N-BODY MODELING OF NONLINEAR, FREE SURFACE
LIQUID FLOW

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ABSTRACT

In this paper a new, n -body approach is developed for the modeling of liquid phenomena. Both long and short range forces are included. Computer examples of several prototype, nonlinear, free surface problems are described and discussed.

1. Introduction. Despite the development of modern mathematical and numerical methodology, fundamental problems in the flow of liquids still remain unsolved. Current mathematical models of turbulence seem to have little or no relationship to reality (1), while the full, three-dimensional Navier-Stokes equations continue to elude numerical approximation and analysis (2). For these reasons, we will explore in this paper a new numerical approach which uses quasi-molecular models and accounts for the natural forces inherent in all liquid phenomena. As recommended by von Neumann (3), the numbers of molecules in such models are scaled down drastically from their actual sizes, while the intramolecular parameters are correspondingly adjusted so as to approximate the correct hydrodynamical situation. The viability of this approach will be demonstrated by the consideration of several prototype, free surface, liquid flow problems (4).

2. Dynamical Equations. Let a 'liquid' consist of N particles

P_i , $i=1,2,3,\dots,N$. For each i , let m_i be the mass of P_i .

For a given $\Delta t > 0$, let $t_k = k \Delta t$, $k=0, 1, 2, \dots$

Assume that, at t_k , each P_i is located at $\vec{r}_{i,k}$, has velocity $\vec{v}_{i,k}$, and has acceleration $\vec{a}_{i,k}$. For computational

economy only, attention in the present paper will be

restricted to two dimensions, so that $\vec{r}_{i,k} = (x_{i,k}, y_{i,k})$,

$\vec{v}_{i,k} = (v_{i,k,x}, v_{i,k,y})$, $\vec{a}_{i,k} = (a_{i,k,x}, a_{i,k,y})$. Let

position, velocity and acceleration be related by the

'leap frog' formulas ((5), p. 107):

$$(2.1) \quad \vec{v}_{i,\frac{1}{2}} = \vec{v}_{i,0} + \frac{1}{2} (\Delta t) \vec{a}_{i,0}$$

$$(2.2) \quad \vec{v}_{i,k+\frac{1}{2}} = \vec{v}_{i,k-\frac{1}{2}} + (\Delta t) \vec{a}_{i,k}, \quad k=1,2,3,\dots$$

$$(2.3) \quad \vec{r}_{i,k+1} = \vec{r}_{i,k} + (\Delta t) \vec{v}_{i,k+\frac{1}{2}}, \quad k=0,1,2,\dots$$

Of course, vector equations (2.1)-(2.3) are dimension independent.

If $\vec{F}_{i,k}$ is the force acting on P_i at t_k , where

$\vec{F}_{i,k} = (F_{i,k,x}, F_{i,k,y})$, then we assume force and acceleration are related dynamically by

$$(2.4) \quad \vec{F}_{i,k} = m_i \vec{a}_{i,k}.$$

Once an exact structure is given to $\vec{F}_{i,k}$, the motion of each particle will be determined recursively and explicitly

by (2.1)-(2.4) from prescribed initial data. The special structure to be used is described as follows.

At time t_k , let $r_{ij,k}$ be the distance between P_i and P_j . Let G (coefficient of attraction), H (coefficient of repulsion), a (exponent of attraction) and b (exponent of repulsion) be constants subject to the classical molecular constraints (6): $G \geq 0$, $H \geq 0$, $b > a \geq 2$. For fixed $r_0 > 0$, the local force $(\bar{F}_{i,k,x}, \bar{F}_{i,k,y})$ exerted on P_i by P_j is given by $\bar{F}_{i,k,x} = \bar{F}_{i,k,y} = 0$ when $r_{ij,k} \geq r_0$, while for $r_{ij,k} < r_0$:

$$(2.5) \quad \bar{F}_{i,k,x} = m_i m_j \left(\frac{H}{(r_{ij,k})^b} - \frac{G}{(r_{ij,k})^a} \right) \frac{x_{i,k} - x_{j,k}}{r_{ij,k}}$$

$$(2.6) \quad \bar{F}_{i,k,y} = m_i m_j \left(\frac{H}{(r_{ij,k})^b} - \frac{G}{(r_{ij,k})^a} \right) \frac{y_{i,k} - y_{j,k}}{r_{ij,k}}$$

The total local force $(F_{i,k,x}^*, F_{i,k,y}^*)$ on P_i due to all other $N-1$ particles is given by

$$(2.7) \quad F_{i,k,x}^* = \sum_{\substack{j=1 \\ j \neq i}}^N \bar{F}_{i,k,x} ; F_{i,k,y}^* = \sum_{\substack{j=1 \\ j \neq i}}^N \bar{F}_{i,k,y}$$

Finally, we include gravity into the model and have

$$(2.8) \quad F_{i,k,x} = F_{i,k,x}^* ; F_{i,k,y} = F_{i,k,y}^* - 980 m_i$$

The general mathematical formulation is now complete. We will, then, next apply it to the solution of several fundamental problems which are of broad general interest

in the description and analysis of liquid flow. The FORTRAN program used is available in Appendix A of Greenspan (7). The time step was always taken to be $\Delta t = 10^{-4}$ and all calculations were executed on the University of Texas IBM 370-155 at Arlington. The parameter δ , to be introduced in the next sections, is a velocity damping factor utilized in particle reflection from container walls and depends, physically, only on the nature of the walls (8)-(10).

3. Flow of a Liquid under Compression. Let us consider first a liquid which has been compressed within a square container and is then allowed to flow out. As shown in Figure 3.1, the liquid is contained within the closed square cavity ABCD, whose side has length 2 units. The wall BC is removed and the liquid is allowed to flow out to the right. As an additional complexity, a step of height 0.3 on $3.5 \leq x \leq 6.0$ is placed in the path of the flow.

We proceed by utilizing the particular cavity liquid generated in Greenspan (8). For this fluid, $N=100$, $G=0$, $H=100$, $b=3$, $m=1$, $\delta=0.1$, $r_0=0.25$. However, the choice $\delta=0.1$ was simply a convenience to speed up the settling process of the liquid, and, since it has settled, we proceed by using $\delta=0.9$. The particle arrangement at t_0 is that shown in Figure 3.1 and, for the convenience of the interested reader, the precise initial data, both positions and velocities, are given in Appendix B of Greenspan (7).

Figure 3.1

The flow after the removal of wall BC is shown in Figures 3.2 - 3.7 at the respective times t_{400} , t_{600} , t_{800} , t_{1000} , t_{1200} , t_{3000} . At t_{400} the compressed liquid has burst out of the container. By t_{600} , it has reached the step and, at t_{800} , it has formed a wave which moves over the step and then breaks into a spray action, which is shown at t_{1000} and t_{1200} .

Through t_{3000} , the motion is chaotic with small wave motions and sloshing. By the time t_{3000} , Figure 3.7 reveals that the fluid is beginning to settle toward a steady state, with the step area now under the liquid completely.

It is now revealing to examine the motion in Figure 3.6, at t_{1000} , in greater detail. Figure 3.8 shows the velocity field of the particles as they near and pass over the step. Figure 3.9 then reveals quite clearly that if one constructs the velocity field relative to the motion of P_{97} , then a counterclockwise vortex must be present at the step, even though all the particles are in motion to the right.

For the example described above, the computer time through t_{3000} was 40 minutes.

A variety of other examples were also run through the time t_{3000} , with similar results. The parameter δ was varied and yielded natural changes of fluid motion due to increasing

Fig. 3.2
 t_{400}

Fig. 3.3
 t_{600}

Fig. 3.4
 t_{800}

Fig. 3.5
 t_{1000}

Fig. 3.6
 t_{1200}

viscosity. The value $\delta = 0.1$, in fact, left the left wall completely wet as the fluid flowed, and was considered to be too small a parameter choice for realistic motion, that is, $\delta = 0.1$ actually resulted in liquid particles always sticking to the walls, even when gravity should have made them fall.

Modifications in which not all of wall BC, but only a portion above B, was removed did not reveal anything which was both new and significant.

4. Liquid Drop Motion. In the next example, we will consider the motion which results from the fall of a liquid drop into a stable liquid well (or cavity, or reservoir). We will allow the drop to be of a different density than that of the liquid in the well and also allow for the possibility of flow out of the well. On a large scale, the problem is analogous to the breakwater problem (4).

For variety, let us consider in the well a liquid which is different from the one used in Section 3 and which was generated originally in Greenspan, Cranmer, and Collier (9). It consists of 190 particles, each of unit mass, and they are shown at t_0 in Figure 4.1. The liquid drop consists of 15 particles, each of mass $m = 2$, and these are represented by the shaded particles in Figure 4.1. At t_0 , the initial drop configuration assumes that the drop has already hit the surface and has flattened. The force parameters are $H = G = 100$, $b = 3$, $a = 1$, while $N = 205$, and we again set $\delta = 0.9$, $r_0 = 0.25$. All initial data are available precisely in Appendix C of Greenspan (7). However, it should be noted that all drop particles were given the relatively large initial velocities $\vec{v}_0 = (0, -50)$ in order to generate interesting consequences.

Figures 4.2-4.10 show the resulting dynamical behavior. Figures 4.2 and 4.3, at t_{200} and t_{400} , respectively, show the entry and initial dispersion of the drop into the well. Figure 4.4 shows clearly the wave reaction of the well liquid. Figure 4.5,

Fig. 4.1
 t_0 Fig. 4.2
 t_{200}

Fig. 4.3

 t_{400}

Fig. 4.4

 t_{600}

Fig. 4.5
 t_{800} Fig. 4.6
 t_{1000}

Fig. 4.7
 t_{1200} Fig. 4.8
 t_{1400}

Fig. 4.9

 t_{1600}

Fig. 4.10

 t_{1800}

Fig. 4.11

 t_0

Fig. 4.12

 t_{400}

Fig. 4.13

 t_{800}

Fig. 4.14

 t_{1600}

at t_{800} , shows two developing reactions within the well, one of which is a backflow over the sinking drop, the second of which is a wave flow over the right-hand wall. These actions continue in Figures 4.6 - 4.10, which show, in addition, a distinct decrease in the drop's vertical velocity as it descends towards the bottom.

Figures 4.11 - 4.14 elucidate the motion of the liquid in the well by illustrating the deformation with time of various liquid columns. The accordian type deformation directly below the drop suggests vortex circulation, while the column motion to the right of the drop indicates that particles on the tops of columns tend to flow over the right barrier while those below tend to flow over the submerging drop.

The computer time for the above example through t_{1800} was 100 minutes.

A large variety of similar examples was also run and the results can be summarized as follows. The use of a square drop, as in (4), yielded results analogous to those described above, as did the use of a rectangular drop. However, in all cases, if the mass of each drop was the same as each particle in the well, and if the initial velocity of each particle was taken to be $\vec{0}$, then the drop merely flowed to the right on top of the liquid in the well. The motion was entirely analogous to that of a wave rolling on top of a liquid base. Also, increasing the mass of each drop particle up to $m = 10$ led to motion which seemed

to be physically excessive. Thus, though larger masses for drop particles can be introduced, the computer results indicated that a change to smaller Δt would probably yield results which were more accurate physically when $m > 5.0$.

5. Explosion Waves in a Sloped Basin. Finally, let us consider still another source of wave generation and utilize a third liquid which is different from both the ones employed in Sections 3 and 4. We will consider 226 particles, each of unit mass, selected appropriately from the larger liquid generated by Hougum and Greenspan (10). These are shown in a sloped basin at time t_0 in Figure 5.1. The equation of the sloped side is

$$y = -(0.3421)x + 1.3 ,$$

which was determined by a fitting through convenient particles of the original, more extensive, particle set. Thirty additional particles, each of mass 3 units and represented by inverted triangles in Figure 4.1, are placed in a relatively flat position above the surface in such a fashion that strong repulsive forces dominate their initial local interaction. In this fashion, we will simulate the wave motion generated by an explosion near the fluid surface. The force parameters are $G = 25$, $H = 50$, $b = 4$, $a = 2$, while $N = 256$, and, again, we set $\bar{\delta} = 0.9$ and $r_0 = 0.25$. For the convenience of the interested reader, all initial data have been recorded precisely in Appendix D of Greenspan (7).

The resulting motion is shown in Figures 5.2-5.6 at the respective times t_{600} , t_{1800} , t_{3000} , t_{5400} , and t_{7800} . Figure 5.2

shows the explosion itself. In Figure 5.3, the descent of particles has set up a wave motion to the left, which continues as shown in Figure 5.4. The descent of the heavier particles and the flow of liquid up the inclined side of the basin are clearly evident in Figures 5.5 and 5.6. In Figure 5.6, the right-hand portion of the liquid has now returned to its original height and is in relative equilibrium, while the motion up the incline has reached its maximum height and is now easily discernible in the figure.

Since the present example has analogies with the motion of a wave on a beach, the particles in the range $-3 \leq x \leq 3$ were

plotted at times t_{2400} , t_{3200} , t_{4000} , t_{5000} and t_{7800} in Figures 5.7-5.11, respectively. Though the figures reveal the gross motion, qualitatively, the analysis is not particularly easy for several reasons. For example, there are not enough particles to yield adequate physical definition of the motion, while local force interactions are so varied in extent and magnitude that velocity field constructions are of little value in displaying the gross motion. Perhaps, though, a general idea of the nature of the motion can be realized as follows. In Figure 5.12 are shown seven 'columns' of particles. The motion of these connected sets is then shown at times t_{3200} and t_{4800} in Figures 5.13 and 5.14, respectively. In Figure 5.13, columns 1 and 2 show an expected bending of the forward section of a breaking wave, as does each of columns 3 and 5. Column 4 and the top of column 7 show vortex type motions. In Figure 5.14, column 1, the front section of the fluid in Figure 5.12, has now stretched out completely on the beach surface; column 2 is breaking in an expected fashion; the top particles of columns 3 and 5 are now over-riding the other particles in the forward fluid motion; and column 4, part of column 6, and part of column 7 show vortex type motions.

The computer running time for the above example through t_{7800} was 10 hours.

Other examples which were run included variations of

masses of the exploding particles and variations in their initial configurations. Increasing these masses to 3.5, 4, 4.5, and 5 increased the resulting motion, but the results were analogous, qualitatively, to those described above. Resetting them into a vertical column, rather than a horizontal one, and separating them sufficiently so as to avoid the initial explosive effect resulted in motion similar to that described in Section 4.

6. Remarks. The study of fluids, both liquids and gases, is of fundamental interest in science and technology. The present paper has attempted to develop a new, computer oriented, and viable method for modeling liquid behavior. The actual forces in action are included qualitatively into the modeling and the results, therefore, yield free surface, chaotic, and mixing motions in a natural way. The formulation extends directly to three dimensions and does not require the unnatural inclusion of artificial viscosity for stability, as is the case with many of the other types of modeling.

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APPENDIX A - FORTRAN PROGRAM

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      DIMENSION PMASS(100),XO(100),YO(100),VXO(100),VYO(100),X(100,2),
      1Y(100,2),VX(100,2),VY(100,2),ACX(100),ACY(100)
C VARIABLES XO, YO, ETC., HAVE BEEN PUNCHED CH, NOT ZERO.
C INITIALIZE ALL VARIABLES TO ZERO.
      DO 4 I=1,100
      PMASS(I)=0.
      XO(I)=0.
      YO(I)=0.
      VXO(I)=0.
      VYO(I)=0.
      X(I,1)=0.
      Y(I,1)=0.
      VX(I,1)=0.
      VY(I,1)=0.
      X(I,2)=0.
      Y(I,2)=0.
      VX(I,2)=0.
      VY(I,2)=0.
      ACX(I)=0.
      ACY(I)=0.
4      CONTINUE
C NM1=N-1
      NM1=99
      K=1
      KPRINT =200
      DEL=.1
C INITIAL DATA INPUT
      READ 10, (PMASS(I),XO(I),YO(I),VXC(I),VYC(I),I=1,100)
10      FORMAT (5F10.4)
C PRINT INITIAL DATA
      DO 20 I=1,100
      PRINT 15,I,PMASS(I),XO(I),YO(I),VXC(I),VYC(I)
15      FORMAT (5X,I5,5F11.5)
20      CONTINUE
C UPDATE. X(I,1) IS X COORDINATE AT PREVIOUS TIME STEP. X(I,2) IS X
C COORDINATE AT PRESENT TIME STEP. SIMILARLY FOR OTHER VARIABLES.
      DO 30 I=1,100
      X(I,1)=XO(I)
      Y(I,1)=YO(I)
      VX(I,1)=VXC(I)
      VY(I,1)=VYC(I)
30      CONTINUE
      GO TO 71
65      DO 70 I=1,100
C THIS RESETS THE INITIAL DATA.
      X(I,1)=X(I,2)
      Y(I,1)=Y(I,2)
      VX(I,1)=VX(I,2)
      VY(I,1)=VY(I,2)

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70      CONTINUE
C CALCULATION OF ACCELERATIONS IS DONE THROUGH STEP 770
      DO 701 I=1,100
        ACX(I)=0.
        ACY(I)=0.
701      CONTINUE
71      DO 77 I=1,99
        IP1=I+1
        DO 76 J=IP1,100
          R=SQRT((X(I,1)-X(J,1))**2+(Y(I,1)-Y(J,1))**2)
          IF (R.GT.0.25) GO TO 73
          FX=100.*PMASS(I)*PMASS(J)*(X(I,1)-X(J,1))/R**4
          FY=100.*PMASS(I)*PMASS(J)*(Y(I,1)-Y(J,1))/R**4
          GO TO 75
73      FX=0.
          FY=0.
C ACCUMULATION OF FORCES ON PARTICLE I DUE TO ALL OTHER PARTICLES IS
C IN THE NEXT FOUR FORMULAS
75      ACX(I)=ACX(I)+FX
          ACX(J)=ACX(J)-FX
          ACY(I)=ACY(I)+FY
          ACY(J)=ACY(J)-FY
76      CONTINUE
77      CONTINUE
C NOTE THAT WE HAVE JUST ACCUMULATED FORCES, NOT ACCELERATIONS - THE
C NOTATION, THOUGH MISLEADING, ENABLES US TO SAVE MEMORY LOCATIONS.
C NOW CALCULATE ACCELERATIONS AND MOVE ONLY THE LIQUID PARTICLES.
      DO 770 I=1,100
        ACX(I)=ACX(I)/PMASS(I)
        ACY(I)=(ACY(I)/PMASS(I))-980.
770      CONTINUE
79      DO 80 I=1,100
        VX(I,2)=VX(I,1)+0.0001*ACX(I)
        VY(I,2)=VY(I,1)+0.0001*ACY(I)
        X(I,2)=X(I,1)+0.0001*VX(I,2)
        Y(I,2)=Y(I,1)+0.0001*VY(I,2)
80      CONTINUE
C WE NOW REFLECT OFF THE WALLS
      DO 8009 I=1,100
        IF (X(I,2).GT.-1.0) GO TO 8001
        X(I,2)=-2.0-X(I,2)
        VX(I,2)=-DEL*VX(I,2)
        VY(I,2)=DEL*VY(I,2)
8001      IF (X(I,2).LT.6.0) GO TO 8002
        X(I,2)=12.0-X(I,2)
        VX(I,2)=-DEL*VX(I,2)
        VY(I,2)=DEL*VY(I,2)
8002      IF (Y(I,2).GT.0.0) GO TO 8003
        Y(I,2)=-Y(I,2)
        VX(I,2)=DEL*VX(I,2)
        VY(I,2)=-DEL*VY(I,2)
8003      IF (Y(I,2).LT.2.0) GO TO 8004
        Y(I,2)=4.0-Y(I,2)

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VX(I,2)=DEL*VX(I,2)
VY(I,2)=-DEL*VY(I,2)
8004  IF (X(I,2).LT.3.5) GO TO 8009
      IF (Y(I,2).GT.0.3) GO TO 8009
      YBAR=-X(I,2)+3.8
      IF (Y(I,2).LT.YBAR) GO TO 8007
      Y(I,2)=0.6-Y(I,2)
      VX(I,2)=DEL*VX(I,2)
      VY(I,2)=-DEL*VY(I,2)
      GO TO 8009
8007  X(I,2)=7.0-X(I,2)
      VX(I,2)=-DEL*VX(I,2)
      VY(I,2)=DEL*VY(I,2)
8009  CONTINUE
      K=K+1
C PRINT ONLY EVERY KPRINT STEPS
      IF (MOD(K,KPRINT).GT.0) GO TO 82
      DO 810 I=1,100
      PRINT 81,K,I,X(I,2),Y(I,2),VX(I,2),VY(I,2)
81    FORMAT (5X,2I5,4F20.10)
810   CCNTINUE
C TERMINATION AFTER A FIXED NUMBER OF STEPS
82    IF (K.LT.3000) GO TO 65
C PUNCH OUTPUT FOR RESTART
      PUNCH 10, (PMASS(I),X(I,2),Y(I,2),VX(I,2),VY(I,2),I=1,100)
      STOP
      END

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APPENDIX C - LIQUID DROP DATA - PARTICLE NUMBER, MASS, AND INITIAL X, Y, VX, VY

1	1.00000	0.0	2.31000	0.42000	-0.90000
2	1.00000	0.0	1.98000	0.20000	-0.60000
3	1.00000	0.0	1.73000	0.0	-0.80000
4	1.00000	0.0	1.48000	0.0	-0.30000
5	1.00000	0.0	1.23000	0.10000	-0.60000
6	1.00000	0.0	0.98000	0.0	0.44000
7	1.00000	0.0	0.73000	-0.80000	-0.80000
8	1.00000	0.0	0.49000	0.0	0.0
9	1.00000	0.0	0.24000	0.0	0.0
10	1.00000	0.0	0.0	0.0	0.0
11	1.00000	0.19000	0.0	0.0	0.13000
12	1.00000	0.21000	2.11000	4.10000	-6.90000
13	1.00000	0.24000	0.19000	-1.42000	3.23000
14	1.00000	0.23000	0.38000	4.50000	4.30000
15	1.00000	0.22000	0.62000	-3.00000	4.00000
16	1.00000	0.22000	0.86000	-4.00000	4.10000
17	1.00000	0.22000	1.10000	0.60000	2.70000
18	1.00000	0.23000	1.35000	1.60000	-1.00000
19	1.00000	0.22000	1.60000	2.20000	0.20000
20	1.00000	0.22000	1.85000	-1.50000	-0.30000
21	1.00000	0.41000	0.0	0.0	0.20000
22	1.00000	0.46000	0.24000	-2.30000	6.70000
23	1.00000	0.44000	0.49000	2.10000	0.78000
24	1.00000	0.45000	0.73000	6.10000	0.75000
25	1.00000	0.44000	0.96000	0.76000	3.40000
26	1.00000	0.44000	1.23000	-2.40000	-6.10000
27	1.00000	0.44400	1.48000	2.10000	-2.40000
28	1.00000	0.44400	1.73000	0.30000	2.00000
29	1.00000	0.44000	1.98000	3.30000	-0.30000
30	1.00000	0.43200	2.24000	0.36000	-0.60000
31	1.00000	0.60500	0.0	0.0	-0.80000
32	1.00000	0.70000	0.19000	-4.30000	-2.30000
33	1.00000	0.67000	0.39000	1.60000	-1.70000
34	1.00000	0.67000	0.61000	-3.40000	1.90000
35	1.00000	0.66000	0.86000	4.76000	-1.90000
36	1.00000	0.66000	1.10000	1.20000	1.20000
37	1.00000	0.67000	1.36000	1.30000	-1.00000
38	1.00000	0.66000	1.61000	-0.66000	-2.00000
39	1.00000	0.67000	1.87000	1.70000	-6.80000
40	1.00000	0.67000	2.11000	4.30000	-1.00000
41	1.00000	0.84000	0.0	0.0	0.0
42	1.00000	0.92000	0.24000	-3.00000	2.20000
43	1.00000	0.90000	0.49000	1.90000	0.20000
44	1.00000	0.88000	0.73000	3.10000	4.00000
45	1.00000	0.88000	0.98000	-3.00000	-1.20000
46	1.00000	0.88000	1.22000	0.90000	-3.00000
47	1.00000	0.89000	1.47000	4.60000	1.20000
48	1.00000	0.88000	1.70000	2.70000	0.28000
49	1.00000	0.89000	1.98000	4.70000	-3.20000
50	1.00000	0.85000	2.29000	-0.80000	-2.00000
51	1.00000	1.04000	0.0	0.0	0.0
52	1.00000	1.16000	0.18000	4.00000	0.60000
53	1.00000	1.12000	0.38000	3.00000	-2.00000
54	1.00000	1.11000	0.61000	-5.50000	-1.60000
55	1.00000	1.11000	0.86000	-1.20000	-2.00000
56	1.00000	1.11000	1.11000	2.10000	1.00000
57	1.00000	1.11000	1.36000	4.60000	-3.40000
58	1.00000	1.11000	1.62000	-1.50000	-4.50000
59	1.00000	1.11000	1.87000	-2.80000	1.90000
60	1.00000	1.10000	2.14000	-2.50000	-5.00000

APPENDIX B - CAVITY INITIAL DATA X, Y, VX, VY

31

-1.000000	0.0	0.02000	0.03000
-1.000000	0.18000	0.09000	0.0
-1.000000	0.39000	0.12000	0.0
-1.000000	0.59000	0.07000	-0.03000
-1.000000	0.81000	0.05000	-0.29000
-1.000000	1.03000	0.12000	0.0
-1.000000	1.28000	0.07000	0.0
-1.000000	1.50000	-0.86000	-0.22000
-1.000000	1.75000	0.04000	0.03000
-1.000000	2.00000	-0.12000	-0.05000
-0.780000	0.0	0.03000	0.13000
-0.530000	0.0	0.01200	0.14000
-0.310000	0.0	-0.01000	0.12000
-0.090000	0.0	-0.13000	-0.59000
0.140000	0.0	0.0	0.12000
0.360000	0.0	0.0	-1.15000
0.600000	0.0	0.01000	0.08000
0.810000	0.0	0.0	0.12000
1.000000	0.0	-0.02000	0.02000
1.000000	0.19000	-0.06000	0.0
1.000000	0.38000	0.04000	0.0
1.000000	0.59000	-0.11000	0.01000
1.000000	0.82000	-0.04000	-0.05000
1.000000	1.05000	-0.05000	-0.04000
1.000000	1.28000	-0.05000	0.01000
1.000000	1.50000	-0.09000	0.02000
1.000000	1.75000	0.50000	-0.22000
1.000000	2.00000	-0.02000	0.0
-0.400000	0.21000	1.07000	-3.10000
-0.620000	0.15000	-0.07000	-1.33000
-0.780000	0.46000	-0.02000	0.86000
-0.770000	0.92000	0.55000	1.27000
-0.710000	1.35000	0.95000	-0.00000
-0.810000	1.58000	0.47000	-0.38000
-0.580000	1.56000	-4.22000	-1.48000
-0.700000	1.78000	-0.96000	0.26000
-0.790000	2.00000	0.0	-0.05000
-0.200000	0.22000	-0.62000	1.55000
-0.560000	0.36000	-0.60000	-0.05000
-0.800000	0.25000	-0.30000	1.83000
-0.800000	0.68000	-2.00000	-1.20000
-0.810000	1.16000	0.84000	0.35000
-0.350000	1.13000	-2.11000	0.91000
-0.600000	1.13000	0.51000	0.39000
-0.450000	1.78000	0.63000	0.18000
-0.560000	2.00000	-0.02000	-0.10000
-0.100000	0.43000	-1.46000	-0.25000
-0.600000	0.78000	-0.28000	-1.46000
-0.400000	0.70000	-1.80000	-1.66000
-0.480000	0.93000	0.44000	0.0
-0.460000	1.34000	2.60000	0.60000
-0.330000	1.55000	1.07000	-0.36000
-0.210000	1.77000	0.09000	-1.78000
0.130000	1.55000	-0.12000	-1.55000
-0.330000	2.00000	-0.89000	-1.62000
-0.340000	0.46000	-0.04000	-0.12000
0.020000	0.21000	1.72000	-1.34000
-0.180000	0.66000	1.60000	-0.80000
-0.240000	0.90000	0.98000	2.67000
-0.210000	1.33000	0.12000	0.10000

-0.10000	1.55000	-0.76000	-0.04000
0.14000	1.06000	-3.60000	0.43000
0.28000	1.35000	2.22000	0.51000
-0.10000	2.00000	-0.35000	-1.10000
0.39000	0.68000	-1.65000	1.77000
0.38000	0.42000	3.46000	-0.22000
0.14000	0.40000	-2.63000	0.72000
-0.56000	0.56000	-0.68000	1.43000
0.18000	0.82000	-0.06000	-2.68000
0.03000	1.32000	-0.25000	0.39000
0.34000	1.16000	0.0	-2.08000
0.01000	1.78000	0.41000	-0.98000
0.13000	2.00000	-0.18000	1.52000
0.26000	0.21000	-1.43000	0.48000
0.50000	0.20000	-0.20000	2.26000
-0.10000	1.11000	-0.56000	1.68000
-0.03000	0.87000	1.78000	2.81000
0.03000	0.63000	2.10000	-0.50000
0.57000	1.07000	-1.08000	-1.44000
0.60000	1.56000	-1.12000	0.36000
0.25000	1.78000	1.31000	-0.04000
0.36000	2.00000	-0.30000	1.42000
0.75000	0.20000	-0.83000	2.60000
0.78000	0.93000	-0.84000	0.19000
0.23000	0.58000	-0.87000	1.40000
0.78000	0.69000	0.05000	-1.17000
0.36000	0.93000	-2.12000	-0.62000
0.82000	1.60000	-0.80000	0.92000
0.58000	0.82000	-1.29000	1.26000
0.53000	1.31000	0.0	1.72000
0.52000	2.00000	0.01000	0.0
0.80000	0.44000	-1.66000	0.0
0.59000	0.57000	-0.68000	-0.27000
0.78000	1.16000	0.28000	0.12000
0.61000	0.37000	2.10000	-0.50000
0.77000	1.40000	-1.33000	1.00000
0.71000	1.80000	-0.80000	0.0
0.48000	1.78000	-0.30000	1.10000
0.38000	1.60000	-0.28000	0.65000
0.80000	2.00000	0.0	-0.10000

61	1.00000	1.29000	0.0	0.0	0.0
62	1.00000	1.38000	0.23000	-0.50000	-3.20000
63	1.00000	1.33000	0.49000	-2.40000	-2.00000
64	1.00000	1.33000	0.74000	6.10000	-5.00000
65	1.00000	1.33000	0.99000	3.70000	0.60000
66	1.00000	1.34000	1.24000	0.90000	2.50000
67	1.00000	1.34000	1.49000	2.00000	-4.00000
68	1.00000	1.34000	1.75000	-1.30000	-0.70000
69	1.00000	1.30000	2.00000	4.60000	2.80000
70	1.00000	1.35000	2.32000	5.30000	-6.00000
71	1.00000	1.55000	2.13000	-4.00000	0.20000
72	1.00000	1.50000	0.0	0.0	0.0
73	1.00000	1.61000	0.18000	-4.00000	4.90000
74	1.00000	1.57000	0.38000	-6.00000	0.40000
75	1.00000	1.55000	0.62000	-4.80000	2.40000
76	1.00000	1.55000	0.87000	-3.00000	5.00000
77	1.00000	1.55000	1.12000	-5.00000	0.50000
78	1.00000	1.56000	1.37000	-1.50000	1.90000
79	1.00000	1.55000	1.62000	1.50000	-0.80000
80	1.00000	1.56000	1.87000	-0.50000	-5.00000
81	1.00000	1.76000	2.26000	-2.50000	2.60000
82	1.00000	1.75000	0.0	0.0	0.0
83	1.00000	1.81000	0.26000	-3.00000	-0.70000
84	1.00000	1.77000	0.50000	-2.00000	0.10000
85	1.00000	1.76000	0.75000	-3.00000	4.80000
86	1.00000	1.77000	1.00000	-2.60000	-0.40000
87	1.00000	1.78000	1.25000	3.80000	1.70000
88	1.00000	1.78000	1.50000	1.20000	0.43000
89	1.00000	1.78000	1.76000	9.00000	-5.00000
90	1.00000	1.77000	2.00000	-4.40000	-1.30000
91	1.00000	1.98000	0.0	0.0	0.12000
92	1.00000	2.04000	0.18000	0.30000	6.00000
93	1.00000	2.00000	0.39000	5.00000	0.0
94	1.00000	1.99000	0.64000	-4.50000	-0.30000
95	1.00000	1.99000	0.88000	-1.90000	0.86000
96	1.00000	2.01000	1.13000	-2.70000	2.70000
97	1.00000	1.98000	2.14000	4.00000	-4.00000
98	1.00000	1.99000	1.38000	0.0	-2.00000
99	1.00000	1.99000	1.63000	-5.60000	-4.00000
100	1.00000	1.99000	1.89000	-2.90000	-0.40000
101	1.00000	2.22000	2.00000	3.40000	-1.80000
102	1.00000	2.22000	0.0	0.0	0.0
103	1.00000	2.22000	0.29000	3.60000	0.40000
104	1.00000	2.20000	2.29000	0.50000	-3.50000
105	1.00000	2.20000	0.52000	-4.00000	-1.00000
106	1.00000	2.22000	0.76000	-6.00000	-7.00000
107	1.00000	2.22000	0.99000	5.00000	0.30000
108	1.00000	2.23000	1.24000	2.00000	-3.00000
109	1.00000	2.22000	1.49000	3.00000	0.10000
110	1.00000	2.23000	1.74000	7.25000	1.20000
111	1.00000	2.44000	2.15000	0.80000	2.30000
112	1.00000	2.67000	2.30000	-4.00000	3.30000
113	1.00000	2.47000	0.0	0.0	0.0
114	1.00000	2.40000	0.18000	3.10000	4.70000
115	1.00000	2.44000	0.41000	-5.50000	-3.00000
116	1.00000	2.44000	0.64000	-1.50000	6.90000
117	1.00000	2.44000	0.88000	6.60000	-2.70000
118	1.00000	2.45000	1.12000	2.60000	0.60000
119	1.00000	2.45000	1.37000	2.60000	-1.37000
120	1.00000	2.45000	1.63000	0.80000	3.50000
121	1.00000	2.44000	1.88000	6.20000	-0.20000

122	1.00000	2.66000	2.02000	-1.00000	-2.00000
123	1.00000	2.69000	0.0	-0.10000	-0.50000
124	1.00000	2.63000	0.26000	0.0	-1.10000
125	1.00000	2.67000	0.51000	1.60000	-2.40000
126	1.00000	2.66000	0.75000	5.30000	1.50000
127	1.00000	2.67000	0.99000	1.70000	2.50000
128	1.00000	2.67000	1.24000	0.0	-6.00000
129	1.00000	2.67000	1.49000	-1.80000	3.40000
130	1.00000	2.66000	1.76000	1.80000	-6.40000
131	1.00000	2.89000	2.12000	-7.00000	0.50000
132	1.00000	2.94000	0.0	0.0	0.0
133	1.00000	2.84000	0.19000	-1.00000	-1.50000
134	1.00000	2.87000	0.39000	2.10000	-5.00000
135	1.00000	2.89000	0.61000	0.90000	-5.00000
136	1.00000	2.89000	0.86000	4.51000	1.00000
137	1.00000	2.89000	1.12000	1.67000	5.60000
138	1.00000	2.89000	1.37000	-0.80000	3.30000
139	1.00000	2.89000	1.61000	1.00000	-2.00000
140	1.00000	2.89000	1.86000	-1.00000	-1.00000
141	1.00000	3.13000	2.25000	-5.00000	-1.00000
142	1.00000	3.15000	0.0	0.10000	-1.00000
143	1.00000	3.08000	0.24000	4.40000	-4.00000
144	1.00000	3.10000	0.50000	3.80000	-5.00000
145	1.00000	3.11000	0.74000	4.00000	0.10000
146	1.00000	3.11000	0.99000	0.95000	-3.00000
147	1.00000	3.12000	1.24000	0.30000	-2.00000
148	1.00000	3.11000	1.49000	-1.00000	-0.20000
149	1.00000	3.12000	1.74000	3.70000	1.90000
150	1.00000	3.12000	1.99000	-8.00000	-0.60000
151	1.00000	3.30000	0.18000	2.00000	1.40000
152	1.00000	3.32000	0.40000	0.0	3.00000
153	1.00000	3.33000	0.62000	0.70000	1.70000
154	1.00000	3.33000	0.86000	-7.00000	0.70000
155	1.00000	3.33000	1.11000	1.50000	1.00000
156	1.00000	3.34000	1.36000	6.60000	6.00000
157	1.00000	3.33000	1.61000	-1.60000	0.10000
158	1.00000	3.34000	1.86000	2.10000	-0.40000
159	1.00000	3.39000	0.0	0.0	0.0
160	1.00000	3.34000	2.12000	1.00000	-6.00000
161	1.00000	3.56000	1.98000	0.20000	-0.30000
162	1.00000	3.59000	0.0	0.0	0.0
163	1.00000	3.52000	0.25000	0.90000	2.70000
164	1.00000	3.55000	0.49000	5.00000	-7.00000
165	1.00000	3.55000	0.73000	1.60000	1.80000
166	1.00000	3.55000	0.98000	-1.30000	-2.40000
167	1.00000	3.56000	1.23000	0.10000	-1.00000
168	1.00000	3.56000	1.48000	0.0	-0.50000
169	1.00000	3.56000	1.73000	-2.40000	-2.00000
170	1.00000	3.77000	2.12000	-2.50000	1.60000
171	1.00000	3.57000	2.25000	3.00000	-1.40000
172	1.00000	3.81000	0.0	0.0	0.0
173	1.00000	3.76000	0.19000	0.0	-0.20000
174	1.00000	3.78000	0.38000	-4.00000	0.70000
175	1.00000	3.78000	0.61000	3.10000	-0.40000
176	1.00000	3.78000	0.86000	-2.00000	-4.00000
177	1.00000	3.78000	1.11000	3.80000	-5.00000
178	1.00000	3.78000	1.36000	1.70000	-2.70000
179	1.00000	3.78000	1.61000	-4.50000	-1.00000
180	1.00000	3.78000	1.86000	0.60000	0.90000
181	1.00000	3.99000	0.0	0.0	0.0
182	1.00000	4.00000	0.24000	0.0	0.0

183	1.00000	4.00000	0.49000	0.0	0.0
184	1.00000	3.99000	0.73000	0.0	0.0
185	1.00000	4.00000	0.98000	0.0	0.0
186	1.00000	4.00000	1.23000	0.0	0.0
187	1.00000	4.00000	1.48000	0.0	0.0
188	1.00000	4.00000	1.73000	0.0	0.0
189	1.00000	4.00000	1.98000	0.0	0.0
190	1.00000	4.00000	2.23000	0.0	0.0
191	2.00000	0.0	2.50000	0.0	-50.00000
192	2.00000	0.25000	2.50000	0.0	-50.00000
193	2.00000	0.50000	2.50000	0.0	-50.00000
194	2.00000	0.75000	2.50000	0.0	-50.00000
195	2.00000	1.00000	2.50000	0.0	-50.00000
196	2.00000	0.12500	2.70000	0.0	-50.00000
197	2.00000	0.37500	2.70000	0.0	-50.00000
198	2.00000	0.62500	2.70000	0.0	-50.00000
199	2.00000	0.87500	2.70000	0.0	-50.00000
200	2.00000	0.25000	2.90000	0.0	-50.00000
201	2.00000	0.50000	2.90000	0.0	-50.00000
202	2.00000	0.75000	2.90000	0.0	-50.00000
203	2.00000	0.37500	3.10000	0.0	-50.00000
204	2.00000	0.62500	3.10000	0.0	-50.00000
205	2.00000	0.50000	3.60000	0.0	-50.00000

APPENDIX D - EXPLOSION WAVE DATA - PARTICLE NUMBER, MASS INITIAL X, Y, VX, VY

1	1.000000	5.580000	0.0	0.776000	-0.960000
2	1.000000	6.850000	0.0	0.0	0.0
3	1.000000	8.873000	0.0	0.0	-0.150000
4	1.000000	7.863000	0.0	0.0	-0.080000
5	1.000000	6.087000	0.0	0.0	-1.800000
6	1.000000	8.115000	0.0	0.0	0.0
7	1.000000	10.000000	0.0	0.0	0.0
8	1.000000	7.354000	0.0	0.0	0.0
9	1.000000	7.610000	0.0	0.0	0.0
10	1.000000	8.621000	0.0	0.0	0.0
11	1.000000	8.369000	0.0	0.0	0.0
12	1.000000	9.374000	0.0	-0.100000	0.220000
13	1.000000	7.103000	0.0	0.0	0.100000
14	1.000000	5.323000	0.0	0.0	0.120000
15	1.000000	4.819000	0.0	0.0	0.120000
16	1.000000	6.339000	0.0	0.0	0.0
17	1.000000	5.831000	0.0	0.0	0.200000
18	1.000000	9.123000	0.0	-0.700000	-0.960000
19	1.000000	6.596000	0.0	0.0	-0.300000
20	1.000000	9.624000	0.0	0.0	0.200000
21	1.000000	5.072000	0.0	-1.100000	-0.200000
22	1.000000	4.331000	0.0	0.0	0.0
23	1.000000	4.564000	0.0	0.0	0.0
24	1.000000	4.053000	0.0	0.0	0.100000
25	1.000000	3.802000	0.0	0.0	0.0
26	1.000000	9.755000	0.210000	-2.800000	-2.100000
27	1.000000	5.959000	0.210000	-12.900000	3.500000
28	1.000000	4.693000	0.215000	1.600000	-3.300000
29	1.000000	8.240000	0.215000	1.800000	-1.300000
30	1.000000	9.500000	0.215000	2.600000	0.300000
31	1.000000	7.000000	0.215000	-1.000000	4.500000
32	1.000000	5.450000	0.216000	-3.100000	4.340000
33	1.000000	9.247000	0.216000	4.350000	-1.200000
34	1.000000	8.500000	0.217000	-1.300000	2.000000
35	1.000000	6.460000	0.217000	-0.780000	7.100000
36	1.000000	4.440000	0.218000	3.440000	-1.500000
37	1.000000	6.212000	0.218000	2.100000	10.500000
38	1.000000	8.000000	0.218000	-4.000000	-2.600000
39	1.000000	9.000000	0.218000	-0.620000	-0.650000
40	1.000000	5.200000	0.218000	2.260000	-5.700000
41	1.000000	3.940000	0.218000	3.350000	2.600000
42	1.000000	5.710000	0.219000	-0.900000	-0.100000
43	1.000000	7.500000	0.219000	-4.000000	-1.000000
44	1.000000	6.720000	0.219000	0.376000	3.230000
45	1.000000	4.180000	0.219000	-2.500000	-0.240000
46	1.000000	4.950000	0.220000	-5.600000	7.200000
47	1.000000	7.740000	0.221000	3.600000	-5.000000
48	1.000000	8.750000	0.226000	2.400000	0.120000
49	1.000000	7.230000	0.223000	3.500000	-0.850000
50	1.000000	10.000000	0.250000	-0.110000	0.0
51	1.000000	3.700000	0.220000	3.500000	7.200000
52	1.000000	3.420000	0.218000	10.600000	3.800000
53	1.000000	3.160000	0.220000	-5.100000	0.320000
54	1.000000	9.640000	0.425000	7.600000	-5.000000
55	1.000000	4.570000	0.431000	-0.500000	2.900000
56	1.000000	4.060000	0.432000	-0.270000	-8.500000
57	1.000000	3.300000	0.434000	-2.200000	-6.600000
58	1.000000	5.600000	0.434000	-2.900000	-7.800000
59	1.000000	4.820000	0.435000	3.100000	3.300000
60	1.000000	3.550000	0.436000	7.500000	-8.800000

122	1.00000	4.81000	0.87500	12.00000	0.20000
123	1.00000	5.60000	0.87500	5.00000	-3.00000
124	1.00000	5.32000	0.87600	-10.00000	-3.00000
125	1.00000	2.78000	0.88000	2.20000	-2.50000
126	1.00000	6.10000	0.88000	1.30000	-7.10000
127	1.00000	2.53000	0.88000	-3.00000	-2.50000
128	1.00000	3.30000	0.88200	-3.70000	1.30000
129	1.00000	9.14000	0.88400	4.20000	-8.00000
130	1.00000	7.37000	0.88000	-5.46000	-5.50000
131	1.00000	8.36000	0.88600	-0.80000	2.50000
132	1.00000	4.33000	0.88600	3.70000	3.60000
133	1.00000	5.80000	0.88700	0.23000	4.00000
134	1.00000	8.90000	0.88800	-1.50000	11.00000
135	1.00000	7.60000	0.89100	-3.30000	0.90000
136	1.00000	3.55000	0.89200	-0.70000	5.90000
137	1.00000	9.40000	0.89300	-0.60000	-3.40000
138	1.00000	7.87000	0.89400	-5.10000	1.40000
139	1.00000	7.11000	0.89500	2.00000	2.00000
140	1.00000	8.12000	0.90000	4.20000	1.60000
141	1.00000	4.06400	0.90400	-1.00000	10.00000
142	1.00000	3.03500	0.90500	4.10000	9.60000
143	1.00000	8.62000	0.90600	7.80000	6.80000
144	1.00000	3.81000	0.90900	-2.00000	-2.00000
145	1.00000	6.35000	0.91100	-0.70000	2.80000
146	1.00000	6.86000	0.91200	9.50000	12.00000
147	1.00000	2.00000	0.88600	5.20000	-4.00000
148	1.00000	1.76000	0.88900	-7.00000	3.10000
149	1.00000	1.51000	0.88200	2.00000	0.80000
150	1.00000	1.26000	0.88600	3.40000	-4.00000
151	1.00000	10.00000	1.00000	0.0	-0.50000
152	1.00000	5.20000	1.10000	-1.70000	-8.00000
153	1.00000	2.66000	1.09000	4.02000	-3.10000
154	1.00000	5.69000	1.09000	-7.00000	0.70000
155	1.00000	2.40000	1.10000	-5.00000	-5.00000
156	1.00000	4.69000	1.10000	0.0	-10.00000
157	1.00000	4.95000	1.10000	3.40000	5.90000
158	1.00000	1.63000	1.10000	0.0	-7.00000
159	1.00000	1.40000	1.10000	3.80000	0.30000
160	1.00000	9.30000	1.10000	4.50000	-8.70000
161	1.00000	9.00000	1.10000	4.30000	-10.00000
162	1.00000	6.70000	1.10000	0.0	6.70000
163	1.00000	8.00000	1.11000	6.80000	-3.60000
164	1.00000	9.54000	1.11000	0.40000	-3.00000
165	1.00000	2.16000	1.11000	2.50000	-5.00000
166	1.00000	6.20000	1.11000	4.00000	-0.90000
167	1.00000	3.16000	1.11000	-9.00000	-3.00000
168	1.00000	5.95000	1.11000	4.10000	-7.00000
169	1.00000	7.23000	1.11000	-3.00000	-6.00000
170	1.00000	1.90000	1.11000	2.00000	-0.90000
171	1.00000	3.67000	1.12000	4.00000	-1.00000
172	1.00000	8.50000	1.12000	0.0	-1.00000
173	1.00000	4.43300	1.11200	-6.00000	3.50000
174	1.00000	2.90000	1.12000	3.40000	-2.00000
175	1.00000	4.18000	1.12000	-11.00000	-1.00000
176	1.00000	9.79000	1.12000	-4.00000	-4.00000
177	1.00000	3.93000	1.13000	-3.00000	7.00000
178	1.00000	7.75000	1.14000	-6.60000	-5.00000
179	1.00000	3.41000	1.14000	1.00000	-0.30000
180	1.00000	7.50000	1.14000	-3.00000	0.40000
181	1.00000	8.75000	1.13000	4.00000	9.00000
182	1.00000	5.44000	1.15000	-9.00000	-7.00000

61	1.000000	6.600000	0.436000	-0.130000	4.200000
62	1.000000	5.330000	0.436000	6.300000	-0.800000
63	1.000000	5.840000	0.436000	-1.200000	-3.700000
64	1.000000	5.071000	0.436000	0.330000	2.800000
65	1.000000	8.370000	0.437000	-2.000000	-2.000000
66	1.000000	8.875000	0.438000	2.000000	-1.200000
67	1.000000	6.340000	0.438000	4.500000	0.210000
68	1.000000	9.129000	0.438000	3.400000	-1.600000
69	1.000000	9.390000	0.439000	-6.200000	0.660000
70	1.000000	6.850000	0.439000	-0.780000	5.100000
71	1.000000	6.090000	0.440000	-2.800000	8.700000
72	1.000000	3.800000	0.440000	-0.250000	0.0
73	1.000000	7.600000	0.440000	-7.200000	8.000000
74	1.000000	4.300000	0.440000	2.700000	0.950000
75	1.000000	7.860000	0.440000	2.000000	-5.000000
76	1.000000	7.100000	0.445000	9.340000	-6.800000
77	1.000000	8.630000	0.450000	8.400000	-0.900000
78	1.000000	8.100000	0.447000	-2.000000	8.000000
79	1.000000	7.360000	0.450000	-1.500000	-1.200000
80	1.000000	3.045000	0.440000	-10.100000	-7.900000
81	1.000000	2.800000	0.440000	4.160000	1.600000
82	1.000000	2.533000	0.439000	6.300000	4.900000
83	1.000000	10.000000	0.500000	-0.770000	-4.000000
84	1.000000	9.770000	0.638000	-4.700000	2.300000
85	1.000000	3.400000	0.648000	-7.200000	0.855000
86	1.000000	9.500000	0.649000	-4.800000	-6.600000
87	1.000000	4.700000	0.652000	2.270000	8.800000
88	1.000000	6.720000	0.653000	-7.600000	-1.800000
89	1.000000	5.200000	0.654000	-2.100000	-8.800000
90	1.000000	5.700000	0.655000	-1.300000	0.420000
91	1.000000	4.440000	0.655000	-11.000000	-5.100000
92	1.000000	2.660000	0.657000	3.900000	10.500000
93	1.000000	6.230000	0.657000	0.550000	-9.000000
94	1.000000	6.500000	0.657000	-9.000000	0.0
95	1.000000	4.900000	0.657000	1.500000	-10.600000
96	1.000000	5.450000	0.658000	-4.000000	7.500000
97	1.000000	8.750000	0.659000	8.300000	-3.800000
98	1.000000	9.000000	0.660000	-2.900000	6.600000
99	1.000000	3.170000	0.662000	-7.200000	-7.300000
100	1.000000	5.960000	0.662000	-3.000000	-7.500000
101	1.000000	6.980000	0.663000	7.100000	10.000000
102	1.000000	3.910000	0.663000	-5.000000	-4.600000
103	1.000000	8.250000	0.664000	-0.680000	4.000000
104	1.000000	3.666000	0.665000	2.000000	-1.200000
105	1.000000	7.750000	0.665000	5.700000	4.800000
106	1.000000	7.500000	0.667000	-3.900000	1.400000
107	1.000000	7.240000	0.669000	14.700000	-1.800000
108	1.000000	8.500000	0.671000	3.100000	6.700000
109	1.000000	9.270000	0.672000	-1.400000	2.600000
110	1.000000	8.000000	0.677000	-3.100000	-1.800000
111	1.000000	2.920000	0.678000	-7.000000	2.576000
112	1.000000	4.170000	0.679000	-15.000000	-2.000000
113	1.000000	2.400000	0.656000	-1.300000	0.320000
114	1.000000	2.150000	0.652000	-7.000000	4.000000
115	1.000000	1.900000	0.666000	-3.600000	2.500000
116	1.000000	10.000000	0.750000	0.0	1.700000
117	1.000000	5.080000	0.871000	-2.000000	0.870000
118	1.000000	4.570000	0.872000	0.940000	8.700000
119	1.000000	2.280000	0.873000	-0.600000	5.900000
120	1.000000	6.600000	0.875000	-1.700000	-4.600000
121	1.000000	9.680000	0.875000	-0.25570	-4.000000

183	1.000000	8.240000	1.150000	-3.000000	-12.000000
184	1.000000	6.450000	1.160000	2.330000	-4.000000
185	1.000000	7.000000	1.170000	5.000000	-1.000000
186	1.000000	1.120000	1.100000	-1.000000	-1.000000
187	1.000000	0.872000	1.090000	-4.500000	-3.800000
188	1.000000	0.623000	1.100000	3.400000	-1.300000
189	1.000000	10.000000	1.250000	0.960000	1.700000
190	1.000000	0.780000	1.340000	1.000000	2.500000
191	1.000000	1.770000	1.330000	6.500000	-4.000000
192	1.000000	1.520000	1.330000	1.500000	-9.000000
193	1.000000	5.260000	1.330000	1.600000	-1.600000
194	1.000000	9.150000	1.340000	-0.400000	2.200000
195	1.000000	1.260000	1.340000	3.000000	-1.000000
196	1.000000	4.880000	1.350000	0.500000	-17.150000
197	1.000000	3.550000	1.350000	-9.000000	1.000000
198	1.000000	3.270000	1.360000	3.000000	4.600000
199	1.000000	4.610000	1.360000	-3.000000	-8.000000
200	1.000000	2.440000	1.360000	4.000000	-4.000000
201	1.000000	3.810000	1.360000	-3.000000	4.000000
202	1.000000	8.880000	1.360000	-4.000000	3.000000
203	1.000000	7.200000	1.370000	-1.500000	-10.000000
204	1.000000	2.700000	1.370000	-9.000000	-1.000000
205	1.000000	2.030000	1.370000	-4.000000	-6.000000
206	1.000000	6.710000	1.380000	5.000000	-15.000000
207	1.000000	9.750000	1.380000	-0.800000	0.800000
208	1.000000	4.080000	1.380000	4.000000	0.000000
209	1.000000	6.170000	1.380000	-4.000000	0.000000
210	1.000000	0.530000	1.340000	0.300000	-0.100000
211	1.000000	0.0	1.300000	0.0	0.0
212	1.000000	0.250000	1.320000	-4.000000	-1.000000
213	1.000000	5.790000	1.380000	-3.000000	-3.000000
214	1.000000	7.990000	1.390000	-4.000000	-2.000000
215	1.000000	8.600000	1.400000	-4.000000	0.500000
216	1.000000	7.740000	1.400000	-2.100000	-0.600000
217	1.000000	4.360000	1.400000	3.200000	-1.600000
218	1.000000	8.250000	1.411000	-8.000000	-13.000000
219	1.000000	6.420000	1.410000	6.000000	1.600000
220	1.000000	9.470000	1.410000	4.000000	0.000000
221	1.000000	7.460000	1.420000	-8.000000	4.000000
222	1.000000	1.020000	1.420000	5.000000	-2.000000
223	1.000000	2.970000	1.430000	4.000000	0.000000
224	1.000000	5.480000	1.430000	5.000000	0.000000
225	1.000000	10.000000	1.500000	-0.100000	1.000000
226	1.000000	6.980000	1.510000	8.300000	-5.000000
227	3.000000	7.000000	1.900000	0.0	0.0
228	3.000000	9.750000	1.500000	0.0	0.0
229	3.000000	9.500000	1.500000	0.0	0.0
230	3.000000	9.250000	1.500000	0.0	0.0
231	3.000000	9.000000	1.500000	0.0	0.0
232	3.000000	8.750000	1.500000	0.0	0.0
233	3.000000	8.500000	1.500000	0.0	0.0
234	3.000000	8.250000	1.500000	0.0	0.0
235	3.000000	8.000000	1.500000	0.0	0.0
236	3.000000	7.750000	1.500000	0.0	0.0
237	3.000000	7.500000	1.500000	0.0	0.0
238	3.000000	7.250000	1.500000	0.0	0.0
239	3.000000	6.750000	1.500000	0.0	0.0
240	3.000000	6.500000	1.500000	0.0	0.0
241	3.000000	9.625000	1.700000	0.0	0.0
242	3.000000	9.375000	1.700000	0.0	0.0
243	3.000000	9.125000	1.700000	0.0	0.0

244	3.00000	8.87500	1.70000	0.0	0.0
245	3.00000	8.62500	1.70000	0.0	0.0
246	3.00000	8.37500	1.70000	0.0	0.0
247	3.00000	8.12500	1.70000	0.0	0.0
248	3.00000	7.87500	1.70000	0.0	0.0
249	3.00000	7.62500	1.70000	0.0	0.0
250	3.00000	7.37500	1.70000	0.0	0.0
251	3.00000	7.12500	1.70000	0.0	0.0
252	3.00000	6.87500	1.70000	0.0	0.0
253	3.00000	6.62500	1.70000	0.0	0.0
254	3.00000	6.37500	1.70000	0.0	0.0
255	3.00000	6.12500	1.70000	0.0	0.0
256	3.00000	5.87500	1.70000	0.0	0.0