FSI-85-TN1

Sample Problem for an Oil/Water/Gas Separator

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A. The Problem

This note describes a demonstration calculation showing how the FLOW-3D program may be used to model free surface flows in a geometry typical of an oil/gas/water separator. For demonstration purposes, we have restricted the test to a two-dimensional slice of a separator. The problem is illustrated in Fig. 1, which shows the basic tank region with elliptical ends. This tank is 5 m long and 2 m high. An outlet to atmospheric conditions exists on the bottom of the tank near the right end. To the left of this outlet there is a vertical baffle extending 0.6 m above the tank floor. An inlet port with a 0.15 m (6 inch) opening is located at the center of the left end of the tank. Inside the tank an elliptically-shaped deflector plate has been placed approximately 1.0 m downstream of the inlet port. The deflector is 0.12 m thick and 1.0 m high with its midpoint on the tank centerline. At the start of the calculation a pool of fluid of depth 0.4 m was set in the bottom of the tank and fluid was entering through the inlet at 4 m/s. As we shall see, this high inlet rate produces some violent fluid transients around the deflector plate and a strong surge wave that splashes over the downstream baffle.

B. Computed Results

In the first cycle plot, Fig. 2, we see the pool to the right of the baffle beginning to drain through the bottom hole. In this and subsequent plots, the fluid region is depicted by velocity vectors (without heads) directed out from the centers of all cells that are more than half full of fluid. The free surface boundary is a contour of the volume fraction of fluid (contour value is 0.5). No obstacles are shown in the plots because no method has yet been devised to correctly draw them with the same generality that they can be modeled in FLOW-3D.

Figure 3, at 0.2 s, shows the early jet injection before it strikes the deflector. It is angled downward because of the action of gravity. The pool to the right of the baffle now shows a depressed surface above the outlet port.

At 0.4 s, Fig. 4, the jet has splashed off the deflector and has created a left and right moving surge in the pool. Although the jet does not appear to extend continuously from the inlet to the deflector, this is not the case, but only a consequence of the limited mesh resolution available for the contour plot. The jet is initially only one mesh cell in width. Thus, where it narrows and shifts to the boundary between two cells, the fluid volume fractions are reduced below the 0.5 value used for the contour and the jet is not plotted. In the calculation, fluid does extend continuously from the inlet to the deflector.

Figure 5 shows the flow at 0.6 s. The surges have grown considerably larger, while the pool to the right is continuing to empty. Here again, the incoming jet and the deflected jet, where it enters the pool, are not resolved in the plot, but are continuous in the calculation.

At 0.76 s, Fig. 6, the left moving surge has merged with the incoming jet. Pressure contours at this time are shown in Fig. 7. A locally high pressure appears at the deflector where it is struck by the jet, while at the bottom deflector edge, the pressure has a minimum value because of the turning of the flow at that point.

In Fig. 8, which is at 1.07 s, there is an impressive wave passing over the baffle and a recirculating flow has been established below the inlet. This structure persists at 1.37 s, Fig. 9, except that the wave over the baffle is now about to fall onto the surface of the almost empty pool at the right end of the tank. The break in the fluid surface just to the left of the baffle is again a consequence of limited resolution.

In Fig. 10, which shows the configuration at t = 1.75 s, fluid is spilling over the baffle and is sending a surge up the right end of the tank, while to the left of the baffle the fluid is spilling backwards towards the deflector and trapping some void. On the front surface of the deflector the fluid height fluctuates, although the primary flow in this region is directed underneath the deflector. Turbulent entrainment with the fluid pool beneath the inlet is reducing the horizontal velocity of the jet causing it to fall more rapidly towards the bottom of the deflector. Based on this calculation, we see that the deflector must be moved closer to the left end of the tank to be more effective.

Finally, in Fig. 11, at t = 2.16 s, the spilling wave returning from the baffle has just reached the back side of the deflector. A considerable amount of void has been trapped under this spill. Pressures at this time are shown in Fig. 12. The maximum pressure occurs where the backward spilling wave has intersected the fluid rushing out from under the deflector.

C. Input and Cost Data

The input file used to set up and run this problem is given in Fig. 15. About half of this data is associated with the definition of the geometry. However, the total input is quite small even though it includes boundary condition specifications, the types of plots wanted for output, computational parameters and data for generating the computational mesh.

This problem was run on a CDC CYBER 855 computer and required about 14.23 min of CPU time for 2.16 s of problem time. Considering the rather violent and complicated phenomena involved, this is quite respectable.

One interesting event in the calculation, which is not evident from the graphical output, occurred when the jet first struck the deflector. FLOW-3D was told to seek its own time step for optimum running conditions, but when the jet first encountered the deflector it produced, in one time step, some relatively large splash velocities that could have driven the calculation unstable. To counter this, FLOW-3D automatically sensed the problem and restarted this cycle with a smaller time step. This is one example of the "expert system" features included in the code.

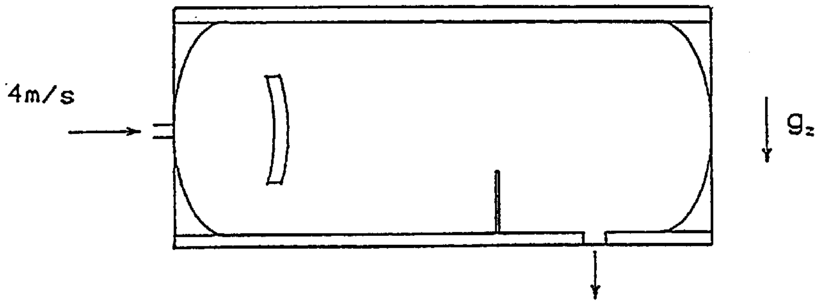

Fig. 1. Schematic of geometric setup showing elliptical tank ends, elliptical deflector, bottom mounted baffle, and inlet/outlet ports.

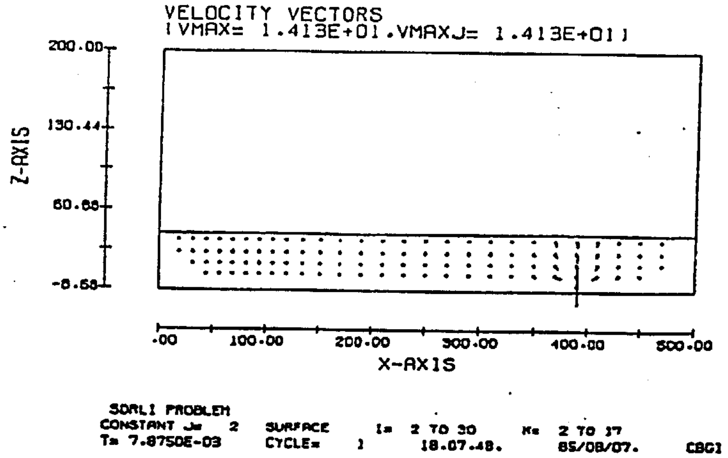

Figure 2.

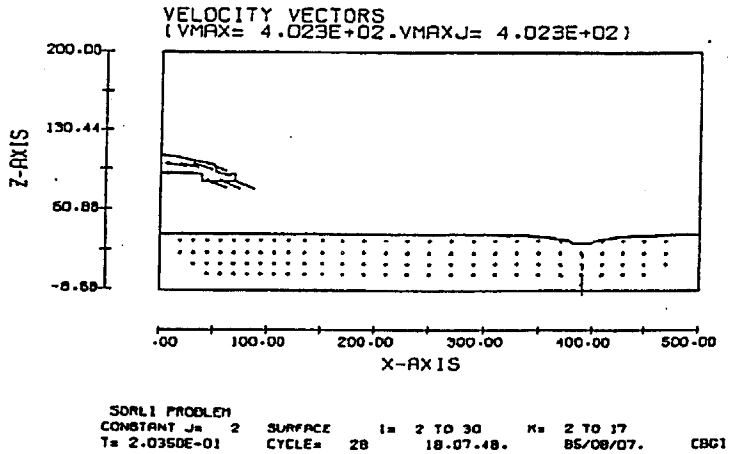

Figure 3.

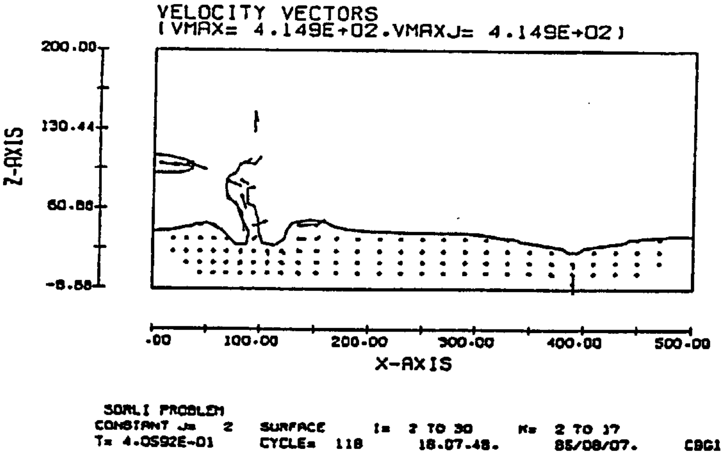

Figure 4.

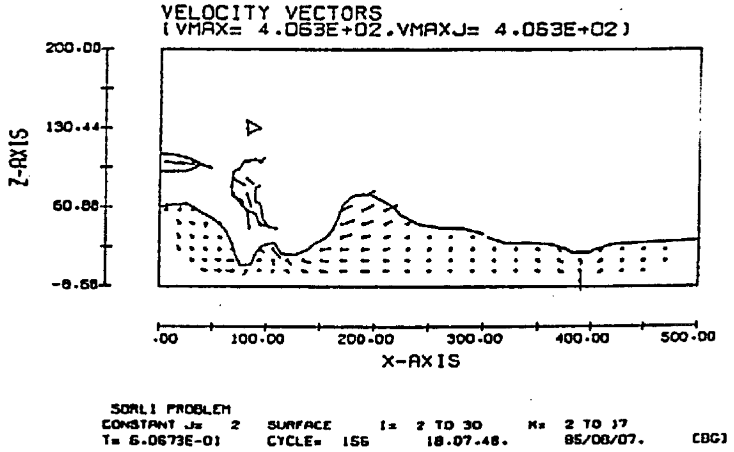

Figure 5.

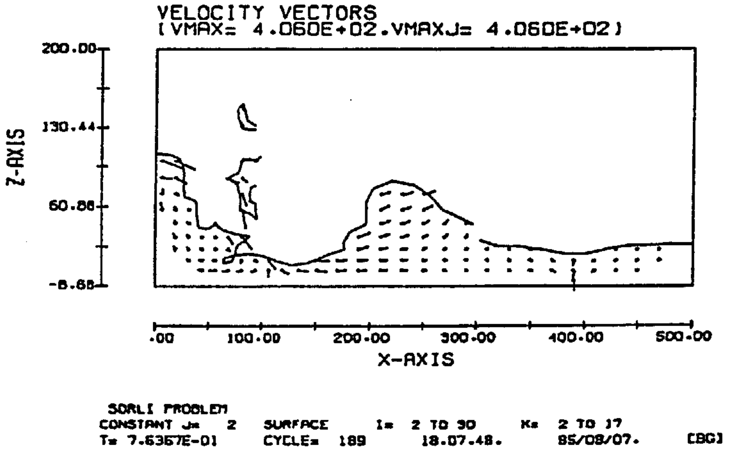

Figure 6.

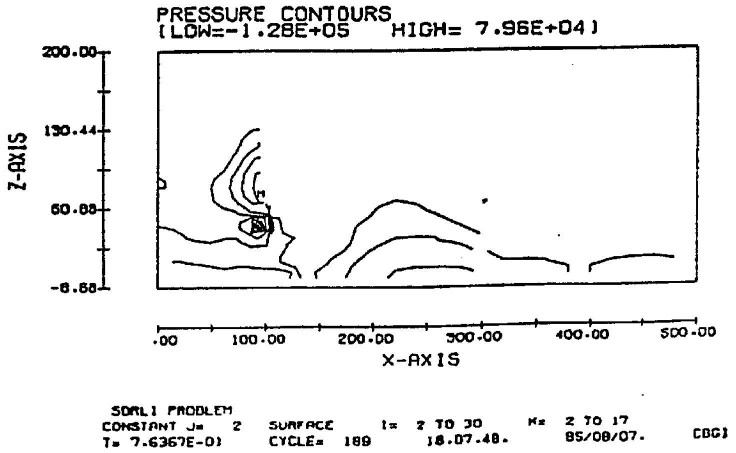

Figure 7.

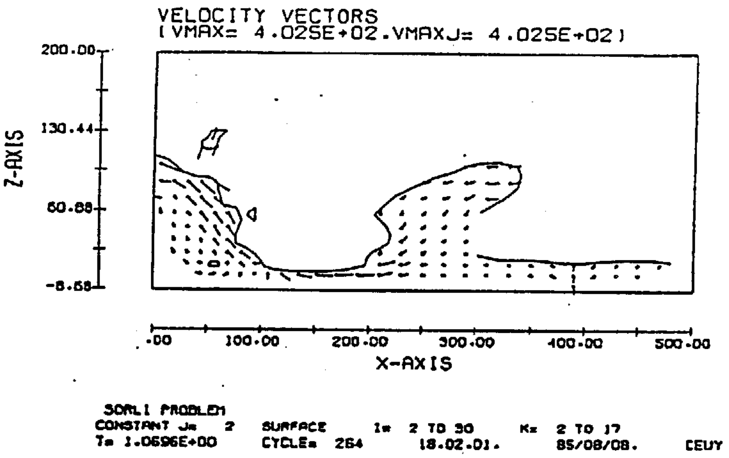

Figure 8.

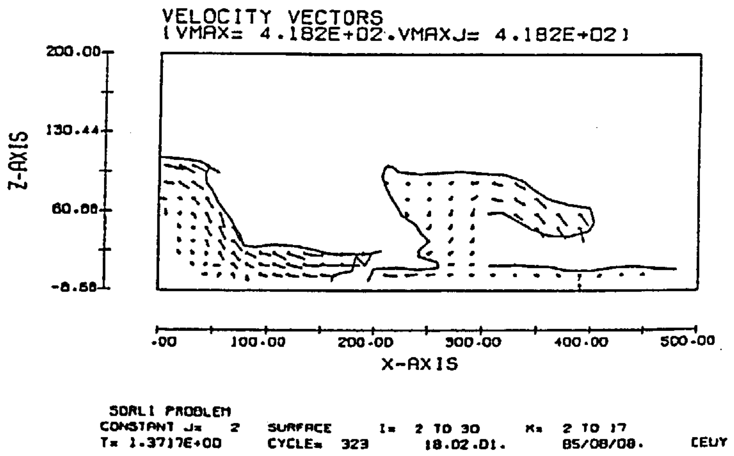

Figure 9.

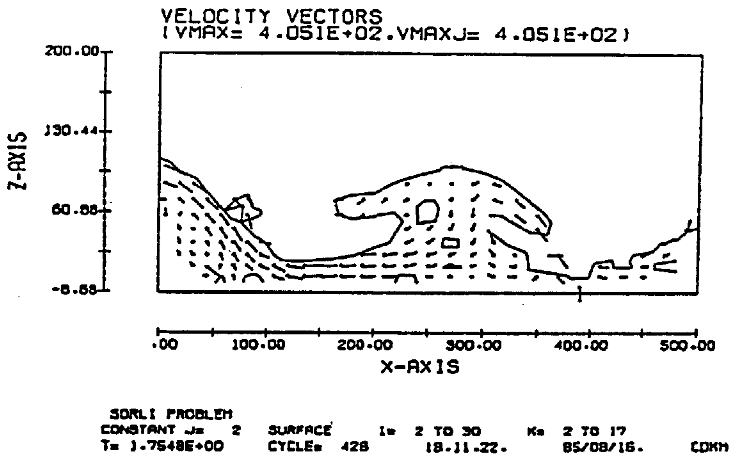

Figure 10.

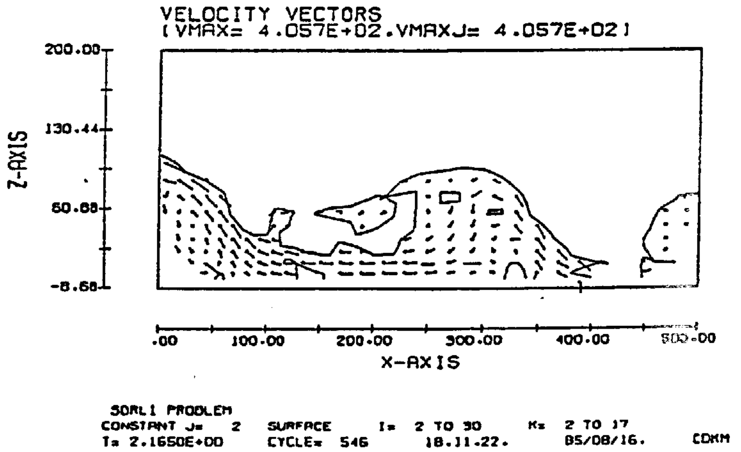

Figure 11.

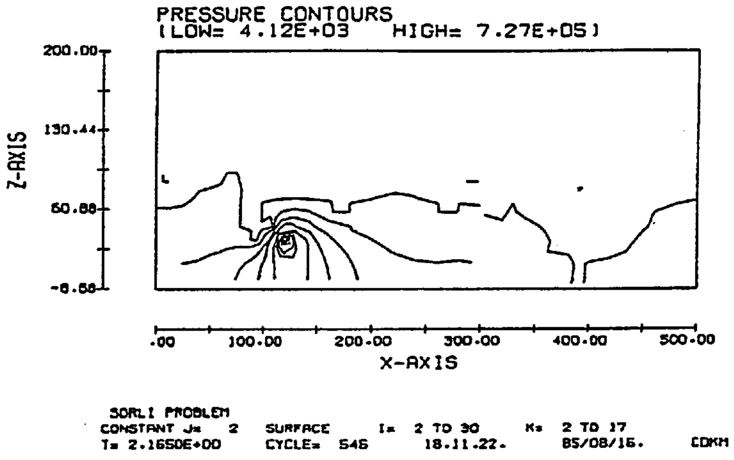

Figure 12.

```
>>>>>>    FILE SORLI    <<<<<<

 SORLI PROBLEM
 $XPUT
     IAF=2,
     TWFIN=2.0,                DELT=.0075,              MUI=61.,
     GZ=-980.,                 ITB=1,                   LPR=2,
     WL=6,                     WB=5,
     TIMBCT(1)=1.0E+10,        UBCT(1,1)=400.,          FBCT(1,1)=1.0,
     TIMBCT(5)=1.0E+10,
 $END
 $MESHGN
     NKX=2,
          XL(1)=0.0,     XC(1)=100.,   XL(2)=200.,
                         XC(2)=300.,   XL(3)=500.,
          NXL(1)=8,      NXR(1)=6,     DXMN(1)=12.5,
          NXL(2)=5,      NXR(2)=10,    DXMN(2)=20.,
     NKY=1,
          YL(1)=0.0,     YC(1)=0.0,    YL(2)=100.,
          NYL(1)=0,      NYR(1)=1,     DYMN(1)=100.0,
     NKZ=2,
          ZL(1)=-8.68,   ZC(1)=0.0,     ZL(2)=107.62,
                         ZC(2)=107.62,  ZL(3)=200.,
          NZL(1)=1,      NZR(1)=9,      DZMN(1)=8.68,
          NZL(2)=0,      NZR(2)=6,      DZMN(2)=15.24,
 $END
 $OBS
     NOBS=8,
     CC(1)=12544.,         CX(1)=-448.,           CZ(1)=-200.,
     CX2(1)=4.0,           CZ2(1)=1.0,            ZO(1)=150.,
     ZHO(1)=-1.0,          XO(1)=50.,             XHO(1)=1.0,
     CC(2)=7744.,          CX(2)=-352.,           CZ(2)=-200.,
     CX2(2)=4.0,           CZ2(2)=1.0,            IOH(2)=0,
     CC(3)=-50.,           CZ(3)=1.0,             IOH(3)=0,
     CC(4)=-1.0E+4,        CX(4)=400.,            CZ(4)=200.,
     CX2(4)=-4.0,          CZ2(4)=-1.0,           XO(4)=50.,
     XHO(4)=-1.0,
     CC(5)=-8.1E+5,        CX(5)=3600.,           CZ(5)=200.,
     CX2(5)=-4.0,          CZ2(5)=-1.0,           XO(5)=450.,
     XHO(5)=1.0,
     CZ(6)=1.0,            XO(6)=380.,            XHO(6)=-1.0,
     CZ(7)=1.0,            XO(7)=400.,            XHO(7)=1.0,
     CZ(8)=1.0,            CC(8)=-107.62,         XO(8)=10.,
     XHO(8)=-1.0,          ZO(8)=92.38,           ZHO(8)=1.0,
     IOH(8)=0,
 $END
 $FL
     FLHT=40.,
 $END
 $BF
     IBFO(1,1)=1,
     NBAFS=1,
     BCX(1)=1.0,         BCC(1)=-300.,       BZO(1)=60.0,
     BZHO(1)=-1.0,
 $END
 $TEMP
 $END
 $GRAFIC
     NVPLTS=1.
```

Fig. 13. HYDR-3D input deck used to set up this problem.

```
Model Oil/Water Separater with Baffles
$xput
    remark='units are mks',
    twfin=4.0,        pltdt=0.25,      prtdt=1000.0,
    nmat=1,           itb=1,
    ifrho=3,
    gz=-9.8,          ipdis=1,
    iaccf=1,
    dfcof=0.05,
$end
$limits
$end
$props
    rhof=1000.0,         mul=0.01,
    rhofs=900.0,         muc3=0.06,
$end
$bcdata
    wl=6,             ubc(1)=1.5,   wbc(1)=-0.4,  fbc(1)=1.0,
                      flhtl=2.0,

    wr=2,
    wf=1,             wbk=2,
    wb=6,             wbc(5)=-1.214,
    wt=2,
$end
$mesh
    nxcelt=55,
     px(1)=-1.5,      px(2)=-1.1,  px(3)=0.85,
     px(4)=1.0,       px(5)=1.2,   px(6)=1.50,
    nycelt=18,
     py(2)=0.50,
    nzcelt=18,
     pz(1)=-0.5,      pz(2)=0.4,   pz(3)=0.5,
$end
$obs
    avrck=-2.1,
    nobs=2,
    iob(1)=1,
      ral(1)=0.5,     roty(1)=90.0,
    iob(2)=1,
      rsl(2)=0.5,   xh(2)=0.0,  trnx(2)=-1.25,  magnx(2)=0.5,
    iob(3)=1,
      rsl(3)=0.5,   xl(3)=0.0,  trnx(3)=1.25,   magnx(3)=0.5,
    iob(4)=1,         ioh(4)=0,      remark='hole for inlet',
      rah(4)=0.075,   zh(4)=0.1,     roty(4)=90.0,
      trnz(4)=0.2,    trnx(4)=-1.0,
    iob(6)=1,         ioh(6)=0,  remark='hole for oil outlet',
      rah(6)=0.075,   zh(6)=-0.4,    trnx(6)=1.2,
    iob(7)=1,         ioh(7)=0,  remark='hole for water outlet',
      rah(7)=0.038,   zh(7)=-0.4,    trnx(7)=0.85,
    iob(5)=2,         remark='floor baffle near outlet',
      xl(5)=0.98,     xh(5)=1.02,    zh(5)=-0.1,
$end
$fl
    nfls=3,
      fzh(1)=0.0,     rhoreg(1)=900.0,
      fzh(2)=-0.3,    fxh(2)=1.0,    rhoreg(2)=1000.0,
      frah(3)=0.075,  fzh(3)=0.4,    froty(3)=90.0,
      ftrnz(3)=0.2,   ftrnx(3)=-1.5,
      ureg(3)=1.0,    rhoreg(3)=925.0,
$end
$bf
    nbafs=1,
      pbaf(1)=0.0,  remark=' kbaf2(1)=2.25',
      ibaf(1)=1,      bx(1)=-0.75,   bzl(1)=-0.45,  bzh(1)=-0.25,
```

THIS SETUP
USED FOR
RESULTS IN
NEWSLETTER 3.3

```
      ibaf(2)=1,      bx(2)=-0.25,   bzl(2)=-0.45,  bzh(2)=-0.25,
      ibaf(3)=1,      bx(3)=0.25,    bzl(3)=-0.45,  bzh(3)=-0.25,
      ibaf(4)=1,      bx(4)=0.75,    bzl(4)=-0.45,  bzh(4)=-0.25,
$end
$temp
$end
$motn
    iatype=0,        a0=0.25,       omg0=1.57,
$end
$grafic
    isymx=0,
    nvplts=1,        contpv(1)='rho', yv1(1)=0.0, yv2(1)=0.0,
    ncplts=0,
    nsplts=1,        contps(1)='f',
$end
$parts
$end
      ibaf(5)=1,      bx(5)=1.25,
```