

APPENDIX D Derivation of Linear Damping Ratio for Liquid Sloshing

Neglecting the nonlinear terms, dispersion terms and forcing terms from Eqs.(A21) and (A.30), the linear basic equations with dissipation term are:

$$\frac{\partial \eta}{\partial t} + h \frac{\partial u}{\partial x} = 0, \quad (D.1)$$

$$\frac{\partial u}{\partial t} + g \frac{\partial \eta}{\partial x} + \lambda u = 0. \quad (D.2)$$

Eliminating u yields,

$$\frac{\partial^2 \eta}{\partial t^2} - gh \frac{\partial^2 \eta}{\partial x^2} + \lambda \frac{\partial \eta}{\partial t} = 0, \quad (D.3)$$

Assuming that η takes the form of

$$\eta(x,t) = X(x) T(t), \quad (D.4)$$

Substituting Eq.(D.4) into Eq. (D.3),

$$\frac{1}{g h} \frac{1}{T} \frac{d^2 T}{dt^2} + \frac{1}{g h} \frac{\lambda}{T} \frac{dT}{dt} = \frac{1}{X} \frac{d^2 X}{dx^2} = -k^2, \quad (D.5)$$

where k is the wave number. Thus,

$$X = X_0 e^{ikx}, \quad (D.6)$$

$$\frac{dT^2}{dt^2} + \lambda \frac{dT}{dt} + \omega^2 T = 0, \quad (D.7)$$

where $C_o = \sqrt{gh}$, is phase velocity of long wave and $\omega = C_o k$, natural frequency of long wave.

Assuming

$$T = T_0 e^{st}. \quad (D.8)$$

So,

$$S^2 + \lambda S + \omega^2 = 0. \quad (D.9)$$

Then,

$$S = \frac{\lambda}{2} \pm \sqrt{\left(\frac{\lambda}{2}\right)^2 - \omega_w^2}, \quad (D.10)$$

Since damping of liquid used in TLD is small, i.e., $\lambda < \omega$, we define

$$\omega_{wd} = \sqrt{\omega_w^2 - \left(\frac{\lambda}{2}\right)^2}, \quad (D.11)$$

Therefore,

$$T = T_0 e^{(-\frac{\lambda + i\omega_{wd}}{2})t} = T_0 e^{(-\frac{\lambda}{2})t} (A \sin \omega_{wd} t + B \cos \omega_{wd} t), \quad (D.12)$$

Letting $\eta = \eta_0$ at $t = t_0$ and $\eta = \eta_N$ at $t = t_0 + N(2\pi/\omega_{wd})$ after N cycle,

$$\frac{\eta_N}{\eta_0} = e^{-N \frac{\lambda \pi}{\omega_{wd}}} \quad (D.13)$$

Therefore, the damping coefficient λ is

$$\lambda = \frac{\omega_{wd}}{N\pi} \ln \frac{\eta_0}{\eta_N} \quad (D.14)$$

$$= \frac{\omega_{wd}}{\pi} \delta, \quad (D.15)$$

where

$$\delta = \frac{1}{N} \ln \frac{\eta_0}{\eta_N}, \quad (D.16)$$

is the logarithmic decrement of liquid sloshing.

Near the fundamental resonance, since $k \gg \lambda$, so $\omega_{wd} \approx \omega_w$, and λ can be approximately expressed as

$$\lambda = \frac{\omega_w}{N\pi} \ln \frac{\eta_0}{\eta_N} \quad (D.17)$$

$$= \frac{\omega_w}{\pi} \delta. \quad (D.18)$$

From Eq. (D.7), We define

$$\lambda \equiv 2\omega \xi_w, \quad (D.19)$$

where ξ_w is damping ratio of liquid sloshing. So,

$$\xi_w = \frac{\lambda}{2\omega}, \quad (D.20)$$

$$\xi = 2\pi\xi_w, \quad (D.21)$$

In dimensionless form,

$$\omega_w' = \frac{a\omega_w}{C_o}, \quad (D.22)$$

$$\kappa' = ak, \quad (D.23)$$

(Near the fundamental resonance, $k' = \pi/2$.)

$$\lambda' = \frac{a\lambda}{C_o}, \quad (D.24)$$

Substituting Eq.(A.36) into Eq.(D.20),

$$\xi_w = \frac{1}{\eta+h} \frac{\sqrt{2}}{2} \frac{\sqrt{\omega\nu}}{2\omega_w'} (1+2h/b+S). \quad (D.25)$$

APPENDIX E Determinations of C_{da} and C_{fr}

E.1 The Criterion for Evaluation

At first, the results from shaking table experiment will be employed to determine the empirical factors. In the experiment, we have detected the wave height of liquid inside TLD, base shear force of TLD due to liquid motion only, and recorded excitation amplitude of the shaking table. The energy loss per cycle was calculated from the base shear force and the excitation amplitude.

The energy loss per cycle is selected here as a criterion to evaluate the simulation results. After breaking wave occurs, the wave height detected in the experiment is not realizable because of liquid splash near the end wall of TLD tank and the base shear force also change to impact-type. The energy loss per cycle due to wave breaking can be equivalent additional damping of TLD.

E.2 Two Empirical Coefficients

The basic equations of shallow liquid sloshing inside TLD are:

$$\frac{\partial \eta}{\partial t} + h\sigma \frac{\partial(\phi u(\eta))}{\partial x} = 0, \quad (E.1)$$

and

$$\frac{\partial u(\eta)}{\partial t} + (1-T_H^2) u(\eta) \frac{\partial u(\eta)}{\partial x} + g \frac{\partial \eta}{\partial x} + gh\sigma\phi \frac{\partial^2 \eta}{\partial x^2} \frac{\partial \eta}{\partial x} = -\lambda u(\eta) - \ddot{x}_s. \quad (E.2)$$

where λ is a damping coefficient.

The value of energy loss can be affected by changing damping of liquid motion in the basic equations, i.e., equivalent damping coefficient λ_{eq} , which is defined as

$$\lambda_{eq} = C_{da} \lambda \quad (E.3)$$

where C_{da} is a damping factor and is one of the empirical factors needed to be obtained from the experiment. The value of energy loss decreases with the increase of C_{da} .

However, the locations of jump frequency and local peaks of energy loss-frequency curve are shifted to lower frequency side when using $C_{da} > 1.0$ in the numerical simulation. This is because that the nonlinearity of liquid sloshing becomes weak when the wave amplitude is reduced with using larger C_{da} . The frequency shift due to C_{da} is expected to be corrected by changing the natural frequency of liquid sloshing in the basic equations.

Linear basic equations of 2 dimensional liquid motion in a rectangular TLD (without external forces) are:

$$\frac{\partial \eta}{\partial t} + h \frac{\partial u}{\partial x} = 0 \quad (E.4)$$

$$\frac{\partial u}{\partial t} + g \frac{\partial \eta}{\partial x} = 0, \quad (E.5)$$

eliminate u and we obtained

$$\frac{\partial^2 \eta}{\partial t^2} - gh \frac{\partial^2 \eta}{\partial x^2} = 0. \quad (E.6)$$

Assume that

$$\eta(x,t) = X(x) \cdot T(t), \quad (E.7)$$

and introduce Eq.(E.7) to Eq.(E.6)

$$\frac{1}{ghT} \frac{\partial^2 T}{\partial t^2} = \frac{1}{X} \frac{\partial^2 X}{\partial x^2} = -k^2, \quad (E.8)$$

where k is a wave number and from this equation we have

$$X = X_0 e^{ikx}, \quad (E.9)$$

$$T = T_0 e^{i\omega t}. \quad (E.10)$$

Actually, $\omega = \sqrt{ghk}$ is the natural frequency of liquid motion.

Change the basic equations of (E.7) as,

$$\frac{\partial u}{\partial t} + C_{fr}^2 g \frac{\partial \eta}{\partial x} = 0, \quad (E.11)$$

and Eq.(E.10) will become to

$$T = T_0 e^{i C_{fr} \omega t} \quad (E.12)$$

In this way, the natural frequency of liquid motion can be changed. Increasing C_{fr} from 1, the natural frequency will be increased and the response curve can be shifted to higher frequency side. The C_{fr} is another empirical factor and is named frequency factor. The modified equation of motion is

$$\frac{\partial u(\eta)}{\partial t} + (1-T_H^2) u(\eta) \frac{\partial u(\eta)}{\partial x} + C_{fr}^2 g \frac{\partial \eta}{\partial x} + gh\sigma\phi \frac{\partial^2 \eta}{\partial x^2} \frac{\partial \eta}{\partial x} = -C_{da}\lambda u(\eta) - \ddot{x}_s. \quad (E.13)$$

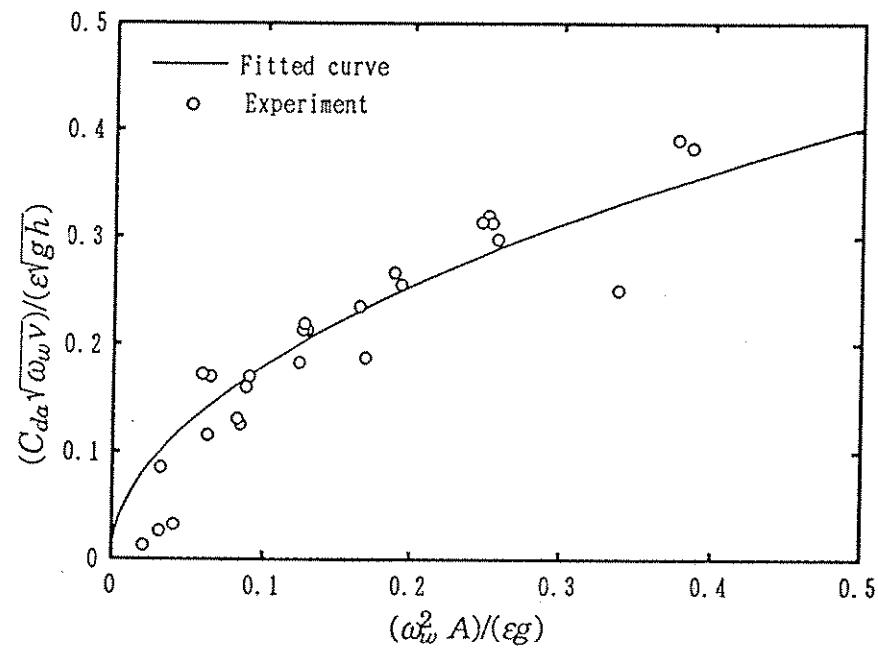
E. 3 Determination by Experiments

The shaking table experiments have been done for the cases with various tank sizes and liquid depths (tank size: $a=29.5cm, 19.5cm$; water depth: $h=3.0cm, 4.0cm$; and excitation amplitude: $A=0.25cm \sim 4.0cm$). C_{da} and C_{fr} are identified on the basis of the experimental results as shown in Table E.1.

Table E.1 Determination of C_{da} and C_{fr}

Case name	TLD	A (cm)	C_{da}	C_{fr}	Error(%)
4N1		0.25	2.00	1.05	.
	2a=39.0cm	0.50	4.00	1.05	
	b=22.5cm	0.70	4.00	1.05	9.3
	h=2.0cm	1.00	5.00	1.05	4.7
	$f_w=0.565hz$	1.50	6.00	1.05	2.6
		2.00	7.00	1.05	1.8
		3.00	9.00	1.05	0.8
		4.00	11.00	1.05	0.8
		0.25	1.50	1.05	
4N2	2a=39.0cm	0.50	6.50	1.07	
	b=22.5cm	0.70	9.00	1.05	8.0
	h=4.0cm	1.00	12.00	1.05	4.6
	$f_w=0.790hz$	1.50	15.00	1.05	2.6
		2.00	18.00	1.05	1.6
		3.00	22.00	1.05	1.4
		4.00	26.00	1.05	0.7
		0.70	5.50	1.05	
6N1	2a=59.0cm	1.00	4.00	1.05	.
	b=33.5cm	1.50	7.00	1.05	2.9
	h=3.0cm	2.00	6.00	1.05	4.2
	$f_w=0.458hz$	3.00	10.00	1.05	2.6
		4.00	8.00	1.05	1.9
		0.25	1.00	1.05	
6N2	2a=59.0cm	0.50	2.50	1.05	
	b=33.5cm	1.00	10.00	1.05	
	h=6.0cm	1.50	14.00	1.05	5.1
	$f_w=0.639hz$	2.00	18.00	1.05	3.1
		3.00	24.00	1.05	1.8

Figure E.1 The Relation Between the Damping term and the Forcing Term.



APPENDIX F Program Lists

The List of Program "WFED1.FOR"

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C ****
C      PROGRAM FOR NUMERICAL SIMULATION OF TLD
C          For shaking tabel experiment and
C          wiht consoderation of wave breaking
C
C      OUTPUT: (1) FREQUENCY RESPONSE OF
C              WAVE HEIGHT WF;
C              BASE SHEAR FF;
C              ENERGY LOSS EF.
C      (2) BASE SHEAR -- DISPLACEMENT
C          RELATIONSHIP
C
C          by    L.M.Sun
C
C      FILENAME: WAVE
C      DATE: Jan. 29, 1988 --- Feb. 10, 1988
C      VER.1.2: May. 14, 1988
C      VER.1.3: May. 15, 1988
C      VER.2.4: July. 22, 1988
C      VER.2.5: June. 7, 1990
C
C      ****NOTE****
C      DT      time step : delta T
C      ETA     wave surface profile
C      N       number of control volume
C      T       time
C      U       velocity of liquid particle along X-direction
C
C      ****MAIN PROGRAM****
C
C      PARAMETER(NR=1000)
C      DIMENSION R(1:NR)
C      CHARACTER FDNAME*5
C      COMMON/CWORK/N1,T,DT,T0,TF
C      COMMON/CWORK1/N,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,A,OMEGA,ROMEGA
C      COMMON/COUT/CR,CH,CB,CDA,CFR
C
C      OPEN(7,FILE='WF.NUM')
C      OPEN(8,FILE='FF')
C      OPEN(9,FILE='EF')
C      OPEN(3,FILE='WF.NAM')
C      READ(3,100) NF
100   FORMAT(I2)
      DO 10 IF=1,NF
      READ(3,200) FDNAME,ROMEGA
200   FORMAT(A6,1X,F6.3)
C~~~~~*
      WRITE(*,230) FDNAME
230   FORMAT(1X,'<',A6,'>')
C~~~~~*
C      OPEN(1,FILE=FDNAME)
C      OPEN(4,FILE='DATA')
C
      CALL INPUT
C
      CALL OUTP1
C
      CALL INITIAL(N1,R(1))
C
      CALL WORK(R(1),R(N1+1),R(2*N1+1),R(4*N1+1))
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C           CLOSE (4, STATUS='KEEP')
C           CALL FREQRESP
C           CLOSE (1, STATUS='KEEP')
10          CONTINUE
           CLOSE (3, STATUS='KEEP')
           CLOSE (7)
           CLOSE (8)
           CLOSE (9)
C           CALL ERROR (NF)
C           STOP
C           END
C           ****SUBROUTINE INPUT*****
C           SUBROUTINE INPUT
COMMON/CWORK/N1,T,DT,T0,TF
COMMON/CWORK1/N,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,A,OMEGA,ROMEGA
COMMON/COUT/CR,CH,CB,CDA,CFR
C           OPEN(2,FILE='WF.INP')
           READ(2,*) CR,CH,CB,A,TF,CDA,CFR
C           N=10               number of control volume
C           CR=50.0            half length of tank
C           CH=5.0              liquid depth
C           CLAMBDA=0.06        viscosity parameter
C           A=0.25              amplitude of excitor
C           ROMEKA=1.05         ratio of frequency OMEGA/OMEGA1
C           T=0.0                initial time
C           TF=40.0             final TAU
C           CLOSE (2)
C           DELTA=CH/CR
C           CK1=0.5*3.1416
C           CKDE=CK1*DELTA
C           TCKDE=TANH (CKDE)
C           SIGMA=TCKDE/CKDE
N=INT (3.1416/(2.0*ACOS (SQRT (TANH (2.*CKDE)
*           /(2.*TANH (CKDE)))))+0.5)
N1=N+1
T0=CR/(SQRT (CH*981.0))
OMEGA=ROMEGA*CK1*(1.0-CK1*CK1/(N*N)/6.0)
C%%%%%
C           CLAMBDA=8.0*SQRT (ROMEGA*OMEGA/T0*0.01)/
C           *(3.0*3.1416*DELTA*SQRT (981.0*CH))*(1.0+2.0*CH/CB+S)
C           CLAMBDA=CDA*SQRT (ROMEGA*OMEGA/T0*0.01/2.0)/
*           (DELTA*SQRT (981.0*CH))*(1.0+2.0*CH/CB+1.0)
C%%%%%
T=0.0
DT=2.0*3.1416/(OMEGA*60.0)
C           RETURN
C           END
C           ****SUBROUTINE INITIAL*****
C           SUBROUTINE INITIAL(N1,R)
DIMENSION R(1)
DO 10 I=1,2*N1

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10      R(I)=0.0
      RETURN
      END
C      ****SUBROUTINE WORK*****
C      FUNCTION: INPUT: N,T,DT,ETAn,Un
C                  OUTPUT: ETAn+1, Un+1, T=T+DT
C
C      NOTE:
C      DT          time step
C      S2          (Sqrt. of 2)/2
C      TAU         exciting wave number
C      <PARAMETER OF RUNGE-KUTTA-GILL>
C      F           =dETA/dT
C      G           =dU/dT
C      RK1...RK4   parameter
C      RL1...RL4   parameter
C
C
C      SUBROUTINE WORK(ETA,U,TEU,R)
C      DIMENSION ETA(1),U(1),TEU(1),R(1)
C      COMMON/CWORK/N1,T,DT,T0,TF
C      COMMON/CWORK1/N,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,A,OMEGA,ROMEGA
C      COMMON/COUT/CR,CH,CB,CDA,CFR
C
C      TAU=0.0
C
C      CALL OUTP2(N1,T,TAU,ETA,U,Q)
C
100     DO 10 I=1,N1
            TEU(I)=ETA(I)
10        TEU(N1+I)=U(I)
            CALL WORK1(T,ETA,U,R(1),R(N1+1),R(8*N1+1))
C
            T=T+0.5*DT
            DO 20 I=1,N1
                ETA(I)=TEU(I)+.5*DT*R(I)
20        U(I)=TEU(N1+I)+.5*DT*R(N1+I)
            CALL WORK1(T,ETA,U,R(2*N1+1),R(3*N1+1),R(8*N1+1))
C
            S2=0.5*SQRT(2.)
            DO 30 I=1,N1
                ETA(I)=TEU(I)+(S2-.5)*DT*R(I)+(1.-S2)*DT*R(2*N1+I)
30        U(I)=TEU(N1+I)+(S2-.5)*DT*R(N1+I)+(1.-S2)*DT*R(3*N1+I)
            CALL WORK1(T,ETA,U,R(4*N1+1),R(5*N1+1),R(8*N1+1))
C
            T=T+0.5*DT
            DO 40 I=1,N1
                ETA(I)=TEU(I)-S2*DT*R(2*N1+I)+(1.+S2)*DT*R(4*N1+I)
40        U(I)=TEU(N1+I)-S2*DT*R(3*N1+I)+(1.+S2)*DT*R(5*N1+I)
            CALL WORK1(T,ETA,U,R(6*N1+1),R(7*N1+1),R(8*N1+1))
C
            DO 50 I=1,N1
                ETA(I)=TEU(I)+DT*(R(I)+2.*(1.-S2)*R(2*N1+I)
*                   +2.*(1.+S2)*R(4*N1+I)+R(6*N1+I))/6.
50        U(I)=TEU(N1+I)+DT*(R(N1+I)+2.*(1.-S2)*R(3*N1+I)
*                   +2.*(1.+S2)*R(5*N1+I)+R(7*N1+I))/6.
C
            Q=0.5*CH*CH*0.001*CB*(ETA(N1)-ETA(1))*(ETA(N1)+ETA(1)+2.)
C
            TAU=T/(60.0*DT)
C
            IF (TAU.GE.80) CALL OUTP2(N1,T,TAU,ETA,U,Q)
C

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IF (TAU.LE.TF) GOTO 100
RETURN
END
C *****SUBROUTINE WORK1*****
C FUNCTION: INPUT: T,ETA(I),U(I)
C           OUTPUT: F(I),G(I)
C
C NOTE:
C A      amplitude of excitor displacement
C CI(I)   coefficient/ I
C CK(I)   coefficient/ K
C CK1     coefficient/ K1=PI/2
C CLAMBDA coefficient/ greek letter LAMBDA
C DELTA    wave height/R
C ETA(I)   wave sorface profile/ greek letter ETA
C F(I)     =dETA/dT
C G(I)     =dU/dT
C H(I)     coefficient/ H
C N      number of control volume
C OMEGA   exciting freqency
C PHI(I)   coefficient/ greek letter PHI
C SIGMA    =tanh(kl*delta)/(kl*delta)
C T      time
C U(I)     velocity of liquid particle along X-direction
C
C SUBROUTINE WORK1(T,ETA,U,F,G,R)
C DIMENSION ETA(1),U(1),F(1),G(1),R(1)
C COMMON/CWORK1/N,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,A,OMEGA,ROMEWA
C COMMON/COUT/CR,CH,CB,CDA,CFR
C
C N1=N+1
C CALCULATION OF PHI(I), H(I) AND C
DO 110 I=2,N1
  R(I)=TANH(CKDE*(1.0+0.5*(ETA(I-1)+ETA(I)))/TCKDE
110  R(N1+I)=0.5*(1.0-R(I)*TCKDE*R(I)*TCKDE)
  C=SIGMA*DELTA*DELTA
C
C CALCULATION OF I(I)
R(2*N1+1)=0.0
DO 120 I=2,N1-1
  R(2*N1+I)=0.5*((ETA(I+1)-ETA(I-1))*0.25*N)**2
120  R(3*N1)=0.0
C
C CALCULATION OF K(I)
R(3*N1+1)=0.
DO 130 I=2,N1-1
  R(3*N1+I)=(0.5*(U(I)+U(I+1)))**2
130  R(4*N1)=0.
C
C CALCULATION OF F(I)
II=2
F(1)=(CFR*CFR)*(-N*R(II)*U(II)*SIGMA)
DO 140 I=2,N1-1
  F(I)=(CFR*CFR)*.5*N*(R(I)*U(I)-R(I+1)*U(I+1))*SIGMA
140  F(N1)=(CFR*CFR)*N*R(N1)*U(N1)*SIGMA
C
C CALCULATION OF G(I)
DO 150 I=2,N1
  ETAA=.5*(ETA(I-1)-ETA(I))
150  G(I)=.5*N*(ETA(I-1)-ETA(I)+R(N1+I)*(R(3*N1+I-1)-R(3*N1+I))
*          +C*R(I)*(R(2*N1+I-1)-R(2*N1+I)))
*          -OMEGA*OMEGA*A/CR*SIN(OMEGA*T)-CLAMBDA*U(I)/(1.+ETAA)
C

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      RETURN
      END
C      ****SUBROUTINE OUTP1*****
      SUBROUTINE OUTP1
      COMMON/CWORK/N1,T,DT,T0,TF
      COMMON/CWORK1/N,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,A,OMEGA,ROMEKA
      COMMON/COUT/CR,CH,CB,CDA,CFR
C
      WRITE(1,20) A
      WRITE(7,20) A
      WRITE(8,20) A
      WRITE(9,20) A
      WRITE(*,20) A
      WRITE(1,30) ROMEKA
      WRITE(7,30) ROMEKA
      WRITE(8,30) ROMEKA
      WRITE(9,30) ROMEKA
      WRITE(*,30) ROMEKA
      WRITE(1,10) CR,CH,DELTA,CLAMBDA
      WRITE(7,10) CR,CH,DELTA,CLAMBDA
      WRITE(8,10) CR,CH,DELTA,CLAMBDA
      WRITE(9,10) CR,CH,DELTA,CLAMBDA
      WRITE(*,10) CR,CH,DELTA,CLAMBDA
      10 FORMAT(1X,'R= ',F6.3,5X,'H= ',F6.3,5X,'DELTA= ',F6.3,
             *      5X,'LAMBDA= ',F6.3)
      20 FORMAT(1X,'A= ',F6.3)
      30 FORMAT(1X,'ROMEKA=',F6.3)
      RETURN
      END
C
C      ****SUBROUTINE OUTP2*****
      SUBROUTINE OUTP2(N1,T,TAU,ETA,U,Q)
      DIMENSION ETA(1),U(1)
C
      WRITE(4,10) TAU,ETA(1),Q
      10 FORMAT(1X,F10.6,',',F20.6,',',F20.6)
      C      WRITE(1,20) (ETA(I),U(I),I=2,N1)
      C      WRITE(*,20) (ETA(I),U(I),I=2,N1)
      20 FORMAT(1X,23X,2F20.4)
      C
      RETURN
      END
C
C      ****SUBROUTINE FREQRESP*****
      SUBROUTINE FREQRESP
      DIMENSION TAU(1300),W(1300),F(1300)
      COMMON/CWORK/N1,T,DT,T0,TF
      COMMON/CWORK1/N,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,A,OMEGA,ROMEKA
      COMMON/COUT/CR,CH,CB,CDA,CFR
C
      OPEN(4,FILE='DATA')
      READ(4,200) (TAU(I),W(I),F(I),I=1,1200)
      200 FORMAT(1X,F10.6,1X,F20.6,1X,F20.6)
      C
      *****INITIALIZATION
      WB=0.0
      WS=0.0
      FB=0.0
      FS=0.0
      ET=0.0
      DO 10 I=1,20
      C
      *****CALCULATING WF AND FF

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      CALL MAXMIN(W((I-1)*60+1),B,S)
      WB=WB+B
      WS=WS+S
      CALL MAXMIN(F((I-1)*60+1),B,S)
      FB=FB+B
      FS=FS+S
C
C*****CALCULATING EF
      E=0.0
      D0=0.0
      DO 20 J=(I-1)*60+1, (I-1)*60+60
      D=A*SIN(2*3.1416*J/60.0)
      DD=D-D0
      D0=D
      E=E+DD*F(J)
      ET=ET+E
10    CONTINUE
C
      WB=WB/20.0
      WS=WS/20.0
      FB=FB/20.0
      FS=FS/20.0
      FM=0.5*(FB-FS)
      E=ET/20.0
C
C*****NONDIMENSIONALIZATION
      OMEGAD=OMEGA/T0
      FM=FM/(0.001*2.*CR*CH*CB*OMEGAD*OMEGAD*A)*981.0
      E=E/(0.5*0.001*2.*CR*CH*CB*OMEGAD*A*OMEGAD*A)*981.0
C
C*****OUTPUT WF, FF, EF
C
      WRITE(7,100) ROMEWA,WB,WS,FM,E
C
C      WRITE(7,100) ROMEWA,WB
C      WRITE(7,100) ROMEWA,WS
C      WRITE(8,100) ROMEWA,FM
C      WRITE(9,100) ROMEWA,E
100   FORMAT(1X,F10.6,', ',4F10.6)
C
C*****CALCULATING FD
      FF=0.0
      DO 30 J=1,60
      D=A*SIN(2*3.1416*J/60.0)
      DO 40 I=1,10
40    FF=FF+F((I-1)*60+J)
      FF=FF/10.0
C      WRITE(1,100) D,FF
30    CONTINUE
C
      CLOSE(4)
      RETURN
      END
C
C ****
SUBROUTINE MAXMIN(T,B,S)
DIMENSION T(1)
N=60
B=T(1)
S=T(1)
DO 20 I=1,N-1
IF (B.LT.T(I+1)) THEN
      B=T(I+1)

```

```

        ENDIF
        IF (S.GT.T(I+1)) THEN
        S=T(I+1)
        ENDIF
20      CONTINUE
        RETURN
        END

C
C *****SUBROUTINE ERROR*****
SUBROUTINE ERROR(NF)
COMMON/CWORK/N1,T,DT,T0,TF
COMMON/CWORK1/N,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,A,OMEGA,ROMEGA
COMMON/COUT/CR,CH,CB,CDA,CFR
C
REAL WB,WS,FM,ENUM,EEXP,SUMQ
SUMQ=0.0
OPEN(7,FILE='WF.NUM')
OPEN(8,FILE='WF.EXP')
DO 100 I=1,NF
READ(7,*,END=110) ROMEGA,WB,WS,FM,ENUM
READ(8,*,END=110) ROMEGA,WB,WS,FM,EEXP
SUMQ=SUMQ+ (ENUM-EEXP) * (ENUM-EEXP)
100    CONTINUE
110    CLOSE(7)
        CLOSE(8)
C
OPEN(1,FILE='WF.SUM')
WRITE(1,200) A, CDA, CFR, SUMQ
200    FORMAT(1X, 4F15.6)
        CLOSE(1)
C
RETURN
END

```

The List of Input File "WF.INP"

29.5
3.0
33.5
1.0
100.0
4.0
1.0

The List of Input File "WF.NAM"

78
FD0800, 0.800
FD0810, 0.810
FD0820, 0.820
FD0830, 0.830
FD0840, 0.840
FD0850, 0.850
FD0860, 0.860
FD0870, 0.870
FD0880, 0.880
FD0890, 0.890
FD0900, 0.900
FD0905, 0.905
FD0910, 0.910
FD0915, 0.915
FD0920, 0.920
FD0925, 0.925
FD0930, 0.930
FD0935, 0.935
FD0940, 0.940
FD0945, 0.945
FD0950, 0.950
FD0955, 0.955
FD0960, 0.960
FD0965, 0.965
FD0970, 0.970
FD0975, 0.975
FD0980, 0.980
FD0985, 0.985
FD0990, 0.990
FD0995, 0.995
FD1000, 1.000
FD1005, 1.005
FD1010, 1.010
FD1015, 1.015
FD1020, 1.020
FD1025, 1.025
FD1030, 1.030
FD1035, 1.035
FD1040, 1.040
FD1045, 1.045
FD1050, 1.050
FD1055, 1.055
FD1060, 1.060
FD1065, 1.065
FD1070, 1.070
FD1075, 1.075
FD1080, 1.080
FD1085, 1.085
FD1090, 1.090
FD1095, 1.095
FD1100, 1.100
FD1105, 1.105
FD1110, 1.110
FD1115, 1.115
FD1120, 1.120
FD1130, 1.130
FD1140, 1.140
FD1150, 1.150
FD1160, 1.160
FD1170, 1.170

FD1180, 1.180
FD1190, 1.190
FD1200, 1.200
FD1220, 1.220
FD1240, 1.240
FD1260, 1.260
FD1280, 1.280
FD1300, 1.300
FD1320, 1.320
FD1340, 1.340
FD1360, 1.360
FD1380, 1.380
FD1400, 1.400
FD1420, 1.420
FD1440, 1.440
FD1460, 1.460
FD1480, 1.480
FD1500, 1.500

The List of Program "SL1.FOR"

```
C ****
C      PROGRAM FOR NUMERICAL SIMULATION OF 2-DOF
C      SYSTEM (TLD AND STRUCTURE)
C      FOR FORCED VIBRATION
C      with consideration of wave breaking
C
C      INPUT:  STRUCTURAL PARAMETER
C              TLD PARAMETER
C              MASS RATIO
C              APPLIED FORCE
C      OUTPUT: TIME HISTORY OF STRUCTURE "X"
C              TIME HISTORY OF WAVE SURFACE "ETA"
C              TIME HISTORY OF INTER FORCE "FSL"
C              ENERGY INPUT INTO SYSTEM "EF"
C
C      by     L.M.Sun
C
C      FILENAME: SL1.FOR
C      DATE: June 7, 1990
C ****
C
C ****NOTE*****
C DT      time step : delta T
C ETA    wave surface profile
C N       number of control volume
C T       time
C U       velocity of liquid particle along X-direction
C
C ****MAINPROGRAM*****
C
C      PARAMETER(NR=1000)
C      DIMENSION R(1:NR)
C
C      COMMON/CWORK/N1,T,TF,TAU
C      COMMON/CWORK1/N,CR,CH,CB,CNU,
&      CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P
C      COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR
C
C      CALL INPUT
C
C      OPEN(9,FILE='SL.RFR')
C
C      OPEN(10,FILE='FF')
C      OPEN(14,FILE='EF')
C      OPEN(7,FILE='WF')
C      OPEN(8,FILE='XF')
C
C      READ(9,210) NF
210      FORMAT(I2)
      DO 500 III=1,NF
          READ(9,220) ROMEGA
220      FORMAT(F6.3)
          WRITE(*,230) ROMEGA
230      FORMAT(1X,'<<ROMEGA=',F6.3,'>>')
C
          OPEN(1,FILE='ETA')
          OPEN(2,FILE='SL.CND')
          OPEN(3,FILE='FSL')
C
          OPEN(11,FILE='X')
```

```

C      OPEN(12,FILE='Y')
C      OPEN(13,FILE='Z')
C
C      CALL INITIAL(N1,R(1))
C
C      *****INITIAL CONDITIONS OF STRUCTURE*****
C      T0=CR/SQRT(981.0*CH)
C      OMEGAD=SQRT(SK/SM-(0.5*SC/SM)*(0.5*SC/SM))*T0
C      TD=2.0*3.1415927/(OMEGAD*ROMEGA)
C      DT=TD/60.0
C      T=0.0
C      TAU=0.0
C
C      X=0.0
C      Y=0.0
C      Z=0.0
C      FSL=0.0
C      ****
C
C      NTF=INT(TF)
C      CDA=1.0
C      CFR=1.0
C      DO 100 JJJ=0, NTF
C          CLAMBDA=CDA*8.0*SQRT(ROMEGA*OMEGAD/T0*CNU)/
C             (3.0*3.1415926*DELTA*SQRT(981.0*CH))
C          XMAX=0.0
C          XMIN=0.0
C          ETAMAX=0.0
C          ETAMIN=0.0
C          DO 110 JJ=1, 60
C
C          CALL STRC(X,Y,Z,FSL)
C
C          CALL WORK(R(1),R(N1+1),R(2*N1+1),R(4*N1+1),Z,FSL)
C
C          TAU=T/TD
C          T=T+DT
C          IF (JJJ.GE.150) THEN
C              IF (XMAX.LT.X) XMAX=X
C              IF (XMIN.GT.X) XMIN=X
C              IF (ETAMAX.LT.R(1)) ETAMAX=R(1)
C              IF (ETAMIN.GT.R(1)) ETAMIN=R(1)
C          ENDIF
C
C          IF (TAU.LE.200) GOTO 110
C
C          WRITE(11,10) TAU,X*CR
C 10        FORMAT(1X,2F10.4)
C          CALL OUTP2(N1,T,TAU,R(1),R(N1+1),FSL)
C
C 110      CONTINUE
C          IF (JJJ.GE.150) THEN
C              XAMP=0.5*(XMAX-XMIN)
C              ETAAMP=ETAMAX-ETAMIN
C              AAA=2.0
C              BBB=2.0
C              IF (ETAAMP.GT.1.0) THEN
C                  CDA=AAA*XAMP*CR+BBB
C                  CFR=1.05
C              ENDIF
C          ENDIF
C          CONTINUE
C
C 100      CONTINUE

```

```

        CLOSE (1)
        CLOSE (2)
        CLOSE (3)
C
        CLOSE (11)
C        CLOSE (12)
C        CLOSE (13)
C
        CALL FREQRESP
500    CONTINUE
        CLOSE (9)
        CLOSE (7)
        CLOSE (8)
        CLOSE (10)
        CLOSE (14)
C
        STOP
        END
C
C ****SUBROUTINE INPUT*****
SUBROUTINE INPUT
COMMON/CWORK/N1,T,TF,TAU
COMMON/CWORK1/N,CR,CH,CB,CNU,
&   CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P
COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR
C
OPEN(2,FILE='SL.INP')
READ(2,*) SM,SK,SC,CR,CB,CH,CNU,CMU,P,TF
C
C      N=10           number of control volume
C      CR=50.0         half lenth of tank
C      CH=5.0          liquid depth
C      CNU             viscosity of liquid
C      CMU             mass ratio
C      P=               amplitude of exciting force
C      T=0.0            initial time
C      TF=40.0          final time (final TAU)
C
CLOSE (2)
C~~~~~-
C      CB=1000*SM*CMU/(2*CH*CR)
C~~~~~-
      DELTA=CH/CR
      CK1=0.5*3.1416
      CKDE=CK1*DELTA
      TCKDE=TANH (CKDE)
      SIGMA=TCKDE/CKDE
      N=INT (3.1416/(2.0*ACOS (SQRT (TANH (2.*CKDE)
      *      /(2.*TANH (CKDE)))))+0.5)
      N1=N+1
C
      RETURN
      END
C ****SUBROUTINE INITIAL*****
SUBROUTINE INITIAL(N1,R)
DIMENSION R(1)
DO 10 I=1,2*N1
10 R(I)=0.0
      RETURN
      END
C ****SUBROUTINE WORK*****
C FUNCTION: INPUT: N, T, DT, ETAn, Un

```

```

C          OUTPUT: ETAn+1, Un+1, T=T+DT
C
C          NOTE:
C          DT      time step
C          S2      (Sqrt. of 2)/2
C          TAU     exciting wave number
C          <PARAMETER OF RUNGE-KUTTA-GILL>
C          F      =dETA/dT
C          G      =dU/dT
C          RK1...RK4   parameter
C          RL1...RL4   parameter
C
C          SUBROUTINE WORK(ETA,U,TEU,R,Z,Q)
C          DIMENSION ETA(1),U(1),TEU(1),R(1)
C          COMMON/CWORK/N1,T,TF,TAU
C          COMMON/CWORK1/N,CR,CH,CB,CNU,
&          CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P
C          COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR
C
C          DO 10 I=1,N1
C              TEU(I)=ETA(I)
C              TEU(N1+I)=U(I)
C              CALL WORK1(TT,ETA,U,R(1),R(N1+1),R(8*N1+1),Z)
C
C              TT=T+0.5*DT
C              DO 20 I=1,N1
C                  ETA(I)=TEU(I)+.5*DT*R(I)
C                  U(I)=TEU(N1+I)+.5*DT*R(N1+I)
C                  CALL WORK1(TT,ETA,U,R(2*N1+1),R(3*N1+1),R(8*N1+1),Z)
C
C                  S2=0.5*SQRT(2.)
C                  DO 30 I=1,N1
C                      ETA(I)=TEU(I)+(S2-.5)*DT*R(I)+(1.-S2)*DT*R(2*N1+I)
C                      U(I)=TEU(N1+I)+(S2-.5)*DT*R(N1+I)+(1.-S2)*DT*R(3*N1+I)
C                      CALL WORK1(TT,ETA,U,R(4*N1+1),R(5*N1+1),R(8*N1+1),Z)
C
C                      TT=T+0.5*DT
C                      DO 40 I=1,N1
C                          ETA(I)=TEU(I)-S2*DT*R(2*N1+I)+(1.+S2)*DT*R(4*N1+I)
C                          U(I)=TEU(N1+I)-S2*DT*R(3*N1+I)+(1.+S2)*DT*R(5*N1+I)
C                          CALL WORK1(TT,ETA,U,R(6*N1+1),R(7*N1+1),R(8*N1+1),Z)
C
C                      DO 50 I=1,N1
C                          ETA(I)=TEU(I)+DT*(R(I)+2.*(1.-S2)*R(2*N1+I)
C                          *           +2.*(1.+S2)*R(4*N1+I)+R(6*N1+I))/6.
C                          U(I)=TEU(N1+I)+DT*(R(N1+I)+2.*(1.-S2)*R(3*N1+I)
C                          *           +2.*(1.+S2)*R(5*N1+I)+R(7*N1+I))/6.
C
C~~~~~
C          WRITE(*,100) TAU,ETA(1)
C100      FORMAT(1X,F7.3,',',F20.6)
C~~~~~
C          Q=0.25*CMU*(ETA(N1)-ETA(1))*(ETA(N1)+ETA(1)+2.)
C
C          RETURN
C          END
C          ****SUBROUTINE WORK1*****
C          FUNCTION: INPUT: T,ETA(I),U(I)
C                      OUTPUT: F(I),G(I)
C
C          NOTE:
C          A           amplitude of excitor displacement

```

```

C      CI(I)      coefficient/ I
C      CK(I)      coefficient/ K
C      CK1       coefficient/ K1=PI/2
C      CLAMBDA   coefficient/ greek letter LAMBDA
C      DELTA      wave height/R
C      ETA(I)    wave sorface profile/ greek letter ETA
C      F(I)       =dETA/dT
C      G(I)       =dU/dT
C      H(I)       coefficient/ H
C      N          number of control volume
C      OMEGA     exciting freqency
C      PHI(I)    coefficient/ greek letter PHI
C      SIGMA     =tanh(k1*delta)/(k1*delta)
C      T          time
C      U(I)       velocity of liquid particle along X-direction
C
-----  

SUBROUTINE WORK1(T,ETA,U,F,G,R,Z)
DIMENSION ETA(1),U(1),F(1),G(1),R(1)
COMMON/CWORK1/N,CR,CH,CB,CNU,
& CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P
COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR
C
      N1=N+1
C      CALCULATION OF PHI(I), H(I) AND C
      DO 110 I=2,N1
         R(I)=TANH(CKDE*(1.0+0.5*(ETA(I-1)+ETA(I)))/TCKDE
110      R(N1+I)=0.5*(1.0-R(I)*TCKDE*R(I)*TCKDE)
         C=SIGMA*DELTA*DELTA
C
C      CALCULATION OF I(I)
      R(2*N1+1)=0.0
      DO 120 I=2,N1-1
120      R(2*N1+I)=0.5*((ETA(I+1)-ETA(I-1))*0.25*N)**2
      R(3*N1)=0.0
C
C      CALCULATION OF K(I)
      R(3*N1+1)=0.
      DO 130 I=2,N1-1
130      R(3*N1+I)=(0.5*(U(I)+U(I+1)))**2
      R(4*N1)=0.
C
C      CALCULATION OF F(I)
      JJ=2
      F(1)=-(CFR*CFR)*N*R(JJ)*U(JJ)*SIGMA
      DO 140 I=2,N1-1
140      F(I)=.5*(CFR*CFR)*N*(R(I)*U(I)-R(I+1)*U(I+1))*SIGMA
      F(N1)=(CFR*CFR)*N*R(N1)*U(N1)*SIGMA
C
C      CALCULATION OF G(I)
      DO 150 I=2,N1
         ETAA=.5*(ETA(I-1)-ETA(I))
C~~~~~  

         CLAMBDAA=CLAMBDA*(1.0+2.0*CH/CB+1.0)/(1.+ETAA)
C         CLAMBDAA=CLAMBDA*(1.0+2.0*CH/CR+1.0)/(1.+ETAA)
C~~~~~  

150      G(I)=.5*N*(ETA(I-1)-ETA(I)+R(N1+I)*(R(3*N1+I-1)-R(3*N1+I))
*           +C*R(I)*(R(2*N1+I-1)-R(2*N1+I)))
*           -Z
*           -CLAMBDAA*U(I)
C
      RETURN
      END
C      *****SUBROUTINE STRC*****

```

```

        SUBROUTINE STRC(X, Y, Z, FSL)
C
C           COMMON/CWORK/N1, T, TF, TAU
C           COMMON/CWORK1/N, CR, CH, CB, CNU,
&           CMU, DELTA, CKDE, TCKDE, SIGMA, CLAMBDA, P
C           COMMON/CSTRC/SM, SK, SC, OMEGAD, TD, DT, T0, ROMEWA, CDA, CFR
C
C           REAL K1, K2, K3, K4
C           REAL L1, L2, L3, L4
C
C           F(X, Y, FSL, T)=-SC*T0*Y/SM-SK*T0*T0*X/SM+FSL
*           +P*T0*T0/(SM*CR)*SIN(OMEGAD*ROMEWA*T)
C
C           ROF2=SQRT(2.0)
C~~~~~-
C           WRITE(11,100) TAU,X*CR
C           WRITE(12,100) TAU,Y*CR/T0
C           WRITE(13,100) TAU,Z*CR/(T0*T0)
C~~~~~-
100      FORMAT(1X,2F10.4)
K1=Y
L1=F(X, Y, FSL, T)
K2=Y+0.5*DT*L1
L2=F(X+0.5*DT*K1, Y+0.5*DT*L1, FSL, T+0.5*DT)
K3=Y+0.5*(ROF2-1.0)*DT*L1+(1.0-0.5*ROF2)*DT*L2
L3=F(X+0.5*(ROF2-1.0)*DT*K1+(1.0-0.5*ROF2)*DT*K2,
*           Y+0.5*(ROF2-1.0)*DT*L1+(1.0-0.5*ROF2)*DT*L2, FSL, T+0.5*DT)
K4=Y-0.5*ROF2*DT*L2+(1.0+0.5*ROF2)*DT*L3
L4=F(X-0.5*ROF2*DT*K2+(1.0+0.5*ROF2)*DT*K3,
*           Y-0.5*ROF2*DT*L2+(1.0+0.5*ROF2)*DT*L3, FSL, T+DT)
X=X+DT/6.0*(K1+(2.0-ROF2)*K2+(2.0+ROF2)*K3+K4)
Y=Y+DT/6.0*(L1+(2.0-ROF2)*L2+(2.0+ROF2)*L3+L4)
Z=F(X, Y, FSL, T+DT)
RETURN
END
C *****SUBROUTINE OUTP1*****
C           SUBROUTINE OUTP1
C           COMMON/CWORK/N1, T, TF, TAU
C           COMMON/CWORK1/N, CR, CH, CB, CNU,
&           CMU, DELTA, CKDE, TCKDE, SIGMA, CLAMBDA, P
C           COMMON/CSTRC/SM, SK, SC, OMEGAD, TD, DT, T0, ROMEWA, CDA, CFR
C
C           WRITE(1,20) P
C           WRITE(2,20) P
C           WRITE(*,20) P
C           WRITE(1,30) OMEGAD
C           WRITE(2,30) OMEGAD
C           WRITE(*,30) OMEGAD
C           WRITE(1,10) CR,CH,DELTA,CLAMBDA
C           WRITE(2,10) CR,CH,DELTA,CLAMBDA
C           WRITE(*,10) CR,CH,DELTA,CLAMBDA
10          FORMAT(1X, 'R= ', F6.3, 5X, 'H= ', F6.3, 5X, 'DELTA= ', F6.3,
*           ' 5X, 'LAMBDA= ', F6.3//)
20          FORMAT(1X, 'P= ', F6.3)
30          FORMAT(1X, 'OMEGAD= ', F6.3)
RETURN
END
C *****SUBROUTINE OUTP2*****
C           SUBROUTINE OUTP2(N1, T, TAU, ETA, U, Q)
C           COMMON/CWORK1/N, CR, CH, CB, CNU,
&           CMU, DELTA, CKDE, TCKDE, SIGMA, CLAMBDA, P
C           COMMON/CSTRC/SM, SK, SC, OMEGAD, TD, DT, T0, ROMEWA, CDA, CFR

```

```

      DIMENSION ETA(1),U(1)
C
      WRITE(1,10) TAU,ETA(1)*CH
      WRITE(3,10) TAU,Q*SM*CR/(T0*T0)
C
      WRITE(*,10) TAU,ETA(1)*CH
10    FORMAT(1X,2F10.4)
C
      WRITE(1,20) (ETA(I),U(I),I=2,N1)
C
      WRITE(*,20) (ETA(I),U(I),I=2,N1)
C20   FORMAT(1X,23X,2F20.4)
C
      RETURN
      END
C
C *****SUBROUTINE FREQRESP*****
C
      SUBROUTINE FREQRESP
      DIMENSION TAU(1500),W(1500),X(1500),F(1500)
      COMMON/CWORK/N1,T,TF,TAU
      COMMON/CWORK1/N,CR,CH,CB,CNU,
&      CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P
      COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR
C
      OPEN(3,FILE='FSL')
      OPEN(4,FILE='ETA')
      OPEN(5,FILE='X')
      READ(3,200) (TAU(I),F(I),I=1,1201)
      READ(4,200) (TAU(I),W(I),I=1,1201)
      READ(5,200) (TAU(I),X(I),I=1,1201)
200   FORMAT(1X,F10.4,F10.4)
C
C*****INITIALIZATION
      FB=0.0
      FS=0.0
      WB=0.0
      WS=0.0
      XB=0.0
      XS=0.0
C
C*****CALCULATING EF, FF, WF AND XF
      DO 10 I=1,20
      CALL MAXMIN(F((I-1)*60+1),B,S)
      FB=FB+B
      FS=FS+S
      CALL MAXMIN(W((I-1)*60+1),B,S)
      WB=WB+B
      WS=WS+S
      CALL MAXMIN(X((I-1)*60+1),B,S)
      XB=XB+B
      XS=XS+S
10    CONTINUE
C
      FB=FB/20.0
      FS=FS/20.0
      WB=WB/20.0
      WS=WS/20.0
      XB=XB/20.0
      XS=XS/20.0
      FM=0.5*(FB-FS)
      XM=0.5*(XB-XS)
C
      EF=0.0
C
      DO 20 I=1,1200
      DD=X(I+1)-X(I)

```

```

      TTT=0.5*(TAU(I)+TAU(I+1))*TD
      FINPUT=P*SIN(OMEGAD*ROMEGA*TTT)
      EF=EF+DD*FINPUT
  20    CONTINUE
      EF=EF/20.0
      C
      WRITE(10,100) ROMEWA,FM
      WRITE(14,100) ROMEWA,EF
      WRITE(7,105) ROMEWA,WB,WS
      WRITE(8,100) ROMEWA,XM
  100   FORMAT(1X,2F10.6)
  105   FORMAT(1X,3F10.6)
      C
      CLOSE(3)
      CLOSE(4)
      CLOSE(5)
      RETURN
      END
      C
      ****
      C
      SUBROUTINE MAXMIN(T,B,S)
      DIMENSION T(1)
      N=60
      B=T(1)
      S=T(1)
      DO 20 I=1,N-1
      IF (B.LT.T(I+1)) THEN
      B=T(I+1)
      ENDIF
      IF (S.GT.T(I+1)) THEN
      S=T(I+1)
      ENDIF
  20    CONTINUE
      RETURN
      END

```

The List of Input File "SL.INP"

1.00
32.698
0.0364
12.6
32.2
2.1
0.01
0.01
0.628
221.0

The List of Input File "SL.RFR"

31
0.800
0.850
0.900
0.920
0.940
0.950
0.955
0.960
0.965
0.970
0.975
0.980
0.985
0.990
0.995
1.000
1.005
1.010
1.015
1.020
1.025
1.030
1.035
1.040
1.045
1.050
1.060
1.080
1.100
1.150
1.200

The List of Program "MTLD.FOR"

```
C ****  
C *      PROGRAME FOR NUMERICAL SIMULATION OF          *  
C *          MULTIPLE TLD-STRUCTURE INTERACTION          *  
C *  
C *      INPUT FILE : INP                            *  
C *  
C *      OUTPUT FILE : OUT                           *  
C *  
C *                      by    L.M.SUN             *  
C *  
C *      FILENAME: MTLD.FOR                         *  
C *      DATE: May  1-14, 1991                        *  
C ****  
C  
C *****NOTE*****  
C DT      time step : delta T  
C ETA     wave surface profile  
C N       number of control volume  
C T       time  
C U       velocity of liquid particle along X-direction  
C  
C *****MAIN PROGRAM*****  
C  
C IMPLICIT REAL*8 (A-H,O-Z)  
C DIMENSION ROMEHAV(1:200),CHV(1:30)  
C DIMENSION ETLDV(1:50,1:50), UTLDV(1:50,1:50)  
C DIMENSION EV(1:50), UV(1:50)  
C DIMENSION TAU(1:1500), ETAV(1:1500), FSLV(1:1500), XV(1:1500),  
C &           XVV(1:50)  
C DIMENSION IBREAKV(1:50), CDAV(1:50), CFRV(1:50)  
C DIMENSION ETAMAXV(1:50), ETAMINV(1:50), ETAAMPV(1:50)  
C  
C COMMON/CWORK/N1,T,TAU  
C COMMON/CWORK1/N,CR,CH0,CB,CNU,  
&   CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P,NTLD,DCH,CH1,EBETA  
C COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEVA,CDA,CFR,TALF  
C COMMON/INP/ROMEHAV,NF,CHV  
C COMMON/OGATA/TAUV,ETAV,FSLV,XV  
C  
C CALL INPUT  
C  
C OPEN(10,FILE='OUT')  
C  
C DO 500 III=1,NF  
C   ROMEVA=ROMEHAV(III)  
C  
C *****INITIAL CONDITIONS OF STRUCTURE*****  
C T0=CR/DSQRT(981.0*CH0)  
C OMEGAD=DSQRT(SK/SM-(0.5*SC/SM)*(0.5*SC/SM))*T0  
C TD=2.0*3.1415927/(OMEGAD*ROMEVA)  
C DT=TD/60.0  
C T=0.0  
C TAU=0.0  
C JCONT=0  
C  
C X=0.0  
C Y=0.0  
C Z=0.0  
C FSL=0.0  
C ****
```

```

        DO 15 I=1, NTLD
        IBREAKV(I)=0
        CDAV(I)=1.0
        CFRV(I)=1.0
15      CONTINUE
C
        CHTOTAL=0.0
        DO 31 I=1,NTLD
        CHTOTAL=CHTOTAL+CHV(I)
31      CONTINUE
C
        NTFMIN=50
        NTFMAX=200
        NDTF=10
        IOUT=0
        NOUT=0
        XVVMIN=0.0
        XVVMAX=0.0
        XERROR0=0.01
        XERROR=1.0
        NCYCLE=-1
100     NCYCLE=NCYCLE+1
C
        XMAX=0.0
        XMIN=0.0
        XAMP=0.0
C
        DO 110 JCYCLE=1, 60
C
        CALL STRC(X,Y,Z,FSL)
C
        FSL=0.0
        DO 30 ITLD=1,NTLD
        CH1=CHV(ITLD)
        DELTA=CH1/CR
        CK1=0.5*3.1416
        CKDE=CK1*DELTA
        TCKDE=DTANH(CKDE)
        SIGMA=TCKDE/CKDE
        TALF=T0/(CR/DSQRT(981.0*CH1))
        N=INT(3.1416/(2.0*DACOS(DSQRT(DTANH(2.*CKDE)
*          /(2.*DTANH(CKDE))))))+0.5
        N1=N+1
        CMU1=CMU*CH1/CHTOTAL
C
        DO 20 I=1,N1
        EV(I)=ETLDV(ITLD,I)
        UV(I)=UTLDV(ITLD,I)
20      CONTINUE
        CDA=CDAV(ITLD)
        CFR=CFRV(ITLD)
        CALL WORK(EV(1),UV(1),Z,Q,CMU1)
C~~~~~
C           IF ((IOUT.EQ.1).AND.(NCYCLE.GE.(NOOUT+21-2)))
C             &      WRITE(*,*) Q
C~~~~~
        FSL=FSL+Q
        DO 25 I=1,N1
        ETLDV(ITLD,I)=EV(I)
        UTLDV(ITLD,I)=UV(I)
25      CONTINUE
C
        IF (ETAMAXV(ITLD).LT.EV(1)) ETAMAXV(ITLD)=EV(1)

```

```

        IF (ETAMINV(ITLD).GT.EV(1)) ETAMINV(ITLD)=EV(1)
C
30      CONTINUE
C
C~~~~~
C      IF ((IOUT.EQ.1).AND.(NCYCLE.GE.(NOUT+21-2)))
C      &      WRITE(*,*) FSL
C~~~~~
C
C      IF (XMAX.LT.X) XMAX=X
C      IF (XMIN.GT.X) XMIN=X
C
C      TAU=T/TD
C      T=T+DT
C
C      IF (IOUT.EQ.0) GOTO 110
C
C      JCONT=JCONT+1
C      TAUV(JCONT)=TAU
C      ETAV(JCONT)=EV(1)*CH1
C      FSLV(JCONT)=FSL*SM*CR/(T0*T0)
C      XV(JCONT)=X*CR
110    CONTINUE
C
IF (NCYCLE.EQ.NTFMAX) THEN
  IOUT=1
  NOUT=NCYCLE
  ENDIF
IF (IOUT.EQ.1) GOTO 120
  IF ((NCYCLE.GE.(NTFMIN-NDTF)).AND.(NCYCLE.LT.NTFMIN)) THEN
    XAMP=(XMAX-XMIN)/2.0
    XV(NCYCLE+NDTF-NTFMIN+1)=XAMP
  ENDIF
C
IF (NCYCLE.GE.NTFMIN) THEN
  DO 33 I=1,NDTF-1
    XVV(I)=XVV(I+1)
33    CONTINUE
  XAMP=(XMAX-XMIN)/2.0
  XVV(NDTF)=XAMP
C
  XVVMAX=XVV(1)
  XVVMIN=XVV(1)
  DO 35 I=1,NDTF-1
    IF (XVVMAX.LT.XVV(I)) XVVMAX=XVV(I+1)
    IF (XVVMIN.GT.XVV(I)) XVVMIN=XVV(I+1)
35    CONTINUE
C
  XERROR=DABS((XVVMAX-XVVMIN)/XVVMIN)
  IF (XERROR.LE.XERROR0) THEN
    IOUT=1
    NOUT=NCYCLE
    ENDIF
  ENDIF
C
120  DO 40 ITLD=1,NTLD
    CH1=CHV(ITLD)
    W0=DSQRT(3.1415*981.0/(2*CR)*DTANH(3.1415*CH1/(2*CR)))
    XAMP=0.5*(XMAX-XMIN)
    ETAAMPV(ITLD)=ETAMAXV(ITLD)-ETAMINV(ITLD)
    IF (ETAAMPV(ITLD).GT.1.0) IBREAKV(ITLD)=1
      IF (IBREAKV(ITLD).EQ.1) THEN
        CDAV(ITLD)=0.57*DSQRT((CH1/CR)*CH1*W0*XAMP*CR/CNU)

```

```

        CFRV(ITLD)=1.05
        ENDIF
40    CONTINUE
C
        IF (IOUT.EQ.0) GOTO 100
        IF (NCYCLE.LT.(NOUT+21)) GOTO 100
C
        CALL FREQRESP
500   CONTINUE
C
C       CLOSE(10)
C
C~~~~~-
C       WRITE(*,*) NOUT
C~~~~~-
C
        STOP
        END
C
C       *****SUBROUTINE INPUT*****
SUBROUTINE INPUT
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION ROMEHAV(1:200),CHV(1:30)
CHARACTER CHAT
COMMON/CWORK/N1,T,TAU
COMMON/CWORK1/N,CR,CHO,CB,CNU,
& CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P,NTLD,DCH,CH1,EBETA
COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR,TALF
COMMON/INP/ROMEHAV,NF,CHV
C
C       OPEN(15,FILE='INP')
READ(15,*) CHAT
READ(15,*) CHAT, SM
READ(15,*) CHAT, SF
READ(15,*) CHAT, SD
READ(15,*) CHAT, SA
READ(15,*) CHAT, CR
READ(15,*) CHAT, CB
READ(15,*) CHAT, CHO
READ(15,*) CHAT, CNU
READ(15,*) CHAT, CMU
READ(15,*) CHAT, EBETA
READ(15,*) CHAT, NTLD
C
        READ(15,*) CHAT, DCH
        DO 50 I=1,NTLD
          READ(15,*) CHAT, CHV(I)
50    CONTINUE
        READ(15,*) CHAT
        READ(15,*) CHAT, NF
        DO 100 I=1,NF
          READ(15,*) CHAT, ROMEHAV(I)
100   CONTINUE
C
        CLOSE(15)
C
        SK=(2.0*3.1415926*SF)*(2.0*3.1415926*SF)*SM
        SC=2.0*SM*(2.0*3.1415926*SF)*SD/(2.0*3.1415926)
        P=2.0*SD/(2.0*3.1415926)*SK*SA
C
        RETURN
        END
C
C       *****SUBROUTINE WORK*****
C
FUNCTION: INPUT: N,T,DT,ETAn,Un
           OUTPUT: ETAn+1, Un+1, T=T+DT

```

```

C
C-----NOTE:
C          DT      time step
C          S2      (Sqrt. of 2)/2
C          TAU     exciting wave number
C <PARAMETER OF RUNGE-KUTTA-GILL>
C          F      =dETA/dT
C          G      =dU/dT
C          RK1...RK4 parameter
C          RL1...RL4 parameter
C
C-----SUBROUTINE WORK(ETA,U,Z,Q,CMU1)
C IMPLICIT REAL*8(A-H,O-Z)
C DIMENSION ETA(1), U(1)
C DIMENSION TETA(1:50), TU(1:50)
C DIMENSION F1(1:50), G1(1:50)
C DIMENSION F2(1:50), G2(1:50)
C DIMENSION F3(1:50), G3(1:50)
C DIMENSION F4(1:50), G4(1:50)
C COMMON/CWORK/N1,T,TAU
C COMMON/CWORK1/N,CR,CHO,CB,CNU,
&   CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P,NTLD,DCH,CH1,EBETA
C COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR,TALF
C
C          DO 10 I=1,N1
C              TETA(I)=ETA(I)
C              TU(I)=U(I)
10        CONTINUE
C          CALL WORK1(TT,ETA,U,F1,G1,Z)
C
C          TT=T+0.5*DT
C          DO 20 I=1,N1
C              ETA(I)=TETA(I)+.5*DT*F1(I)
C              U(I)=TU(I)+.5*DT*G1(I)
20        CALL WORK1(TT,ETA,U,F2,G2,Z)
C
C          S2=0.5*SQRT(2.)
C          DO 30 I=1,N1
C              ETA(I)=TETA(I)+(S2-.5)*DT*F1(I)+(1.-S2)*DT*F2(I)
C              U(I)=TU(I)+(S2-.5)*DT*G1(I)+(1.-S2)*DT*G2(I)
30        CALL WORK1(TT,ETA,U,F3,G3,Z)
C
C          TT=T+0.5*DT
C          DO 40 I=1,N1
C              ETA(I)=TETA(I)-S2*DT*F2(I)+(1.+S2)*DT*F3(I)
C              U(I)=TU(I)-S2*DT*G2(I)+(1.+S2)*DT*G3(I)
40        CALL WORK1(TT,ETA,U,F4,G4,Z)
C
C          DO 50 I=1,N1
C              ETA(I)=TETA(I)+DT*(F1(I)+2.*(1.-S2)*F2(I)
C              *           +2.*(1.+S2)*F3(I)+F4(I))/6.
C              U(I)=TU(I)+DT*(G1(I)+2.*(1.-S2)*G2(I)
C              *           +2.*(1.+S2)*G3(I)+G4(I))/6.
50
C          Q=0.25*CMU1*(ETA(N1)-ETA(1))*(ETA(N1)+ETA(1)+2.)
C
C          RETURN
C          END
C *****SUBROUTINE WORK1*****
C FUNCTION: INPUT: T,ETA(I),U(I)
C           OUTPUT: F(I),G(I)
C-----
```

```

C      NOTE:
C      A      amplitude of excitor displacement
C      CI(I) coefficient/ I
C      CK(I) coefficient/ K
C      CK1   coefficient/ K1=PI/2
C      CLAMBDA coefficient/ greek letter LAMBDA
C      DELTA  wave height/R
C      ETA(I) wave sorface profile/ greek letter ETA
C      F(I)   =dETA/dT
C      G(I)   =dU/dT
C      H(I)   coefficient/ H
C      N      number of control volume
C      OMEGA  exciting freqency
C      PHI(I) coefficient/ greek letter PHI
C      SIGMA  =tanh(k1*delta)/(k1*delta)
C      T      time
C      U(I)   velocity of liquid particle along X-direction
C
SUBROUTINE WORK1(T,ETA,U,F,G,Z)
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION ETA(1), U(1), F(1), G(1)
DIMENSION PHI(1:50), H(1:50), CI(1:50), CK(1:50)
COMMON/CWORK1/N,CR,CH0,CB,CNU,
& CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P,NTLD,DCH,CH1,EBETA
COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR,TALF
C
C      N1=N+1
C      CALCULATION OF PHI(I), H(I) AND C
DO 110 I=2,N1
    PHI(I)=DTANH(CKDE*(1.0+0.5*(ETA(I-1)+ETA(I)))/TCKDE
110    H(I)=0.5*(1.0-PHI(I)*TCKDE*PHI(I)*TCKDE)
    C=SIGMA*DELTA*DELTA
C
C      CALCULATION OF I(I)
CI(1)=0.0
DO 120 I=2,N1-1
120    CI(I)=0.5*((ETA(I+1)-ETA(I-1))*0.25*N)**2
    CI(N1)=0.0
C
C      CALCULATION OF K(I)
CK(1)=0.0
DO 130 I=2,N1-1
130    CK(I)=(0.5*(U(I)+U(I+1)))**2
    CK(N1)=0.0
C
C      CALCULATION OF F(I)
JJ=2
F(1)=TALF*(-(CFR*CFR)*N*PHI(JJ)*U(JJ)*SIGMA)
DO 140 I=2,N1-1
140    F(I)=TALF*(.5*(CFR*CFR)*N*(PHI(I)*U(I)
& -PHI(I+1)*U(I+1))*SIGMA)
    F(N1)=TALF*((CFR*CFR)*N*PHI(N1)*U(N1)*SIGMA)
C
C      CALCULATION OF G(I)
DO 150 I=2,N1
    ETAA=0.5*(ETA(I-1)+ETA(I))
    CLAMBDA=EBETA*CDA*DSQRT(ROMEGA*OMEGAD/T0*CNU)/
    *(SQRT(2.0)*DELTA*DSQRT(981.0*CH1))
    CLAMBDAA=CLAMBDA*(1.0+2.0*CH1/CB+1.0)/(1.+ETAA)
150    G(I)=TALF*(.5*N*(ETA(I-1)-ETA(I)+H(I)*(CK(I-1)-CK(I))
& +C*PHI(I)*(CI(I-1)-CI(I))))
& -Z
& -CLAMBDAA*U(I))

```

```

C
C      RETURN
C      END
C      ****SUBROUTINE STRC*****
C      SUBROUTINE STRC(X, Y, Z, FSL)
C      IMPLICIT REAL*8 (A-H,O-Z)
C      COMMON/CWORK/N1,T,TAU
C      COMMON/CWORK1/N,CR,CH0,CB,CNU,
&      CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P,NTLD,DCH,CH1,EBETA
C      COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR,TALF
C
C      REAL K1, K2, K3, K4
C      REAL L1, L2, L3, L4
C
C      F(X, Y, FSL, T)=-SC*T0*Y/SM-SK*T0*T0*X/SM+FSL
*          +P*T0*T0/(SM*CR)*DSIN(OMEGAD*ROMEGA*T)
C
C      ROF2=SQRT(2.0)
100    FORMAT(1X,2F10.4)
      K1=Y
      L1=F(X, Y, FSL, T)
      K2=Y+0.5*DT*L1
      L2=F(X+0.5*DT*K1, Y+0.5*DT*L1, FSL, T+0.5*DT)
      K3=Y+0.5*(ROF2-1.0)*DT*L1+(1.0-0.5*ROF2)*DT*L2
      L3=F(X+0.5*(ROF2-1.0)*DT*K1+(1.0-0.5*ROF2)*DT*K2,
*          Y+0.5*(ROF2-1.0)*DT*L1+(1.0-0.5*ROF2)*DT*L2, FSL, T+0.5*DT)
      K4=Y-0.5*ROF2*DT*L2+(1.0+0.5*ROF2)*DT*L3
      L4=F(X-0.5*ROF2*DT*K2+(1.0+0.5*ROF2)*DT*K3,
*          Y-0.5*ROF2*DT*L2+(1.0+0.5*ROF2)*DT*L3, FSL, T+DT)
      X=X+DT/6.0*(K1+(2.0-ROF2)*K2+(2.0+ROF2)*K3+K4)
      Y=Y+DT/6.0*(L1+(2.0-ROF2)*L2+(2.0+ROF2)*L3+L4)
      Z=F(X, Y, FSL, T+DT)
      RETURN
      END
C
C      ****SUBROUTINE FREQRESP*****
C      SUBROUTINE FREQRESP
C      IMPLICIT REAL*8 (A-H,O-Z)
C      DIMENSION TAUV(1:1500), ETAV(1:1500), FSLV(1:1500), XV(1:1500)
C      COMMON/CWORK/N1,T,TAU
C      COMMON/CWORK1/N,CR,CH0,CB,CNU,
&      CMU,DELTA,CKDE,TCKDE,SIGMA,CLAMBDA,P,NTLD,DCH,CH1,EBETA
C      COMMON/CSTRC/SM,SK,SC,OMEGAD,TD,DT,T0,ROMEGA,CDA,CFR,TALF
C      COMMON/OGATA/TAUV,ETAV,FSLV,XV
C
C*****INITIALIZATION
      FB=0.0
      FS=0.0
      WB=0.0
      WS=0.0
      XB=0.0
      XS=0.0
C
C*****CALCULATING EF, FF, WF AND XF
      DO 10 I=1,20
      CALL MAXMIN(FSLV((I-1)*60+1),B,S)
      FB=FB+B
      FS=FS+S
      CALL MAXMIN(ETAV((I-1)*60+1),B,S)
      WB=WB+B
      WS=WS+S
      CALL MAXMIN(XV((I-1)*60+1),B,S)
      XB=XB+B

```

```

10      XS=XS+S
      CONTINUE
C
      FB=FB/20.0
      FS=FS/20.0
      WB=WB/20.0
      WS=WS/20.0
      XB=XB/20.0
      XS=XS/20.0
      XM=0.5*(XB-XS)
C
      EF=0.0
C
      DO 20 I=1,1200
      DD=XV(I+1)-XV(I)
      TTT=0.5*(TAUV(I)+TAUV(I+1))*TD
      FINPUT=P*SIN(OMEGAD*ROMEGA*TTT)
      EF=EF+DD*FINPUT
20      CONTINUE
      EF=EF/20.0
      WRITE(10,100) ROMEWA,WB,WS,XM,CDA
100     FORMAT(1X,5F10.6)
      RETURN
      END
C
C *****SUBROUTINE MAXMIN(T,B,S)
C *****IMPLICIT REAL*8 (A-H,O-Z)
C *****DIMENSION T(1)
N=60
B=T(1)
S=T(1)
DO 20 I=1,N-1
IF (B.LT.T(I+1)) THEN
B=T(I+1)
ENDIF
IF (S.GT.T(I+1)) THEN
S=T(I+1)
ENDIF
20      CONTINUE
      RETURN
      END

```

The List of Input File "INP"

'SM: struc. mass	:	1.00
'SF: struc. frequency	:	0.458
'SD: struc. damping (log. decrement)	:	0.02
'SA: struc. resonance amp. (cm) (w/oTLD)	:	0.1
'CR: TLD tank half length	:	29.5
'CB: TLD tank width	:	33.5
'CH0: standard liquid depth	:	3.0
'CNU: liquid viscosity	:	0.01
'CMU: mass ratio (TLD/struc.)	:	0.01
'EBETA: damping factor	:	1.0
'NTLD: # of TLD	:	5
'CHV: liquid depth for each TLD	:	2.71
'CHV: liquid depth for each TLD	:	2.85
'CHV: liquid depth for each TLD	:	3.00
'CHV: liquid depth for each TLD	:	3.16
'CHV: liquid depth for each TLD	:	3.32
'NF: number of sweep points	:	41
'ROMEGAV: sweep freq. ratio	:	0.900
'ROMEGAV: sweep freq. ratio	:	0.905
'ROMEGAV: sweep freq. ratio	:	0.910
'ROMEGAV: sweep freq. ratio	:	0.915
'ROMEGAV: sweep freq. ratio	:	0.920
'ROMEGAV: sweep freq. ratio	:	0.925
'ROMEGAV: sweep freq. ratio	:	0.930
'ROMEGAV: sweep freq. ratio	:	0.935
'ROMEGAV: sweep freq. ratio	:	0.940
'ROMEGAV: sweep freq. ratio	:	0.945
'ROMEGAV: sweep freq. ratio	:	0.950
'ROMEGAV: sweep freq. ratio	:	0.955
'ROMEGAV: sweep freq. ratio	:	0.960
'ROMEGAV: sweep freq. ratio	:	0.965
'ROMEGAV: sweep freq. ratio	:	0.970
'ROMEGAV: sweep freq. ratio	:	0.975
'ROMEGAV: sweep freq. ratio	:	0.980
'ROMEGAV: sweep freq. ratio	:	0.985
'ROMEGAV: sweep freq. ratio	:	0.990
'ROMEGAV: sweep freq. ratio	:	0.995
'ROMEGAV: sweep freq. ratio	:	1.000
'ROMEGAV: sweep freq. ratio	:	1.005
'ROMEGAV: sweep freq. ratio	:	1.010
'ROMEGAV: sweep freq. ratio	:	1.015
'ROMEGAV: sweep freq. ratio	:	1.020
'ROMEGAV: sweep freq. ratio	:	1.025
'ROMEGAV: sweep freq. ratio	:	1.030
'ROMEGAV: sweep freq. ratio	:	1.035
'ROMEGAV: sweep freq. ratio	:	1.040
'ROMEGAV: sweep freq. ratio	:	1.045
'ROMEGAV: sweep freq. ratio	:	1.050
'ROMEGAV: sweep freq. ratio	:	1.055
'ROMEGAV: sweep freq. ratio	:	1.060
'ROMEGAV: sweep freq. ratio	:	1.065
'ROMEGAV: sweep freq. ratio	:	1.070
'ROMEGAV: sweep freq. ratio	:	1.075
'ROMEGAV: sweep freq. ratio	:	1.080
'ROMEGAV: sweep freq. ratio	:	1.085
'ROMEGAV: sweep freq. ratio	:	1.090
'ROMEGAV: sweep freq. ratio	:	1.095
'ROMEGAV: sweep freq. ratio	:	1.100