

EXAMPLES OF 3D FREE-SURFACE PLOTS

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One of the unusual capabilities of FLOW-3D is its transient treatment of free surfaces and two-fluid interfaces in three dimensions. This capability is perhaps best demonstrated by the perspective plots of the interface generated by the FLOW-3D postprocessor, FLSCON. These plots provide a physical understanding of the free-surface behavior, complementing the more quantitative history and 2D slice plots also created by FLSCON.

FLSCON represents the interface by drawing (in three-dimensional perspective) the outline of each mesh cell containing the free surface. This outline is projected onto the surface location itself. The obstacles (and containers) that disrupt the flow are not represented on these plots at the current time, and hidden lines are not removed. These limitations are dictated by the desire for a fast algorithm that will provide a "quick look" at the surface. As the examples shown later will demonstrate, this algorithm usually provides a reasonable picture of the surface. Sometimes, however, the presentation is not very clear. This is particularly true when a coarse computational mesh is used or when the free surface is very contorted. We do recognize the need for more sophisticated free-surface depictions

(particularly for reports and presentations) and intend to implement such algorithms in the future.

Figure 1 shows a very simple free-surface plot. This plot shows a nearly horizontal plane surface in half a cylindrical container. You can plainly see the wedge-shape cell outlines at the free-surface level.

Figure 2 shows a slightly more complex surface. In this figure we see the equilibrium free surface for a liquid in a spinning dish. The outline of the computational region confuses the picture somewhat from this perspective. Figure 3 shows the same surface seen from a higher point of view.

Figures 4-6 are a sequence of displays from a calculation of the rupture of a water tank. An initial column of water restrained by an inner tank is displayed in Fig. 4. At $t=0$ a rupture forms in the tank wall allowing the water to flow into the annular gap between the inner and outer tanks. Figure 5 shows the fluid free surface at $t=0.1569$, and Fig. 6 at $t=0.2504$. Note that one can visualize the free surface fairly well in spite of the confusion caused by the appearance of "hidden lines" if one has knowledge of the flow being simulated.

Figures 7-12 are examples of calculations by FLOW-3D customers. Figure 7 was actually generated by a modified version of HYDR-3D (which preceded FLOW-3D). The calculation and display were provided by Ernst Hansen of the Norwegian research institute, SINTEF. The flow shows a stream of molten metal

impinging on a flat disc. A spray of metal fans out below the disc, eventually thinning to the point that the free surface is omitted from the plot. Figure 8 shows a 2D contour plot of fluid fraction. These two plots show the importance of using a variety of output to understand the computed results; Figure 8 aides in the interpretation of Fig. 7.

Figures 9-11 are a sequence of free-surface plots from a simulation of a drop tower test. The test was performed by NASA Lewis, and the simulation by Prof. John Hochstein of Washington University (St. Louis). Figure 9 shows the initial location of a gas bubble in an ellipsoidal tank. Figure 10 shows the surface at a later time. The tank has been accelerated in the downward direction (in this figure) at 0.22 g. A jet of liquid can be seen penetrating the bubble from the bottom. Again 2D slices assist this interpretation. The figure shows typical distortions introduced by the complex surface geometry. At $t=0.22$ the liquid jet has penetrated the bubble, changing its geometry to an annulus as depicted in Fig. 11. This same phenomenon was observed in the drop tower test.

Figure 12 shows an initial bubble in a full scale CENTAUR liquid oxygen tank. The high resolution mesh used by John Schultz of General Dynamics, provides a good picture of this free surface. The edge of the bubble appears somewhat "fuzzy" because of the interaction of the free surface with the tank geometry.

FREE SURFACE PLOT

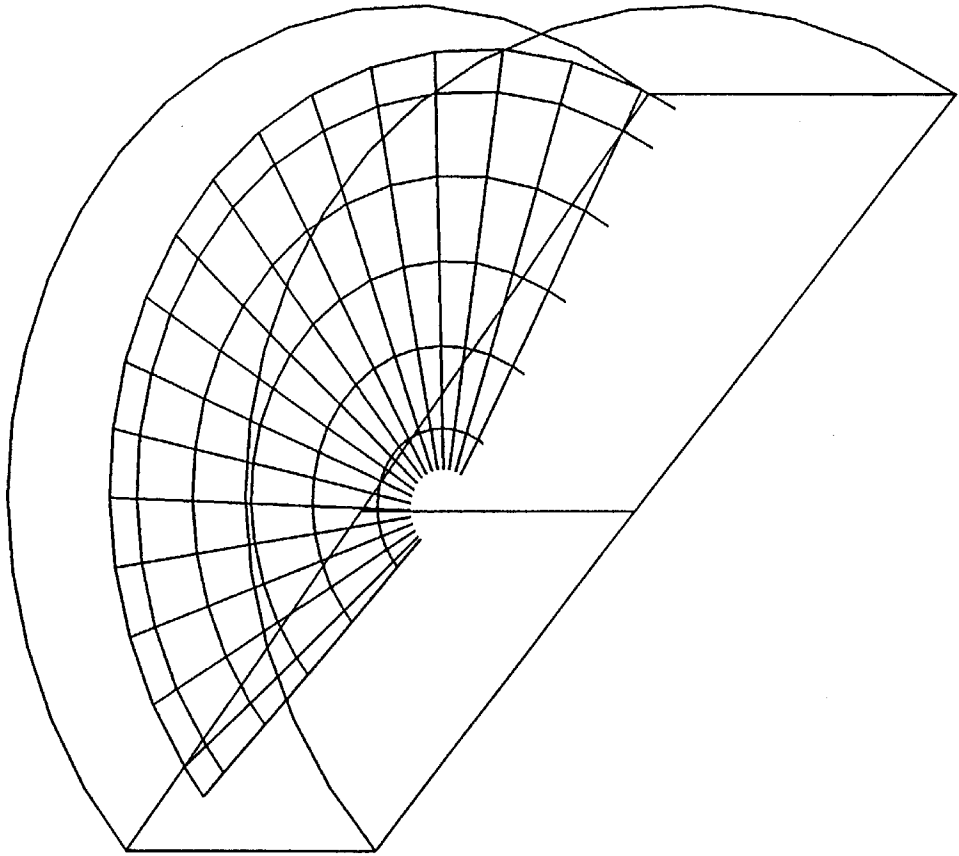


Figure 1

HYDR3D 10:34:59 1-JUL-88 EDUU VERSION 3, MOD 0, MVX 1988 TIME= 1.006E+00
CYLINDRICAL TANK TEST 50 CM AO=7.92 OMG=5.385 (CYLINDRICAL GEOMETRY)

HYDR3D 16:18:47 18-MAR-88 IHID
PAM_D SLAG

VERSION 2, MOD 3, MXX 1988
TIME= 9.069E+00

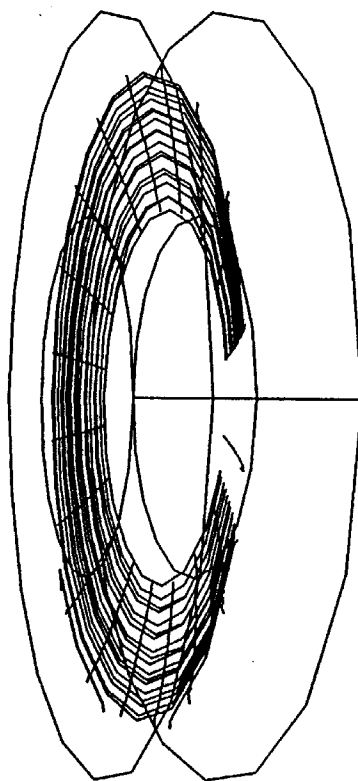


Figure 2

FREE SURFACE PLOT

PAM_D SLAG

HYDR3D 16:18:47 18-MAR-88 IHID VERSION 2, MOD 3, MVX 1988 TIME= 9.0699E+00

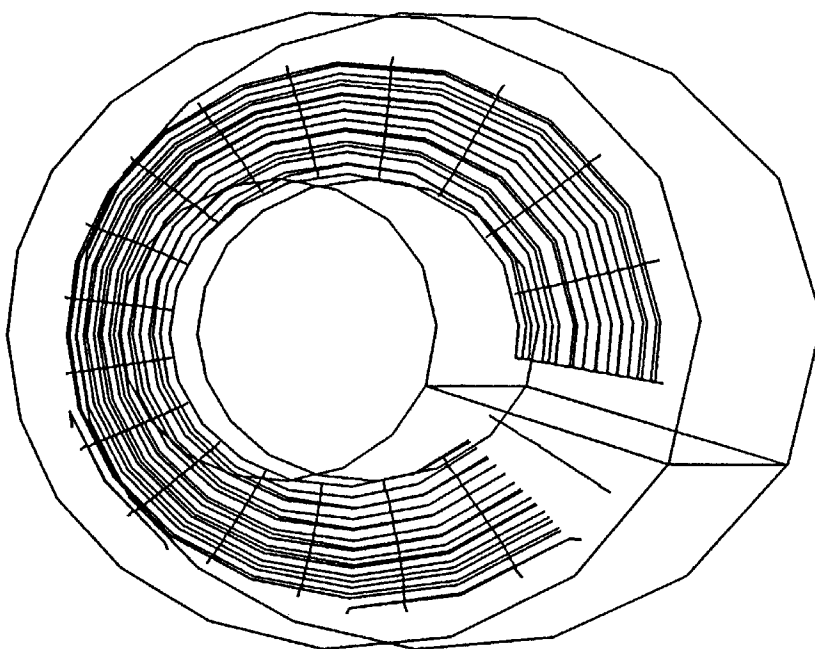


Figure 3

FREE SURFACE PLOT

FREE SURFACE PLOT

HYDR3D 10:49:54 4-MAY-88 BRUK VERSION 3, MOD 0, MAX 1988 TIME= 6.669E-03 RUPTURE

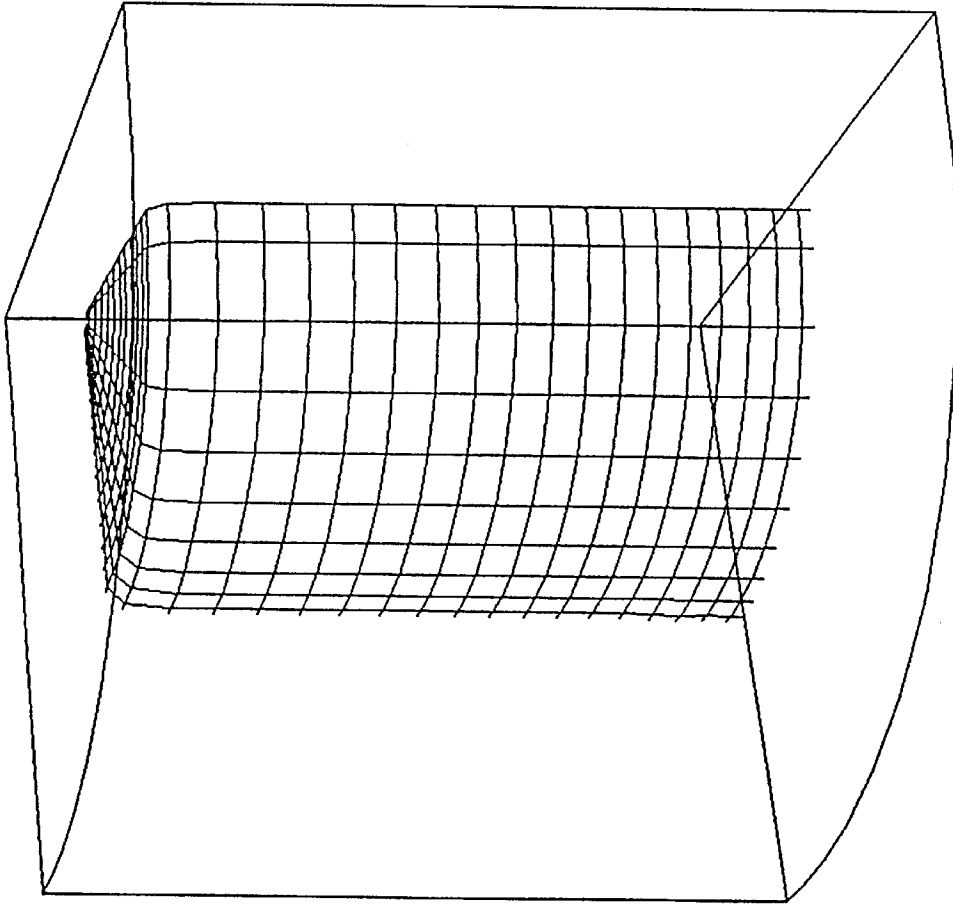
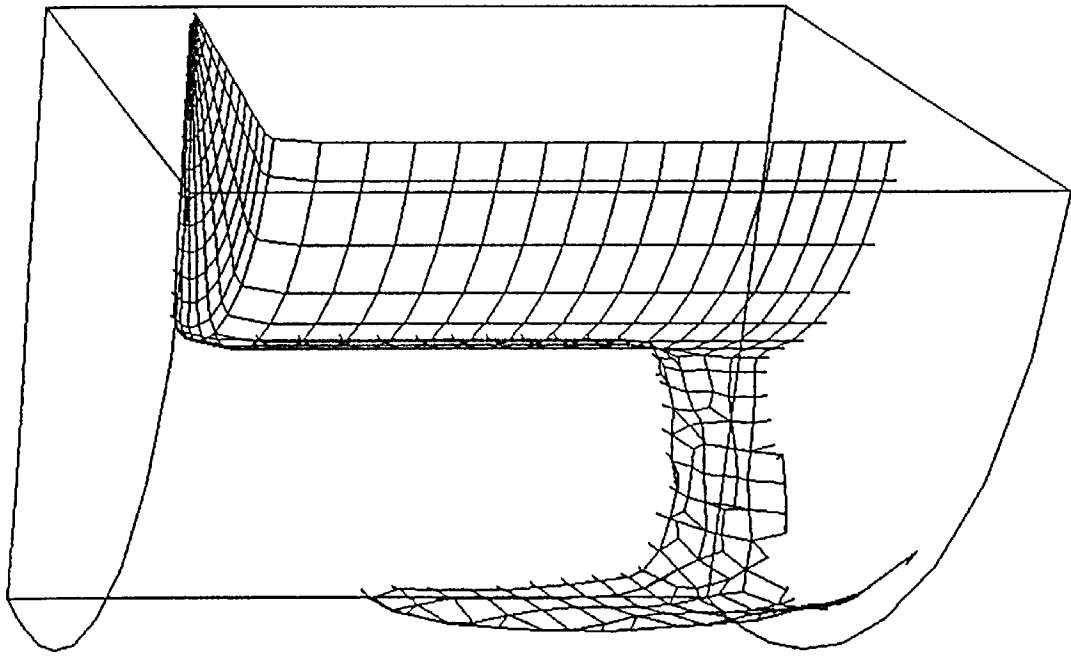


Figure 4

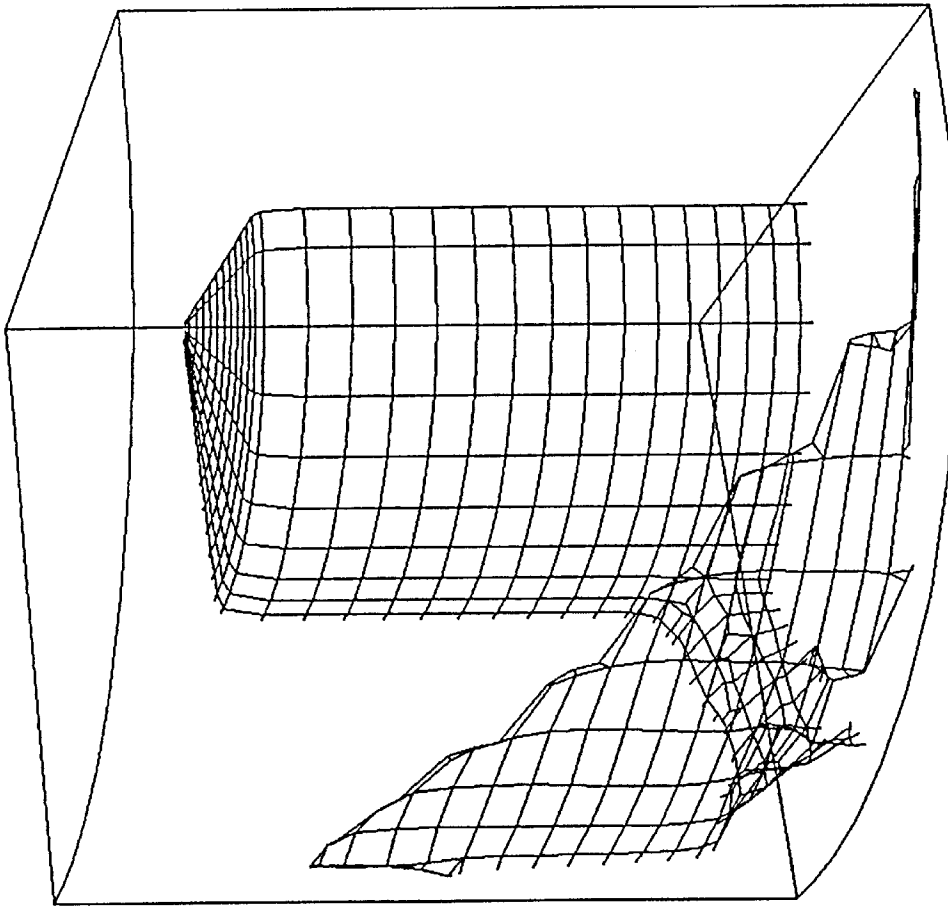
FREE SURFACE PLOT



HYDR3D 10:49:54 4-MAY-88 BRUK VERSION 3, MOD 0, MXX 1988 TIME= 1.569E-01 RUPTURE

Figure 5

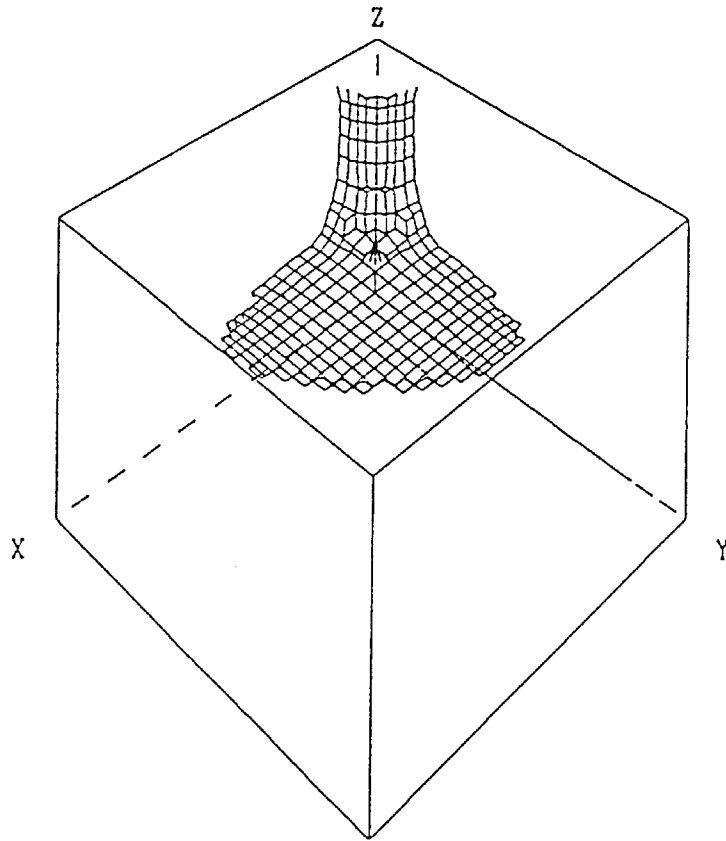
FREE SURFACE PLOT



HYDR3D 10:49:54 4-MAY-88 BRUK VERSION 3, MOD 0, MVX 1988 TIME= 2.504E-01 RUPTURE

Figure 6

NUMERISK SIMULERING AV METALLSTRÅLE (T3)



PERSPECTIVE SURFACE

T= 0.06005 CYCLE= 6299

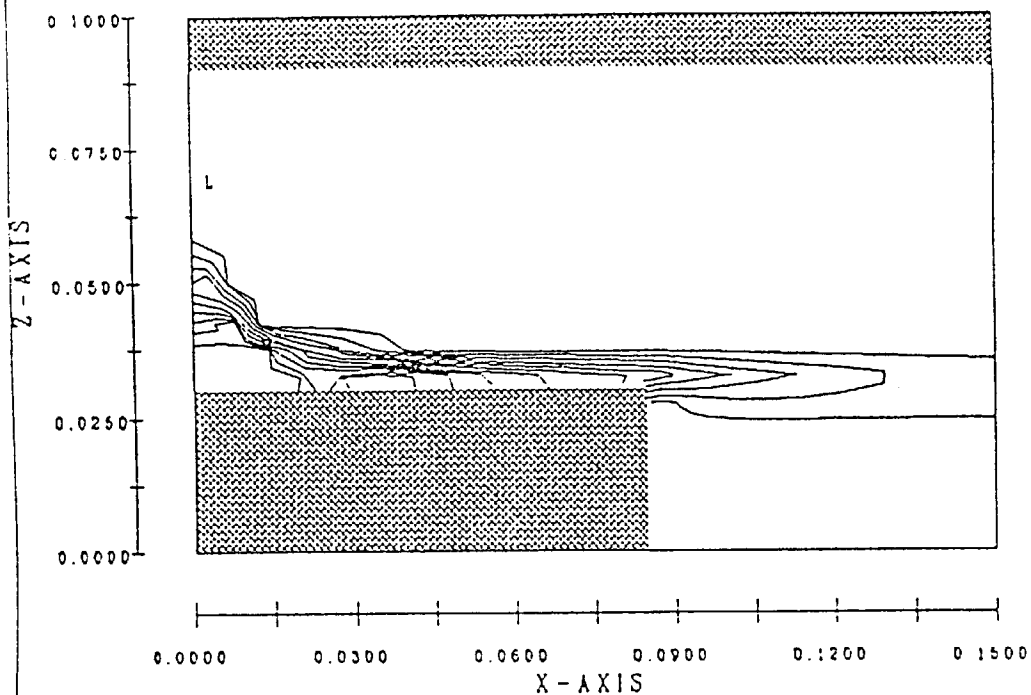
SINTEF/ITV

Figure 7

NUMERISK SIMULERING AV METALLSTRÅLE (T3)

(LOW = 5.00E-02.

HIG = 0.95)



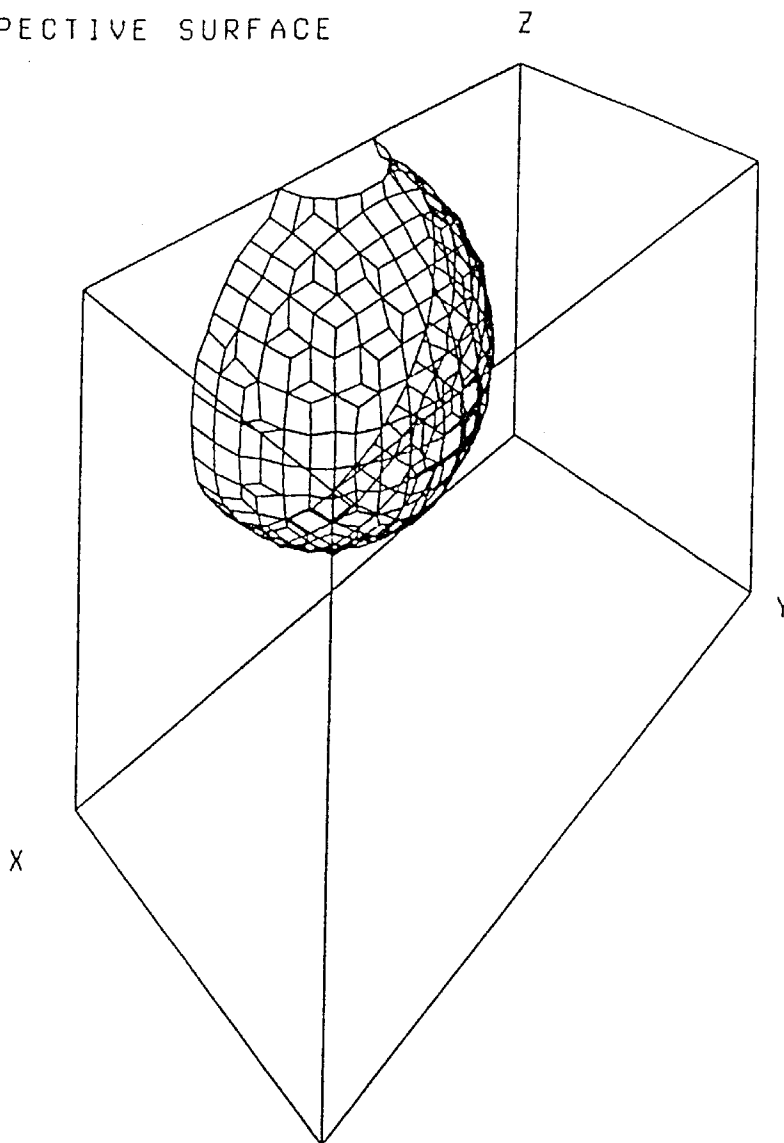
FLUID FRACTION CONTOURS

CONSTANT J= 6 SURFACE I= 2 TO 28 K= 2 TO 15

T= 0.06005 CYCLE= 6299 SINTEP/ITV

Figure 8

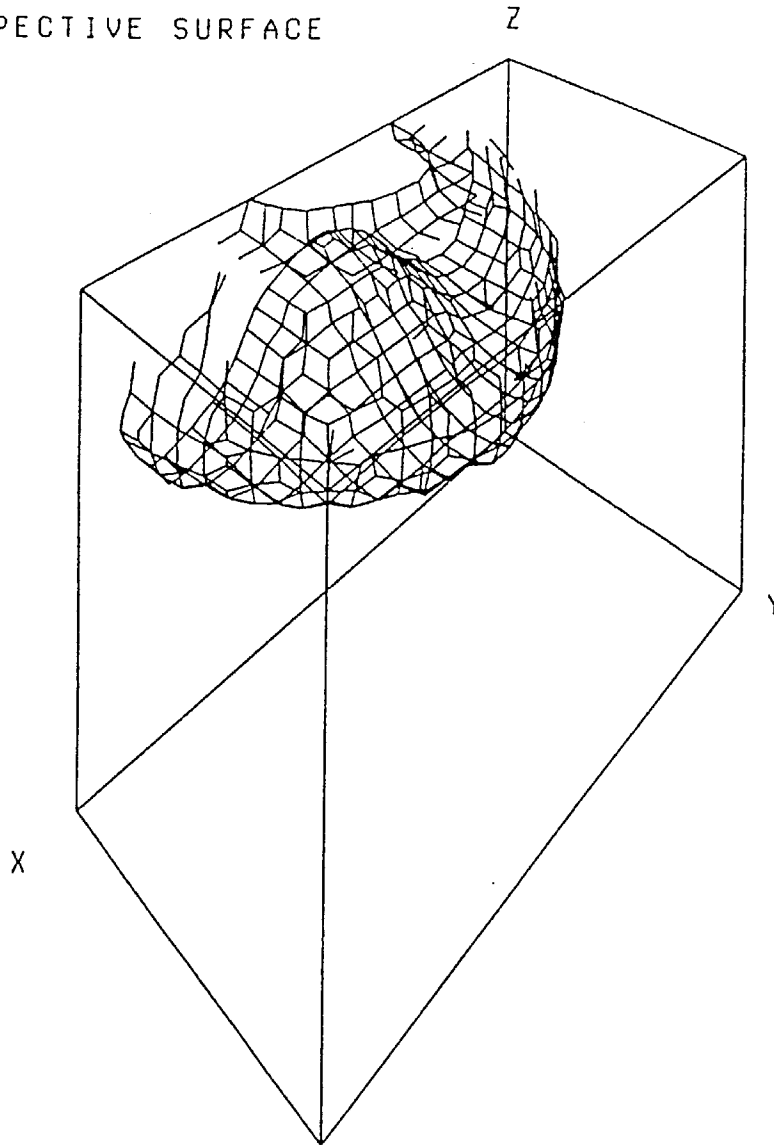
PERSPECTIVE SURFACE



{R-12-Z} DROP TOWER - ETHANOL (25%U) (0.226) (IMPT=0.109) (MN1)
t= 0.0000E+00 CYCLE= 0 12:06:03 11/30/85

Figure 9

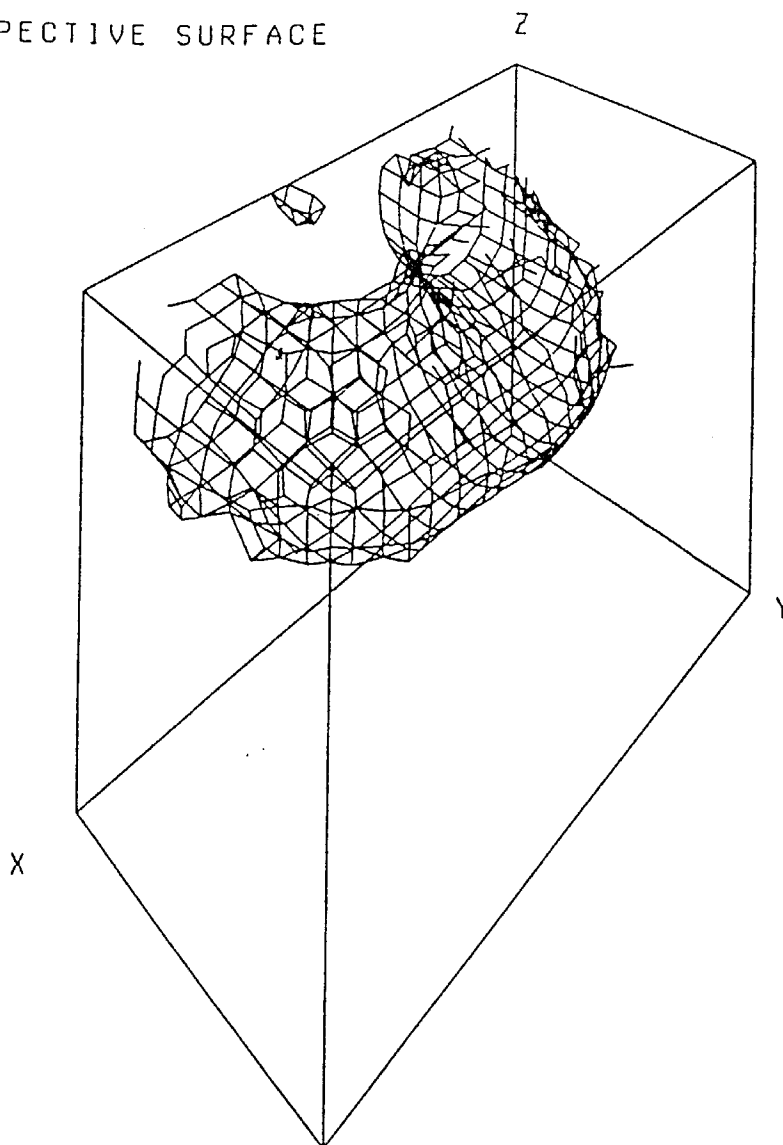
PERSPECTIVE SURFACE



{R-12-7} DROP TOWER - ETHANOL (25%U) (0.226) (IMPT=0.109) (MN1)
t = 1.2012E-01 CYCLE = 192 12:06:03 11/30/85

Figure 10

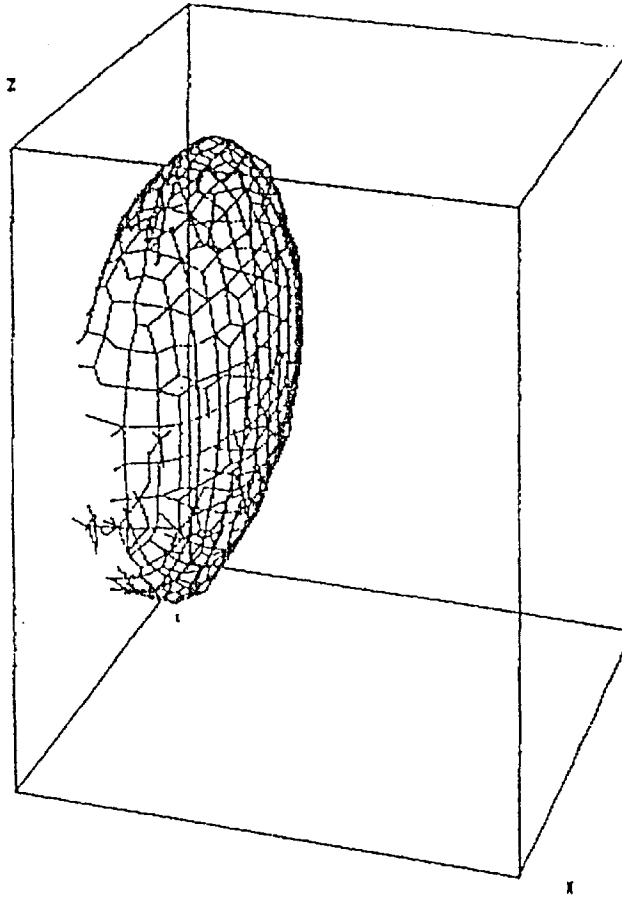
PERSPECTIVE SURFACE



{R-12-7} DROP TOWER - ETHANOL (25%U) (Q,226) (IMPT=0.109) (MN1)
t= 2.2166E-01 CYCLE= 443 12:27:32 11/30/85

Figure 11

FREE SURFACE PLOT



HTWCS 13.2812 08/28/88 IDN VERSION 3. MOD 0. 00 0000 1988 TYPE 1.010E-01
T/C ALL 00, VVV, SPOU, PVE-HCS2

Figure 12