

OUTPUT

Device 6 = TERMINAL

Device 9 = OUTZER1 DATA A

Device 11 = OUTZER1A DATA A

---

*File included in Chapter II.

**Files included in Chapter VI.

```
R; T=0.01/0.01 17:14:29
rclindy3 rcjoa01 outzer1 rc2dzerr outzer1a outzer1e
FI 8 DISK RCJOA01 DATA A ( RECFM FB LRECL 80 BLKSIZE 800
FI 9 DISK OUTZER1 DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 10 DISK RC2DZERR DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 11 DISK OUTZER1A DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
FI 12 DISK OUTZER1E DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
GLOBAL TXTLIB VFORTLIB CMSLIB NAG1 NAG2
LOAD RCLINDY3 ( START
EXECUTION BEGINS...
MNP=151
2-D STATIC SOLUTION FROM DEVICE 10
NP = 54
MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =0.000000D+00
2-D STATIC SOLUTION SUCCESFULLY READ
MAXIMUM STATIC EFFECTIVE TENSION/WA*L = 0.5547D+00
DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS
IF YES INPUT 1 , IF NO INPUT 0
?
0
MNP=151
INITIAL APPROXIMATION FROM DEVICE 12
NP = 54 MODE NUMBER = 1 SIGMAD =0.4900D-01
DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION
IF YES INPUT 1
?
2
ASSUMED BOUNDARY CONDITION
OMEGA XI (0) =-.136137D+02
MAXIMUM ABSOLUTE VALUE OF N-D OMEGA XI IS =0.158754D+02
THIS NUMBER CAN BE USED TO ESTIMATE
A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS
INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE
E.G. INPUT 0.01 OR 0.1 IF THE INITIAL ESTIMATE FOR OMEGA XI
IS SMALL
AFTER THE RUN CHECK THE ACCURACY OF THE SOLUTION
?
0.08
IF YOU WISH TO STOP INPUT 0
IF YOU WISH TO CONTINUE WITH ITERATIONS INPUT 1
?
1
INPUT INITIAL INCREMENT OF CONTINUATION PARAMETER DELEPS
IF NO CONTINUATION IS REQUIRED INPUT DELEPS = 1.D0
IF CONTINUATION IS REQUIRED THEN 0.D0 < DELEPS < 1.D0
RECOMMENDATION :
USUALLY DELEPS = 0.1D0 WILL SUFFICE
FOR LARGE CHANGES BETWEEN INITIAL AND FINAL PROBLEM
A SMALLER VALUE OF DELEPS, E.G. 0.05D0 OR 0.025D0 MIGHT BE
NECESSARY
?
.1

DO2RAF MONITORING INFORMATION

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =    54
  CORRECTION NUMBER     0   RESIDUAL SHOULD BE .LE.   1.00D+00
   ITERATION NUMBER     0   RESIDUAL =  1.52D-01
    SQUARED NORM OF CORRECTION =  3.49D-01
```

```
    SQUARED NORM OF GRADIENT    =  1.94D+00
    SCALAR PRODUCT OF CORRECTION AND GRADIENT =  2.30D-02
   ITERATION NUMBER     1    RESIDUAL =  1.51D-05

 CONTINUATION PARAMETER EPSILON =  2.00D-01   DELEPS =  2.00D-01

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =   54
  CORRECTION NUMBER     0   RESIDUAL SHOULD BE .LE.  1.00D+00
   ITERATION NUMBER     0   RESIDUAL =  2.83D-02

 CONTINUATION PARAMETER EPSILON =  6.00D-01   DELEPS =  4.00D-01

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =   54
  CORRECTION NUMBER     0   RESIDUAL SHOULD BE .LE.  1.00D+00
   ITERATION NUMBER     0   RESIDUAL =  8.49D-02

 CONTINUATION PARAMETER EPSILON =  1.00D+00   DELEPS =  8.00D-01

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =   54
  CORRECTION NUMBER     0   RESIDUAL SHOULD BE .LE.  1.27D-04
   ITERATION NUMBER     0   RESIDUAL =  1.72D-01
    SQUARED NORM OF CORRECTION =  4.81D+01
    SQUARED NORM OF GRADIENT    =  2.96D-02
    SCALAR PRODUCT OF CORRECTION AND GRADIENT =  2.96D-02
   ITERATION NUMBER     1   RESIDUAL =  2.22D-02
    SQUARED NORM OF CORRECTION =  1.38D+00
    SQUARED NORM OF GRADIENT    =  8.23D-05
    SCALAR PRODUCT OF CORRECTION AND GRADIENT =  4.92D-04
   ITERATION NUMBER     2   RESIDUAL =  6.56D-05

 MESH SELECTION
  NUMBER OF NEW POINTS    2

 CORRECTION NUMBER     0   ESTIMATED MAXIMUM ERROR =  2.70D-01
 ESTIMATED ERROR BY COMPONENTS
   1.71D-02  4.55D-03  2.70D-01  2.60D-02  2.16D-02  5.02D-03  1.52D-02
IFAIL =  0
R; T=2.34/2.63 17:16:31
cp spool console stop close
```

OUTZER1 DATA A

INITIAL CONDITION FOR EPS=0. AND NP = 54 POINTS, NATURAL FREQUENCY = 0.4900D-01 RAD/S

I	ARC	SHEAR ETA	OMEGA ZETA	OMEGA XI	THETA	BETA	R	SIGMA
1	0.000000D+00	0.142261D+01	-.160160D+00	-.136137D+02	0.000000D+00	0.000000D+00	0.000000D+00	0.416474D+01
2	0.102730D-02	0.143388D+01	-.158951D+00	-.136785D+02	-.140192D-01	-.989260D-04	0.719546D-05	0.416474D+01
3	0.410499D-02	0.146779D+01	-.155146D+00	-.138713D+02	-.564130D-01	0.412048D-03	0.115440D-03	0.416474D+01
4	0.922042D-02	0.152451D+01	-.148215D+00	-.141852D+02	-.128083D+00	0.409655D-02	0.586765D-03	0.416474D+01
5	0.163526D-01	0.160403D+01	-.137290D+00	-.146022D+02	-.230108D+00	0.156439D-01	0.186297D-02	0.416474D+01
6	0.254721D-01	0.170548D+01	-.121216D+00	-.150843D+02	-.362907D+00	0.422806D-01	0.456594D-02	0.416474D+01
7	0.365416D-01	0.182610D+01	-.990766D-01	-.155488D+02	-.524672D+00	0.939300D-01	0.948019D-02	0.416474D+01
8	0.495156D-01	0.195975D+01	-.697622D-01	-.158754D+02	-.709046D+00	0.182533D+00	0.174938D-01	0.416474D+01
9	0.643406D-01	0.209552D+01	-.324159D-01	-.158693D+02	-.902589D+00	0.319317D+00	0.294693D-01	0.416474D+01
10	0.809559D-01	0.221724D+01	0.122805D-01	-.153177D+02	-.108365D+01	0.510020D+00	0.460299D-01	0.416474D+01
11	0.901246D-01	0.226758D+01	0.376869D-01	-.147001D+02	-.116249D+01	0.626943D+00	0.563391D-01	0.416474D+01
12	0.992932D-01	0.230540D+01	0.631098D-01	-.138517D+02	-.122424D+01	0.748020D+00	0.672933D-01	0.416474D+01
13	0.119277D+00	0.234194D+01	0.104680D+00	-.101547D+02	-.129677D+01	0.998210D+00	0.926107D-01	0.416474D+01
14	0.126460D+00	0.233875D+01	0.112748D+00	-.831385D+01	-.130412D+01	0.107317D+01	0.101956D+00	0.416474D+01
15	0.133643D+00	0.232805D+01	0.118208D+00	-.651370D+01	-.130433D+01	0.113661D+01	0.111328D+00	0.416474D+01
16	0.140825D+00	0.231144D+01	0.121586D+00	-.476414D+01	-.129952D+01	0.118821D+01	0.120681D+00	0.416474D+01
17	0.163850D+00	0.222674D+01	0.124336D+00	0.414776D+00	-.126850D+01	0.127468D+01	0.150274D+00	0.416474D+01
18	0.188255D+00	0.209381D+01	0.126117D+00	0.510010D+01	-.123300D+01	0.124444D+01	0.180809D+00	0.416474D+01
19	0.213942D+00	0.191025D+01	0.140132D+00	0.904649D+01	-.119276D+01	0.109829D+01	0.211999D+00	0.416474D+01
20	0.240804D+00	0.167423D+01	0.175048D+00	0.118668D+02	-.111668D+01	0.854944D+00	0.243118D+00	0.416474D+01
21	0.268731D+00	0.139904D+01	0.230143D+00	0.130540D+02	-.965909D+00	0.562293D+00	0.272348D+00	0.416474D+01
22	0.297608D+00	0.111881D+01	0.293823D+00	0.123397D+02	-.732974D+00	0.292751D+00	0.296997D+00	0.416474D+01
23	0.327317D+00	0.870460D+00	0.349961D+00	0.100768D+02	-.460693D+00	0.107613D+00	0.314739D+00	0.416474D+01
24	0.342527D+00	0.764172D+00	0.371618D+00	0.862793D+01	-.330271D+00	0.532867D-01	0.320742D+00	0.416474D+01
25	0.357736D+00	0.671285D+00	0.388156D+00	0.716236D+01	-.215183D+00	0.217680D-01	0.324871D+00	0.416474D+01
26	0.388740D+00	0.512863D+00	0.408660D+00	0.451765D+01	-.376947D-01	0.540248D-02	0.328616D+00	0.416474D+01
27	0.420200D+00	0.376396D+00	0.417498D+00	0.263385D+01	0.711936D-01	0.213141D-01	0.327944D+00	0.416474D+01
28	0.451988D+00	0.249377D+00	0.420642D+00	0.158724D+01	0.133315D+00	0.448206D-01	0.324604D+00	0.416474D+01
29	0.483974D+00	0.127684D+00	0.421602D+00	0.121382D+01	0.174196D+00	0.653977D-01	0.319653D+00	0.416474D+01
30	0.516026D+00	0.122720D-01	0.421719D+00	0.127507D+01	0.212745D+00	0.802249D-01	0.313456D+00	0.416474D+01
31	0.548012D+00	-.940520D-01	0.421286D+00	0.154510D+01	0.259198D+00	0.890200D-01	0.305931D+00	0.416474D+01
32	0.579800D+00	-.188488D+00	0.420350D+00	0.184583D+01	0.316411D+00	0.920601D-01	0.296808D+00	0.416474D+01
33	0.611260D+00	-.269212D+00	0.419033D+00	0.205670D+01	0.382108D+00	0.899324D-01	0.285837D+00	0.416474D+01
34	0.642264D+00	-.335845D+00	0.417551D+00	0.211104D+01	0.451161D+00	0.836515D-01	0.272924D+00	0.416474D+01
35	0.672683D+00	-.389535D+00	0.416135D+00	0.198500D+01	0.517470D+00	0.745852D-01	0.258181D+00	0.416474D+01
36	0.702392D+00	-.432774D+00	0.414957D+00	0.168349D+01	0.575278D+00	0.641851D-01	0.241926D+00	0.416474D+01
37	0.731269D+00	-.469005D+00	0.414113D+00	0.122698D+01	0.619887D+00	0.536959D-01	0.224638D+00	0.416474D+01
38	0.759196D+00	-.502184D+00	0.413626D+00	0.641515D+00	0.647932D+00	0.439722D-01	0.206897D+00	0.416474D+01
39	0.786058D+00	-.536351D+00	0.413483D+00	-.473038D-01	0.657372D+00	0.354323D-01	0.189325D+00	0.416474D+01
40	0.811745D+00	-.575283D+00	0.413659D+00	-.816762D+00	0.647373D+00	0.281172D-01	0.172526D+00	0.416474D+01
41	0.836150D+00	-.622176D+00	0.414143D+00	-.164672D+01	0.618150D+00	0.218123D-01	0.157043D+00	0.416474D+01
42	0.859175D+00	-.679403D+00	0.414950D+00	-.251827D+01	0.570840D+00	0.162046D-01	0.143316D+00	0.416474D+01
43	0.880723D+00	-.748880D+00	0.419004D+00	-.344466D+01	0.506676D+00	0.109437D-01	0.131678D+00	0.416474D+01
44	0.900707D+00	-.827039D+00	0.391765D+00	-.393140D+01	0.432650D+00	0.622988D-02	0.122276D+00	0.416474D+01
45	0.919044D+00	-.905753D+00	0.347458D+00	-.403295D+01	0.359561D+00	0.252546D-02	0.115006D+00	0.416474D+01
46	0.935659D+00	-.981565D+00	0.316623D+00	-.419302D+01	0.291287D+00	-.183078D-03	0.109595D+00	0.416474D+01
47	0.950484D+00	-.105384D+01	0.293482D+00	-.434758D+01	0.227959D+00	-.199611D-02	0.105744D+00	0.416474D+01
48	0.963458D+00	-.112102D+01	0.276377D+00	-.448478D+01	0.170601D+00	-.292964D-02	0.103156D+00	0.416474D+01
49	0.974528D+00	-.118138D+01	0.263737D+00	-.459535D+01	0.120270D+00	-.306826D-02	0.101545D+00	0.416474D+01
50	0.983647D+00	-.123323D+01	0.254686D+00	-.467773D+01	0.779364D-01	-.259136D-02	0.100641D+00	0.416474D+01
51	0.990780D+00	-.127516D+01	0.247908D+00	-.475019D+01	0.442801D-01	-.176633D-02	0.100205D+00	0.416474D+01
52	0.995895D+00	-.130603D+01	0.243230D+00	-.480561D+01	0.198262D-01	-.892554D-03	0.100041D+00	0.416474D+01
53	0.998973D+00	-.132494D+01	0.240489D+00	-.484024D+01	0.497726D-02	-.240236D-03	0.100003D+00	0.416474D+01

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 54 0.100000D+01 -.133130D+01 0.239586D+00 -.485199D+01 0.000000D+00 0.000000D+00 0.100000D+00 0.416474D+01
CHINESE LANTERN FROM JOAO,   APRIL 1985
 9            = NUMBER OF RISER SEGMENTS
0.883920D+02 = UNSTRETCHED RISER LENGTH IN M
0.292000D+01 = APPROXIMATE AVERAGE EFFECTIVE WEIGHT PER UNIT LENGTH IN N/M
0.820000D+03 = INNER FLUID DENSITY IN KG/M3
0.102500D+04 = SALT WATER DENSITY IN KG/M3
0.115434D-01 = INNER CROSS SECTIONAL AREA IN M2
0.000000D+00 = INNER FLUID SPEED IN M/S
0.345000D+07 = INNER FLUID OVERPRESSURE IN N/M2
0.258105D+03 = APPROXIMATE TOTAL EFFECTIVE WEIGHT IN WATER IN N
0.143164D+03 = MAXIMUM STATIC TENSION IN N
0.000000D+00 = MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S
```

D A T A P E R R I S E R S E G M E N T F O R NSEG = 9 S E G M E N T S
D I M E N S I O N A L Q U A N T I T I E S I N T H E S . I . S Y S T E M

RLENG	DXI	PXIETA	AO	WEIGHT	MASS	TMASS	AMAXI	AMAETA	AMAZI	TMAXI	TMAETA
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.6839D+02	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.1003D+03

EA	EIETA	EIETAS	EIXI	EIXIS	GIP	GIPS	DETA	JZI	AJZI	TJZI
0.2670D+09	0.6600D+04	-.3300D+03	0.2440D+05	-.1220D+04	0.1164D+07	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.5775D+04	-.3300D+03	0.2135D+05	-.1220D+04	0.1019D+07	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4950D+04	-.3300D+03	0.1830D+05	-.1220D+04	0.8730D+06	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4125D+04	-.3300D+03	0.1525D+05	-.1220D+04	0.7275D+06	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.3300D+04	0.0000D+00	0.1220D+05	0.0000D+00	0.5820D+06	0.0000D+00	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4125D+04	0.3300D+03	0.1525D+05	0.1220D+04	0.7275D+06	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4950D+04	0.3300D+03	0.1830D+05	0.1220D+04	0.8730D+06	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.5775D+04	0.3300D+03	0.2135D+05	0.1220D+04	0.1019D+07	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.6600D+04	0.3300D+03	0.2440D+05	0.1220D+04	0.1164D+07	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00

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*****************************************************
  M O D E   N U M B E R =  1
  N A T U R A L   F R E Q U E N C Y = 0.5357D-01 RAD/S
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ORTHONORMALIZED NONDIMENSIONAL RESULTS AT NP = 54 POINTS

S	QETA	OMEGAZETA	OMEGAXI	THETA	BETA	R	SIGMA
0.0000D+00	0.8581D+01	-.1004D+01	-.7467D+02	0.0000D+00	0.0000D+00	0.0000D+00	0.4553D+01
0.1027D-02	0.8643D+01	-.9981D+00	-.7505D+02	-.7691D-01	-.6708D-03	0.3950D-04	0.4553D+01
0.4105D-02	0.8829D+01	-.9790D+00	-.7616D+02	-.3096D+00	0.1775D-02	0.6342D-03	0.4553D+01
0.9220D-02	0.9141D+01	-.9438D+00	-.7800D+02	-.7033D+00	0.2148D-01	0.3225D-02	0.4553D+01
0.1635D-01	0.9578D+01	-.8877D+00	-.8048D+02	-.1265D+01	0.8430D-01	0.1024D-01	0.4553D+01
0.2547D-01	0.1014D+02	-.8045D+00	-.8341D+02	-.1997D+01	0.2301D+00	0.2512D-01	0.4553D+01
0.3654D-01	0.1080D+02	-.6891D+00	-.8637D+02	-.2892D+01	0.5134D+00	0.5218D-01	0.4553D+01
0.4952D-01	0.1154D+02	-.5352D+00	-.8870D+02	-.3918D+01	0.1000D+01	0.9635D-01	0.4553D+01
0.6434D-01	0.1230D+02	-.3387D+00	-.8939D+02	-.5003D+01	0.1752D+01	0.1625D+00	0.4553D+01
0.8096D-01	0.1298D+02	-.1024D+00	-.8720D+02	-.6036D+01	0.2802D+01	0.2542D+00	0.4553D+01
0.9012D-01	0.1326D+02	0.3193D-01	-.8437D+02	-.6499D+01	0.3452D+01	0.3117D+00	0.4553D+01
0.9929D-01	0.1348D+02	0.1653D+00	-.8025D+02	-.6872D+01	0.4126D+01	0.3730D+00	0.4553D+01
0.1193D+00	0.1369D+02	0.3892D+00	-.6108D+02	-.7368D+01	0.5503D+01	0.5152D+00	0.4553D+01
0.1265D+00	0.1367D+02	0.4384D+00	-.5096D+02	-.7446D+01	0.5928D+01	0.5685D+00	0.4553D+01
0.1336D+00	0.1361D+02	0.4725D+00	-.4094D+02	-.7484D+01	0.6290D+01	0.6221D+00	0.4553D+01
0.1408D+00	0.1351D+02	0.4943D+00	-.3112D+02	-.7493D+01	0.6585D+01	0.6759D+00	0.4553D+01
0.1638D+00	0.1302D+02	0.5208D+00	-.1570D+01	-.7435D+01	0.7084D+01	0.8477D+00	0.4553D+01
0.1883D+00	0.1224D+02	0.5356D+00	0.2602D+02	-.7314D+01	0.6908D+01	0.1028D+01	0.4553D+01
0.2139D+00	0.1114D+02	0.6148D+00	0.5013D+02	-.7107D+01	0.6049D+01	0.1213D+01	0.4553D+01
0.2408D+00	0.9710D+01	0.8122D+00	0.6845D+02	-.6618D+01	0.4623D+01	0.1397D+01	0.4553D+01
0.2687D+00	0.8027D+01	0.1131D+01	0.7794D+02	-.5622D+01	0.2930D+01	0.1568D+01	0.4553D+01
0.2976D+00	0.6276D+01	0.1511D+01	0.7666D+02	-.4085D+01	0.1409D+01	0.1708D+01	0.4553D+01
0.3273D+00	0.4682D+01	0.1863D+01	0.6595D+02	-.2268D+01	0.4238D+00	0.1803D+01	0.4553D+01
0.3425D+00	0.3987D+01	0.2007D+01	0.5817D+02	-.1371D+01	0.1757D+00	0.1830D+01	0.4553D+01
0.3577D+00	0.3379D+01	0.2120D+01	0.4995D+02	-.5656D+00	0.7181D-01	0.1845D+01	0.4553D+01
0.3887D+00	0.2346D+01	0.2272D+01	0.3447D+02	0.7206D+00	0.1352D+00	0.1843D+01	0.4553D+01
0.4202D+00	0.1494D+01	0.2345D+01	0.2237D+02	0.1577D+01	0.3789D+00	0.1807D+01	0.4553D+01
0.4520D+00	0.7461D+00	0.2375D+01	0.1453D+02	0.2117D+01	0.6295D+00	0.1748D+01	0.4553D+01
0.4840D+00	0.6643D-01	0.2384D+01	0.1038D+02	0.2484D+01	0.8104D+00	0.1674D+01	0.4553D+01
0.5160D+00	-.5500D+00	0.2386D+01	0.8751D+01	0.2784D+01	0.9058D+00	0.1590D+01	0.4553D+01
0.5480D+00	-.1095D+01	0.2383D+01	0.8464D+01	0.3077D+01	0.9254D+00	0.1496D+01	0.4553D+01
0.5798D+00	-.1559D+01	0.2379D+01	0.8571D+01	0.3379D+01	0.8866D+00	0.1393D+01	0.4553D+01
0.6113D+00	-.1938D+01	0.2373D+01	0.8426D+01	0.3683D+01	0.8074D+00	0.1282D+01	0.4553D+01
0.6423D+00	-.2233D+01	0.2368D+01	0.7664D+01	0.3968D+01	0.7051D+00	0.1164D+01	0.4553D+01
0.6727D+00	-.2454D+01	0.2363D+01	0.6150D+01	0.4207D+01	0.5942D+00	0.1039D+01	0.4553D+01
0.7024D+00	-.2617D+01	0.2360D+01	0.3896D+01	0.4378D+01	0.4862D+00	0.9119D+00	0.4553D+01
0.7313D+00	-.2743D+01	0.2358D+01	0.1000D+01	0.4466D+01	0.3884D+00	0.7842D+00	0.4553D+01
0.7592D+00	-.2855D+01	0.2358D+01	-.2415D+01	0.4458D+01	0.3046D+00	0.6596D+00	0.4553D+01
0.7861D+00	-.2975D+01	0.2360D+01	-.6226D+01	0.4350D+01	0.2354D+00	0.5413D+00	0.4553D+01
0.8117D+00	-.3123D+01	0.2364D+01	-.1032D+02	0.4143D+01	0.1792D+00	0.4322D+00	0.4553D+01
0.8362D+00	-.3316D+01	0.2369D+01	-.1461D+02	0.3843D+01	0.1333D+00	0.3348D+00	0.4553D+01
0.8592D+00	-.3565D+01	0.2375D+01	-.1900D+02	0.3459D+01	0.9477D-01	0.2507D+00	0.4553D+01
0.8807D+00	-.3877D+01	0.2384D+01	-.2336D+02	0.3004D+01	0.6078D-01	0.1811D+00	0.4553D+01
0.9007D+00	-.4230D+01	0.2236D+01	-.2524D+02	0.2520D+01	0.3186D-01	0.1259D+00	0.4553D+01
0.9190D+00	-.4582D+01	0.1994D+01	-.2501D+02	0.2060D+01	0.1013D-01	0.8391D-01	0.4553D+01
0.9357D+00	-.4917D+01	0.1817D+01	-.2510D+02	0.1643D+01	-.4943D-02	0.5315D-01	0.4553D+01
0.9505D+00	-.5231D+01	0.1684D+01	-.2529D+02	0.1270D+01	-.1442D-01	0.3156D-01	0.4553D+01
0.9635D+00	-.5521D+01	0.1586D+01	-.2547D+02	0.9401D+00	-.1878D-01	0.1722D-01	0.4553D+01

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0.9745D+00 -.5780D+01 0.1513D+01 -.2562D+02 0.6569D+00 -.1871D-01 0.8381D-02 0.4553D+01
0.9836D+00 -.6001D+01 0.1460D+01 -.2570D+02 0.4226D+00 -.1538D-01 0.3459D-02 0.4553D+01
0.9908D+00 -.6179D+01 0.1421D+01 -.2580D+02 0.2387D+00 -.1031D-01 0.1101D-02 0.4553D+01
0.9959D+00 -.6310D+01 0.1394D+01 -.2588D+02 0.1064D+00 -.5155D-02 0.2185D-03 0.4553D+01
0.9990D+00 -.6389D+01 0.1378D+01 -.2593D+02 0.2665D-01 -.1379D-02 0.1368D-04 0.4553D+01
0.1000D+01 -.6416D+01 0.1373D+01 -.2595D+02 0.1563D-16 0.0000D+00 0.4302D-21 0.4553D+01
MAXIMUM ESTIMATED ERROR BY COMPONENTS
           0.9395D-01 0.2495D-01 0.1481D+01 0.1426D+00 0.1186D+00 0.2755D-01 0.1519D-01
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OUTZERIA DATA A

1 54 0.5357D-01

0.000000D+00	0.858120D+01	-.100419D+01	-.746714D+02	0.000000D+00	0.000000D+00	0.000000D+00	0.455274D+01	0.000000D+00
0.102730D-02	0.864306D+01	-.998126D+00	-.750457D+02	-.769053D-01	-.670767D-03	0.395024D-04	0.455274D+01	0.000000D+00
0.410499D-02	0.882921D+01	-.978965D+00	-.761637D+02	-.309577D+00	0.177487D-02	0.634239D-03	0.455274D+01	0.000000D+00
0.922042D-02	0.914089D+01	-.943772D+00	-.780005D+02	-.703315D+00	0.214804D-01	0.322493D-02	0.455274D+01	0.000000D+00
0.163526D-01	0.957835D+01	-.887735D+00	-.804786D+02	-.126471D+01	0.842990D-01	0.102431D-01	0.455274D+01	0.000000D+00
0.254721D-01	0.101375D+02	-.804464D+00	-.834136D+02	-.199715D+01	0.230058D+00	0.251164D-01	0.455274D+01	0.000000D+00
0.365416D-01	0.108037D+02	-.689104D+00	-.863653D+02	-.289230D+01	0.513434D+00	0.521782D-01	0.455274D+01	0.000000D+00
0.495156D-01	0.115440D+02	-.535241D+00	-.887041D+02	-.391770D+01	0.100013D+01	0.963547D-01	0.455274D+01	0.000000D+00
0.643406D-01	0.122989D+02	-.338730D+00	-.893892D+02	-.500350D+01	0.175221D+01	0.162483D+00	0.455274D+01	0.000000D+00
0.809559D-01	0.129792D+02	-.102413D+00	-.872021D+02	-.603610D+01	0.280235D+01	0.254196D+00	0.455274D+01	0.000000D+00
0.901246D-01	0.132637D+02	0.319292D-01	-.843732D+02	-.649874D+01	0.345173D+01	0.311660D+00	0.455274D+01	0.000000D+00
0.992932D-01	0.134787D+02	0.165251D+00	-.802519D+02	-.687211D+01	0.412617D+01	0.372956D+00	0.455274D+01	0.000000D+00
0.119277D+00	0.136868D+02	0.389243D+00	-.610806D+02	-.736843D+01	0.550341D+01	0.515246D+00	0.455274D+01	0.000000D+00
0.126460D+00	0.136703D+02	0.438396D+00	-.509592D+02	-.744612D+01	0.592822D+01	0.568453D+00	0.455274D+01	0.000000D+00
0.133643D+00	0.136099D+02	0.472457D+00	-.409432D+02	-.748388D+01	0.628960D+01	0.622074D+00	0.455274D+01	0.000000D+00
0.140825D+00	0.135143D+02	0.494263D+00	-.311218D+02	-.749253D+01	0.658481D+01	0.675854D+00	0.455274D+01	0.000000D+00
0.163850D+00	0.130234D+02	0.520782D+00	-.157041D+01	-.743488D+01	0.708412D+01	0.847706D+00	0.455274D+01	0.000000D+00
0.188255D+00	0.122356D+02	0.535573D+00	0.260207D+02	-.731442D+01	0.690796D+01	0.102768D+01	0.455274D+01	0.000000D+00
0.213942D+00	0.111356D+02	0.614820D+00	0.501319D+02	-.710659D+01	0.604861D+01	0.121290D+01	0.455274D+01	0.000000D+00
0.240804D+00	0.970987D+01	0.812237D+00	0.684526D+02	-.661798D+01	0.462253D+01	0.139724D+01	0.455274D+01	0.000000D+00
0.268731D+00	0.802707D+01	0.113070D+01	0.779419D+02	-.562231D+01	0.292959D+01	0.156815D+01	0.455274D+01	0.000000D+00
0.297608D+00	0.627635D+01	0.151119D+01	0.766618D+02	-.408471D+01	0.140902D+01	0.170831D+01	0.455274D+01	0.000000D+00
0.327317D+00	0.468168D+01	0.186331D+01	0.659467D+02	-.226894D+01	0.423750D+00	0.180268D+01	0.455274D+01	0.000000D+00
0.342527D+00	0.398688D+01	0.200687D+01	0.581655D+02	-.137051D+01	0.175747D+00	0.183035D+01	0.455274D+01	0.000000D+00
0.357736D+00	0.337857D+01	0.212026D+01	0.499522D+02	-.565632D+00	0.718095D-01	0.184508D+01	0.455274D+01	0.000000D+00
0.388740D+00	0.234601D+01	0.227151D+01	0.344725D+02	0.720634D+00	0.135171D+00	0.184267D+01	0.455274D+01	0.000000D+00
0.420200D+00	0.149412D+01	0.234496D+01	0.223651D+02	0.157730D+01	0.378913D+00	0.180653D+01	0.455274D+01	0.000000D+00
0.451988D+00	0.746069D+00	0.237474D+01	0.145317D+02	0.211735D+01	0.629468D+00	0.174780D+01	0.455274D+01	0.000000D+00
0.483974D+00	0.664256D-01	0.238449D+01	0.103811D+02	0.248374D+01	0.810364D+00	0.167422D+01	0.455274D+01	0.000000D+00
0.516026D+00	-.549957D+00	0.238589D+01	0.875102D+01	0.278416D+01	0.905779D+00	0.158980D+01	0.455274D+01	0.000000D+00
0.548012D+00	-.109510D+01	0.238344D+01	0.846396D+01	0.307679D+01	0.925434D+00	0.149606D+01	0.455274D+01	0.000000D+00
0.579800D+00	-.155941D+01	0.237884D+01	0.857138D+01	0.337933D+01	0.886573D+00	0.139345D+01	0.455274D+01	0.000000D+00
0.611260D+00	-.193787D+01	0.237320D+01	0.842557D+01	0.368339D+01	0.807437D+00	0.128235D+01	0.455274D+01	0.000000D+00
0.642264D+00	-.223266D+01	0.236755D+01	0.766392D+01	0.396754D+01	0.705097D+00	0.116375D+01	0.455274D+01	0.000000D+00
0.672683D+00	-.245360D+01	0.236281D+01	0.614954D+01	0.420675D+01	0.594243D+00	0.103942D+01	0.455274D+01	0.000000D+00
0.702392D+00	-.261694D+01	0.235960D+01	0.389645D+01	0.437849D+01	0.486196D+00	0.911890D+00	0.455274D+01	0.000000D+00
0.731269D+00	-.274329D+01	0.235816D+01	0.100011D+01	0.446568D+01	0.388412D+00	0.784194D+00	0.455274D+01	0.000000D+00
0.759196D+00	-.285519D+01	0.235849D+01	-.241484D+01	0.445760D+01	0.304604D+00	0.659593D+00	0.455274D+01	0.000000D+00
0.786058D+00	-.297498D+01	0.236045D+01	-.622567D+01	0.434971D+01	0.235391D+00	0.541302D+00	0.455274D+01	0.000000D+00
0.811745D+00	-.312295D+01	0.236392D+01	-.103239D+02	0.414287D+01	0.179211D+00	0.432228D+00	0.455274D+01	0.000000D+00
0.836150D+00	-.331581D+01	0.236888D+01	-.146129D+02	0.384263D+01	0.133322D+00	0.334785D+00	0.455274D+01	0.000000D+00
0.859175D+00	-.356542D+01	0.237548D+01	-.189990D+02	0.345857D+01	0.947683D-01	0.250730D+00	0.455274D+01	0.000000D+00
0.880723D+00	-.387729D+01	0.238412D+01	-.233580D+02	0.300425D+01	0.607795D-01	0.181099D+00	0.455274D+01	0.000000D+00
0.900707D+00	-.422988D+01	0.223626D+01	-.252412D+02	0.251989D+01	0.318589D-01	0.125902D+00	0.455274D+01	0.000000D+00
0.919044D+00	-.458238D+01	0.199373D+01	-.250126D+02	0.205969D+01	0.101299D-01	0.839143D-01	0.455274D+01	0.000000D+00
0.935659D+00	-.491683D+01	0.181690D+01	-.250966D+02	0.164347D+01	-.494276D-02	0.531503D-01	0.455274D+01	0.000000D+00
0.950484D+00	-.523143D+01	0.168391D+01	-.252858D+02	0.126977D+01	-.144231D-01	0.315559D-01	0.455274D+01	0.000000D+00
0.963458D+00	-.552115D+01	0.158581D+01	-.254737D+02	0.940102D+00	-.187763D-01	0.172205D-01	0.455274D+01	0.000000D+00
0.974528D+00	-.577972D+01	0.151289D+01	-.256200D+02	0.656894D+00	-.187150D-01	0.838111D-02	0.455274D+01	0.000000D+00
0.983647D+00	-.600074D+01	0.146046D+01	-.257034D+02	0.422561D+00	-.153815D-01	0.345933D-02	0.455274D+01	0.000000D+00
0.990780D+00	-.617882D+01	0.142129D+01	-.257987D+02	0.238676D+00	-.103095D-01	0.110103D-02	0.455274D+01	0.000000D+00
0.995895D+00	-.630952D+01	0.139419D+01	-.258807D+02	0.106414D+00	-.515478D-02	0.218463D-03	0.455274D+01	0.000000D+00
0.998973D+00	-.638941D+01	0.137828D+01	-.259347D+02	0.266463D-01	-.137928D-02	0.136829D-04	0.455274D+01	0.000000D+00
0.100000D+01	-.641628D+01	0.137304D+01	-.259535D+02	0.156311D-16	0.000000D+00	0.430233D-21	0.455274D+01	0.000000D+00

Chapter VIII

VIII.1 Input-Output Manual for the In-Plane Forced Linear Dynamic Problem Solution Program, RCFORCE

This program is written in FORTRAN 77 and allows the interactive solution of the in-plane forced undamped linear dynamic problem for a compliant riser with a planar static configuration without torsion for a given frequency and amplitude of excitation at the top, as described in [4]. Excitation at the top involving p and/or q is allowed. The output of this program can be used as input to RCLINDY2 to solve the in-plane linear dynamic problem with homogeneous boundary conditions (in-plane eigenproblem).

Before executing the program the user must make sure that

- o Devices five and six correspond to input/output from the terminal
- o Device eight must be associated with the data file containing geometric, structural and hydrodynamic characteristics of the compliant riser created by a previous execution of the data preprocessing program RCINPUT. This file has a logical record length of 80 characters.
- o Device ten must be associated with the input data file containing the non-dimensional static planar solution created by RCSTAT2D. This file has a logical record length of 132 characters.
- o Device eleven must be associated with an output file with logical record length of 117 characters. This file contains the converged solution of the problem in a concise form appropriate for use in

the preparation of illustrations and/or as an input to RCLINDY2 from device twelve in a subsequent execution of this program.

Input Variables [Free Format]

At the beginning of the program the static 2-D solution created from RCSTAT2D is read from device ten. The values of the mean current velocity in the x direction and the maximum non-dimensional static effective tension are printed on the terminal. If the number of static discretization points is less than four or greater than the value of MNP (maximum number of allowable points), the program halts execution.

Then the geometric, structural and hydrodynamic characteristics of the compliant riser are read from the file associated with device eight. The user has the opportunity to review this data on his terminal and decide either to continue with the program or stop, see [3]. Then the user is asked for the excitation frequency in (rad/s). In order to get meaningful results, this frequency should be close to one of the in-plane natural frequencies of the compliant riser. Next he is asked for the p and q amplitudes of excitation at the top of the riser. Appropriate values for these amplitudes range from 1 to 0. Then the user is asked to supply the tolerance for convergence of iterations. Suggested values are the excitation amplitudes or 1/10 of these values. However, at the end of the run, the results should be checked, since the maximum of the resulting variables will be evaluated within this tolerance. Then the user is asked to input the mode number corresponding to the frequency of excitation.

Subsequently, the program enters NAG subroutine D02GBF, which provides the numerical solution to the linear problem. The manual of this subroutine is included in Chapter X. The input value of IFAIL is 111, indicating that the soft failure option with error message and monitoring information printing has been selected. Error messages are directed to device six. Once the execution of D02GBF is completed, the current value of IFAIL is printed on the terminal. For an explanation of this parameter, see NAG manual for D02GBF, Chapter X.

Only if IFAIL = 0 or IFAIL = 4, the execution of the program continues with printout of the final solution of the problem. Otherwise, the program stops. When IFAIL≠0, the user should consult the manual quoted above for interpretation of the results and a possible course of action. If IFAIL = 0 or 4, the solution is printed in the file associated with device eleven. The following quantities are printed:

MODE, NP, SIGMAD, XTOP, YTOP = Mode number, number of points at which converged solution is available, dimensional natural frequency (in rad/s) and x and y displacements at the top with
FORMAT (1X,I2,1X,I3,3(1X,D10.4)) and
for I=1, NP: the non-dimensional
$s, T_1, Q_1^{\xi}, \Omega_1^{\eta}, \phi_1, p, q, \sigma$ with
FORMAT (8(1X,D12.6))

The data written in the file associated with device eleven can be used as input to program RCLINDY2.

VIII.2 Sample Run, Input and Output

VIII.2.1 Zero Current Excitation

VIII.2.1.1 Interactive Session

INPUT

Device 5 = TERMINAL

Device 8 = RCJOA01 DATA A*

Device 10 = RC2DZERR DATA A**

OUTPUT

Device 6 = TERMINAL

Device 11 = RC2DZEE DATA A

*File included in Chapter II.

**File included in Chapter VI.

```
rcforce rcjoa01 rc2dzerr rc2dzee
FI 8 DISK RCJOA01 DATA A ( RECFM FB LRECL 80 BLKSIZE 800
FI 10 DISK RC2DZERR DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 11 DISK RC2DZEE DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
GLOBAL TXTLIB VFORTLIB CMSLIB NAG1 NAG2
LOAD RCFORCE ( START
EXECUTION BEGINS...
MNP=151
2-D STATIC SOLUTION FROM DEVICE 10
NP = 54
MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =0.000000D+00
2-D STATIC SOLUTION SUCCESFULLY READ
MAXIMUM STATIC EFFECTIVE TENSION/WA*L = 0.5547D+00
DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS
IF YES INPUT 1 , IF NO INPUT 0
?
0
 INPUT EXCITATION FREQUENCY IN RAD/S
?
.05
 INPUT AMPLITUDE OF EXCITATION AT TOP OF RISER FOR P
?
.1
 INPUT AMPLITUDE OF EXCITATION AT TOP OF RISER FOR Q
?
.1
 INPUT TOLERANCE FOR CONVERGENCE OF ITERATIONS
 SUGGESTED VALUE IS THE EXCITATION AMPLITUDE OR 1/10 OF THE EXCITATION AMPLITUDE
?
.01
 INPUT MODE NUMBER CORRESPONDING TO FREQUENCY OF EXCITATION
?
1

D02GBF MONITORING INFORMATION
 NUMBER OF POINTS IN CURRENT MESH =    57

 CORRECTION NUMBER    0   ESTIMATED MAXIMUM ERROR =  5.98D-01
 ESTIMATED ERROR BY COMPONENTS
   3.31D-02  5.01D-02  5.98D-01  6.13D-02  5.09D-03  1.04D-02
 NUMBER OF POINTS IN CURRENT MESH =    57

 CORRECTION NUMBER    1   ESTIMATED MAXIMUM ERROR =  4.24D-02
 ESTIMATED ERROR BY COMPONENTS
   1.62D-03  3.28D-03  4.24D-02  3.68D-03  2.70D-04  6.40D-04
 NUMBER OF POINTS IN CURRENT MESH =    57

 CORRECTION NUMBER    2   ESTIMATED MAXIMUM ERROR =  1.73D-02
 ESTIMATED ERROR BY COMPONENTS
   3.97D-04  5.08D-04  1.73D-02  8.05D-04  6.80D-05  8.33D-05
 NUMBER OF POINTS IN CURRENT MESH =    57

 CORRECTION NUMBER    3   ESTIMATED MAXIMUM ERROR =  1.98D-02
 ESTIMATED ERROR BY COMPONENTS
   5.84D-04  8.18D-04  1.98D-02  7.59D-04  6.21D-05  8.94D-05
 NUMBER OF POINTS IN CURRENT MESH =   107

 CORRECTION NUMBER    2   ESTIMATED MAXIMUM ERROR =  4.21D-03
 ESTIMATED ERROR BY COMPONENTS

   2.95D-04  2.66D-04  4.21D-03  2.69D-04  7.06D-05  7.45D-05
IFAIL =  0
R; T=3.29/3.50 14:41:44
```

VIII.2.1.2 RC2DZEE DATA A

1 107 0.5000D-01 0.0000D+00 0.7931D+00

0.000000D+00	0.428179D+00	-.102337D+00	0.119780D+02	0.000000D+00	0.000000D+00	0.000000D+00	0.424973D+01
0.102730D-02	0.431381D+00	-.884579D-01	0.120492D+02	0.123418D-01	-.193521D-07	0.633307D-05	0.424973D+01
0.410499D-02	0.439751D+00	-.463325D-01	0.122497D+02	0.497389D-01	-.127683D-05	0.101696D-03	0.424973D+01
0.922042D-02	0.449351D+00	0.251938D-01	0.125393D+02	0.113166D+00	-.149823D-04	0.517418D-03	0.424973D+01
0.163526D-01	0.453003D+00	0.126931D+00	0.128479D+02	0.203766D+00	-.872234D-04	0.164320D-02	0.424973D+01
0.254721D-01	0.439897D+00	0.257471D+00	0.130732D+02	0.322106D+00	-.345260D-03	0.402096D-02	0.424973D+01
0.310068D-01	0.421901D+00	0.335070D+00	0.131165D+02	0.394617D+00	-.637251D-03	0.597600D-02	0.424973D+01
0.365416D-01	0.396291D+00	0.410274D+00	0.130833D+02	0.467158D+00	-.106492D-02	0.831049D-02	0.424973D+01
0.397851D-01	0.377852D+00	0.452777D+00	0.130260D+02	0.509508D+00	-.138913D-02	0.985076D-02	0.424973D+01
0.430286D-01	0.356990D+00	0.493823D+00	0.129413D+02	0.551628D+00	-.177400D-02	0.115149D-01	0.424973D+01
0.495156D-01	0.308235D+00	0.570986D+00	0.126931D+02	0.634831D+00	-.274850D-02	0.152003D-01	0.424973D+01
0.532218D-01	0.276556D+00	0.611604D+00	0.125009D+02	0.681531D+00	-.343846D-02	0.175096D-01	0.424973D+01
0.569281D-01	0.242456D+00	0.649313D+00	0.122674D+02	0.727443D+00	-.423204D-02	0.199587D-01	0.424973D+01
0.606343D-01	0.206143D+00	0.683943D+00	0.119911D+02	0.772411D+00	-.513593D-02	0.225395D-01	0.424973D+01
0.643406D-01	0.167834D+00	0.715335D+00	0.116692D+02	0.816270D+00	-.615686D-02	0.252429D-01	0.424973D+01
0.684944D-01	0.123057D+00	0.746373D+00	0.112628D+02	0.863912D+00	-.744250D-02	0.284077D-01	0.424973D+01
0.726482D-01	0.769117D-01	0.772810D+00	0.108198D+02	0.909787D+00	-.887892D-02	0.317026D-01	0.424973D+01
0.747252D-01	0.534342D-01	0.784297D+00	0.105854D+02	0.932017D+00	-.965547D-02	0.333943D-01	0.424973D+01
0.768021D-01	0.297507D-01	0.794627D+00	0.103429D+02	0.953752D+00	-.104717D-01	0.351129D-01	0.424973D+01
0.788790D-01	0.590962D-02	0.803801D+00	0.100928D+02	0.974974D+00	-.113280D-01	0.368566D-01	0.424973D+01
0.809559D-01	-.180480D-01	0.811824D+00	0.983600D+01	0.995671D+00	-.122252D-01	0.386232D-01	0.424973D+01
0.832481D-01	-.444971D-01	0.819333D+00	0.953872D+01	0.101788D+01	-.132609D-01	0.405979D-01	0.424973D+01
0.855402D-01	-.708145D-01	0.825422D+00	0.921927D+01	0.103938D+01	-.143423D-01	0.425972D-01	0.424973D+01
0.878324D-01	-.969330D-01	0.830100D+00	0.887712D+01	0.106013D+01	-.154696D-01	0.446183D-01	0.424973D+01
0.901246D-01	-.122781D+00	0.833369D+00	0.850910D+01	0.108006D+01	-.166431D-01	0.466585D-01	0.424973D+01
0.924167D-01	-.148216D+00	0.835290D+00	0.812444D+01	0.109912D+01	-.178605D-01	0.487159D-01	0.424973D+01
0.947089D-01	-.173114D+00	0.835946D+00	0.773360D+01	0.111730D+01	-.191196D-01	0.507884D-01	0.424973D+01
0.958550D-01	-.185347D+00	0.835813D+00	0.753570D+01	0.112605D+01	-.197646D-01	0.518295D-01	0.424973D+01
0.970010D-01	-.197427D+00	0.835380D+00	0.733627D+01	0.113457D+01	-.204199D-01	0.528735D-01	0.424973D+01
0.981471D-01	-.209347D+00	0.834655D+00	0.713539D+01	0.114286D+01	-.210854D-01	0.539199D-01	0.424973D+01
0.992932D-01	-.221104D+00	0.833643D+00	0.693327D+01	0.115093D+01	-.217610D-01	0.549685D-01	0.424973D+01
0.101791D+00	-.245960D+00	0.830486D+00	0.647682D+01	0.116768D+01	-.232572D-01	0.572646D-01	0.424973D+01
0.103040D+00	-.257907D+00	0.828439D+00	0.623569D+01	0.117562D+01	-.240122D-01	0.584195D-01	0.424973D+01
0.104289D+00	-.269528D+00	0.826089D+00	0.598678D+01	0.118325D+01	-.247720D-01	0.595786D-01	0.424973D+01
0.106787D+00	-.291761D+00	0.820519D+00	0.546611D+01	0.119757D+01	-.263045D-01	0.619082D-01	0.424973D+01
0.109285D+00	-.312591D+00	0.813849D+00	0.491603D+01	0.121054D+01	-.278516D-01	0.642521D-01	0.424973D+01
0.111783D+00	-.331955D+00	0.806155D+00	0.433811D+01	0.122210D+01	-.294105D-01	0.666086D-01	0.424973D+01
0.114281D+00	-.349796D+00	0.797516D+00	0.373425D+01	0.123219D+01	-.309781D-01	0.689761D-01	0.424973D+01
0.115530D+00	-.358129D+00	0.792867D+00	0.342325D+01	0.123666D+01	-.317642D-01	0.701635D-01	0.424973D+01
0.116779D+00	-.366062D+00	0.788013D+00	0.310662D+01	0.124074D+01	-.325514D-01	0.713529D-01	0.424973D+01
0.118028D+00	-.373590D+00	0.782964D+00	0.278471D+01	0.124442D+01	-.333391D-01	0.725442D-01	0.424973D+01
0.119277D+00	-.380710D+00	0.777729D+00	0.245760D+01	0.124769D+01	-.341273D-01	0.737370D-01	0.424973D+01
0.121073D+00	-.390150D+00	0.769917D+00	0.198558D+01	0.125168D+01	-.352535D-01	0.754576D-01	0.424973D+01
0.122868D+00	-.398567D+00	0.761822D+00	0.151956D+01	0.125483D+01	-.363617D-01	0.771883D-01	0.424973D+01
0.124664D+00	-.405988D+00	0.753483D+00	0.105838D+01	0.125714D+01	-.374515D-01	0.789286D-01	0.424973D+01
0.126460D+00	-.412420D+00	0.744939D+00	0.602336D+00	0.125863D+01	-.385210D-01	0.806784D-01	0.424973D+01
0.130052D+00	-.422365D+00	0.727449D+00	-.293920D+00	0.125918D+01	-.405912D-01	0.842073D-01	0.424973D+01
0.133643D+00	-.428506D+00	0.709727D+00	-.116872D+01	0.125655D+01	-.425566D-01	0.877755D-01	0.424973D+01
0.137234D+00	-.431023D+00	0.691938D+00	-.202176D+01	0.125081D+01	-.444019D-01	0.913824D-01	0.424973D+01
0.140825D+00	-.430110D+00	0.674222D+00	-.285319D+01	0.124205D+01	-.461118D-01	0.950287D-01	0.424973D+01
0.152338D+00	-.405980D+00	0.618574D+00	-.537489D+01	0.119448D+01	-.505171D-01	0.106965D+00	0.424973D+01
0.163850D+00	-.353701D+00	0.565111D+00	-.768383D+01	0.111911D+01	-.528892D-01	0.119213D+00	0.424973D+01
0.176053D+00	-.274274D+00	0.508675D+00	-.990511D+01	0.101156D+01	-.526995D-01	0.132310D+00	0.424973D+01
0.188255D+00	-.177113D+00	0.447743D+00	-.118855D+02	0.878354D+00	-.492145D-01	0.145135D+00	0.424973D+01
0.201098D+00	-.651678D-01	0.372658D+00	-.136764D+02	0.713854D+00	-.416415D-01	0.157655D+00	0.424973D+01

0.213942D+00	0.462310D-01	0.280079D+00	-.151042D+02	0.528604D+00	-.298064D-01	0.168238D+00	0.424973D+01
0.227373D+00	0.149483D+00	0.162259D+00	-.161196D+02	0.318320D+00	-.130823D-01	0.176033D+00	0.424973D+01
0.240804D+00	0.225670D+00	0.239814D-01	-.165503D+02	0.982212D-01	0.747108D-02	0.179154D+00	0.424973D+01
0.268731D+00	0.256910D+00	-.290917D+00	-.152834D+02	-.353242D+00	0.577280D-01	0.166021D+00	0.424973D+01
0.283169D+00	0.200215D+00	-.433148D+00	-.135001D+02	-.561876D+00	0.829434D-01	0.148120D+00	0.424973D+01
0.297608D+00	0.103632D+00	-.540078D+00	-.111017D+02	-.740113D+00	0.105077D+00	0.123318D+00	0.424973D+01
0.312462D+00	-.193165D-01	-.602567D+00	-.820353D+01	-.883886D+00	0.122966D+00	0.923383D-01	0.424973D+01
0.327317D+00	-.146282D+00	-.613636D+00	-.512103D+01	-.982921D+00	0.134842D+00	0.580344D-01	0.424973D+01
0.342527D+00	-.263387D+00	-.579086D+00	-.202908D+01	-.103707D+01	0.140922D+00	0.216902D-01	0.424973D+01
0.357736D+00	-.354192D+00	-.511427D+00	0.792840D+00	-.104603D+01	0.141497D+00	-.135646D-01	0.424973D+01
0.388740D+00	-.450327D+00	-.331428D+00	0.524232D+01	-.947551D+00	0.131334D+00	-.762276D-01	0.424973D+01
0.420200D+00	-.457438D+00	-.158265D+00	0.782262D+01	-.737166D+00	0.115318D+00	-.122906D+00	0.424973D+01
0.451988D+00	-.427457D+00	-.268749D-01	0.877718D+01	-.469554D+00	0.101779D+00	-.152849D+00	0.424973D+01
0.483974D+00	-.400436D+00	0.612895D-01	0.855444D+01	-.189818D+00	0.943708D-01	-.167906D+00	0.424973D+01
0.516026D+00	-.393869D+00	0.115102D+00	0.756909D+01	0.701332D-01	0.931726D-01	-.170402D+00	0.424973D+01
0.548012D+00	-.409814D+00	0.142721D+00	0.615095D+01	0.290350D+00	0.964459D-01	-.162652D+00	0.424973D+01
0.579800D+00	-.442947D+00	0.150423D+00	0.455641D+01	0.460749D+00	0.102001D+00	-.147021D+00	0.424973D+01
0.611260D+00	-.486010D+00	0.143729D+00	0.297759D+01	0.579070D+00	0.108001D+00	-.125922D+00	0.424973D+01
0.642264D+00	-.532731D+00	0.127894D+00	0.154430D+01	0.648737D+00	0.113269D+00	-.101655D+00	0.424973D+01
0.672683D+00	-.578866D+00	0.107616D+00	0.327736D+00	0.676678D+00	0.117269D+00	-.762220D-01	0.424973D+01
0.702392D+00	-.622120D+00	0.865759D-01	-.649905D+00	0.671367D+00	0.119924D+00	-.511879D-01	0.424973D+01
0.731269D+00	-.661587D+00	0.672384D-01	-.140108D+01	0.641298D+00	0.121406D+00	-.276508D-01	0.424973D+01
0.759196D+00	-.697161D+00	0.509411D-01	-.195821D+01	0.594031D+00	0.121974D+00	-.628542D-02	0.424973D+01
0.786058D+00	-.729117D+00	0.381468D-01	-.236146D+01	0.535753D+00	0.121878D+00	0.125772D-01	0.424973D+01
0.811745D+00	-.757855D+00	0.287846D-01	-.265097D+01	0.471201D+00	0.121309D+00	0.288546D-01	0.424973D+01
0.823947D+00	-.770989D+00	0.252000D-01	-.276241D+01	0.438158D+00	0.120889D+00	0.359703D-01	0.424973D+01
0.836150D+00	-.783833D+00	0.221604D-01	-.286019D+01	0.403840D+00	0.120377D+00	0.426786D-01	0.424973D+01
0.847662D+00	-.795722D+00	0.196806D-01	-.294171D+01	0.370434D+00	0.119803D+00	0.486448D-01	0.424973D+01
0.859175D+00	-.807409D+00	0.175372D-01	-.301425D+01	0.336142D+00	0.119136D+00	0.542603D-01	0.424973D+01
0.864562D+00	-.812840D+00	0.165799D-01	-.304540D+01	0.319819D+00	0.118787D+00	0.567761D-01	0.424973D+01
0.869949D+00	-.818264D+00	0.155964D-01	-.307478D+01	0.303333D+00	0.118408D+00	0.592276D-01	0.424973D+01
0.875336D+00	-.823683D+00	0.145885D-01	-.310201D+01	0.286697D+00	0.118001D+00	0.616133D-01	0.424973D+01
0.880723D+00	-.829095D+00	0.135627D-01	-.312986D+01	0.269907D+00	0.117564D+00	0.639326D-01	0.424973D+01
0.885719D+00	-.834111D+00	0.125957D-01	-.313643D+01	0.254242D+00	0.117134D+00	0.660192D-01	0.424973D+01
0.890715D+00	-.839124D+00	0.115276D-01	-.310773D+01	0.238630D+00	0.116681D+00	0.680398D-01	0.424973D+01
0.895711D+00	-.844127D+00	0.102229D-01	-.305037D+01	0.223236D+00	0.116206D+00	0.699952D-01	0.424973D+01
0.900707D+00	-.849112D+00	0.856482D-02	-.296755D+01	0.208195D+00	0.115708D+00	0.718867D-01	0.424973D+01
0.909875D+00	-.858192D+00	0.445730D-02	-.279932D+01	0.181765D+00	0.114742D+00	0.751864D-01	0.424973D+01
0.914460D+00	-.862695D+00	0.191880D-02	-.272341D+01	0.169108D+00	0.114237D+00	0.767516D-01	0.424973D+01
0.919044D+00	-.867170D+00	-.923155D-03	-.264991D+01	0.156792D+00	0.113717D+00	0.782628D-01	0.424973D+01
0.927351D+00	-.875214D+00	-.695428D-02	-.251712D+01	0.135327D+00	0.112728D+00	0.808815D-01	0.424973D+01
0.935659D+00	-.883164D+00	-.142941D-01	-.237676D+01	0.114994D+00	0.111669D+00	0.833674D-01	0.424973D+01
0.943071D+00	-.890149D+00	-.220652D-01	-.225011D+01	0.978473D-01	0.110659D+00	0.854861D-01	0.424973D+01
0.950484D+00	-.897007D+00	-.310731D-01	-.212632D+01	0.816270D-01	0.109579D+00	0.875244D-01	0.424973D+01
0.956971D+00	-.902879D+00	-.400482D-01	-.201426D+01	0.681932D-01	0.108572D+00	0.892523D-01	0.424973D+01
0.963458D+00	-.908599D+00	-.501623D-01	-.189329D+01	0.555151D-01	0.107501D+00	0.909376D-01	0.424973D+01
0.974528D+00	-.917900D+00	-.703058D-01	-.167924D+01	0.357342D-01	0.105513D+00	0.937334D-01	0.424973D+01
0.983647D+00	-.924995D+00	-.899200D-01	-.149263D+01	0.212577D-01	0.103704D+00	0.959865D-01	0.424973D+01
0.990780D+00	-.930066D+00	-.107425D+00	-.132901D+01	0.111845D-01	0.102168D+00	0.977342D-01	0.424973D+01
0.995895D+00	-.933375D+00	-.121303D+00	-.120133D+01	0.470925D-02	0.100992D+00	0.989885D-01	0.424973D+01
0.998973D+00	-.935209D+00	-.130235D+00	-.111995D+01	0.113587D-02	0.100252D+00	0.997464D-01	0.424973D+01
0.100000D+01	-.935792D+00	-.133318D+00	-.109200D+01	0.000000D+00	0.100000D+00	0.100000D+00	0.424973D+01

Chapter IX

IX.1 Input-Output Manual for the In-Plane Linear Eigenproblem Solution Program, RCLINDY2

This program is written in FORTRAN 77 and allows the interactive solution of the in-plane linear dynamic eigenproblem for a compliant riser with a planar static configuration, as described in [4]. The initial (ε=0) approximation is prepared by RCFORCE. This program is particularly useful in the case of zero current velocity where the asymptotic theory is not valid.

Before executing the program the user must make sure that:

- Devices five and six correspond to input/output from the terminal
- Device eight must be associated with the data file containing geometric, structural and hydrodynamic characteristics of the compliant riser created by a previous execution of the data preprocessing program RCINPUT. This file has a logical record length of 80 characters.
- Device nine must be associated with an output data file with logical record length of 132 characters which upon completion of the program contains a complete list of the input, initial approximation and the converged solution of the problem.
- Device ten must be associated with the input data file containing the non-dimensional static planar solution created by RCSTAT2D. This file has a logical record length of 132 characters.

- o Device eleven must be associated with an output file with logical record length of 117 characters. This file contains the converged solution of the problem in a concise form appropriate for use in the preparation of illustrations and/or as an input to RCLINDY1 from device twelve.
- o Device twelve must be associated with an input file containing the initial approximate solution of the undamped forced in-plane linear dynamic problem, resulting from a previous execution of RCFORCE.

Input Variables [Free Format]

At the beginning of the program the static 2-D solution created from RCSTAT2D is read from device ten. The values of the mean current velocity in the x direction and the maximum non-dimensional static effective tension are printed on the terminal. If the number of static discretization points is less than four or greater than the value of MNP (maximum number of allowable points), the program halts execution.

Then the geometric, structural and hydrodynamic characteristics of the compliant riser are read from the file associated with device eight. The user has the opportunity to review this data on his terminal and decide either to continue with the program or stop, see [3].

In this case an initial (ε=0) approximation to the solution is available from a previous run of RCFORCE. The program reads the information from the previous run concerning the number of discretization points NP, the mode number and the corresponding frequency of excitation. If the number of discretization points is greater than MNP, the program stops execution. The same happens if NP is less than the number of static discretization points. Then the user has the option to review the initial approximation by displaying it on his terminal. The assumed boundary condition for the curvature at the lower ball point of the riser is printed at the terminal. Subsequently, the initial solution provided by RCFORCE is printed in the file associated with the device nine. The following quantities are printed:

- o Number of discretization points NP
- o Natural frequency (rad/s)
- o Order of point (starting from the lower end)
- o Non-dimensional arc length
- o Non-dimensional dynamic effective tension, T_1
- o Non-dimensional shear force in the $\vec{\xi}$ direction, Q_1^{ξ}
- o Non-dimensional component of rate of rotation about $\vec{\eta}, \Omega_1^{\eta}$
- o Euler angle ϕ_1
- o Non-dimensional displacement p
- o Non-dimensional displacement q
- o Non-dimensional natural frequency

Subsequently, the program prints the maximum of the absolute value of the initial rate of rotation about $\vec{\eta}$ direction. This number is used to estimate a reasonable tolerance for convergence of iterations. The user is requested to input a tolerance as a fraction of this number; e.g., 0.01 for 1% tolerance or better for all quantities of interest. Typically, Ω_1^{η} will be determined with an accuracy a little better than the above fraction and all other variables will be even more accurate. After the run the accuracy of the results should be checked. The user is given the opportunity to stop the program at this point if he wishes.

If he chooses to continue, he is asked to input the initial increment of the continuation parameter $\delta\varepsilon$ (condition $0<\delta\varepsilon\leq 1$). If no continuation is required, then use $\delta\varepsilon=1$. If continuation is required, then $\delta\varepsilon=0.1$ will usually suffice. For large changes between initial and final problem, a smaller value of $\delta\varepsilon$, e.g., 0.05 or 0.25 might be necessary.

After the initial approximation is fully defined, the program enters NAG subroutine D02RAF, which provides the iterative numerical solution of the problem. The manual of this subroutine is included in Chapter X. The input value of IFAIL is 111, indicating that the soft failure option with error message and monitoring information printing has been selected. Error messages are directed to device six. Once the execution of D02RAF is completed, the current value of IFAIL is printed on the terminal. For an explanation of this parameter, see NAG manual for D02RAF, Chapter X. Only if IFAIL = 0 or IFAIL = 4 the execution of the program continues with printout of the riser characteristics and the final solution of the problem. Otherwise, the program stops. When <u>IFAIL≠0</u>, the user <u>should</u> consult the manual quoted above for interpretation of the results and a possible course of action. If IFAIL = 0 or 4, the riser characteristics and the final solution of the problem are printed in the file associated with device nine. For the riser characteristics, the format used in the static program RCSTAT2D is also used here. This is described in [3], (pp. 23-25).

Next the non-dimensional in-plane solution is written in the file associated with device nine. The mode number, natural frequency and final number of points NP at which the solution is available is printed first. Then the following data is printed for I=1 to NP:

$s, T_1, Q_1^{\xi}, \Omega_1^{\eta}, \phi_1, p, q, \sigma$ with

FORMAT (8(1X,D10.4)). Next the maximum (non-dimensional) estimated errors of $T_1, Q_1^{\xi}, \Omega_1^{\eta}, \phi_1, p, q, \sigma$ provided by the NAG subroutine D02RAF are printed. Subsequently, the following data is written in the file associated with device eleven:

MODE, NP, SIGMAD, XTOP, YTOP: Mode number, number of points at which converged solution is available and dimensional natural frequency (in rad/s) and x and y displacements at the top with

FORMAT (1X,I2,1X,I3,3(1X,D10.4)) and

For I=1 to NP: the non-dimensional

$s, T_1, Q_1^{\xi}, \Omega_1^{\eta}, \phi_1, p, q, \sigma$ and the dimensional current velocity $V_c(s)$ with

FORMAT (9(1X,D12.6)). The data written in the file associated with device eleven due to their simple form can be easily used as input to plotting programs. In addition, this data is useful in subsequent runs of RCLINDY1 if such an option is selected.

IX.2 Sample Run, Input and Output

IX.2.1 Zero Current Excitation

IX.2.1.1 Interactive Session

INPUT

Device 5 = TERMINAL

Device 8 = RCJOA01 DATA A*

Device 10 = RC2DZERR DATA A**

Device 12 = RC2DZEE DATA A***

OUTPUT

Device 6 = TERMINAL

Device 9 = RC2DZ1 DATA A

Device 11 = RC2DZ1A DATA A

---

*File included in Chapter II.

**Files included in Chapter VI.

***File included in Chapter VIII.

```
rclindy2 rcjoao1 rc2dz1 rc2dzerr rc2dz1a rc2dzee
FI 8 DISK RCJOAO1 DATA A ( RECFM FB LRECL 80 BLKSIZE 800
FI 9 DISK RC2DZ1 DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 10 DISK RC2DZERR DATA A ( RECFM FB LRECL 132 BLKSIZE 1320
FI 11 DISK RC2DZ1A DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
FI 12 DISK RC2DZEE DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
GLOBAL TXTLIB VFORTLIB CMSLIB NAG1 NAG2
LOAD RCLINDY2 ( START
EXECUTION BEGINS...
MNP=151
2-D STATIC SOLUTION FROM DEVICE 10
NP = 54
MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =0.000000D+00
2-D STATIC SOLUTION SUCCESFULLY READ
MAXIMUM STATIC EFFECTIVE TENSION/WA*L = 0.5547D+00
DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS
IF YES INPUT 1 , IF NO INPUT 0
?
0
MNP=151
INITIAL APPROXIMATION FROM DEVICE 12
NP =107 MODE NUMBER = 1 SIGMAD =0.5000D-01
X AT TOP =0.0000D+00 Y AT TOP =0.7931D+00
DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION
IF YES INPUT 1
?
2
ASSUMED BOUNDARY CONDITION
OMEGA ETA (0) =0.119780D+02
MAXIMUM ABSOLUTE VALUE OF N-D OMEGA ETA IS =0.165503D+02
THIS NUMBER CAN BE USED TO ESTIMATE
A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS
INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE
E.G. INPUT 0.01 OR 0.1 IF THE INITIAL ESTIMATE FOR OMEGA ETA
IS SMALL
AFTER THE RUN CHECK THE ACCURACY OF THE SOLUTION
?
.01
IF YOU WISH TO STOP INPUT 0
IF YOU WISH TO CONTINUE WITH ITERATIONS INPUT 1
?
1
INPUT INITIAL INCREMENT OF CONTINUATION PARAMETER DELEPS
IF NO CONTINUATION IS REQUIRED INPUT DELEPS = 1.D0
IF CONTINUATION IS REQUIRED THEN 0.D0 < DELEPS < 1.D0
RECOMMENDATION :
USUALLY DELEPS = 0.1D0 WILL SUFFICE
FOR LARGE CHANGES BETWEEN INITIAL AND FINAL PROBLEM
A SMALLER VALUE OF DELEPS, E.G. 0.05D0 OR 0.025D0 MIGHT BE
NECESSARY
?
.05

D02RAF MONITORING INFORMATION

 MONITORING NEWTON ITERATION
  NUMBER OF POINTS IN CURRENT MESH =   107
```

```
CORRECTION NUMBER     O   RESIDUAL SHOULD BE .LE.  1.00D+00
 ITERATION NUMBER     O   RESIDUAL =  9.20D-02
  SQUARED NORM OF CORRECTION =  2.12D+01
  SQUARED NORM OF GRADIENT   =  6.56D-01
  SCALAR PRODUCT OF CORRECTION AND GRADIENT =  8.47D-03
 ITERATION NUMBER     1   RESIDUAL =  2.35D-03

CONTINUATION PARAMETER EPSILON =  1.00D-01   DELEPS =  1.00D-01

MONITORING NEWTON ITERATION
 NUMBER OF POINTS IN CURRENT MESH =  107
 CORRECTION NUMBER     O   RESIDUAL SHOULD BE .LE.  1.00D+00
  ITERATION NUMBER     O   RESIDUAL =  2.47D-02

CONTINUATION PARAMETER EPSILON =  3.00D-01   DELEPS =  2.00D-01

MONITORING NEWTON ITERATION
 NUMBER OF POINTS IN CURRENT MESH =  107
 CORRECTION NUMBER     O   RESIDUAL SHOULD BE .LE.  1.00D+00
  ITERATION NUMBER     O   RESIDUAL =  1.23D-01

CONTINUATION PARAMETER EPSILON =  7.00D-01   DELEPS =  4.00D-01

MONITORING NEWTON ITERATION
 NUMBER OF POINTS IN CURRENT MESH =  107
 CORRECTION NUMBER     O   RESIDUAL SHOULD BE .LE.  1.00D+00
  ITERATION NUMBER     O   RESIDUAL =  6.00D-01

CONTINUATION PARAMETER EPSILON =  1.00D+00   DELEPS =  8.00D-01

MONITORING NEWTON ITERATION
 NUMBER OF POINTS IN CURRENT MESH =  107
 CORRECTION NUMBER     O   RESIDUAL SHOULD BE .LE.  1.03D-04
  ITERATION NUMBER     O   RESIDUAL =  3.09D+00
   SQUARED NORM OF CORRECTION =  5.46D+03
   SQUARED NORM OF GRADIENT   =  4.63D+01
   SCALAR PRODUCT OF CORRECTION AND GRADIENT =  9.55D+00
  ITERATION NUMBER     1   RESIDUAL =  4.70D-01
   SQUARED NORM OF CORRECTION =  5.81D+02
   SQUARED NORM OF GRADIENT   =  7.23D-01
   SCALAR PRODUCT OF CORRECTION AND GRADIENT =  2.21D-01
  ITERATION NUMBER     2   RESIDUAL =  1.14D-01
   SQUARED NORM OF CORRECTION =  7.34D+01
   SQUARED NORM OF GRADIENT   =  2.61D-02
   SCALAR PRODUCT OF CORRECTION AND GRADIENT =  1.30D-02
  ITERATION NUMBER     3   RESIDUAL =  3.67D-03
   SQUARED NORM OF CORRECTION =  6.09D-02
   SQUARED NORM OF GRADIENT   =  2.54D-05
   SCALAR PRODUCT OF CORRECTION AND GRADIENT =  1.34D-05
  ITERATION NUMBER     4   RESIDUAL =  1.23D-05

MESH SELECTION
 NUMBER OF NEW POINTS    2

CORRECTION NUMBER     O   ESTIMATED MAXIMUM ERROR =  2.50D-01
ESTIMATED ERROR BY COMPONENTS
  1.42D-02  1.21D-02  2.50D-01  1.85D-02  2.49D-03  2.28D-03  8.54D-02

MONITORING NEWTON ITERATION
 NUMBER OF POINTS IN CURRENT MESH =  107
```

```
  CORRECTION NUMBER     1    RESIDUAL SHOULD BE .LE.  2.50D-04
   ITERATION NUMBER     0    RESIDUAL =  1.33D-01
   ITERATION NUMBER     1    RESIDUAL =  2.04D-04

 CORRECTION NUMBER     1    ESTIMATED MAXIMUM ERROR =  2.33D-02
 ESTIMATED ERROR BY COMPONENTS
   1.19D-03  1.70D-03  2.33D-02  1.53D-03  1.34D-04  2.08D-04  1.98D-05
IFAIL =  0
R; T=4.60/4.89 14:44:26
cp spool console stop close
```

IX.2.1.2 RC2DZ1 DATA A

INITIAL CONDITION FOR EPS=0. AND NP = 86 POINTS, NATURAL FREQUENCY = 0.3600D-01 RAD/S

I	ARC	TENSION	QXI	OMEGA ETA	PHI	P	Q	SIGMA
1	0.000000D+00	-.682778D+00	0.314342D+00	-.774100D+01	0.000000D+00	0.000000D+00	0.000000D+00	0.305981D+01
2	0.102730D-02	-.687134D+00	0.301582D+00	-.782997D+01	-.799818D-02	0.122874D-07	-.410039D-05	0.305981D+01
3	0.410499D-02	-.699326D+00	0.262483D+00	-.808540D+01	-.324938D-01	0.828692D-06	-.662013D-04	0.305981D+01
4	0.922042D-02	-.716443D+00	0.194839D+00	-.847111D+01	-.748619D-01	0.979658D-05	-.339739D-03	0.305981D+01
5	0.163526D-01	-.732786D+00	0.959157D-01	-.892174D+01	-.136949D+00	0.575489D-04	-.109111D-02	0.305981D+01
6	0.254721D-01	-.739050D+00	-.358201D-01	-.933652D+01	-.220342D+00	0.230081D-03	-.270509D-02	0.305981D+01
7	0.365416D-01	-.722166D+00	-.198251D+00	-.959176D+01	-.325370D+00	0.718868D-03	-.566983D-02	0.305981D+01
8	0.430286D-01	-.699424D+00	-.291628D+00	-.959873D+01	-.387676D+00	0.120444D-02	-.791453D-02	0.305981D+01
9	0.495156D-01	-.667314D+00	-.381809D+00	-.948886D+01	-.449650D+00	0.187671D-02	-.105192D-01	0.305981D+01
10	0.569281D-01	-.620037D+00	-.478771D+00	-.921155D+01	-.519070D+00	0.290713D-02	-.139106D-01	0.305981D+01
11	0.643406D-01	-.562696D+00	-.567177D+00	-.874032D+01	-.585725D+00	0.425471D-02	-.177038D-01	0.305981D+01
12	0.684944D-01	-.526958D+00	-.612186D+00	-.839614D+01	-.621334D+00	0.515767D-02	-.199861D-01	0.305981D+01
13	0.726482D-01	-.489201D+00	-.653526D+00	-.800285D+01	-.655410D+00	0.616980D-02	-.223680D-01	0.305981D+01
14	0.768021D-01	-.449772D+00	-.691085D+00	-.756087D+01	-.687749D+00	0.729479D-02	-.248377D-01	0.305981D+01
15	0.809559D-01	-.408963D+00	-.724823D+00	-.707890D+01	-.718171D+00	0.853741D-02	-.273820D-01	0.305981D+01
16	0.832481D-01	-.386073D+00	-.741734D+00	-.678680D+01	-.734067D+00	0.927202D-02	-.288138D-01	0.305981D+01
17	0.855402D-01	-.363071D+00	-.757383D+00	-.646803D+01	-.749264D+00	0.100399D-01	-.302630D-01	0.305981D+01
18	0.901246D-01	-.317022D+00	-.784865D+00	-.573882D+01	-.777289D+00	0.116763D-01	-.332040D-01	0.305981D+01
19	0.947089D-01	-.271659D+00	-.807335D+00	-.491859D+01	-.801741D+00	0.134402D-01	-.361869D-01	0.305981D+01
20	0.970010D-01	-.249493D+00	-.816773D+00	-.449000D+01	-.812526D+00	0.143668D-01	-.376885D-01	0.305981D+01
21	0.992932D-01	-.227733D+00	-.825067D+00	-.404940D+01	-.822316D+00	0.153233D-01	-.391930D-01	0.305981D+01
22	0.104289D+00	-.182692D+00	-.839085D+00	-.301144D+01	-.840009D+00	0.174743D-01	-.424844D-01	0.305981D+01
23	0.106787D+00	-.161858D+00	-.844002D+00	-.243847D+01	-.846823D+00	0.185668D-01	-.441370D-01	0.305981D+01
24	0.109285D+00	-.142232D+00	-.847629D+00	-.183390D+01	-.852166D+00	0.196696D-01	-.457904D-01	0.305981D+01
25	0.114281D+00	-.106953D+00	-.851291D+00	-.537034D+00	-.858136D+00	0.218961D-01	-.490903D-01	0.305981D+01
26	0.119277D+00	-.774215D-01	-.850694D+00	0.863407D+00	-.857354D+00	0.241378D-01	-.523615D-01	0.305981D+01
27	0.126460D+00	-.471653D-01	-.843344D+00	0.293646D+01	-.843703D+00	0.272590D-01	-.570130D-01	0.305981D+01
28	0.130052D+00	-.380178D-01	-.837347D+00	0.395940D+01	-.831317D+00	0.287194D-01	-.593192D-01	0.305981D+01
29	0.133643D+00	-.327818D-01	-.830231D+00	0.497456D+01	-.815271D+00	0.301015D-01	-.616048D-01	0.305981D+01
30	0.137234D+00	-.313719D-01	-.822166D+00	0.598029D+01	-.795599D+00	0.313940D-01	-.638646D-01	0.305981D+01
31	0.140825D+00	-.336708D-01	-.813276D+00	0.697569D+01	-.772333D+00	0.325862D-01	-.660938D-01	0.305981D+01
32	0.163850D+00	-.129707D+00	-.741364D+00	0.130598D+02	-.540587D+00	0.372029D-01	-.792239D-01	0.305981D+01
33	0.188255D+00	-.347017D+00	-.619605D+00	0.187342D+02	-.150586D+00	0.348549D-01	-.889087D-01	0.305981D+01
34	0.213942D+00	-.624539D+00	-.395249D+00	0.232415D+02	0.392717D+00	0.237022D-01	-.896601D-01	0.305981D+01
35	0.240804D+00	-.841606D+00	-.261003D-01	0.252573D+02	0.105169D+01	0.595840D-02	-.734984D-01	0.305981D+01
36	0.268731D+00	-.852259D+00	0.433652D+00	0.233207D+02	0.174017D+01	-.976833D-02	-.335446D-01	0.305981D+01
37	0.283169D+00	-.760828D+00	0.640820D+00	0.206752D+02	0.205901D+01	-.128696D-01	-.420155D-02	0.305981D+01
38	0.297608D+00	-.616669D+00	0.798802D+00	0.171286D+02	0.233286D+01	-.108237D-01	0.295655D-01	0.305981D+01
39	0.312462D+00	-.439603D+00	0.893909D+00	0.128362D+02	0.255601D+01	-.292075D-02	0.671802D-01	0.305981D+01
40	0.327317D+00	-.261727D+00	0.915401D+00	0.825161D+01	0.271277D+01	0.106956D-01	0.105858D+00	0.305981D+01
41	0.342527D+00	-.103472D+00	0.872765D+00	0.361770D+01	0.280275D+01	0.296305D-01	0.144923D+00	0.305981D+01
42	0.357736D+00	0.108843D-01	0.783740D+00	-.667202D+00	0.282461D+01	0.519698D-01	0.182278D+00	0.305981D+01
43	0.388740D+00	0.101229D+00	0.548494D+00	-.768954D+01	0.268857D+01	0.101210D+00	0.251133D+00	0.305981D+01
44	0.420200D+00	0.434964D-01	0.323486D+00	-.122972D+02	0.236787D+01	0.146269D+00	0.311250D+00	0.305981D+01
45	0.451988D+00	-.858558D-01	0.152831D+00	-.148099D+02	0.193215D+01	0.179232D+00	0.363857D+00	0.305981D+01
46	0.483974D+00	-.222449D+00	0.331277D-01	-.157786D+02	0.143950D+01	0.196950D+00	0.409177D+00	0.305981D+01
47	0.516026D+00	-.333086D+00	-.515986D-01	-.156528D+02	0.933331D+00	0.199885D+00	0.445787D+00	0.305981D+01
48	0.548012D+00	-.406858D+00	-.112235D+00	-.147461D+02	0.445410D+00	0.190808D+00	0.471598D+00	0.305981D+01
49	0.579800D+00	-.445478D+00	-.153568D+00	-.132982D+02	-.150734D-02	0.173610D+00	0.485065D+00	0.305981D+01
50	0.611260D+00	-.456470D+00	-.177840D+00	-.115173D+02	-.392535D+00	0.152249D+00	0.485873D+00	0.305981D+01
51	0.642264D+00	-.448792D+00	-.187554D+00	-.958611D+01	-.719943D+00	0.129999D+00	0.474994D+00	0.305981D+01
52	0.672683D+00	-.430332D+00	-.186344D+00	-.765093D+01	-.982076D+00	0.109098D+00	0.454322D+00	0.305981D+01
53	0.702392D+00	-.406903D+00	-.178618D+00	-.580961D+01	-.118183D+01	0.907501D-01	0.426196D+00	0.305981D+01

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54 0.731269D+00 -.382227D+00 -.168924D+00 -.410868D+01 -.132481D+01 0.753517D-01 0.392999D+00 0.305981D+01
55 0.759196D+00 -.358394D+00 -.161587D+00 -.254767D+01 -.141759D+01 0.627712D-01 0.356915D+00 0.305981D+01
56 0.786058D+00 -.336366D+00 -.160751D+00 -.108665D+01 -.146638D+01 0.525920D-01 0.319823D+00 0.305981D+01
57 0.811745D+00 -.316412D+00 -.170606D+00 0.346047D+00 -.147608D+01 0.443443D-01 0.283276D+00 0.305981D+01
58 0.823947D+00 -.307238D+00 -.180880D+00 0.107145D+01 -.146747D+01 0.407920D-01 0.265858D+00 0.305981D+01
59 0.836150D+00 -.298177D+00 -.196003D+00 0.184899D+01 -.144972D+01 0.374477D-01 0.248558D+00 0.305981D+01
60 0.847662D+00 -.289635D+00 -.215850D+00 0.265059D+01 -.142389D+01 0.344303D-01 0.232459D+00 0.305981D+01
61 0.853419D+00 -.285311D+00 -.228215D+00 0.308352D+01 -.140740D+01 0.329564D-01 0.224526D+00 0.305981D+01
62 0.859175D+00 -.280937D+00 -.242439D+00 0.354235D+01 -.138834D+01 0.315121D-01 0.216689D+00 0.305981D+01
63 0.864562D+00 -.276709D+00 -.257639D+00 0.399862D+01 -.136804D+01 0.301717D-01 0.209458D+00 0.305981D+01
64 0.869949D+00 -.272265D+00 -.274876D+00 0.448468D+01 -.134521D+01 0.288295D-01 0.202341D+00 0.305981D+01
65 0.875336D+00 -.267573D+00 -.294348D+00 0.500243D+01 -.131967D+01 0.274901D-01 0.195352D+00 0.305981D+01
66 0.880723D+00 -.262588D+00 -.316320D+00 0.556601D+01 -.129122D+01 0.261542D-01 0.188505D+00 0.305981D+01
67 0.885719D+00 -.257680D+00 -.339080D+00 0.607692D+01 -.126211D+01 0.249263D-01 0.182294D+00 0.305981D+01
68 0.890715D+00 -.252482D+00 -.364024D+00 0.652424D+01 -.123061D+01 0.237159D-01 0.176231D+00 0.305981D+01
69 0.895711D+00 -.246964D+00 -.390963D+00 0.691670D+01 -.119701D+01 0.225230D-01 0.170325D+00 0.305981D+01
70 0.900707D+00 -.241100D+00 -.419726D+00 0.725354D+01 -.116160D+01 0.213478D-01 0.164586D+00 0.305981D+01
71 0.909875D+00 -.229400D+00 -.476904D+00 0.783084D+01 -.109246D+01 0.192517D-01 0.154516D+00 0.305981D+01
72 0.919044D+00 -.216414D+00 -.540127D+00 0.846722D+01 -.101779D+01 0.172569D-01 0.145081D+00 0.305981D+01
73 0.923198D+00 -.209954D+00 -.570994D+00 0.877733D+01 -.981984D+00 0.163757D-01 0.141030D+00 0.305981D+01
74 0.927351D+00 -.203042D+00 -.603380D+00 0.910947D+01 -.944844D+00 0.155027D-01 0.137128D+00 0.305981D+01
75 0.935659D+00 -.187722D+00 -.673185D+00 0.984573D+01 -.866171D+00 0.137828D-01 0.129790D+00 0.305981D+01
76 0.943071D+00 -.172032D+00 -.741741D+00 0.105586D+02 -.790564D+00 0.122664D-01 0.123802D+00 0.305981D+01
77 0.950484D+00 -.154074D+00 -.816651D+00 0.112900D+02 -.709606D+00 0.107566D-01 0.118383D+00 0.305981D+01
78 0.956971D+00 -.136143D+00 -.887743D+00 0.119763D+02 -.634179D+00 0.943293D-02 0.114137D+00 0.305981D+01
79 0.963458D+00 -.115778D+00 -.964546D+00 0.127391D+02 -.554051D+00 0.809925D-02 0.110384D+00 0.305981D+01
80 0.968993D+00 -.961656D-01 -.103498D+01 0.134230D+02 -.481653D+00 0.694838D-02 0.107595D+00 0.305981D+01
81 0.974528D+00 -.742115D-01 -.111009D+01 0.141114D+02 -.405456D+00 0.578002D-02 0.105208D+00 0.305981D+01
82 0.983647D+00 -.321974D-01 -.124454D+01 0.153287D+02 -.271339D+00 0.380537D-02 0.102205D+00 0.305981D+01
83 0.990780D+00 0.675194D-02 -.135985D+01 0.164026D+02 -.158235D+00 0.219723D-02 0.100716D+00 0.305981D+01
84 0.995895D+00 0.385894D-01 -.144856D+01 0.172392D+02 -.722201D-01 0.997480D-03 0.100144D+00 0.305981D+01
85 0.998973D+00 0.595270D-01 -.150451D+01 0.177713D+02 -.183446D-01 0.252743D-03 0.100009D+00 0.305981D+01
86 0.100000D+01 0.668333D-01 -.152363D+01 0.179538D+02 0.000000D+00 0.165017D-19 0.100000D+00 0.305981D+01
CHINESE LANTERN FROM JOAO,  LINEAR DYNAMICS PROGRAMS, MARCH 1985
  9          = NUMBER OF RISER SEGMENTS
0.883920D+02 = UNSTRETCHED RISER LENGTH IN M
0.292000D+01 = APPROXIMATE AVERAGE EFFECTIVE WEIGHT PER UNIT LENGTH IN N/M
0.820000D+03 = INNER FLUID DENSITY IN KG/M3
0.102500D+04 = SALT WATER DENSITY IN KG/M3
0.115434D-01 = INNER CROSS SECTIONAL AREA IN M2
0.000000D+00 = INNER FLUID SPEED IN M/S
0.345000D+07 = INNER FLUID OVERPRESSURE IN N/M2
0.258105D+03 = APPROXIMATE TOTAL EFFECTIVE WEIGHT IN WATER IN N
0.143164D+03 = MAXIMUM STATIC TENSION IN N
0.000000D+00 = MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S
0.000000D+00 = X COORDINATE AT TOP IN M
0.701037D+02 = Y COORDINATE AT TOP IN M


D A T A   P E R   R I S E R   S E G M E N T   F O R   NSEG =   9  S E G M E N T S
D I M E N S I O N A L   Q U A N T I T I E S   I N   T H E   S . I .   S Y S T E M
  RLENG        DXI        PXIETA        AO         WEIGHT       MASS        TMASS       AMAXI       AMAETA       AMAZI        TMAXI       TMAZI
0.2500D+01 0.3100D+00 0.9300D+00 0.2374D-01 0.2920D+01 0.4993D+02 0.4047D+02 0.8244D+02 0.5032D+02 0.0000D+00 0.1324D+03 0.4993D+02

0.2500D+01 0.3100D+00 0.9300D+00 0.2374D-01 0.2920D+01 0.4993D+02 0.4047D+02 0.8244D+02 0.5032D+02 0.0000D+00 0.1324D+03 0.4993D+02
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0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.6839D+02	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02
0.2500D+01	0.3100D+00	0.9300D+00	0.2374D-01	0.2920D+01	0.4993D+02	0.4047D+02	0.8244D+02	0.5032D+02	0.0000D+00	0.1324D+03	0.4993D+02

EA	EIETA	EIETAS	EIXI	EIXIS	GIP	GIPS	DETA	JZI	AJZI	TJZI
0.2670D+09	0.6600D+04	-.3300D+03	0.2440D+05	-.1220D+04	0.1164D+07	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.5775D+04	-.3300D+03	0.2135D+05	-.1220D+04	0.1019D+07	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4950D+04	-.3300D+03	0.1830D+05	-.1220D+04	0.8730D+06	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4125D+04	-.3300D+03	0.1525D+05	-.1220D+04	0.7275D+06	-.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.3300D+04	0.0000D+00	0.1220D+05	0.0000D+00	0.5820D+06	0.0000D+00	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4125D+04	0.3300D+03	0.1525D+05	0.1220D+04	0.7275D+06	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.4950D+04	0.3300D+03	0.1830D+05	0.1220D+04	0.8730D+06	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.5775D+04	0.3300D+03	0.2135D+05	0.1220D+04	0.1019D+07	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00
0.2670D+09	0.6600D+04	0.3300D+03	0.2440D+05	0.1220D+04	0.1164D+07	0.5820D+05	0.2000D+00	0.4932D+00	0.7806D-01	0.5713D+00

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*****************************************************
  M O D E   N U M B E R =   1
  N A T U R A L   F R E Q U E N C Y = 0.3947D-01 RAD/S
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ORTHONORMALIZED NONDIMENSIONAL RESULTS AT NP = 86 POINTS

S	TENSION	QXI	OMEGAETA	PHI	P	Q	SIGMA
0.0000D+00	-.2805D+01	0.1344D+01	-.3675D+02	0.0000D+00	0.0000D+00	0.0000D+00	0.3355D+01
0.1027D-02	-.2824D+01	0.1287D+01	-.3714D+02	-.3795D-01	0.5843D-07	-.1946D-04	0.3355D+01
0.4105D-02	-.2878D+01	0.1114D+01	-.3828D+02	-.1540D+00	0.3928D-05	-.3139D-03	0.3355D+01
0.9220D-02	-.2953D+01	0.8154D+00	-.4001D+02	-.3544D+00	0.4642D-04	-.1609D-02	0.3355D+01
0.1635D-01	-.3024D+01	0.3789D+00	-.4202D+02	-.6472D+00	0.2725D-03	-.5162D-02	0.3355D+01
0.2547D-01	-.3049D+01	-.2008D+00	-.4390D+02	-.1040D+01	0.1088D-02	-.1278D-01	0.3355D+01
0.3654D-01	-.2969D+01	-.9130D+00	-.4508D+02	-.1533D+01	0.3395D-02	-.2676D-01	0.3355D+01
0.4303D-01	-.2865D+01	-.1321D+01	-.4516D+02	-.1826D+01	0.5686D-02	-.3733D-01	0.3355D+01
0.4952D-01	-.2718D+01	-.1714D+01	-.4473D+02	-.2118D+01	0.8856D-02	-.4960D-01	0.3355D+01
0.5693D-01	-.2504D+01	-.2135D+01	-.4357D+02	-.2446D+01	0.1372D-01	-.6557D-01	0.3355D+01
0.6434D-01	-.2246D+01	-.2517D+01	-.4159D+02	-.2762D+01	0.2007D-01	-.8345D-01	0.3355D+01
0.6849D-01	-.2085D+01	-.2710D+01	-.4014D+02	-.2932D+01	0.2432D-01	-.9422D-01	0.3355D+01
0.7265D-01	-.1915D+01	-.2887D+01	-.3847D+02	-.3095D+01	0.2909D-01	-.1055D+00	0.3355D+01
0.7680D-01	-.1737D+01	-.3047D+01	-.3660D+02	-.3251D+01	0.3440D-01	-.1171D+00	0.3355D+01

0.8096D-01	-.1554D+01	-.3189D+01	-.3456D+02	-.3399D+01	0.4026D-01	-.1292D+00	0.3355D+01
0.8325D-01	-.1451D+01	-.3260D+01	-.3332D+02	-.3477D+01	0.4372D-01	-.1360D+00	0.3355D+01
0.8554D-01	-.1348D+01	-.3326D+01	-.3197D+02	-.3552D+01	0.4735D-01	-.1428D+00	0.3355D+01
0.9012D-01	-.1141D+01	-.3439D+01	-.2889D+02	-.3691D+01	0.5507D-01	-.1568D+00	0.3355D+01
0.9471D-01	-.9371D+00	-.3531D+01	-.2543D+02	-.3816D+01	0.6340D-01	-.1710D+00	0.3355D+01
0.9700D-01	-.8374D+00	-.3568D+01	-.2362D+02	-.3872D+01	0.6778D-01	-.1782D+00	0.3355D+01
0.9929D-01	-.7395D+00	-.3601D+01	-.2176D+02	-.3924D+01	0.7231D-01	-.1854D+00	0.3355D+01
0.1043D+00	-.5368D+00	-.3654D+01	-.1736D+02	-.4022D+01	0.8248D-01	-.2011D+00	0.3355D+01
0.1068D+00	-.4427D+00	-.3672D+01	-.1492D+02	-.4062D+01	0.8765D-01	-.2091D+00	0.3355D+01
0.1093D+00	-.3540D+00	-.3684D+01	-.1234D+02	-.4097D+01	0.9288D-01	-.2171D+00	0.3355D+01
0.1143D+00	-.1939D+00	-.3691D+01	-.6778D+01	-.4145D+01	0.1034D+00	-.2331D+00	0.3355D+01
0.1193D+00	-.5910D-01	-.3681D+01	-.7356D+00	-.4163D+01	0.1141D+00	-.2490D+00	0.3355D+01
0.1265D+00	0.8125D-01	-.3637D+01	0.8222D+01	-.4137D+01	0.1290D+00	-.2720D+00	0.3355D+01
0.1301D+00	0.1252D+00	-.3606D+01	0.1263D+02	-.4099D+01	0.1359D+00	-.2834D+00	0.3355D+01
0.1336D+00	0.1520D+00	-.3570D+01	0.1700D+02	-.4046D+01	0.1425D+00	-.2949D+00	0.3355D+01
0.1372D+00	0.1622D+00	-.3530D+01	0.2132D+02	-.3977D+01	0.1487D+00	-.3063D+00	0.3355D+01
0.1408D+00	0.1562D+00	-.3486D+01	0.2559D+02	-.3893D+01	0.1545D+00	-.3176D+00	0.3355D+01
0.1638D+00	-.2327D+00	-.3150D+01	0.5158D+02	-.2999D+01	0.1768D+00	-.3875D+00	0.3355D+01
0.1883D+00	-.1151D+01	-.2622D+01	0.7565D+02	-.1436D+01	0.1649D+00	-.4474D+00	0.3355D+01
0.2139D+00	-.2330D+01	-.1678D+01	0.9470D+02	0.7708D+00	0.1072D+00	-.4735D+00	0.3355D+01
0.2408D+00	-.3257D+01	-.1403D+00	0.1033D+03	0.3461D+01	0.9415D-02	-.4291D+00	0.3355D+01
0.2687D+00	-.3338D+01	0.1763D+01	0.9560D+02	0.6278D+01	-.9367D-01	-.2795D+00	0.3355D+01
0.2832D+00	-.2971D+01	0.2631D+01	0.8479D+02	0.7586D+01	-.1293D+00	-.1612D+00	0.3355D+01
0.2976D+00	-.2383D+01	0.3293D+01	0.7019D+02	0.8708D+01	-.1442D+00	-.2074D-01	0.3355D+01
0.3125D+00	-.1654D+01	0.3695D+01	0.5247D+02	0.9622D+01	-.1348D+00	0.1391D+00	0.3355D+01
0.3273D+00	-.9161D+00	0.3792D+01	0.3350D+02	0.1026D+02	-.9981D-01	0.3059D+00	0.3355D+01
0.3425D+00	-.2563D+00	0.3620D+01	0.1429D+02	0.1062D+02	-.4087D-01	0.4761D+00	0.3355D+01
0.3577D+00	0.2272D+00	0.3254D+01	-.3500D+01	0.1070D+02	0.3525D-01	0.6393D+00	0.3355D+01
0.3887D+00	0.6299D+00	0.2267D+01	-.3269D+02	0.1012D+02	0.2142D+00	0.9375D+00	0.3355D+01
0.4202D+00	0.4237D+00	0.1315D+01	-.5169D+02	0.8765D+01	0.3848D+00	0.1189D+01	0.3355D+01
0.4520D+00	-.7458D-01	0.5874D+00	-.6175D+02	0.6940D+01	0.5113D+00	0.1396D+01	0.3355D+01
0.4840D+00	-.5967D+00	0.7583D-01	-.6517D+02	0.4893D+01	0.5793D+00	0.1560D+01	0.3355D+01
0.5160D+00	-.1005D+01	-.2837D+00	-.6391D+02	0.2813D+01	0.5905D+00	0.1679D+01	0.3355D+01
0.5480D+00	-.1259D+01	-.5360D+00	-.5938D+02	0.8326D+00	0.5567D+00	0.1748D+01	0.3355D+01
0.5798D+00	-.1368D+01	-.7018D+00	-.5263D+02	-.9530D+00	0.4935D+00	0.1765D+01	0.3355D+01
0.6113D+00	-.1367D+01	-.7922D+00	-.4460D+02	-.2485D+01	0.4166D+00	0.1730D+01	0.3355D+01
0.6423D+00	-.1296D+01	-.8195D+00	-.3608D+02	-.3737D+01	0.3382D+00	0.1650D+01	0.3355D+01
0.6727D+00	-.1186D+01	-.8007D+00	-.2769D+02	-.4707D+01	0.2666D+00	0.1535D+01	0.3355D+01
0.7024D+00	-.1063D+01	-.7554D+00	-.1984D+02	-.5412D+01	0.2055D+00	0.1394D+01	0.3355D+01
0.7313D+00	-.9392D+00	-.7028D+00	-.1270D+02	-.5880D+01	0.1560D+00	0.1237D+01	0.3355D+01
0.7592D+00	-.8238D+00	-.6602D+00	-.6263D+01	-.6144D+01	0.1173D+00	0.1073D+01	0.3355D+01
0.7861D+00	-.7196D+00	-.6438D+00	-.3552D+00	-.6233D+01	0.8746D-01	0.9095D+00	0.3355D+01
0.8117D+00	-.6267D+00	-.6694D+00	0.5321D+01	-.6170D+01	0.6469D-01	0.7519D+00	0.3355D+01
0.8239D+00	-.5845D+00	-.7029D+00	0.8153D+01	-.6088D+01	0.5546D-01	0.6779D+00	0.3355D+01
0.8362D+00	-.5432D+00	-.7548D+00	0.1116D+02	-.5970D+01	0.4711D-01	0.6049D+00	0.3355D+01
0.8477D+00	-.5047D+00	-.8247D+00	0.1423D+02	-.5824D+01	0.3994D-01	0.5375D+00	0.3355D+01
0.8534D+00	-.4853D+00	-.8688D+00	0.1588D+02	-.5737D+01	0.3658D-01	0.5045D+00	0.3355D+01
0.8592D+00	-.4659D+00	-.9199D+00	0.1763D+02	-.5641D+01	0.3339D-01	0.4720D+00	0.3355D+01
0.8646D+00	-.4472D+00	-.9747D+00	0.1936D+02	-.5541D+01	0.3051D-01	0.4421D+00	0.3355D+01
0.8699D+00	-.4278D+00	-.1037D+01	0.2119D+02	-.5432D+01	0.2773D-01	0.4127D+00	0.3355D+01
0.8753D+00	-.4074D+00	-.1108D+01	0.2315D+02	-.5313D+01	0.2504D-01	0.3839D+00	0.3355D+01
0.8807D+00	-.3860D+00	-.1188D+01	0.2527D+02	-.5183D+01	0.2247D-01	0.3558D+00	0.3355D+01
0.8857D+00	-.3652D+00	-.1271D+01	0.2716D+02	-.5051D+01	0.2020D-01	0.3304D+00	0.3355D+01
0.8907D+00	-.3432D+00	-.1362D+01	0.2877D+02	-.4912D+01	0.1805D-01	0.3056D+00	0.3355D+01
0.8957D+00	-.3201D+00	-.1460D+01	0.3013D+02	-.4764D+01	0.1603D-01	0.2816D+00	0.3355D+01

0.9007D+00	-.2958D+00	-.1564D+01	0.3125D+02	-.4611D+01	0.1414D-01	0.2582D+00	0.3355D+01
0.9099D+00	-.2478D+00	-.1770D+01	0.3314D+02	-.4316D+01	0.1102D-01	0.2175D+00	0.3355D+01
0.9190D+00	-.1951D+00	-.1997D+01	0.3527D+02	-.4002D+01	0.8373D-02	0.1795D+00	0.3355D+01
0.9232D+00	-.1692D+00	-.2107D+01	0.3632D+02	-.3854D+01	0.7318D-02	0.1632D+00	0.3355D+01
0.9274D+00	-.1417D+00	-.2223D+01	0.3745D+02	-.3701D+01	0.6344D-02	0.1475D+00	0.3355D+01
0.9357D+00	-.8122D-01	-.2472D+01	0.3997D+02	-.3379D+01	0.4634D-02	0.1182D+00	0.3355D+01
0.9431D+00	-.1997D-01	-.2715D+01	0.4241D+02	-.3074D+01	0.3366D-02	0.9430D-01	0.3355D+01
0.9505D+00	0.4949D-01	-.2981D+01	0.4495D+02	-.2750D+01	0.2328D-02	0.7274D-01	0.3355D+01
0.9570D+00	0.1183D+00	-.3233D+01	0.4733D+02	-.2451D+01	0.1598D-02	0.5588D-01	0.3355D+01
0.9635D+00	0.1959D+00	-.3505D+01	0.4998D+02	-.2136D+01	0.1025D-02	0.4101D-01	0.3355D+01
0.9690D+00	0.2701D+00	-.3754D+01	0.5236D+02	-.1852D+01	0.6516D-03	0.2998D-01	0.3355D+01
0.9745D+00	0.3529D+00	-.4019D+01	0.5477D+02	-.1556D+01	0.3760D-03	0.2054D-01	0.3355D+01
0.9836D+00	0.5102D+00	-.4494D+01	0.5902D+02	-.1038D+01	0.1066D-03	0.8689D-02	0.3355D+01
0.9908D+00	0.6552D+00	-.4901D+01	0.6278D+02	-.6033D+00	0.2020D-04	0.2820D-02	0.3355D+01
0.9959D+00	0.7733D+00	-.5214D+01	0.6571D+02	-.2748D+00	0.1844D-05	0.5677D-03	0.3355D+01
0.9990D+00	0.8507D+00	-.5412D+01	0.6757D+02	-.6973D-01	0.2862D-07	0.3586D-04	0.3355D+01
0.1000D+01	0.8777D+00	-.5479D+01	0.6821D+02	0.0000D+00	-.1245D-16	-.2552D-16	0.3355D+01

MAXIMUM ESTIMATED ERROR BY COMPONENTS

0.7407D-02	0.2005D-01	0.2382D+00	0.1898D-01	0.1460D-02	0.4141D-02	0.2697D-02

IX.2.1.3 RC2DZ1A DATA A

1 86 0.3947D-01 0.0000D+00 0.7931D+00

0.000000D+00	-.280488D+01	0.134392D+01	-.367462D+02	0.000000D+00	0.000000D+00	0.000000D+00	0.335458D+01	0.000000D+00
0.102730D-02	-.282420D+01	0.128741D+01	-.371430D+02	-.379539D-01	0.584282D-07	-.194577D-04	0.335458D+01	0.000000D+00
0.410499D-02	-.287815D+01	0.111436D+01	-.382827D+02	-.154042D+00	0.392809D-05	-.313918D-03	0.335458D+01	0.000000D+00
0.922042D-02	-.295348D+01	0.815355D+00	-.400056D+02	-.354378D+00	0.464196D-04	-.160936D-02	0.335458D+01	0.000000D+00
0.163526D-01	-.302438D+01	0.378917D+00	-.420237D+02	-.647185D+00	0.272463D-03	-.516225D-02	0.335458D+01	0.000000D+00
0.254721D-01	-.304900D+01	-.200839D+00	-.438958D+02	-.103958D+01	0.108839D-02	-.127814D-01	0.335458D+01	0.000000D+00
0.365416D-01	-.296906D+01	-.913045D+00	-.450804D+02	-.153324D+01	0.339501D-02	-.267567D-01	0.335458D+01	0.000000D+00
0.430286D-01	-.286462D+01	-.132119D+01	-.451579D+02	-.182620D+01	0.568644D-02	-.373309D-01	0.335458D+01	0.000000D+00
0.495156D-01	-.271848D+01	-.171407D+01	-.447262D+02	-.211803D+01	0.885587D-02	-.495990D-01	0.335458D+01	0.000000D+00
0.569281D-01	-.250426D+01	-.213501D+01	-.435691D+02	-.244577D+01	0.137155D-01	-.655734D-01	0.335458D+01	0.000000D+00
0.643406D-01	-.224558D+01	-.251667D+01	-.415914D+02	-.276191D+01	0.200653D-01	-.834513D-01	0.335458D+01	0.000000D+00
0.684944D-01	-.208458D+01	-.271007D+01	-.401370D+02	-.293173D+01	0.243217D-01	-.942167D-01	0.335458D+01	0.000000D+00
0.726482D-01	-.191466D+01	-.288692D+01	-.384714D+02	-.309507D+01	0.290931D-01	-.105461D+00	0.335458D+01	0.000000D+00
0.768021D-01	-.173730D+01	-.304676D+01	-.366044D+02	-.325107D+01	0.343993D-01	-.117133D+00	0.335458D+01	0.000000D+00
0.809559D-01	-.155393D+01	-.318933D+01	-.345591D+02	-.339895D+01	0.402590D-01	-.129173D+00	0.335458D+01	0.000000D+00
0.832481D-01	-.145108D+01	-.326035D+01	-.333219D+02	-.347677D+01	0.437248D-01	-.135956D+00	0.335458D+01	0.000000D+00
0.855402D-01	-.134775D+01	-.332571D+01	-.319724D+02	-.355162D+01	0.473485D-01	-.142828D+00	0.335458D+01	0.000000D+00
0.901246D-01	-.114090D+01	-.343936D+01	-.288889D+02	-.369131D+01	0.550732D-01	-.156798D+00	0.335458D+01	0.000000D+00
0.947089D-01	-.937067D+00	-.353070D+01	-.254259D+02	-.381592D+01	0.634047D-01	-.171003D+00	0.335458D+01	0.000000D+00
0.970010D-01	-.837400D+00	-.356839D+01	-.236170D+02	-.387214D+01	0.677847D-01	-.178169D+00	0.335458D+01	0.000000D+00
0.992932D-01	-.739531D+00	-.360100D+01	-.217581D+02	-.392416D+01	0.723068D-01	-.185363D+00	0.335458D+01	0.000000D+00
0.104289D+00	-.536768D+00	-.365420D+01	-.173612D+02	-.402212D+01	0.824798D-01	-.201150D+00	0.335458D+01	0.000000D+00
0.106787D+00	-.442725D+00	-.367170D+01	-.149237D+02	-.406247D+01	0.876549D-01	-.209103D+00	0.335458D+01	0.000000D+00
0.109285D+00	-.353994D+00	-.368354D+01	-.123422D+02	-.409656D+01	0.928815D-01	-.217081D+00	0.335458D+01	0.000000D+00
0.114281D+00	-.193920D+00	-.369149D+01	-.677774D+01	-.414454D+01	0.103446D+00	-.233073D+00	0.335458D+01	0.000000D+00
0.119277D+00	-.591018D-01	-.368073D+01	-.735620D+00	-.416346D+01	0.114097D+00	-.249034D+00	0.335458D+01	0.000000D+00
0.126460D+00	0.812466D-01	-.363720D+01	0.822172D+01	-.413663D+01	0.128957D+00	-.271951D+00	0.335458D+01	0.000000D+00
0.130052D+00	0.125207D+00	-.360564D+01	0.126315D+02	-.409917D+01	0.135931D+00	-.283420D+00	0.335458D+01	0.000000D+00
0.133643D+00	0.152041D+00	-.356951D+01	0.169988D+02	-.404595D+01	0.142539D+00	-.294867D+00	0.335458D+01	0.000000D+00
0.137234D+00	0.162191D+00	-.352957D+01	0.213197D+02	-.397714D+01	0.148731D+00	-.306277D+00	0.335458D+01	0.000000D+00
0.140825D+00	0.156159D+00	-.348645D+01	0.255900D+02	-.389290D+01	0.154455D+00	-.317630D+00	0.335458D+01	0.000000D+00
0.163850D+00	-.232668D+00	-.314955D+01	0.515801D+02	-.299904D+01	0.176792D+00	-.387467D+00	0.335458D+01	0.000000D+00
0.188255D+00	-.115070D+01	-.262194D+01	0.756509D+02	-.143626D+01	0.164920D+00	-.447380D+00	0.335458D+01	0.000000D+00
0.213942D+00	-.232968D+01	-.167785D+01	0.947011D+02	0.770753D+00	0.107246D+00	-.473545D+00	0.335458D+01	0.000000D+00
0.240804D+00	-.325678D+01	-.140283D+00	0.103289D+03	0.346079D+01	0.941529D-02	-.429102D+00	0.335458D+01	0.000000D+00
0.268731D+00	-.333778D+01	0.176271D+01	0.955968D+02	0.627828D+01	-.936739D-01	-.279454D+00	0.335458D+01	0.000000D+00
0.283169D+00	-.297125D+01	0.263061D+01	0.847852D+02	0.758554D+01	-.129263D+00	-.161154D+00	0.335458D+01	0.000000D+00
0.297608D+00	-.238346D+01	0.329310D+01	0.701922D+02	0.870842D+01	-.144183D+00	-.207449D-01	0.335458D+01	0.000000D+00
0.312462D+00	-.165400D+01	0.369540D+01	0.524740D+02	0.962214D+01	-.134776D+00	0.139067D+00	0.335458D+01	0.000000D+00
0.327317D+00	-.916050D+00	0.379233D+01	0.335011D+02	0.102616D+02	-.998120D-01	0.305900D+00	0.335458D+01	0.000000D+00
0.342527D+00	-.256349D+00	0.362038D+01	0.142878D+02	0.106242D+02	-.408735D-01	0.476071D+00	0.335458D+01	0.000000D+00
0.357736D+00	0.227213D+00	0.325439D+01	-.350045D+01	0.107041D+02	0.352453D-01	0.639257D+00	0.335458D+01	0.000000D+00
0.388740D+00	0.629902D+00	0.226715D+01	-.326857D+02	0.101182D+02	0.214248D+00	0.937483D+00	0.335458D+01	0.000000D+00
0.420200D+00	0.423677D+00	0.131517D+01	-.516937D+02	0.876499D+01	0.384816D+00	0.118879D+01	0.335458D+01	0.000000D+00
0.451988D+00	-.745765D-01	0.587430D+00	-.617493D+02	0.693978D+01	0.511324D+00	0.139557D+01	0.335458D+01	0.000000D+00
0.483974D+00	-.596727D+00	0.758282D-01	-.651706D+02	0.489331D+01	0.579299D+00	0.155998D+01	0.335458D+01	0.000000D+00
0.516026D+00	-.100525D+01	-.283659D+00	-.639147D+02	0.281268D+01	0.590539D+00	0.167924D+01	0.335458D+01	0.000000D+00
0.548012D+00	-.125858D+01	-.536021D+00	-.593763D+02	0.832585D+00	0.556668D+00	0.174843D+01	0.335458D+01	0.000000D+00
0.579800D+00	-.136787D+01	-.701848D+00	-.526292D+02	-.953043D+00	0.493499D+00	0.176479D+01	0.335458D+01	0.000000D+00
0.611260D+00	-.136735D+01	-.792152D+00	-.445974D+02	-.248542D+01	0.416569D+00	0.173002D+01	0.335458D+01	0.000000D+00
0.642264D+00	-.129580D+01	-.819463D+00	-.360772D+02	-.373711D+01	0.338239D+00	0.165030D+01	0.335458D+01	0.000000D+00
0.672683D+00	-.118634D+01	-.800742D+00	-.276896D+02	-.470669D+01	0.266553D+00	0.153477D+01	0.335458D+01	0.000000D+00
0.702392D+00	-.106263D+01	-.755443D+00	-.198370D+02	-.541165D+01	0.205496D+00	0.139365D+01	0.335458D+01	0.000000D+00
0.731269D+00	-.939236D+00	-.702763D+00	-.126999D+02	-.588025D+01	0.156026D+00	0.123684D+01	0.335458D+01	0.000000D+00
0.759196D+00	-.823842D+00	-.660195D+00	-.626321D+01	-.614416D+01	0.117262D+00	0.107304D+01	0.335458D+01	0.000000D+00

0.786058D+00	-.719571D+00	-.643752D+00	-.355202D+00	-.623281D+01	0.874587D-01	0.909471D+00	0.335458D+01	0.000000D+00
0.811745D+00	-.626689D+00	-.669387D+00	0.532086D+01	-.616957D+01	0.646932D-01	0.751910D+00	0.335458D+01	0.000000D+00
0.823947D+00	-.584529D+00	-.702881D+00	0.815252D+01	-.608753D+01	0.554563D-01	0.677865D+00	0.335458D+01	0.000000D+00
0.836150D+00	-.543242D+00	-.754769D+00	0.111594D+02	-.596993D+01	0.471080D-01	0.604923D+00	0.335458D+01	0.000000D+00
0.847662D+00	-.504675D+00	-.824691D+00	0.142331D+02	-.582405D+01	0.399426D-01	0.537545D+00	0.335458D+01	0.000000D+00
0.853419D+00	-.485335D+00	-.868801D+00	0.158843D+02	-.573740D+01	0.365836D-01	0.504507D+00	0.335458D+01	0.000000D+00
0.859175D+00	-.465876D+00	-.919880D+00	0.176279D+02	-.564101D+01	0.333859D-01	0.471983D+00	0.335458D+01	0.000000D+00
0.864562D+00	-.447219D+00	-.974715D+00	0.193564D+02	-.554144D+01	0.305112D-01	0.442060D+00	0.335458D+01	0.000000D+00
0.869949D+00	-.427782D+00	-.103709D+01	0.211919D+02	-.543228D+01	0.277265D-01	0.412687D+00	0.335458D+01	0.000000D+00
0.875336D+00	-.407446D+00	-.110779D+01	0.231487D+02	-.531291D+01	0.250436D-01	0.383917D+00	0.335458D+01	0.000000D+00
0.880723D+00	-.386045D+00	-.118779D+01	0.252655D+02	-.518252D+01	0.224699D-01	0.355808D+00	0.335458D+01	0.000000D+00
0.885719D+00	-.365160D+00	-.127078D+01	0.271589D+02	-.505149D+01	0.201979D-01	0.330380D+00	0.335458D+01	0.000000D+00
0.890715D+00	-.343214D+00	-.136174D+01	0.287720D+02	-.491166D+01	0.180510D-01	0.305618D+00	0.335458D+01	0.000000D+00
0.895711D+00	-.320111D+00	-.145979D+01	0.301338D+02	-.476440D+01	0.160301D-01	0.281561D+00	0.335458D+01	0.000000D+00
0.900707D+00	-.295766D+00	-.156408D+01	0.312540D+02	-.461098D+01	0.141363D-01	0.258244D+00	0.335458D+01	0.000000D+00
0.909875D+00	-.247778D+00	-.177029D+01	0.331442D+02	-.431577D+01	0.110159D-01	0.217473D+00	0.335458D+01	0.000000D+00
0.919044D+00	-.195147D+00	-.199707D+01	0.352691D+02	-.400231D+01	0.837321D-02	0.179452D+00	0.335458D+01	0.000000D+00
0.923198D+00	-.169245D+00	-.210744D+01	0.363184D+02	-.385365D+01	0.731823D-02	0.163182D+00	0.335458D+01	0.000000D+00
0.927351D+00	-.141710D+00	-.222301D+01	0.374475D+02	-.370050D+01	0.634361D-02	0.147536D+00	0.335458D+01	0.000000D+00
0.935659D+00	-.812238D-01	-.247165D+01	0.399668D+02	-.337914D+01	0.463410D-02	0.118182D+00	0.335458D+01	0.000000D+00
0.943071D+00	-.199710D-01	-.271519D+01	0.424144D+02	-.307393D+01	0.336633D-02	0.943027D-01	0.335458D+01	0.000000D+00
0.950484D+00	0.494942D-01	-.298089D+01	0.449463D+02	-.275023D+01	0.232763D-02	0.727380D-01	0.335458D+01	0.000000D+00
0.956971D+00	0.118276D+00	-.323280D+01	0.473311D+02	-.245105D+01	0.159785D-02	0.558806D-01	0.335458D+01	0.000000D+00
0.963458D+00	0.195871D+00	-.350467D+01	0.499798D+02	-.213554D+01	0.102467D-02	0.410095D-01	0.335458D+01	0.000000D+00
0.968993D+00	0.270143D+00	-.375376D+01	0.523603D+02	-.185235D+01	0.651587D-03	0.299752D-01	0.335458D+01	0.000000D+00
0.974528D+00	0.352854D+00	-.401926D+01	0.547653D+02	-.155592D+01	0.376034D-03	0.205416D-01	0.335458D+01	0.000000D+00
0.983647D+00	0.510206D+00	-.449423D+01	0.590215D+02	-.103750D+01	0.106649D-03	0.868877D-02	0.335458D+01	0.000000D+00
0.990780D+00	0.655207D+00	-.490133D+01	0.627783D+02	-.603342D+00	0.201973D-04	0.282041D-02	0.335458D+01	0.000000D+00
0.995895D+00	0.773256D+00	-.521437D+01	0.657095D+02	-.274829D+00	0.184433D-05	0.567715D-03	0.335458D+01	0.000000D+00
0.998973D+00	0.850695D+00	-.541178D+01	0.675743D+02	-.697264D-01	0.286221D-07	0.358650D-04	0.335458D+01	0.000000D+00
0.100000D+01	0.877686D+00	-.547921D+01	0.682139D+02	0.000000D+00	-.124485D-16	-.255245D-16	0.335458D+01	0.000000D+00

Chapter X

INPUT-OUTPUT MANUALS FOR NAG SUBROUTINES D02RAF, D02GBF, C05NBF, C05PBF, F04ATF, F03AAF

D02RAF – NAG FORTRAN Library Routine Document

NOTE: before using this routine, please read the appropriate implementation document to check the interpretation of **bold italicised** terms and other implementation-dependent details. The routine name may be precision-dependent.

1. Purpose

D02RAF solves the two-point boundary-value problem with general boundary conditions for a system of ordinary differential equations, using a deferred correction technique and Newton iteration.

2. Specification

```
      SUBROUTINE D02RAF (N, MNP, NP, NUMBEG, NUMMIX, TOL, INIT, X,
     1   Y, IY, ABT, FCN, G, IJAC, JACOBF, JACOBG, DELEPS,
     2   JACEPS, JACGEP, WORK, LWORK, IWORK, LIWORK, IFAIL)
C     INTEGER N, MNP, NP, NUMBEG, NUMMIX, INIT, IY, IJAC, LWORK,
C    1   IWORK(LIWORK), LIWORK, IFAIL
C     real TOL, X(MNP), Y(IY,MNP), ABT(N), DELEPS, WORK(LWORK)
C     EXTERNAL FCN, G, JACOBF, JACOBG, JACEPS, JACGEP
```

3. Description

D02RAF solves a two-point boundary-value problem for a system of N ordinary differential equations in a range (A,B) with B > A. The system is written in the form

$$y'_i = f_i(x,y_1,y_2,...,y_N), \qquad i = 1,2,...,N \tag{1}$$

and the derivatives f_i are evaluated by a subroutine FCN supplied by the user. With the differential equations (1) must be given a system of N (nonlinear) boundary conditions

$$g_i(y(A),y(B)) = 0, \qquad i = 1,2,...,N$$

where

$$y(x) = [y_1(x),y_2(x),...,y_N(x)]^T. \tag{2}$$

The functions g_i are evaluated by a subroutine G supplied by the user. The solution is computed using a finite-difference technique with deferred correction allied to a Newton iteration to solve the finite-difference equations. The technique used is described fully in [1].

The user must supply an absolute error tolerance and may also supply an initial mesh for the finite-difference equations and an initial approximate solution (alternatively a default mesh and approximation are used). The approximate solution is corrected using Newton iteration and deferred correction. Then, additional points are added to the mesh and the solution is recomputed with the aim of making the error everywhere less than the user's tolerance and of approximately equidistributing the error on the final mesh. The solution is returned on this final mesh.

If the solution is required at a few specific points then these should be included in the initial mesh. If, on the other hand, the solution is required at several specific points then the user should use the interpolation routines provided in the E01 chapter if these points do not themselves form a convenient mesh.

The Newton iteration requires Jacobian matrices

$$\left(\frac{\partial f_i}{\partial y_j}\right), \left(\frac{\partial g_i}{\partial y_j(A)}\right) \text{ and } \left(\frac{\partial g_i}{\partial y_j(B)}\right).$$

These may be supplied by the user through subroutines JACOBF for $\left(\frac{\partial f_i}{\partial y_j}\right)$ and JACOBG for the others. Alternatively the Jacobians may be calculated by numerical differentiation using the algorithm described in [2].

For problems of the type (1) and (2) for which it is difficult to determine an initial approximation from which the Newton iteration will converge, a continuation facility is provided. The user must set up a family of problems

$$y' = f(x,y,\epsilon), \quad g(y(A),y(B),\epsilon) = 0 \tag{3}$$

where $f = [f_1,f_2,...,f_N]^T$ etc., and where ϵ is a continuation parameter. The choice $\epsilon = 0$ must give a problem (3) which is easy to solve and $\epsilon = 1$ must define the problem whose solution is actually required. The routine solves a sequence of problems with ϵ values

$$0 = \epsilon_1 < \epsilon_2 < ... < \epsilon_p = 1 \tag{4}$$

The number p and the values ϵ_i are chosen by the routine so that each problem can be solved using the solution of its predecessor as a starting approximation. Jacobians $\frac{\partial f}{\partial \epsilon}$ and $\frac{\partial g}{\partial \epsilon}$ are required and they may be supplied by the user via routines JACEPS and JACGEP respectively or may be computed by numerical differentiation.

4. References

[1] PEREYRA, V.
PASVA3: An Adaptive Finite-Difference Fortran Program for First Order Nonlinear, Ordinary Boundary Problems. In Childs, B., Scott, M., Daniel, J.W., Denman, E., and Nelson, P. (eds.)
'Codes for Boundary Value Problems in Ordinary Differential Equations', Lecture Notes in Computer Science, 76, 1979.

[2] CURTIS, A.R., POWELL, M.J.D. and REID, J.K.
On the Estimation of Sparse Jacobian Matrices.
J. Inst. Maths. Applics, 13, pp. 117–119, 1974.

5. Parameters

N – INTEGER.

On entry, N must specify the number of differential equations.

Unchanged on exit.

MNP – INTEGER.

On entry, MNP must be set to the maximum permitted number of points in the finite-difference mesh, MNP $\geq$ 32. If LWORK or LIWORK (see below) is too small then internally MNP will be replaced by the maximum permitted by these values. (A warning message will be output if on entry IFAIL is set to obtain monitoring information.)

Unchanged on exit.

NP – INTEGER.

Before entry, NP must be set to the number of points to be used in the initial mesh $4 \leq$ NP $\leq$ MNP.

On exit, NP contains the number of points in the final mesh.

NUMBEG – INTEGER.

On entry, NUMBEG must specify the number of left hand boundary conditions (that is the number involving y(A) only).
$0 \leq$ NUMBEG $<$ N.

Unchanged on exit.

NUMMIX – INTEGER.

On entry, NUMMIX must specify the number of coupled boundary conditions (that is the number involving both y(A) and y(B)).
$0 \leq$ NUMMIX;
NUMBEG + NUMMIX $\leq$ N.

Unchanged on exit.

TOL – *real*.

On entry, TOL must specify a positive absolute error tolerance. If

$$A = x_1 < x_2 < \ldots < x_{NP} = B$$

is the final mesh, $z_j(x_i)$ is the j(th) component of the approximate solution at x_i, and $y_j(x)$ is the j(th) component of the true solution of (1) and (2), then, except in extreme circumstances, it is expected that

$$|z_j(x_i) - y_j(x_i)| \leq \text{TOL}, \quad i = 1,2,\ldots,NP, \quad j = 1,2,\ldots,N. \qquad (5)$$

Unchanged on exit.

INIT – INTEGER.

On entry, INIT must specify whether the user wishes to supply an initial mesh and approximate solution (INIT$\neq$0) or whether default values are to be used, (INIT = 0).

Unchanged on exit.

X – *real* array of DIMENSION (MNP).

Before entry, the user must set X(1) = A and X(NP) = B. If INIT = 0 on entry a default equispaced mesh will be used, otherwise the user must specify a mesh satisfying

$$A = X(1) < X(2) < \ldots < X(NP) = B \qquad (6)$$

On exit, X(1),X(2),...,X(NP) define the final mesh (with the returned value of NP) satisfying (6).

Y – *real* array of DIMENSION (IY,MNP).

If INIT=0 on entry, then Y need not be set.

If INIT$\neq$0 before entry, then the array Y must contain an initial approximation to the solution such that Y(J, I) contains an approximation to

$$y_J(x_I), \quad I = 1,2,\ldots,NP, \quad J = 1,2,\ldots,N.$$

On a successful exit Y contains the approximate solution $z_j(x_i)$ satisfying (5) on the final mesh, that is

$$Y(J,I) = z_J(x_I), \quad I = 1,2,\ldots,NP, \quad J = 1,2,\ldots,N,$$

where NP is the number of points in the final mesh. If an error has occurred then Y contains the latest approximation to the solution. The remaining columns of Y are not used.

IY – INTEGER.

On entry, IY must specify the first dimension of Y as declared in the calling (sub)program. IY ≥ N.

Unchanged on exit.

ABT – *real* array of DIMENSION (N).

On successful exit, ABT(I), I = 1,2,...,N, holds the largest estimated error (in magnitude) of the I(th) component of the the solution over all mesh points.

FCN – SUBROUTINE, supplied by the user.

FCN must evaluate the functions f_i (i.e., the derivatives y'_i) at the general point X for a given value of EPS (see equation 3).

Its specification is:

```
SUBROUTINE FCN(X,EPS,Y,F,N)
INTEGER N
real X,EPS,Y(N),F(N)
```

X – *real*.

On entry, X specifies the value of the argument X. Its value must not be changed.

EPS – *real*.

On entry, EPS specifies the value of the continuation parameter, ϵ. This is 1 if continuation is not being used. Its value must not be changed.

Y – *real* array of DIMENSION (N).

On entry, Y(i) contains the value of the argument y_i for i = 1,2,...,N. These values must not be changed.

F – *real* array of DIMENSION (N).

On exit, F(i) must contain the values of f_i, i = 1,2,...,N.

N – INTEGER.

On entry, N specifies the number of equations. Its value must not be changed.

→ FCN must be declared as EXTERNAL in the (sub)program from which D02RAF is called.

G – SUBROUTINE, supplied by the user.

G must evaluate the boundary conditions in equation (3) and place them in BC(i) i = 1,2,...,N.

Its specification is:

```
SUBROUTINE G(EPS,YA,YB,BC,N)
INTEGER N
real EPS,YA(N),YB(N),BC(N)
```

EPS – *real*.

On entry, EPS specifies the value of the continuation parameter, ϵ. This is 1 if continuation is not being used. Its value must not be changed.

YA – *real* array of DIMENSION (N).

On entry, YA(i) contains the value $y_i(A)$, i = 1,2,...,N. These values must not be changed.

YB – *real* array of DIMENSION (N).

On entry, YB(i) contains the value $y_i(B)$, i= 1,2,...,N. These values must not be changed.

BC – *real* array of DIMENSION (N).

On exit, BC(i) must contain the value $g_i(y(A),y(B),\epsilon)$, i = 1,2,...,N. These must be ordered as follows:

(i) First, the NUMBEG conditions involving only y(A) (that is YA).

(ii) Next, the NUMMIX coupled conditions involving both y(A) and y(B) (that is YA and YB).

(iii) Finally, the N – NUMBEG – NUMMIX conditions involving y(B) (that is YB).

N – INTEGER.

On entry, N specifies the number of equations. Its value must not be changed.

G must be declared as EXTERNAL in the (sub)program from which D02RAF is called.

IJAC – INTEGER.

If, on entry, IJAC = 0 then the Jacobian matrices for the Newton iterations are calculated by numerical differentiation, and the parameters JACOBF, JACOBG, JACEPS and JACGEP may be replaced by dummy actual parameters in the call to D02RAF. (The NAG routines D02GAZ, D02GAY, D02GAZ and D02GAX respectively may be used as the dummy parameters.) If IJAC ≠ 0 then the user must supply routines JACOBF and JACOBG and also when continuation is used, routines JACEPS and JACGEP.

Unchanged on exit.

JACOBF – SUBROUTINE, supplied by the user.

JACOBF must evaluate the Jacobian $\left(\frac{\partial f_i}{\partial y_j}\right)$ at the point (x,y) and place $\frac{\partial f_i}{\partial y_j}$ in F(i,j), i,j = 1,2,...,N.
Its specification is:

```
SUBROUTINE JACOBF(X,EPS,Y,F,N)
INTEGER N
real X,EPS,Y(N),F(N,N)
```

X – ***real***.

On entry, X specifies the value of the argument X. Its value must not be changed.

EPS – ***real***.

On entry, EPS specifies the value of the continuation parameter ε. This is 1 if continuation is not being used. Its value must not be changed.

Y – ***real*** array of DIMENSION (N).

On entry, Y(i) contains the value of the argument y_i, i = 1,2,...,N. These values must not be changed.

F – ***real*** array of DIMENSION (N,N).

On exit, F(i,j) contains the value of $\frac{\partial f_i}{\partial y_j}$, evaluated at the point (x,y), for i,j = 1,2,...,N.

N – INTEGER.

On entry, N specifies the number of equations. Its value must not be changed.

JACOBF must be declared as EXTERNAL in the (sub)program from which D02RAF is called.

JACOBG – SUBROUTINE, supplied by the user.

JACOBG must evaluate the Jacobians $\left(\frac{\partial g_i}{\partial y_j(A)}\right.$ and $\left.\frac{\partial g_i}{\partial y_j(B)}\right)$ and place them in AJ and BJ respectively. The ordering of the rows of AJ and BJ must correspond to the ordering of the boundary conditions described in the specification of subroutine G above.

The specification of JACOBG is:

```
SUBROUTINE JACOBG(EPS,YA,YB,
1 AJ,BJ,N)
INTEGER N
real EPS,YA(N),YB(N),
1 AJ(N,N),BJ(N,N)
```

EPS – ***real***.

On entry, EPS specifies the value of the continuation parameter, ε. This is 1 if continuation is not being used. Its value must not be changed.

YA – ***real*** array of DIMENSION (N).

On entry, YA(i) contains $y_i(A)$, i = 1,2,...,N. These values must not be changed.

YB – ***real*** array of DIMENSION (N).

On entry, YB(i) contains the value of $y_i(B)$, i = 1,2,...,N. These values must not be changed.

AJ – ***real*** array of DIMENSION (N,N).

On exit, AJ(i,j) contains $\frac{\partial g_i}{\partial y_j(A)}$, i,j = 1,2,...,N.

BJ – ***real*** array of DIMENSION (N,N).

On exit, BJ(i,j) contains $\frac{\partial g_i}{\partial y_j(B)}$, i,j = 1,2...,N.

N – INTEGER.

On entry, N specifies the number of equations. Its value must not be changed.

JACOBG must be declared as EXTERNAL in the (sub)program from which D02RAF is called.

DELEPS – ***real***.

Before entry, DELEPS must be given a value which specifies whether continuation is required. If DELEPS $\leq$ 0.0 or DELEPS $\geq$ 1.0 then it is assumed that continuation is not required. If 0.0 < DELEPS < 1.0 then it is assumed that continuation is required unless DELEPS < macheps$^{\frac{1}{2}}$ (where macheps macheps is the smallest number such that 1.0 + macheps > 1.0) when an error exit is taken. DELEPS is used as the increment $\varepsilon_2 - \varepsilon_1$ (see (4)) and the choice DELEPS = 0.1 is recommended.

On exit, DELEPS contains an overestimate of the increment $\varepsilon_p - \varepsilon_{p-1}$ (in fact the value of the increment which would have been tried if the restriction $\epsilon_p = 1$ had not been imposed).

If continuation was not requested then DELEPS = 0.0 on exit.

If continuation is not requested then the parameters JACEPS and JACGEP may be replaced by dummy actual parameters in the call to D02RAF. (The NAG routines D02GAZ and D02GAX respectively may be used as the dummy parameters.)

JACEPS – SUBROUTINE, supplied by the user.

JACEPS must evaluate the derivative $\frac{\partial f_i}{\partial \epsilon}$ at the point X if continuation is being used. Otherwise the user is advised to use D02GAZ as the actual parameter JACEPS.

The specification of JACEPS is:

```
SUBROUTINE JACEPS(X,EPS,Y,F,N)
INTEGER N
real X,EPS,Y(N),F(N)
```

X – *real*.

On entry, X specifies the value of the argument X. Its value must not be changed.

EPS – *real*.

On entry, EPS must specify the value of the continuation parameter, ϵ. Its value must not be changed.

Y – *real* array of DIMENSION (N).

On entry, Y(i) contains the solution values y_i at the point X, i = 1,2,...,N. These values must not be changed.

F – *real* array of DIMENSION (N).

On exit, F(i) must contain $\frac{\partial f_i}{\partial \epsilon}$ at the point (x,y), i = 1,2,...,N.

N – INTEGER.

On entry, N specifies the number of equations. Its value must not be changed.

JACEPS must be declared as EXTERNAL in the (sub)program from which D02RAF is called.

JACGEP – SUBROUTINE, supplied by the user.

JACGEP must evaluate the derivatives $\frac{\partial g_i}{\partial \epsilon}$ if continuation is being used. Otherwise the user is advised to use D02GAX as the actual parameter for JACGEP.

The specification of JACGEP is:

```
      SUBROUTINE JACGEP(EPS,YA,YB,
     1 BCEP,N)
      INTEGER N
      real EPS,YA(N),YB(N),BCEP(N)
```

EPS – *real*.

On entry, EPS must specify the value of the continuation parameter ϵ. Its value must not be changed.

YA – *real* array of DIMENSION (N).

On entry, YA(i) contains the value of $y_i(A)$, i = 1,2,...,N. These values must not be changed.

YB – *real* array of DIMENSION (N).

On entry, YB(i) contains the value of $y_i(B)$, i = 1,2,...,N. These values must not be changed.

BCEP – *real* array of DIMENSION (N).

On exit, BCEP(i) must contain $\frac{\partial g_i}{\partial \epsilon}$, i = 1,2,...,N.

N – INTEGER.

On entry, N specifies the number of equations. Its value must not be changed.

JACGEP must be declared as EXTERNAL in the (sub)program from which D02RAF is called.

WORK – *real* array of DIMENSION (LWORK).

Used as working space.

LWORK – INTEGER.

On entry, LWORK must specify the dimension of the array WORK.

$LWORK \geq MNP(3N^2+6N+2)+4N^2+3N$

Unchanged on exit.

IWORK – INTEGER array of DIMENSION (LIWORK).

Used as working space.

LIWORK – INTEGER.

On entry, LIWORK must specify the dimension of the array IWORK:

$LIWORK \geq MNP \times (2 \times N+1) + N$ if IJAC $\neq 0$

and

$$LIWORK \geq MNP \times (2\times N+1) + N^2 + 4 \times N + 2,$$

if IJAC = 0.
Unchanged on exit.

IFAIL – INTEGER.

For this routine, the normal use of IFAIL is extended to control the printing of error messages and monitoring information as well as specifying hard or soft failure (see Chapter P01).

Before entry, IFAIL must be set to a value with the decimal expansion cba, where each of the decimal digits c, b and a must have the value 0 or 1.

a = 0 specifies hard failure, otherwise soft failure;

b = 0 suppresses error messages, otherwise error messages will be printed (see Section 6);

c = 0 suppresses monitoring information, otherwise monitoring information will be printed.

The recommended value for inexperienced users is 110 (i.e. hard failure with all error messages and monitoring information printed).

Unless the routine detects an error (see Section 6), IFAIL contains 0 on exit.

6. Error Indicators and Warnings

Errors detected by the routine:

IFAIL = 1

One or more of the parameters N, MNP, NP, NUMBEG, NUMMIX, TOL, DELEPS, LWORK or LIWORK has been incorrectly set,
or X(1) ≥ X(NP)
or the mesh points X(I) are not ordered as in (6).

IFAIL = 2

A finer mesh is required for the accuracy requested: that is MNP is not large enough. This error exit normally occurs when the problem being solved is difficult (for example, there is a boundary layer) and high accuracy is requested. A poor initial choice of mesh points will make this error exit more likely.

IFAIL = 3

The Newton iteration has failed to converge. There are several possible causes for this error:

(i) Faulty coding in one of the Jacobian calculation routines;

(ii) If IJAC = 0 then inaccurate Jacobians may have been calculated numerically (this is a very unlikely cause);

(iii) A poor initial mesh or initial approximate solution has been selected either by the user or by default or there are not enough points in the initial mesh. Possibly, the user should try the continuation facility.

IFAIL = 4

The Newton iteration has reached roundoff error level. It could be however that the answer returned is satisfactory. The error is likely to occur if too high an accuracy is requested.

IFAIL = 5

The Jacobian calculated by JACOBG (or the equivalent matrix calculated by numerical differentiation) is singular. This may occur due to faulty coding of JACOBG or, in some circumstances, to a zero initial choice of approximate solution (such as is chosen when INIT = 0).

IFAIL = 6

There is no dependence on ε when continuation is being used. This can be due to faulty coding of JACEPS or JACGEP or, in some circumstances, to a zero initial choice of approximate solution (such as is chosen when INIT = 0).

IFAIL = 7

DELEPS is required to be less than macheps for continuation to proceed. It is likely that either the problem (3) has no solution for some value near the current value of EPS (see the advisory print out from D02RAF) or that the problem is so difficult that even with continuation it is unlikely to be solved using this routine. If the latter cause is suspected then using more mesh points initially may help.

IFAIL = 8
IFAIL = 9

Indicates that a serious error has occurred in a call to D02RAF or D02RAR respectively. Check all array subscripts and subroutine parameter lists in calls to D02RAF. Seek expert help.

7. Auxiliary Routines

Details are distributed to sites in machine-readable form.

8. Timing

There are too many factors present to quantify the timing. The time taken is negligible only on very simple problems.

9. Storage

The storage occupied by internally declared arrays is 250 ***real*** elements.

10. Accuracy

The solution returned by the routine will be accurate to the user's tolerance as defined by the relation (5) except in extreme circumstances. The final error estimate over the whole mesh for each component is given in the array ABT. If too many points are specified in the initial mesh, the solution may be more accurate than requested and the error may not be approximately equidistributed.

11. Further Comments

The routine uses a labelled COMMON block AD02RA.

The user is strongly recommended to set IFAIL to obtain self-explanatory error messages, and also monitoring information about the course of the computation. The user may select the channel numbers on which this output is to appear by calls of X04AAF (for error messages) or X04ABF (for monitoring information) – see Section 13 for an example. Otherwise the default channel numbers will be used, as specified in the implementation document.

In the case where the user wishes to solve a sequence of similar problems, the use of the final mesh and solution from one case as the initial mesh is strongly recommended for the next.

12. Keywords

Boundary Value Problems,
Deferred Correction,
Differential Equations, ordinary,
Finite – Difference Method.

---

13. Example

We solve the differential equation

$$y''' = -yy'' - 2\epsilon(1-y'^2)$$

with $\epsilon = 1$ and boundary conditions

$$y(0) = y'(0) = 0, \; y'(10) = 1$$

to an accuracy specified by TOL = 1.0E–4. The continuation facility is used with the continuation parameter ϵ introduced as in the differential equation above and with DELEPS = 0.1 initially. (The continuation facility is not needed for this problem and is used here for illustration.)

Note the calls to X04AAF and X04ABF prior to the call to D02RAF.

WARNING: This **single precision** example program may require amendment for certain implementations. The results produced may not be the same. If in doubt, please seek further advice (see **Essential Introduction** to the Library Manual).

13.1. Program Text

```
C      D02RAF EXAMPLE PROGRAM TEXT
C      MARK 8 RELEASE. NAG COPYRIGHT 1979.
C      .. LOCAL SCALARS ..
       REAL DELEPS, TOL
       INTEGER I, IFAIL, IJAC, INIT, J, LIWORK, LWORK, MNP, N, NOUT,
      * NP, NUMBEG, NUMMIX
C      .. LOCAL ARRAYS ..
       REAL ABT(3), WORK(2128), X(40), Y(3,40)
       INTEGER IWORK(303)
C      .. SUBROUTINE REFERENCES ..
```

```
C     D02RAF, X04AAF, X04ABF
C     ..
      EXTERNAL FCN, G, JACEPS, JACGEP, JACOBF, JACOBG
      DATA NOUT /6/
      WRITE (NOUT,99997)
      WRITE (NOUT,99996)
      CALL X04AAF(1, NOUT)
      CALL X04ABF(1, NOUT)
      TOL = 1.0E-4
      LWORK = 2128
      LIWORK = 303
      MNP = 40
      N = 3
      NP = 17
      NUMBEG = 2
      NUMMIX = 0
      X(1) = 0.0
      X(NP) = 10.0
      INIT = 0
      DELEPS = 0.1
      IJAC = 1
      IFAIL = 111
      CALL D02RAF(N, MNP, NP, NUMBEG, NUMMIX, TOL, INIT, X, Y, 3,
     * ABT, FCN, G, IJAC, JACOBF, JACOBG, DELEPS, JACEPS, JACGEP,
     * WORK, LWORK, IWORK, LIWORK, IFAIL)
      IF (IFAIL.NE.0) GO TO 20
      WRITE (NOUT,99999) NP
      WRITE (NOUT,99998) (X(J),(Y(I,J),I=1,N),J=1,NP)
      WRITE (NOUT,99995) (ABT(I),I=1,N)
   20 STOP
99999 FORMAT (27H0SOLUTION ON FINAL MESH OF , I2, 7H POINTS/7X,
     * 4HX(I), 5X, 5HY1(I), 8X, 5HY2(I), 8X, 5HY3(I))
99998 FORMAT (1X, 0PF10.3, 1P3E13.4)
99997 FORMAT (4(1X/), 31H D02RAF EXAMPLE PROGRAM RESULTS/1X)
99996 FORMAT (1X/37H0CALCULATION USING ANALYTIC JACOBIANS)
99995 FORMAT (38H0MAXIMUM ESTIMATED ERROR BY COMPONENTS/1H , 10X,
     * 1P3E13.4)
      END
      SUBROUTINE FCN(X, EPS, Y, F, M)
C     .. SCALAR ARGUMENTS ..
      REAL EPS, X
      INTEGER M
C     .. ARRAY ARGUMENTS ..
      REAL F(M), Y(M)
C     ..
      F(1) = Y(2)
      F(2) = Y(3)
      F(3) = -Y(1)*Y(3) - 2.0*(1.0-Y(2)*Y(2))*EPS
      RETURN
      END
      SUBROUTINE G(EPS, Y, Z, AL, M)
C     .. SCALAR ARGUMENTS ..
      REAL EPS
      INTEGER M
C     .. ARRAY ARGUMENTS ..
```

```
      REAL AL(M), Y(M), Z(M)
C     ..
      AL(1) = Y(1)
      AL(2) = Y(2)
      AL(3) = Z(2) - 1.0
      RETURN
      END
      SUBROUTINE JACEPS(X, EPS, Y, F, M)
C     .. SCALAR ARGUMENTS ..
      REAL EPS, X
      INTEGER M
C     .. ARRAY ARGUMENTS ..
      REAL F(M), Y(M)
C     ..
      F(1) = 0.0
      F(2) = 0.0
      F(3) = -2.0*(1.0-Y(2)*Y(2))
      RETURN
      END
      SUBROUTINE JACGEP(EPS, Y, Z, AL, M)
C     .. SCALAR ARGUMENTS ..
      REAL EPS
      INTEGER M
C     .. ARRAY ARGUMENTS ..
      REAL AL(M), Y(M), Z(M)
C     ..
C     .. LOCAL SCALARS ..
      INTEGER I
C     ..
      DO 20 I=1,3
         AL(I) = 0.0
   20 CONTINUE
      RETURN
      END
      SUBROUTINE JACOBF(X, EPS, Y, F, M)
C     .. SCALAR ARGUMENTS ..
      REAL EPS, X
      INTEGER M
C     .. ARRAY ARGUMENTS ..
      REAL F(M,M), Y(M)
C     ..
C     .. LOCAL SCALARS ..
      INTEGER I, J
C     ..
      DO 40 I=1,3
         DO 20 J=1,3
            F(I,J) = 0.0
   20    CONTINUE
   40 CONTINUE
      F(1,2) = 1.0
      F(2,3) = 1.0
      F(3,1) = -Y(3)
      F(3,2) = 4.0*Y(2)*EPS
      F(3,3) = -Y(1)
      RETURN
```

```
      END
      SUBROUTINE JACOBG(EPS  Y, Z, A, B, M)
C     .. SCALAR ARGUMENTS ..
      REAL EPS
      INTEGER M
C     .. ARRAY ARGUMENTS ..
      REAL A(M,M), B(M,M), Y(M), Z(M)
C     ..
C     .. LOCAL SCALARS ..
      INTEGER I, J
C     ..
      DO 40 I=1,3
         DO 20 J=1,3
            A(I,J) = 0.0
            B(I,J) = 0.0
   20    CONTINUE
   40 CONTINUE
      A(1,1) = 1.0
      A(2,2) = 1.0
      B(3,2) = 1.0
      RETURN
      END
```

13.2. Program Data

None.

13.3. Program Results

```
 D02RAF EXAMPLE PROGRAM RESULTS


 CALCULATION USING ANALYTIC JACOBIANS

 D02RAF MONITORING INFORMATION

  MONITORING NEWTON ITERATION

   NUMBER OF POINTS IN CURRENT MESH =    17
   CORRECTION NUMBER    0   RESIDUAL SHOULD BE .LE.  1.00E 00
    ITERATION NUMBER    0   RESIDUAL =  1.00E 00
     SQUARED NORM OF CORRECTION =  9.90E 01
     SQUARED NORM OF GRADIENT   =  1.00E 00
     SCALAR PRODUCT OF CORRECTION AND GRADIENT =  1.00E 00
    ITERATION NUMBER    1   RESIDUAL =  5.59E-01
  CONTINUATION PARAMETER EPSILON =  2.00E-01   DELEPS =  2.00E-01

  MONITORING NEWTON ITERATION

                          Monitoring information omitted.
   NUMBER OF NEW POINTS   5
  MONITORING NEWTON ITERATION

   NUMBER OF POINTS IN CURRENT MESH =    33
   CORRECTION NUMBER    1   RESIDUAL SHOULD BE .LE.  1.22E-05
    ITERATION NUMBER    0   RESIDUAL =  3.58E-04
```

```
  SQUARED NORM OF CORRECTION =  1.70E-06
  SQUARED NORM OF GRADIENT   =  2.89E-07
  SCALAR PRODUCT OF CORRECTION AND GRADIENT =  1.28E-07
 ITERATION NUMBER    1   RESIDUAL =  2.70E-08
MESH SELECTION

 NUMBER OF NEW POINTS   0
CORRECTION NUMBER    1   ESTIMATED MAXIMUM ERROR =  6.92E-05

ESTIMATED ERROR BY COMPONENTS
   6.92E-05  1.81E-05  6.42E-05
SOLUTION ON FINAL MESH OF 33 POINTS
```

X(I)	Y1(I)	Y2(I)	Y3(I)
0.000	0.0000E 00	0.0000E 00	1.6872E 00
0.062	3.2142E-03	1.0155E-01	1.5626E 00
0.125	1.2532E-02	1.9536E-01	1.4398E 00
0.188	2.7476E-02	2.8159E-01	1.3203E 00
0.250	4.7578E-02	3.6049E-01	1.2054E 00
0.375	1.0149E-01	4.9760E-01	9.9235E-01
0.500	1.7093E-01	6.0965E-01	8.0477E-01
0.625	2.5299E-01	6.9991E-01	6.4376E-01
0.703	3.0954E-01	7.4673E-01	5.5629E-01
0.781	3.6950E-01	7.8708E-01	4.7842E-01
0.938	4.9776E-01	8.5129E-01	3.4901E-01
1.094	6.3461E-01	8.9774E-01	2.5017E-01
1.250	7.7761E-01	9.3077E-01	1.7628E-01
1.458	9.7480E-01	9.5983E-01	1.0768E-01
1.667	1.1768E 00	9.7733E-01	6.3852E-02
1.875	1.3815E 00	9.8758E-01	3.6741E-02
2.031	1.5362E 00	9.9224E-01	2.3792E-02
2.188	1.6915E 00	9.9523E-01	1.5143E-02
2.500	2.0031E 00	9.9828E-01	5.8470E-03
2.656	2.1591E 00	9.9900E-01	3.5275E-03
2.813	2.3153E 00	9.9943E-01	2.0894E-03
3.125	2.6277E 00	9.9983E-01	7.0180E-04
3.750	3.2526E 00	9.9998E-01	1.1337E-04
4.375	3.8776E 00	1.0000E 00	6.5600E-06
5.000	4.5026E 00	1.0000E 00	5.7085E-06
5.625	5.1276E 00	1.0000E 00	-1.2928E-06
6.250	5.7526E 00	1.0000E 00	5.4482E-07
6.875	6.3776E 00	1.0000E 00	-2.2880E-07
7.500	7.0026E 00	1.0000E 00	8.9176E-08
8.125	7.6276E 00	1.0000E 00	-3.5784E-08
8.750	8.2526E 00	1.0000E 00	1.5339E-08
9.375	8.8776E 00	1.0000E 00	-6.7001E-09
10.000	9.5026E 00	1.0000E 00	3.5393E-09

```
 MAXIMUM ESTIMATED ERROR BY COMPONENTS

              6.9244E-05    1.8051E-05    6.4213E-05
```

D02GBF – NAG FORTRAN Library Routine Document

NOTE: before using this routine, please read the appropriate implementation document to check the interpretation of ***bold italicised*** terms and other implementation-dependent details. The routine name may be precision-dependent.

1. Purpose

D02GBF solves a general linear two-point boundary value problem for a system of ordinary differential equations using a deferred correction technique.

2. Specification

```
      SUBROUTINE D02GBF (A, B, N, TOL, FCNF, FCNG, C, D, GAM, MNP,
     1   X, Y, NP, W, LW, IW, LIW, IFAIL)
C     INTEGER N, MNP, NP, LW, IW(LIW), LIW, IFAIL
C     real A, B, TOL, C(N,N), D(N,N), GAM(N), X(MNP), Y(N,MNP),
C    1   W(LW)
C     EXTERNAL FCNF, FCNG
```

3. Description

D02GBF solves the linear two-point boundary value problem for a system of N ordinary differential equations in the range (A,B). The system is written in the form

$$y' = F(x)y + G(x) \quad (1)$$

and the boundary conditions are written in the form

$$Cy(A) + Dy(B) = \gamma \quad (2)$$

Here F(x), C and D are N × N matrices, and G(x) and γ are N–component vectors. The approximate solution to (1) and (2) is found using a finite-difference method with deferred correction. The algorithm is a specialisation of that used in subroutine D02RAF which solves a nonlinear version of (1) and (2). The nonlinear version of the algorithm is described fully in [1].

The user supplies an absolute error tolerance and may also supply an initial mesh for the construction of the finite-difference equations (alternatively a default mesh is used). The algorithm constructs a solution on a mesh defined by adding points to the initial mesh. This solution is chosen so that the error is everywhere less than the user's tolerance and so that the error is approximately equidistributed on the final mesh. The solution is returned on this final mesh.

If the solution is required at a few specific points then these should be included in the initial mesh. If, on the other hand, the solution is required at several specific points, then the user should use the interpolation routines provided in the E01 chapter if these points do not themselves form a convenient mesh.

4. References

[1] PEREYRA, V.
PASVA3: An Adaptive Finite-Difference Fortran Program for First Order Nonlinear, Ordinary Boundary Problems.
In Childs, B., Scott, M., Daniel, J. W., Denman, E. and Nelson, P. (eds.)
'Codes for Boundary Value Problems in Ordinary Differential Equations.'
Springer – Verlag, Lecture Notes in Computer Science, 76, 1979.

5. Parameters

A – ***real***.

On entry, A must specify the left hand boundary point, A.

Unchanged on exit.

B – ***real***.

On entry, B must specify the right hand boundary point, B.

B > A.

Unchanged on exit.

N – INTEGER.

On entry, N must specify the number of equations; that is N is the order of system (1).

Unchanged on exit.

TOL – ***real***.

On entry, TOL must specify a positive absolute error tolerance. If

$$A = x_1 < x_2 < \ldots < x_{NP} = B$$

is the final mesh, z(x) is the approximate solution from D02GBF and y(x) is the true solution of equations (1) and (2) then, except in extreme cases, it is expected that

$$||z-y|| \leq TOL \quad (3)$$

where

$$||u|| = \max_{1\leq i\leq N} \max_{1\leq j\leq NP} |u_i(x_j)|.$$

Unchanged on exit.

FCNF – SUBROUTINE, supplied by the user.

FCNF must evaluate the matrix F(x) in (1) at a general point x = X and place $F_{ij}(x)$ in F(i,j), i,j = 1,2,...,N.

Its specification is :–

```
SUBROUTINE FCNF (X,F)
real X, F(n,n)
```

where n is the numerical value of N.

X – ***real***.

On entry, X specifies the value of the independent variable x. Its value must not be changed.

F – ***real*** array of DIMENSION (n,n).

On exit, F(i,j) must contain the (i,j) (th) element of the matrix F(x), i,j = 1,2,...,n. See Section 13 for an example.

FCNF must be declared as EXTERNAL in the (sub)program from which D02GBF is called.

FCNG – SUBROUTINE, supplied by the user.

FCNG must evaluate the vector G(x) in (1) at a general point x = X and place $G_i(x)$ in G(I), I = 1,2,...,N.

Its specification is:–

```
SUBROUTINE FCNG(X,G)
real X, G(n)
```

where n is the numerical value of N.

X – ***real***.

On entry, X specifies the value of the independent variable x. Its value must not be changed.

G – ***real*** array of DIMENSION (n)

On exit, G(i) must contain the i(th) element of the vector G(x). See Section 13 for an example.

FCNG must be declared as EXTERNAL in the (sub)program from which D02GBF is called.

C, D – ***real*** arrays of DIMENSION (N,N)

GAM – ***real*** array of DIMENSION (N)

Before entry the arrrays C and D must be set to the matrices C and D in (2). GAM must be set to the vector γ in (2).

The routine re-orders the rows of C and D and the components of GAM so that the boundary conditions are in the order:

(i) conditions on y(A) only

(ii) condition involving y(A) and y(B)

(iii) conditions on y(B) only.

The routine will be slightly more efficient if the arrays C,D and GAM are ordered in this way before entry, and in this event they will be unchanged on exit.

MNP – INTEGER.

On entry, MNP must specify the maximum permitted number of mesh points.

MNP ≥ 32.

Unchanged on exit.

X – ***real*** array of DIMENSION (MNP).

On entry, if NP ≥ 4 (see NP below) the elements X(1),X(2),...,X(NP) must define an initial mesh satisfying

$$A = X(1) < X(2) < ... < X(NP) = B \quad (4)$$

On exit, X(1),X(2),...,X(NP) define the final mesh (with the returned value of NP) satisfying the relation (4).

Y – ***real*** array of DIMENSION (N,MNP).

On successful exit, the array Y contains the approximate solution z(x) satisfying (3), on the final mesh, that is

$$Y(J,I) = z_j(x_i), \qquad I = 1,2,...,NP, \quad J = 1,2,...,N.$$

where NP is the number of points in the final mesh.

The remaining columns of Y are not used.

NP – INTEGER.

On entry, NP must satisfy NP = 0 or 4 ≤ NP ≤ MNP. If NP = 0 on entry, a default value of 4 for NP and a corresponding equispaced mesh X(1),X(2),...,X(NP) are used. If NP ≥ 4 on entry, then the user must define an initial mesh X as in (4) above.

On exit, NP contains the number of points in the final (returned) mesh.

W – ***real*** array of DIMENSION (LW).

Used as workspace.

LW - INTEGER.

On entry, LW must specify the length of the array W,

$LW \geq MNP \times (3N^2+5N+2)+3N^2+5N$

Unchanged on exit.

IW - INTEGER array of DIMENSION (LIW).

Used as workspace.

LIW - INTEGER.

On entry, LIW must specify the length of the array IW.

$LIW \geq MNP \times (2N+1)+N$

Unchanged on exit.

IFAIL - INTEGER.

For this routine, the normal use of IFAIL is extended to control the printing of error and warning messages as well as specifying hard or soft failure (see Chapter P01).

Before entry, IFAIL must be set to a value with the decimal expansion cba, where each of the decimal digits c, b and a must have the value 0 or 1.

- a = 0 specifies hard failure, otherwise soft failure;
- b = 0 suppresses error messages, otherwise error messages will be printed (see Section 6);
- c = 0 suppresses warning messages, otherwise warning messages will be printed (see Section 6).

The recommended value for inexperienced users is 110 (i.e. hard failure with all messages printed).

Unless the routine detects an error (see Section 6), IFAIL contains 0 on exit.

6. Error Indicators and Warnings

Errors detected by the routine:-

For some errors, the routine outputs an explanatory error message on the current error message unit (see NAG Library routine X04AAF), unless suppressed by the value of IFAIL on entry.

IFAIL = 1

One or more of the parameters N, TOL, NP, MNP, LW or LIW is incorrectly set, $B \leq A$ or the condition (4) on X is not satisfied.

IFAIL = 2

Either a row of C and the corresponding row of D are both identically zero (that is the boundary conditions are rank deficient) or one of the matrices C or D is identically zero (that is the problem is of initial value and not boundary value type).

IFAIL = 3

The routine has failed to find a solution to the specified accuracy. There are a variety of possible reasons including:

- (i) The boundary conditions are rank deficient. This will usually be indicated by a message that the Jacobian is singular (simple cases of rank deficiency are flagged with IFAIL = 2).
- (ii) Not enough mesh points are permitted in order to attain the required accuracy. This is indicated by NP = MNP on return from a call to D02GBF . This difficulty may be aggravated by a poor initial choice of mesh points.
- (iii) The accuracy requested cannot be attained on the computer being used.

IFAIL = 4

A serious error has occurred in a call to D02GBF . Check all array subscripts and subroutine parameter lists in calls to D02GBF. Seek expert help.

7. Auxiliary Routines

Details are distributed to sites in machine-readable form.

8. Timing

This depends on the difficulty of the problem, the number of mesh points (and meshes) used and the number of deferred corrections.

9. Storage

The storage occupied by internally declared arrays is 250 *real* elements.

10. Accuracy

The solution returned by the routine will be accurate to the user's tolerance as defined by the relation (3) except in extreme circumstances. If too many points are specified in the initial mesh, the solution may be more accurate than requested and the error may not be approximately equidistributed.

11. Further Comments

The routine uses a labelled COMMON block AD02RA.

The user is strongly recommended to set IFAIL to obtain self-explanatory error messages, and also monitoring information about the course of the computation. The user may select the channel numbers on which this output is to appear by calls of X04AAF (for error messages) or X04ABF (for monitoring information) – see Section 13 for an example. Otherwise the default channel numbers will be used, as specified in the implementation document.

In the case where the user wishes to solve a sequence of similar problems, the use of the final mesh from one case is strongly recommended as the initial mesh for the next.

12. Keywords

Linear Boundary Value Problems,
Deferred Correction,
Ordinary Differential Equations,
Finite-Difference Method.

---

13. Example

We solve the problem (written as a first order system)

$$\epsilon y'' + y' = 0$$

with boundary conditions

$$y(0) = 0, \ y(1) = 1$$

for the cases $\epsilon = 10^{-1}$ and $\epsilon = 10^{-2}$ using the default initial mesh in the first case, and the final mesh of the first case as initial mesh for the second (more difficult) case. We give the solution and the error at each mesh point to illustrate the accuracy of the method given the accuracy request TOL = 1.0E-3.

Note the calls to X04AAF and X04ABF prior to the call to D02GBF.

13.1. Program Text

WARNING: This **single precision** example program may require amendment for certain implementations. The results produced may not be the same. If in doubt, please seek further advice (see **Essential Introduction** to the Library Manual).

```
C     D02GBF EXAMPLE PROGRAM TEXT
C     MARK 8 RELEASE. NAG COPYRIGHT 1979.
C     .. SCALARS IN COMMON ..
      REAL EPS
C     ..
C     .. LOCAL SCALARS ..
      REAL A, B, TOL
      INTEGER I, IFAIL, J, LIW, LW, MNP, N, NOUT, NP
C     .. LOCAL ARRAYS ..
      REAL C(2,2), D(2,2), GAM(2), W(2052), X(70), Y(2,70)
      INTEGER IW(352)
C     .. FUNCTION REFERENCES ..
      REAL SOL
C     .. SUBROUTINE REFERENCES ..
C     D02GBF, X04AAF, X04ABF
C     ..
      EXTERNAL FCNF, FCNG
      COMMON EPS
      DATA NOUT /6/
      WRITE (NOUT,99999)
      TOL = 1.0E-3
      MNP = 70
      NP = 0
      N = 2
```

```
      LW = 2052
      LIW = 352
      A = 0.0
      B = 1.0
      CALL X04AAF(1, NOUT)
      CALL X04ABF(1, NOUT)
      DO 40 I=1,2
         GAM(I) = 0.0
         DO 20 J=1,2
            C(I,J) = 0.0
            D(I,J) = 0.0
   20    CONTINUE
   40 CONTINUE
      C(1,1) = 1.0
      D(2,1) = 1.0
      GAM(2) = 1.0
      DO 80 I=1,2
         EPS = 10.0**(-I)
         WRITE (NOUT,99998) EPS
         IFAIL = 111
         CALL D02GBF(A, B, N, TOL, FCNF, FCNG, C, D, GAM, MNP, X,
     *    Y, NP, W, LW, IW, LIW, IFAIL)
         IF (IFAIL.GT.0) GO TO 100
         WRITE (NOUT,99997) NP
         DO 60 J=1,NP
            W(J) = Y(1,J) - SOL(X(J))
   60    CONTINUE
         WRITE (NOUT,99996) (X(J),Y(1,J),W(J),J=1,NP)
   80 CONTINUE
  100 STOP
99999 FORMAT (4(1X/), 31H D02GBF EXAMPLE PROGRAM RESULTS/1X)
99998 FORMAT (1X/24H0PROBLEM WITH EPSILON = , E10.2)
99997 FORMAT (37H0SOLUTION AND ERROR ON FINAL MESH OF , I2,
     * 7H POINTS/7X, 4HX(I), 4X, 6HY(1,I), 5X, 5HERROR)
99996 FORMAT (1X, 2F10.4, E12.2)
      END
      SUBROUTINE FCNF(X, F)
C     .. SCALAR ARGUMENTS ..
      REAL X
C     .. ARRAY ARGUMENTS ..
      REAL F(2,2)
C     ..
C     .. SCALARS IN COMMON ..
      REAL EPS
C     ..
      COMMON EPS
      F(1,1) = 0.0
      F(1,2) = 1
      F(2,1) = 0.0
      F(2,2) = -1.0/EPS
      RETURN
      END
      SUBROUTINE FCNG(X, G)
C     .. SCALAR ARGUMENTS ..
      REAL X
```

```
C     .. ARRAY ARGUMENTS ..
      REAL G(2)
C     ..
      G(1) = 0.0
      G(2) = 0.0
      RETURN
      END
      REAL FUNCTION SOL(X)
C     .. SCALAR ARGUMENTS ..
      REAL X
C     ..
C     .. SCALARS IN COMMON ..
      REAL EPS
C     ..
C     .. FUNCTION REFERENCES ..
      REAL EXP
C     ..
      COMMON EPS
      SOL = (EXP(-X/EPS)-1.0)/(EXP(-1.0/EPS)-1.0)
      RETURN
      END
```

13.2. Program Data

None.

13.3. Program Results

```
 D02GBF EXAMPLE PROGRAM RESULTS


 PROBLEM WITH EPSILON =   0.10E 00

 D02GBF MONITORING INFORMATION

  NUMBER OF POINTS IN CURRENT MESH =    15
  CORRECTION NUMBER    0   ESTIMATED MAXIMUM ERROR =  6.59E-02

  ESTIMATED ERROR BY COMPONENTS
     6.57E-03  6.59E-02
  NUMBER OF POINTS IN CURRENT MESH =    15
  CORRECTION NUMBER    1   ESTIMATED MAXIMUM ERROR =  3.60E-03

  ESTIMATED ERROR BY COMPONENTS
     3.61E-04  3.60E-03
  NUMBER OF POINTS IN CURRENT MESH =    15
  CORRECTION NUMBER    2   ESTIMATED MAXIMUM ERROR =  4.36E-04

  ESTIMATED ERROR BY COMPONENTS
     4.45E-05  4.36E-04
 SOLUTION AND ERROR ON FINAL MESH OF 15 POINTS

      X(I)     Y(1,I)      ERROR
     0.0000    0.0000    0.00E 00
     0.0278    0.2425    0.14E-05
     0.0556    0.4263   -0.11E-05
```

```
   0.1111    (.6708    0.16E-05
   0.1667    (.8112    0.12E-04
   0.2222    ).8917    0.18E-04
   0.2778    0.9379    0.15E-04
   0.3333    0.9644    0.11E-04
   0.4444    0.9883    0.24E-04
   0.5556    0.9962    0.36E-04
   0.6667    0.9988    0.18E-04
   0.7500    0.9995    0.59E-05
   0.8333    0.9998    0.12E-05
   0.9167    0.9999   -0.91E-06
   1.0000    1.0000    0.00E 00

PROBLEM WITH EPSILON =   0.10E-01

D02GBF MONITORING INFORMATION

 NUMBER OF POINTS IN CURRENT MESH =   49
 CORRECTION NUMBER    0   ESTIMATED MAXIMUM ERROR =  5.29E-02

 ESTIMATED ERROR BY COMPONENTS
    5.29E-04  5.29E-02
 NUMBER OF POINTS IN CURRENT MESH =   49
 CORRECTION NUMBER    1   ESTIMATED MAXIMUM ERROR =  1.26E-03

 ESTIMATED ERROR BY COMPONENTS
    1.27E-05  1.26E-03
 NUMBER OF POINTS IN CURRENT MESH =   49
 CORRECTION NUMBER    2   ESTIMATED MAXIMUM ERROR =  2.45E-04

 ESTIMATED ERROR BY COMPONENTS
    1.67E-06  2.45E-04
SOLUTION AND ERROR ON FINAL MESH OF 49 POINTS

     X(I)     Y(1,I)     ERROR
   0.0000    0.0000    0.00E 00
   0.0009    0.0884    0.69E-08
   0.0019    0.1690    0.16E-07
   0.0028    0.2425    0.25E-07
   0.0037    0.3095    0.33E-07
   0.0046    0.3706    0.41E-07
   0.0056    0.4262    0.47E-07
   0.0065    0.4770    0.53E-07
   0.0074    0.5232    0.59E-07
   0.0083    0.5654    0.64E-07
   0.0093    0.6038    0.70E-07
   0.0111    0.6708    0.72E-07
   0.0130    0.7265    0.69E-07
   0.0148    0.7727    0.92E-07
   0.0167    0.8111    0.11E-06
   0.0185    0.8431    0.11E-06
   0.0204    0.8696    0.12E-06
   0.0222    0.8916    0.12E-06
   0.0241    0.9100    0.12E-06
   0.0259    0.9252    0.13E-06
```

0.0278	0.9378	0.13E-06
0.0306	0.9529	0.12E-06
0.0333	0.9643	0.13E-06
0.0361	0.9730	0.15E-06
0.0389	0.9795	0.15E-06
0.0417	0.9845	0.15E-06
0.0444	0.9883	0.15E-06
0.0472	0.9911	0.14E-06
0.0500	0.9933	0.14E-06
0.0528	0.9949	0.13E-06
0.0556	0.9961	0.13E-06
0.0648	0.9985	0.33E-06
0.0741	0.9994	0.13E-05
0.0833	0.9998	0.15E-05
0.0926	0.9999	0.69E-06
0.1019	1.0000	0.36E-06
0.1111	1.0000	0.28E-06
0.1389	1.0000	0.16E-05
0.1667	1.0000	0.94E-06
0.2222	1.0000	0.50E-06
0.2778	1.0000	-0.15E-06
0.3333	1.0000	0.39E-06
0.4444	1.0000	-0.34E-06
0.5556	1.0000	0.47E-06
0.6667	1.0000	-0.13E-06
0.7500	1.0000	0.26E-06
0.8333	1.0000	0.20E-07
0.9167	1.0000	0.19E-06
1.0000	1.0000	0.00E 00

C05NBF – NAG FORTRAN Library Routine Document

NOTE: before using this routine, please read the appropriate implementation document to check the interpretation of ***bold italicised*** terms and other implementation-dependent details. The routine name may be precision-dependent.

1. Purpose

C05NBF is an easy-to-use routine to find a zero of a system of N nonlinear functions in N variables by a modification of the Powell hybrid method.

2. Specification

```
      SUBROUTINE C05NBF (FCN, N, X, FVEC, XTOL, WA, LWA, IFAIL)
C     INTEGER N, LWA, IFAIL
C     real X(N), FVEC(N), XTOL, WA(LWA)
C     EXTERNAL FCN
```

3. Description

C05NBF is based upon the MINPACK routine HYBRD1. It chooses the correction at each step as a convex combination of the Newton and scaled gradient directions. Under reasonable conditions this guarantees global convergence for starting points far from the solution and a fast rate of convergence. The Jacobian is updated by the rank–1 method of Broyden. At the starting point the Jacobian is approximated by forward differences, but these are not used again until the rank–1 method fails to produce satisfactory progress.

4. References

[1] POWELL, M.J.D.
A hybrid method for nonlinear algebraic equations. In 'Numerical Methods for Nonlinear Algebraic Equations', Ed. Rabinowitz, P., Gordon and Breach, 1970.

[2] MORE, J.J., GARBOW, B.S. and HILLSTROM, K.E.
User Guide for MINPACK–1.
ANL–80–74, Argonne National Laboratory.

5. Parameters

FCN – SUBROUTINE, supplied by the user.

FCN must calculate the values of the functions at X and return these in the vector FVEC.
Its specification is:–

```
SUBROUTINE FCN(N,X,FVEC,IFLAG)
INTEGER N,IFLAG
real X(N),FVEC(N)
```

N – INTEGER.

On entry, N contains the number of equations. The value of N must not be changed by FCN.

X – ***real*** array of DIMENSION (N).

On entry, X contains the point at which the functions are to be evaluated. The values in X must not be changed by FCN.

FVEC – ***real*** array of DIMENSION (N).

On exit, unless IFLAG is reset to a negative number, FVEC(i) must contain the value of the (i)th function evaluated at X.

IFLAG – INTEGER.

In general, IFLAG should not be reset by FCN. If, however, the user wishes to terminate execution (perhaps because some illegal point X has been reached) then IFLAG should be set to a negative integer. This value will be returned through IFAIL.

FCN must be declared as EXTERNAL in the (sub)program from which C05NBF is called.

N – INTEGER.

On entry, N must specify the number of equations. $N > 0$.

Unchanged on exit.

X – ***real*** array of DIMENSION at least (N).

Before entry, X(j) must be set to a guess at the j(th) component of the solution ($j = 1,2,...,N$).

On exit, X contains the final estimate of the solution vector.

FVEC – ***real*** array of DIMENSION at least (N).

On exit, FVEC contains the function values at the final point, X.

XTOL – ***real***.

On entry, XTOL must specify the accuracy in X to which the solution is required. XTOL $\geq$ 0.0. If XTOL is less than machine precision (see NAG FORTRAN Library routine X02AAF), then machine precision is used. See Section 10. The recommended value is the square root of machine precision.

Unchanged on exit.

WA – ***real*** array of DIMENSION at least (LWA).

Used as workspace.

LWA – INTEGER.

On entry, LWA must specify the dimension of the array WA. LWA$\geq\frac{1}{2}$N$\times$(3$\times$N+13).

Unchanged on exit.

IFAIL – INTEGER.

Before entry, IFAIL must be assigned a value. For users not familiar with this parameter (described in Chapter P01) the recommended value is 0.

Unless the routine detects an error (see next section), IFAIL contains 0 on exit.

6. Error Indicators and Warnings

Errors detected by the routine:–

IFAIL $<$ 0

This indicates an exit from C05NBF because the user has set IFLAG negative in FCN. The value of IFAIL will be the same as the user's setting of IFLAG.

IFAIL = 1

On entry, N $\leq$ 0, XTOL $<$ 0.0, or LWA$<\frac{1}{2}$N$\times$(3$\times$N+13).

IFAIL = 2

There have been at least 200 $\times$ (N+1) evaluations of FCN. Consider restarting the calculation from the final point held in X.

IFAIL = 3

No further improvement in the approximate solution X is possible; XTOL is too small.

IFAIL = 4

The iteration is not making good progress. This failure exit may indicate that the system does not have a zero. Otherwise, rerunning C05NBF from a different starting point may avoid the region of difficulty. Alternatively consider using C05PBF or C05PCF which require an analytic Jacobian.

7. Auxiliary Routines

Details are distributed to sites in machine-readable form.

8. Timing

The time required by C05NBF to solve a given problem depends on N, the behaviour of the functions, the accuracy requested and the starting point. The number of arithmetic operations executed by C05NBF to process each call of FCN is about 11.5$\times$N^2. Unless FCN can be evaluated quickly, the timing of C05NBF will be strongly influenced by the time spent in FCN.

9. Storage

There are no internally declared arrays.

10. Accuracy

C05NBF tries to ensure that $||X-XSOL||_2 \leq XTOL \times ||XSOL||_2$. If this condition is satisfied with XTOL = 10^{-k} then the larger components of X have k significant decimal digits. There is a danger that the smaller components of X may have large relative errors, but the fast rate of convergence of C05NBF usually avoids this possibility.

The test assumes that the functions are reasonably well behaved. If this condition is not satisfied, then C05NBF may incorrectly indicate convergence. The validity of the answer can be checked, for example, by rerunning C05NBF with a tighter tolerance.

11. Further Comments

Ideally the problem should be scaled so that at the solution the function values are of comparable magnitude.

12. Keywords

Equations, nonlinear algebraic, easy-to-use; Powell hybrid method, easy-to-use.

13. Example

To determine the values $x_1,\ldots,x_9$ which satisfy the tridiagonal equations:–

$$(3-2x_1)x_1 - 2x_2 = -1$$
$$-x_{i-1} + (3-2x_i)x_i - 2x_{i+1} = -1,\ i = 2,3,\ldots,8.$$
$$-x_8 + (3-2x_9)x_9 = -1.$$

13.1. Program Text

```
C     C05NBF EXAMPLE PROGRAM TEXT
C     MARK 9 RELEASE. NAG COPYRIGHT 1981
C     .. LOCAL SCALARS ..
      REAL FNORM, TOL
      INTEGER IFAIL, J, NOUT
C     .. LOCAL ARRAYS ..
      REAL FVEC(9), WA(180), X(9)
C     .. FUNCTION REFERENCES ..
      REAL F05ABF, SQRT, X02AAF
C     .. SUBROUTINE REFERENCES ..
C     C05NBF
C     ..
      EXTERNAL FCN
      DATA NOUT /6/
      WRITE (NOUT,99999)
C     THE FOLLOWING STARTING VALUES PROVIDE A ROUGH SOLUTION.
      DO 20 J=1,9
         X(J) = -1.E0
   20 CONTINUE
      TOL = SQRT(X02AAF(0.0))
      IFAIL = 0
      CALL C05NBF(FCN, 9, X, FVEC, TOL, WA, 180, IFAIL)
      FNORM = F05ABF(FVEC,9)
      WRITE (NOUT,99998) FNORM, IFAIL, (X(J),J=1,9)
      STOP
99999 FORMAT (4(1X/), 31H C05NBF EXAMPLE PROGRAM RESULTS/1X)
99998 FORMAT (5X, 31H FINAL L2 NORM OF THE RESIDUALS, E12.4//5X,
     * 15H EXIT PARAMETER, I10//5X, 27H FINAL APPROXIMATE SOLUTION//
     * (5X, 3E12.4))
      END
      SUBROUTINE FCN(N, X, FVEC, IFLAG)
C     .. SCALAR ARGUMENTS ..
      INTEGER IFLAG, N
C     .. ARRAY ARGUMENTS ..
      REAL FVEC(N), X(N)
C     ..
C     .. LOCAL SCALARS ..
      REAL ONE, TEMP, TEMP1, TEMP2, THREE, TWO, ZERO
      INTEGER K
C     ..
      DATA ZERO, ONE, TWO, THREE /0.E0,1.E0,2.E0,3.E0/
      DO 20 K=1,N
         TEMP = (THREE-TWO*X(K))*X(K)
         TEMP1 = ZERO
         IF (K.NE.1) TEMP1 = X(K-1)
         TEMP2 = ZERO
```

```
      IF (K.NE.N) TEMP2 = X(K+1)
      FVEC(K) = TEMP - TEMP1 - TWO*TEMP2 + ONE
   20 CONTINUE
      RETURN
      END
```

13.2. Program Data

None.

13.3. Program Results

```
 C05NBF EXAMPLE PROGRAM RESULTS

      FINAL L2 NORM OF THE RESIDUALS  0.1193E-07

      EXIT PARAMETER         0

      FINAL APPROXIMATE SOLUTION

      -0.5707E+00 -0.6816E+00 -0.7017E+00
      -0.7042E+00 -0.7014E+00 -0.6919E+00
      -0.6658E+00 -0.5960E+00 -0.4164E+00
```

C05PBF – NAG FORTRAN Library Routine Document

NOTE: before using this routine, please read the appropriate implementation document to check the interpretation of ***bold italicised*** terms and other implementation-dependent details. The routine name may be precision-dependent.

1. Purpose

C05PBF is an easy-to-use routine to find a zero of a system of N nonlinear functions in N variables by a modification of the Powell hybrid method. The user must provide the Jacobian.

2. Specification

```
      SUBROUTINE C05PBF (FCN, N, X, FVEC, FJAC, LDFJAC, XTOL, WA,
     1   LWA, IFAIL)
C     INTEGER N, LDFJAC, LWA, IFAIL
C     real X(N), FVEC(N), FJAC(LDFJAC,N), XTOL, WA(LWA)
C     EXTERNAL FCN
```

3. Description

C05PBF is based upon the MINPACK routine HYBRJ1. It chooses the correction at each step as a convex combination of the Newton and scaled gradient directions. Under reasonable conditions this guarantees global convergence for starting points far from the solution and a fast rate of convergence. The Jacobian is updated by the rank-1 method of Broyden. At the starting point the Jacobian is calculated, but it is not recalculated until the rank-1 method fails to produce satisfacory progress.

4. References

[1] POWELL, M.J.D.
A hybrid method for nonlinear algebraic equations. In 'Numerical methods for Nonlinear Algebraic Equations', Ed. Rabinowitz, P., Gordon and Breach, 1970.

[2] MORE, J.J., GARBOW, B.S. and HILLSTROM, K.E.
User Guide for MINPACK-1.
ANL-80-74, Argonne National Laboratory.

5. Parameters

FCN – SUBROUTINE, supplied by the user.

Depending upon the value of IFLAG, FCN must either calculate the values of the functions at X or calculate the Jacobian at X, returning these in FVEC and FJAC respectively.
Its specification is:–

```
      SUBROUTINE FCN(N,X,FVEC,FJAC,
     1   LDFJAC,IFLAG)
      INTEGER N,LDFJAC,IFLAG
      real X(N),FVEC(N),FJAC(LDFJAC,N)
```

N – INTEGER.

On entry, N contains the number of equations. The value of N must not be changed by FCN.

X – ***real*** array of DIMENSION (N).

On entry, X contains the point at which the functions or the Jacobian are to be evaluated. The values in X must not be changed by FCN.

FVEC – ***real*** array of DIMENSION (N).

On exit, unless IFLAG is reset to a negative number, or IFLAG = 2 on entry, FVEC(i) must contain the value of the i(th) function evaluated at X. FVEC must only be changed if IFLAG = 1 on entry.

FJAC – ***real*** array of DIMENSION (LDFJAC,N).

On exit, unless IFLAG is reset to a negative number, or IFLAG = 1 on entry, FJAC(i,j) must contain the value of $\frac{\partial F_i}{\partial X_j}$, i,j = 1,....N (where F_i is the i(th) function, and X_j the j(th) variable) evaluated at X. FJAC must only be changed if IFLAG = 2 on entry.

LDFJAC – INTEGER.

On entry, LDFJAC specifies the first dimension of FJAC. LDFJAC must not be changed by FCN.

IFLAG – INTEGER.

On entry, IFLAG is 1 if FVEC is to be updated and IFLAG is 2 if FJAC is to be updated.

In general, IFLAG should not be reset by FCN. If, however, the user wishes to terminate execution (perhaps because some illegal point X has been reached) then IFLAG should be set to a negative integer. This value will be returned through IFAIL.

FCN must be declared as EXTERNAL in the (sub)program from which C05PBF is called.

N – INTEGER.

On entry, N must specify the number of equations. N > 0.

Unchanged on exit.

X – *real* array of DIMENSION at least (N).

Before entry, X(j) must be set to a guess at the j(th) component of the solution (j = 1,2,...,N).

On exit, X contains the final estimate of the solution vector.

FVEC – *real* array of DIMENSION at least (N).

On exit, FVEC contains the function values at the final point, X.

FJAC – *real* array of DIMENSION (LDFJAC,p), where p ≥ N.

On exit, FJAC contains the orthogonal matrix Q produced by the QR factorisation of the final approximate Jacobian.

LDFJAC – INTEGER.

On entry, LDFJAC must specify the first dimension of FJAC as declared in the calling (sub)program. LDFJAC ≥ N.

Unchanged on exit.

XTOL – *real*.

On entry, XTOL must specify the accuracy in X to which the solution is required. XTOL ≥ 0.0. If XTOL is less than machine precision (see NAG FORTRAN Library routine X02AAF) then machine precision is used. See Section 10. The recommended value is the square root of machine precision.

Unchanged on exit.

WA – *real* array of DIMENSION at least (LWA).

Used as workspace.

LWA – INTEGER.

On entry, LWA must specify the dimension of the array WA. $LWA \geq \frac{1}{2}N \times (N+13)$.

Unchanged on exit.

IFAIL – INTEGER.

Before entry, IFAIL must be assigned a value. For users not familiar with this parameter (described in Chapter P01) the recommended value is 0.

Unless the routine detects an error (see next section), IFAIL contains 0 on exit.

6. Error Indicators and Warnings

Errors detected by the routine:–

IFAIL < 0

A negative value of IFAIL indicates an exit from C05PBF because the user has set IFLAG negative in FCN. The value of IFAIL will be the same as the user's setting of IFLAG.

IFAIL = 1

On entry, N ≤ 0, LDFJAC < N, XTOL < 0.0 or $LWA < \frac{1}{2}N \times (N+13)$.

IFAIL = 2

There have been 100 × (N+1) evaluations of the functions. Consider restarting the calculation from the final point held in X.

IFAIL = 3

No further improvement in the approximate solution X is possible; XTOL is too small.

IFAIL = 4

The iteration is not making good progress. This failure exit may indicate that the system does not have a zero. Otherwise, rerunning C05PBF from a different starting point may avoid the region of difficulty.

7. Auxiliary Routines

Details are distributed to sites in machine-readable form.

8. Timing

The time required by C05PBF to solve a given problem depends on N, the behaviour of the functions, the accuracy requested and the starting point. The number of arithmetic operations executed by C05PBF is about $11.5 \times N^2$ to process each evaluation of the functions and about $1.3 \times N^3$ to process each evaluation of the Jacobian. Unless FCN can be evaluated quickly, the timing of C05PBF will be strongly influenced by the time spent in FCN.

9. Storage

There are no internally declared arrays.

10. Accuracy

C05PBF tries to ensure that

$$||X-XSOL||_2 \leq XTOL \times ||XSOL||_2.$$

If this condition is satisfied with XTOL $= 10^{-k}$ then the larger components of X have k significant decimal digits. There is a danger that the smaller components of X may have large relative errors, but the fast rate of convergence of C05PBF usually avoids the possiblity.

The test assumes that the functions and Jacobian are coded consistently and that the functions are reasonably well behaved. If these conditions are not satisfied then C05PBF may incorrectly indicate convergence. The coding of the Jacobian can be checked using C05ZAF. If the Jacobian is coded correctly, then the validity of the answer can be checked by rerunning C05PBF with a tighter tolerance.

11. Further Comments

Ideally the problem should be scaled so that, at the solution, the function values are of comparable magnitude.

12. Keywords

Equations, nonlinear algebraic, user-supplied Jacobian, easy-to-use; Powell hybrid method, user-supplied Jacobian, easy-to-use.

---

13. Example

To determine the values $x_1,...,x_9$ which satisfy the tridiagonal equations:–

$$(3-2x_1)x_1 - 2x_2 = -1$$

$$-x_{i-1} + (3-2x_i)x_i - 2x_{i+1} = -1, \ i = 2,3,...,8.$$

$$-x_8 + (3-2x_9)x_9 = -1.$$

13.1. Program Text

```
C     C05PBF EXAMPLE PROGRAM TEXT
C     MARK 9 RELEASE. NAG COPYRIGHT 1981
C     .. LOCAL SCALARS ..
      REAL FNORM, TOL
      INTEGER IFAIL, J, NOUT
C     .. LOCAL ARRAYS ..
      REAL FJAC(9,9), FVEC(9), WA(99), X(9)
C     .. FUNCTION REFERENCES ..
      REAL F05ABF, SQRT, X02AAF
C     .. SUBROUTINE REFERENCES ..
C     C05PBF
C     ..
      EXTERNAL FCN
      DATA NOUT /6/
      WRITE (NOUT,99999)
C     THE FOLLOWING STARTING VALUES PROVIDE A ROUGH SOLUTION.
      DO 20 J=1,9
         X(J) = -1.E0
   20 CONTINUE
      TOL = SQRT(X02AAF(0.0))
      IFAIL = 0
      CALL C05PBF(FCN, 9, X, FVEC, FJAC, 9, TOL, WA, 99, IFAIL)
      FNORM = F05ABF(FVEC,9)
      WRITE (NOUT,99998) FNORM, IFAIL, (X(J),J=1,9)
      STOP
99999 FORMAT (4(1X/), 31H C05PBF EXAMPLE PROGRAM RESULTS/1X)
```

```
99998 FORMAT (5X, 31H FINAL L2 NORM OF  HE RESIDUALS, E12.4//5X,
     * 15H EXIT PARAMETER, I10//5X, 27H FINAL APPROXIMATE SOLUTION//
     * (5X, 3E12.4))
      END
      SUBROUTINE FCN(N, X, FVEC, FJAC, LDFJAC, IFLAG)
C     .. SCALAR ARGUMENTS ..
      INTEGER IFLAG, LDFJAC, N
C     .. ARRAY ARGUMENTS ..
      REAL FJAC(LDFJAC,N), FVEC(N), X(N)
C     ..
C     .. LOCAL SCALARS ..
      REAL FOUR, ONE, TEMP, TEMP1, TEMP2, THREE, TWO, ZERO
      INTEGER J, K
C     ..
      DATA ZERO, ONE, TWO, THREE, FOUR /0.E0,1.E0,2.E0,3.E0,4.E0/
      IF (IFLAG.EQ.2) GO TO 40
      DO 20 K=1,N
         TEMP = (THREE-TWO*X(K))*X(K)
         TEMP1 = ZERO
         IF (K.NE.1) TEMP1 = X(K-1)
         TEMP2 = ZERO
         IF (K.NE.N) TEMP2 = X(K+1)
         FVEC(K) = TEMP - TEMP1 - TWO*TEMP2 + ONE
   20 CONTINUE
      GO TO 100
   40 CONTINUE
      DO 80 K=1,N
         DO 60 J=1,N
            FJAC(K,J) = ZERO
   60    CONTINUE
         FJAC(K,K) = THREE - FOUR*X(K)
         IF (K.NE.1) FJAC(K,K-1) = -ONE
         IF (K.NE.N) FJAC(K,K+1) = -TWO
   80 CONTINUE
  100 CONTINUE
      RETURN
      END
```

13.2. Program Data

None.

13.3. Program Results

```
 C05PBF EXAMPLE PROGRAM RESULTS

      FINAL L2 NORM OF THE RESIDUALS  0.1193E-07

      EXIT PARAMETER          0

      FINAL APPROXIMATE SOLUTION

     -0.5707E+00 -0.6816E+00 -0.7017E+00
     -0.7042E+00 -0.7014E+00 -0.6919E+00
     -0.6658E+00 -0.5960E+00 -0.4164E+00
```

F04ATF – NAG FORTRAN Library Routine Document

NOTE: before using this routine, please read the appropriate implementation document to check the interpretation of ***bold italicised*** terms and other implementation–dependent details. The routine name may be precision–dependent.

1. Purpose

F04ATF calculates the accurate solution of a set of real linear equations with a single right hand side, Ax=b, by Crout's factorisation method.

2. Specification

```
      SUBROUTINE F04ATF (A, IA, B, N, C, AA, IAA, WKS1, WKS2,
     1   IFAIL)
C     INTEGER IA, N, IAA, IFAIL
C     real A(IA,N), B(N), C(N), AA(IAA,N), WKS1(N), WKS2(N)
```

3. Description

Given a set of linear equations, Ax = b, the routine first decomposes A using Crout's factorisation with partial pivoting PA = LU, where P is a permutation matrix, L is lower triangular and U is unit upper triangular. An approximation to x is found by forward and backward substitution in Ly = Pb and Ux = y. The residual vector r = b – Ax is then calculated and a correction, d, to x is found by the solution of LUd = r. x is replaced by (x+d) and the process repeated until full machine accuracy is obtained. ***Additional precision*** accumulation of innerproducts is used throughout the calculation.

4. References

[1] WILKINSON, J.H. and REINSCH, C.
Handbook for Automatic Computation.
Volume II, Linear Algebra.
Springer–Verlag, 1971, pp. 93–110.

5. Parameters

A – ***real*** array of DIMENSION (IA,p) where p ≥ N.

Before entry, A must contain the elements of the real matrix.

Unchanged on exit.

IA – INTEGER.

On entry, IA must specify the first dimension of array A as declared in the calling (sub)program.
IA ≥ N.

Unchanged on exit.

B – ***real*** array of DIMENSION at least (N).

Before entry, B must contain the elements of the right hand side. (See Section 11).

Unchanged on exit.

N – INTEGER.

On entry, N must specify the order of matrix A.

Unchanged on exit.

C – ***real*** array of DIMENSION at least (N).

On successful exit, C will contain the solution vector.

AA – ***real*** array of DIMENSION (IAA,q) where q ≥ N.

Used as working space.

On successful exit, AA will contain the LU decomposition.

IAA – INTEGER.

On entry, IAA must specify the first dimension of array AA as declared in the calling (sub)program.
IAA ≥ N.

Unchanged on exit.

WKS1 – ***real*** array of DIMENSION at least (N).

WKS2 – ***real*** array of DIMENSION at least (N).

Used as working space.

IFAIL – INTEGER.

On entry, IFAIL must be set to 0 or 1. For users not familiar with this parameter (described in Chapter P01) the recommended value is 0.

Unless the routine detects an error (see next section), IFAIL contains 0 on exit.

6. Error Indicators and Warnings

Errors detected by the routine:–

IFAIL = 1

The matrix A is singular, possibly due to rounding errors.

IFAIL = 2

The matrix A is too ill-conditioned to produce a correctly rounded solution.

7. Auxiliary Routines

Details are distributed to sites in machine-readable form.

8. Timing

The time taken is approximately proportional to N^3.

9. Storage

There are no internally declared arrays.

10. Accuracy

The computed solutions should be correct to full machine accuracy. For a detailed error analysis see [1], page 107.

11. Further Comments

The routine **must not** be called with the same name for parameters B and C.

12. Keywords

Accurate Solution of Linear Equations,
Crout Factorisation,
Real Matrix,
Single Right Hand Side.

13. Example

To solve the set of linear equations Ax = b where

$$A = \begin{pmatrix} 33 & 16 & 72 \\ -24 & -10 & -57 \\ -8 & -4 & -17 \end{pmatrix} \text{ and } b = \begin{pmatrix} -359 \\ 281 \\ 85 \end{pmatrix}$$

13.1. Program Text

WARNING: This **single precision** example program may require amendment for certain implementations. The results produced may not be the same. If in doubt, please seek further advice (see **Essential Introduction** to the Library Manual).

```
C     F04ATF EXAMPLE PROGRAM TEXT
C     NAG COPYRIGHT 1975
C     MARK 4.5 REVISED
C
      REAL A(5,5), B(5), C(5), AA(5,5), WKS1(18), WKS2(3)
      INTEGER NIN, NOUT, I, N, J, IA, IAA, IFAIL
      DATA NIN /5/, NOUT /6/
      READ (NIN,99999) (WKS1(I),I=1,7)
      WRITE (NOUT,99997) (WKS1(I),I=1,6)
      N = 3
      READ (NIN,99998) ((A(I,J),J=1,N),I=1,N), (B(I),I=1,N)
      IA = 5
      IAA = 5
      IFAIL = 1
      CALL F04ATF(A, IA, B, N, C, AA, IAA, WKS1, WKS2, IFAIL)
      IF (IFAIL.EQ.0) GO TO 20
      WRITE (NOUT,99996) IFAIL
      STOP
   20 WRITE (NOUT,99995) (C(I),I=1,N)
      STOP
99999 FORMAT (6A4, 1A3)
```

```
99998 FORMAT (3F5.0)
99997 FORMAT (4(1X/), 1H , 5A4, 1A3, 7HRESULTS/1X)
99996 FORMAT (25HOERROR IN F04ATF IFAIL = , I2)
99995 FORMAT (10HOSOLUTIONS/(1H , F4.1))
      END
```

13.2. Program Data

```
F04ATF EXAMPLE PROGRAM DATA
   33   16   72
  -24  -10  -57
   -8   -4  -17
 -359  281   85
```

13.3. Program Results

```
 F04ATF EXAMPLE PROGRAM RESULTS

 SOLUTIONS
  1.0
 -2.0
 -5.0
```

F03AAF – NAG FORTRAN Library Routine Document

NOTE: before using this routine, please read the appropriate implementation document to check the interpretation of ***bold italicised*** terms and other implementation–dependent details. The routine name may be precision–dependent.

1. Purpose

F03AAF calculates the determinant of a real matrix using the factorisation method of Crout.

2. Specification

```
      SUBROUTINE F03AAF (A,IA,N,DET,WKSPCE,IFAIL)
C     INTEGER IA,N,IFAIL
C     real A(IA,N),DET,WKSPCE(N)
```

3. Description

The routine calculates the determinant of A using the Crout factorisation with partial pivoting, PA = LU, where P is a permutation matrix, L is lower triangular and U is unit upper triangular. The determinant of A is the product of the diagonal elements of L with the correct sign determined by the row interchanges. ***Additional precision*** accumulation of inner-products is used throughout.

4. References

[1] WILKINSON, J.H. and REINSCH, C.
Handbook for Automatic Computation, Volume II, Linear Algebra, pp. 93–110.
Springer–Verlag, 1971.

5. Parameters

A – ***real*** array of DIMENSION (IA,p), where p ≥ N.

Before entry, A must contain the elements of the real matrix.

On exit, it will contain the Crout factorisation, with the unit diagonal of U understood, unless an error has occurred.

IA – INTEGER.

On entry, IA must specify the first dimension of array A as declared in the calling (sub)program.

IA ≥ N

Unchanged on exit.

N – INTEGER.

On entry, N must specify the order of the matrix.

Unchanged on exit.

DET – ***real***.

On exit, DET will contain the value of the determinant, unless an error has occurred (See Section 6).

WKSPCE – ***real*** array of DIMENSION at least (N).

Used as working space.

IFAIL – INTEGER.

Before entry, IFAIL must be set to 0 or 1. Users who are unfamiliar with this parameter should refer to Chapter P01 for details. Unless the routine detects an error or gives a warning (see Section 6), IFAIL contains 0 on exit.

For this routine, because the values of output parameters may be useful even if IFAIL ≠ 0 on exit, users are recommended to set IFAIL to 1 before entry. **It is then essential to test the value of IFAIL on exit.**

6. Error Indicators and Warnings

Errors detected by the routine:–

IFAIL = 1

The matrix A is singular, possibly due to rounding errors. DET is set to 0.0.

IFAIL = 2

Overflow. The value of the determinant is too large to be held in the computer.

IFAIL = 3

Underflow. The value of the determinant is too small to be held in the computer.

7. Auxiliary Routines

Details are distributed to sites in machine-readable form.

8. Timing

The time taken is approximately proportional to N^3.

9. Storage

There are no internally declared arrays.

10. Accuracy

The accuracy of the determinant depends on the conditioning of the original matrix. For a detailed error analysis see [1], p. 107.

11. Further Comments

None.

12. Keywords

Crout Factorisation,
Determinant,
Real Matrix.

13. Example

To calculate the determinant of the real matrix:

$$\begin{pmatrix} 33 & 16 & 72 \\ -24 & -10 & -57 \\ -8 & -4 & -17 \end{pmatrix}$$

13.1. Program Text

WARNING: This **single precision** example program may require amendment for certain implementations. The results produced may not be the same. If in doubt, please seek further advice (see **Essential Introduction** to the Library Manual).

```
C     F03AAF EXAMPLE PROGRAM TEXT
C     NAG COPYRIGHT 1975
C     MARK 4.5 REVISED
C
      REAL DETERM, A(4,4), WKSPCE(18)
      INTEGER NIN, NOUT, I, N, J, IA, IFAIL
      DATA NIN /5/, NOUT /6/
      READ (NIN,99999) (WKSPCE(I),I=1,7)
      WRITE (NOUT,99997) (WKSPCE(I),I=1,6)
      N = 3
      READ (NIN,99998) ((A(I,J),J=1,N),I=1,N)
      IA = 4
      IFAIL = 1
      CALL F03AAF(A, IA, N, DETERM, WKSPCE, IFAIL)
      IF (IFAIL.EQ.0) GO TO 20
      WRITE (NOUT,99996) IFAIL
      STOP
   20 WRITE (NOUT,99995) DETERM
      STOP
99999 FORMAT (6A4, 1A3)
99998 FORMAT (3F5.0)
99997 FORMAT (4(1X/), 1H , 5A4, 1A3, 7HRESULTS/1X)
99996 FORMAT (25H0ERROR IN F03AAF IFAIL = , I2)
99995 FORMAT (24H0VALUE OF DETERMINANT = , F4.1)
      END
```

13.2. Program Data

```
F03AAF EXAMPLE PROGRAM DATA
   33   16   72
  -24  -10  -57
   -8   -4  -17
```

13.3. Program Results

```
 F03AAF EXAMPLE PROGRAM RESULTS


 VALUE OF DETERMINANT =  6.0
```

Chapter XI

Listing of Program RCNATOUT FORTRAN

```
C RCNATOUT
C PROGRAM TO EVALUATE TRANSCENDENTAL EQUATION FOR A RANGE OF
C FREQUENCIES IN ORDER TO DETERMINE APPROXIMATE VALUES OF THE NATURAL
C FREQUENCIES OF COMPLIANT RISERS FOR OUT OF PLANE DYNAMICS WITH A 2-D
C STATIC CONFIGURATION.
C THIS PROGRAM CAN BE USED TO DETERMINE APPROXIMATE ESTIMATES OF NATURAL
C FREQUENCIES TO USE AS INPUT IN THE OUT OF PLANE DYNAMICS PROGRAM,
C WHICH IMPROVES THESE INITIAL ESTIMATES.
C DOUBLE PRECISION AND THE NAG FORTRAN LIBRARY ARE USED THROUGHOUT.
C***********************************************************************
C COPYRIGHT, 1985, MASSACHUSETTS INSTITUTE OF TECHNOLOGY
C ALL RIGHTS RESERVED.
C***********************************************************************
C PROGRAMMER GEORGE A. KRIEZIS     JUNE 3, 1985    M.I.T.
C***********************************************************************
C
C DEFINITION OF DEVICES:
C DEVICE 5  : INPUT FROM TERMINAL
C DEVICE 6  : OUTPUT TO TERMINAL
C DEVICE 8  : INPUT FROM FILE PREPARED BY RCINPUT  (LRECL=80)
C DEVICE 10 : INPUT FROM FILE CONTAINING APPROXIMATE N-D STATIC
C             SOLUTION CREATED BY RCSTAT2D (LRECL=132)
C DEVICE 11 : OUTPUT TO FILE  (LRECL=80)
C
C DEFINITIONS OF PARAMETERS
C MNP = MAXIMUM NUMBER OF FREQUENCIES TO EVALUATE FUNCTION.
C
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=300)
      CHARACTER*80 NAME
      COMMON/INPUT0/NAME
      DIMENSION FREQ(MNP),FVALUE(MNP),RANG1(MNP),RANG2(MNP)
C
C     READ2D READS 2-D STATIC COMPLIANT RISER
C     SOLUTION CALCULATED FROM RCSTAT2D PROGRAM AND EVALUATES
C     THE MAXIMUM NONDIMENSIONAL STATIC EFFECTIVE TENSION (TOMAX)
C
      CALL READ2D(TOMAX,VM,ICCC)
      IF(ICCC.EQ.0) STOP
C
C     CHARAC READS RISER CHARACTERISTICS FROM UNIT 8 AND EVALUATES THE
C     NONDIMENSIONAL COEFFICIENTS TO BE USED FOR THE ESTIMATION OF
C     THE NATURAL FREQUENCIES.
C
      CALL CHARAC(TOMAX,TMAXAV,TLENG)
C
C
C
1499  WRITE(6,1500) MNP
1500  FORMAT(/' INPUT'/' THE MAXIMUM FREQUENCY AND FREQUENCY SPACING (IN
     * RAD/S)'/' FOR WHICH YOU WISH TO EVALUATE THE FREQUENCY FUNCTION'/
     *' MAXIMUM PERMISSIBLE NUMBER OF FREQUENCY POINTS IS = ',I3)
      READ(5,*) FREQH,DF
      DIV = FREQH/DF
      XP = FLOAT(MNP-1)
      IF(DIV.GT.XP) GOTO 1499
```

```
C
C     APPROX : EVALUATES THE TRANSCENDENTAL EQUATION FOR ALL FREQUENCIES
C     IN THE RANGE REQUESTED.
C
      CALL APPROX(FREQ,FVALUE,TLENG,TMAXAV,TOMAX,FREQH,DF,NDIV)
C
C     DETERMINE THE APPROXIMATE VALUES OF EACH NATURAL FREQUENCY IN THE
C     SPECIFIED RANGE. THE EQUATION CHANGES SIGN AT EACH NATURAL
C     FREQUENCY.
C
      K = 0
      DO 452 I=1,NDIV-1
       CHECK = FVALUE(I)*FVALUE(I+1)
       IF (CHECK.LT.0.D0) THEN
        K = K + 1
        RANG1(K) = FREQ(I)
        RANG2(K) = FREQ(I+1)
       END IF
 452  CONTINUE
C
C     OUTPUT THE RESULTS
C
      WRITE(11,8866) NAME
 8866 FORMAT(80A)
      WRITE(11,66)
  66  FORMAT(/' ESTIMATES OF OUT-OF PLANE NATURAL FREQUENCIES FOR A 2-D
     *STATIC CONFIGURATION'/)
      WRITE(11,85)K
  85  FORMAT(' NUMBER OF NATURAL FREQUENCIES IN SPECIFIED RANGE: ',I3)

      DO 76 I=1,K
       WRITE(11,86) I,RANG1(I),RANG2(I)
  76  CONTINUE
  86  FORMAT(' MODE = ',I3/' NATURAL FREQUENCY BETWEEN'/1X,D12.6,' AND '
     *,D12.6,' RAD/SEC'/' ******************************************')
      WRITE(11,24)
   24 FORMAT(/' FREQUENCY (RAD/SEC)',2X,'EQUATION VALUE')
      DO 89 I=1,NDIV
        WRITE(11,25)FREQ(I),FVALUE(I)
   89 CONTINUE
   25 FORMAT(5X,D12.6,4X,D12.6)
      STOP
      END

      SUBROUTINE CHARAC(TOMAX,TMAXAV,TLENG)
C     SUBROUTINE CHARAC READS THE COMPLIANT RISER CHARACTERISTICS FROM
C     DEVICE 8 AND EVALUATES ALL THE NONDIMENSIONAL COEFFICIENTS USED
C     IN THE EVALUATION OF THE TRANSCENDENTAL EQUATION AND THE
C     NONDIMENSIONALIZED FREQUENCIES.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      CHARACTER*80 NAME
      COMMON/INPUT0/NAME
      COMMON/COEF/EPSXI(2),HETAM
      DIMENSION EIXI(MNP),RLENG(MNP),AMAETA(MNP),TMAETA(MNP)
      DIMENSION RMASS(MNP),AMAXI(MNP),TMAXI(MNP)
```

```
C
      READ (8,1000) NAME
1000  FORMAT(80A)
      READ (8,1008) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
1008  FORMAT(1X,I3,2(1X,D12.6)/4(1X,D12.6))
      TLENG = TLEN
      DO 1502 I=1,NSEG
      READ (8,1003) RLENG(I),RMASS(I),RMASST,AMAXI(I),WEIGHT,DXI,
     *PXIETA,EA,EIETA,AO,EIETAS
1502  CONTINUE
1003  FORMAT(5(1X,D12.6)/6(1X,D12.6))
C
      DO 1332 I=1,NSEG
      READ(8,1333) AMAETA(I),DETA,EIXI(I),EIXIS,GIP,GIPS,AMAZI,XJ,ZI
1332  CONTINUE
1333  FORMAT(6(1X,D12.6)/3(1X,D12.6))
C
C
C     NON - DIMENSIONALIZATIONS
C
      GRAV=9.81D0
      WAM=WA/GRAV
      WT=WA*TLEN
      TOMAX = TOMAX*WT
C
C     NONDIMENSIONAL COEFFICIENTS USED IN THE EQUATIONS
C
      TOMAXL = TOMAX/TLEN
      TOML1  = TOMAX*TLEN
      TOML2  = TOML1*TLEN
      TLEN2  = TLEN**2
      TMAXAV = 0.D0
      DO 2000 I=1,NSEG
       RLENG(I)=RLENG(I)/TLEN
       TMAXI(I) = RMASS(I) + AMAXI(I)
       TMAETA(I) = RMASS(I) + AMAETA(I)
       TMAXAV = TMAXI(I)*RLENG(I) + TMAXAV
2000  CONTINUE
C
      EPSXI(1) = EIXI(1)/TOML2
      EPSXI(2) = EIXI(NSEG)/TOML2
C
      HETAM = 0.D0
      DO 4321 I=1,NSEG
       HETA = TMAETA(I)/TMAXAV
       HETAM = HETAM + HETA*RLENG(I)
4321  CONTINUE
      RETURN
      END
C
      SUBROUTINE READ2D(TOMAX,VM,ICCC)
C     THIS SUBROUTINE READS THE STATIC COMPLIANT RISER SOLUTION FROM
C     DEVICE 10. IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC TENSION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      DIMENSION STATIC(MNP),XI(MNP)
```

```
C
C     STATIC(I) = STATIC EFFECTIVE TENSION TO
C
      WRITE(6,2000) MNP
2000  FORMAT(' MNP=',I3)
C
      ICCC = 1
      READ(10,36459) NP,VM
36459 FORMAT(1X,I3,1X,D12.6)
      WRITE(6,2311) NP,VM
2311  FORMAT(' 2-D STATIC SOLUTION FROM DEVICE 10'/
     *' NP =',I3/
     *' MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =',D12.6)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
      IF (VM.EQ.0.D0) THEN
       WRITE(6,124)
  124  FORMAT(' PROGRAM IS NOT VALID FOR ZERO MEAN CURRENT SPEED'/
     * ' RUN STOPS')
       ICCC = 0
       RETURN
      END IF
C
C     READING FROM DEVICE 10
C
      DO 1021 I=1,NP
      READ(10,1033) X,STATIC(I),STATI2,STATI3,STAT4,XCOOR,YCOOR,
     *STRARC,TENSI,VLOCXI
      XI(I) = X
1021  CONTINUE
1033  FORMAT(10(1X,D12.6))
C     EVALUATE MAXIMUM STATIC EFFECTIVE TENSION
      TOMAX=DMAX1(STATIC(1),STATIC(2))
      DO 9859 I=3,NP
        TOMAX = DMAX1(TOMAX,STATIC(I))
9859  CONTINUE
C
      WRITE(6,1654) TOMAX
1654  FORMAT(' 2-D STATIC SOLUTION SUCCESFULLY READ'/' MAXIMUM STATIC EF
     *FECTIVE TENSION/WA*L = ',D10.4)
C
      RETURN
      END
C
      SUBROUTINE APPROX(FREQ,FVALUE,TLENG,TMAXAV,TOMAX,FREQH,DF,NDIV)
C     THIS SUBROUTINE EVALUATES THE TRANSCENDENTAL EQUATION AT ALL THE
C     SPECIFIED FREQUENCY POINTS IN ORDER TO LOCATE REGIONS OF CHANGING
C     SIGN.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=300)
```

```
      COMMON/COEF/EPSXI(2),HETAM
      DIMENSION FVALUE(MNP),FREQ(MNP)
C     EVALUATE NU. IT IS EXACT IF THE STRAIN RELIEF UNITS ARE THE SAME
C     AT THE TWO ENDS OF THE RISER.
      XNU = DSQRT((EPSXI(1)+EPSXI(2))/2.D0)
      WRITE(6,581) XNU
  581 FORMAT(' THE VALUE OF NU TO BE USED IS = ',D10.4/' IF YOU WANT TO
     *CHANGE NU INPUT 1')
      READ(5,*) INU
      IF (INU.EQ.1) THEN
       WRITE(6,*) ' INPUT NU'
       READ(5,*) XNU
      END IF
C
C     EVALUATE THE TRANSCENDENTAL EQUATION FOR EACH FREQUENCY.
C     EVALUATE NUMBER OF INCREMENTS.
      NDIV = NINT(FREQH/DF)+ 1
C     INITIAL FREQUENCY FOR EVALUATION IS 0.01 RAD/SEC
      SIGMA = 0.01D0*TLENG*DSQRT(TMAXAV*HETAM/TOMAX)
      DS = DF*TLENG*DSQRT(TMAXAV*HETAM/TOMAX)
      DO 765 L=1,NDIV
      FREQ(L) = .01 + (L-1)*DF
C     EVALUATE TRANSCENDENTAL EQUATION
C
      FV = (1.D0-SIGMA**2*XNU**2)*DSIN(SIGMA)-2.D0*SIGMA*XNU*DCOS(SIGMA)
      SIGMA = SIGMA + DS
      FVALUE(L) = FV
  765 CONTINUE
      RETURN
      END
```

Chapter XII

Listing of Program RCLINDYN FORTRAN A

```
C RCLINDYN
C THIS PROGRAM CALCULATES THE OUT OF PLANE LINEAR DYNAMIC RESPONSE OF A
C COMPLIANT RISER WITH A 2-D STATIC CONFIGURATION BASED ON AN EMBEDDING
C TECHNIQUE. THE PROGRAM PROVIDES AN INITIAL ANALYTIC APPROXIMATION
C WHICH IT SUBSEQUENTLY IMPROVES USING MODIFIED NEWTON'S ITERATION AND
C A NON-UNIFORM GRID FINITE DIFFERENCE METHOD.
C DOUBLE PRECISION AND THE NAG FORTRAN LIBRARY ARE USED.
C***********************************************************************
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C***********************************************************************
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C***********************************************************************
C
C DEFINITION OF DEVICES:
C DEVICE 5  : INPUT FROM TERMINAL
C DEVICE 6  : OUTPUT TO TERMINAL
C DEVICE 8  : INPUT FROM FILE PREPARED BY RCINPUT  (LRECL=80)
C DEVICE 9  : COMPLETE OUTPUT TO FILE  (LRECL=132)
C DEVICE 10 : INPUT FROM FILE CONTAINING N-D 2-D STATIC
C             SOLUTION CREATED BY RCSTAT2D  (LRECL=132)
C DEVICE 11 : OUTPUT TO FILE FOR PLOTS OR INPUT TO A NEW RUN
C             OF RCLINDYN  (LRECL=117)
C DEVICE 12 : INPUT FROM FILE CONTAINING APPROXIMATE N-D SOLUTION
C             CREATED BY A PREVIOUS RUN OF RCLINDYN  (LRECL=117)
C
C COMMON BLOCK CONTENTS (OVERALL REFERENCE):
C SOLUT  = INITIAL APPROXIMATION AND SOLUTION MATRICES
C STAT   = STATIC COMPLIANT RISER SOLUTION. (EFFECTIVE TENSION, SHEAR
C          FORCE, OMEGA ETA, PHIO, MAXIMUM STATIC EFFECTIVE TENSION,
C          MEAN CURRENT VELOCITY AND NUMBER OF STATIC DIVISION POINTS)
C STAT1  = FUNCTIONS OF STATIC RESULTS.
C INPUT0 = OUTPUT FILE HEADING
C INPUT1 = RISER LENGTH, AVERAGE AND TOTAL WEIGHT AND NUMBER OF SEGMENTS
C INPUT2 = RISER TUBE INTERIOR CHARACTERISTICS
C INPUTL = RISER SEGMENTS LENGTH
C INPUT3 = WEIGHT, STIFFNESSES AND STIFNESS DERIVATIVES.
C INPUT4 = CHARACTERISTIC DIAMETERS AND PERIMETER OF RISER TUBE.
C INPUT5 = MASS AND ADDED MASS CHARACTERISTICS IN THREE DIRECTIONS
C INPUT6 = RISER POLAR AND ADDED POLAR MOMENT OF INERTIA.
C COEF   = NONDIMENSIONAL RISER CHARACTERISTICS USED IN THE EQUATIONS
C COEF1  = NONDIMENSIONAL RISER CHARACTERISTICS AT A SPECIFIC POINT
C CONST  = PROBLEM CONSTANTS (PI,GRAVITY,WATER DENSITY)
C BOUNDA = BOUNDARY CONDITION FOR OMEGA XI AT S=0
C COUN   = INTEGER COUNTING VARIABLE TO DETERMINE EACH DIVISION POINT
C DEF    = NU USED TO DETERMINE THE APPROXIMATE NATURAL FREQUENCY,
C          NU = 1/SQRT(EPSETA)
C
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4,IY=7)
      PARAMETER(LWORK=MNP*(3*N**2+6*N+2)+4*N**2+3*N)
      PARAMETER(LIWORK=MNP*(2*N+1)+N)
      DIMENSION WORK(LWORK),IWORK(LIWORK)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COUN/ICOUNT
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C     EXTERNAL SUBROUTINES USED BY NAG LIBRARY
      EXTERNAL FCN,G,JACEPS,JACGEP,JACOBF,JACOBG
      DATA NOUT /6/
C
C     READ2D READS 2-D STATIC SOLUTION CALCULATED FROM RCSTAT2D PROGRAM.
C     IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC TENSION (TOMAX)
C
      CALL READ2D(NPI)
C
C     CHARAC READS RISER CHARACTERISTICS FROM UNIT 8 AND EVALUATES THE
C     NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE EQUATIONS.
C
      CALL CHARAC(TLENG,IC,NPI)
      IF(IC.EQ.0) STOP
C
C     DEFINITIONS OF PARAMETERS  ...
C     N  = NUMBER OF EQUATIONS TO BE SOLVED BY D02RAF
C     IY = NUMBER OF VARIABLES
C     MNP= MAXIMUM NUMBER OF PERMITTED POINTS IN THE NON-UNIFORM
C     F.D. MESH ( MNP >= 32)
      IF(MNP.LT.32) THEN
      WRITE(6,1257) MNP
1257  FORMAT(' MNP = ',I3,' IS NOT PERMISSIBLE')
      STOP
      ENDIF
C     NUMBER OF BOUNDARY CONDITIONS AT S=0
1276  NUMBEG=4
C     NUMBER OF MIXED BOUNDARY CONDITIONS
      NUMMIX=0
C     PARAMETER DECLARING THAT INITIAL APPROXIMATION IS USER SPECIFIED
      INIT=1
C     PARAMETER DECLARING THAT JACOBIANS ARE USER SPECIFIED
      IJAC=1
C     PARAMETER CONTROLLING MONITORING OF CALCULATIONS
      IFAIL=111
C
C
1499  WRITE(6,1500)
1500  FORMAT(' INPUT 1 IF YOU WISH TO READ INITIAL APPROXIMATION,'/
     *'         CREATED BY A PREVIOUS RUN OF THIS PROGRAM'/
     *' ELSE INPUT 0 (AN INITIAL APPROXIMATION WILL BE CALCULATED LOCALL
     *Y)')
      READ(5,*) IEXIST
      IF((IEXIST.NE.1).AND.(IEXIST.NE.0)) GOTO 1499
      IF(IEXIST.EQ.1) THEN
C
C       READAS : READS APPROXIMATE SOLUTION FROM DEVICE 10 FROM A
C                PREVIOUS RUN OF RCLINDYN (DELEPS = 1.D0)
C                IT ALSO PROVIDES ICCC,NP, TOL= TOLERANCE OF ITERATIONS
C       THIS ALTERNATIVE MAY, FOR EXAMPLE, BE USED IF GREATER ACCURACY
C       IS REQUIRED FOR THE PROBLEM SOLUTION.
C
        CALL READAS(ICCC,NP,TOL)
C
C       IF THE NUMBER OF POINTS FROM THIS SOLUTION IS GREATER THAN THE
C       STATIC SOLUTION POINTS, INTERPOLATE ALL CHARACTERISTICS TO THE
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C       NEW NUMBER OF POINTS.
C       ASSUMPTION : NP ALWAYS GREATER OR EQUAL TO NPI
C       THIS IS VALID IF THE SAME STATIC SOLUTION WAS USED TO OBTAIN
C       THE APPROXIMATE SOLUTION IN DEVICE 10.
C
        IF (NP.GT.NPI) THEN
         CALL INTERP(NP)
         NPI=NP
        ELSE IF (NP.LT.NPI) THEN
         WRITE(6,314)
 314     FORMAT(' APPROXIMATE SOLUTION IN DEVICE 10 WAS NOT OBTAINED'/
     *   ' FROM THE SAME STATIC SOLUTION, PROGRAM STOPS')
         STOP
        END IF
        DELEPS = 1.D0
C
      ELSE
C
C     APPROX : PROVIDES INITIAL APPROXIMATE SOLUTION FOR EPS=0.
C              IT ALSO PROVIDES ICCC,NP, TOL.
C
      CALL APPROX(TLENG,ICCC,NPI,TOL)
      NP = NPI
C
C     INCREMENT OF CONTINUATION PARAMETER
 7891 WRITE(6,7890)
 7890 FORMAT(' INPUT INITIAL INCREMENT OF CONTINUATION PARAMETER DELEPS'
     */' IF NO CONTINUATION IS REQUIRED INPUT DELEPS = 1.D0'/
     *' IF CONTINUATION IS REQUIRED THEN 0.D0 < DELEPS < 1.D0'/
     *' RECOMMENDATION :'/
     *' USUALLY DELEPS = 0.1D0 WILL SUFFICE'/
     *' FOR LARGE CHANGES BETWEEN INITIAL AND FINAL PROBLEM'/
     *' A SMALLER VALUE OF DELEPS, E.G. 0.05D0 OR 0.025D0 MIGHT BE'/
     *' NECESSARY')
      READ(5,*) DELEPS
      IF((DELEPS.GT.1.D0).OR.(DELEPS.LE.0.D0)) THEN
        WRITE(6,7892)
7892    FORMAT(' 0. <  DELEPS  <= 1.')
        GOTO 7891
      ENDIF
C
      ENDIF
C     SET COUNTING VARIABLE
      ICOUNT = 1
      IF(ICCC.EQ.0) STOP
C
      CALL X04AAF(1,NOUT)
      CALL X04ABF(1,NOUT)
C
C     CALL NAG SUBROUTINE D02RAF TO SOLVE THE TWO-POINT BOUNDARY VALUE
C     PROBLEM USING A DEFERRED CORRECTION TECHNIQUE AND NEWTON'S
C     ITERATION.
C
      CALL D02RAF(N,MNP,NP,NUMBEG,NUMMIX,TOL,INIT,X,Y,IY,ABT,FCN,G,IJAC,
     *JACOBF,JACOBG,DELEPS,JACEPS,JACGEP,WORK,LWORK,IWORK,LIWORK,IFAIL)
C
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      WRITE(6,9000) IFAIL
 9000 FORMAT(' IFAIL =',I3)
C
C     OUTPUT THE RESULTS
C
      IF((IFAIL.EQ.0).OR.(IFAIL.EQ.4)) THEN
        CALL OUTPUT(NP)
      ENDIF
C
      STOP
      END

      SUBROUTINE CHARAC(TLENG,IC,NP)
C     THIS SUBROUTINE READS THE COMPLIANT RISER CHARACTERISTICS AND
C     EVALUATES THE NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE
C     GOVERNING EQUATIONS.,
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      CHARACTER*80 NAME
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/INPUT0/NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUT2/RHOO,AI,CFLUID,PRESS,AO(MNP)
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/INPUT3/WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP)
     *,EIXIS(MNP),GIP(MNP),GIPS(MNP)
      COMMON/INPUT4/DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP)
      COMMON/INPUT5/RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(
     *MNP),TMAXI(MNP),TMAETA(MNP)
      COMMON/INPUT6/XJZI(MNP),AJZI(MNP),TJZI(MNP)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/STAT1/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION TENO(MNP),QXO(MNP),TOS(MNP),QXIOS(MNP)
C
C     READ RISER CHARACTERISTICS FROM DEVICE 8
      READ (8,1000) NAME
 1000 FORMAT(80A)
      READ (8,1008) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
 1008 FORMAT(1X,I3,2(1X,D12.6)/4(1X,D12.6))
      TLENG = TLEN
      DO 1502 I=1,NSEG
      READ (8,1003) RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI(I
     *),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
 1502 CONTINUE
 1003 FORMAT(5(1X,D12.6)/6(1X,D12.6))
C
      DO 1332 I=1,NSEG
      READ(8,1333) AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),AMA
     *ZI(I),XJZI(I),AJZI(I)
 1332 CONTINUE
 1333 FORMAT(6(1X,D12.6)/3(1X,D12.6))
C
      IC=1
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C
7650  WRITE(6,7651)
7651  FORMAT(' DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS'/
     *' IF YES INPUT 1 , IF NO INPUT 0')
      READ(5,*) IPRINT
      IF((IPRINT.NE.1).AND.(IPRINT.NE.0)) GOTO 7650
      IF(IPRINT.EQ.1) THEN
C
      WRITE(6,1000) NAME
      WRITE(6,2500)
2500  FORMAT(' NSEG   TLEN            WA            RHOO          AI
     * CFLUID        PRESS')
      WRITE(6,2001) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
2001  FORMAT(1X,I3,6(1X,D12.6))
      WRITE(6,3400)
3400  FORMAT('    I    RLENG         RMASS         RMASST        AMAXI
     *  WEIGHT'   /'         DXI          PXIETA           EA          EIETA
     *           AO        EIETAS')
      DO 3002 I=1,NSEG
      WRITE(6,3003) I,RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI
     *(I),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
3002  CONTINUE
3003  FORMAT(1X,I3,5(1X,D12.6)/4X,6(1X,D12.6))
C
      WRITE(6,1334)
1334  FORMAT('    I   AMAETA          DETA          EIXI          EIXIS
     *    GIP          GIPS'/'         AMAZI          JZI           AJZI' )
      DO 1335 I=1,NSEG
      WRITE(6,1336) I,AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),
     *AMAZI(I),XJZI(I),AJZI(I)
1335  CONTINUE
1336  FORMAT(1X,I3,6(1X,D12.6)/4X,3(1X,D12.6))
C
1701  WRITE(6,1700)
1700  FORMAT(' INPUT 1 IF RISER DATA ARE CORRECT'/' INPUT 0 TO STOP')
      READ(5,*) IC
      IF((IC.NE.0).AND.(IC.NE.1)) GOTO 1701
      IF(IC.EQ.0) RETURN
C
      ENDIF
C
C     NON - DIMENSIONALIZATIONS
C
      GRAV=9.81D0
      WAM=WA/GRAV
      WT=WA*TLEN
      XPI=4.D0*DATAN(1.D0)
      XPI2=XPI/2.D0
      RHOW=1.025D3
C
C     NONDIMENSIONALIZE CORRECTLY QXIO, TO  FROM 2-D STATIC SOLUTION
C
      TOMAX = TOMAX*WT
      TND = WT/TOMAX
      DO 229 I=1,NP
        STATIC(1,I) = STATIC(1,I)*TND
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        STATIC(2,I) = STATIC(2,I)*TND
  229  CONTINUE
C
C      NONDIMENSIONAL COEFFICIENTS USED IN THE EQUATIONS
C
       TOMAXL = TOMAX/TLEN
       TOML1  = TOMAX*TLEN
       TOML2  = TOML1*TLEN
       TLEN2  = TLEN**2
       TMAXAV = 0.D0
       DO 2000 I=1,NSEG
        RLENG(I)=RLENG(I)/TLEN
        WEIGHT(I)=WEIGHT(I)/TOMAXL
        EPSXI(I) = EIXI(I)/TOML2
        EPSXIS(I) = EIXIS(I)/TOML1
        EPSETA(I) = EIETA(I)/TOML2
        EPSETS(I) = EIETAS(I)/TOML1
        EPSPI(I) = GIP(I)/TOML2
        EPSPIS(I) = GIPS(I)/TOML1
        TMAETA(I) = RMASS(I) + AMAETA(I)
        TMAXI(I) = RMASS(I) + AMAXI(I)
        TMAXAV = TMAXI(I)*RLENG(I) + TMAXAV
        TJZI(I) = XJZI(I) + AJZI(I)
        DXIETA(I) = DXI(I)-DETA(I)
 2000  CONTINUE
       HETAM = 0.D0
       DO 4321 I=1,NSEG
        HETA(I) = TMAETA(I)/TMAXAV
        HETAM = HETAM + HETA(I)*RLENG(I)
        TLAMB2(I) = TLEN2*TMAXAV/TJZI(I)
 4321 CONTINUE
C
C      EVALUATE FUNCTIONS OF STATIC RESULTS
       DO 521 I=1,NP
        TENO(I) = STATIC(1,I)
        QXO(I) = STATIC(2,I)
  521 CONTINUE
C      EVALUATE DERIVATIVES OF STATIC QUANTITIES
       CALL DER1(TENO,XI,TOS,NP)
       CALL DER1(QXO,XI,QXIOS,NP)
       DO 56 I=1,NP
         CONST1(I) = TOS(I) - STATIC(2,I)*STATIC(3,I)
         CONST2(I) = QXIOS(I) + STATIC(1,I)*STATIC(3,I)
   56 CONTINUE
C      SEG(I)=LEFT ORDINATE OF SEGMENT I
       SEG(1)=0.D0
       SEG(NSEG+1)=1.D0
       DO 4000 I=2,NSEG
       SEG(I)=RLENG(I-1)+SEG(I-1)
 4000  CONTINUE
C      INTRERPOLATE STRUCTURAL DIMENSIONS TO NP POINTS
C      ASSUMPTION: NUMBER OF RISER SEGMENTS WITH DIFFERENT
C      CHARACTERISTICS IS SMALLER THAN THE STATIC SOLUTION POINTS
C      NSEG < NPI
C
       IF (NSEG.GE.NPI) THEN
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        WRITE(6,188)
 188    FORMAT(' NSEG => NPI,   PROGRAM STOPS')
        IC = 0
        RETURN
      END IF
      CALL STRUCT(EPSXI,X,NP)
      CALL STRUCT(EPSXIS,X,NP)
      CALL STRUCT(EPSETA,X,NP)
      CALL STRUCT(EPSETS,X,NP)
      CALL STRUCT(EPSPI,X,NP)
      CALL STRUCT(EPSPIS,X,NP)
      CALL STRUCT(HETA,X,NP)
      CALL STRUCT(TLAMB2,X,NP)
      RETURN
      END
C
      SUBROUTINE DER1(ARRAY,X,DERIV,NP)
C     THIS SUBROUTINE EVALUATES THE FIRST DERIVATIVE OF A SERIES OF DATA
C     POINTS USING A SECOND ORDER APPROXIMATION (NONUNIFORM GRID FINITE
C     DIFFERENCES)
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (MNP=151)
      DIMENSION ARRAY(MNP),DERIV(MNP),X(MNP)
C     END POINTS DERIVATIVE FIRST ORDER
      DERIV(1) = (-ARRAY(1) + ARRAY(2))/(X(2)-X(1))
      DERIV(NP) = (-ARRAY(NP-1) + ARRAY(NP))/(X(NP)-X(NP-1))
C
      DO 836 I=2,NP-1
       DX = X(I) - X(I-1)
       DX1 = X(I+1) - X(I)
       D = DX/DX1
       DERIV(I) = (D*(ARRAY(I+1)-ARRAY(I)) - (ARRAY(I-1)-ARRAY(I))/D)
       DERIV(I) = DERIV(I)/(DX + DX1)
  836 CONTINUE
      RETURN
      END
C
      SUBROUTINE READ2D(NP)
C     THIS SUBROUTINE READS THE STATIC COMPLIANT RISER SOLUTION FROM
C     DEVICE 10. IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC TENSION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
C
C     STATIC(1,I) = STATIC TENSION TO
C     STATIC(2,I) = STATIC SHEAR FORCE IN THE XI DIRECTION
C     STATIC(3,I) = STATIC OMEGA AROUND THE ETA DIRECTION
C     STATIC(4,I) = STATIC ANGLE PHI
C
      WRITE(6,2000) MNP
2000  FORMAT(' MNP=',I3)
C     READ STATIC SOLUTION
      READ(10,36459) NP,VM
36459 FORMAT(1X,I3,1X,D12.6)
      WRITE(6,2311) NP,VM
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2311  FORMAT(' 2-D STATIC SOLUTION FROM DEVICE 10'/
     *' NP =',I3/
     *' MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S , VM =',D12.6)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING FROM DEVICE 10
C
      DO 1021 I=1,NP
      READ(10,1033) X(I),STATIC(1,I),STATIC(2,I),STATIC(3,I),STATIC(4,I)
     *,XCOOR,YCOOR,STRARC,TENSI,VLOCXI(I)
      XI(I) = X(I)
1021  CONTINUE
1033  FORMAT(10(1X,D12.6))
C     EVALUATE MAXIMUM STATIC TENSION
      TOMAX=DMAX1(STATIC(1,1),STATIC(1,2))
      DO 9859 I=3,NP
      TOMAX=DMAX1(TOMAX,STATIC(1,I))
9859  CONTINUE
C
      WRITE(6,1654) TOMAX
1654  FORMAT(' 2-D STATIC SOLUTION SUCCESFULLY READ'/' MAXIMUM STATIC TE
     *NSION/WAL = ',D10.4)
C
      RETURN
      END

      SUBROUTINE READAS(ICCC,NP,TOL)
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/BOUNDA/BOUND
C
C      READAS READS INITIAL APPROXIMATION RESULTING FROM A PREVIOUS
C      RUN OF RCLINDYN (CORRESPONDS TO EPS = 1.D0)
C
C      Y(1,I)  = SHEAR FORCE IN THE ETA DIRECTION
C      Y(2,I)  = OMEGA ABOUT ZETA
C      Y(3,I)  = OMEGA ABOUT XI
C      Y(4,I)  = THETA
C      Y(5,I)  = ANGLE BETA
C      Y(6,I)  = OUT OF PLANE DISPLACEMENT R IN THE ETA DIRECTION
C      Y(7,I)  = NATURAL FREQUENCY
C      X(I)    = UNSTRETCHED ARC LENGTH S
C
      WRITE(6,2000) MNP
2000  FORMAT(' MNP=',I3)
C     READ SOLUTION FROM DEVICE 12
      READ(12,36459) MODE,NP,SIGMAD
36459 FORMAT(1X,I2,1X,I3,1X,D10.4)
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      WRITE(6,2311) NP,MODE,SIGMAD
2311  FORMAT(' INITIAL APPROXIMATION FROM DEVICE 12'/
     *' NP =',I3,' MODE NUMBER =',I2,' SIGMAD =',D10.4)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING DATA FROM DEVICE 12 ...
C
      DO 10011 I=1,NP
      READ(12,10012) X(I),(Y(J,I),J=1,7),VLOCXI(I)
10011 CONTINUE
10012 FORMAT(9(1X,D12.6))
C     SET BOUNDARY CONDITION OMEGA XI(0)
      BOUND = Y(3,1)
C
      WRITE(9,1052) NP,SIGMAD
 1052 FORMAT(' INITIAL CONDITION FOR EPS=1. AND NP = ',I3,' POINTS,  NAT
     *URAL FREQUENCY = ',D10.4,' RAD/S'/
     *'   I     ARC        SHEAR ETA    OMEGA ZETA    OMEGA XI      THETA
     *         BETA          R              SIGMA')
      DO 1601 I=1,NP
       WRITE(9,1603) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     * Y(7,I)
 1601 CONTINUE
 1603 FORMAT(1X,I3,8(1X,D12.6))
C
      WRITE(6,9561)
 9561 FORMAT(' DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION'/
     *' IF YES INPUT 1')
      READ(5,*)IPRINT
      IF(IPRINT.EQ.1) THEN
       WRITE(6,1052) NP
       DO 9659 I=1,NP
        WRITE(6,1603) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     *  Y(7,I)
 9659  CONTINUE
      END IF
      WRITE(6,1722) BOUND
1722  FORMAT(' ASSUMED BOUNDARY CONDITION '/
     *' OMEGA XI (0) =',D12.6)
C
      TOL1 = 0.D0
      DO 3933 I=1,NP
        TOL1 = DMAX1(TOL1,DABS(Y(3,I)))
 3933 CONTINUE
      WRITE(6,3934) TOL1
 3934 FORMAT(' MAXIMUM ABSOLUTE VALUE OF N-D OMEGA XI IS =',D12.6/
     *' THIS NUMBER CAN BE USED TO ESTIMATE '/
     *' A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS'/
     *' INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE'/
     *' E.G. INPUT 0.01 FOR 1% ACCURACY')
```

```
      READ(5,*) TOLV
      TOL = DABS(TOLV)*TOL1
C
1005  WRITE(6,1004)
1004  FORMAT(' IF YOU WISH TO STOP INPUT 0'/
     *' IF YOU WISH TO CONTINUE WITH ITERATIONS INPUT 1')
      READ(5,*) ICCC
      IF((ICCC.NE.0).AND.(ICCC.NE.1)) GOTO 1005
C
      RETURN
      END
C
      SUBROUTINE APPROX(TLENG,ICCC,NP,TOL)
C     THIS SUBROUTINE EVALUATES THE APPROXIMATE ASYMPTOTIC ANALYTIC
C     SOLUTION OF THE OUT OF PLANE DYNAMIC EQUATIONS.
C
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/SOLUT/ X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/DEF/XNU
      DIMENSION FVEC(1),XS(1),FJAC(1,1),WA(7)
      EXTERNAL FCNS
C
C     APPROX DEFINES INITIAL APPROXIMATION (EPS=0.)
C
C     Y(1,I) = SHEAR FORCE IN THE ETA DIRECTION
C     Y(2,I) = OMEGA ABOUT ZETA
C     Y(3,I) = OMEGA ABOUT XI
C     Y(4,I) = THETA
C     Y(5,I) = ANGLE BETA
C     Y(6,I) = OUT OF PLANE DISPLACEMENT R IN THE ETA DIRECTION
C     Y(7,I) = NATURAL FREQUENCY
C
C     DETERMINE THE INITIAL APPROXIMATION TO THE NATURAL FREQUENCY
C     SIGMA.
C     NU IS EXACT IF THE STRAIN RELIEF UNITS ARE THE SAME AT THE TWO
C     ENDS OF THE RISER.
      XNU = DSQRT((EPSXI(1)+EPSXI(NP))/2.D0)
      WRITE(6,581) XNU
 581  FORMAT(' THE VALUE OF NU TO BE USED IS = ',D10.4/' IF YOU WANT TO
     *CHANGE NU INPUT 1')
      READ(5,*) INU
      IF (INU.EQ.1) THEN
       WRITE(6,*) ' INPUT NU'
       READ(5,*) XNU
      END IF
   23 WRITE(6,98)
   98 FORMAT(' INPUT INITIAL GUESS FOR SIGMA IN RAD/SEC ')
      READ(5,*) XS(1)
C     NONDIMENSIONALIZE SIGMA
      XS(1) = XS(1)*TLENG*DSQRT(TMAXAV*HETAM/TOMAX)
      XTOL = 1.D-8
      NS = 1
```

```
      LDFJAC = 1
      LWA = 7
      IFAIL = 0
C     CALL C05PBF TO EVALUATE SIGMA USING A MODIFICATION OF THE POWELL
C     HYBRID METHOD
      CALL C05PBF(FCNS,NS,XS,FVEC,FJAC,LDFJAC,XTOL,WA,LWA,IFAIL)
      WRITE(6,*) ' IFAIL FOR APPROXIMATE EVALUATION OF SIGMA IS ',IFAIL
      SIGMAD = XS(1)*DSQRT(TOMAX/(TMAXAV*HETAM))/TLENG
      WRITE(6,24) FVEC(1),SIGMAD
   24 FORMAT(1X,'THE FUNCTION IS F = ',D10.4/' THE CONVERGED SIGMA IS ',
     *D10.4/' INPUT 1 IF YOU WANT TO REDO THE CALCULATION'/
     *' INPUT 2 IF YOU WANT TO STOP')
      READ(5,*)ISIGMA
      IF (ISIGMA.EQ.1) THEN
       GO TO 23
      ELSE IF (ISIGMA.EQ.2) THEN
       ICCC = 0
       RETURN
      END IF
      SIGMA = XS(1)
      WRITE(6,*) ' INPUT MODE NUMBER CORRESPONDING TO ABOVE APPROXIMATE
     *SIGMA'
      READ(5,*) MODE
C
C     CALL SUBROUTINES TO EVALUATE INITIAL APPROXIMATION
      CALL INITAP(SIGMA,NP)
C     OUTPUT INITIAL APPROXIMATION TO DEVICE 9
      WRITE(9,1002) NP,SIGMAD
 1002 FORMAT(' INITIAL CONDITION FOR EPS=0. AND NP = ',I3,' POINTS,  NAT
     *URAL FREQUENCY = ',D10.4,' RAD/SEC'/
     *'   I     ARC         SHEAR ETA     OMEGA ZETA     OMEGA XI      THETA
     *          BETA             R              SIGMA')
      DO 1001 I=1,NP
       WRITE(9,1003) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     * Y(7,I)
 1001 CONTINUE
 1003 FORMAT(1X,I3,8(1X,D12.6))
C
      WRITE(6,7561)
 7561 FORMAT(' DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION'/
     *' IF YES INPUT 1')
      READ(5,*)IPRINT
      IF(IPRINT.EQ.1) THEN
       WRITE(6,1002) NP,SIGMAD
       DO 7659 I=1,NP
        WRITE(6,1003) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     *  Y(7,I)
 7659  CONTINUE
      END IF
      TOL1 = 0.D0
      DO 3931 I=1,NP
        TOL1 = DMAX1(TOL1,DABS(Y(3,I)))
 3931 CONTINUE
      WRITE(6,3932) TOL1
 3932 FORMAT(' MAXIMUM ABSOLUTE VALUE OF N-D OMEGA XI IS =',D12.6/
     *' THIS NUMBER CAN BE USED TO ESTIMATE '/
```

```
     *' A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS'/
     *' INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE'/
     *' E.G. INPUT 0.01 FOR 1% ACCURACY')
      READ(5,*) TOLV
      TOL = DABS(TOLV)*TOL1
      WRITE(6,*) ' IF YOU WANT TO STOP INPUT 0'
      READ(5,*) ICCC
      IF (ICCC.NE.0) ICCC = 1
C
      RETURN
      END
C
      SUBROUTINE FCNS(N,X,FVEC,FJAC,LDFJAC,IFLAG)
C     THIS SUBROUTINE IS USED BY NAG ROUTINE C05PBF TO EVALUATE
C     THE FUNCTION WHICH DETERMINES SIGMA
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/DEF/XNU
      DIMENSION X(1),FVEC(1),FJAC(1,1)
      IF (IFLAG.EQ.1) THEN
       FVEC(1)=(1.D0-X(1)**2*XNU**2)*DSIN(X(1))-2.D0*X(1)*XNU*DCOS(X(1))
      ELSE IF (IFLAG.EQ.2) THEN
       FJAC(1,1) = (1.D0-X(1)**2*XNU**2-2.D0*XNU)*DCOS(X(1))
       FJAC(1,1) = FJAC(1,1) + 2.D0*X(1)*XNU*(1.D0-XNU)*DSIN(X(1))
      ELSE IF (IFLAG.LT.0) THEN
       STOP
      END IF
      RETURN
      END
C
      SUBROUTINE INITAP(SIGMA,NP)
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/BOUNDA/BOUND
      DIMENSION R(MNP),RS(MNP),RSS(MNP),RSSS(MNP),EPSI(MNP),RSI(MNP)
      DIMENSION RSSI(MNP),RSSEI(MNP),A1(MNP)
C
C     THIS SUBROUTINE CALCULATES THE INITIAL APPROXIMATION OF THE
C     SOLUTION ONCE SIGMA IS DETERMINED
C
C     FIND SIGMA
      S2HETA = SIGMA/DSQRT(HETAM)
      DO 444 K=1,NP
       Y(7,K) = S2HETA
  444 CONTINUE
      CONST = DCOS(SIGMA) + SIGMA*XNU*DSIN(SIGMA)
C
C     IBM RANGE OF A REAL*8 NUMBER SO THAT DEXP(X) IS REAL*8
C     CONDITION XMINR<X. USE A STRICTER LIMIT.
C
      XMINR=-65.D0*DLOG(16.D0)
      XMINR=XMINR/3.D0
C
```

```
C     CALCULATE THE OUT OF PLANE DISPLACEMENT R AND ITS THREE
C     DERIVATIVES (ANALYTIC EXPRESSIONS)
C
      XNU1 = DSQRT(EPSXI(1))
      XNU2 = DSQRT(EPSXI(NP))
      XNU = XNU1
      DO 815 I=1,NP
       SIG = SIGMA*X(I)
       COSS = DCOS(SIG)
       SINS = DSIN(SIG)
       POWER1 = -X(I)/XNU1
       POWER2 = -(1-X(I))/XNU2
       IF (POWER1.GT.XMINR) THEN
         EXPO1 = DEXP(POWER1)
       ELSE
         EXPO1 = 0.D0
       END IF
       IF (POWER2.GT.XMINR) THEN
         EXPO2 = CONST*DEXP(POWER2)
       ELSE
         EXPO2 = 0.D0
       END IF
C      CALCULATE R, RS, RSS, RSSS
       R(I) = -SINS/(XNU*SIGMA) + COSS - EXPO1 + EXPO2
       RS(I) = -COSS/XNU - SIGMA*SINS + (EXPO1 + EXPO2)/XNU
       RSS(I) = SIGMA*SINS/XNU - SIGMA**2*COSS + (EXPO2 - EXPO1)/XNU**2
       RSSS(I)=SIGMA**2*COSS/XNU + SIGMA**3*SINS + (EXPO1+EXPO2)/XNU**3
C      DEFINE FIRST PART OF INITIAL APPROXIMATION
C      SHEAR FORCE IN THE ETA, OMEGA XI, THETA, R
C
       Y(1,I) = EPSXI(I)*(-RSSS(I)) + EPSXIS(I)*(-RSS(I))
       Y(3,I) = -RSS(I)
       Y(4,I) = -RS(I)
       Y(6,I) = R(I)
  815 CONTINUE
C
C     EVALUATE THE INDEFINITE INTEGRALS TO CALCULATE ANGLE BETA USING
C     THE TRAPEZOIDAL INTEGRATION ALGORITHM.
C
      EPSI(1) = 0.D0
      RSI(1) = 0.D0
      RSSI(1) = 0.D0
      RSSEI(1) = 0.D0
      DO 839 I=2,NP
       DX2 = (X(I)-X(I-1))*0.5D0
C
       EPSI(I) = EPSI(I-1) + (1.D0/EPSPI(I)+1.D0/EPSPI(I-1))*DX2
C
       RSI(I) = RSI(I-1) + (STATIC(3,I)*RS(I)+STATIC(3,I-1)*RS(I-1))*DX2
C
       E1 = (EPSETA(I)-EPSXI(I))*STATIC(3,I)
       E2 = (EPSETA(I-1)-EPSXI(I-1))*STATIC(3,I-1)
       RSSI(I) = RSSI(I-1) + (E1*RSS(I) + E2*RSS(I-1))*DX2
C
       E3 = RSSI(I)/EPSPI(I) + RSSI(I-1)/EPSPI(I-1)
       RSSEI(I) = RSSEI(I-1) + E3*DX2
```

```
  839 CONTINUE
C     EVALUATE THE CONSTANT OF INTEGRATION
      C1 = (RSI(NP)-RSSEI(NP))/EPSI(NP)
C     EVALUATE THE SECOND PART OF THE APPROXIMATE SOLUTION
      DO 853 I=1,NP
        Y(2,I) = (RSSI(I) + C1)/EPSPI(I)
        Y(5,I) = -RSI(I) + C1*EPSI(I) + RSSEI(I)
        A1(I) = Y(5,I)**2/TLAMB2(I) + HETA(I)*Y(6,I)**2
  853 CONTINUE
C     CALCULATE THE ORTHONORMALIZING CONSTANT FOR R AND BETA
      A = 0.D0
      DO 842 I=2,NP
        DX2 = (X(I)-X(I-1))*0.5D0
        A = A + (A1(I)+A1(I-1))*DX2
  842 CONTINUE
      A = DSQRT(A)
C     ORTHONORMALIZE THE SOLUTION EXCEPT SIGMA
      DO 843 I=1,NP
        DO 843 K=1,N-1
          Y(K,I) = Y(K,I)/A
  843 CONTINUE
C     DETERMINE THE FOURTH BOUNDARY CONDITION AT S=0
      BOUND = Y(3,1)
      WRITE(6,84) A,BOUND
   84 FORMAT(' THE ORTHONORMALIZING CONSTANT FOR THE APPROXIMATE'/
     *' SOLUTION IS SQRT(A) = ',D10.4/' THE BOUNDARY CONDITION AT S=0
     * OMEGAXI(0) = ',D10.4)
      RETURN
      END
C
      SUBROUTINE STRUCT(ARRAY,X,NP)
C     THIS SUBROUTINE CHANGES A SERIES OF DATA GIVEN IN
C     SEGMENTS TO A SERIES OF DATA CORRESPONDING TO SPECIFIC POINTS
C     ASSUMPTION: NSEG < NP
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      DIMENSION ARRAY(MNP),HELP(MNP),X(MNP)
C
      IF(NSEG.EQ.1) THEN
        DO 83 I=1,NP
         HELP(I) = ARRAY(1)
83      CONTINUE
      ELSE
        HELP(1) = ARRAY(1)
        HELP(NP) = ARRAY(NSEG)
        I=2
        DO 84 K=2,NP-1
         IF ((X(K).GT.SEG(I-1)).AND.(X(K).LT.SEG(I))) THEN
           HELP(K) = ARRAY(I-1)
         ELSE IF (X(K).EQ.SEG(I)) THEN
           HELP(K) = 0.5D0*(ARRAY(I-1) + ARRAY(I))
         ELSE IF (X(K).GT.SEG(I)) THEN
           HELP(K) = ARRAY(I)
           I = I + 1
```

```
          END IF
   84   CONTINUE
        END IF
        DO 85 K=1,NP
          ARRAY(K) = HELP(K)
   85   CONTINUE
        RETURN
        END
C
      SUBROUTINE OUTPUT(NP)
C     THIS SUBROUTINE OUTPUTS THE RESULTS IN TWO FORMATS; A COMPLETE
C     FORMAL FORM AND A FORM TO BE USED FOR PLOTTING.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      CHARACTER*80 NAME
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/INPUT0/NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUT2/RHOO,AI,CFLUID,PRESS,AO(MNP)
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/INPUT3/WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP)
     *,EIXIS(MNP),GIP(MNP),GIPS(MNP)
      COMMON/INPUT4/DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP)
      COMMON/INPUT5/RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(
     *MNP),TMAXI(MNP),TMAETA(MNP)
      COMMON/INPUT6/XJZI(MNP),AJZI(MNP),TJZI(MNP)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,TO,QXIO,OMEGAO,
     *CONS1,CONS2
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION A1(MNP)
C     CALCULATE THE ORTHONORMALIZING CONSTANT FOR R AND BETA
C
      DO 542 I=1,NP
        CALL COUNT(X(I))
        A1(I) = Y(5,I)**2/TLAM2 + HH*Y(6,I)**2
  542 CONTINUE
      A = 0.D0
      DO 642 I=2,NP
        DX2 = (X(I)-X(I-1))*0.5D0
        A = A + (A1(I)+A1(I-1))*DX2
  642 CONTINUE
      A = DSQRT(A)
C     ORTHONORMALIZE THE SOLUTION EXCEPT SIGMA
      DO 643 I=1,NP
          Y(N,I) = DABS(Y(N,I))
        DO 643 K=1,N-1
          Y(K,I) = Y(K,I)/A
  643 CONTINUE
C     OUTPUT RESULTS
      WRITE(9,1000) NAME
 1000 FORMAT(80A)
      WRITE(9,1001) NSEG,TLEN,WA,RHOO,RHOW,AI,CFLUID,PRESS,WT,TOMAX,VM*
C
```

```
1001  FORMAT(1X,I3,9X,' = NUMBER OF RISER SEGMENTS'/
     *1X,D12.6,' = UNSTRETCHED RISER LENGTH IN M'/
     *1X,D12.6,' = APPROXIMATE AVERAGE EFFECTIVE WEIGHT PER UNIT LENGTH
     *IN N/M'/
     *1X,D12.6,' = INNER FLUID DENSITY IN KG/M3'/
     *1X,D12.6,' = SALT WATER DENSITY IN KG/M3'/
     *1X,D12.6,' = INNER CROSS SECTIONAL AREA IN M2'/
     *1X,D12.6,' = INNER FLUID SPEED IN M/S'/
     *1X,D12.6,' = INNER FLUID OVERPRESSURE IN N/M2'/
     *1X,D12.6,' = APPROXIMATE TOTAL EFFECTIVE WEIGHT IN WATER IN N'/
     *1X,D12.6,' = MAXIMUM STATIC TENSION IN N'/
     *1X,D12.6,' = MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S')
C     EVALUATE DIMENSIONAL NATURAL FREQUENCY
      SIGMAD = Y(N,1)*DSQRT(TOMAX/TMAXAV)/TLEN
      WRITE(9,1002) NSEG
1002  FORMAT(//' D A T A   P E R   R I S E R   S E G M E N T   F O R   NSEG =
     * ',I3,'   S E G M E N T S'/' D I M E N S I O N A L   Q U A N T I T I
     * E S   I N   T H E   S . I .   S Y S T E M'/
     *'    RLENG        DXI       PXIETA        AO         WEIGHT       MASS
     *     TMASS        AMAXI       AMAETA      AMAZI        TMAXI       TMAETA
     *')
      TL = TOMAX/TLEN
      DO 1004 I=1,NSEG
      WRITE(9,1003) RLENG(I)*TLEN,DXI(I),PXIETA(I),AO(I),WEIGHT(I)*TL,RM
     *ASS(I),RMASST(I),AMAXI(I),AMAETA(I),AMAZI(I),TMAXI(I),TMAETA(I)
1004  CONTINUE
1003  FORMAT(12(1X,D10.4)/)
C
      WRITE(9,10022)
10022 FORMAT('     EA        EIETA       EIETAS       EIXI        EIXIS
     *  GIP       GIPS        DETA         JZI         AJZI        TJZI')
      DO 10023 I=1,NSEG
      WRITE(9,10024) EA(I),EIETA(I),EIETAS(I),EIXI(I),EIXIS(I),GIP(I),
     *GIPS(I),DETA(I),XJZI(I),AJZI(I),TJZI(I)
10023 CONTINUE
10024 FORMAT(11(1X,D10.4)/)
C
      WRITE(9,761) MODE,SIGMAD
  761 FORMAT(' **********************************************************'
     */'   M O D E   N U M B E R = ',I2/'   N A T U R A L   F R E Q U E N
     *C Y = ',D10.4,' RAD/S'/' *****************************************
     ****************')
C
      WRITE(9,1009) NP
1009  FORMAT(/' ORTHONORMALIZED NONDIMENSIONAL RESULTS AT NP = ',
     *I3,' POINTS'/
     *'      S          QETA      OMEGAZETA  OMEGAXI       THETA        BETA
     *       R         SIGMA')
C     NORMALIZE ERROR BY COMPONENTS.
      DO 181 I=1,N-1
        ABT(I) = ABT(I)/A
 181  CONTINUE
      DO 1010 I=1,NP
      WRITE(9,1011) X(I),(Y(J,I),J=1,7)
1010  CONTINUE
1011  FORMAT(8(1X,D10.4))
```

```
      WRITE(9,10119) (ABT(I),I=1,7)
10119 FORMAT(' MAXIMUM ESTIMATED ERROR BY COMPONENTS'/11X,7(1X,D10.4))
C
C
C     OUTPUT TO FILE CONNECTED TO DEVICE 11
C     THIS CAN BE USED FOR PLOTS OR INPUT TO ANOTHER RUN OF RCLINDYN
C
C
      CALL STRUC(VLOCXI,NP,NPI)
      WRITE(11,36459) MODE,NP,SIGMAD
36459 FORMAT(1X,I2,1X,I3,1X,D10.4)
      DO 3666 I=1,NP
      WRITE(11,3667) X(I),(Y(J,I),J=1,7),VLOCXI(I)
 3666 CONTINUE
 3667 FORMAT(9(1X,D12.6))
C
      RETURN
      END
C
      SUBROUTINE FCN(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE FUNCTIONS USED BY D02RAF TO SOLVE
C     THE PROBLEM
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,T0,QXI0,OMEGA0,
     *CONS1,CONS2
      DIMENSION Y(N),F(N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      F(1) = -EPS*QXI0*Y(2) + (1.D0+EPS*(T0-1.D0))*Y(3)
      F(1) = F(1) + EPS*Y(4)*CONS1
      F(1) = F(1) - EPS*Y(5)*CONS2
      F(1) = F(1) - Y(7)**2*(HETAM+EPS*(HH-HETAM))*Y(6)
C
      F(2) = (-EPIS*Y(2) - EPS*Y(7)**2*Y(5)/TLAM2)/EPI
      F(2) = F(2) + Y(3)*OMEGA0*(EXI-EETA)/EPI
C
      F(3) = (-EXIS*Y(3) + Y(1))/EXI
      F(3) = F(3) + EPS*Y(2)*OMEGA0*(EETA-EPI)/EXI
C
      F(4) = Y(3) - EPS*OMEGA0*Y(5)
C
      F(5) = Y(2) + OMEGA0*Y(4)
C
      F(6) = -Y(4)
C
      F(7) = 0.D0
      RETURN
      END
C
      SUBROUTINE G(EPS,YA,YB,BC,N)
C     BOUNDARY CONDITIONS USED BY D02RAF
      IMPLICIT REAL*8(A-H,O-Z)
```

```
      DIMENSION YA(N),YB(N),BC(N)
      COMMON/BOUNDA/BOUND
C
      BC(1)=YA(4)
      BC(2)=YA(5)
      BC(3)=YA(6)
      BC(4)=YA(3) - BOUND
C
      BC(5)=YB(4)
      BC(6)=YB(5)
      BC(7)=YB(6)
C
      RETURN
      END
C
      SUBROUTINE JACOBF(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE JACOBIAN OF THE EQUATIONS TO USE IN
C     NEWTON'S ITERATION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,TO,QXIO,OMEGAO,
     *CONS1,CONS2
      DIMENSION Y(N),F(N,N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      DO 817 I=1,N
        DO 817 M=1,N
          F(I,M) = O.DO
  817 CONTINUE
C
      F(1,2) = -EPS*QXIO
      F(1,3) = 1.DO + EPS*(TO-1.DO)
      F(1,4) = EPS*CONS1
      F(1,5) = -EPS*CONS2
      F(1,6) = -Y(7)**2*(HETAM+EPS*(HH-HETAM))
      F(1,7) = -2.DO*Y(7)*Y(6)*(HETAM+EPS*(HH-HETAM))
C
      F(2,2) = -EPIS/EPI
      F(2,3) = OMEGAO*(EXI-EETA)/EPI
      F(2,5) = -EPS*Y(7)**2/EPI/TLAM2
      F(2,7) = -EPS*2.DO*Y(7)*Y(5)/EPI/TLAM2
C
      F(3,1) = 1.DO/EXI
      F(3,2) = EPS*OMEGAO*(EETA-EPI)/EXI
      F(3,3) = -EXIS/EXI
C
      F(4,3) = 1.DO
      F(4,5) = -EPS*OMEGAO
C
      F(5,2) = 1.DO
      F(5,4) = OMEGAO
C
      F(6,4) = -1.DO
```

```
      RETURN
      END
C
      SUBROUTINE JACOBG(EPS,YA,YB,AJ,BJ,N)
C     THIS SUBROUTINE EVALUATES THE JACOBIAN OF THE BOUNDARY CONDITIONS.
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION YA(N),YB(N),AJ(N,N),BJ(N,N)
      DO 876 K=1,N
        DO 876 I=1,N
         AJ(K,I) = 0.DO
         BJ(K,I) = 0.DO
  876 CONTINUE
C
      AJ(1,4) = 1.DO
      AJ(2,5) = 1.DO
      AJ(3,6) = 1.DO
      AJ(4,3) = 1.DO
C
      BJ(5,4) = 1.DO
      BJ(6,5) = 1.DO
      BJ(7,6) = 1.DO
      RETURN
      END
C
      SUBROUTINE JACEPS(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE DERIVATIVES OF THE FUNCTIONS WITH
C     RESPECT TO THE CONTINUATION PARAMETER EPS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(NA=4,MNP=151)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,TO,QXIO,OMEGAO,
     *CONS1,CONS2
      DIMENSION Y(N),F(N)
C     LOCATE MESH POINT TO EVALUATE THE COEFFICIENTS
      CALL COUNT(X)
C
      F(1) = Y(4)*CONS1 - Y(5)*CONS2
      F(1) = F(1) - QXIO*Y(2) + (TO-1.DO)*Y(3)
      F(1) = F(1) - Y(7)**2*Y(6)*(HH-HETAM)
C
      F(2) = -Y(7)**2*Y(5)/EPI/TLAM2
C
      F(3) = (EETA-EPI)*OMEGAO*Y(2)/EXI
C
      F(4) = -OMEGAO*Y(5)
C
      F(5) = 0.DO
      F(6) = 0.DO
      F(7) = 0.DO
      RETURN
      END
C
      SUBROUTINE JACGEP(EPS,YA,YB,BCEP,N)
C     THIS SUBROUTINE EVALUATES THE DERIVATIVES OF THE BOUNDARY
```

```
C     CONDITIONS WITH RESPECT TO THE CONTINUATION PARAMETER EPS.
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION YA(N),YB(N),BCEP(N)
      DO 871 K=1,N
        BCEP(K) = 0.D0
  871 CONTINUE
      RETURN
      END
C
      SUBROUTINE INTERP(NP)
C     THIS SUBROUTINE INTERPOLATES THE RISER CHARACTERISTICS AND THE
C     STATIC SOLUTION TO THE NEW NUMBER OF POINTS NP.
C     ASSUMPTION: NP .GE. NPI
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION HELP(MNP)
C     INTERPOLATE STRUCTURAL DATA TO THE NEW NUMBER OF POINTS
      CALL STRUC(EPSXI,NP,NPI)
      CALL STRUC(EPSXIS,NP,NPI)
      CALL STRUC(EPSETA,NP,NPI)
      CALL STRUC(EPSETS,NP,NPI)
      CALL STRUC(EPSPI,NP,NPI)
      CALL STRUC(EPSPIS,NP,NPI)
      CALL STRUC(HETA,NP,NPI)
      CALL STRUC(TLAMB2,NP,NPI)
      CALL STRUC(CONST1,NP,NPI)
      CALL STRUC(CONST2,NP,NPI)
      CALL STRUC(VLOCXI,NP,NPI)
C     INTERPOLATE STATIC SOLUTION TO THE NEW NUMBER OF POINTS
      DO 459 K=1,3
        DO 458 I=1,NPI
         HELP(I) = STATIC(K,I)
  458   CONTINUE
        CALL STRUC(HELP,NP,NPI)
        DO 457 I=1,NP
         STATIC(K,I) = HELP(I)
  457   CONTINUE
  459 CONTINUE
      DO 339 I=1,NP
         XI(I) = X(I)
  339 CONTINUE
      RETURN
      END
C
      SUBROUTINE STRUC(ARRAY,NP,NPOLD)
C     THIS SUBROUTINE INTERPOLATES A SERIES OF DIVISION POINTS TO A NEW
C     SERIES OF DIVISION POINTS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
```

```
      DIMENSION ARRAY(MNP),HELP(MNP)
C
      HELP(1) = ARRAY(1)
      HELP(NP) = ARRAY(NPOLD)
      DO 82 I=2,NPOLD
      DO 81 K=2,NP-1
       IF ((X(K).GT.XI(I-1)).AND.(X(K).LT.XI(I))) THEN
         CONV = (X(K)-XI(I-1))*(ARRAY(I)-ARRAY(I-1))/(XI(I)-XI(I-1))
         HELP(K) = ARRAY(I-1) + CONV
       ELSE IF (X(K).EQ.XI(I)) THEN
         HELP(K) = ARRAY(I)
       END IF
 81   CONTINUE
 82   CONTINUE
      DO 85 K=1,NP
        ARRAY(K) = HELP(K)
 85   CONTINUE
      RETURN
      END
C
      SUBROUTINE COUNT(X)
C     THIS SUBROUTINE EVALUATES THE RISER CHARACTERISTICS AS WELL AS THE
C     STATIC SOLUTION AT A POINT X.
C     IT RETURNS THEIR VALUE IN COMMON BLOCK COEF1.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/CONST1(MNP),CONST2(MNP)
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,TO,QXIO,OMEGAO,
     *CONS1,CONS2
      COMMON/COUN/ICOUNT
      M = ICOUNT
      IF (X.EQ.XI(M)) THEN
       EXI = EPSXI(M)
       EXIS = EPSXIS(M)
       EETA = EPSETA(M)
       EETAS = EPSETS(M)
       EPI = EPSPI(M)
       EPIS = EPSPIS(M)
       HH = HETA(M)
       TLAM2 = TLAMB2(M)
       TO = STATIC(1,M)
       QXIO = STATIC(2,M)
       OMEGAO = STATIC(3,M)
       CONS1 = CONST1(M)
       CONS2 = CONST2(M)
       ICOUNT = ICOUNT + 1
       IF(X.EQ.1.D0) ICOUNT = 1
      ELSE IF ((X.LT.XI(M)).AND.(X.GT.XI(M-1))) THEN
       DIFF = DABS(XI(M)-X)
C      THIS IF STATEMENT IS TO ACCOUNT FOR A COMPUTER INACCURACY IN
C      REPRESENTATING AND EQUATING REAL NUMBERS.
       IF (DIFF.LT.1.D-7) THEN
        ICOUNT = ICOUNT + 1
```

```
         IF (XI(M).EQ.1.D0) ICOUNT = 1
        END IF
        DX = (X-XI(M-1))/(XI(M)-XI(M-1))
        EXI = EPSXI(M-1) + (EPSXI(M)-EPSXI(M-1))*DX
        EXIS = EPSXIS(M-1) + (EPSXIS(M)-EPSXIS(M-1))*DX
        EETA = EPSETA(M-1) + (EPSETA(M)-EPSETA(M-1))*DX
        EETAS = EPSETS(M-1) + (EPSETS(M)-EPSETS(M-1))*DX
        EPI = EPSPI(M-1) + (EPSPI(M)-EPSPI(M-1))*DX
        EPIS = EPSPIS(M-1) + (EPSPIS(M)-EPSPIS(M-1))*DX
        HH = HETA(M-1) + (HETA(M)-HETA(M-1))*DX
        TLAM2 = TLAMB2(M-1) + (TLAMB2(M)-TLAMB2(M-1))*DX
        TO = STATIC(1,M-1) + (STATIC(1,M)-STATIC(1,M-1))*DX
        QXIO = STATIC(2,M-1) + (STATIC(2,M)-STATIC(2,M-1))*DX
        OMEGAO = STATIC(3,M-1) + (STATIC(3,M)-STATIC(3,M-1))*DX
        CONS1 = CONST1(M-1) + (CONST1(M)-CONST1(M-1))*DX
        CONS2 = CONST2(M-1) + (CONST2(M)-CONST2(M-1))*DX
       ELSE
C
        WRITE(6,*) ' ERROR OCCURED IN COUNTER, NP =',M
       END IF
       RETURN
       END
```

Chapter XIII

Listing of Program RCNATIN FORTRAN A

```
C RCNATIN
C PROGRAM TO EVALUATE THE DETERMINANT OF MATRIX P FOR A RANGE OF
C FREQUENCIES IN ORDER TO DETERMINE APPROXIMATE VALUES OF THE NATURAL
C FREQUENCIES OF COMPLIANT RISERS FOR IN PLANE DYNAMICS WITH A 2-D
C STATIC CONFIGURATION.
C THIS PROGRAM CAN BE USED TO DETERMINE APPROXIMATE ESTIMATES OF
C NATURAL FREQUENCIES TO USE AS INPUT IN THE IN-PLANE DYNAMICS PROGRAMS,
C WHICH IMPROVE THESE INITIAL ESTIMATES.
C DOUBLE PRECISION AND THE NAG FORTRAN LIBRARY ARE USED THROUGHOUT.
C WKB VERSION OF THE PROGRAM.
C***********************************************************************
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C***********************************************************************
C PROGRAMMER GEORGE A. KRIEZIS     JUNE 5, 1985    M.I.T.
C***********************************************************************
C
C DEFINITION OF DEVICES:
C DEVICE 5  : INPUT FROM TERMINAL
C DEVICE 6  : OUTPUT TO TERMINAL
C DEVICE 8  : INPUT FROM FILE PREPARED BY RCINPUT  (LRECL=80)
C DEVICE 10 : INPUT FROM FILE CONTAINING APPROXIMATE N-D STATIC
C             SOLUTION CREATED BY RCSTAT2D (LRECL=132)
C DEVICE 11 : OUTPUT TO FILE (LRECL=80)
C
C DEFINITIONS OF PARAMETERS
C MNP = MAXIMUM NUMBER OF FREQUENCIES TO EVALUATE DETERMINANT.
C
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=300)
      CHARACTER*80 NAME
      COMMON/INPUTO/NAME
      DIMENSION FREQ(MNP),PVALUE(MNP),RANG1(MNP),RANG2(MNP)
C
C     READ2D READS 2-D STATIC COMPLIANT RISER
C     SOLUTION CALCULATED FROM RCSTAT2D PROGRAM AND EVALUATES
C     THE MAXIMUM NONDIMENSIONAL STATIC EFFECTIVE TENSION (TOMAX).
C
      CALL READ2D(TOMAX,VM,ICCC)
      IF(ICCC.EQ.0) STOP
C
C     CHARAC READS RISER CHARACTERISTICS FROM UNIT 8 AND EVALUATES THE
C     NONDIMENSIONAL COEFFICIENTS TO BE USED FOR THE ESTIMATION OF
C     THE NATURAL FREQUENCIES.
C
      CALL CHARAC(TOMAX,TMAXAV,TLENG,VM)
C
C
C
1499  WRITE(6,1500) MNP
1500  FORMAT(/' INPUT'/' THE MAXIMUM FREQUENCY AND FREQUENCY SPACING (IN
     * RAD/S) FOR'/' WHICH YOU WISH TO EVALUATE THE DETERMINANT OF MATRI
     *X P'/' MAXIMUM PERMISSIBLE NUMBER OF FREQUENCY POINTS IS = ',I3)
      READ(5,*) FREQH,DF
      DIV = FREQH/DF
      XP = FLOAT(MNP-1)
```

```
      IF(DIV.GT.XP) GOTO 1499
C
C     APPROX:EVALUATES THE DETERMINANT OF P FOR ALL FREQUENCIES SELECTED
C     IT USES THE FAST AND SLOW ASYMPTOTIC SOLUTIONS AND APPLIES THE
C     BOUNDARY CONDITIONS FOR THE COMPLIANT RISER.
C
      CALL APPROX(FREQ,PVALUE,TLENG,TMAXAV,TOMAX,FREQH,DF,NDIV)
C
C     DETERMINE THE APPROXIMATE VALUES OF EACH NATURAL FREQUENCY IN THE
C     SPECIFIED RANGE. THE DETERMINANT CHANGES SIGN AT EACH NATURAL
C     FREQUENCY.
C
      K = 0
      DO 452 I=1,NDIV-1
       CHECK = PVALUE(I)*PVALUE(I+1)
       IF (CHECK.LT.0.D0) THEN
        K = K + 1
        RANG1(K) = FREQ(I)
        RANG2(K) = FREQ(I+1)
       END IF
  452 CONTINUE
C
C     OUTPUT THE RESULTS
C
      WRITE(11,8666) NAME
 8666 FORMAT(80A)
      WRITE(11,36)
   36 FORMAT(/' ESTIMATES OF IN-PLANE NATURAL FREQUENCIES FOR A 2-D STAT
     *IC CONFIGURATION')
      WRITE(11,85)K
   85 FORMAT(/' NUMBER OF NATURAL FREQUENCIES IN SPECIFIED RANGE: ',I3)

      DO 76 I=1,K
       WRITE(11,86) I,RANG1(I),RANG2(I)
   76 CONTINUE
   86 FORMAT(' MODE = ',I3/' NATURAL FREQUENCY BETWEEN'/1X,D12.6,' AND '
     *,D12.6,' RAD/SEC'/' ******************************************')
      WRITE(11,24)
   24 FORMAT(/' FREQUENCY (RAD/SEC)',2X,'DETERMINANT')
      DO 89 I=1,NDIV
        WRITE(11,25)FREQ(I),PVALUE(I)
   89 CONTINUE
   25 FORMAT(5X,D12.6,4X,D12.6)
      STOP
      END

      SUBROUTINE CHARAC(TOMAX,TMAXAV,TLENG,VM1)
C     SUBROUTINE CHARAC READS THE COMPLIANT RISER CHARACTERISTICS FROM
C     DEVICE 8 AND EVALUATES ALL THE NONDIMENSIONAL COEFFICIENTS USED
C     IN THE EVALUATION OF THE P MATRIX AND THE DIMENSIONAL NATURAL
C     FREQUENCIES.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      CHARACTER*80 NAME
      COMMON/INPUTO/NAME
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
```

```
      COMMON/COEF/EPSETA(2),HZETAM,DXIM,VM,XL
      DIMENSION EIETA(MNP),DXI(MNP),RLENG(MNP)
      DIMENSION RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(MNP)
     *,TMAXI(MNP),TMAZI(MNP),HZETA(MNP)
C
      VM = VM1
      READ (8,1000) NAME
1000  FORMAT(80A)
      READ (8,1008) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
1008  FORMAT(1X,I3,2(1X,D12.6)/4(1X,D12.6))
      TLENG = TLEN
      DO 1502 I=1,NSEG
      READ (8,1003) RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT,DXI(I),
     *PXIETA,EA,EIETA(I),AO,EIETAS
1502  CONTINUE
1003  FORMAT(5(1X,D12.6)/6(1X,D12.6))
C
      DO 1332 I=1,NSEG
      READ(8,1333) AMAETA(I),DETA,EIXI,EIXIS,GIP,GIPS,AMAZI(I),XJZI,AJZI
1332  CONTINUE
1333  FORMAT(6(1X,D12.6)/3(1X,D12.6))
C
C
C     NON - DIMENSIONALIZATIONS
C
      GRAV=9.81D0
      WAM=WA/GRAV
      WT=WA*TLEN
      XPI=4.D0*DATAN(1.D0)
      XPI2=XPI/2.D0
      RHOW=1.025D3
      TOMAX = TOMAX*WT
C
C     NONDIMENSIONAL COEFFICIENTS USED IN THE EQUATIONS
C
      TOMAXL = TOMAX/TLEN
      TOML1  = TOMAX*TLEN
      TOML2  = TOML1*TLEN
      TLEN2  = TLEN**2
      TMAXAV = 0.D0
      DXIM = 0.D0
      DO 2000 I=1,NSEG
       RLENG(I)=RLENG(I)/TLEN
       TMAZI(I) = RMASS(I) + AMAZI(I)
       TMAXI(I) = RMASS(I) + AMAXI(I)
       TMAXAV = TMAXI(I)*RLENG(I) + TMAXAV
       DXIM = DXIM + DXI(I)*RLENG(I)
2000  CONTINUE
      EPSETA(1) = EIETA(1)/TOML2
      EPSETA(2) = EIETA(NSEG)/TOML2
      HZETAM = 0.D0
      DO 4321 I=1,NSEG
       HZETA(I) = TMAZI(I)/TMAXAV
       HZETAM = HZETAM + HZETA(I)*RLENG(I)
 4321 CONTINUE
      RETURN
```

```
      END
C
      SUBROUTINE READ2D(TOMAX,VM,ICCC)
C     THIS SUBROUTINE READS THE STATIC COMPLIANT RISER SOLUTION FROM
C     DEVICE 10. IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC TENSION.
C     IT PROVIDES ALSO THE X AND Y DISPLACEMENTS AT THE TOP OF THE
C     COMPLIANT RISER.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/STAT1/XTOP,YTOP
      DIMENSION XCOOR(MNP),YCOOR(MNP),STATIC(MNP),XI(MNP)
C
C     STATIC(I) = STATIC EFFECTIVE TENSION TO
C
      WRITE(6,2000) MNP
 2000 FORMAT(' MNP=',I3)
C
      ICCC = 1
      READ(10,36459) NP,VM
36459 FORMAT(1X,I3,1X,D12.6)
      WRITE(6,2311) NP,VM
 2311 FORMAT(' 2-D STATIC SOLUTION FROM DEVICE 10'/
     *' NP =',I3/
     *' MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =',D12.6)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
      IF (VM.EQ.0.D0) THEN
       WRITE(6,1240)
 1240  FORMAT(' PROGRAM IS NOT VALID FOR ZERO MEAN CURRENT SPEED'/
     * ' RUN STOPS')
       ICCC = 0
       RETURN
      END IF
C
C     READING FROM DEVICE 10
C
      DO 1021 I=1,NP
      READ(10,1033) X,STATIC(I),STATI2,STATI3,STAT4,XCOOR(I),YCOOR(I),
     *STRARC,TENSI,VLOCXI
      XI(I) = X
 1021 CONTINUE
 1033 FORMAT(10(1X,D12.6))
C     EVALUATE RISER TOP X AND Y COORDINATES
      XTOP = XCOOR(NP)
      YTOP = YCOOR(NP)
C     EVALUATE MAXIMUM STATIC EFFECTIVE TENSION
      TOMAX=DMAX1(STATIC(1),STATIC(2))
      DO 9859 I=3,NP
        TOMAX = DMAX1(TOMAX,STATIC(I))
 9859 CONTINUE
```

```
C
      WRITE(6,1654) TOMAX
1654  FORMAT(' 2-D STATIC SOLUTION SUCCESFULLY READ'/' MAXIMUM STATIC EF
     *FECTIVE TENSION/WA*L = ',D10.4)
C
      RETURN
      END
C
      SUBROUTINE APPROX(FREQ,PVALUE,TLENG,TMAXAV,TOMAX,FREQH,DF,NDIV)
C     THIS SUBROUTINE EVALUATES THE DETERMINANT OF MATRIX P AT ALL THE
C     SPECIFIED FREQUENCY POINTS IN ORDER TO LOCATE REGIONS OF CHANGING
C     SIGN.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=300)
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/COEF/EPSETA(2),HZETAM,DXIM,VM,XL
      COMMON/OMA/OMAPP(2),PHI00(2)
      DIMENSION FVEC(2),XS(2),WAS(19),WKSPCE(6)
      DIMENSION PVALUE(MNP),FREQ(MNP),A(6,6),P(6,6)
      EXTERNAL FCNS
C     DETERMINATION OF THE CABLE APPROXIMATION  OF 2-D STATIC SOLUTION.
C     THE POWELL HYBRID METHOD IS USED (SEE PROGRAM RCSTAT2D FOR
C     DETAILS FOR THE SLOW SOLUTION)
C     EVALUATE K
      WRITE(6,1781)
 1781 FORMAT(' INPUT NORMAL DRAG COEFFICIENT USED IN STATIC SOLUTION')
      READ(5,*)CD
      XK = 0.5D0*RHOW*DXIM*CD*VM*DABS(VM)*TLENG
      WRITE(6,8881) VM,CD
 8881 FORMAT(' MEAN CURRENT SPEED =',D12.6/' NORMAL DRAG COEFFICIENT =',
     *D12.6)
C
 2601 WRITE(6,1501)
 1501 FORMAT(' INPUT ESTIMATES OF LAMBDA AND C'/
     *' LAMBDA MUST HAVE THE SIGN OF MEAN CURRENT SPEED'/
     *'  FOR SMALL XTOP A GOOD ESTIMATE OF C IS -0.5*LAMBDA')
      READ(5,*) XL,XC
C
      XS(1) = XL
      XS(2) = XC
      XTOL = 1.D-8
      NS = 2
      LWA = 19
C
C     CALL NAG SUBROUTINE C05NBF TO DETERMINE THE CABLE APPROXIMATION
      IFAIL = 0
      CALL C05NBF(FCNS,NS,XS,FVEC,XTOL,WAS,LWA,IFAIL)
C
      WRITE(6,1356) IFAIL,XS(1),XS(2)
 1356 FORMAT(' SOLUTION FOR CABLE ...'/' IFAIL =',I2/
     *' LAMBDA =',D12.6/
     *' C      =',D12.6)
C
      WRITE(6,2500) FVEC(1),FVEC(2)
 2500 FORMAT(' VALUE OF FUNCTION FOR HORIZONTAL DISPLACEMENT =',D12.6/
     *' VALUE OF FUNCTION FOR VERTICAL DISPLACEMENT =',D12.6/
```

```
     *' DO YOU WISH TO TRY A DIFFERENT INITIAL LAMDA, OR C,'/
     *' IF YES INPUT 1')
      READ(5,*) IPP
      IF (IPP.EQ.1) GO TO 2601
      IF (IFAIL.NE.0) GO TO 2601
C
      XL = XS(1)
      XC = XS(2)
      TE = XK/XL
      WRITE(6,1654) XL,XC,TE
 1654 FORMAT(' CABLE APPROXIMATION '/
     *' LAMBDA =',D12.6,' C =',D12.6,' TENSION =',D12.6)
C
C     DETERMINE VALUES OF PHI00 AND OMEGA ETA AT THE TOP AND BOTTOM OF
C     THE RISER USING CABLE APPROXIMATION.
        S = 0.D0
        PHI00(1) = PHI0(S,XL,XC)
        OMAPP(1)=XL*DSIN(PHI00(1))**2
C
        S = 1.D0
        PHI00(2) = PHI0(S,XL,XC)
        OMAPP(2)=XL*DSIN(PHI00(2))**2
C
C     CALCULATE FUNCTIONS F THAT DETERMINE THE SLOW DYNAMIC SOLUTION
C     AT THE TOP AND BOTTOM OF THE RISER.
      CALL FUNC(PHI00,HZETAM,XL)
C
C     EVALUATE THE P MATRIX FOR EACH FREQUENCY
      IOS = 0
C     EVALUATE NUMBER OF INCREMENTS
      NDIV = NINT(FREQH/DF)+ 1
C     INITIAL FREQUENCY FOR EVALUATION IS 0.01 RAD/SEC
      SIGMA = 0.01D0*TLENG*DSQRT(TMAXAV/TOMAX)
      DS = DF*TLENG*DSQRT(TMAXAV/TOMAX)
      N = 6
      DO 765 L=1,NDIV
      FREQ(L) = .01 + (L-1)*DF
C     EVALUATE MATRIX P
      CALL XMATR(P,SIGMA,IOS)
      IOS = 1
C     FIND ITS DETERMINANT USING NAG SUBROUTINE F03AAF (CROUT
C     FACTORISATION METHOD).
      DO 652 I=1,6
        DO 652 K=1,6
          A(I,K) = P(I,K)
  652 CONTINUE
      IFAI = 1
      CALL F03AAF(A,N,N,DET,WKSPCE,IFAI)
      SIGMA = SIGMA + DS
      PVALUE(L) = DET
  765 CONTINUE
      RETURN
      END
C
      SUBROUTINE FCNS(NS,XS,FVEC,IFLAG)
C     THIS SUBROUTINE EVALUATES THE FUNCTIONS FOR THE HORIZONTAL AND
```

```
C     VERTICAL DISPLACEMENT OF THE CABLE SOLUTION. IT IS USED BY NAG
C     SUBROUTINE C05NBF.
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/STAT1/XTOP,YTOP
      DIMENSION XS(NS),FVEC(NS)
C     LAMBDA AND C ARE UNKNOWNS
      XL = XS(1)
      XC = XS(2)
      XLINV = 1.D0/XL
      PHI00 = PHI0(0.D0,XL,XC)
      PHI01 = PHI0(1.D0,XL,XC)
C
      F1 = XLINV*(1.D0/DSIN(PHI00)-1.D0/DSIN(PHI01))
      F1 = F1-XTOP
      FVEC(1) = F1
C
      TT1 = DTAN(PHI01/2.D0)
      TT0 = DTAN(PHI00/2.D0)
      F2 = XLINV*DLOG(TT1/TT0)
      F2 = F2-YTOP
      FVEC(2) = F2
      RETURN
      END
C
      FUNCTION PHI0(S,XL,XC)
C     THIS FUNCTION EVALUATES PHI00 OF THE CABLE SOLUTION AS A FUNCTION
C     OF S, LAMBDA AND C.
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
C
      XVAR = -(XL*S+XC)
      PHI0 = DATAN(1.D0/XVAR)
      IF (XVAR.LT.0.D0) THEN
       PHI0 = PHI0 + XPI
      END IF
      RETURN
      END
C
      SUBROUTINE XMATR(P,SIGMA,IOS)
C     THIS SUBROUTINE EVALUATES THE 6X6 MATRIX P ELEMENTS
C     AT FREQUENCY SIGMA.
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/SLOW/F1(2),F2(2),F3(2),F4(2),F5(2),F6(2)
      COMMON/COEF/EPSETA(2),HZETAM,DXIM,VM,XL
      COMMON/OMA/OMAPP(2),PHI00(2)
      DIMENSION P(6,6)
C     EVALUATE ALL CONSTANT ELEMENTS (NOT A FUNCTION OF SIGMA)
      IF (IOS.EQ.0) THEN
        DO 881 I=1,6
         DO 881 K=1,6
           P(I,K) = 0.D0
  881   CONTINUE
        P(1,2) = DSIN(PHI00(1))**2
        P(1,3) = 1.D0
        P(1,5) = F1(1)
        P(1,6) = F2(1)
```

```
      P(2,2) = DSIN(2.D0*PHI00(1))
      P(2,3) = -1.D0/(DSQRT(EPSETA(1))*OMAPP(1))
      P(2,5) = F3(1)
      P(2,6) = F4(1)
      P(3,3) = 1.D0/(EPSETA(1)*OMAPP(1))
      P(3,5) = F5(1)
      P(3,6) = F6(1)
      P(4,4) = 1.D0
      P(4,5) = F1(2)
      P(4,6) = F2(2)
      P(5,4) = 1.D0/(DSQRT(EPSETA(2))*OMAPP(2))
      P(5,5) = F3(2)
      P(5,6) = F4(2)
      P(6,4) = 1.D0/(EPSETA(2)*OMAPP(2))
      P(6,5) = F5(2)
      P(6,6) = F6(2)
     END IF
C    EVALUATE ELEMENTS THAT ARE A FUNCTION OF SIGMA
     COSS = DCOS(SIGMA)
     SINS = DSIN(SIGMA)
     P(2,1) = SIGMA/XL
     P(3,1) = SIGMA*DSIN(PHI00(1)*2.D0)
     P(3,2) = - SIGMA**2/XL + 2.D0*OMAPP(1)*DCOS(2.D0*PHI00(1))
     P(4,1) = SINS*DSIN(PHI00(2))**2
     P(4,2) = COSS*DSIN(PHI00(2))**2
     P(5,1) = SINS*DSIN(PHI00(2)*2.D0) + SIGMA*COSS/XL
     P(5,2) = COSS*DSIN(PHI00(2)*2.D0) - SIGMA*SINS/XL
C
     P(6,1) = (2.D0*OMAPP(2)*DCOS(PHI00(2)*2.D0) - SIGMA**2/XL)*SINS
     P(6,1) = P(6,1) + SIGMA*COSS*DSIN(PHI00(2)*2.D0)
C
     P(6,2) = (2.D0*OMAPP(2)*DCOS(PHI00(2)*2.D0) - SIGMA**2/XL)*COSS
     P(6,2) = P(6,2) - SIGMA*SINS*DSIN(PHI00(2)*2.D0)
     RETURN
     END
C
     SUBROUTINE FUNC(PHI00,HZETAM,XL)
C    THIS SUBROUTINE EVALUATES THE FUNCTIONS THAT RESULT FROM THE
C    APPROXIMATE SLOW SOLUTION FOR IN-PLANE DYNAMICS OF COMPLIANT
C    RISERS. THIS SUBROUTINE EVALUATES THESE FUNCTIONS AT THE TWO ENDS
C    OF THE RISER.
     IMPLICIT REAL*8(A-H,O-Z)
     COMMON/SLOW/F1(2),F2(2),F3(2),F4(2),F5(2),F6(2)
     DIMENSION PHI00(2)
     XPI2 = 2.D0*DATAN(1.D0)
     H = HZETAM
     H2 = H**2
     DO 537 I=1,2
       COSPHI = DCOS(PHI00(I))
       SINPHI = DSIN(PHI00(I))
       COS2PH = DCOS(2.D0*PHI00(I))
       COSPH2 = COSPHI**2
       SINPH2 = SINPHI**2
C
       F1(I) = COSPHI*(1.D0+(H-1.D0)*COSPH2/6.D0*(3.D0+H)/20.D0*COSPH2)
       F1(I) = F1(I) + COSPHI*(H-1.D0)*COSPH2/6.D0*
```

```
C
      F2(I) = 1.D0 - H2 - H*(H-1.D0)/2.D0*COSPH2
      F2(I) = F2(I) + H2*(SINPHI + COSPHI*(XPI2 - PHI00(I)))
C
      F3(I) =-SINPHI*(H-1.D0)/2.D0*COSPH2*(1.D0+(3.D0+H)*COSPH2/12.D0)
      F3(I) = F3(I) - SINPHI
C
      F4(I) = SINPHI*(H*(H-1.D0)*COSPHI - H2*(XPI2 - PHI00(I)))
C
      F5(I) = 2.D0 - H + (H-1.D0)*(6.D0-H)*COSPH2/6.D0
      F5(I) = F5(I) + 5.D0/24.D0*(H-1.D0)*(H+3.D0)*COSPH2**2
      F5(I) = -F5(I)*XL*SINPH2*COSPHI
C
      F6(I) = H*(H-1)*COS2PH + H2*SINPHI - H2*(XPI2 - PHI00(I))*COSPHI
      F6(I) = XL*SINPH2*F6(I)
  537 CONTINUE
      RETURN
      END
```

Chapter XIV

Listing of Program RCLINDY1 FORTRAN A

```
C RCLINDY1
C THIS PROGRAM CALCULATES THE IN-PLANE LINEAR DYNAMIC RESPONSE OF A
C COMPLIANT RISER WITH A 2-D STATIC CONFIGURATION BASED ON AN
C EMBEDDING TECHNIQUE. THE PROGRAM PROVIDES AN INITIAL ANALYTIC
C APPROXIMATION WHICH IT SUBSEQUENTLY IMPROVES USING MODIFIED NEWTON'S
C ITERATION AND A NON-UNIFORM GRID FINITE DIFFERENCE METHOD.
C DOUBLE PRECISION AND THE NAG FORTRAN LIBRARY ARE USED.
C*********************************************************************
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C*********************************************************************
C PROGRAMMER  GEORGE A. KRIEZIS          JUNE 5, 1985       M.I.T.
C*********************************************************************
C
C DEFINITION OF DEVICES:
C DEVICE 5  : INPUT FROM TERMINAL
C DEVICE 6  : OUTPUT TO TERMINAL
C DEVICE 8  : INPUT FROM FILE PREPARED BY RCINPUT  (LRECL=80)
C DEVICE 9  : COMPLETE OUTPUT TO FILE  (LRECL=132)
C DEVICE 10 : INPUT FROM FILE CONTAINING N-D STATIC 2-D
C             SOLUTION CREATED BY RCSTAT2D  (LRECL=132)
C DEVICE 11 : OUTPUT TO FILE FOR PLOTS OR INPUT TO A NEW RUN
C             OF RCLINDY1  (LRECL=117)
C DEVICE 12 : INPUT FROM FILE CONTAINING APPROXIMATE N-D SOLUTION
C             CREATED BY A PREVIOUS RUN OF RCLINDY1  (LRECL=117)
C
C COMMON BLOCK CONTENTS (OVERALL REFERENCE):
C SOLUT  = INITIAL APPROXIMATION AND SOLUTION MATRICES
C STAT   = STATIC COMPLIANT RISER SOLUTION. (EFFECTIVE TENSION, SHEAR
C          FORCE, OMEGA ETA, PHIO, MAXIMUM STATIC EFFECTIVE TENSION,
C          MEAN CURRENT VELOCITY AND NUMBER OF STATIC DIVISION POINTS).
C STAT1  = X AND Y DISPLACEMENTS AT TOP OF RISER.
C STAT2  = FUNCTIONS OF STATIC RESULTS.
C INPUT0 = OUTPUT FILE HEADING
C INPUT1 = RISER LENGTH, AVERAGE AND TOTAL WEIGHT AND NUMBER OF SEGMENTS
C INPUT2 = RISER TUBE INTERIOR CHARACTERISTICS
C INPUTL = RISER SEGMENTS LENGTH
C INPUT3 = WEIGHT, STIFFNESSES AND STIFNESS DERIVATIVES.
C INPUT4 = CHARACTERISTIC DIAMETERS AND PERIMETER OF RISER TUBE.
C INPUT5 = MASS AND ADDED MASS CHARACTERISTICS IN THREE DIRECTIONS
C INPUT6 = RISER POLAR AND ADDED POLAR MOMENT OF INERTIA.
C COEF   = NONDIMENSIONAL RISER CHARACTERISTICS USED IN THE EQUATIONS
C COEF1  = NONDIMENSIONAL RISER CHARACTERISTICS AT A SPECIFIC POINT
C CONST  = PROBLEM CONSTANTS (PI, GRAVITY, WATER DENSITY)
C BOUNDA = BOUNDARY CONDITION FOR OMEGA ETA AT S=0
C COUN   = INTEGER COUNTING VARIABLE TO DETERMINE EACH DIVISION POINT
C MATRIX = MATRIX P FOR ESTIMATION OF THE APPROXIMATE NATURAL
C          FREQUENCIES.
C SLOW   = APPROXIMATE SLOW SOLUTION VECTORS
C OMA    = LAMBDA, PHIOO AND OMEGA ETA FOR THE CABLE APPROXIMATION
C
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4,IY=7)
      PARAMETER(LWORK=MNP*(3*N**2+6*N+2)+4*N**2+3*N)
      PARAMETER(LIWORK=MNP*(2*N+1)+N)
      DIMENSION WORK(LWORK),IWORK(LIWORK)
```

```
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COUN/ICOUNT
C     EXTERNAL SUBROUTINES USED BY NAG LIBRARY
      EXTERNAL FCN,G,JACEPS,JACGEP,JACOBF,JACOBG
      DATA NOUT /6/
C
C     READ2D READS 2-D STATIC SOLUTION CALCULATED FROM RCSTAT2D PROGRAM.
C     IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC EFFECTIVE TENSION
C
      CALL READ2D(NPI)
C
C     CHARAC READS RISER CHARACTERISTICS FROM UNIT 8 AND EVALUATES THE
C     NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE EQUATIONS.
C
      CALL CHARAC(TLENG,IC,NPI)
      IF(IC.EQ.0) STOP
C
C     DEFINITIONS OF PARAMETERS  ...
C     N   = NUMBER OF EQUATIONS TO BE SOLVED BY D02RAF
C     IY  = NUMBER OF VARIABLES
C     MNP= MAXIMUM NUMBER OF PERMITTED POINTS IN THE NON-UNIFORM
C     F.D. MESH ( MNP >= 32)
      IF(MNP.LT.32) THEN
        WRITE(6,1257) MNP
 1257   FORMAT(' MNP = ',I3,' IS NOT PERMISSIBLE')
        STOP
      ENDIF
C     NUMBER OF BOUNDARY CONDITIONS AT S=0
      NUMBEG=4
C     NUMBER OF MIXED BOUNDARY CONDITIONS
      NUMMIX=0
C     PARAMETER DECLARING THAT INITIAL APPROXIMATION IS USER SPECIFIED
      INIT=1
C     PARAMETER DECLARING THAT JACOBIANS ARE USER SPECIFIED
      IJAC=1
C     PARAMETER CONTROLLING MONITORING OF CALCULATIONS
      IFAIL=111
C
C
 1499 WRITE(6,1500)
 1500 FORMAT(' INPUT 1 IF YOU WISH TO READ INITIAL APPROXIMATION,'/
     *'          CREATED BY A PREVIOUS RUN OF THIS PROGRAM'/
     *' ELSE INPUT 0 (AN INITIAL APPROXIMATION WILL BE CALCULATED LOCALL
     *Y)')
      READ(5,*) IEXIST
      IF((IEXIST.NE.1).AND.(IEXIST.NE.0)) GOTO 1499
      IF(IEXIST.EQ.1) THEN
C
C       READAS : READS APPROXIMATE SOLUTION FROM DEVICE 10 FROM A
C                PREVIOUS RUN OF RCLINDY1 (DELEPS = 1.D0)
C                IT ALSO PROVIDES ICCC,NP, TOL= TOLERANCE OF ITERATIONS
C       THIS ALTERNATIVE MAY, FOR EXAMPLE, BE USED IF GREATER ACCURACY
C       IS REQUIRED FOR THE PROBLEM SOLUTION.
C
        CALL READAS(ICCC,NP,TOL)
```

```
C
C       IF THE NUMBER OF POINTS FROM THIS SOLUTION IS GREATER THAN THE
C       STATIC SOLUTION POINTS, INTERPOLATE ALL CHARACTERISTICS TO THE
C       NEW NUMBER OF POINTS.
C       ASSUMPTION : NP ALWAYS GREATER OR EQUAL TO NPI
C       THIS IS VALID IF THE SAME STATIC SOLUTION WAS USED TO OBTAIN THE
C       APPROXIMATE SOLUTION IN DEVICE 10.
C
        IF (NP.GE.NPI) THEN
          CALL INTERP(NP)
          NPI=NP
        ELSE IF (NP.LT.NPI) THEN
          WRITE(6,314)
314       FORMAT(' APPROXIMATE SOLUTION IN DEVICE 10 WAS NOT OBTAINED'/
     *    ' FROM THE SAME STATIC SOLUTION, PROGRAM STOPS')
          STOP
        END IF
        DELEPS = 1.D0
C
      ELSE
C
C       INCREMENT OF CONTINUATION PARAMETER
7891  WRITE(6,7890)
7890  FORMAT(' INPUT INITIAL INCREMENT OF CONTINUATION PARAMETER DELEPS'
     */' IF NO CONTINUATION IS REQUIRED INPUT DELEPS = 1.D0'/
     *' IF CONTINUATION IS REQUIRED THEN 0.D0 < DELEPS < 1.D0'/
     *' RECOMMENDATION :'/
     *' USUALLY DELEPS = 0.1D0 WILL SUFFICE'/
     *' FOR LARGE CHANGES BETWEEN INITIAL AND FINAL PROBLEM'/
     *' A SMALLER VALUE OF DELEPS, E.G. 0.05D0 OR 0.025D0 MIGHT BE'/
     *' NECESSARY')
      READ(5,*) DELEPS
      IF((DELEPS.GT.1.D0).OR.(DELEPS.LE.0.D0)) THEN
        WRITE(6,7892)
7892    FORMAT(' 0. <  DELEPS  <= 1.')
        GOTO 7891
      ENDIF
C
C     APPROX : PROVIDES INITIAL APPROXIMATE SOLUTION FOR EPS=0.
C              IT ALSO PROVIDES ICCC,NP, TOL.
C
      CALL APPROX(TLENG,ICCC,NPI,TOL)
      NP = NPI
C
      ENDIF
C     SET COUNTING VARIABLE
      ICOUNT = 1
      IF(ICCC.EQ.0) STOP
C
      CALL X04AAF(1,NOUT)
      CALL X04ABF(1,NOUT)
C
C     CALL NAG SUBROUTINE D02RAF TO SOLVE THE TWO-POINT BOUNDARY VALUE
C     PROBLEM USING A DEFERRED CORRECTION TECHNIQUE AND NEWTON'S
C     ITERATION.
C
```

```
      CALL D02RAF(N,MNP,NP,NUMBEG,NUMMIX,TOL,INIT,X,Y,IY,ABT,FCN,G,IJAC,
     *JACOBF,JACOBG,DELEPS,JACEPS,JACGEP,WORK,LWORK,IWORK,LIWORK,IFAIL)
C
      WRITE(6,9000) IFAIL
9000  FORMAT(' IFAIL =',I3)
C
C     OUTPUT THE RESULTS
C
      IF((IFAIL.EQ.0).OR.(IFAIL.EQ.4)) THEN
        CALL OUTPUT(NP)
      ENDIF
C
      STOP
      END

      SUBROUTINE CHARAC(TLENG,IC,NP)
C     THIS SUBROUTINE READS THE COMPLIANT RISER CHARACTERISTICS AND
C     EVALUATES THE NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE
C     GOVERNING EQUATIONS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      CHARACTER*80 NAME
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/INPUT0/NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUT2/RHOO,AI,CFLUID,PRESS,AO(MNP)
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/INPUT3/WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP)
     *,EIXIS(MNP),GIP(MNP),GIPS(MNP)
      COMMON/INPUT4/DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP)
      COMMON/INPUT5/RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(
     *MNP),TMAXI(MNP),TMAZI(MNP)
      COMMON/INPUT6/XJZI(MNP),AJZI(MNP),TJZI(MNP)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION TENO(MNP),QXO(MNP),TOS(MNP),QXIOS(MNP)
C
C     READ RISER CHARACTERISTICS FROM DEVICE 8
      READ (8,1000) NAME
1000  FORMAT(80A)
      READ (8,1008) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
1008  FORMAT(1X,I3,2(1X,D12.6)/4(1X,D12.6))
      TLENG = TLEN
      DO 1502 I=1,NSEG
      READ (8,1003) RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI(I
     *),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
1502  CONTINUE
1003  FORMAT(5(1X,D12.6)/6(1X,D12.6))
C
      DO 1332 I=1,NSEG
      READ(8,1333) AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),AMA
     *ZI(I),XJZI(I),AJZI(I)
1332  CONTINUE
```

```
 1333 FORMAT(6(1X,D12.6)/3(1X,D12.6))
C
      IC=1
C
 7650 WRITE(6,7651)
 7651 FORMAT(' DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS'/
     *' IF YES INPUT 1 , IF NO INPUT 0')
      READ(5,*) IPRINT
      IF((IPRINT.NE.1).AND.(IPRINT.NE.0)) GOTO 7650
      IF(IPRINT.EQ.1) THEN
C
      WRITE(6,1000) NAME
      WRITE(6,2500)
 2500 FORMAT(' NSEG   TLEN          WA           RHOO          AI
     * CFLUID        PRESS')
      WRITE(6,2001) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
 2001 FORMAT(1X,I3,6(1X,D12.6))
      WRITE(6,3400)
 3400 FORMAT('   I    RLENG         RMASS        RMASST        AMAXI
     *  WEIGHT'   /'          DXI           PXIETA           EA          EIETA
     *          AO         EIETAS')
      DO 3002 I=1,NSEG
      WRITE(6,3003) I,RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI
     *(I),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
 3002 CONTINUE
 3003 FORMAT(1X,I3,5(1X,D12.6)/4X,6(1X,D12.6))
C
      WRITE(6,1334)
 1334 FORMAT('   I   AMAETA         DETA         EIXI          EIXIS
     *   GIP         GIPS'/'        AMAZI          JZI           AJZI' )
      DO 1335 I=1,NSEG
      WRITE(6,1336) I,AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),
     *AMAZI(I),XJZI(I),AJZI(I)
 1335 CONTINUE
 1336 FORMAT(1X,I3,6(1X,D12.6)/4X,3(1X,D12.6))
C
 1701 WRITE(6,1700)
 1700 FORMAT(' INPUT 1 IF RISER DATA ARE CORRECT'/' INPUT 0 TO STOP')
      READ(5,*) IC
      IF((IC.NE.0).AND.(IC.NE.1)) GOTO 1701
      IF(IC.EQ.0) RETURN
C
      ENDIF
C
C     NON - DIMENSIONALIZATIONS
C
      GRAV=9.81D0
      WAM=WA/GRAV
      WT=WA*TLEN
      XPI=4.D0*DATAN(1.D0)
      XPI2=XPI/2.D0
      RHOW=1.025D3
C
C     NONDIMENSIONALIZE CORRECTLY QXIO, TO  FROM 2-D STATIC SOLUTION
C
      TOMAX = TOMAX*WT
```

```
      TND = WT/TOMAX
      DO 229 I=1,NP
        STATIC(1,I) = STATIC(1,I)*TND
        STATIC(2,I) = STATIC(2,I)*TND
  229 CONTINUE
C
C     NONDIMENSIONAL COEFFICIENTS USED IN THE EQUATIONS
C
      TOMAXL = TOMAX/TLEN
      TOML1  = TOMAX*TLEN
      TOML2  = TOML1*TLEN
      TLEN2  = TLEN**2
      TMAXAV = 0.D0
      DXIM = 0.D0
      DO 2000 I=1,NSEG
       RLENG(I)=RLENG(I)/TLEN
       WEIGHT(I)=WEIGHT(I)/TOMAXL
       EOM(I) = TOMAX/EA(I)
       EPSETA(I) = EIETA(I)/TOML2
       EPSETS(I) = EIETAS(I)/TOML1
       TJZI(I) = XJZI(I) + AJZI(I)
       TMAZI(I) = RMASS(I) + AMAZI(I)
       TMAXI(I) = RMASS(I) + AMAXI(I)
       TMAXAV = TMAXI(I)*RLENG(I) + TMAXAV
       DXIM = DXIM + DXI(I)*RLENG(I)
       DXIETA(I) = DXI(I)-DETA(I)
 2000 CONTINUE
      HZETAM = 0.D0
      DO 4321 I=1,NSEG
       HZETA(I) = TMAZI(I)/TMAXAV
       HZETAM = HZETAM + HZETA(I)*RLENG(I)
       HXI(I) = TMAXI(I)/TMAXAV
 4321 CONTINUE
C
C      CALCULATE DERIVATIVES OF STATIC QUANTITIES
       DO 737 I=1,NP
        TENO(I) = STATIC(1,I)
        QXO(I) = STATIC(2,I)
  737  CONTINUE
       CALL DER1(TENO,XI,TOS,NP)
       CALL DER1(QXO,XI,QXIOS,NP)
C      EVALUATE FUNCTIONS OF STATIC RESULTS
       DO 56 I=1,NP
        CONST1(I) = TOS(I) - STATIC(2,I)*STATIC(3,I)
        CONST2(I) = QXIOS(I) + STATIC(1,I)*STATIC(3,I)
   56  CONTINUE
C
C     SEG(I)=LEFT ORDINATE OF SEGMENT I
      SEG(1)=0.D0
      SEG(NSEG+1)=1.D0
      DO 4000 I=2,NSEG
      SEG(I)=RLENG(I-1)+SEG(I-1)
 4000 CONTINUE
C     INTRERPOLATE STRUCTURAL DIMENSIONS TO NP POINTS
C     ASSUMPTION: NUMBER OF RISER SEGMENTS WITH DIFFERENT
C     CHARACTERISTICS IS SMALLER THAN THE STATIC SOLUTION POINTS
```

```
C     NSEG < NPI
C
      IF (NSEG.GE.NPI) THEN
        WRITE(6,188)
 188    FORMAT(' NSEG => NPI, PROGRAM STOPS')
        IC = 0
        RETURN
      END IF
      CALL STRUCT(EPSETA,X,NP)
      CALL STRUCT(EPSETS,X,NP)
      CALL STRUCT(EOM,X,NP)
      CALL STRUCT(HZETA,X,NP)
      CALL STRUCT(HXI,X,NP)
      RETURN
      END
C
      SUBROUTINE READ2D(NP)
C     THIS SUBROUTINE READS THE STATIC COMPLIANT RISER SOLUTION FROM
C     DEVICE 10. IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC TENSION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/XTOP,YTOP
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION XCOOR(MNP),YCOOR(MNP)
C
C     STATIC(1,I) = STATIC EFFECTIVE TENSION TO
C     STATIC(2,I) = STATIC SHEAR FORCE IN THE XI DIRECTION
C     STATIC(3,I) = STATIC OMEGA AROUND ETA DIRECTION
C     STATIC(4,I) = STATIC ANGLE PHI
C
      WRITE(6,2000) MNP
 2000 FORMAT(' MNP=',I3)
C     READ STATIC SOLUTION
      READ(10,36459) NP,VM
36459 FORMAT(1X,I3,1X,D12.6)
      WRITE(6,2311) NP,VM
 2311 FORMAT(' 2-D STATIC SOLUTION FROM DEVICE 10'/
     *' NP =',I3/
     *' MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =',D12.6)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING FROM DEVICE 10
C
      DO 1021 I=1,NP
      READ(10,1033) X(I),STATIC(1,I),STATIC(2,I),STATIC(3,I),STATIC(4,I)
     *,XCOOR(I),YCOOR(I),STRARC,TENSI,VLOCXI(I)
      XI(I) = X(I)
 1021 CONTINUE
 1033 FORMAT(10(1X,D12.6))
```

```
C     EVALUATE RISER TOP X AND Y DISPLACEMENTS
      XTOP = XCOOR(NP)
      YTOP = YCOOR(NP)
C     EVALUATE MAXIMUM STATIC EFFECTIVE TENSION
      TOMAX=DMAX1(STATIC(1,1),STATIC(1,2))
      DO 9859 I=3,NP
        TOMAX = DMAX1(TOMAX,STATIC(1,I))
9859  CONTINUE
C
      WRITE(6,1654) TOMAX
1654  FORMAT(' 2-D STATIC SOLUTION SUCCESFULLY READ'/' MAXIMUM STATIC EF
     *FECTIVE TENSION/WA*L = ',D10.4)
C
      RETURN
      END

      SUBROUTINE READAS(ICCC,NP,TOL)
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/XTOP,YTOP
      COMMON/BOUNDA/BOUND
C
C      READAS READS INITIAL APPROXIMATION RESULTING FROM A PREVIOUS
C      RUN OF RCLINDY1 (CORRESPONDS TO EPS = 1.D0)
C
C      Y(1,I)  = DYNAMIC TENSION
C      Y(2,I)  = SHEAR FORCE IN THE XI DIRECTION
C      Y(3,I)  = OMEGA ABOUT ETA
C      Y(4,I)  = DYNAMIC ANGLE PHI
C      Y(5,I)  = DISPLACEMENT IN THE ZI DIRECTION, P (TANGENTIAL)
C      Y(6,I)  = DISPLACEMENT IN THE XI DIRECTION, Q (NORMAL)
C      Y(7,I)  = NATURAL FREQUENCY
C      X(I)    = UNSTRETCHED ARC LENGTH S
C
      WRITE(6,2000) MNP
2000  FORMAT(' MNP=',I3)
C     READ SOLUTION FROM DEVICE 12
      READ(12,36459) MODE,NP,SIGMAD,XTOP,YTOP
36459 FORMAT(1X,I2,1X,I3,3(1X,D10.4))
      WRITE(6,2311) NP,MODE,SIGMAD,XTOP,YTOP
2311  FORMAT(' INITIAL APPROXIMATION FROM DEVICE 12'/
     *' NP =',I3,' MODE NUMBER =',I2,' SIGMAD =',D10.4/' X AT TOP =',
     *D10.4,' Y AT TOP =',D10.4)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING DATA FROM DEVICE 12 ...
C
      DO 10011 I=1,NP
```

```
      READ(12,10012) X(I),(Y(J,I),J=1,7),VLOCXI(I)
10011 CONTINUE
10012 FORMAT(9(1X,D12.6))
C     SET BOUNDARY CONDITION OMEGA ETA(0)
      BOUND = Y(3,1)
C
      WRITE(9,1052) NP,SIGMAD
 1052 FORMAT(' INITIAL CONDITION FOR EPS=1. AND NP = ',I3,' POINTS,  NAT
     *URAL FREQUENCY = ',D10.4,' RAD/S'/
     *'   I     ARC         TENSION         QXI        OMEGA ETA        PHI
     *          P             Q             SIGMA')
      DO 1601 I=1,NP
       WRITE(9,1603) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     * Y(7,I)
 1601 CONTINUE
 1603 FORMAT(1X,I3,8(1X,D12.6))
C
      WRITE(6,9561)
 9561 FORMAT(' DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION'/
     *' IF YES INPUT 1')
      READ(5,*)IPRINT
      IF(IPRINT.EQ.1) THEN
       WRITE(6,1052) NP
       DO 9659 I=1,NP
        WRITE(6,1603) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     *  Y(7,I)
 9659  CONTINUE
      END IF
      WRITE(6,1722) BOUND
 1722 FORMAT(' ASSUMED BOUNDARY CONDITION '/
     *' OMEGA ETA (0) =',D12.6)
C
      TOL1 = 0.D0
      DO 3933 I=1,NP
        TOL1 = DMAX1(TOL1,DABS(Y(3,I)))
 3933 CONTINUE
      WRITE(6,3934) TOL1
 3934 FORMAT(' MAXIMUM ABSOLUTE VALUE OF N-D OMEGA ETA IS =',D12.6/
     *' THIS NUMBER CAN BE USED TO ESTIMATE '/
     *' A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS'/
     *' INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE'/
     *' E.G. INPUT 0.01 FOR 1% ACCURACY')
      READ(5,*) TOLV
      TOL = DABS(TOLV)*TOL1
C
 1005 WRITE(6,1004)
 1004 FORMAT(' IF YOU WISH TO STOP INPUT 0'/
     *' IF YOU WISH TO CONTINUE WITH ITERATIONS INPUT 1')
      READ(5,*) ICCC
      IF((ICCC.NE.0).AND.(ICCC.NE.1)) GOTO 1005
C
      RETURN
      END
C
      SUBROUTINE APPROX(TLENG,ICCC,NP,TOL)
C     THIS SUBROUTINE EVALUATES THE APPROXIMATE ASYMPTOTIC ANALYTIC
```

```
C     SOLUTION OF THE IN-PLANE DYNAMIC EQUATIONS.
C     THE SOLUTION CONSISTS OF A SLOW AND A FAST PART.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/SOLUT/ X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/MATRIX/P(6,6),IOS
      COMMON/OMA/OMAPP(MNP),PHI00(MNP),XL
      DIMENSION FVEC(2),XS(2),WAS(19),FVEC1(1),XSS(1),WAS1(8)
      DIMENSION A(5,5),B(5),C(5),AA(5,5),WKS1(5),WKS2(5)
      EXTERNAL FCNS,FCNSS
C
C     APPROX DEFINES INITIAL APPROXIMATION (EPS=0.)
C
C     Y(1,I) = DYNAMIC TENSION
C     Y(2,I) = SHEAR FORCE IN THE XI DIRECTION
C     Y(3,I) = OMEGA ABOUT ETA
C     Y(4,I) = DYNAMIC ANGLE PHI
C     Y(5,I) = DISPLACEMENT P IN THE ZETA DIRECTION (TANGENTIAL)
C     Y(6,I) = DISPLACEMENT Q IN THE XI DIRECTION (NORMAL)
C     Y(7,I) = NATURAL FREQUENCY
C
C     DETERMINATION OF THE CABLE APPROXIMATION OF 2-D STATIC SOLUTION
C     THE POWELL HYBRID METHOD IS USED (SEE PROGRAM RCSTAT2D FOR
C     DETAILS FOR THE SLOW SOLUTION)
      WRITE(6,1781)
 1781 FORMAT(' INPUT NORMAL DRAG COEFFICIENT USED IN STATIC SOLUTION')
      READ(5,*)CD
      XK = 0.5D0*RHOW*DXIM*CD*VM*DABS(VM)*TLENG
      WRITE(6,8881) VM,CD
 8881 FORMAT(' MEAN CURRENT SPEED =',D12.6/' NORMAL DRAG COEFFICIENT =',
     *D12.6)
C
 2601 WRITE(6,1501)
 1501 FORMAT(' INPUT ESTIMATES OF LAMBDA AND C'/
     *' LAMBDA MUST HAVE THE SIGN OF MEAN CURRENT SPEED'/
     *'  FOR SMALL XTOP A GOOD ESTIMATE OF C IS -0.5*LAMBDA')
      READ(5,*) XL,XC
C
      XS(1) = XL
      XS(2) = XC
      XTOL  = 1.D-8
      NS = 2
      LWA = 19
C
C     CALL NAG SUBROUTINE C05NBF TO DETERMINE THE CABLE APPROXIMATION
      IFAIL = 0
      CALL C05NBF(FCNS,NS,XS,FVEC,XTOL,WAS,LWA,IFAIL)
C
      WRITE(6,1356) IFAIL,XS(1),XS(2)
 1356 FORMAT(' SOLUTION FOR CABLE ...'/' IFAIL =',I2/
     *' LAMBDA =',D12.6/
     *' C      =',D12.6)
```

```
C
      WRITE(6,2500) FVEC(1),FVEC(2)
 2500 FORMAT(' VALUE OF FUNCTION FOR HORIZONTAL DISPLACEMENT =',D12.6/
     *' VALUE OF FUNCTION FOR VERTICAL DISPLACEMENT =',D12.6/
     *' DO YOU WISH TO TRY A DIFFERENT INITIAL LAMDA, C, OR TOLERANCE'/
     *' IF YES INPUT 1')
      READ(5,*) IPP
      IF (IPP.EQ.1) GO TO 2601
      IF (IFAIL.NE.0) GO TO 2601
C
      XL = XS(1)
      XC = XS(2)
      TE = XK/XL
      WRITE(6,1654) XL,XC,TE
 1654 FORMAT(' CABLE APPROXIMATION '/
     *' LAMBDA =',D12.6,' C =',D12.6,' TENSION =',D12.6)
C
C     DETERMINE SERIES PHI00 AND OMEGA ETA USING THE CABLE APPROXIMATION
C
      DO 1239 I=1,NPI
        S = XI(I)
        PHI00(I) = PHI0(S,XL,XC)
        OMAPP(I)=XL*DSIN(PHI00(I))**2
 1239 CONTINUE
C
C     CALCULATE FUNCTIONS F THAT DETERMINE THE SLOW DYNAMIC SOLUTION
C
      CALL FUNC(PHI00,HZETAM,XL,NPI)
C
C     DETERMINE THE INITIAL APPROXIMATION TO THE NATURAL FREQUENCY
C     DETERMINANT OF THE 6X6 MATRIX P SHOULD BE ZERO.
      IOS = 0
      NSS = 1
      LWA1 = 8
   23 WRITE(6,*) ' INPUT INITIAL GUESS FOR SIGMA IN RAD/S'
      READ(5,*) XSS(1)
C     NONDIMENSIONALIZE SIGMA
      XSS(1) = XSS(1)*TLENG*DSQRT(TMAXAV/TOMAX)
      XTOL = 1.D-8
      IFAIL = 0
C
C     CALL C05NBF TO EVALUATE SIGMA USING A MODIFICATION OF THE POWELL
C     HYBRID METHOD
      CALL C05NBF(FCNSS,NSS,XSS,FVEC1,XTOL,WAS1,LWA1,IFAIL)
      WRITE(6,*) ' IFAIL FOR APPROXIMATE EVALUATION OF SIGMA IS ',IFAIL
      SIGMAD = XSS(1)*DSQRT(TOMAX/TMAXAV)/TLENG
C
      WRITE(6,24) FVEC1(1),SIGMAD
   24 FORMAT(1X,'THE DETERMINANT IS = ',D10.4/' THE CONVERGED SIGMA IS '
     *,D10.4/' INPUT 1 IF YOU WANT TO REDO THE CALCULATION'/' INPUT 2 IF
     * YOU WANT TO STOP')
      READ(5,*)ISIGMA
      IF (ISIGMA.EQ.1) THEN
       GO TO 23
      ELSE IF (ISIGMA.EQ.2) THEN
       ICCC = 0
```

```
        RETURN
       END IF
       SIGMA = XSS(1)
       WRITE(6,*) ' INPUT MODE NUMBER CORRESPONDING TO ABOVE APPROXIMATE
     *SIGMA'
       READ(5,*) MODE
C
C      ELIMINATE ONE ROW AND ONE COLUMN FROM P MATRIX, AND DETERMINE
C      THE LINEAR SYSTEM OF EQUATIONS TO SOLVE FOR THE CONSTANT
C      COEFFICIENTS OF THE APPROXIMATE SOLUTION. (SET A1=1.)
C
       CALL XMATR(P,SIGMA,IOS)
       DO 750 K=1,5
        DO 751 I=2,6
         A(K,I-1) = P(K,I)
  751   CONTINUE
        B(K) = -P(K,1)
  750 CONTINUE
C
C      USE NAG SUBROUTINE F04ATF TO SOLVE THE LINEAR SYSTEM TO DETERMINE
C      THE CONSTANT COEFFICIENTS USING CROUT'S FACTORISATION METHOD.
C
       IFA = 0
       IA = 5
       CALL F04ATF(A,IA,B,IA,C,AA,IA,WKS1,WKS2,IFA)
       WRITE(6,*) ' IFAIL FOR THE EVALUATION OF CONSTANT COEFFICIENTS IS'
     *,IFA
       WRITE(6,863) (C(I),I=1,IA)
  863 FORMAT(' CONSTANT COEFFICIENTS ARE:'/' A1 = 1.00          B1 =',
     *D10.4/' G1 =',D10.4,'  D1 =',D10.4/' C1 =',D10.4,'  C2 =',D10.4)
C      CHECK IF SIXTH EQUATION IS SATISFIED
       TEST = P(6,1)
       DO 766 I=1,5
        TEST = TEST + P(6,I+1)*C(I)
  766  CONTINUE
       WRITE(6,775) TEST
  775  FORMAT(' SIXTH EQUATION = ',D10.4)
C
C      CALL SUBROUTINES TO EVALUATE INITIAL APPROXIMATION
       CALL INITAP(C,SIGMA,NP)
C      OUTPUT INITIAL APPROXIMATION TO DEVICE 9
       WRITE(9,1002) NP,SIGMAD
 1002 FORMAT(' INITIAL CONDITION FOR EPS=0. AND NP = ',I3,' POINTS,  NAT
     *URAL FREQUENCY = ',D10.4,' RAD/SEC'/
     *'   I      ARC        TENSION      SHEAR XI      OMEGA ETA      PHI1
     *          P             Q            SIGMA')
       DO 1001 I=1,NP
        WRITE(9,1003) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     * Y(7,I)
 1001 CONTINUE
 1003 FORMAT(1X,I3,8(1X,D12.6))
C
       WRITE(6,7561)
 7561 FORMAT(' DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION'/
     *' IF YES INPUT 1')
       READ(5,*)IPRINT
```

```
      IF(IPRINT.EQ.1) THEN
       WRITE(6,1002) NP,SIGMAD
       DO 7659 I=1,NP
        WRITE(6,1003) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     *  Y(7,I)
 7659  CONTINUE
      END IF
C
      TOL1 = 0.D0
      DO 3931 I=1,NP
        TOL1 = DMAX1(TOL1,DABS(Y(3,I)))
 3931 CONTINUE
      WRITE(6,3932) TOL1
 3932 FORMAT(' MAXIMUM ABSOLUTE VALUE OF N-D OMEGA ETA IS =',D12.6/
     *' THIS NUMBER CAN BE USED TO ESTIMATE '/
     *' A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS'/
     *' INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE'/
     *' E.G. INPUT 0.01 FOR 1% ACCURACY')
      READ(5,*) TOLV
      TOL = DABS(TOLV)*TOL1
      WRITE(6,*) ' IF YOU WANT TO STOP INPUT 0'
      READ(5,*) ICCC
      IF (ICCC.NE.0) ICCC = 1
C
      RETURN
      END
C
      SUBROUTINE FCNS(NS,XS,FVEC,IFLAG)
C     THIS SUBROUTINE IS USED BY NAG ROUTINE C05NBF TO DETERMINE THE
C     CABLE APPROXIMATION.
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/STAT1/XTOP,YTOP
      DIMENSION XS(NS),FVEC(NS)
C
      XL = XS(1)
      XC = XS(2)
      XLINV = 1.D0/XL
      PHI00 = PHI0(0.D0,XL,XC)
      PHI01 = PHI0(1.D0,XL,XC)
C
      F1 = XLINV*(1.D0/DSIN(PHI00)-1.D0/DSIN(PHI01))
      F1 = F1-XTOP
      FVEC(1) = F1
C
      TT1 = DTAN(PHI01/2.D0)
      TT0 = DTAN(PHI00/2.D0)
      F2 = XLINV*DLOG(TT1/TT0)
      F2 = F2-YTOP
      FVEC(2) = F2
      RETURN
      END
C
      FUNCTION PHI0(S,XL,XC)
C     THIS FUNCTION EVALUATES PHI00 GIVEN S, LAMBDA AND C
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
```

```
C
      XVAR = -(XL*S+XC)
      PHIO = DATAN(1.DO/XVAR)
      IF (XVAR.LT.O.DO) THEN
       PHIO = PHIO + XPI
      END IF
      RETURN
      END
C
      SUBROUTINE FCNSS(NSS,XSS,FVEC1,IFLAG)
C     THIS SUBROUTINE IS USED BY NAG ROUTINE C05NBF TO EVALUATE THE
C     DETERMINANT OF MATRIX P AND SOLVE FOR THE APPROXIMATE NATURAL
C     FREQUENCY.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=6)
      COMMON/MATRIX/ P(6,6),IOS
      DIMENSION XSS(NSS),FVEC1(NSS),A(N,N),WKSPCE(N)
C     CREATE THE MATRIX P
      SIGMA = XSS(1)
      CALL XMATR(P,SIGMA,IOS)
      IOS = 1
C     FIND ITS DETERMINANT USING NAG SUBROUTINE F03AAF (CROUT
C     FACTORISATION METHOD).
      DO 652 I=1,6
        DO 652 K=1,6
         A(I,K) = P(I,K)
  652 CONTINUE
      IFAI = 1
      CALL F03AAF(A,N,N,DET,WKSPCE,IFAI)
      WRITE(6,842) IFAI,DET
  842 FORMAT(' IFAIL FOR THE DETERMINANT OF P =',I2/' DET =',D12.6)
C
      FVEC1(1) = DET
      RETURN
      END
C
      SUBROUTINE XMATR(P,SIGMA,IOS)
C     THIS SUBROUTINE EVALUATES THE MATRIX P(6,6) ELEMENTS
C     AT FREQUENCY SIGMA.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),HR
     *ZETAM,TMAXAV,DXIM
      COMMON/SLOW/F1(MNP),F2(MNP),F3(MNP),F4(MNP),F5(MNP),F6(MNP)
      COMMON/OMA/OMAPP(MNP),PHI00(MNP),XL
      DIMENSION P(6,6)
C     EVALUATE ALL CONSTANT ELEMENTS (NOT A FUNCTION OF SIGMA)
      IF (IOS.EQ.0) THEN
        SINP0 = DSIN(PHI00(1))
        SINP1 = DSIN(PHI00(NPI))
        SIN2P0 = DSIN(2.DO*PHI00(1))
        SIN2P1 = DSIN(2.DO*PHI00(NPI))
        COSP0 = DCOS(PHI00(1))
        COSP1 = DCOS(PHI00(NPI))
        COS2P0 = DCOS(2.DO*PHI00(1))
```

```
      COS2P1 = DCOS(2.D0*PHI00(NPI))
      DO 881 I=1,6
       DO 881 K=1,6
         P(I,K) = 0.D0
  881 CONTINUE
      P(1,2) = SINP0**2
      P(1,3) = 1.D0
      P(1,5) = F1(1)
      P(1,6) = F2(1)
      P(2,2) = SIN2P0
      P(2,3) = -1.D0/(DSQRT(EPSETA(1))*OMAPP(1))
      P(2,5) = F3(1)
      P(2,6) = F4(1)
      P(3,3) = 1.D0/(EPSETA(1)*OMAPP(1))
      P(3,5) = F5(1)
      P(3,6) = F6(1)
      P(4,4) = 1.D0
      P(4,5) = F1(NPI)
      P(4,6) = F2(NPI)
      P(5,4) = 1.D0/(DSQRT(EPSETA(NPI))*OMAPP(NPI))
      P(5,5) = F3(NPI)
      P(5,6) = F4(NPI)
      P(6,4) = 1.D0/(EPSETA(NPI)*OMAPP(NPI))
      P(6,5) = F5(NPI)
      P(6,6) = F6(NPI)
   END IF
C     EVALUATE ELEMENTS THAT ARE A FUNCTION OF SIGMA
   COSS = DCOS(SIGMA)
   SINS = DSIN(SIGMA)
   P(2,1) = SIGMA/XL
C
   P(3,1) = SIGMA*SIN2P0
   P(3,2) = - SIGMA**2/XL + 2.D0*OMAPP(1)*COS2P0
C
   P(4,1) = SINS*SINP1**2
   P(4,2) = COSS*SINP1**2
C
   P(5,1) = SIGMA*COSS/XL + SIN2P1*SINS
   P(5,2) = -SIGMA*SINS/XL + SIN2P1*COSS
C
   P(6,1) = SINS*(2.D0*OMAPP(NPI)*COS2P1 - SIGMA**2/XL)
   P(6,1) = P(6,1) + SIGMA*COSS*SIN2P1
   P(6,2) = COSS*(-SIGMA**2/XL + 2.D0*OMAPP(NPI)*COS2P1)
   P(6,2) = P(6,2) - SIGMA*SIN2P1*SINS
   RETURN
   END
C
   SUBROUTINE INITAP(C,SIGMA,NP)
   IMPLICIT REAL*8(A-H,O-Z)
   PARAMETER(N=7,MNP=151,NA=4)
   COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
   COMMON/STAT2/CONST1(MNP),CONST2(MNP)
   COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
   COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
  *ZETAM,TMAXAV,DXIM
   COMMON/SLOW/F1(MNP),F2(MNP),F3(MNP),F4(MNP),F5(MNP),F6(MNP)
```

```
      COMMON/BOUNDA/BOUND
      COMMON/OMA/OMAPP(MNP),PHI00(MNP),XL
      DIMENSION P(MNP),Q(MNP),QS(MNP),A1(MNP),C(5),PHI1(MNP)
      DIMENSION OMETA1(MNP),OMET1S(MNP),Y2(MNP),Y2S(MNP)
C
C     THIS SUBROUTINE CALCULATES THE INITIAL APPROXIMATION OF THE
C     SOLUTION ONCE SIGMA AND THE CONSTANT COEFFICIENTS ARE DETERMINED.
C
      DO 444 K=1,NP
       Y(7,K) = SIGMA
 444  CONTINUE
C
C     IBM RANGE OF A REAL*8 NUMBER SO THAT DEXP(X) IS REAL*8
C     CONDITION XMINR<X. USE A STRICTER LIMIT.
C
      XMINR=-65.D0*DLOG(16.D0)
      XMINR=XMINR/3.D0
C
C     CALCULATE THE IN PLANE DISPLACEMENTS P AND Q AS WELL AS QS
C     (ANALYTIC EXPRESSIONS)
C
      XNU1 = DSQRT(EPSETA(1))
      XNU2 = DSQRT(EPSETA(NP))
      DO 815 I=1,NP
       SIG = SIGMA*X(I)
       COSS = DCOS(SIG)
       SINS = DSIN(SIG)
       SINP = DSIN(PHI00(I))
       COSP = DCOS(PHI00(I))
       SIN2P = DSIN(PHI00(I)*2.D0)
       COS2P = DCOS(PHI00(I)*2.D0)
       SINP2 = SINP**2
       POWER1 = -X(I)/XNU1
       POWER2 = -(1-X(I))/XNU2
       IF (POWER1.GT.XMINR) THEN
         EXPO1 = DEXP(POWER1)
       ELSE
         EXPO1 = 0.D0
       END IF
       IF (POWER2.GT.XMINR) THEN
         EXPO2 = DEXP(POWER2)
       ELSE
         EXPO2 = 0.D0
       END IF
C      CALCULATE P
C
       P(I) = SINS*SINP2 + C(1)*COSS*SINP2 + C(2)*EXPO1 + C(3)*EXPO2
       P(I) = P(I) + C(4)*F1(I) + C(5)*F2(I)
C      CALCULATE Q
C
       Q(I) = SIGMA*COSS/XL + SIN2P*SINS
       Q(I) = Q(I) + C(1)*(-SIGMA*SINS/XL + SIN2P*COSS)
       Q(I) = Q(I) - C(2)*EXPO1/(XNU1*OMAPP(I)) + C(4)*F3(I)
       Q(I) = Q(I) + C(3)*EXPO2/(XNU2*OMAPP(I)) + C(5)*F4(I)
C      CALCULATE QS
C
```

```
      D1 = SINS*(2.D0*OMAPP(I)*COS2P - SIGMA**2/XL)
      D1 = D1 + SIGMA*SIN2P*COSS
C
      D2 = COSS*(- SIGMA**2/XL + 2.D0*OMAPP(I)*COS2P)
      D2 = D2 - SIN2P*SIGMA*SINS
C
      QS(I) = D1 + C(1)*D2 + C(2)*EXPO1/(XNU1**2*OMAPP(I)) + C(4)*F5(I)
      QS(I) = QS(I) + C(3)*EXPO2/(XNU2**2*OMAPP(I)) + C(5)*F6(I)
C
      A1(I) = P(I)**2*HZETAM + Q(I)**2
  815 CONTINUE
C     CALCULATE THE ORTHONORMALIZING CONSTANT FOR P AND Q
      A = 0.D0
      DO 842 I=2,NP
        DX2 = (X(I)-X(I-1))*0.5D0
        A = A + (A1(I)+A1(I-1))*DX2
  842 CONTINUE
      A = DSQRT(A)
C     ORTHONORMALIZE P, Q AND QS AND DETERMINE PHI1
      DO 843 I=1;NP
       P(I) = P(I)/A
       Q(I) = Q(I)/A
       QS(I) = QS(I)/A
       PHI1(I) = (QS(I)+STATIC(3,I)*P(I))/(1.D0+EOM(I))
  843 CONTINUE
C
C     EVALUATE THE DERIVATIVES OF PHI1 AND OMETA1 NUMERICALLY.
      CALL DER1(PHI1,X,OMETA1,NP)
      CALL DER1(OMETA1,X,OMET1S,NP)
C     DETERMINE THE INITIAL APPROXIMATION
      DO 853 I=1,NP
        Y(2,I) = -EPSETS(I)*OMETA1(I) - EPSETA(I)*OMET1S(I)
        Y(3,I) = OMETA1(I)
        Y(4,I) = PHI1(I)
        Y(5,I) = P(I)
        Y2(I) = Y(2,I)
        Y(6,I) = Q(I)
  853 CONTINUE
C     EVALUATE DYNAMIC TENSION FROM THE FIRST EQUATION BY INTEGRATION
C     USING THE TRAPEZOIDAL RULE. THE INTEGRATION CONSTANT IS DETERMINED
C     USING THE SECOND EQUATION AND EVALUATING TENSION IN THE MIDDLE OF
C     THE RISER.
      CALL DER1(Y2,X,Y2S,NP)
C     EVALUATE CONSTANT OF INTEGRATION AT NI POINT
      NI = NINT(NP/2.D0)
      Y(1,NI) = -(Y2S(NI) + Y(3,NI) + Q(NI)*Y(7,1)**2)/STATIC(3,NI)
      Y(1,NI) = Y(1,NI) - CONST1(NI)*PHI1(NI)/STATIC(3,NI)
C     INTEGRATE FIRST EQUATION, FORWARDS AND BACKWARDS
      DO 871 I=NI+1,NP
        DX2 = (X(I)-X(I-1))*0.5D0
        TERM = (STATIC(2,I)*OMETA1(I) + STATIC(2,I-1)*OMETA1(I-1))*DX2
        TERM = TERM + (STATIC(3,I)*Y2(I) + STATIC(3,I-1)*Y2(I-1))*DX2
        TERM = TERM + (CONST2(I)*PHI1(I) + CONST2(I-1)*PHI1(I-1))*DX2
        Y(1,I) = Y(1,I-1) - HZETAM*Y(7,1)**2*(P(I)+P(I-1))*DX2 + TERM
  871 CONTINUE
      DO 872 I=NI,2,-1
```

```
      DX2 = (-X(I)+X(I-1))*0.5D0
      TERM = (STATIC(2,I)*OMETA1(I) + STATIC(2,I-1)*OMETA1(I-1))*DX2
      TERM = TERM + (STATIC(3,I)*Y2(I) + STATIC(3,I-1)*Y2(I-1))*DX2
      TERM = TERM + (CONST2(I)*PHI1(I) + CONST2(I-1)*PHI1(I-1))*DX2
      Y(1,I-1) = Y(1,I) - HZETAM*Y(7,1)**2*(P(I)+P(I-1))*DX2 + TERM
 872  CONTINUE
C     DETERMINE THE FOURTH BOUNDARY CONDITION AT S=0
      BOUND = Y(3,1)
      WRITE(6,84) A,BOUND
   84 FORMAT(' THE ORTHONORMALIZING CONSTANT FOR THE APPROXIMATE'/
     *' SOLUTION IS SQRT(A) = ',D10.4/' THE BOUNDARY CONDITION AT S=0 IS
     * OMEGAETA(0) = ',D10.4)
      RETURN
      END
C
      SUBROUTINE FUNC(PHI00,HZETAM,XL,NP)
C     THIS SUBROUTINE EVALUATES THE FUNCTIONS THAT RESULT FROM THE
C     APPROXIMATE SLOW SOLUTION FOR IN-PLANE DYNAMICS OF COMPLIANT
C     RISERS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/SLOW/F1(MNP),F2(MNP),F3(MNP),F4(MNP),F5(MNP),F6(MNP)
      DIMENSION PHI00(MNP)
      XPI2 = 2.D0*DATAN(1.D0)
      H = HZETAM
      H2 = H**2
      DO 537 I=1,NP
        COSPHI = DCOS(PHI00(I))
        SINPHI = DSIN(PHI00(I))
        COS2PH = DCOS(2.D0*PHI00(I))
        COSPH2 = COSPHI**2
        SINPH2 = SINPHI**2
C
        F1(I) = COSPHI*(1.D0+(H-1.D0)*COSPH2/6.D0*(3.D0+H)/20.D0*COSPH2)
        F1(I) = F1(I) + COSPHI*(H-1.D0)*COSPH2/6.D0
C
        F2(I) = 1.D0 - H2 - H*(H-1.D0)/2.D0*COSPH2
        F2(I) = F2(I) + H2*(SINPHI + COSPHI*(XPI2 - PHI00(I)))
C
        F3(I) =-SINPHI*(H-1.D0)/2.D0*COSPH2*(1.D0+(3.D0+H)*COSPH2/12.D0)
        F3(I) = F3(I) - SINPHI
C
        F4(I) = SINPHI*(H*(H-1.D0)*COSPHI - H2*(XPI2 - PHI00(I)))
C
        F5(I) = 2.D0 - H + (H-1.D0)*(6.D0-H)*COSPH2/6.D0
        F5(I) = F5(I) + 5.D0/24.D0*(H-1.D0)*(H+3.D0)*COSPH2**2
        F5(I) = -F5(I)*XL*SINPH2*COSPHI
C
        F6(I) = H*(H-1)*COS2PH + H2*SINPHI - H2*(XPI2 - PHI00(I))*COSPHI
        F6(I) = XL*SINPH2*F6(I)
  537 CONTINUE
   88 FORMAT(I3,7(2X,D12.6))
      RETURN
      END
C
      SUBROUTINE STRUCT(ARRAY,X,NP)
```

```
C     THIS SUBROUTINE CHANGES A SERIES OF DATA GIVEN IN
C     SEGMENTS TO A SERIES OF DATA CORRESPONDING TO SPECIFIC POINTS
C     ASSUMPTION: NSEG < NP
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      DIMENSION ARRAY(MNP),HELP(MNP),X(MNP)
C
      IF(NSEG.EQ.1) THEN
        DO 83 I=1,NP
         HELP(I) = ARRAY(1)
83      CONTINUE
      ELSE
        HELP(1) = ARRAY(1)
        HELP(NP) = ARRAY(NSEG)
        I=2
        DO 84 K=2,NP-1
         IF ((X(K).GT.SEG(I-1)).AND.(X(K).LT.SEG(I))) THEN
           HELP(K) = ARRAY(I-1)
         ELSE IF (X(K).EQ.SEG(I)) THEN
           HELP(K) = 0.5D0*(ARRAY(I-1) + ARRAY(I))
         ELSE IF (X(K).GT.SEG(I)) THEN
           HELP(K) = ARRAY(I)
           I = I + 1
         END IF
   84   CONTINUE
      END IF
      DO 85 K=1,NP
        ARRAY(K) = HELP(K)
   85 CONTINUE
      RETURN
      END
C
      SUBROUTINE DER1(ARRAY,X,DERIV,NP)
C     THIS SUBROUTINE EVALUATES THE FIRST DERIVATIVE OF A SERIES OF DATA
C     POINTS USING A SECOND ORDER APPROXIMATION (NONUNIFORM GRID FINITE
C     DIFFERENCES).
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (MNP=151)
      DIMENSION ARRAY(MNP),DERIV(MNP),X(MNP)
C     USE FIRST ORDER FOR END POINTS DERIVATIVES
      DERIV(1) = (-ARRAY(1) + ARRAY(2))/(X(2)-X(1))
      DERIV(NP) = (-ARRAY(NP-1) + ARRAY(NP))/(X(NP)-X(NP-1))
C
      DO 836 I=2,NP-1
       DX = X(I) - X(I-1)
       DX1 = X(I+1) - X(I)
       D = DX/DX1
       DERIV(I) = (D*(ARRAY(I+1)-ARRAY(I)) - (ARRAY(I-1)-ARRAY(I))/D)
       DERIV(I) = DERIV(I)/(DX+DX1)
  836 CONTINUE
      RETURN
      END
C
      SUBROUTINE OUTPUT(NP)
```

```
C     THIS SUBROUTINE OUTPUTS THE RESULTS IN TWO FORMATS; A COMPLETE
C     FORMAL FORM AND A FORM TO BE USED FOR PLOTTING.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      CHARACTER*80 NAME
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/INPUT0/NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUT2/RHOO,AI,CFLUID,PRESS,AO(MNP)
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/INPUT3/WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP)
     *,EIXIS(MNP),GIP(MNP),GIPS(MNP)
      COMMON/INPUT4/DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP)
      COMMON/INPUT5/RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(
     *MNP),TMAXI(MNP),TMAZI(MNP)
      COMMON/INPUT6/XJZI(MNP),AJZI(MNP),TJZI(MNP)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/XTOP,YTOP
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,TO,QXIC,OMEGA0,CONS1,CONS2
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION A1(MNP)
C     CALCULATE THE ORTHONORMALIZING CONSTANT FOR P AND Q
C
      DO 542 I=1,NP
        CALL COUNT(X(I))
        A1(I) = Y(5,I)**2*HZET + HX*Y(6,I)**2
  542 CONTINUE
      A = 0.D0
      DO 642 I=2,NP
        DX2 = (X(I)-X(I-1))*0.5D0
        A = A + (A1(I)+A1(I-1))*DX2
  642 CONTINUE
      A = DSQRT(A)
C     ORTHONORMALIZE THE SOLUTION EXCEPT SIGMA (POSITIVE)
      DO 643 I=1,NP
          Y(N,I) = DABS(Y(N,I))
        DO 643 K=1,N-1
          Y(K,I) = Y(K,I)/A
  643 CONTINUE
C     OUTPUT RESULTS
      WRITE(9,1000) NAME
1000  FORMAT(80A)
      WRITE(9,1001) NSEG,TLEN,WA,RHOO,RHOW,AI,CFLUID,PRESS,WT,TOMAX,VM,
     *XTOP*TLEN,YTOP*TLEN
C
1001  FORMAT(1X,I3,9X,' = NUMBER OF RISER SEGMENTS'/
     *1X,D12.6,' = UNSTRETCHED RISER LENGTH IN M'/
     *1X,D12.6,' = APPROXIMATE AVERAGE EFFECTIVE WEIGHT PER UNIT LENGTH
     *IN N/M'/
     *1X,D12.6,' = INNER FLUID DENSITY IN KG/M3'/
     *1X,D12.6,' = SALT WATER DENSITY IN KG/M3'/
     *1X,D12.6,' = INNER CROSS SECTIONAL AREA IN M2'/
     *1X,D12.6,' = INNER FLUID SPEED IN M/S'/
     *1X,D12.6,' = INNER FLUID OVERPRESSURE IN N/M2'/
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     *1X,D12.6,' = APPROXIMATE TOTAL EFFECTIVE WEIGHT IN WATER IN N'/
     *1X,D12.6,' = AVERAGE STATIC TENSION IN N'/
     *1X,D12.6,' = MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S'/
     *1X,D12.6,' = X COORDINATE AT TOP IN M'/
     *1X,D12.6,' = Y COORDINATE AT TOP IN M')
C     EVALUATE DIMENSIONAL NATURAL FREQUENCY
      SIGMAD = Y(N,1)*DSQRT(TOMAX/TMAXAV)/TLEN
      WRITE(9,1002) NSEG
 1002 FORMAT(//' D A T A  P E R  R I S E R  S E G M E N T  F O R  NSEG =
     * ',I3,'  S E G M E N T S'/' D I M E N S I O N A L  Q U A N T I T I
     * E S  I N  T H E  S . I .  S Y S T E M'/
     *'   RLENG      DXI      PXIETA      AO         WEIGHT       MASS
     *    TMASS      AMAXI      AMAETA      AMAZI       TMAXI       TMAZI
     *')
      TL = TOMAX/TLEN
      DO 1004 I=1,NSEG
      WRITE(9,1003) RLENG(I)*TLEN,DXI(I),PXIETA(I),AO(I),WEIGHT(I)*TL,RM
     *ASS(I),RMASST(I),AMAXI(I),AMAETA(I),AMAZI(I),TMAXI(I),TMAZI(I)
 1004 CONTINUE
 1003 FORMAT(12(1X,D10.4)/)
C
      WRITE(9,10022)
10022 FORMAT('     EA        EIETA       EIETAS       EIXI        EIXIS
     *  GIP       GIPS       DETA        JZI        AJZI        TJZI')
      DO 10023 I=1,NSEG
      WRITE(9,10024) EA(I),EIETA(I),EIETAS(I),EIXI(I),EIXIS(I),GIP(I),
     *GIPS(I),DETA(I),XJZI(I),AJZI(I),TJZI(I)
10023 CONTINUE
10024 FORMAT(11(1X,D10.4)/)
C
      WRITE(9,761) MODE,SIGMAD
  761 FORMAT(' *********************************************************
     */'   M O D E  N U M B E R = ',I2/'   N A T U R A L  F R E Q U E N
     *C Y = ',D10.4,' RAD/S'/' *****************************************
     ****************')
C
      WRITE(9,1009) NP
 1009 FORMAT(/' ORTHONORMALIZED NONDIMENSIONAL RESULTS AT NP = ',
     *I3,' POINTS'/
     *'      S        TENSION        QXI     OMEGAETA        PHI          P
     *      Q         SIGMA')
      DO 1010 I=1,NP
      WRITE(9,1011) X(I),(Y(J,I),J=1,7)
 1010 CONTINUE
 1011 FORMAT(8(1X,D10.4))
      DO 189 I=1,N-1
        ABT(I) = ABT(I)/A
  189 CONTINUE
      WRITE(9,10119) (ABT(I),I=1,7)
10119 FORMAT(' MAXIMUM ESTIMATED ERROR BY COMPONENTS'/11X,7(1X,D10.4))
C
C
C     OUTPUT TO FILE CONNECTED TO DEVICE 11
C     THIS CAN BE USED FOR PLOTS OR INPUT TO ANOTHER RUN OF RCLINDY1
C
C
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```
      CALL STRUC(VLOCXI,NP,NPI)
      WRITE(11,36459) MODE,NP,SIGMAD,XTOP,YTOP
36459 FORMAT(1X,I2,1X,I3,3(1X,D10.4))
      DO 3666 I=1,NP
      WRITE(11,3667) X(I),(Y(J,I),J=1,7),VLOCXI(I)
3666  CONTINUE
3667  FORMAT(9(1X,D12.6))
C
      RETURN
      END
C
      SUBROUTINE FCN(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE FUNCTIONS USED BY D02RAF TO SOLVE
C     THE PROBLEM.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,T0,QXI0,OMEGA0,CONS1,CONS2
      DIMENSION Y(N),F(N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      F(1) = QXI0*Y(3) + OMEGA0*Y(2) + CONS2*Y(4)
      F(1) = F(1) - (HZETAM + EPS*(HZET-HZETAM))*Y(5)*Y(7)**2
C
      F(2) = -(1.D0 + EPS*(T0-1.D0))*Y(3) - OMEGA0*Y(1)
      F(2) = F(2) - CONS1*Y(4)
      F(2) = F(2) - (1.D0 + EPS*(HX-1.D0))*Y(6)*Y(7)**2
C
      F(3) = - Y(2)/EETA - EETAS*Y(3)/EETA
C
      F(4) = Y(3)
C
      F(5) = OMEGA0*Y(6) + EPS*EOMI*Y(1)
C
      F(6) = Y(4) + Y(4)*EOMI*T0 - OMEGA0*Y(5)
C
      F(7) = 0.D0
      RETURN
      END
C
      SUBROUTINE G(EPS,YA,YB,BC,N)
C     BOUNDARY CONDITIONS USED BY D02RAF
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION YA(N),YB(N),BC(N)
      COMMON/BOUNDA/BOUND
C
      BC(1)=YA(4)
      BC(2)=YA(5)
      BC(3)=YA(6)
      BC(4)=YA(3) - BOUND
C
      BC(5)=YB(4)
      BC(6)=YB(5)
      BC(7)=YB(6)
```

```
C
      RETURN
      END
C
      SUBROUTINE JACOBF(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE JACOBIAN OF THE EQUATIONS TO USE IN
C     NEWTON'S ITERATION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,T0,QXI0,OMEGA0,CONS1,CONS2
      DIMENSION Y(N),F(N,N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      DO 817 I=1,N
        DO 817 M=1,N
          F(I,M) = 0.D0
  817 CONTINUE
C
      F(1,2) = OMEGA0
      F(1,3) = QXI0
      F(1,4) = CONS2
      F(1,5) = -(HZETAM + EPS*(HZET-HZETAM))*Y(7)**2
      F(1,7) = -2.D0*Y(7)*(HZETAM+EPS*(HZET-HZETAM))*Y(5)
C
      F(2,1) = -OMEGA0
      F(2,3) = -(1.D0 + EPS*(T0-1.D0))
      F(2,4) = -CONS1
      F(2,6) = -(1.D0 + EPS*(HX-1.D0))*Y(7)**2
      F(2,7) = -2.D0*Y(7)*Y(6)*(1.D0 + EPS*(HX-1.D0))
C
      F(3,2) = -1.D0/EETA
      F(3,3) = -EETAS/EETA
C
      F(4,3) = 1.D0
C
      F(5,1) = EOMI*EPS
      F(5,6) = OMEGA0
C
      F(6,4) = 1.D0 + EOMI*T0
      F(6,5) = -OMEGA0
      RETURN
      END
C
      SUBROUTINE JACOBG(EPS,YA,YB,AJ,BJ,N)
C     THIS SUBROUTINE EVALUATES THE JACOBIAN OF THE BOUNDARY CONDITIONS.
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION YA(N),YB(N),AJ(N,N),BJ(N,N)
      DO 876 K=1,N
        DO 876 I=1,N
          AJ(K,I) = 0.D0
          BJ(K,I) = 0.D0
  876 CONTINUE
C
```

```
      AJ(1,4) = 1.D0
      AJ(2,5) = 1.D0
      AJ(3,6) = 1.D0
      AJ(4,3) = 1.D0
C
      BJ(5,4) = 1.D0
      BJ(6,5) = 1.D0
      BJ(7,6) = 1.D0
      RETURN
      END
C
      SUBROUTINE JACEPS(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE DERIVATIVES OF THE FUNCTIONS WITH
C     RESPECT TO THE CONTINUATION PARAMETER EPS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(NA=4,MNP=151)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,TO,QXI0,OMEGA0,CONS1,CONS2
      DIMENSION Y(N),F(N)
C     LOCATE MESH POINT TO EVALUATE THE COEFFICIENTS
      CALL COUNT(X)
C
      F(1) = -(HZET-HZETAM)*Y(5)*Y(7)**2
C
      F(2) = -(HX-1.D0)*Y(6)*Y(7)**2 - (TO-1.D0)*Y(3)
C
      F(3) = 0.D0
      F(4) = 0.D0
      F(5) = EOMI*Y(1)
C
      F(6) = 0.D0
      F(7) = 0.D0
      RETURN
      END
C
      SUBROUTINE JACGEP(EPS,YA,YB,BCEP,N)
C     THIS SUBROUTINE EVALUATES THE DERIVATIVES OF THE BOUNDARY
C     CONDITIONS WITH RESPECT TO THE CONTINUATION PARAMETER EPS.
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION YA(N),YB(N),BCEP(N)
      DO 871 K=1,N
        BCEP(K) = 0.D0
  871 CONTINUE
      RETURN
      END
C
      SUBROUTINE INTERP(NP)
C     THIS SUBROUTINE INTERPOLATES THE RISER CHARACTERISTICS AND THE
C     STATIC SOLUTION TO THE NEW NUMBER OF POINTS NP.
C     ASSUMPTION: NP .GE. NPI
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
```

```
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION HELP(MNP)
C     INTERPOLATE STRUCTURAL DATA TO THE NEW NUMBER OF POINTS
      CALL STRUC(EPSETA,NP,NPI)
      CALL STRUC(EPSETS,NP,NPI)
      CALL STRUC(EOM,NP,NPI)
      CALL STRUC(HXI,NP,NPI)
      CALL STRUC(HZETA,NP,NPI)
      CALL STRUC(CONST1,NP,NPI)
      CALL STRUC(CONST2,NP,NPI)
      CALL STRUC(VLOCXI,NP,NPI)
C     INTERPOLATE STATIC SOLUTION TO THE NEW NUMBER OF POINTS
      DO 459 K=1,3
        DO 458 I=1,NPI
         HELP(I) = STATIC(K,I)
 458    CONTINUE
        CALL STRUC(HELP,NP,NPI)
        DO 457 I=1,NP
         STATIC(K,I) = HELP(I)
 457    CONTINUE
 459  CONTINUE
      DO 339 I=1,NP
         XI(I) = X(I)
 339  CONTINUE
      RETURN
      END
C
      SUBROUTINE STRUC(ARRAY,NP,NPOLD)
C     THIS SUBROUTINE INTERPOLATES A SERIES OF DIVISION POINTS TO A NEW
C     SERIES OF DIVISION POINTS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      DIMENSION ARRAY(MNP),HELP(MNP)
C
        HELP(1) = ARRAY(1)
        HELP(NP) = ARRAY(NPOLD)
        DO 82 I=2,NPOLD
        DO 81 K=2,NP-1
         IF ((X(K).GT.XI(I-1)).AND.(X(K).LT.XI(I))) THEN
           CONV = (X(K)-XI(I-1))*(ARRAY(I)-ARRAY(I-1))/(XI(I)-XI(I-1))
           HELP(K) = ARRAY(I-1) + CONV
         ELSE IF (X(K).EQ.XI(I)) THEN
           HELP(K) = ARRAY(I)
         END IF
 81     CONTINUE
 82     CONTINUE
        DO 85 K=1,NP
          ARRAY(K) = HELP(K)
 85     CONTINUE
      RETURN
      END
C
```

```
      SUBROUTINE COUNT(X)
C     THIS SUBROUTINE EVALUATES THE RISER CHARACTERISTICS AS WELL AS THE
C     STATIC SOLUTION AT A POINT X.
C     IT RETURNS THEIR VALUE IN COMMON BLOCK COEF1.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4)
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,TO,QXIO,OMEGAO,CONS1,CONS2
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/COUN/ICOUNT
      M = ICOUNT
      IF (X.EQ.XI(M)) THEN
       EETA = EPSETA(M)
       EETAS = EPSETS(M)
       HX = HXI(M)
       HZET = HZETA(M)
       EOMI = EOM(M)
       TO = STATIC(1,M)
       QXIO = STATIC(2,M)
       OMEGAO = STATIC(3,M)
       CONS1 = CONST1(M)
       CONS2 = CONST2(M)
       ICOUNT = ICOUNT + 1
       IF(X.EQ.1.DO) ICOUNT = 1
      ELSE IF ((X.LT.XI(M)).AND.(X.GT.XI(M-1))) THEN
       DIFF = DABS(XI(M)-X)
C     THIS IF STATEMENT IS TO ACCOUNT FOR A COMPUTER INACCURACY IN
C     REPRESENTING AND EQUATING REAL NUMBERS.
       IF (DIFF.LT.1.D-7) THEN
        ICOUNT = ICOUNT + 1
        IF (XI(M).EQ.1.DO) ICOUNT = 1
       END IF
       DX = (X-XI(M-1))/(XI(M)-XI(M-1))
       EETA = EPSETA(M-1) + (EPSETA(M)-EPSETA(M-1))*DX
       EETAS = EPSETS(M-1) + (EPSETS(M)-EPSETS(M-1))*DX
       HX = HXI(M-1) + (HXI(M)-HXI(M-1))*DX
       HZET = HZETA(M-1) + (HZETA(M)-HZETA(M-1))*DX
       EOMI = EOM(M-1) + (EOM(M)-EOM(M-1))*DX
       TO = STATIC(1,M-1) + (STATIC(1,M)-STATIC(1,M-1))*DX
       QXIO = STATIC(2,M-1) + (STATIC(2,M)-STATIC(2,M-1))*DX
       OMEGAO = STATIC(3,M-1) + (STATIC(3,M)-STATIC(3,M-1))*DX
       CONS1 = CONST1(M-1) + (CONST1(M)-CONST1(M-1))*DX
       CONS2 = CONST2(M-1) + (CONST2(M)-CONST2(M-1))*DX
      ELSE
C
       WRITE(6,*) ' ERROR OCCURED IN COUNTER, NP =',M
      END IF
      RETURN
      END
```

Chapter XV

Listing of Program RCFORC1 FORTRAN A

```
C RCFORC1
C THIS PROGRAM CALCULATES THE OUT OF PLANE LINEAR DYNAMIC RESPONSE OF A
C COMPLIANT RISER WITH A 2-D STATIC CONFIGURATION FOR A GIVEN FREQUENCY
C AND AMPLITUDE OF EXCITATION AT THE TOP (R OR B EXCITATION IS ALLOWED).
C A NONUNIFORM GRID FINITE DIFFERENCES AND DEFERRED CORRECTION TECHNIQUE
C IS USED.THE OUTPUT OF THIS PROGRAM CAN BE USED AS INPUT TO RCLINDY3 TO
C SOLVE THE OUT OF PLANE DYNAMICS PROBLEM WITH HOMOGENEOUS BOUNDARY
C CONDITIONS (EIGENPROBLEM).
C THIS PROGRAM WILL BE PARTICULARLY USEFUL IN THE CASE OF ZERO CURRENT
C VELOCITY WHERE THE ASYMPTOTIC THEORY IS NO LONGER VALID.
C DOUBLE PRECISION AND THE NAG FORTRAN LIBRARY ARE USED.
C***********************************************************************
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C ALL RIGHTS RESERVED.
C***********************************************************************
C PROGRAMMER GEORGE A. KRIEZIS          OCTOBER 5, 1985       M.I.T.
C***********************************************************************
C
C DEFINITION OF DEVICES:
C DEVICE 5  : INPUT FROM TERMINAL
C DEVICE 6  : OUTPUT TO TERMINAL
C DEVICE 8  : INPUT FROM FILE PREPARED BY RCINPUT  (LRECL=80)
C DEVICE 10 : INPUT FROM FILE CONTAINING APPROXIMATE N-D STATIC
C             SOLUTION CREATED BY RCSTAT2D  (LRECL=132)
C DEVICE 11 : OUTPUT TO FILE FOR PLOTS OR INPUT TO A RUN
C             OF RCLINDY3  (LRECL=117)
C
C COMMON BLOCK CONTENTS (OVERALL REFERENCE):
C SOLUT  = SOLUTION MATRICES
C STAT   = STATIC COMPLIANT RISER SOLUTION
C STAT2  = FUNCTIONS OF STATIC RESULTS
C INPUT1 = RISER LENGTH, AVERAGE AND TOTAL WEIGHT AND NUMBER OF SEGMENTS
C INPUTL = RISER SEGMENTS LENGTH
C COEF   = NONDIMENSIONAL RISER CHARACTERISTICS USED IN THE EQUATIONS
C COEF1  = NONDIMENSIONAL RISER CHARACTERISTICS AT A SPECIFIC POINT
C COUN   = INTEGER COUNTING VARIABLE TO DETERMINE EACH DIVISION POINT
C FREQ   = NONDIMENSIONAL FREQUENCY OF EXCITATION
C
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=6,MNP=151,NA=4,IY=6)
      PARAMETER(LW=MNP*(3*N**2+5*N+2)+3*N**2+5*N)
      PARAMETER(LIW=MNP*(2*N+1)+N)
      DIMENSION W(LW),IW(LIW),C(N,N),D(N,N),GAM(N)
      COMMON/SOLUT/X(MNP),Y(N,MNP),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/COUN/ICOUNT
      COMMON/FREQ/XLAMDA
C     EXTERNAL SUBROUTINES USED BY NAG LIBRARY
      EXTERNAL FCNF,FCNG
      DATA NOUT /6/
C
C     READ2D READS 2-D STATIC SOLUTION CALCULATED FROM RCSTAT2D PROGRAM.
C     IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC EFFECTIVE TENSION
C
```

```
      CALL READ2D(NPI)
C
C     CHARAC READS RISER CHARACTERISTICS FROM UNIT 8 AND EVALUATES THE
C     NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE EQUATIONS.
C
      CALL CHARAC(TLENG,IC,NPI)
      IF(IC.EQ.0) STOP
C
C     DEFINITIONS OF PARAMETERS  ...
C     N  = NUMBER OF EQUATIONS TO BE SOLVED BY D02GBF
C     MNP= MAXIMUM NUMBER OF PERMITTED POINTS IN THE NON-UNIFORM
C     F.D. MESH ( MNP >= 32)
      IF(MNP.LT.32) THEN
        WRITE(6,1257) MNP
1257    FORMAT(' MNP = ',I3,' IS NOT PERMISSIBLE')
        STOP
      ENDIF
C     PARAMETER CONTROLLING MONITORING OF CALCULATIONS
      IFAIL=111
C     BOUNDARY POINTS FOR TWO-POINT BOUNDARY VALUE PROBLEM
      A=0.D0
      B=1.D0
C
      WRITE(6,*)' INPUT EXCITATION FREQUENCY IN RAD/S'
      READ(5,*) SIGM
C     NONDIMENSIONALIZE SIGMA
      SIGMA = SIGM*TLENG*DSQRT(TMAXAV/TOMAX)
      XLAMDA = SIGMA**2
      WRITE(6,*)' INPUT AMPLITUDE OF EXCITATION AT TOP OF RISER FOR R'
      READ(5,*)BOUNDR
      WRITE(6,*)' INPUT AMPLITUDE OF EXCITATION AT TOP OF RISER FOR B'
      READ(5,*)BOUNDB
      WRITE(6,*)' INPUT TOLERANCE FOR CONVERGENCE OF ITERATIONS'
      WRITE(6,*)' SUGGESTED VALUE IS THE EXCITATION AMPLITUDE OR 1/10 OF
     * THE EXCITATION AMPLITUDE'
      READ(5,*)TOL
      WRITE(6,*)' INPUT MODE NUMBER CORRESPONDING TO FREQUENCY OF EXCITA
     *TION'
      READ(5,*)MODE
      NP = NPI
      DO 632 I=1,N
        GAM(I) = 0.D0
       DO 632 K=1,N
        C(I,K)=0.D0
        D(I,K)=0.D0
  632 CONTINUE
C     DEFINE BOUNDARY CONDITIONS USED IN THE EQUATIONS.
      GAM(5) = BOUNDB
      GAM(6) = BOUNDR
      C(1,4) = 1.D0
      C(2,5) = 1.D0
      C(3,6) = 1.D0
      D(4,4) = 1.D0
      D(5,5) = 1.D0
      D(6,6) = 1.D0
C     SET COUNTING VARIABLE
```

```
      ICOUNT = 1
C
      CALL X04AAF(1,NOUT)
      CALL X04ABF(1,NOUT)
C
C     CALL NAG SUBROUTINE D02GBF TO SOLVE THE LINEAR TWO-POINT
C     BOUNDARY VALUE PROBLEM USING A DEFERRED CORRECTION TECHNIQUE.
C
      CALL D02GBF(A,B,N,TOL,FCNF,FCNG,C,D,GAM,MNP,X,Y,NP,W,LW,IW,LIW,IFA
     *IL)
C
      WRITE(6,9000) IFAIL
 9000 FORMAT(' IFAIL =',I3)
C
C     OUTPUT THE RESULTS
C
      IF((IFAIL.EQ.0).OR.(IFAIL.EQ.4)) THEN
        CALL OUTPUT(NP)
      ENDIF
C
      STOP
      END

      SUBROUTINE CHARAC(TLENG,IC,NP)
C     THIS SUBROUTINE READS THE COMPLIANT RISER CHARACTERISTICS AND
C     EVALUATES THE NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE
C     GOVERNING EQUATIONS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=6)
      CHARACTER*80 NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),MODE
      DIMENSION RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(MNP)
     *,TMAXI(MNP),TMAZI(MNP),TMAETA(MNP)
      DIMENSION XJZI(MNP),AJZI(MNP),TJZI(MNP)
      DIMENSION DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP),AO(MNP)
      DIMENSION WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP),
     *EIXIS(MNP),GIP(MNP),GIPS(MNP)
      DIMENSION TENO(MNP),QXO(MNP),TOS(MNP),QXIOS(MNP)
C
C     READ RISER CHARACTERISTICS FROM DEVICE 8.
      READ (8,1000) NAME
 1000 FORMAT(80A)
      READ (8,1008) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
 1008 FORMAT(1X,I3,2(1X,D12.6)/4(1X,D12.6))
      TLENG = TLEN
      DO 1502 I=1,NSEG
      READ (8,1003) RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI(I
     *),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
 1502 CONTINUE
 1003 FORMAT(5(1X,D12.6)/6(1X,D12.6))
```

```
C
      DO 1332 I=1,NSEG
      READ(8,1333) AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),AMA
     *ZI(I),XJZI(I),AJZI(I)
 1332 CONTINUE
 1333 FORMAT(6(1X,D12.6)/3(1X,D12.6))
C
      IC=1
C
 7650 WRITE(6,7651)
 7651 FORMAT(' DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS'/
     *' IF YES INPUT 1 , IF NO INPUT 0')
      READ(5,*) IPRINT
      IF((IPRINT.NE.1).AND.(IPRINT.NE.0)) GOTO 7650
      IF(IPRINT.EQ.1) THEN
C
      WRITE(6,1000) NAME
      WRITE(6,2500)
 2500 FORMAT(' NSEG   TLEN          WA           RHOO           AI
     * CFLUID        PRESS')
      WRITE(6,2001) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
 2001 FORMAT(1X,I3,6(1X,D12.6))
      WRITE(6,3400)
 3400 FORMAT('    I    RLENG         RMASS         RMASST         AMAXI
     *  WEIGHT'   /'         DXI          PXIETA           EA           EIETA
     *          AO          EIETAS')
      DO 3002 I=1,NSEG
      WRITE(6,3003) I,RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI
     *(I),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
 3002 CONTINUE
 3003 FORMAT(1X,I3,5(1X,D12.6)/4X,6(1X,D12.6))
C
      WRITE(6,1334)
 1334 FORMAT('    I   AMAETA         DETA          EIXI          EIXIS
     *   GIP          GIPS'/'        AMAZI          JZI           AJZI' )
      DO 1335 I=1,NSEG
      WRITE(6,1336) I,AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),
     *AMAZI(I),XJZI(I),AJZI(I)
 1335 CONTINUE
 1336 FORMAT(1X,I3,6(1X,D12.6)/4X,3(1X,D12.6))
C
 1701 WRITE(6,1700)
 1700 FORMAT(' INPUT 1 IF RISER DATA ARE CORRECT'/' INPUT 0 TO STOP')
      READ(5,*) IC
      IF((IC.NE.0).AND.(IC.NE.1)) GOTO 1701
      IF(IC.EQ.0) RETURN
C
      ENDIF
C
C     NON - DIMENSIONALIZATIONS
C
      GRAV=9.81D0
      WAM=WA/GRAV
      WT=WA*TLEN
      XPI=4.D0*DATAN(1.D0)
      XPI2=XPI/2.D0
```

```
      RHOW=1.025D3
C
C     NONDIMENSIONALIZE CORRECTLY QXIO, TO  FROM 2-D STATIC SOLUTION
C
      TOMAX = TOMAX*WT
      TND = WT/TOMAX
      DO 229 I=1,NP
        STATIC(1,I) = STATIC(1,I)*TND
        STATIC(2,I) = STATIC(2,I)*TND
 229  CONTINUE
C
C     NONDIMENSIONAL COEFFICIENTS USED IN THE EQUATIONS
C
      TOMAXL = TOMAX/TLEN
      TOML1  = TOMAX*TLEN
      TOML2  = TOML1*TLEN
      TLEN2  = TLEN**2
      TMAXAV = 0.D0
      DO 2000 I=1,NSEG
       RLENG(I)=RLENG(I)/TLEN
       WEIGHT(I)=WEIGHT(I)/TOMAXL
       EPSXIS(I) = EIXIS(I)/TOML1
       EPSXI(I) = EIXI(I)/TOML2
       EPSETA(I) = EIETA(I)/TOML2
       EPSETS(I) = EIETAS(I)/TOML1
       TJZI(I) = XJZI(I) + AJZI(I)
       TMAETA(I) = RMASS(I) + AMAETA(I)
       TMAXI(I) = RMASS(I) + AMAXI(I)
       TMAXAV = TMAXI(I)*RLENG(I) + TMAXAV
       EPSPI(I) = GIP(I)/TOML2
       EPSPIS(I) = GIPS(I)/TOML1
       DXIETA(I) = DXI(I)-DETA(I)
2000  CONTINUE
      HETAM = 0.D0
      DO 4321 I=1,NSEG
       HETA(I) = TMAETA(I)/TMAXAV
       HETAM = HETAM + HETA(I)*RLENG(I)
       TLAMB2(I) = TLEN2*TMAXAV/TJZI(I)
 4321 CONTINUE
C
C      CALCULATE DERIVATIVES OF STATIC QUANTITIES
       DO 737 I=1,NP
        TENO(I) = STATIC(1,I)
        QXO(I) = STATIC(2,I)
  737  CONTINUE
       CALL DER1(TENO,XI,TOS,NP)
       CALL DER1(QXO,XI,QXIOS,NP)
C      EVALUATE FUNCTIONS OF STATIC RESULTS.
       DO 56 I=1,NP
        CONST1(I) = TOS(I) - STATIC(2,I)*STATIC(3,I)
        CONST2(I) = QXIOS(I) + STATIC(1,I)*STATIC(3,I)
   56  CONTINUE
C
C     SEG(I)=LEFT ORDINATE OF SEGMENT I
      SEG(1)=0.D0
      SEG(NSEG+1)=1.D0
```

```
      DO 4000 I=2,NSEG
      SEG(I)=RLENG(I-1)+SEG(I-1)
 4000 CONTINUE
C     INTRERPOLATE STRUCTURAL DIMENSIONS TO NP POINTS
C     ASSUMPTION: NUMBER OF RISER SEGMENTS WITH DIFFERENT
C     CHARACTERISTICS IS SMALLER THAN THE STATIC SOLUTION POINTS
C     NSEG < NPI
C
      IF (NSEG.GE.NPI) THEN
        WRITE(6,188)
  188   FORMAT(' NSEG => NPI, PROGRAM STOPS')
        IC = 0
        RETURN
      END IF
      CALL STRUCT(EPSETA,X,NP)
      CALL STRUCT(EPSETS,X,NP)
      CALL STRUCT(EPSPI,X,NP)
      CALL STRUCT(EPSPIS,X,NP)
      CALL STRUCT(EPSXI,X,NP)
      CALL STRUCT(EPSXIS,X,NP)
      CALL STRUCT(HETA,X,NP)
      CALL STRUCT(TLAMB2,X,NP)
      RETURN
      END
C
      SUBROUTINE READ2D(NP)
C     THIS SUBROUTINE READS THE STATIC COMPLIANT RISER SOLUTION FROM
C     DEVICE 10. IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC TENSION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=6,MNP=151,NA=4)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
C
C     STATIC(1,I) = STATIC TENSION TO
C     STATIC(2,I) = STATIC SHEAR FORCE IN THE XI DIRECTION
C     STATIC(3,I) = STATIC OMEGA IN THE ETA DIRECTION
C     STATIC(4,I) = STATIC ANGLE PHI
C
      WRITE(6,2000) MNP
 2000 FORMAT(' MNP=',I3)
C     READ STATIC SOLUTION
      READ(10,36459) NP,VM
36459 FORMAT(1X,I3,1X,D12.6)
      WRITE(6,2311) NP,VM
 2311 FORMAT(' 2-D STATIC SOLUTION FROM DEVICE 10'/
     *' NP =',I3/
     *' MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =',D12.6)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING FROM DEVICE 10
```

```
C
      DO 1021 I=1,NP
      READ(10,1033) X(I),STATIC(1,I),STATIC(2,I),STATIC(3,I),STATIC(4,I)
     *,XCOOR,YCOOR,STRARC,TENSI,VLOCXI(I)
      XI(I) = X(I)
1021  CONTINUE
1033  FORMAT(10(1X,D12.6))
C     EVALUATE MAXIMUM STATIC EFFECTIVE TENSION
      TOMAX=DMAX1(STATIC(1,1),STATIC(1,2))
      DO 9859 I=3,NP
      TOMAX=DMAX1(TOMAX,STATIC(1,I))
9859  CONTINUE
C
      WRITE(6,1654) TOMAX
1654  FORMAT(' 2-D STATIC SOLUTION SUCCESFULLY READ'/' MAXIMUM STATIC EF
     *FECTIVE TENSION/WA*L = ',D10.4)
C
      RETURN
      END
C
      SUBROUTINE STRUCT(ARRAY,X,NP)
C     THIS SUBROUTINE CHANGES A SERIES OF DATA GIVEN IN SEGMENTS
C     TO A SERIES OF DATA CORRESPONDING TO SPECIFIC POINTS
C     ASSUMPTION: NSEG < NP
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      DIMENSION ARRAY(MNP),HELP(MNP),X(MNP)
C
      IF(NSEG.EQ.1) THEN
        DO 83 I=1,NP
         HELP(I) = ARRAY(1)
83      CONTINUE
      ELSE
        HELP(1) = ARRAY(1)
        HELP(NP) = ARRAY(NSEG)
        I=2
        DO 84 K=2,NP-1
         IF ((X(K).GT.SEG(I-1)).AND.(X(K).LT.SEG(I))) THEN
           HELP(K) = ARRAY(I-1)
         ELSE IF (X(K).EQ.SEG(I)) THEN
           HELP(K) = 0.5D0*(ARRAY(I-1) + ARRAY(I))
         ELSE IF (X(K).GT.SEG(I)) THEN
           HELP(K) = ARRAY(I)
           I = I + 1
         END IF
   84   CONTINUE
      END IF
      DO 85 K=1,NP
        ARRAY(K) = HELP(K)
   85 CONTINUE
      RETURN
      END
C
      SUBROUTINE DER1(ARRAY,X,DERIV,NP)
```

```
C     THIS SUBROUTINE EVALUATES THE FIRST DERIVATIVE OF A SERIES OF DATA
C     POINTS USING A SECOND ORDER APPROXIMATION (NONUNIFORM GRID FINITE
C     DIFFERENCES).
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (MNP=151)
      DIMENSION ARRAY(MNP),DERIV(MNP),X(MNP)
C     USE FIRST ORDER FOR END POINTS DERIVATIVES
      DERIV(1) = (-ARRAY(1) + ARRAY(2))/(X(2)-X(1))
      DERIV(NP) = (-ARRAY(NP-1) + ARRAY(NP))/(X(NP)-X(NP-1))
C
      DO 836 I=2,NP-1
       DX = X(I) - X(I-1)
       DX1 = X(I+1) - X(I)
       D = DX/DX1
       DERIV(I) = (D*(ARRAY(I+1)-ARRAY(I)) - (ARRAY(I-1)-ARRAY(I))/D)
       DERIV(I) = DERIV(I)/(DX+DX1)
  836 CONTINUE
      RETURN
      END
C
      SUBROUTINE OUTPUT(NP)
C     THIS SUBROUTINE OUTPUTS THE RESULTS IN A FORM TO BE USED AS INPUT
C     FOR A RUN OF RCLINDY3.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=6)
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/SOLUT/X(MNP),Y(N,MNP),MODE
      COMMON/FREQ/XLAMDA
C
      SIGMAD = DSQRT(XLAMDA*TOMAX/TMAXAV)/TLEN
      SIGMA = DSQRT(XLAMDA)
C
C
C     OUTPUT TO FILE CONNECTED TO DEVICE 11
C     THIS CAN BE USED FOR PLOTS OR INPUT TO A RUN OF RCLINDY3
C
C
      WRITE(11,36459) MODE,NP,SIGMAD
36459 FORMAT(1X,I2,1X,I3,1X,D10.4)
      DO 3666 I=1,NP
      WRITE(11,3667) X(I),(Y(J,I),J=1,6),SIGMA
3666  CONTINUE
3667  FORMAT(8(1X,D12.6))
C
      RETURN
      END
C
      SUBROUTINE FCNF(X,F)
C     THIS SUBROUTINE EVALUATES THE MATRIX F(X) AT A GENERAL POINT X
C     THIS MATRIX IS USED BY NAG SUBROUTINE D02GBF.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,N=6)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
```

```
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,TO,QXIO,OMEGAO,
     *CONS1,CONS2
      COMMON/FREQ/XLAMDA
      DIMENSION F(N,N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      DO 875 I=1,N
        DO 875 K=1,N
          F(I,K) = 0.DO
875   CONTINUE
C
      F(1,2) = -QXIO
      F(1,3) = TO
      F(1,4) = CONS1
      F(1,5) = -CONS2
      F(1,6) = -XLAMDA*HH
C
      F(2,2) = -EPIS/EPI
      F(2,3) = (EXI-EETA)*OMEGAO/EPI
      F(2,5) = -XLAMDA/TLAM2/EPI
C
      F(3,1) = 1.DO/EXI
      F(3,2) = (EETA-EPI)*OMEGAO/EXI
      F(3,3) = -EXIS/EXI
C
      F(4,3) = 1.DO
      F(4,5) = -OMEGAO
C
      F(5,2) = 1.DO
      F(5,4) = OMEGAO
C
      F(6,4) = -1.DO
      RETURN
      END
C
      SUBROUTINE FCNG(X,G)
C     THIS SUBROUTINE EVALUATES VECTOR G(X) AT A GENERAL POINT X.
C     IT IS USED BY NAG SUBROUTINE DO2GBF.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=6)
      DIMENSION G(N)
      DO 817 I=1,N
        G(I) = 0.DO
  817 CONTINUE
      RETURN
      END
C
      SUBROUTINE COUNT(X)
C     THIS SUBROUTINE EVALUATES THE RISER CHARACTERISTICS AS WELL AS THE
C     STATIC SOLUTION AT A GENERAL POINT X.
C     IT RETURNS THEIR VALUE IN COMMON BLOCK COEF1.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
```

```
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,TO,QXIO,OMEGAO,
     *CONS1,CONS2
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/COUN/ICOUNT
      M = ICOUNT
      IF (X.EQ.XI(M)) THEN
       EETA = EPSETA(M)
       EETAS = EPSETS(M)
       EXI = EPSXI(M)
       EXIS = EPSXIS(M)
       EPI = EPSPI(M)
       EPIS = EPSPIS(M)
       HH = HETA(M)
       TLAM2 = TLAMB2(M)
       TO = STATIC(1,M)
       QXIO = STATIC(2,M)
       OMEGAO = STATIC(3,M)
       CONS1 = CONST1(M)
       CONS2 = CONST2(M)
       ICOUNT = ICOUNT + 1
       IF(X.EQ.1.DO) ICOUNT = 1
      ELSE IF ((X.LT.XI(M)).AND.(X.GT.XI(M-1))) THEN
       DIFF = DABS(XI(M)-X)
C     THIS IF STATEMENT IS TO ACCOUNT FOR A COMPUTER INACCURACY IN
C     REPRESENTING AND EQUATING REAL NUMBERS.
       IF (DIFF.LT.1.D-7) THEN
        ICOUNT = ICOUNT + 1
        IF (XI(M).EQ.1.DO) ICOUNT = 1
       END IF
       DX = (X-XI(M-1))/(XI(M)-XI(M-1))
       EXI = EPSXI(M-1) + (EPSXI(M)-EPSXI(M-1))*DX
       EXIS = EPSXIS(M-1) + (EPSXIS(M)-EPSXIS(M-1))*DX
       EETA = EPSETA(M-1) + (EPSETA(M)-EPSETA(M-1))*DX
       EETAS = EPSETS(M-1) + (EPSETS(M)-EPSETS(M-1))*DX
       EPI = EPSPI(M-1) + (EPSPI(M)-EPSPI(M-1))*DX
       EPIS = EPSPIS(M-1) + (EPSPIS(M)-EPSPIS(M-1))*DX
       HH = HETA(M-1) + (HETA(M)-HETA(M-1))*DX
       TLAM2 = TLAMB2(M-1) + (TLAMB2(M)-TLAMB2(M-1))*DX
       TO = STATIC(1,M-1) + (STATIC(1,M)-STATIC(1,M-1))*DX
       QXIO = STATIC(2,M-1) + (STATIC(2,M)-STATIC(2,M-1))*DX
       OMEGAO = STATIC(3,M-1) + (STATIC(3,M)-STATIC(3,M-1))*DX
       CONS1 = CONST1(M-1) + (CONST1(M)-CONST1(M-1))*DX
       CONS2 = CONST2(M-1) + (CONST2(M)-CONST2(M-1))*DX
      ELSE
C
       WRITE(6,*) ' ERROR OCCURED IN COUNTER, NP =',M
      END IF
      RETURN
      END
```

Chapter XVI

Listing of Program RCLINDY3 FORTRAN A

```
C RCLINDY3
C THIS PROGRAM CALCULATES THE OUT OF PLANE LINEAR DYNAMIC RESPONSE OF A
C COMPLIANT RISER WITH A 2-D STATIC CONFIGURATION BASED ON AN
C EMBEDDING TECHNIQUE. THE INITIAL EMBEDDED APPROXIMATION IS PREPARED
C BY PROGRAM RCFORC1 AND THE FINAL SOLUTION IS OBTAINED USING MODIFIED
C NEWTON'S ITERATION AND A NON-UNIFORM GRID FINITE DIFFERENCE METHOD.
C DOUBLE PRECISION AND THE NAG FORTRAN LIBRARY ARE USED.
C*********************************************************************
C COPYRIGHT, 1985, MASSACHUSETTS INSTITUTE OF TECHNOLOGY
C ALL RIGHTS RESERVED.
C*********************************************************************
C PROGRAMMER    GEORGE A. KRIEZIS       OCTOBER 5, 1985      M.I.T.
C*********************************************************************
C
C DEFINITION OF DEVICES:
C DEVICE 5  : INPUT FROM TERMINAL
C DEVICE 6  : OUTPUT TO TERMINAL
C DEVICE 8  : INPUT FROM FILE PREPARED BY RCINPUT  (LRECL=80)
C DEVICE 9  : COMPLETE OUTPUT TO FILE  (LRECL=132)
C DEVICE 10 : INPUT FROM FILE CONTAINING APPROXIMATE N-D STATIC
C             SOLUTION CREATED BY RCSTAT2D  (LRECL=132)
C DEVICE 11 : OUTPUT TO FILE FOR PLOTS OR INPUT TO A NEW RUN
C             OF RCLINDY3  (LRECL=117)
C DEVICE 12 : INPUT FROM FILE CONTAINING APPROXIMATE EMBEDDED SOLUTION
C             CREATED BY RCFORC1  (LRECL=117)
C
C COMMON BLOCK CONTENTS (OVERALL REFERENCE):
C SOLUT  = INITIAL EMBEDDED APPROXIMATION AND SOLUTION MATRICES
C STAT   = STATIC COMPLIANT RISER SOLUTION
C STAT2  = FUNCTIONS OF STATIC RESULTS
C INPUT0 = OUTPUT FILE HEADING
C INPUT1 = RISER LENGTH, AVERAGE AND TOTAL WEIGHT AND NUMBER OF SEGMENTS
C INPUT2 = RISER TUBE INTERIOR CHARACTERISTICS
C INPUTL = RISER SEGMENTS LENGTH
C INPUT3 = WEIGHT, STIFFNESSES AND STIFFNESS DERIVATIVES
C INPUT4 = CHARACTERISTIC DIAMETERS AND PERIMETER OF RISER TUBE.
C INPUT5 = MASS AND ADDED MASS CHARACTERISTICS IN THREE DIRECTIONS
C INPUT6 = RISER POLAR AND ADDED POLAR MOMENT OF INERTIA.
C COEF   = NONDIMENSIONAL RISER CHARACTERISTICS USED IN THE EQUATIONS
C COEF1  = NONDIMENSIONAL RISER CHARACTERISTICS AT A SPECIFIC POINT
C CONST  = PROBLEM CONSTANTS (PI, GRAVITY, WATER DENSITY)
C BOUNDA = BOUNDARY CONDITION FOR OMEGA XI AT S=0 AND EMBEDDED BOUNDARY
C          CONDITIONS FROM PROGRAM RCFORC1
C COUN   = INTEGER COUNTING VARIABLE TO DETERMINE EACH DIVISION POINT
C
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4,IY=7)
      PARAMETER(LWORK=MNP*(3*N**2+6*N+2)+4*N**2+3*N)
      PARAMETER(LIWORK=MNP*(2*N+1)+N)
      DIMENSION WORK(LWORK),IWORK(LIWORK)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COUN/ICOUNT
C     EXTERNAL SUBROUTINES USED BY NAG LIBRARY
      EXTERNAL FCN,G,JACEPS,JACGEP,JACOBF,JACOBG
      DATA NOUT /6/
```

```
C
C     READ2D READS 2-D STATIC SOLUTION CALCULATED FROM RCSTAT2D PROGRAM.
C     IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC EFFECTIVE TENSION
C
      CALL READ2D(NPI)
C
C     CHARAC READS RISER CHARACTERISTICS FROM UNIT 8 AND EVALUATES THE
C     NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE EQUATIONS.
C
      CALL CHARAC(TLENG,IC,NPI)
      IF(IC.EQ.0) STOP
C
C     DEFINITIONS OF PARAMETERS  ...
C     N  = NUMBER OF EQUATIONS TO BE SOLVED BY D02RAF
C     IY = NUMBER OF VARIABLES
C     MNP= MAXIMUM NUMBER OF PERMITTED POINTS IN THE NON-UNIFORM
C     F.D. MESH ( MNP >= 32)
      IF(MNP.LT.32) THEN
        WRITE(6,1257) MNP
 1257   FORMAT(' MNP = ',I3,' IS NOT PERMISSIBLE')
        STOP
      ENDIF
C     NUMBER OF BOUNDARY CONDITIONS AT S=0
 1276 NUMBEG=4
C     NUMBER OF MIXED BOUNDARY CONDITIONS
      NUMMIX=0
C     PARAMETER DECLARING THAT INITIAL APPROXIMATION IS USER SPECIFIED
      INIT=1
C     PARAMETER DECLARING THAT JACOBIANS ARE USER SPECIFIED
      IJAC=1
C     PARAMETER CONTROLLING MONITORING OF CALCULATIONS
      IFAIL=111
C
C
C     READAS : READS APPROXIMATE EMBEDDED SOLUTION FROM DEVICE 10
C              IT ALSO PROVIDES ICCC,NP, TOL= TOLERANCE OF ITERATIONS
C
      CALL READAS(ICCC,NP,TOL)
C
C     IF THE NUMBER OF POINTS FROM THIS SOLUTION IS GREATER THAN THE
C     STATIC SOLUTION POINTS, INTERPOLATE ALL CHARACTERISTICS TO THE
C     NEW NUMBER OF POINTS.
C     ASSUMPTION : NP ALWAYS GREATER OR EQUAL TO NPI
C     THIS IS VALID IF THE SAME STATIC SOLUTION WAS USED TO OBTAIN THE
C     APPROXIMATE EMBEDDED SOLUTION IN DEVICE 10.
C
      IF (NP.GE.NPI) THEN
          CALL INTERP(NP)
          NPI=NP
      ELSE IF (NP.LT.NPI) THEN
          WRITE(6,314)
  314     FORMAT(' APPROXIMATE SOLUTION IN DEVICE 10 WAS NOT OBTAINED'/
     *    ' FROM THE SAME STATIC SOLUTION, PROGRAM STOPS')
          STOP
      END IF
C
```

```
C     INCREMENT OF CONTINUATION PARAMETER
7891  WRITE(6,7890)
7890  FORMAT(' INPUT INITIAL INCREMENT OF CONTINUATION PARAMETER DELEPS'
     */' IF NO CONTINUATION IS REQUIRED INPUT DELEPS = 1.D0'/
     *' IF CONTINUATION IS REQUIRED THEN 0.D0 < DELEPS < 1.D0'/
     *' RECOMMENDATION :'/
     *' USUALLY DELEPS = 0.1D0 WILL SUFFICE'/
     *' FOR LARGE CHANGES BETWEEN INITIAL AND FINAL PROBLEM'/
     *' A SMALLER VALUE OF DELEPS, E.G. 0.05D0 OR 0.025D0 MIGHT BE'/
     *' NECESSARY')
      READ(5,*) DELEPS
      IF((DELEPS.GT.1.D0).OR.(DELEPS.LE.0.D0)) THEN
        WRITE(6,7892)
7892    FORMAT(' 0. <  DELEPS  <= 1.')
        GOTO 7891
      END IF
C     SET COUNTING VARIABLE
      ICOUNT = 1
      IF(ICCC.EQ.0) STOP
C
      CALL X04AAF(1,NOUT)
      CALL X04ABF(1,NOUT)
C
C     CALL NAG SUBROUTINE D02RAF TO SOLVE THE TWO-POINT BOUNDARY VALUE
C     PROBLEM USING A DEFERRED CORRECTION TECHNIQUE AND NEWTON'S
C     ITERATION.
      CALL D02RAF(N,MNP,NP,NUMBEG,NUMMIX,TOL,INIT,X,Y,IY,ABT,FCN,G,IJAC,
     *JACOBF,JACOBG,DELEPS,JACEPS,JACGEP,WORK,LWORK,IWORK,LIWORK,IFAIL)
C
      WRITE(6,9000) IFAIL
9000  FORMAT(' IFAIL =',I3)
C
C     OUTPUT THE RESULTS
C
      IF((IFAIL.EQ.0).OR.(IFAIL.EQ.4)) THEN
        CALL OUTPUT(NP)
      ENDIF
C
      STOP
      END

      SUBROUTINE CHARAC(TLENG,IC,NP)
C     THIS SUBROUTINE READS THE COMPLIANT RISER CHARACTERISTICS AND
C     EVALUATES THE NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE
C     GOVERNING EQUATIONS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      CHARACTER*80 NAME
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/INPUT0/NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUT2/RHOO,AI,CFLUID,PRESS,AO(MNP)
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/INPUT3/WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP)
     *,EIXIS(MNP),GIP(MNP),GIPS(MNP)
      COMMON/INPUT4/DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP)
```

```
      COMMON/INPUT5/RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(
     *MNP),TMAXI(MNP),TMAETA(MNP)
      COMMON/INPUT6/XJZI(MNP),AJZI(MNP),TJZI(MNP)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION TENO(MNP),QXO(MNP),TOS(MNP),QXIOS(MNP)
C
C     READ RISER CHARACTERISTICS FROM DEVICE 8
      READ (8,1000) NAME
1000  FORMAT(80A)
      READ (8,1008) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
1008  FORMAT(1X,I3,2(1X,D12.6)/4(1X,D12.6))
      TLENG = TLEN
      DO 1502 I=1,NSEG
      READ (8,1003) RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI(I
     *),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
1502  CONTINUE
1003  FORMAT(5(1X,D12.6)/6(1X,D12.6))
C
      DO 1332 I=1,NSEG
      READ(8,1333) AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),AMA
     *ZI(I),XJZI(I),AJZI(I)
1332  CONTINUE
1333  FORMAT(6(1X,D12.6)/3(1X,D12.6))
C
      IC=1
C
7650  WRITE(6,7651)
7651  FORMAT(' DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS'/
     *' IF YES INPUT 1 , IF NO INPUT 0')
      READ(5,*) IPRINT
      IF((IPRINT.NE.1).AND.(IPRINT.NE.0)) GOTO 7650
      IF(IPRINT.EQ.1) THEN
C
      WRITE(6,1000) NAME
      WRITE(6,2500)
2500  FORMAT(' NSEG   TLEN          WA            RHOO          AI
     * CFLUID       PRESS')
      WRITE(6,2001) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
2001  FORMAT(1X,I3,6(1X,D12.6))
      WRITE(6,3400)
3400  FORMAT('    I    RLENG         RMASS         RMASST        AMAXI
     *  WEIGHT'   /'          DXI           PXIETA          EA           EIETA
     *           AO           EIETAS')
      DO 3002 I=1,NSEG
      WRITE(6,3003) I,RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI
     *(I),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
3002  CONTINUE
3003  FORMAT(1X,I3,5(1X,D12.6)/4X,6(1X,D12.6))
C
      WRITE(6,1334)
1334  FORMAT('    I   AMAETA        DETA          EIXI          EIXIS
     *   GIP         GIPS'/'          AMAZI         JZI           AJZI')
```

```
      DO 1335 I=1,NSEG
      WRITE(6,1336) I,AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),
     *AMAZI(I),XJZI(I),AJZI(I)
 1335 CONTINUE
 1336 FORMAT(1X,I3,6(1X,D12.6)/4X,3(1X,D12.6))
C
 1701 WRITE(6,1700)
 1700 FORMAT(' INPUT 1 IF RISER DATA ARE CORRECT'/' INPUT 0 TO STOP')
      READ(5,*) IC
      IF((IC.NE.0).AND.(IC.NE.1)) GOTO 1701
      IF(IC.EQ.0) RETURN
C
      ENDIF
C
C     NON - DIMENSIONALIZATIONS
C
      GRAV=9.81D0
      WAM=WA/GRAV
      WT=WA*TLEN
      XPI=4.D0*DATAN(1.D0)
      XPI2=XPI/2.D0
      RHOW=1.025D3
C
C     NONDIMENSIONALIZE CORRECTLY QXIO, TO  FROM 2-D STATIC SOLUTION
C
      TOMAX = TOMAX*WT
      TND = WT/TOMAX
      DO 229 I=1,NP
        STATIC(1,I) = STATIC(1,I)*TND
        STATIC(2,I) = STATIC(2,I)*TND
 229  CONTINUE
C
C     NONDIMENSIONAL COEFFICIENTS USED IN THE EQUATIONS
C
      TOMAXL = TOMAX/TLEN
      TOML1  = TOMAX*TLEN
      TOML2  = TOML1*TLEN
      TLEN2  = TLEN**2
      TMAXAV = 0.D0
      DO 2000 I=1,NSEG
       RLENG(I)=RLENG(I)/TLEN
       WEIGHT(I)=WEIGHT(I)/TOMAXL
       EPSXI(I) = EIXI(I)/TOML2
       EPSXIS(I) = EIXIS(I)/TOML1
       EPSETA(I) = EIETA(I)/TOML2
       EPSETS(I) = EIETAS(I)/TOML1
       EPSPI(I) = GIP(I)/TOML2
       EPSPIS(I) = GIPS(I)/TOML1
       TJZI(I) = XJZI(I) + AJZI(I)
       TMAETA(I) = RMASS(I) + AMAETA(I)
       TMAXI(I) = RMASS(I) + AMAXI(I)
       TMAXAV = TMAXI(I)*RLENG(I) + TMAXAV
       DXIM = DXIM + DXI(I)*RLENG(I)
       DXIETA(I) = DXI(I)-DETA(I)
 2000 CONTINUE
      HETAM = 0.D0
```

```
      DO 4321 I=1,NSEG
       HETA(I) = TMAETA(I)/TMAXAV
       HETAM = HETAM + HETA(I)*RLENG(I)
       TLAMB2(I) = TLEN2*TMAXAV/TJZI(I)
 4321 CONTINUE
C
C       CALCULATE DERIVATIVES OF STATIC QUANTITIES
        DO 737 I=1,NP
         TENO(I) = STATIC(1,I)
         QXO(I) = STATIC(2,I)
  737   CONTINUE
        CALL DER1(TENO,XI,TOS,NP)
        CALL DER1(QXO,XI,QXIOS,NP)
C       EVALUATE FUNCTIONS OF STATIC RESULTS
        DO 56 I=1,NP
         CONST1(I) = TOS(I) - STATIC(2,I)*STATIC(3,I)
         CONST2(I) = QXIOS(I) + STATIC(1,I)*STATIC(3,I)
   56   CONTINUE
C
C     SEG(I)=LEFT ORDINATE OF SEGMENT I
      SEG(1)=0.D0
      SEG(NSEG+1)=1.D0
      DO 4000 I=2,NSEG
      SEG(I)=RLENG(I-1)+SEG(I-1)
 4000 CONTINUE
C     INTRERPOLATE STRUCTURAL DIMENSIONS TO NP POINTS
C     ASSUMPTION: NUMBER OF RISER SEGMENTS WITH DIFFERENT
C     CHARACTERISTICS IS SMALLER THAN THE STATIC SOLUTION POINTS
C     NSEG < NPI
C
      IF (NSEG.GE.NPI) THEN
        WRITE(6,188)
 188    FORMAT(' NSEG => NPI, PROGRAM STOPS')
        IC = 0
        RETURN
      END IF
      CALL STRUCT(EPSXI,X,NP)
      CALL STRUCT(EPSXIS,X,NP)
      CALL STRUCT(EPSETA,X,NP)
      CALL STRUCT(EPSETS,X,NP)
      CALL STRUCT(EPSPI,X,NP)
      CALL STRUCT(EPSPIS,X,NP)
      CALL STRUCT(HETA,X,NP)
      CALL STRUCT(TLAMB2,X,NP)
      RETURN
      END
C
      SUBROUTINE READ2D(NP)
C     THIS SUBROUTINE READS THE STATIC COMPLIANT RISER SOLUTION FROM
C     DEVICE 10. IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC TENSION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
C
C     STATIC(1,I) = STATIC EFFECTIVE TENSION TO
```

```
C     STATIC(2,I) = STATIC SHEAR FORCE IN THE XI DIRECTION
C     STATIC(3,I) = STATIC OMEGA IN THE ETA DIRECTION
C     STATIC(4,I) = STATIC ANGLE PHI
C
      WRITE(6,2000) MNP
2000  FORMAT(' MNP=',I3)
C     READ STATIC SOLUTION
      READ(10,36459) NP,VM
36459 FORMAT(1X,I3,1X,D12.6)
      WRITE(6,2311) NP,VM
2311  FORMAT(' 2-D STATIC SOLUTION FROM DEVICE 10'/
     *' NP =',I3/
     *' MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =',D12.6)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING FROM DEVICE 10
C
      DO 1021 I=1,NP
      READ(10,1033) X(I),STATIC(1,I),STATIC(2,I),STATIC(3,I),STATIC(4,I)
     *,XCOOR,YCOOR,STRARC,TENSI,VLOCXI(I)
      XI(I) = X(I)
1021  CONTINUE
1033  FORMAT(10(1X,D12.6))
C     EVALUATE MAXIMUM STATIC EFFECTIVE TENSION
      TOMAX=DMAX1(STATIC(1,1),STATIC(1,2))
      DO 9859 I=3,NP
      TOMAX=DMAX1(TOMAX,STATIC(1,I))
9859  CONTINUE
C
      WRITE(6,1654) TOMAX
1654  FORMAT(' 2-D STATIC SOLUTION SUCCESFULLY READ'/' MAXIMUM STATIC EF
     *FECTIVE TENSION/WA*L = ',D10.4)
C
      RETURN
      END

      SUBROUTINE READAS(ICCC,NP,TOL)
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/BOUNDA/BOUND,BOUNDR,BOUNDB
C
C     READAS READS INITIAL EMBEDDED APPROXIMATION RESULTING FROM A
C     RUN OF RCFORC1
C
C     Y(1,I)  = SHEAR FORCE IN THE ETA DIRECTION
C     Y(2,I)  = OMEGA ABOUT ZETA
C     Y(3,I)  = OMEGA ABOUT XI
C     Y(4,I)  = DYNAMIC ANGLE THETA
```

```
C       Y(5,I)  = DYNAMIC ANGLE BETA
C       Y(6,I)  = OUT OF PLANE DISPLACEMENT, R
C       Y(7,I)  = NATURAL FREQUENCY
C       X(I)    = UNSTRETCHED ARC LENGTH S
C
      WRITE(6,2000) MNP
2000  FORMAT(' MNP=',I3)
C
      READ(12,36459) MODE,NP,SIGMAD
36459 FORMAT(1X,I2,1X,I3,1X,D10.4)
      WRITE(6,2311) NP,MODE,SIGMAD
2311  FORMAT(' INITIAL APPROXIMATION FROM DEVICE 12'/
     *' NP =',I3,' MODE NUMBER =',I2,' SIGMAD =',D10.4)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING DATA FROM DEVICE 12 ...
C
      DO 10011 I=1,NP
      READ(12,10012) X(I),(Y(J,I),J=1,7)
10011 CONTINUE
10012 FORMAT(8(1X,D12.6))
C     EMBEDDED BOUNDARY CONDITIONS AND OMEGA XI(0)
      BOUND = Y(3,1)
      BOUNDB = Y(5,NP)
      BOUNDR = Y(6,NP)
C
      WRITE(9,1052) NP,SIGMAD
 1052 FORMAT(' INITIAL CONDITION FOR EPS=0. AND NP = ',I3,' POINTS,  NAT
     *URAL FREQUENCY = ',D10.4,' RAD/S'/
     *'   I     ARC        SHEAR ETA    OMEGA ZETA    OMEGA XI      THETA
     *        BETA          R             SIGMA')
      DO 1601 I=1,NP
       WRITE(9,1603) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     * Y(7,I)
 1601 CONTINUE
 1603 FORMAT(1X,I3,8(1X,D12.6))
C
      WRITE(6,9561)
 9561 FORMAT(' DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION'/
     *' IF YES INPUT 1')
      READ(5,*)IPRINT
      IF(IPRINT.EQ.1) THEN
       WRITE(6,1052) NP
       DO 9659 I=1,NP
        WRITE(6,1603) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     *  Y(7,I)
 9659  CONTINUE
      END IF
      WRITE(6,1722) BOUND
1722  FORMAT(' ASSUMED BOUNDARY CONDITION '/
```

```
     *' OMEGA XI (0) =',D12.6)
C
      TOL1 = 0.D0
      DO 3931 I=1,NP
        TOL1 = DMAX1(TOL1,DABS(Y(3,I)))
 3931 CONTINUE
      WRITE(6,3932) TOL1
 3932 FORMAT(' MAXIMUM ABSOLUTE VALUE OF N-D OMEGA XI IS =',D12.6/
     *' THIS NUMBER CAN BE USED TO ESTIMATE '/
     *' A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS'/
     *' INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE'/
     *' E.G. INPUT 0.01 OR 0.1 IF THE INITIAL ESTIMATE FOR OMEGA XI'/
     *' IS SMALL'/' AFTER THE RUN CHECK THE ACCURACY OF THE SOLUTION')
      READ(5,*) TOLV
      TOL = DABS(TOLV)*TOL1
C
 1005 WRITE(6,1004)
 1004 FORMAT(' IF YOU WISH TO STOP INPUT 0'/
     *' IF YOU WISH TO CONTINUE WITH ITERATIONS INPUT 1')
      READ(5,*) ICCC
      IF((ICCC.NE.0).AND.(ICCC.NE.1)) GOTO 1005
C
      RETURN
      END
C
      SUBROUTINE STRUCT(ARRAY,X,NP)
C     THIS SUBROUTINE CHANGES A SERIES OF DATA GIVEN IN
C     SEGMENTS TO A SERIES OF DATA CORRESPONDING TO SPECIFIC POINTS
C     ASSUMPTION: NSEG < NP
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      DIMENSION ARRAY(MNP),HELP(MNP),X(MNP)
C
      IF(NSEG.EQ.1) THEN
        DO 83 I=1,NP
         HELP(I) = ARRAY(1)
83      CONTINUE
      ELSE
        HELP(1) = ARRAY(1)
        HELP(NP) = ARRAY(NSEG)
        I=2
        DO 84 K=2,NP-1
         IF ((X(K).GT.SEG(I-1)).AND.(X(K).LT.SEG(I))) THEN
           HELP(K) = ARRAY(I-1)
         ELSE IF (X(K).EQ.SEG(I)) THEN
           HELP(K) = 0.5D0*(ARRAY(I-1) + ARRAY(I))
         ELSE IF (X(K).GT.SEG(I)) THEN
           HELP(K) = ARRAY(I)
           I = I + 1
         END IF
 84   CONTINUE
      END IF
      DO 85 K=1,NP
        ARRAY(K) = HELP(K)
```

```
   85 CONTINUE
      RETURN
      END
C
      SUBROUTINE DER1(ARRAY,X,DERIV,NP)
C     THIS SUBROUTINE EVALUATES THE FIRST DERIVATIVE OF A SERIES OF DATA
C     POINTS USING A SECOND ORDER APPROXIMATION (NONUNIFORM GRID FINITE
C     DIFFERENCES).
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (MNP=151)
      DIMENSION ARRAY(MNP),DERIV(MNP),X(MNP)
C     USE FIRST ORDER FOR END POINTS DERIVATIVES
      DERIV(1) = (-ARRAY(1) + ARRAY(2))/(X(2)-X(1))
      DERIV(NP) = (-ARRAY(NP-1) + ARRAY(NP))/(X(NP)-X(NP-1))
C
      DO 836 I=2,NP-1
       DX = X(I) - X(I-1)
       DX1 = X(I+1) - X(I)
       D = DX/DX1
       DERIV(I) = (D*(ARRAY(I+1)-ARRAY(I)) - (ARRAY(I-1)-ARRAY(I))/D)
       DERIV(I) = DERIV(I)/(DX+DX1)
  836 CONTINUE
      RETURN
      END
C
      SUBROUTINE OUTPUT(NP)
C     THIS SUBROUTINE OUTPUTS THE RESULTS IN TWO FORMATS; A COMPLETE
C     FORMAL FORM AND A FORM TO BE USED FOR PLOTTING.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      CHARACTER*80 NAME
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/INPUT0/NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUT2/RHOO,AI,CFLUID,PRESS,AO(MNP)
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/INPUT3/WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP)
     *,EIXIS(MNP),GIP(MNP),GIPS(MNP)
      COMMON/INPUT4/DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP)
      COMMON/INPUT5/RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(
     *MNP),TMAXI(MNP),TMAETA(MNP)
      COMMON/INPUT6/XJZI(MNP),AJZI(MNP),TJZI(MNP)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/XTOP,YTOP
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,TO,QXI0,OMEGA0,
     *CONS1,CONS2
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION A1(MNP)
C     CALCULATE THE ORTHONORMALIZING CONSTANT FOR R AND BETA
C
      DO 542 I=1,NP
        CALL COUNT(X(I))
        A1(I) = Y(5,I)**2/TLAM2 + HH*Y(6,I)**2
  542 CONTINUE
```

```
      A = 0.DO
      DO 642 I=2,NP
        DX2 = (X(I)-X(I-1))*0.5DO
        A = A + (A1(I)+A1(I-1))*DX2
  642 CONTINUE
      A = DSQRT(A)
C     ORTHONORMALIZE THE SOLUTION EXCEPT SIGMA
      DO 643 I=1,NP
          Y(N,I) = DABS(Y(N,I))
        DO 643 K=1,N-1
          Y(K,I) = Y(K,I)/A
  643 CONTINUE
C     OUTPUT RESULTS
      WRITE(9,1000) NAME
 1000 FORMAT(80A)
      WRITE(9,1001) NSEG,TLEN,WA,RHOO,RHOW,AI,CFLUID,PRESS,WT,TOMAX,VM
C
 1001 FORMAT(1X,I3,9X,' = NUMBER OF RISER SEGMENTS'/
     *1X,D12.6,' = UNSTRETCHED RISER LENGTH IN M'/
     *1X,D12.6,' = APPROXIMATE AVERAGE EFFECTIVE WEIGHT PER UNIT LENGTH
     *IN N/M'/
     *1X,D12.6,' = INNER FLUID DENSITY IN KG/M3'/
     *1X,D12.6,' = SALT WATER DENSITY IN KG/M3'/
     *1X,D12.6,' = INNER CROSS SECTIONAL AREA IN M2'/
     *1X,D12.6,' = INNER FLUID SPEED IN M/S'/
     *1X,D12.6,' = INNER FLUID OVERPRESSURE IN N/M2'/
     *1X,D12.6,' = APPROXIMATE TOTAL EFFECTIVE WEIGHT IN WATER IN N'/
     *1X,D12.6,' = MAXIMUM STATIC TENSION IN N'/
     *1X,D12.6,' = MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S')
C     EVALUATE DIMENSIONAL NATURAL FREQUENCY
      SIGMAD = Y(N,1)*DSQRT(TOMAX/TMAXAV)/TLEN
      WRITE(9,1002) NSEG
 1002 FORMAT(//' D A T A   P E R   R I S E R   S E G M E N T   F O R   NSEG =
     * ',I3,'  S E G M E N T S'/' D I M E N S I O N A L   Q U A N T I T I
     * E S   I N   T H E   S . I .   S Y S T E M'/
     *'   RLENG        DXI        PXIETA        AO        WEIGHT        MASS
     *    TMASS        AMAXI        AMAETA        AMAZI        TMAXI        TMAETA
     *')
      TL = TOMAX/TLEN
      DO 1004 I=1,NSEG
      WRITE(9,1003) RLENG(I)*TLEN,DXI(I),PXIETA(I),AO(I),WEIGHT(I)*TL,RM
     *ASS(I),RMASST(I),AMAXI(I),AMAETA(I),AMAZI(I),TMAXI(I),TMAETA(I)
 1004 CONTINUE
 1003 FORMAT(12(1X,D10.4)/)
C
      WRITE(9,10022)
10022 FORMAT('     EA          EIETA         EIETAS        EIXI         EIXIS
     *  GIP        GIPS         DETA          JZI          AJZI         TJZI')
      DO 10023 I=1,NSEG
      WRITE(9,10024) EA(I),EIETA(I),EIETAS(I),EIXI(I),EIXIS(I),GIP(I),
     *GIPS(I),DETA(I),XJZI(I),AJZI(I),TJZI(I)
10023 CONTINUE
10024 FORMAT(11(1X,D10.4)/)
C
      WRITE(9,761) MODE,SIGMAD
  761 FORMAT(' *************************************************************'
```

```
     */'  M O D E  N U M B E R = ',I2/'  N A T U R A L  F R E Q U E N
     *C Y = ',D10.4,' RAD/S'/' *****************************************
     ****************')
C
      WRITE(9,1009) NP
 1009 FORMAT(/' ORTHONORMALIZED NONDIMENSIONAL RESULTS AT NP = ',
     *I3,' POINTS'/
     *'     S            QETA      OMEGAZETA   OMEGAXI      THETA       BETA
     *      R          SIGMA')
      DO 1010 I=1,NP
      WRITE(9,1011) X(I),(Y(J,I),J=1,7)
 1010 CONTINUE
 1011 FORMAT(8(1X,D10.4))
C     NORMALIZE ESTIMATED ERROR BY COMPONENTS.
      DO 189 I=1,N-1
      ABT(I)=ABT(I)/A
 189  CONTINUE
      WRITE(9,10119) (ABT(I),I=1,7)
10119 FORMAT(' MAXIMUM ESTIMATED ERROR BY COMPONENTS'/11X,7(1X,D10.4))
C
C
C     OUTPUT TO FILE CONNECTED TO DEVICE 11
C     THIS CAN BE USED FOR PLOTS OR INPUT TO ANOTHER RUN OF RCLINDY3
C
C
      CALL STRUC(VLOCXI,NP,NPI)
      WRITE(11,36459) MODE,NP,SIGMAD
36459 FORMAT(1X,I2,1X,I3,1X,D10.4)
      DO 3666 I=1,NP
      WRITE(11,3667) X(I),(Y(J,I),J=1,7),VLOCXI(I)
 3666 CONTINUE
 3667 FORMAT(9(1X,D12.6))
C
      RETURN
      END
C
      SUBROUTINE FCN(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE FUNCTIONS USED BY DO2RAF TO SOLVE
C     THE PROBLEM.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,TO,QXIO,OMEGAO,
     *CONS1,CONS2
      DIMENSION Y(N),F(N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      F(1) = TO*Y(3) - QXIO*Y(2) + CONS1*Y(4) - CONS2*Y(5)
      F(1) = F(1) - HH*Y(6)*Y(7)**2
C
      F(2) = -EPIS*Y(2) + (EXI-EETA)*OMEGAO*Y(3)
      F(2) = (F(2) - Y(5)*Y(7)**2/TLAM2)/EPI
C
      F(3) = (-EXIS*Y(3) + Y(1) + (EETA-EPI)*Y(2)*OMEGAO)/EXI
```

```
C
      F(4) = Y(3) - OMEGA0*Y(5)
C
      F(5) = OMEGA0*Y(4) + Y(2)
C
      F(6) = -Y(4)
C
      F(7) = 0.D0
      RETURN
      END
C
      SUBROUTINE G(EPS,YA,YB,BC,N)
C     BOUNDARY CONDITIONS USED BY D02RAF
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION YA(N),YB(N),BC(N)
      COMMON/BOUNDA/BOUND,BOUNDR,BOUNDB
C
      BC(1)=YA(4)
      BC(2)=YA(5)
      BC(3)=YA(6)
      BC(4)=YA(3) - BOUND
C
      BC(5)=YB(4)
      BC(6)=YB(5) - BOUNDB + EPS*BOUNDB
      BC(7)=YB(6) - BOUNDR + EPS*BOUNDR
C
      RETURN
      END
C
      SUBROUTINE JACOBF(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE JACOBIAN OF THE EQUATIONS TO USE IN
C     NEWTON'S ITERATION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,T0,QXI0,OMEGA0,
     *CONS1,CONS2
      DIMENSION Y(N),F(N,N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      DO 817 I=1,N
        DO 817 M=1,N
         F(I,M) = 0.D0
  817 CONTINUE
C
      F(1,2) = -QXI0
      F(1,3) = T0
      F(1,4) = CONS1
      F(1,5) = -CONS2
      F(1,6) = -HH*Y(7)**2
      F(1,7) = -2.D0*Y(7)*HH*Y(6)
C
      F(2,2) = -EPIS/EPI
      F(2,3) = (EXI-EETA)*OMEGA0/EPI
```

```
      F(2,5) = -Y(7)**2/TLAM2/EPI
      F(2,7) = -2.D0*Y(7)*Y(5)/TLAM2/EPI
C
      F(3,1) = 1.D0/EXI
      F(3,2) = (EETA-EPI)*OMEGA0/EXI
      F(3,3) = -EXIS/EXI
C
      F(4,3) = 1.D0
      F(4,5) = -OMEGA0
C
      F(5,2) = 1.D0
      F(5,4) = OMEGA0
C
      F(6,4) = -1.D0
      RETURN
      END
C
      SUBROUTINE JACOBG(EPS,YA,YB,AJ,BJ,N)
C     THIS SUBROUTINE EVALUATES THE JACOBIAN OF THE BOUNDARY CONDITIONS.
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION YA(N),YB(N),AJ(N,N),BJ(N,N)
      DO 876 K=1,N
        DO 876 I=1,N
          AJ(K,I) = 0.D0
          BJ(K,I) = 0.D0
  876 CONTINUE
C
      AJ(1,4) = 1.D0
      AJ(2,5) = 1.D0
      AJ(3,6) = 1.D0
      AJ(4,3) = 1.D0
C
      BJ(5,4) = 1.D0
      BJ(6,5) = 1.D0
      BJ(7,6) = 1.D0
      RETURN
      END
C
      SUBROUTINE JACEPS(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE DERIVATIVES OF THE FUNCTIONS WITH
C     RESPECT TO THE CONTINUATION PARAMETER EPS.
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION Y(N),F(N)
C
      F(1) = 0.D0
C
      F(2) = 0.D0
C
      F(3) = 0.D0
      F(4) = 0.D0
      F(5) = 0.D0
C
      F(6) = 0.D0
      F(7) = 0.D0
      RETURN
      END
```

```
C
      SUBROUTINE JACGEP(EPS,YA,YB,BCEP,N)
C     THIS SUBROUTINE EVALUATES THE DERIVATIVES OF THE BOUNDARY
C     CONDITIONS WITH RESPECT TO THE CONTINUATION PARAMETER EPS.
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/BOUNDA/BOUND,BOUNDR,BOUNDB
      DIMENSION YA(N),YB(N),BCEP(N)
      DO 871 K=1,N
        BCEP(K) = 0.D0
  871 CONTINUE
      BCEP(5) = BOUNDB
      BCEP(6) = BOUNDR
      RETURN
      END
C
      SUBROUTINE INTERP(NP)
C     THIS SUBROUTINE INTERPOLATES THE RISER CHARACTERISTICS AND THE
C     STATIC SOLUTION TO THE NEW NUMBER OF POINTS NP.
C     ASSUMPTION: NP .GE. NPI
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION HELP(MNP)
C     INTERPOLATE STRUCTURAL DATA TO THE NEW NUMBER OF POINTS
      CALL STRUC(EPSXI,NP,NPI)
      CALL STRUC(EPSXIS,NP,NPI)
      CALL STRUC(EPSETA,NP,NPI)
      CALL STRUC(EPSETS,NP,NPI)
      CALL STRUC(EPSPI,NP,NPI)
      CALL STRUC(EPSPIS,NP,NPI)
      CALL STRUC(HETA,NP,NPI)
      CALL STRUC(TLAMB2,NP,NPI)
      CALL STRUC(CONST1,NP,NPI)
      CALL STRUC(CONST2,NP,NPI)
      CALL STRUC(VLOCXI,NP,NPI)
C     INTERPOLATE STATIC SOLUTION TO THE NEW NUMBER OF POINTS
      DO 459 K=1,3
        DO 458 I=1,NPI
         HELP(I) = STATIC(K,I)
  458   CONTINUE
        CALL STRUC(HELP,NP,NPI)
        DO 457 I=1,NP
         STATIC(K,I) = HELP(I)
  457   CONTINUE
  459 CONTINUE
      DO 339 I=1,NP
        XI(I) = X(I)
  339 CONTINUE
      RETURN
      END
C
      SUBROUTINE STRUC(ARRAY,NP,NPOLD)
```

```
C     THIS SUBROUTINE INTERPOLATES A SERIES OF DIVISION POINTS TO A NEW
C     SERIES OF DIVISION POINTS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      DIMENSION ARRAY(MNP),HELP(MNP)
C
        HELP(1) = ARRAY(1)
        HELP(NP) = ARRAY(NPOLD)
        DO 82 I=2,NPOLD
        DO 81 K=2,NP-1
         IF ((X(K).GT.XI(I-1)).AND.(X(K).LT.XI(I))) THEN
           CONV = (X(K)-XI(I-1))*(ARRAY(I)-ARRAY(I-1))/(XI(I)-XI(I-1))
           HELP(K) = ARRAY(I-1) + CONV
         ELSE IF (X(K).EQ.XI(I)) THEN
           HELP(K) = ARRAY(I)
         END IF
   81   CONTINUE
   82   CONTINUE
        DO 85 K=1,NP
          ARRAY(K) = HELP(K)
   85   CONTINUE
      RETURN
      END
C
      SUBROUTINE COUNT(X)
C     THIS SUBROUTINE EVALUATES THE RISER CHARACTERISTICS AS WELL AS THE
C     STATIC SOLUTION AT A POINT X.
C     IT RETURNS THEIR VALUE IN COMMON BLOCK COEF1.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4)
      COMMON/COEF/EPSXI(MNP),EPSXIS(MNP),EPSETA(MNP),EPSETS(MNP),EPSPI(M
     *NP),EPSPIS(MNP),HETA(MNP),TLAMB2(MNP),HETAM,TMAXAV
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF1/EXI,EXIS,EETA,EETAS,EPI,EPIS,HH,TLAM2,TO,QXIO,OMEGAO,
     *CONS1,CONS2
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/COUN/ICOUNT
      M = ICOUNT
      IF (X.EQ.XI(M)) THEN
       EXI = EPSXI(M)
       EXIS = EPSXIS(M)
       EETA = EPSETA(M)
       EETAS = EPSETS(M)
       EPI = EPSPI(M)
       EPIS = EPSPIS(M)
       HH = HETA(M)
       TLAM2 = TLAMB2(M)
       TO = STATIC(1,M)
       QXIO = STATIC(2,M)
       OMEGAO = STATIC(3,M)
       CONS1 = CONST1(M)
       CONS2 = CONST2(M)
       ICOUNT = ICOUNT + 1
       IF(X.EQ.1.D0) ICOUNT = 1
```

```
      ELSE IF ((X.LT.XI(M)).AND.(X.GT.XI(M-1))) THEN
       DIFF = DABS(XI(M)-X)
C     THIS IF STATEMENT IS TO ACCOUNT FOR A COMPUTER INACCURACY IN
C     REPRESENTING AND EQUATING REAL NUMBERS.
       IF (DIFF.LT.1.D-7) THEN
        ICOUNT = ICOUNT + 1
        IF (XI(M).EQ.1.D0) ICOUNT = 1
       END IF
       DX = (X-XI(M-1))/(XI(M)-XI(M-1))
       EXI = EPSXI(M-1) + (EPSXI(M)-EPSXI(M-1))*DX
       EXIS = EPSXIS(M-1) + (EPSXIS(M)-EPSXIS(M-1))*DX
       EETA = EPSETA(M-1) + (EPSETA(M)-EPSETA(M-1))*DX
       EETAS = EPSETS(M-1) + (EPSETS(M)-EPSETS(M-1))*DX
       EPI = EPSPI(M-1) + (EPSPI(M)-EPSPI(M-1))*DX
       EPIS = EPSPIS(M-1) + (EPSPIS(M)-EPSPIS(M-1))*DX
       HH = HETA(M-1) + (HETA(M)-HETA(M-1))*DX
       TLAM2 = TLAMB2(M-1) + (TLAMB2(M)-TLAMB2(M-1))*DX
       TO = STATIC(1,M-1) + (STATIC(1,M)-STATIC(1,M-1))*DX
       QXIO = STATIC(2,M-1) + (STATIC(2,M)-STATIC(2,M-1))*DX
       OMEGAO = STATIC(3,M-1) + (STATIC(3,M)-STATIC(3,M-1))*DX
       CONS1 = CONST1(M-1) + (CONST1(M)-CONST1(M-1))*DX
       CONS2 = CONST2(M-1) + (CONST2(M)-CONST2(M-1))*DX
      ELSE
C
       WRITE(6,*) ' ERROR OCCURED IN COUNTER, NP =',M
      END IF
      RETURN
      END
```

Chapter XVII

Listing of Program RCFORCE FORTRAN A

```
C RCFORCE
C THIS PROGRAM CALCULATES THE IN-PLANE LINEAR DYNAMIC RESPONSE OF A
C COMPLIANT RISER WITH A 2-D STATIC CONFIGURATION FOR A GIVEN FREQUENCY
C AND AMPLITUDE OF EXCITATION AT THE TOP (P OR Q EXCITATION IS ALLOWED).
C A NONUNIFORM GRID FINITE DIFFERENCES AND DEFERRED CORRECTION TECHNIQUE
C IS USED.THE OUTPUT OF THIS PROGRAM CAN BE USED AS INPUT TO RCLINDY2 TO
C SOLVE THE IN-PLANE DYNAMICS PROBLEM WITH HOMOGENEOUS BOUNDARY
C CONDITIONS (EIGENPROBLEM).
C THIS PROGRAM WILL BE PARTICULARLY USEFUL IN THE CASE OF ZERO CURRENT
C VELOCITY WHERE THE ASYMPTOTIC THEORY IS NO LONGER VALID.
C DOUBLE PRECISION AND THE NAG FORTRAN LIBRARY ARE USED.
C*********************************************************************
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C ALL RIGHTS RESERVED.
C*********************************************************************
C PROGRAMMER GEORGE A. KRIEZIS          JUNE 6, 1985      M.I.T.
C*********************************************************************
C
C DEFINITION OF DEVICES:
C DEVICE 5  : INPUT FROM TERMINAL
C DEVICE 6  : OUTPUT TO TERMINAL
C DEVICE 8  : INPUT FROM FILE PREPARED BY RCINPUT  (LRECL=80)
C DEVICE 10 : INPUT FROM FILE CONTAINING APPROXIMATE N-D STATIC
C             SOLUTION CREATED BY RCSTAT2D  (LRECL=132)
C DEVICE 11 : OUTPUT TO FILE FOR PLOTS OR INPUT TO A RUN
C             OF RCLINDY2  (LRECL=117)
C
C COMMON BLOCK CONTENTS (OVERALL REFERENCE):
C SOLUT  = SOLUTION MATRICES
C STAT   = STATIC COMPLIANT RISER SOLUTION
C STAT1  = X AND Y DISPLACEMENTS AT TOP OF RISER
C STAT2  = FUNCTIONS OF STATIC RESULTS
C INPUT1 = RISER LENGTH, AVERAGE AND TOTAL WEIGHT AND NUMBER OF SEGMENTS
C INPUTL = RISER SEGMENTS LENGTH
C COEF   = NONDIMENSIONAL RISER CHARACTERISTICS USED IN THE EQUATIONS
C COEF1  = NONDIMENSIONAL RISER CHARACTERISTICS AT A SPECIFIC POINT
C COUN   = INTEGER COUNTING VARIABLE TO DETERMINE EACH DIVISION POINT
C FREQ   = NONDIMENSIONAL FREQUENCY OF EXCITATION
C
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=6,MNP=151,NA=4,IY=6)
      PARAMETER(LW=MNP*(3*N**2+5*N+2)+3*N**2+5*N)
      PARAMETER(LIW=MNP*(2*N+1)+N)
      DIMENSION W(LW),IW(LIW),C(N,N),D(N,N),GAM(N)
      COMMON/SOLUT/X(MNP),Y(N,MNP),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COUN/ICOUNT
      COMMON/FREQ/XLAMDA
C     EXTERNAL SUBROUTINES USED BY NAG LIBRARY
      EXTERNAL FCNF,FCNG
      DATA NOUT /6/
C
C     READ2D READS 2-D STATIC SOLUTION CALCULATED FROM RCSTAT2D PROGRAM.
C     IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC EFFECTIVE TENSION
```

```
C
      CALL READ2D(NPI)
C
C     CHARAC READS RISER CHARACTERISTICS FROM UNIT 8 AND EVALUATES THE
C     NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE EQUATIONS.
C
      CALL CHARAC(TLENG,IC,NPI)
      IF(IC.EQ.0) STOP
C
C     DEFINITIONS OF PARAMETERS  ...
C     N  = NUMBER OF EQUATIONS TO BE SOLVED BY D02GBF
C     MNP= MAXIMUM NUMBER OF PERMITTED POINTS IN THE NON-UNIFORM
C     F.D. MESH ( MNP >= 32)
      IF(MNP.LT.32) THEN
        WRITE(6,1257) MNP
1257    FORMAT(' MNP = ',I3,' IS NOT PERMISSIBLE')
        STOP
      ENDIF
C     PARAMETER CONTROLLING MONITORING OF CALCULATIONS
      IFAIL=111
C     BOUNDARY POINTS FOR TWO-POINT BOUNDARY VALUE PROBLEM
      A=0.D0
      B=1.D0
C
      WRITE(6,*)' INPUT EXCITATION FREQUENCY IN RAD/S'
      READ(5,*) SIGM
C     NONDIMENSIONALIZE SIGMA
      SIGMA = SIGM*TLENG*DSQRT(TMAXAV/TOMAX)
      XLAMDA = SIGMA**2
      WRITE(6,*)' INPUT AMPLITUDE OF EXCITATION AT TOP OF RISER FOR P'
      READ(5,*)BOUNDP
      WRITE(6,*)' INPUT AMPLITUDE OF EXCITATION AT TOP OF RISER FOR Q'
      READ(5,*)BOUNDQ
      WRITE(6,*)' INPUT TOLERANCE FOR CONVERGENCE OF ITERATIONS'
      WRITE(6,*)' SUGGESTED VALUE IS THE EXCITATION AMPLITUDE OR 1/10 OF
     * THE EXCITATION AMPLITUDE'
      READ(5,*)TOL
      WRITE(6,*)' INPUT MODE NUMBER CORRESPONDING TO FREQUENCY OF EXCITA
     *TION'
      READ(5,*)MODE
      NP = NPI
      DO 632 I=1,N
        GAM(I) = 0.D0
       DO 632 K=1,N
        C(I,K)=0.D0
        D(I,K)=0.D0
  632 CONTINUE
C     DEFINE BOUNDARY CONDITIONS USED IN THE EQUATIONS.
      GAM(5) = BOUNDP
      GAM(6) = BOUNDQ
      C(1,4) = 1.D0
      C(2,5) = 1.D0
      C(3,6) = 1.D0
      D(4,4) = 1.D0
      D(5,5) = 1.D0
      D(6,6) = 1.D0
```

```
C     SET COUNTING VARIABLE
      ICOUNT = 1
C
      CALL X04AAF(1,NOUT)
      CALL X04ABF(1,NOUT)
C
C     CALL NAG SUBROUTINE D02GBF TO SOLVE THE LINEAR TWO-POINT
C     BOUNDARY VALUE PROBLEM USING A DEFERRED CORRECTION TECHNIQUE.
C
      CALL D02GBF(A,B,N,TOL,FCNF,FCNG,C,D,GAM,MNP,X,Y,NP,W,LW,IW,LIW,IFA
     *IL)
C
      WRITE(6,9000) IFAIL
 9000 FORMAT(' IFAIL =',I3)
C
C     OUTPUT THE RESULTS
C
      IF((IFAIL.EQ.0).OR.(IFAIL.EQ.4)) THEN
        CALL OUTPUT(NP)
      ENDIF
C
      STOP
      END

      SUBROUTINE CHARAC(TLENG,IC,NP)
C     THIS SUBROUTINE READS THE COMPLIANT RISER CHARACTERISTICS AND
C     EVALUATES THE NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE
C     GOVERNING EQUATIONS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=6)
      CHARACTER*80 NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),MODE
      DIMENSION RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(MNP)
     *,TMAXI(MNP),TMAZI(MNP)
      DIMENSION XJZI(MNP),AJZI(MNP),TJZI(MNP)
      DIMENSION DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP),AO(MNP)
      DIMENSION WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP),
     *EIXIS(MNP),GIP(MNP),GIPS(MNP)
      DIMENSION TENO(MNP),QXO(MNP),TOS(MNP),QXIOS(MNP)
C
C     READ RISER CHARACTERISTICS FROM DEVICE 8.
      READ (8,1000) NAME
 1000 FORMAT(80A)
      READ (8,1008) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
 1008 FORMAT(1X,I3,2(1X,D12.6)/4(1X,D12.6))
      TLENG = TLEN
      DO 1502 I=1,NSEG
      READ (8,1003) RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI(I
     *),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
 1502 CONTINUE
```

```
1003  FORMAT(5(1X,D12.6)/6(1X,D12.6))
C
      DO 1332 I=1,NSEG
      READ(8,1333) AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),AMA
     *ZI(I),XJZI(I),AJZI(I)
1332  CONTINUE
1333  FORMAT(6(1X,D12.6)/3(1X,D12.6))
C
      IC=1
C
7650  WRITE(6,7651)
7651  FORMAT(' DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS'/
     *' IF YES INPUT 1 , IF NO INPUT 0')
      READ(5,*) IPRINT
      IF((IPRINT.NE.1).AND.(IPRINT.NE.0)) GOTO 7650
      IF(IPRINT.EQ.1) THEN
C
      WRITE(6,1000) NAME
      WRITE(6,2500)
2500  FORMAT(' NSEG   TLEN          WA          RHOO          AI
     * CFLUID        PRESS')
      WRITE(6,2001) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
2001  FORMAT(1X,I3,6(1X,D12.6))
      WRITE(6,3400)
3400  FORMAT('   I    RLENG        RMASS        RMASST       AMAXI
     *  WEIGHT'   /'          DXI          PXIETA          EA          EIETA
     *          AO         EIETAS')
      DO 3002 I=1,NSEG
      WRITE(6,3003) I,RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI
     *(I),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
3002  CONTINUE
3003  FORMAT(1X,I3,5(1X,D12.6)/4X,6(1X,D12.6))
C
      WRITE(6,1334)
1334  FORMAT('   I   AMAETA         DETA         EIXI         EIXIS
     *   GIP          GIPS'/'         AMAZI         JZI          AJZI' )
      DO 1335 I=1,NSEG
      WRITE(6,1336) I,AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),
     *AMAZI(I),XJZI(I),AJZI(I)
1335  CONTINUE
1336  FORMAT(1X,I3,6(1X,D12.6)/4X,3(1X,D12.6))
C
1701  WRITE(6,1700)
1700  FORMAT(' INPUT 1 IF RISER DATA ARE CORRECT'/' INPUT 0 TO STOP')
      READ(5,*) IC
      IF((IC.NE.0).AND.(IC.NE.1)) GOTO 1701
      IF(IC.EQ.0) RETURN
C
      ENDIF
C
C     NON - DIMENSIONALIZATIONS
C
      GRAV=9.81D0
      WAM=WA/GRAV
      WT=WA*TLEN
      XPI=4.D0*DATAN(1.D0)
```

```
      XPI2=XPI/2.D0
      RHOW=1.025D3
C
C     NONDIMENSIONALIZE CORRECTLY QXIO, TO  FROM 2-D STATIC SOLUTION
C
      TOMAX = TOMAX*WT
      TND = WT/TOMAX
      DO 229 I=1,NP
        STATIC(1,I) = STATIC(1,I)*TND
        STATIC(2,I) = STATIC(2,I)*TND
  229 CONTINUE
C
C     NONDIMENSIONAL COEFFICIENTS USED IN THE EQUATIONS
C
      TOMAXL = TOMAX/TLEN
      TOML1  = TOMAX*TLEN
      TOML2  = TOML1*TLEN
      TLEN2  = TLEN**2
      TMAXAV = 0.D0
      DXIM = 0.D0
      DO 2000 I=1,NSEG
       RLENG(I)=RLENG(I)/TLEN
       WEIGHT(I)=WEIGHT(I)/TOMAXL
       EOM(I) = TOMAX/EA(I)
       EPSETA(I) = EIETA(I)/TOML2
       EPSETS(I) = EIETAS(I)/TOML1
       TJZI(I) = XJZI(I) + AJZI(I)
       TMAZI(I) = RMASS(I) + AMAZI(I)
       TMAXI(I) = RMASS(I) + AMAXI(I)
       TMAXAV = TMAXI(I)*RLENG(I) + TMAXAV
       DXIM = DXIM + DXI(I)*RLENG(I)
       DXIETA(I) = DXI(I)-DETA(I)
 2000 CONTINUE
      HZETAM = 0.D0
      DO 4321 I=1,NSEG
       HZETA(I) = TMAZI(I)/TMAXAV
       HZETAM = HZETAM + HZETA(I)*RLENG(I)
       HXI(I) = TMAXI(I)/TMAXAV
 4321 CONTINUE
C
C     CALCULATE DERIVATIVES OF STATIC QUANTITIES
      DO 737 I=1,NP
       TENO(I) = STATIC(1,I)
       QXO(I) = STATIC(2,I)
  737 CONTINUE
      CALL DER1(TENO,XI,TOS,NP)
      CALL DER1(QXO,XI,QXIOS,NP)
C     EVALUATE FUNCTIONS OF STATIC RESULTS.
      DO 56 I=1,NP
       CONST1(I) = TOS(I) - STATIC(2,I)*STATIC(3,I)
       CONST2(I) = QXIOS(I) + STATIC(1,I)*STATIC(3,I)
   56 CONTINUE
C
C     SEG(I)=LEFT ORDINATE OF SEGMENT I
      SEG(1)=0.D0
      SEG(NSEG+1)=1.D0
```

```
      DO 4000 I=2,NSEG
      SEG(I)=RLENG(I-1)+SEG(I-1)
 4000 CONTINUE
C     INTERPOLATE STRUCTURAL DIMENSIONS TO NP POINTS
C     ASSUMPTION: NUMBER OF RISER SEGMENTS WITH DIFFERENT
C     CHARACTERISTICS IS SMALLER THAN THE STATIC SOLUTION POINTS
C     NSEG < NPI
C
      IF (NSEG.GE.NPI) THEN
        WRITE(6,188)
  188   FORMAT(' NSEG => NPI, PROGRAM STOPS')
        IC = 0
        RETURN
      END IF
      CALL STRUCT(EPSETA,X,NP)
      CALL STRUCT(EPSETS,X,NP)
      CALL STRUCT(EOM,X,NP)
      CALL STRUCT(HZETA,X,NP)
      CALL STRUCT(HXI,X,NP)
      RETURN
      END
C
      SUBROUTINE READ2D(NP)
C     THIS SUBROUTINE READS THE STATIC COMPLIANT RISER SOLUTION FROM
C     DEVICE 10. IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC TENSION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=6,MNP=151,NA=4)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/XTOP,YTOP
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION XCOOR(MNP),YCOOR(MNP)
C
C     STATIC(1,I) = STATIC TENSION TO
C     STATIC(2,I) = STATIC SHEAR FORCE IN THE XI DIRECTION
C     STATIC(3,I) = STATIC OMEGA IN THE ETA DIRECTION
C     STATIC(4,I) = STATIC ANGLE PHI
C
      WRITE(6,2000) MNP
 2000 FORMAT(' MNP=',I3)
C     READ STATIC SOLUTION
      READ(10,36459) NP,VM
36459 FORMAT(1X,I3,1X,D12.6)
      WRITE(6,2311) NP,VM
 2311 FORMAT(' 2-D STATIC SOLUTION FROM DEVICE 10'/
     *' NP =',I3/
     *' MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S',VM =',D12.6)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING FROM DEVICE 10
C
```

```
      DO 1021 I=1,NP
      READ(10,1033) X(I),STATIC(1,I),STATIC(2,I),STATIC(3,I),STATIC(4,I)
     *,XCOOR(I),YCOOR(I),STRARC,TENSI,VLOCXI(I)
      XI(I) = X(I)
 1021 CONTINUE
 1033 FORMAT(10(1X,D12.6))
C     EVALUATE RISER TOP X AND Y COORDINATES
      XTOP = XCOOR(NP)
      YTOP = YCOOR(NP)
C     EVALUATE MAXIMUM STATIC EFFECTIVE TENSION
      TOMAX=DMAX1(STATIC(1,1),STATIC(1,2))
      DO 9859 I=3,NP
      TOMAX=DMAX1(TOMAX,STATIC(1,I))
 9859 CONTINUE
C
      WRITE(6,1654) TOMAX
 1654 FORMAT(' 2-D STATIC SOLUTION SUCCESFULLY READ'/' MAXIMUM STATIC EF
     *FECTIVE TENSION/WA*L = ',D10.4)
C
      RETURN
      END
C
      SUBROUTINE STRUCT(ARRAY,X,NP)
C     THIS SUBROUTINE CHANGES A SERIES OF DATA GIVEN IN SEGMENTS
C     TO A SERIES OF DATA CORRESPONDING TO SPECIFIC POINTS
C     ASSUMPTION: NSEG < NP
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      DIMENSION ARRAY(MNP),HELP(MNP),X(MNP)
C
      IF(NSEG.EQ.1) THEN
        DO 83 I=1,NP
         HELP(I) = ARRAY(1)
83      CONTINUE
      ELSE
        HELP(1) = ARRAY(1)
        HELP(NP) = ARRAY(NSEG)
        I=2
        DO 84 K=2,NP-1
         IF ((X(K).GT.SEG(I-1)).AND.(X(K).LT.SEG(I))) THEN
           HELP(K) = ARRAY(I-1)
         ELSE IF (X(K).EQ.SEG(I)) THEN
           HELP(K) = 0.5D0*(ARRAY(I-1) + ARRAY(I))
         ELSE IF (X(K).GT.SEG(I)) THEN
           HELP(K) = ARRAY(I)
           I = I + 1
         END IF
 84     CONTINUE
      END IF
      DO 85 K=1,NP
        ARRAY(K) = HELP(K)
 85   CONTINUE
      RETURN
      END
```

```
C
      SUBROUTINE DER1(ARRAY,X,DERIV,NP)
C     THIS SUBROUTINE EVALUATES THE FIRST DERIVATIVE OF A SERIES OF DATA
C     POINTS USING A SECOND ORDER APPROXIMATION (NONUNIFORM GRID FINITE
C     DIFFERENCES).
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (MNP=151)
      DIMENSION ARRAY(MNP),DERIV(MNP),X(MNP)
C     USE FIRST ORDER FOR END POINTS DERIVATIVES
      DERIV(1) = (-ARRAY(1) + ARRAY(2))/(X(2)-X(1))
      DERIV(NP) = (-ARRAY(NP-1) + ARRAY(NP))/(X(NP)-X(NP-1))
C
      DO 836 I=2,NP-1
       DX = X(I) - X(I-1)
       DX1 = X(I+1) - X(I)
       D = DX/DX1
       DERIV(I) = (D*(ARRAY(I+1)-ARRAY(I)) - (ARRAY(I-1)-ARRAY(I))/D)
       DERIV(I) = DERIV(I)/(DX+DX1)
  836 CONTINUE
      RETURN
      END
C
      SUBROUTINE OUTPUT(NP)
C     THIS SUBROUTINE OUTPUTS THE RESULTS IN A FORM TO BE USED AS INPUT
C     FOR A RUN OF RCLINDY2.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=6)
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/XTOP,YTOP
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/SOLUT/X(MNP),Y(N,MNP),MODE
      COMMON/FREQ/XLAMDA
C
      SIGMAD = DSQRT(XLAMDA*TOMAX/TMAXAV)/TLEN
      SIGMA = DSQRT(XLAMDA)
C
C
C     OUTPUT TO FILE CONNECTED TO DEVICE 11
C     THIS CAN BE USED FOR PLOTS OR INPUT TO A RUN OF RCLINDY2
C
C
      WRITE(11,36459) MODE,NP,SIGMAD,XTOP,YTOP
36459 FORMAT(1X,I2,1X,I3,3(1X,D10.4))
      DO 3666 I=1,NP
      WRITE(11,3667) X(I),(Y(J,I),J=1,6),SIGMA
3666  CONTINUE
3667  FORMAT(8(1X,D12.6))
C
      RETURN
      END
C
      SUBROUTINE FCNF(X,F)
C     THIS SUBROUTINE EVALUATES THE MATRIX F(X) AT A GENERAL POINT X
C     THIS MATRIX IS USED BY NAG SUBROUTINE D02GBF.
```

```
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,N=6)
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,TO,QXIO,OMEGAO,CONS1,CONS2
      COMMON/FREQ/XLAMDA
      DIMENSION F(N,N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      DO 875 I=1,N
        DO 875 K=1,N
          F(I,K) = 0.DO
875   CONTINUE
C
      F(1,2) = OMEGAO
      F(1,3) = QXIO
      F(1,4) = CONS2
      F(1,5) = -XLAMDA*HZET
C
      F(2,1) = - OMEGAO
      F(2,3) = -TO
      F(2,4) = -CONS1
      F(2,6) = -XLAMDA*HX
C
      F(3,2) = -1.DO/EETA
      F(3,3) = -EETAS/EETA
C
      F(4,3) = 1.DO
C
      F(5,1) = EOMI
      F(5,6) = OMEGAO
C
      F(6,4) = 1.DO + EOMI*TO
      F(6,5) = -OMEGAO
      RETURN
      END
C
      SUBROUTINE FCNG(X,G)
C     THIS SUBROUTINE EVALUATES VECTOR G(X) AT A GENERAL POINT X.
C     IT IS USED BY NAG SUBROUTINE DO2GBF.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=6)
      DIMENSION G(N)
      DO 817 I=1,N
        G(I) = 0.DO
817   CONTINUE
      RETURN
      END
C
      SUBROUTINE COUNT(X)
C     THIS SUBROUTINE EVALUATES THE RISER CHARACTERISTICS AS WELL AS THE
C     STATIC SOLUTION AT A GENERAL POINT X.
C     IT RETURNS THEIR VALUE IN COMMON BLOCK COEF1.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4)
```

```
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,T0,QXI0,OMEGA0,CONS1,CONS2
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/COUN/ICOUNT
      M = ICOUNT
      IF (X.EQ.XI(M)) THEN
       EETA = EPSETA(M)
       EETAS = EPSETS(M)
       HX = HXI(M)
       HZET = HZETA(M)
       EOMI = EOM(M)
       T0 = STATIC(1,M)
       QXI0 = STATIC(2,M)
       OMEGA0 = STATIC(3,M)
       CONS1 = CONST1(M)
       CONS2 = CONST2(M)
       ICOUNT = ICOUNT + 1
       IF(X.EQ.1.D0) ICOUNT = 1
      ELSE IF ((X.LT.XI(M)).AND.(X.GT.XI(M-1))) THEN
       DIFF = DABS(XI(M)-X)
C     THIS IF STATEMENT IS TO ACCOUNT FOR A COMPUTER INACCURACY IN
C     REPRESENTING AND EQUATING REAL NUMBERS.
       IF (DIFF.LT.1.D-7) THEN
        ICOUNT = ICOUNT + 1
        IF (XI(M).EQ.1.D0) ICOUNT = 1
       END IF
       DX = (X-XI(M-1))/(XI(M)-XI(M-1))
       EETA = EPSETA(M-1) + (EPSETA(M)-EPSETA(M-1))*DX
       EETAS = EPSETS(M-1) + (EPSETS(M)-EPSETS(M-1))*DX
       HX = HXI(M-1) + (HXI(M)-HXI(M-1))*DX
       HZET = HZETA(M-1) + (HZETA(M)-HZETA(M-1))*DX
       EOMI = EOM(M-1) + (EOM(M)-EOM(M-1))*DX
       T0 = STATIC(1,M-1) + (STATIC(1,M)-STATIC(1,M-1))*DX
       QXI0 = STATIC(2,M-1) + (STATIC(2,M)-STATIC(2,M-1))*DX
       OMEGA0 = STATIC(3,M-1) + (STATIC(3,M)-STATIC(3,M-1))*DX
       CONS1 = CONST1(M-1) + (CONST1(M)-CONST1(M-1))*DX
       CONS2 = CONST2(M-1) + (CONST2(M)-CONST2(M-1))*DX
      ELSE
C
       WRITE(6,*) ' ERROR OCCURED IN COUNTER, NP=',M
      END IF
      RETURN
      END
```

Chapter XVIII

Listing of Program RCLINDY2 FORTRAN A

```
C RCLINDY2
C THIS PROGRAM CALCULATES THE IN-PLANE LINEAR DYNAMIC RESPONSE OF A
C COMPLIANT RISER WITH A 2-D STATIC CONFIGURATION BASED ON AN
C EMBEDDING TECHNIQUE. THE INITIAL EMBEDDED APPROXIMATION IS PREPARED
C BY PROGRAM RCFORCE AND THE FINAL SOLUTION IS OBTAINED USING MODIFIED
C NEWTON'S ITERATION AND A NON-UNIFORM GRID FINITE DIFFERENCE METHOD.
C DOUBLE PRECISION AND THE NAG FORTRAN LIBRARY ARE USED.
C***********************************************************************
C COPYRIGHT, 1985, MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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C***********************************************************************
C PROGRAMMER    GEORGE A. KRIEZIS      JUNE 6, 1985      M.I.T.
C***********************************************************************
C
C DEFINITION OF DEVICES:
C DEVICE 5  : INPUT FROM TERMINAL
C DEVICE 6  : OUTPUT TO TERMINAL
C DEVICE 8  : INPUT FROM FILE PREPARED BY RCINPUT  (LRECL=80)
C DEVICE 9  : COMPLETE OUTPUT TO FILE  (LRECL=132)
C DEVICE 10 : INPUT FROM FILE CONTAINING APPROXIMATE N-D STATIC
C             SOLUTION CREATED BY RCSTAT2D  (LRECL=132)
C DEVICE 11 : OUTPUT TO FILE FOR PLOTS OR INPUT TO A NEW RUN
C             OF RCLINDY2  (LRECL=117)
C DEVICE 12 : INPUT FROM FILE CONTAINING APPROXIMATE EMBEDDED SOLUTION
C             CREATED BY RCFORCE  (LRECL=117)
C
C COMMON BLOCK CONTENTS (OVERALL REFERENCE):
C SOLUT  = INITIAL EMBEDDED APPROXIMATION AND SOLUTION MATRICES
C STAT   = STATIC COMPLIANT RISER SOLUTION
C STAT1  = X AND Y DISPLACEMENTS AT TOP OF RISER
C STAT2  = FUNCTIONS OF STATIC RESULTS
C INPUT0 = OUTPUT FILE HEADING
C INPUT1 = RISER LENGTH, AVERAGE AND TOTAL WEIGHT AND NUMBER OF SEGMENTS
C INPUT2 = RISER TUBE INTERIOR CHARACTERISTICS
C INPUTL = RISER SEGMENTS LENGTH
C INPUT3 = WEIGHT, STIFFNESSES AND STIFFNESS DERIVATIVES
C INPUT4 = CHARACTERISTIC DIAMETERS AND PERIMETER OF RISER TUBE.
C INPUT5 = MASS AND ADDED MASS CHARACTERISTICS IN THREE DIRECTIONS
C INPUT6 = RISER POLAR AND ADDED POLAR MOMENT OF INERTIA.
C COEF   = NONDIMENSIONAL RISER CHARACTERISTICS USED IN THE EQUATIONS
C COEF1  = NONDIMENSIONAL RISER CHARACTERISTICS AT A SPECIFIC POINT
C CONST  = PROBLEM CONSTANTS (PI, GRAVITY, WATER DENSITY)
C BOUNDA = BOUNDARY CONDITION FOR OMEGA ETA AT S=0 AND EMBEDDED BOUNDARY
C          CONDITIONS FROM PROGRAM RCFORCE
C COUN   = INTEGER COUNTING VARIABLE TO DETERMINE EACH DIVISION POINT
C
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4,IY=7)
      PARAMETER(LWORK=MNP*(3*N**2+6*N+2)+4*N**2+3*N)
      PARAMETER(LIWORK=MNP*(2*N+1)+N)
      DIMENSION WORK(LWORK),IWORK(LIWORK)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COUN/ICOUNT
C     EXTERNAL SUBROUTINES USED BY NAG LIBRARY
      EXTERNAL FCN,G,JACEPS,JACGEP,JACOBF,JACOBG
```

```
      DATA NOUT /6/
C
C     READ2D READS 2-D STATIC SOLUTION CALCULATED FROM RCSTAT2D PROGRAM.
C     IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC EFFECTIVE TENSION
C
      CALL READ2D(NPI)
C
C     CHARAC READS RISER CHARACTERISTICS FROM UNIT 8 AND EVALUATES THE
C     NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE EQUATIONS.
C
      CALL CHARAC(TLENG,IC,NPI)
      IF(IC.EQ.0) STOP
C
C     DEFINITIONS OF PARAMETERS ...
C     N  = NUMBER OF EQUATIONS TO BE SOLVED BY D02RAF
C     IY = NUMBER OF VARIABLES
C     MNP= MAXIMUM NUMBER OF PERMITTED POINTS IN THE NON-UNIFORM
C     F.D. MESH ( MNP >= 32)
      IF(MNP.LT.32) THEN
        WRITE(6,1257) MNP
1257    FORMAT(' MNP = ',I3,' IS NOT PERMISSIBLE')
        STOP
      ENDIF
C     NUMBER OF BOUNDARY CONDITIONS AT S=0
1276  NUMBEG=4
C     NUMBER OF MIXED BOUNDARY CONDITIONS
      NUMMIX=0
C     PARAMETER DECLARING THAT INITIAL APPROXIMATION IS USER SPECIFIED
      INIT=1
C     PARAMETER DECLARING THAT JACOBIANS ARE USER SPECIFIED
      IJAC=1
C     PARAMETER CONTROLLING MONITORING OF CALCULATIONS
      IFAIL=111
C
C
C     READAS : READS APPROXIMATE EMBEDDED SOLUTION FROM DEVICE 10
C              IT ALSO PROVIDES ICCC,NP, TOL= TOLERANCE OF ITERATIONS
C
      CALL READAS(ICCC,NP,TOL)
C
C     IF THE NUMBER OF POINTS FROM THIS SOLUTION IS GREATER THAN THE
C     STATIC SOLUTION POINTS, INTERPOLATE ALL CHARACTERISTICS TO THE
C     NEW NUMBER OF POINTS.
C     ASSUMPTION : NP ALWAYS GREATER OR EQUAL TO NPI
C     THIS IS VALID IF THE SAME STATIC SOLUTION WAS USED TO OBTAIN THE
C     APPROXIMATE EMBEDDED SOLUTION IN DEVICE 10.
C
      IF (NP.GE.NPI) THEN
         CALL INTERP(NP)
         NPI=NP
      ELSE IF (NP.LT.NPI) THEN
         WRITE(6,314)
314      FORMAT(' APPROXIMATE SOLUTION IN DEVICE 10 WAS NOT OBTAINED'/
     *   ' FROM THE SAME STATIC SOLUTION, PROGRAM STOPS')
         STOP
      END IF
```

```
C
C     INCREMENT OF CONTINUATION PARAMETER
7891  WRITE(6,7890)
7890  FORMAT(' INPUT INITIAL INCREMENT OF CONTINUATION PARAMETER DELEPS'
     */' IF NO CONTINUATION IS REQUIRED INPUT DELEPS = 1.D0'/
     *' IF CONTINUATION IS REQUIRED THEN 0.D0 < DELEPS < 1.D0'/
     *' RECOMMENDATION :'/
     *' USUALLY DELEPS = 0.1D0 WILL SUFFICE'/
     *' FOR LARGE CHANGES BETWEEN INITIAL AND FINAL PROBLEM'/
     *' A SMALLER VALUE OF DELEPS, E.G. 0.05D0 OR 0.025D0 MIGHT BE'/
     *' NECESSARY')
      READ(5,*) DELEPS
      IF((DELEPS.GT.1.D0).OR.(DELEPS.LE.0.D0)) THEN
        WRITE(6,7892)
7892    FORMAT(' 0. <  DELEPS  <= 1.')
        GOTO 7891
      END IF
C     SET COUNTING VARIABLE
      ICOUNT = 1
      IF(ICCC.EQ.0) STOP
C
      CALL X04AAF(1,NOUT)
      CALL X04ABF(1,NOUT)
C
C     CALL NAG SUBROUTINE D02RAF TO SOLVE THE TWO-POINT BOUNDARY VALUE
C     PROBLEM USING A DEFERRED CORRECTION TECHNIQUE AND NEWTON'S
C     ITERATION.
      CALL D02RAF(N,MNP,NP,NUMBEG,NUMMIX,TOL,INIT,X,Y,IY,ABT,FCN,G,IJAC,
     *JACOBF,JACOBG,DELEPS,JACEPS,JACGEP,WORK,LWORK,IWORK,LIWORK,IFAIL)
C
      WRITE(6,9000) IFAIL
9000  FORMAT(' IFAIL =',I3)
C
C     OUTPUT THE RESULTS
C
      IF((IFAIL.EQ.0).OR.(IFAIL.EQ.4)) THEN
        CALL OUTPUT(NP)
      ENDIF
C
      STOP
      END

      SUBROUTINE CHARAC(TLENG,IC,NP)
C     THIS SUBROUTINE READS THE COMPLIANT RISER CHARACTERISTICS AND
C     EVALUATES THE NONDIMENSIONAL COEFFICIENTS TO BE USED IN THE
C     GOVERNING EQUATIONS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      CHARACTER*80 NAME
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/INPUT0/NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUT2/RHOO,AI,CFLUID,PRESS,AO(MNP)
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/INPUT3/WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP)
     *,EIXIS(MNP),GIP(MNP),GIPS(MNP)
```

```
      COMMON/INPUT4/DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP)
      COMMON/INPUT5/RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(
     *MNP),TMAXI(MNP),TMAZI(MNP)
      COMMON/INPUT6/XJZI(MNP),AJZI(MNP),TJZI(MNP)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION TENO(MNP),QXO(MNP),TOS(MNP),QXIOS(MNP)
C
C     READ RISER CHARACTERISTICS FROM DEVICE 8
      READ (8,1000) NAME
 1000 FORMAT(80A)
      READ (8,1008) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
 1008 FORMAT(1X,I3,2(1X,D12.6)/4(1X,D12.6))
      TLENG = TLEN
      DO 1502 I=1,NSEG
      READ (8,1003) RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI(I
     *),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
 1502 CONTINUE
 1003 FORMAT(5(1X,D12.6)/6(1X,D12.6))
C
      DO 1332 I=1,NSEG
      READ(8,1333) AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),AMA
     *ZI(I),XJZI(I),AJZI(I)
 1332 CONTINUE
 1333 FORMAT(6(1X,D12.6)/3(1X,D12.6))
C
      IC=1
C
 7650 WRITE(6,7651)
 7651 FORMAT(' DO YOU WISH A TERMINAL COPY OF RISER CHARACTERISTICS'/
     *' IF YES INPUT 1 , IF NO INPUT 0')
      READ(5,*) IPRINT
      IF((IPRINT.NE.1).AND.(IPRINT.NE.0)) GOTO 7650
      IF(IPRINT.EQ.1) THEN
C
      WRITE(6,1000) NAME
      WRITE(6,2500)
 2500 FORMAT(' NSEG   TLEN            WA            RHOO           AI
     * CFLUID         PRESS')
      WRITE(6,2001) NSEG,TLEN,WA,RHOO,AI,CFLUID,PRESS
 2001 FORMAT(1X,I3,6(1X,D12.6))
      WRITE(6,3400)
 3400 FORMAT('   I    RLENG          RMASS          RMASST         AMAXI
     *  WEIGHT'   /'           DXI           PXIETA          EA            EIETA
     *          AO          EIETAS')
      DO 3002 I=1,NSEG
      WRITE(6,3003) I,RLENG(I),RMASS(I),RMASST(I),AMAXI(I),WEIGHT(I),DXI
     *(I),PXIETA(I),EA(I),EIETA(I),AO(I),EIETAS(I)
 3002 CONTINUE
 3003 FORMAT(1X,I3,5(1X,D12.6)/4X,6(1X,D12.6))
C
      WRITE(6,1334)
 1334 FORMAT('   I    AMAETA          DETA           EIXI           EIXIS
```

```
     *   GIP          GIPS'/'         AMAZI          JZI          AJZI' )
      DO 1335 I=1,NSEG
      WRITE(6,1336) I,AMAETA(I),DETA(I),EIXI(I),EIXIS(I),GIP(I),GIPS(I),
     *AMAZI(I),XJZI(I),AJZI(I)
 1335 CONTINUE
 1336 FORMAT(1X,I3,6(1X,D12.6)/4X,3(1X,D12.6))
C
 1701 WRITE(6,1700)
 1700 FORMAT(' INPUT 1 IF RISER DATA ARE CORRECT'/' INPUT 0 TO STOP')
      READ(5,*) IC
      IF((IC.NE.0).AND.(IC.NE.1)) GOTO 1701
      IF(IC.EQ.0) RETURN
C
      ENDIF
C
C     NON - DIMENSIONALIZATIONS
C
      GRAV=9.81D0
      WAM=WA/GRAV
      WT=WA*TLEN
      XPI=4.D0*DATAN(1.D0)
      XPI2=XPI/2.D0
      RHOW=1.025D3
C
C     NONDIMENSIONALIZE CORRECTLY QXIO, TO  FROM 2-D STATIC SOLUTION
C
      TOMAX = TOMAX*WT
      TND = WT/TOMAX
      DO 229 I=1,NP
        STATIC(1,I) = STATIC(1,I)*TND
        STATIC(2,I) = STATIC(2,I)*TND
  229 CONTINUE
C
C     NONDIMENSIONAL COEFFICIENTS USED IN THE EQUATIONS
C
      TOMAXL = TOMAX/TLEN
      TOML1  = TOMAX*TLEN
      TOML2  = TOML1*TLEN
      TLEN2  = TLEN**2
      TMAXAV = 0.D0
      DXIM = 0.D0
      DO 2000 I=1,NSEG
       RLENG(I)=RLENG(I)/TLEN
       WEIGHT(I)=WEIGHT(I)/TOMAXL
       EOM(I) = TOMAX/EA(I)
       EPSETA(I) = EIETA(I)/TOML2
       EPSETS(I) = EIETAS(I)/TOML1
       TJZI(I) = XJZI(I) + AJZI(I)
       TMAZI(I) = RMASS(I) + AMAZI(I)
       TMAXI(I) = RMASS(I) + AMAXI(I)
       TMAXAV = TMAXI(I)*RLENG(I) + TMAXAV
       DXIM = DXIM + DXI(I)*RLENG(I)
       DXIETA(I) = DXI(I)-DETA(I)
 2000 CONTINUE
      HZETAM = 0.D0
      DO 4321 I=1,NSEG
```

```
      HZETA(I) = TMAZI(I)/TMAXAV
      HZETAM = HZETAM + HZETA(I)*RLENG(I)
      HXI(I) = TMAXI(I)/TMAXAV
 4321 CONTINUE
C
C     CALCULATE DERIVATIVES OF STATIC QUANTITIES
      DO 737 I=1,NP
       TENO(I) = STATIC(1,I)
       QXO(I) = STATIC(2,I)
  737 CONTINUE
      CALL DER1(TENO,XI,TOS,NP)
      CALL DER1(QXO,XI,QXIOS,NP)
C     EVALUATE FUNCTIONS OF STATIC RESULTS
      DO 56 I=1,NP
       CONST1(I) = TOS(I) - STATIC(2,I)*STATIC(3,I)
       CONST2(I) = QXIOS(I) + STATIC(1,I)*STATIC(3,I)
   56 CONTINUE
C
C     SEG(I)=LEFT ORDINATE OF SEGMENT I
      SEG(1)=0.D0
      SEG(NSEG+1)=1.D0
      DO 4000 I=2,NSEG
      SEG(I)=RLENG(I-1)+SEG(I-1)
 4000 CONTINUE
C     INTRERPOLATE STRUCTURAL DIMENSIONS TO NP POINTS
C     ASSUMPTION: NUMBER OF RISER SEGMENTS WITH DIFFERENT
C     CHARACTERISTICS IS SMALLER THAN THE STATIC SOLUTION POINTS
C     NSEG < NPI
C
      IF (NSEG.GE.NPI) THEN
        WRITE(6,188)
  188   FORMAT(' NSEG => NPI, PROGRAM STOPS')
        IC = 0
        RETURN
      END IF
      CALL STRUCT(EPSETA,X,NP)
      CALL STRUCT(EPSETS,X,NP)
      CALL STRUCT(EOM,X,NP)
      CALL STRUCT(HZETA,X,NP)
      CALL STRUCT(HXI,X,NP)
      RETURN
      END
C
      SUBROUTINE READ2D(NP)
C     THIS SUBROUTINE READS THE STATIC COMPLIANT RISER SOLUTION FROM
C     DEVICE 10. IT EVALUATES THE MAXIMUM NONDIMENSIONAL STATIC TENSION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/XTOP,YTOP
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION XCOOR(MNP),YCOOR(MNP)
C
C     STATIC(1,I) = STATIC EFFECTIVE TENSION TO
C     STATIC(2,I) = STATIC SHEAR FORCE IN THE XI DIRECTION
C     STATIC(3,I) = STATIC OMEGA IN THE ETA DIRECTION
```

```
C     STATIC(4,I) = STATIC ANGLE PHI
C
      WRITE(6,2000) MNP
2000  FORMAT(' MNP=',I3)
C     READ STATIC SOLUTION
      READ(10,36459) NP,VM
36459 FORMAT(1X,I3,1X,D12.6)
      WRITE(6,2311) NP,VM
2311  FORMAT(' 2-D STATIC SOLUTION FROM DEVICE 10'/
     *' NP =',I3/
     *' MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S ,VM =',D12.6)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING FROM DEVICE 10
C
      DO 1021 I=1,NP
      READ(10,1033) X(I),STATIC(1,I),STATIC(2,I),STATIC(3,I),STATIC(4,I)
     *,XCOOR(I),YCOOR(I),STRARC,TENSI,VLOCXI(I)
      XI(I) = X(I)
1021  CONTINUE
1033  FORMAT(10(1X,D12.6))
C     EVALUATE RISER TOP X AND Y COORDINATES
      XTOP = XCOOR(NP)
      YTOP = YCOOR(NP)
C     EVALUATE MAXIMUM STATIC EFFECTIVE TENSION
      TOMAX=DMAX1(STATIC(1,1),STATIC(1,2))
      DO 9859 I=3,NP
      TOMAX=DMAX1(TOMAX,STATIC(1,I))
9859  CONTINUE
C
      WRITE(6,1654) TOMAX
1654  FORMAT(' 2-D STATIC SOLUTION SUCCESFULLY READ'/' MAXIMUM STATIC EF
     *FECTIVE TENSION/WA*L = ',D10.4)
C
      RETURN
      END

      SUBROUTINE READAS(ICCC,NP,TOL)
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(N=7,MNP=151,NA=4)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/XTOP,YTOP
      COMMON/BOUNDA/BOUND,BOUNDP,BOUNDQ
C
C     READAS READS INITIAL EMBEDDED APPROXIMATION RESULTING FROM A
C     RUN OF RCFORCE
C
C     Y(1,I)  = DYNAMIC TENSION
C     Y(2,I)  = SHEAR FORCE IN THE XI DIRECTION
```

```
C       Y(3,I)  = OMEGA ABOUT ETA
C       Y(4,I)  = DYNAMIC ANGLE PHI
C       Y(5,I)  = DISPLACEMENT IN THE ZI DIRECTION, P (TANGENTIAL)
C       Y(6,I)  = DISPLACEMENT IN THE XI DIRECTION, Q (NORMAL)
C       Y(7,I)  = NATURAL FREQUENCY
C       X(I)    = UNSTRETCHED ARC LENGTH S
C
      WRITE(6,2000) MNP
 2000 FORMAT(' MNP=',I3)
C
      READ(12,36459) MODE,NP,SIGMAD,XTOP,YTOP
36459 FORMAT(1X,I2,1X,I3,3(1X,D10.4))
      WRITE(6,2311) NP,MODE,SIGMAD,XTOP,YTOP
 2311 FORMAT(' INITIAL APPROXIMATION FROM DEVICE 12'/
     *' NP =',I3,' MODE NUMBER =',I2,' SIGMAD =',D10.4/' X AT TOP =',
     *D10.4,' Y AT TOP =',D10.4)
C
      IF((NP.LT.4).OR.(NP.GT.MNP)) THEN
        ICCC=0
        WRITE(6,12439)
12439   FORMAT(' NP IS INAPPROPRIATE ; RUN STOPS')
        RETURN
      ENDIF
C
C     READING DATA FROM DEVICE 12 ...
C
      DO 10011 I=1,NP
      READ(12,10012) X(I),(Y(J,I),J=1,7)
10011 CONTINUE
10012 FORMAT(8(1X,D12.6))
C     EMBEDDED BOUNDARY CONDITIONS AND OMEGA ETA(0)
      BOUND = Y(3,1)
      BOUNDP = Y(5,NP)
      BOUNDQ = Y(6,NP)
C
      WRITE(9,1052) NP,SIGMAD
 1052 FORMAT(' INITIAL CONDITION FOR EPS=0. AND NP = ',I3,' POINTS,  NAT
     *URAL FREQUENCY = ',D10.4,' RAD/S'/
     *'   I      ARC           TENSION          QXI         OMEGA ETA          PHI
     *          P              Q              SIGMA')
      DO 1601 I=1,NP
       WRITE(9,1603) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     * Y(7,I)
 1601 CONTINUE
 1603 FORMAT(1X,I3,8(1X,D12.6))
C
      WRITE(6,9561)
 9561 FORMAT(' DO YOU WISH A TERMINAL COPY OF INITIAL APPROXIMATION'/
     *' IF YES INPUT 1')
      READ(5,*)IPRINT
      IF(IPRINT.EQ.1) THEN
       WRITE(6,1052) NP
       DO 9659 I=1,NP
        WRITE(6,1603) I,X(I),Y(1,I),Y(2,I),Y(3,I),Y(4,I),Y(5,I),Y(6,I),
     *  Y(7,I)
 9659  CONTINUE
```

```
      END IF
      WRITE(6,1722) BOUND
 1722 FORMAT(' ASSUMED BOUNDARY CONDITION '/
     *' OMEGA ETA (0) =',D12.6)
C
      TOL1 = 0.D0
      DO 3931 I=1,NP
        TOL1 = DMAX1(TOL1,DABS(Y(3,I)))
 3931 CONTINUE
      WRITE(6,3932) TOL1
 3932 FORMAT(' MAXIMUM ABSOLUTE VALUE OF N-D OMEGA ETA IS =',D12.6/
     *' THIS NUMBER CAN BE USED TO ESTIMATE '/
     *' A REASONABLE TOLERANCE FOR CONVERGENCE OF ITERATIONS'/
     *' INPUT A FRACTION OF THIS NUMBER TO DETERMINE THE TOLERANCE'/
     *' E.G. INPUT 0.01 OR 0.1 IF THE INITIAL ESTIMATE FOR OMEGA ETA'/
     *' IS SMALL'/' AFTER THE RUN CHECK THE ACCURACY OF THE SOLUTION')
      READ(5,*) TOLV
      TOL = DABS(TOLV)*TOL1
C
 1005 WRITE(6,1004)
 1004 FORMAT(' IF YOU WISH TO STOP INPUT 0'/
     *' IF YOU WISH TO CONTINUE WITH ITERATIONS INPUT 1')
      READ(5,*) ICCC
      IF((ICCC.NE.0).AND.(ICCC.NE.1)) GOTO 1005
C
      RETURN
      END
C
      SUBROUTINE STRUCT(ARRAY,X,NP)
C     THIS SUBROUTINE CHANGES A SERIES OF DATA GIVEN IN
C     SEGMENTS TO A SERIES OF DATA CORRESPONDING TO SPECIFIC POINTS
C     ASSUMPTION: NSEG < NP
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      DIMENSION ARRAY(MNP),HELP(MNP),X(MNP)
C
      IF(NSEG.EQ.1) THEN
        DO 83 I=1,NP
         HELP(I) = ARRAY(1)
83      CONTINUE
      ELSE
        HELP(1) = ARRAY(1)
        HELP(NP) = ARRAY(NSEG)
        I=2
        DO 84 K=2,NP-1
         IF ((X(K).GT.SEG(I-1)).AND.(X(K).LT.SEG(I))) THEN
           HELP(K) = ARRAY(I-1)
         ELSE IF (X(K).EQ.SEG(I)) THEN
           HELP(K) = 0.5D0*(ARRAY(I-1) + ARRAY(I))
         ELSE IF (X(K).GT.SEG(I)) THEN
           HELP(K) = ARRAY(I)
           I = I + 1
         END IF
  84    CONTINUE
```

```
      END IF
      DO 85 K=1,NP
        ARRAY(K) = HELP(K)
   85 CONTINUE
      RETURN
      END
C
      SUBROUTINE DER1(ARRAY,X,DERIV,NP)
C     THIS SUBROUTINE EVALUATES THE FIRST DERIVATIVE OF A SERIES OF DATA
C     POINTS USING A SECOND ORDER APPROXIMATION (NONUNIFORM GRID FINITE
C     DIFFERENCES).
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (MNP=151)
      DIMENSION ARRAY(MNP),DERIV(MNP),X(MNP)
C     USE FIRST ORDER FOR END POINTS DERIVATIVES
      DERIV(1) = (-ARRAY(1) + ARRAY(2))/(X(2)-X(1))
      DERIV(NP) = (-ARRAY(NP-1) + ARRAY(NP))/(X(NP)-X(NP-1))
C
      DO 836 I=2,NP-1
       DX = X(I) - X(I-1)
       DX1 = X(I+1) - X(I)
       D = DX/DX1
       DERIV(I) = (D*(ARRAY(I+1)-ARRAY(I)) - (ARRAY(I-1)-ARRAY(I))/D)
       DERIV(I) = DERIV(I)/(DX+DX1)
  836 CONTINUE
      RETURN
      END
C
      SUBROUTINE OUTPUT(NP)
C     THIS SUBROUTINE OUTPUTS THE RESULTS IN TWO FORMATS; A COMPLETE
C     FORMAL FORM AND A FORM TO BE USED FOR PLOTTING.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      CHARACTER*80 NAME
      COMMON/CONST/XPI,XPI2,RHOW,GRAV
      COMMON/INPUT0/NAME
      COMMON/INPUT1/TLEN,WA,WT,NSEG
      COMMON/INPUT2/RHOO,AI,CFLUID,PRESS,AO(MNP)
      COMMON/INPUTL/RLENG(MNP),SEG(MNP+1)
      COMMON/INPUT3/WEIGHT(MNP),EA(MNP),EIETA(MNP),EIETAS(MNP),EIXI(MNP)
     *,EIXIS(MNP),GIP(MNP),GIPS(MNP)
      COMMON/INPUT4/DXI(MNP),PXIETA(MNP),DETA(MNP),DXIETA(MNP)
      COMMON/INPUT5/RMASS(MNP),RMASST(MNP),AMAXI(MNP),AMAETA(MNP),AMAZI(
     *MNP),TMAXI(MNP),TMAZI(MNP)
      COMMON/INPUT6/XJZI(MNP),AJZI(MNP),TJZI(MNP)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT1/XTOP,YTOP
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,TO,QXI0,OMEGA0,CONS1,CONS2
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION A1(MNP)
C     CALCULATE THE ORTHONORMALIZING CONSTANT FOR P AND Q
C
      DO 542 I=1,NP
        CALL COUNT(X(I))
```

```
         A1(I) = Y(5,I)**2*HZET + HX*Y(6,I)**2
   542 CONTINUE
       A = 0.D0
       DO 642 I=2,NP
         DX2 = (X(I)-X(I-1))*0.5D0
         A = A + (A1(I)+A1(I-1))*DX2
   642 CONTINUE
       A = DSQRT(A)
C      ORTHONORMALIZE THE SOLUTION EXCEPT SIGMA
       DO 643 I=1,NP
           Y(N,I) = DABS(Y(N,I))
         DO 643 K=1,N-1
           Y(K,I) = Y(K,I)/A
   643 CONTINUE
C      OUTPUT RESULTS
       WRITE(9,1000) NAME
 1000  FORMAT(80A)
       WRITE(9,1001) NSEG,TLEN,WA,RHOO,RHOW,AI,CFLUID,PRESS,WT,TOMAX,VM,
      *XTOP*TLEN,YTOP*TLEN
C
 1001  FORMAT(1X,I3,9X,' = NUMBER OF RISER SEGMENTS'/
      *1X,D12.6,' = UNSTRETCHED RISER LENGTH IN M'/
      *1X,D12.6,' = APPROXIMATE AVERAGE EFFECTIVE WEIGHT PER UNIT LENGTH
      *IN N/M'/
      *1X,D12.6,' = INNER FLUID DENSITY IN KG/M3'/
      *1X,D12.6,' = SALT WATER DENSITY IN KG/M3'/
      *1X,D12.6,' = INNER CROSS SECTIONAL AREA IN M2'/
      *1X,D12.6,' = INNER FLUID SPEED IN M/S'/
      *1X,D12.6,' = INNER FLUID OVERPRESSURE IN N/M2'/
      *1X,D12.6,' = APPROXIMATE TOTAL EFFECTIVE WEIGHT IN WATER IN N'/
      *1X,D12.6,' = MAXIMUM STATIC TENSION IN N'/
      *1X,D12.6,' = MEAN CURRENT VELOCITY IN THE X DIRECTION IN M/S'/
      *1X,D12.6,' = X COORDINATE AT TOP IN M'/
      *1X,D12.6,' = Y COORDINATE AT TOP IN M')
C      EVALUATE DIMENSIONAL NATURAL FREQUENCY
       SIGMAD = Y(N,1)*DSQRT(TOMAX/TMAXAV)/TLEN
       WRITE(9,1002) NSEG
 1002  FORMAT(//' D A T A   P E R   R I S E R   S E G M E N T   F O R   NSEG =
      * ',I3,'  S E G M E N T S'/' D I M E N S I O N A L   Q U A N T I T I
      * E S   I N   T H E   S . I .   S Y S T E M'/
      *'   RLENG      DXI      PXIETA      AO        WEIGHT       MASS
      *    TMASS      AMAXI      AMAETA      AMAZI       TMAXI       TMAZI
      *')
       TL = TOMAX/TLEN
       DO 1004 I=1,NSEG
       WRITE(9,1003) RLENG(I)*TLEN,DXI(I),PXIETA(I),AO(I),WEIGHT(I)*TL,RM
      *ASS(I),RMASST(I),AMAXI(I),AMAETA(I),AMAZI(I),TMAXI(I),TMAZI(I)
 1004  CONTINUE
 1003  FORMAT(12(1X,D10.4)/)
C
       WRITE(9,10022)
10022 FORMAT('      EA          EIETA        EIETAS        EIXI        EIXIS
      *  GIP        GIPS         DETA          JZI          AJZI        TJZI')
       DO 10023 I=1,NSEG
       WRITE(9,10024) EA(I),EIETA(I),EIETAS(I),EIXI(I),EIXIS(I),GIP(I),
      *GIPS(I),DETA(I),XJZI(I),AJZI(I),TJZI(I)
```

```
10023 CONTINUE
10024 FORMAT(11(1X,D10.4)/)
C
      WRITE(9,761) MODE,SIGMAD
  761 FORMAT(' ***********************************************************'
     */'   M O D E   N U M B E R = ',I2/'    N A T U R A L   F R E Q U E N
     *C Y = ',D10.4,' RAD/S'/' ********************************************
     ****************')
C
      WRITE(9,1009) NP
 1009 FORMAT(/' ORTHONORMALIZED NONDIMENSIONAL RESULTS AT NP = ',
     *I3,' POINTS'/
     *'     S          TENSION          QXI     OMEGAETA        PHI          P
     *      Q          SIGMA')
      DO 1010 I=1,NP
      WRITE(9,1011) X(I),(Y(J,I),J=1,7)
 1010 CONTINUE
 1011 FORMAT(8(1X,D10.4))
C     NORMALIZE ESTIMATED ERROR BY COMPONENTS.
      DO 189 I=1,N-1
      ABT(I)=ABT(I)/A
 189  CONTINUE
      WRITE(9,10119) (ABT(I),I=1,7)
10119 FORMAT(' MAXIMUM ESTIMATED ERROR BY COMPONENTS'/11X,7(1X,D10.4))
C
C
C     OUTPUT TO FILE CONNECTED TO DEVICE 11
C     THIS CAN BE USED FOR PLOTS OR INPUT TO ANOTHER RUN OF RCLINDY1
C
C
      CALL STRUC(VLOCXI,NP,NPI)
      WRITE(11,36459) MODE,NP,SIGMAD,XTOP,YTOP
36459 FORMAT(1X,I2,1X,I3,3(1X,D10.4))
      DO 3666 I=1,NP
      WRITE(11,3667) X(I),(Y(J,I),J=1,7),VLOCXI(I)
 3666 CONTINUE
 3667 FORMAT(9(1X,D12.6))
C
      RETURN
      END
C
      SUBROUTINE FCN(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE FUNCTIONS USED BY DO2RAF TO SOLVE
C     THE PROBLEM.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,TO,QXIO,OMEGAO,CONS1,CONS2
      DIMENSION Y(N),F(N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      F(1) = QXIO*Y(3) + OMEGAO*Y(2) + CONS2*Y(4)
      F(1) = F(1) - HZET*Y(5)*Y(7)**2
C
```

```
      F(2) = -T0*Y(3) - OMEGA0*Y(1)
      F(2) = F(2) - CONS1*Y(4)
      F(2) = F(2) - HX*Y(6)*Y(7)**2
C
      F(3) = - Y(2)/EETA - EETAS*Y(3)/EETA
C
      F(4) = Y(3)
C
      F(5) = OMEGA0*Y(6) + EOMI*Y(1)
C
      F(6) = Y(4) + Y(4)*EOMI*T0 - OMEGA0*Y(5)
C
      F(7) = 0.D0
      RETURN
      END
C
      SUBROUTINE G(EPS,YA,YB,BC,N)
C     BOUNDARY CONDITIONS USED BY D02RAF
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION YA(N),YB(N),BC(N)
      COMMON/BOUNDA/BOUND,BOUNDP,BOUNDQ
C
      BC(1)=YA(4)
      BC(2)=YA(5)
      BC(3)=YA(6)
      BC(4)=YA(3) - BOUND
C
      BC(5)=YB(4)
      BC(6)=YB(5) - BOUNDP + EPS*BOUNDP
      BC(7)=YB(6) - BOUNDQ + EPS*BOUNDQ
C
      RETURN
      END
C
      SUBROUTINE JACOBF(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE JACOBIAN OF THE EQUATIONS TO USE IN
C     NEWTON'S ITERATION.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,T0,QXI0,OMEGA0,CONS1,CONS2
      DIMENSION Y(N),F(N,N)
C     LOCATE MESH POINT TO EVALUATE COEFFICIENTS
      CALL COUNT(X)
C
      DO 817 I=1,N
        DO 817 M=1,N
         F(I,M) = 0.D0
  817 CONTINUE
C
      F(1,2) = OMEGA0
      F(1,3) = QXI0
      F(1,4) = CONS2
      F(1,5) = -HZET*Y(7)**2
      F(1,7) = -2.D0*Y(7)*HZET*Y(5)
```

```
C
      F(2,1) = -OMEGAO
      F(2,3) = -TO
      F(2,4) = -CONS1
      F(2,6) = -HX*Y(7)**2
      F(2,7) = -2.D0*Y(7)*Y(6)*HX
C
      F(3,2) = -1.D0/EETA
      F(3,3) = -EETAS/EETA
C
      F(4,3) = 1.D0
C
      F(5,1) = EOMI
      F(5,6) = OMEGAO
C
      F(6,4) = 1.D0 + EOMI*TO
      F(6,5) = -OMEGAO
      RETURN
      END
C
      SUBROUTINE JACOBG(EPS,YA,YB,AJ,BJ,N)
C     THIS SUBROUTINE EVALUATES THE JACOBIAN OF THE BOUNDARY CONDITIONS.
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION YA(N),YB(N),AJ(N,N),BJ(N,N)
      DO 876 K=1,N
        DO 876 I=1,N
         AJ(K,I) = 0.D0
         BJ(K,I) = 0.D0
  876 CONTINUE
C
      AJ(1,4) = 1.D0
      AJ(2,5) = 1.D0
      AJ(3,6) = 1.D0
      AJ(4,3) = 1.D0
C
      BJ(5,4) = 1.D0
      BJ(6,5) = 1.D0
      BJ(7,6) = 1.D0
      RETURN
      END
C
      SUBROUTINE JACEPS(X,EPS,Y,F,N)
C     THIS SUBROUTINE EVALUATES THE DERIVATIVES OF THE FUNCTIONS WITH
C     RESPECT TO THE CONTINUATION PARAMETER EPS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(NA=4,MNP=151)
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,TO,QXIO,OMEGAO,CONS1,CONS2
      DIMENSION Y(N),F(N)
C
      F(1) = 0.D0
C
      F(2) = 0.D0
C
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```
      F(3) = 0.D0
      F(4) = 0.D0
      F(5) = 0.D0
C
      F(6) = 0.D0
      F(7) = 0.D0
      RETURN
      END
C
      SUBROUTINE JACGEP(EPS,YA,YB,BCEP,N)
C     THIS SUBROUTINE EVALUATES THE DERIVATIVES OF THE BOUNDARY
C     CONDITIONS WITH RESPECT TO THE CONTINUATION PARAMETER EPS.
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/BOUNDA/BOUND,BOUNDP,BOUNDQ
      DIMENSION YA(N),YB(N),BCEP(N)
      DO 871 K=1,N
        BCEP(K) = 0.D0
  871 CONTINUE
      BCEP(5) = BOUNDP
      BCEP(6) = BOUNDQ
      RETURN
      END
C
      SUBROUTINE INTERP(NP)
C     THIS SUBROUTINE INTERPOLATES THE RISER CHARACTERISTICS AND THE
C     STATIC SOLUTION TO THE NEW NUMBER OF POINTS NP.
C     ASSUMPTION: NP .GE. NPI
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151,NA=4,N=7)
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),H
     *ZETAM,TMAXAV,DXIM
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE
      DIMENSION HELP(MNP)
C     INTERPOLATE STRUCTURAL DATA TO THE NEW NUMBER OF POINTS
      CALL STRUC(EPSETA,NP,NPI)
      CALL STRUC(EPSETS,NP,NPI)
      CALL STRUC(EOM,NP,NPI)
      CALL STRUC(HXI,NP,NPI)
      CALL STRUC(HZETA,NP,NPI)
      CALL STRUC(CONST1,NP,NPI)
      CALL STRUC(CONST2,NP,NPI)
      CALL STRUC(VLOCXI,NP,NPI)
C     INTERPOLATE STATIC SOLUTION TO THE NEW NUMBER OF POINTS
      DO 459 K=1,3
        DO 458 I=1,NPI
         HELP(I) = STATIC(K,I)
  458   CONTINUE
        CALL STRUC(HELP,NP,NPI)
        DO 457 I=1,NP
         STATIC(K,I) = HELP(I)
  457   CONTINUE
  459 CONTINUE
      DO 339 I=1,NP
        XI(I) = X(I)
```

```
  339 CONTINUE
      RETURN                                                            RCL08410
      END                                                               RCL08420
C                                                                       RCL08430
      SUBROUTINE STRUC(ARRAY,NP,NPOLD)                                  RCL08440
C     THIS SUBROUTINE INTERPOLATES A SERIES OF DIVISION POINTS TO A NEW RCL08450
C     SERIES OF DIVISION POINTS.                                        RCL08460
      IMPLICIT REAL*8(A-H,O-Z)                                          RCL08470
      PARAMETER(MNP=151,NA=4,N=7)                                       RCL08480
      COMMON/SOLUT/X(MNP),Y(N,MNP),ABT(N),MODE                          RCL08490
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI       RCL08500
      DIMENSION ARRAY(MNP),HELP(MNP)                                    RCL08510
C                                                                       RCL08520
        HELP(1) = ARRAY(1)                                              RCL08530
        HELP(NP) = ARRAY(NPOLD)                                         RCL08540
        DO 82 I=2,NPOLD                                                 RCL08550
        DO 81 K=2,NP-1                                                  RCL08560
         IF ((X(K).GT.XI(I-1)).AND.(X(K).LT.XI(I))) THEN                RCL08570
           CONV = (X(K)-XI(I-1))*(ARRAY(I)-ARRAY(I-1))/(XI(I)-XI(I-1))  RCL08580
           HELP(K) = ARRAY(I-1) + CONV                                  RCL08590
         ELSE IF (X(K).EQ.XI(I)) THEN                                   RCL08600
           HELP(K) = ARRAY(I)                                           RCL08610
         END IF                                                         RCL08620
   81   CONTINUE                                                        RCL08630
   82   CONTINUE                                                        RCL08640
        DO 85 K=1,NP                                                    RCL08650
          ARRAY(K) = HELP(K)                                            RCL08660
   85   CONTINUE                                                        RCL08670
      RETURN                                                            RCL08680
      END                                                               RCL08690
C                                                                       RCL08700
      SUBROUTINE COUNT(X)                                               RCL08710
C     THIS SUBROUTINE EVALUATES THE RISER CHARACTERISTICS AS WELL AS THERCL08720
C     STATIC SOLUTION AT A POINT X.                                     RCL08730
C     IT RETURNS THEIR VALUE IN COMMON BLOCK COEF1.                     RCL08740
      IMPLICIT REAL*8(A-H,O-Z)                                          RCL08750
      PARAMETER(MNP=151,NA=4)                                           RCL08760
      COMMON/COEF/EPSETA(MNP),EPSETS(MNP),HZETA(MNP),HXI(MNP),EOM(MNP),HRCL08770
     *ZETAM,TMAXAV,DXIM                                                 RCL08780
      COMMON/STAT/XI(MNP),STATIC(NA,MNP),VLOCXI(MNP),TOMAX,VM,NPI       RCL08790
      COMMON/COEF1/EETA,EETAS,HZET,HX,EOMI,TO,QXIO,OMEGAO,CONS1,CONS2   RCL08800
      COMMON/STAT2/CONST1(MNP),CONST2(MNP)                              RCL08810
      COMMON/COUN/ICOUNT                                                RCL08820
      M = ICOUNT                                                        RCL08830
      IF (X.EQ.XI(M)) THEN                                              RCL08840
       EETA = EPSETA(M)                                                 RCL08850
       EETAS = EPSETS(M)                                                RCL08860
       HX = HXI(M)                                                      RCL08870
       HZET = HZETA(M)                                                  RCL08880
       EOMI = EOM(M)                                                    RCL08890
       TO = STATIC(1,M)                                                 RCL08900
       QXIO = STATIC(2,M)                                               RCL08910
       OMEGAO = STATIC(3,M)                                             RCL08920
       CONS1 = CONST1(M)                                                RCL08930
       CONS2 = CONST2(M)                                                RCL08940
       ICOUNT = ICOUNT + 1                                              RCL08950
                                                                        RCL08960
```

```
        IF(X.EQ.1.D0) ICOUNT = 1
       ELSE IF ((X.LT.XI(M)).AND.(X.GT.XI(M-1))) THEN
        DIFF = DABS(XI(M)-X)
C      THIS IF STATEMENT IS TO ACCOUNT FOR A COMPUTER INACCURACY IN
C      REPRESENTING AND EQUATING REAL NUMBERS.
        IF (DIFF.LT.1.D-7) THEN
         ICOUNT = ICOUNT + 1
         IF (XI(M).EQ.1.D0) ICOUNT = 1
        END IF
        DX = (X-XI(M-1))/(XI(M)-XI(M-1))
        EETA = EPSETA(M-1) + (EPSETA(M)-EPSETA(M-1))*DX
        EETAS = EPSETS(M-1) + (EPSETS(M)-EPSETS(M-1))*DX
        HX = HXI(M-1) + (HXI(M)-HXI(M-1))*DX
        HZET = HZETA(M-1) + (HZETA(M)-HZETA(M-1))*DX
        EOMI = EOM(M-1) + (EOM(M)-EOM(M-1))*DX
        TO = STATIC(1,M-1) + (STATIC(1,M)-STATIC(1,M-1))*DX
        QXIO = STATIC(2,M-1) + (STATIC(2,M)-STATIC(2,M-1))*DX
        OMEGAO = STATIC(3,M-1) + (STATIC(3,M)-STATIC(3,M-1))*DX
        CONS1 = CONST1(M-1) + (CONST1(M)-CONST1(M-1))*DX
        CONS2 = CONST2(M-1) + (CONST2(M)-CONST2(M-1))*DX
       ELSE
C
        WRITE(6,*) ' ERROR OCCURED IN COUNTER, NP =',M
       END IF
       RETURN
       END
```

Appendix A

Programs ORTHOG and ORTHOG1

1. Input-Output Manual for Program ORTHOG

This program is written in FORTRAN 77 and allows the user to check the orthogonality condition for the out-of-plane eigenvectors. The orthogonality condition is derived in [4].

Before executing the program the user must make sure that

- o Devices five and six correspond to input-output from the terminal
- o Device four must be associated with an input data file containing an out-of-plane eigensolution resulting from an execution of Program RCLINDYN or RCLINDY3. The input file has a logical record length of 117 characters.
- o Device three must be associated with an input data file containing another (or the same) out-of-plane eigensolution resulting from an execution of Program RCLINDYN or RCLINDY3. This input file also has a logical record length of 117 characters.

Input Variables

At the beginning of the program the user is asked to input the total mass per unit length in the $\vec{\eta}$ direction, m_T^{η} and the total mass per unit length in the $\vec{\xi}$ direction, m_T^{ξ}. These values should be given in kg/m. Then, the user is asked to input the riser length in meters and the total polar moment of mass inertia per unit length $J_T^{\xi\xi}$ in kg·m. For simplicity, the above values are assumed to be constant along the length of the riser for the purposes of this program. The program then evaluates and prints the value of the orthogonality condition.

2. Sample Run, Input and Output

Interactive Session

INPUT

Device 5 = TERMINAL

Device 4 = JOA01A DATA A*

Device 3 = JOA02A DATA A

OUTPUT

Device 6 = TERMINAL

*File included in Chapter III.

```
R; T=0.01/0.01 15:55:06
orthog joao1a joao2a
FI 4 DISK JOAO1A DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
FI 3 DISK JOAO2A DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
GLOBAL TXTLIB VFORTLIB CMSLIB
LOAD ORTHOG ( START
EXECUTION BEGINS...
INPUT TOTAL MASS PER UNIT LENGTH IN ETA DIRECTION AND
TOTAL MASS PER UNIT LENGTH IN XI DIRECTION IN KG/M
?
100.3,132.4
INPUT RISER LENGTH IN M AND
TOTAL POLAR MOMENT OF MASS INERTIA PER UNIT LENGTH IN KG*M
?
88.392,0.5713
ORTHOGONAL VALUE = -.2452500-03
R; T=0.43/0.50 15:55:43
cp spool console stop close
```

JOA02A DATA A

2 96 0.6485D+00

0.000000D+00	-.103632D+02	0.106327D+02	0.281375D+03	0.000000D+00	0.000000D+00	0.000000D+00	0.738635D+01	0.103000D+01
0.493318D-03	-.102797D+02	0.104803D+02	0.289141D+03	0.140771D+00	0.243418D-02	-.347224D-04	0.738635D+01	0.103031D+01
0.986636D-03	-.101901D+02	0.103305D+02	0.295937D+03	0.285122D+00	-.590629D-03	-.139773D-03	0.738635D+01	0.103062D+01
0.172564D-02	-.100453D+02	0.101120D+02	0.304448D+03	0.506561D+00	-.145766D-01	-.432300D-03	0.738635D+01	0.103108D+01
0.246464D-02	-.988891D+01	0.990234D+01	0.311104D+03	0.732651D+00	-.389026D-01	-.890190D-03	0.738635D+01	0.103154D+01
0.320364D-02	-.972230D+01	0.970282D+01	0.316090D+03	0.961739D+00	-.723979D-01	-.151627D-02	0.738635D+01	0.103199D+01
0.394265D-02	-.954692D+01	0.951430D+01	0.319582D+03	0.119244D+01	-.113863D+00	-.231225D-02	0.738635D+01	0.103244D+01
0.476160D-02	-.934400D+01	0.931883D+01	0.321909D+03	0.144857D+01	-.167750D+00	-.339368D-02	0.738635D+01	0.103293D+01
0.558056D-02	-.913375D+01	0.913781D+01	0.322806D+03	0.170400D+01	-.228546D+00	-.468458D-02	0.738635D+01	0.103342D+01
0.639951D-02	-.891778D+01	0.897129D+01	0.322457D+03	0.195769D+01	-.294902D+00	-.618396D-02	0.738635D+01	0.103389D+01
0.721847D-02	-.869764D+01	0.881898D+01	0.321032D+03	0.220886D+01	-.365552D+00	-.789007D-02	0.738635D+01	0.103436D+01
0.803742D-02	-.847461D+01	0.868047D+01	0.318679D+03	0.245685D+01	-.439383D+00	-.980056D-02	0.738635D+01	0.103481D+01
0.885637D-02	-.824988D+01	0.855518D+01	0.315535D+03	0.270119D+01	-.515381D+00	-.119126D-01	0.738635D+01	0.103527D+01
0.999838D-02	-.793578D+01	0.840099D+01	0.310079D+03	0.303509D+01	-.623413D+00	-.151881D-01	0.738635D+01	0.103588D+01
0.111404D-01	-.762280D+01	0.826924D+01	0.303590D+03	0.336052D+01	-.731948D+00	-.188400D-01	0.738635D+01	0.103650D+01
0.122824D-01	-.731291D+01	0.815804D+01	0.296294D+03	0.367702D+01	-.839343D+00	-.228585D-01	0.738635D+01	0.103708D+01
0.134244D-01	-.700788D+01	0.806528D+01	0.288394D+03	0.398431D+01	-.944292D+00	-.272331D-01	0.738635D+01	0.103766D+01
0.157084D-01	-.641715D+01	0.792747D+01	0.271397D+03	0.457105D+01	-.114211D+01	-.370033D-01	0.738635D+01	0.103878D+01
0.178993D-01	-.587910D+01	0.784483D+01	0.254307D+03	0.509886D+01	-.131435D+01	-.475962D-01	0.738635D+01	0.103981D+01
0.200901D-01	-.537225D+01	0.780016D+01	0.237072D+03	0.559297D+01	-.146710D+01	-.593081D-01	0.738635D+01	0.104080D+01
0.222809D-01	-.489771D+01	0.778500D+01	0.220109D+03	0.605435D+01	-.159976D+01	-.720665D-01	0.738635D+01	0.104177D+01
0.244717D-01	-.445522D+01	0.779261D+01	0.203702D+03	0.648421D+01	-.171286D+01	-.858013D-01	0.738635D+01	0.104272D+01
0.280184D-01	-.380379D+01	0.783926D+01	0.178813D+03	0.711706D+01	-.185819D+01	-.109921D+00	0.738635D+01	0.104421D+01
0.315651D-01	-.323077D+01	0.792567D+01	0.154315D+03	0.767395D+01	-.196111D+01	-.136151D+00	0.738635D+01	0.104567D+01
0.333384D-01	-.297344D+01	0.798195D+01	0.142073D+03	0.792373D+01	-.199825D+01	-.149981D+00	0.738635D+01	0.104639D+01
0.351118D-01	-.273482D+01	0.804264D+01	0.130535D+03	0.815481D+01	-.202649D+01	-.164237D+00	0.738635D+01	0.104711D+01
0.413491D-01	-.202455D+01	0.827877D+01	0.951616D+02	0.883546D+01	-.207065D+01	-.217224D+00	0.738635D+01	0.104959D+01
0.475865D-01	-.148635D+01	0.853846D+01	0.672562D+02	0.933421D+01	-.205173D+01	-.273890D+00	0.738635D+01	0.105206D+01
0.547166D-01	-.102879D+01	0.885179D+01	0.428143D+02	0.972776D+01	-.198367D+01	-.341846D+00	0.738635D+01	0.105487D+01
0.618467D-01	-.697615D+00	0.920620D+01	0.234464D+02	0.997051D+01	-.188571D+01	-.412072D+00	0.738635D+01	0.105770D+01
0.778360D-01	-.251742D+00	0.101176D+02	-.706995D+01	0.101218D+02	-.161253D+01	-.572703D+00	0.738635D+01	0.106409D+01
0.866637D-01	-.128955D+00	0.106824D+02	-.175197D+02	0.100252D+02	-.144172D+01	-.661629D+00	0.738635D+01	0.106767D+01
0.954915D-01	-.527751D-01	0.113366D+02	-.262252D+02	0.984330D+01	-.126235D+01	-.749326D+00	0.738635D+01	0.107126D+01
0.114743D+00	0.235602D-01	0.120986D+02	-.396194D+02	0.922968D+01	-.853752D+00	-.932918D+00	0.738635D+01	0.107926D+01
0.135516D+00	0.490801D-01	0.120838D+02	-.484122D+02	0.832914D+01	-.409263D+00	-.111529D+01	0.738635D+01	0.108808D+01
0.157726D+00	0.695142D-01	0.120637D+02	-.560696D+02	0.717313D+01	0.530085D-01	-.128745D+01	0.738635D+01	0.109775D+01
0.181288D+00	0.924205D-01	0.120375D+02	-.627461D+02	0.576485D+01	0.521992D+00	-.143987D+01	0.738635D+01	0.110829D+01
0.206107D+00	0.118969D+00	0.120046D+02	-.680285D+02	0.411707D+01	0.981073D+00	-.156250D+01	0.738635D+01	0.111973D+01
0.232087D+00	0.149269D+00	0.119646D+02	-.714650D+02	0.226006D+01	0.140999D+01	-.164534D+01	0.738635D+01	0.113208D+01
0.259123D+00	0.182949D+00	0.119176D+02	-.726163D+02	0.244089D+00	0.178410D+01	-.167919D+01	0.738635D+01	0.114537D+01
0.287110D+00	0.219343D+00	0.118643D+02	-.711425D+02	-.186125D+01	0.207536D+01	-.165656D+01	0.738635D+01	0.115961D+01
0.315938D+00	0.257431D+00	0.118063D+02	-.668509D+02	-.396929D+01	0.225377D+01	-.157252D+01	0.738635D+01	0.117480D+01
0.345492D+00	0.295842D+00	0.117462D+02	-.597513D+02	-.598108D+01	0.229013D+01	-.142548D+01	0.738635D+01	0.119094D+01
0.375655D+00	0.332897D+00	0.116877D+02	-.500894D+02	-.779262D+01	0.216022D+01	-.121775D+01	0.738635D+01	0.120799D+01
0.406309D+00	0.366735D+00	0.116352D+02	-.383460D+02	-.930347D+01	0.185030D+01	-.955720D+00	0.738635D+01	0.122589D+01
0.437333D+00	0.395514D+00	0.115938D+02	-.251880D+02	-.104259D+02	0.136316D+01	-.649679D+00	0.738635D+01	0.124453D+01
0.468605D+00	0.417659D+00	0.115680D+02	-.113663D+02	-.110935D+02	0.723287D+00	-.313202D+00	0.738635D+01	0.126375D+01
0.500000D+00	0.432237D+00	0.115615D+02	0.242707D+01	-.112677D+02	-.211887D-01	0.378124D-01	0.738635D+01	0.128335D+01
0.531395D+00	0.438919D+00	0.115759D+02	0.156938D+02	-.109402D+02	-.802222D+00	0.386420D+00	0.738635D+01	0.130307D+01
0.562667D+00	0.437097D+00	0.116111D+02	0.281243D+02	-.101323D+02	-.154139D+01	0.715910D+00	0.738635D+01	0.132262D+01
0.593691D+00	0.425831D+00	0.116646D+02	0.394508D+02	-.889302D+01	-.216350D+01	0.101103D+01	0.738635D+01	0.134172D+01
0.624345D+00	0.404903D+00	0.117322D+02	0.493345D+02	-.729545D+01	-.261065D+01	0.125915D+01	0.738635D+01	0.136011D+01
0.654508D+00	0.375331D+00	0.118083D+02	0.573709D+02	-.543186D+01	-.285142D+01	0.145110D+01	0.738635D+01	0.137757D+01
0.684062D+00	0.339204D+00	0.118874D+02	0.631725D+02	-.340516D+01	-.288275D+01	0.158168D+01	0.738635D+01	0.139398D+01
0.712890D+00	0.299266D+00	0.119641D+02	0.664702D+02	-.131964D+01	-.272482D+01	0.164979D+01	0.738635D+01	0.140923D+01

0.740877D+00	0.258339D+00	0.120346D+02	0.671906D+02	0.727812D+00	-.241253D+01	0.165807D+01	0.738635D+01	0.142332D+01
0.767913D+00	0.218840D+00	0.120963D+02	0.654763D+02	0.265500D+01	-.198665D+01	0.161234D+01	0.738635D+01	0.143624D+01
0.793893D+00	0.182504D+00	0.121480D+02	0.616473D+02	0.439895D+01	-.148709D+01	0.152071D+01	0.738635D+01	0.144804D+01
0.818712D+00	0.150391D+00	0.121896D+02	0.561487D+02	0.591743D+01	-.949040D+00	0.139269D+01	0.738635D+01	0.145876D+01
0.842274D+00	0.122785D+00	0.122220D+02	0.494448D+02	0.718888D+01	-.400663D+00	0.123828D+01	0.738635D+01	0.146847D+01
0.864484D+00	0.990925D-01	0.122463D+02	0.419971D+02	0.820931D+01	0.136026D+00	0.106728D+01	0.738635D+01	0.147722D+01
0.885257D+00	0.735839D-01	0.122636D+02	0.337727D+02	0.898483D+01	0.647302D+00	0.888698D+00	0.738635D+01	0.148508D+01
0.904508D+00	0.311112D-02	0.114923D+02	0.215164D+02	0.949459D+01	0.111367D+01	0.710824D+00	0.738635D+01	0.149209D+01
0.913336D+00	-.678272D-01	0.108293D+02	0.135545D+02	0.963600D+01	0.131779D+01	0.626382D+00	0.738635D+01	0.149519D+01
0.922164D+00	-.183918D+00	0.102566D+02	0.394919D+01	0.969846D+01	0.151213D+01	0.541039D+00	0.738635D+01	0.149830D+01
0.938153D+00	-.617748D+00	0.933165D+01	-.245370D+02	0.950693D+01	0.182586D+01	0.387502D+00	0.738635D+01	0.150377D+01
0.945283D+00	-.945791D+00	0.897141D+01	-.429205D+02	0.925640D+01	0.194156D+01	0.320611D+00	0.738635D+01	0.150616D+01
0.952414D+00	-.140563D+01	0.865224D+01	-.664750D+02	0.886145D+01	0.202746D+01	0.256011D+00	0.738635D+01	0.150854D+01
0.958651D+00	-.195362D+01	0.838715D+01	-.936294D+02	0.836681D+01	0.206193D+01	0.202285D+00	0.738635D+01	0.151062D+01
0.964888D+00	-.268542D+01	0.814560D+01	-.128336D+03	0.769563D+01	0.203251D+01	0.152194D+00	0.738635D+01	0.151272D+01
0.966661D+00	-.293291D+01	0.808347D+01	-.139700D+03	0.746830D+01	0.200811D+01	0.138748D+00	0.738635D+01	0.151332D+01
0.968435D+00	-.320056D+01	0.802593D+01	-.151770D+03	0.722283D+01	0.197452D+01	0.125720D+00	0.738635D+01	0.151393D+01
0.971982D+00	-.379902D+01	0.793801D+01	-.175924D+03	0.667648D+01	0.187757D+01	0.101070D+00	0.738635D+01	0.151517D+01
0.975528D+00	-.448209D+01	0.789217D+01	-.200382D+03	0.605747D+01	0.173616D+01	0.784927D-01	0.738635D+01	0.151645D+01
0.977719D+00	-.494736D+01	0.788686D+01	-.216426D+03	0.563803D+01	0.162410D+01	0.656803D-01	0.738635D+01	0.151727D+01
0.979910D+00	-.544689D+01	0.790655D+01	-.232880D+03	0.518903D+01	0.149120D+01	0.538193D-01	0.738635D+01	0.151812D+01
0.982101D+00	-.598046D+01	0.795888D+01	-.249372D+03	0.470976D+01	0.133681D+01	0.429752D-01	0.738635D+01	0.151900D+01
0.984292D+00	-.654571D+01	0.805342D+01	-.265356D+03	0.419988D+01	0.116146D+01	0.332146D-01	0.738635D+01	0.151992D+01
0.986005D+00	-.700679D+01	0.816382D+01	-.277026D+03	0.377998D+01	0.101112D+01	0.263799D-01	0.738635D+01	0.152067D+01
0.987718D+00	-.748062D+01	0.831340D+01	-.287392D+03	0.334190D+01	0.851523D+00	0.202800D-01	0.738635D+01	0.152146D+01
0.988574D+00	-.772081D+01	0.840500D+01	-.291884D+03	0.311631D+01	0.768998D+00	0.175143D-01	0.738635D+01	0.152187D+01
0.989431D+00	-.796196D+01	0.850897D+01	-.295778D+03	0.288660D+01	0.685569D+00	0.149435D-01	0.738635D+01	0.152228D+01
0.990288D+00	-.820295D+01	0.862620D+01	-.298951D+03	0.265303D+01	0.601935D+00	0.125712D-01	0.738635D+01	0.152271D+01
0.991144D+00	-.844255D+01	0.875745D+01	-.301266D+03	0.241597D+01	0.518911D+00	0.104004D-01	0.738635D+01	0.152315D+01
0.991963D+00	-.866901D+01	0.889669D+01	-.302533D+03	0.218645D+01	0.440986D+00	0.851570D-02	0.738635D+01	0.152358D+01
0.992782D+00	-.889146D+01	0.904987D+01	-.302716D+03	0.195472D+01	0.365447D+00	0.681990D-02	0.738635D+01	0.152402D+01
0.993600D+00	-.910807D+01	0.921717D+01	-.301638D+03	0.172161D+01	0.293426D+00	0.531536D-02	0.738635D+01	0.152447D+01
0.994419D+00	-.931727D+01	0.939870D+01	-.299107D+03	0.148786D+01	0.226055D+00	0.400189D-02	0.738635D+01	0.152493D+01
0.995238D+00	-.951714D+01	0.959426D+01	-.294903D+03	0.125445D+01	0.164629D+00	0.287891D-02	0.738635D+01	0.152541D+01
0.996057D+00	-.970558D+01	0.980297D+01	-.288792D+03	0.102289D+01	0.110575D+00	0.194634D-02	0.738635D+01	0.152589D+01
0.996796D+00	-.986408D+01	0.100014D+02	-.281437D+03	0.816918D+00	0.693627D-01	0.126653D-02	0.738635D+01	0.152633D+01
0.997535D+00	-.100100D+02	0.102080D+02	-.272122D+03	0.615344D+00	0.364512D-01	0.737310D-03	0.738635D+01	0.152678D+01
0.998274D+00	-.101418D+02	0.104207D+02	-.260640D+03	0.419959D+00	0.129413D-01	0.354765D-03	0.738635D+01	0.152724D+01
0.999013D+00	-.102583D+02	0.106368D+02	-.246778D+03	0.232868D+00	-.176602D-03	0.113546D-03	0.738635D+01	0.152770D+01
0.999506D+00	-.103270D+02	0.107813D+02	-.236107D+03	0.113649D+00	-.271504D-02	0.280429D-04	0.738635D+01	0.152801D+01
0.100000D+01	-.103882D+02	0.109246D+02	-.224221D+03	0.452180D-18	0.257594D-18	-.171372D-17	0.738635D+01	0.152832D+01

3. Input-Output Manual for Program ORTHOG1

This program is written in FORTRAN 77 and allows the user to check the orthogonality condition for the in-plane eigenvectors. The orthogonality condition is derived in [4].

Before executing the program the user must make sure that

- o Devices five and six correspond to input-output from the terminal
- o Device four must be associated with an input data file containing an in-plane eigensolution resulting from an execution of Program RCLINDY1 or RCLINDY2. The input file has a logical record length of 117 characters.
- o Device three must be associated with an input data file containing another (or the same) in-plane eigensolution resulting from an execution of Program RCLINDY1 or RCLINDY2. This input file also has a logical record length of 117 characters.

Input Variables

At the beginning of the program the user is asked to input the total mass per unit length in the $\vec{\zeta}$ direction, m_T^{ζ} and the total mass per unit length in the $\vec{\xi}$ direction, m_T^{ξ}. These values should be given in kg·m. For simplicity, these values are assumed to be constant along the length of the riser for the purposes of this program. The program then evaluates and prints the value of the orthogonality condition.

4. Sample Run, Input and Output

Interactive Session

<u>INPUT</u>

Device 5 = TERMINAL

Device 4 = INPLA1A DATA A*

Device 3 = INPLA2A DATA A

<u>OUTPUT</u>

Device 6 = TERMINAL

*File included in Chapter V.

```
R; T=0.01/0.01 16:28:29
orthog1 inpla1a inpla2a
FI 4 DISK INPLA1A DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
FI 3 DISK INPLA2A DATA A ( RECFM FB LRECL 117 BLKSIZE 1170
GLOBAL TXTLIB VFORTLIB CMSLIB
LOAD ORTHOG1 ( START
EXECUTION BEGINS...
INPUT TOTAL MASS PER UNIT LENGTH IN ZETA DIRECTION AND
TOTAL MASS PER UNIT LENGTH IN XI DIRECTION IN KG/M
?
49.93,132.4
ORTHOGONAL VALUE = -.192075D-03
R; T=0.40/0.48 16:29:03
cp spool console stop close
```

INPLA2A DATA A

2 83 0.7665D+00 0.2145D-18 0.7931D+00

0.000000D+00	0.106400D+02	0.676645D+01	0.105237D+04	0.000000D+00	0.000000D+00	0.000000D+00	0.872960D+01	0.103000D+01
0.493318D-03	0.997573D+01	0.689239D+01	0.102283D+04	0.511867D+00	-.233487D-05	0.126213D-03	0.872960D+01	0.103031D+01
0.986636D-03	0.934213D+01	0.696996D+01	0.992756D+03	0.100903D+01	-.141414D-04	0.501050D-03	0.872960D+01	0.103062D+01
0.172564D-02	0.845240D+01	0.700894D+01	0.947170D+03	0.172583D+01	-.682663D-04	0.150939D-02	0.872960D+01	0.103108D+01
0.246464D-02	0.763534D+01	0.696960D+01	0.901437D+03	0.240890D+01	-.183723D-03	0.303081D-02	0.872960D+01	0.103154D+01
0.320364D-02	0.689036D+01	0.686727D+01	0.856049D+03	0.305829D+01	-.376861D-03	0.503761D-02	0.872960D+01	0.103199D+01
0.394265D-02	0.621541D+01	0.671573D+01	0.811399D+03	0.367442D+01	-.658572D-03	0.750220D-02	0.872960D+01	0.103244D+01
0.558056D-02	0.494902D+01	0.626407D+01	0.716596D+03	0.492578D+01	-.162633D-02	0.144456D-01	0.872960D+01	0.103342D+01
0.721847D-02	0.396307D+01	0.571900D+01	0.628837D+03	0.602763D+01	-.306823D-02	0.232375D-01	0.872960D+01	0.103436D+01
0.885637D-02	0.320836D+01	0.514407D+01	0.549130D+03	0.699232D+01	-.494854D-02	0.336364D-01	0.872960D+01	0.103527D+01
0.111404D-01	0.245121D+01	0.436499D+01	0.451681D+03	0.813526D+01	-.816460D-02	0.504135D-01	0.872960D+01	0.103650D+01
0.134244D-01	0.195017D+01	0.365640D+01	0.369361D+03	0.907289D+01	-.118844D-01	0.694453D-01	0.872960D+01	0.103766D+01
0.157084D-01	0.162537D+01	0.303950D+01	0.300567D+03	0.983795D+01	-.158928D-01	0.903463D-01	0.872960D+01	0.103878D+01
0.178993D-01	0.142658D+01	0.253514D+01	0.245571D+03	0.104362D+02	-.198341D-01	0.111860D+00	0.872960D+01	0.103981D+01
0.200901D-01	0.130221D+01	0.210961D+01	0.199703D+03	0.109240D+02	-.237305D-01	0.134570D+00	0.872960D+01	0.104080D+01
0.222809D-01	0.122810D+01	0.175335D+01	0.161512D+03	0.113196D+02	-.274787D-01	0.158280D+00	0.872960D+01	0.104177D+01
0.244717D-01	0.118821D+01	0.145616D+01	0.129738D+03	0.116387D+02	-.310053D-01	0.182824D+00	0.872960D+01	0.104272D+01
0.280184D-01	0.116766D+01	0.107476D+01	0.890897D+02	0.120267D+02	-.361308D-01	0.223942D+00	0.872960D+01	0.104421D+01
0.315651D-01	0.117931D+01	0.793040D+00	0.571396D+02	0.122861D+02	-.404289D-01	0.266384D+00	0.872960D+01	0.104567D+01
0.351118D-01	0.120877D+01	0.588706D+00	0.315015D+02	0.124432D+02	-.437922D-01	0.309743D+00	0.872960D+01	0.104711D+01
0.413491D-01	0.127944D+01	0.355958D+00	0.221336D+00	0.125422D+02	-.475690D-01	0.387155D+00	0.872960D+01	0.104959D+01
0.475865D-01	0.135636D+01	0.226526D+00	-.196811D+02	0.124815D+02	-.490683D-01	0.465019D+00	0.872960D+01	0.105206D+01
0.547166D-01	0.144251D+01	0.143535D+00	-.348953D+02	0.122869D+02	-.486819D-01	0.553351D+00	0.872960D+01	0.105487D+01
0.618467D-01	0.152626D+01	0.967311D-01	-.463575D+02	0.119973D+02	-.466123D-01	0.640088D+00	0.872960D+01	0.105770D+01
0.778360D-01	0.170512D+01	0.453688D-01	-.659453D+02	0.110994D+02	-.377802D-01	0.825232D+00	0.872960D+01	0.106409D+01
0.954915D-01	0.188294D+01	0.296312D-01	-.835841D+02	0.977942D+01	-.229090D-01	0.101003D+01	0.872960D+01	0.107126D+01
0.114743D+00	0.204712D+01	0.315108D-01	-.993068D+02	0.801896D+01	-.179335D-02	0.118159D+01	0.872960D+01	0.107926D+01
0.135516D+00	0.217990D+01	0.290177D-01	-.111175D+03	0.583280D+01	0.258835D-01	0.132519D+01	0.872960D+01	0.108808D+01
0.157726D+00	0.225662D+01	0.164296D-01	-.120702D+03	0.325780D+01	0.604658D-01	0.142505D+01	0.872960D+01	0.109775D+01
0.181288D+00	0.224850D+01	0.331616D-02	-.125094D+03	0.362085D+00	0.102000D+00	0.146534D+01	0.872960D+01	0.110829D+01
0.206107D+00	0.212251D+01	-.113067D-01	-.123222D+03	-.271938D+01	0.149432D+00	0.143193D+01	0.872960D+01	0.111973D+01
0.232087D+00	0.184573D+01	-.263975D-01	-.113976D+03	-.580058D+01	0.200624D+00	0.131468D+01	0.872960D+01	0.113208D+01
0.259123D+00	0.138971D+01	-.409733D-01	-.967836D+02	-.864962D+01	0.251968D+00	0.110966D+01	0.872960D+01	0.114537D+01
0.287110D+00	0.737065D+00	-.537780D-01	-.717538D+02	-.110081D+02	0.298320D+00	0.821217D+00	0.872960D+01	0.115961D+01
0.315938D+00	-.110334D+00	-.634417D-01	-.398581D+02	-.126168D+02	0.333081D+00	0.463310D+00	0.872960D+01	0.117480D+01
0.345492D+00	-.112258D+01	-.685819D-01	-.302952D+01	-.132506D+02	0.348695D+00	0.598872D-01	0.872960D+01	0.119094D+01
0.375655D+00	-.223457D+01	-.679795D-01	0.358499D+02	-.127556D+02	0.337666D+00	-.356251D+00	0.872960D+01	0.120799D+01
0.406309D+00	-.334346D+01	-.608063D-01	0.731123D+02	-.110855D+02	0.294116D+00	-.746163D+00	0.872960D+01	0.122589D+01
0.437333D+00	-.431471D+01	-.469032D-01	0.104653D+03	-.832804D+01	0.215760D+00	-.106903D+01	0.872960D+01	0.124453D+01
0.468605D+00	-.500041D+01	-.270759D-01	0.126489D+03	-.471390D+01	0.105786D+00	-.128774D+01	0.872960D+01	0.126375D+01
0.500000D+00	-.526945D+01	-.333142D-02	0.135500D+03	-.601323D+00	-.261853D-01	-.137496D+01	0.872960D+01	0.128335D+01
0.531395D+00	-.504311D+01	0.214687D-01	0.130125D+03	0.356833D+01	-.164951D+00	-.131843D+01	0.872960D+01	0.130307D+01
0.562667D+00	-.432256D+01	0.441583D-01	0.110754D+03	0.733472D+01	-.292631D+00	-.112399D+01	0.872960D+01	0.132262D+01
0.593691D+00	-.319519D+01	0.615381D-01	0.798031D+02	0.102906D+02	-.392921D+00	-.815211D+00	0.872960D+01	0.134172D+01
0.624345D+00	-.181368D+01	0.712738D-01	0.413757D+02	0.121480D+02	-.455112D+00	-.429214D+00	0.872960D+01	0.136011D+01
0.654508D+00	-.356047D+00	0.727040D-01	0.384864D+00	0.127778D+02	-.476143D+00	-.990284D-02	0.872960D+01	0.137757D+01
0.684062D+00	0.101652D+01	0.667145D-01	-.385065D+02	0.122144D+02	-.460100D+00	0.399524D+00	0.872960D+01	0.139398D+01
0.712890D+00	0.218800D+01	0.551623D-01	-.716694D+02	0.106264D+02	-.415795D+00	0.762663D+00	0.872960D+01	0.140923D+01
0.740877D+00	0.309705D+01	0.402032D-01	-.968615D+02	0.826802D+01	-.353817D+00	0.105362D+01	0.872960D+01	0.142332D+01
0.767913D+00	0.373106D+01	0.238313D-01	-.113202D+03	0.542838D+01	-.284110D+00	0.125819D+01	0.872960D+01	0.143624D+01
0.793893D+00	0.411218D+01	0.763469D-02	-.120918D+03	0.238715D+01	-.214574D+00	0.137300D+01	0.872960D+01	0.144804D+01
0.818712D+00	0.428231D+01	-.726941D-02	-.121004D+03	-.614985D+00	-.150642D+00	0.140348D+01	0.872960D+01	0.145876D+01
0.842274D+00	0.429062D+01	-.200025D-01	-.114939D+03	-.339463D+01	-.953571D-01	0.136120D+01	0.872960D+01	0.146847D+01
0.864484D+00	0.418567D+01	-.314758D-01	-.104147D+03	-.582758D+01	-.500199D-01	0.126133D+01	0.872960D+01	0.147722D+01
0.885257D+00	0.400874D+01	-.335542D-01	-.913965D+02	-.785859D+01	-.143423D-01	0.112016D+01	0.872960D+01	0.148508D+01

0.904508D+00	0.379384D+01	-.319958D-01	-.755089D+02	-.946514D+01	0.124517D-01	0.953440D+00	0.872960D+01	0.149209D+01
0.922164D+00	0.356536D+01	-.467227D-01	-.583054D+02	-.106465D+02	0.311546D-01	0.775431D+00	0.872960D+01	0.149830D+01
0.938153D+00	0.333913D+01	-.967660D-01	-.392719D+02	-.114265D+02	0.425697D-01	0.598373D+00	0.872960D+01	0.150377D+01
0.945283D+00	0.323398D+01	-.143269D+00	-.280900D+02	-.116667D+02	0.455990D-01	0.515808D+00	0.872960D+01	0.150616D+01
0.952414D+00	0.312611D+01	-.225724D+00	-.131551D+02	-.118137D+02	0.468657D-01	0.431972D+00	0.872960D+01	0.150854D+01
0.958651D+00	0.302956D+01	-.353195D+00	0.642572D+01	-.118347D+02	0.460811D-01	0.358325D+00	0.872960D+01	0.151062D+01
0.964888D+00	0.293852D+01	-.579221D+00	0.371064D+02	-.116990D+02	0.429576D-01	0.285384D+00	0.872960D+01	0.151272D+01
0.968435D+00	0.289747D+01	-.775258D+00	0.621301D+02	-.115230D+02	0.399257D-01	0.244677D+00	0.872960D+01	0.151393D+01
0.971982D+00	0.287462D+01	-.104251D+01	0.931264D+02	-.112476D+02	0.359145D-01	0.204974D+00	0.872960D+01	0.151517D+01
0.975528D+00	0.288523D+01	-.139973D+01	0.132231D+03	-.108481D+02	0.310189D-01	0.166684D+00	0.872960D+01	0.151645D+01
0.977719D+00	0.292056D+01	-.167499D+01	0.162597D+03	-.105251D+02	0.275988D-01	0.143915D+00	0.872960D+01	0.151727D+01
0.979910D+00	0.299234D+01	-.200127D+01	0.198860D+03	-.101291D+02	0.239270D-01	0.122001D+00	0.872960D+01	0.151812D+01
0.982101D+00	0.311793D+01	-.238560D+01	0.242086D+03	-.964605D+01	0.200754D-01	0.101096D+00	0.872960D+01	0.151900D+01
0.984292D+00	0.332386D+01	-.283237D+01	0.293449D+03	-.905937D+01	0.161474D-01	0.813838D-01	0.872960D+01	0.151992D+01
0.986005D+00	0.356367D+01	-.322488D+01	0.340019D+03	-.851680D+01	0.131068D-01	0.669288D-01	0.872960D+01	0.152067D+01
0.987718D+00	0.389945D+01	-.365060D+01	0.392829D+03	-.788912D+01	0.101837D-01	0.534417D-01	0.872960D+01	0.152146D+01
0.989431D+00	0.436215D+01	-.409797D+01	0.452272D+03	-.716529D+01	0.747037D-02	0.410532D-01	0.872960D+01	0.152228D+01
0.991144D+00	0.499021D+01	-.454363D+01	0.518459D+03	-.633386D+01	0.506590D-02	0.299144D-01	0.872960D+01	0.152315D+01
0.992782D+00	0.578628D+01	-.493090D+01	0.587697D+03	-.542792D+01	0.314500D-02	0.205924D-01	0.872960D+01	0.152402D+01
0.994419D+00	0.681514D+01	-.522073D+01	0.661605D+03	-.440536D+01	0.166846D-02	0.127556D-01	0.872960D+01	0.152493D+01
0.995238D+00	0.742900D+01	-.530529D+01	0.699826D+03	-.384786D+01	0.110981D-02	0.944558D-02	0.872960D+01	0.152541D+01
0.996057D+00	0.811423D+01	-.532996D+01	0.738331D+03	-.325893D+01	0.674862D-03	0.658361D-02	0.872960D+01	0.152589D+01
0.996796D+00	0.879493D+01	-.528681D+01	0.772890D+03	-.270054D+01	0.385944D-03	0.440937D-02	0.872960D+01	0.152633D+01
0.997535D+00	0.953438D+01	-.516638D+01	0.806768D+03	-.211685D+01	0.187966D-03	0.264538D-02	0.872960D+01	0.152678D+01
0.998274D+00	0.103293D+02	-.495193D+01	0.839368D+03	-.150860D+01	0.697382D-04	0.131343D-02	0.872960D+01	0.152724D+01
0.999013D+00	0.111737D+02	-.462565D+01	0.869980D+03	-.877000D+00	0.144026D-04	0.434591D-03	0.872960D+01	0.152770D+01
0.999506D+00	0.117606D+02	-.433672D+01	0.888936D+03	-.442988D+00	0.236103D-05	0.109254D-03	0.872960D+01	0.152801D+01
0.100000D+01	0.123613D+02	-.398336D+01	0.906355D+03	-.841281D-18	0.000000D+00	-.984623D-19	0.872960D+01	0.152832D+01

5. Listing of Program

ORTHOG FORTRAN A

```
C     PROGRAM ORTHOG CHECKS ORTHOGONALITY OF EIGENVECTORS FOR THE
C     LINEAR DYNAMICS OF COMPLIANT RISERS (OUT OF PLANE DYNAMICS).
C     DOUBLE PRECISION IS USED THROUGHOUT.
C***********************************************************************
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C     ALL RIGHTS RESERVED.
C***********************************************************************
C     PROGRAMMER GEORGE A. KRIEZIS        JUNE 5,  1985     M.I.T.
C***********************************************************************
C
C     DEFINITION OF DEVICES:
C     DEVICE  4 : INPUT FROM FILE CONTAINING AN OUT OF PLANE
C                 DYNAMICS SOLUTION (LRECL=117)
C     DEVICE  3 : INPUT FROM FILE CONTAINING AN OUT OF PLANE
C                 DYNAMICS SOLUTION (LRECL=117)
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      DIMENSION X1(MNP),X2(MNP),BETA1(MNP),BETA2(MNP),R1(MNP),R2(MNP)
      DIMENSION A1(MNP)
      WRITE(6,54)
   54 FORMAT(' INPUT TOTAL MASS PER UNIT LENGTH IN ETA DIRECTION AND'/
     *' TOTAL MASS PER UNIT LENGTH IN XI DIRECTION IN KG/M')
      READ(5,*) TMAETA,TMAXI
      HETA = TMAETA/TMAXI
      WRITE(6,72)
   72 FORMAT(' INPUT RISER LENGTH IN M AND'/' TOTAL POLAR MOMENT OF MASS
     * INERTIA PER UNIT LENGTH IN KG*M')
      READ(5,*) TLEN,TJZI
      TLAMB2 = TLEN**2*TMAXI/TJZI
      READ(4,30) MODE1,NP1,SIGMA1
      DO 50 I=1,NP1
        READ(4,28) X1(I),BETA1(I),R1(I)
   50 CONTINUE
   30 FORMAT(1X,I2,1X,I3,1X,D10.4)
   28 FORMAT(1X,D12.6,53X,D12.6,1X,D12.6,26X)
      READ(3,30) MODE2,NP2,SIGMA2
      DO 51 I=1,NP2
        READ(3,28) X2(I),BETA2(I),R2(I)
   51 CONTINUE
C     INTERPOLATE DATA TO THE SAME NUMBER OF POINTS (HIGHER NUMBER)
      IF (NP2.GT.NP1) THEN
        NP=NP2
        CALL STRUC(BETA1,X1,X2,NP2,NP1)
        CALL STRUC(R1,X1,X2,NP2,NP1)
        DO 66 I=1,NP2
          X1(I) = X2(I)
   66   CONTINUE
      ELSE IF (NP1.GE.NP2) THEN
        CALL STRUC(BETA2,X2,X1,NP1,NP2)
        CALL STRUC(R2,X2,X1,NP1,NP2)
        NP = NP1
      END IF
C     CALCULATE THE ORTHONORMALIZING CONSTANT
      DO 99 I=1,NP
        E = BETA1(I)*BETA2(I)/TLAMB2
        A1(I) = HETA*R1(I)*R2(I) + E
```

```
   99 CONTINUE
      A = 0.D0
      DO 42 I=2,NP
        DX2=(X1(I)-X1(I-1))*0.5D0
        A = A + (A1(I) + A1(I-1))*DX2
   42 CONTINUE
      WRITE(6,14) A
   14 FORMAT(' ORTHOGONAL VALUE = ',D12.6)
      STOP
      END
C
      SUBROUTINE STRUC(ARRAY,XI,X,NP,NPOLD)
C     THIS SUBROUTINE INTERPOLATES A SERIES AT NPOLD DIVISION POINTS TO
C     A NEW SERIES AT NP DIVISION POINTS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      DIMENSION ARRAY(MNP),HELP(MNP),XI(MNP),X(MNP)
      HELP(1) = ARRAY(1)
      HELP(NP) = ARRAY(NPOLD)
      DO 82 I=2,NPOLD
       DO 81 K=2,NP-1
        IF((X(K).GT.XI(I-1)).AND.(X(K).LT.XI(I))) THEN
         CONV = (X(K)-XI(I-1))*(ARRAY(I)-ARRAY(I-1))/(XI(I)-XI(I-1))
         HELP(K) = ARRAY(I-1) + CONV
        ELSE IF (X(K).EQ.XI(I)) THEN
         HELP(K) = ARRAY(I)
        END IF
   81  CONTINUE
   82 CONTINUE
      DO 85 K=1,NP
        ARRAY(K) = HELP(K)
   85 CONTINUE
      RETURN
      END
```

6. Listing of Program

ORTHOG1 FORTRAN A

```
C     PROGRAM ORTHOG1 CHECKS ORTHOGONALITY OF EIGENVECTORS FOR THE
C     LINEAR DYNAMICS OF COMPLIANT RISERS (IN-PLANE DYNAMICS).
C     DOUBLE PRECISION IS USED THROUGHOUT.
C**********************************************************************
C     COPYRIGHT, 1985, MASSACHUSETTS INSTITUTE OF TECHNOLOGY
C     ALL RIGHTS RESERVED.
C**********************************************************************
C     PROGRAMMER GEORGE A. KRIEZIS      JUNE 5, 1985
C**********************************************************************
C
C     DEFINITION OF DEVICES:
C     DEVICE  4 : INPUT FROM FILE CONTAINING AN IN-PLANE DYNAMICS
C                 SOLUTION (LRECL=117)
C     DEVICE  5 : INPUT FROM FILE CONTAINING AN IN-PLANE DYNAMICS
C                 SOLUTION (LRECL=117)
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      DIMENSION X1(MNP),X2(MNP),BETA1(MNP),BETA2(MNP),R1(MNP),R2(MNP)
      DIMENSION A1(MNP)
      HXI = 1.D0
      WRITE(6,45)
   45 FORMAT(' INPUT TOTAL MASS PER UNIT LENGTH IN ZETA DIRECTION AND'/
     *' TOTAL MASS PER UNIT LENGTH IN XI DIRECTION IN KG/M')
      READ(5,*) TZETA,TXI
      HZETA = TZETA/TXI
      READ(4,30) MODE1,NP1,SIGMA1,XTOP,YTOP
      DO 50 I=1,NP1
        READ(4,28) X1(I),BETA1(I),R1(I)
   50 CONTINUE
   30 FORMAT(1X,I2,1X,I3,1X,D10.4,1X,D10.4,1X,D10.4)
   28 FORMAT(1X,D12.6,53X,D12.6,1X,D12.6,26X)
      READ(3,30) MODE2,NP2,SIGMA2,XTOP2,YTOP2
      DO 51 I=1,NP2
        READ(3,28) X2(I),BETA2(I),R2(I)
   51 CONTINUE
C     INTERPOLATE DATA TO THE SAME NUMBER OF POINTS.
      IF (NP2.GT.NP1) THEN
        NP=NP2
        CALL STRUC(BETA1,X1,X2,NP2,NP1)
        CALL STRUC(R1,X1,X2,NP2,NP1)
        DO 66 I=1,NP2
          X1(I) = X2(I)
   66   CONTINUE
      ELSE IF (NP1.GE.NP2) THEN
        CALL STRUC(BETA2,X2,X1,NP1,NP2)
        CALL STRUC(R2,X2,X1,NP1,NP2)
        NP = NP1
      END IF
C     CALCULATE THE ORTHONORMALIZING CONSTANT
      DO 99 I=1,NP
        E = BETA1(I)*BETA2(I)*HZETA
        A1(I) = HXI*R1(I)*R2(I) + E
   99 CONTINUE
      A = 0.D0
      DO 42 I=2,NP
        DX2=(X1(I)-X1(I-1))*0.5D0
```

```
         A = A + (A1(I) + A1(I-1))*DX2
   42 CONTINUE
      WRITE(6,14) A
   14 FORMAT(' ORTHOGONAL VALUE = ',D12.6)
      STOP
      END
C
      SUBROUTINE STRUC(ARRAY,XI,X,NP,NPOLD)
C     THIS SUBROUTINE INTERPOLATES A SERIES AT NPOLD DIVISION POINTS TO
C     A NEW SERIES AT NP DIVISION POINTS.
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER(MNP=151)
      DIMENSION ARRAY(MNP),HELP(MNP),XI(MNP),X(MNP)
      HELP(1) = ARRAY(1)
      HELP(NP) = ARRAY(NPOLD)
      DO 82 I=2,NPOLD
       DO 81 K=2,NP-1
        IF((X(K).GT.XI(I-1)).AND.(X(K).LT.XI(I))) THEN
         CONV = (X(K)-XI(I-1))*(ARRAY(I)-ARRAY(I-1))/(XI(I)-XI(I-1))
         HELP(K) = ARRAY(I-1) + CONV
        ELSE IF (X(K).EQ.XI(I)) THEN
         HELP(K) = ARRAY(I)
        END IF
   81  CONTINUE
   82 CONTINUE
      DO 85 K=1,NP
        ARRAY(K) = HELP(K)
   85 CONTINUE
      RETURN
      END
```