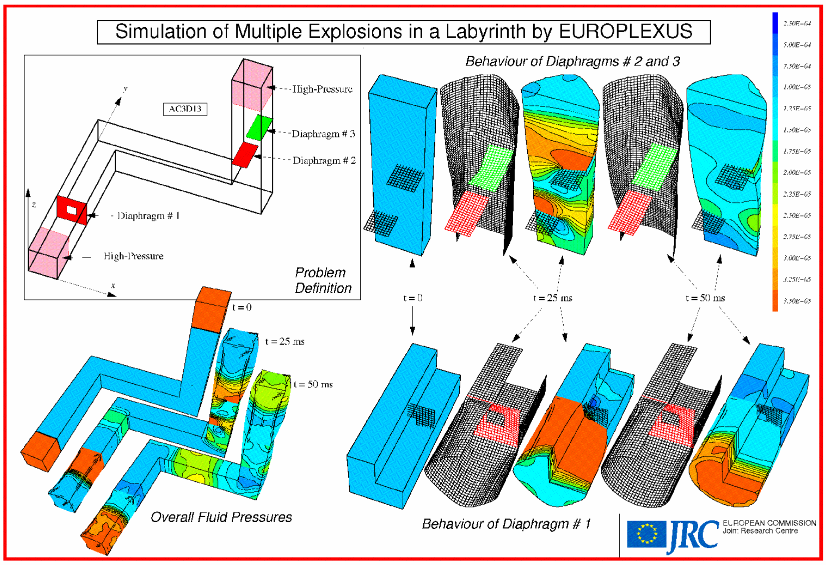
Exercise/Example 5 – Explosion in a 3-D Labyrinth



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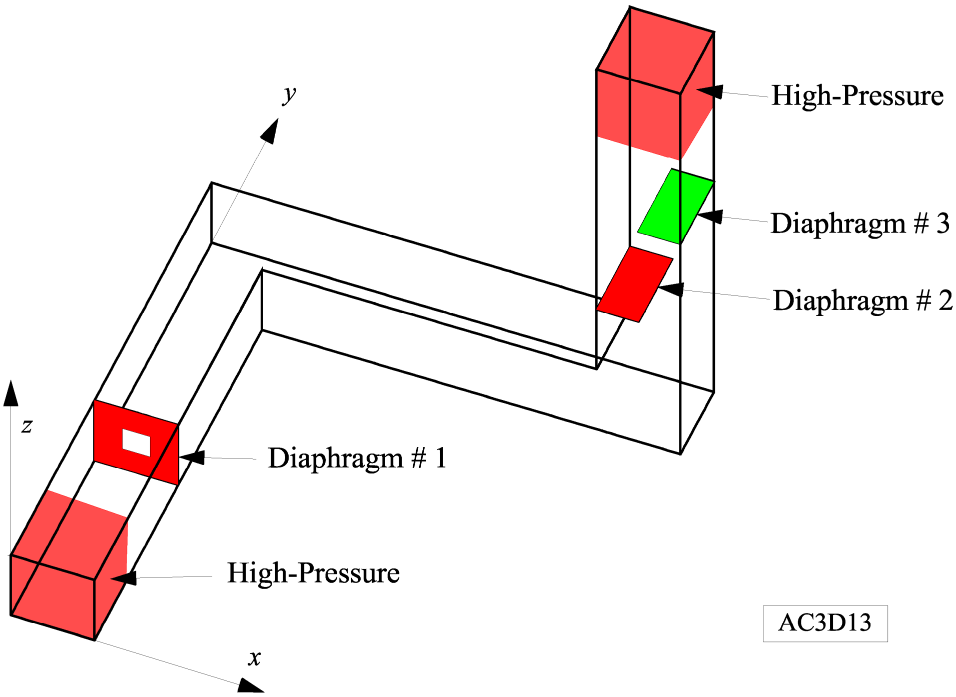
This example consists in a long 3D metallic pipe with a square cross section of 3×3 units, sealed at both ends, containing a gas at room pressure. At the initial time, two "explosions" take place at the ends of the pipe, simulated by the presence of the same gas, but at a much higher initial pressure.

The gas starts flowing through the pipe, but its motion is partly affected by the presence of internal structures within the pipe: a diaphragm (#1) with a square central hole near the first extremity, and two diaphragms (#2 and #3) that obstruct one half of the flow section, creating a sort of labyrinth, at the second extremity. All the pipe walls, and the internal structures, are deformable and characterized by an elasto-plastic behaviour. The pressures and structural material properties are so chosen that very large motions and relatively large deformations occur in the structure. The whole model measures $18\times18\times18$ units.

The above figure shows the deformed shapes of the pipe, with superposed fluid pressure maps. The displacements are the real ones (not scaled up). Note the strong wave propagation effects, the partial wave reflections at obstacles, and the "ballooning" effect of the thin pipe walls in regions at high pressure. This is a severe test, among other things, for the automatic rezoning algorithms, which must keep the fluid mesh reasonably uniform under large motions. Details of the pressure drop across the various obstacles and of the deformation of diaphragms and pipe walls are also illustrated.

It may be interesting for users to note that the EUROPLEXUS input file for this application consists of less than 60 lines of data. The mesh is prepared by a pre-processor and the two domains, structure and fluid, are meshed separately (but with matching nodes in this first example). Suitable FSI conditions are then computed by the code in a totally automatic way and without any user directive or intervention.

Geometric data:



Materials

The explosive bubbles are made of a high-pressure perfect gas (10 bar). The rest of the fluid domain is filled by the same gas but at a lower pressure (1 bar).

The structure is elasto-plastic steel material. The tube is 1.2 cm thick, the first diaphragm is 1.0 cm thick and the other two diaphragms are 1.5 cm thick.

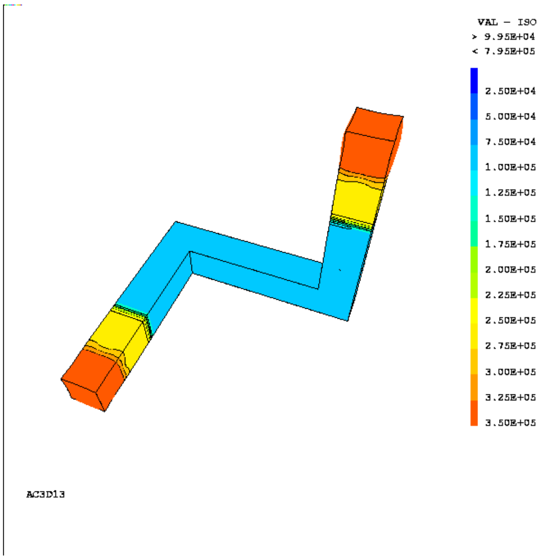
Numerical Solution

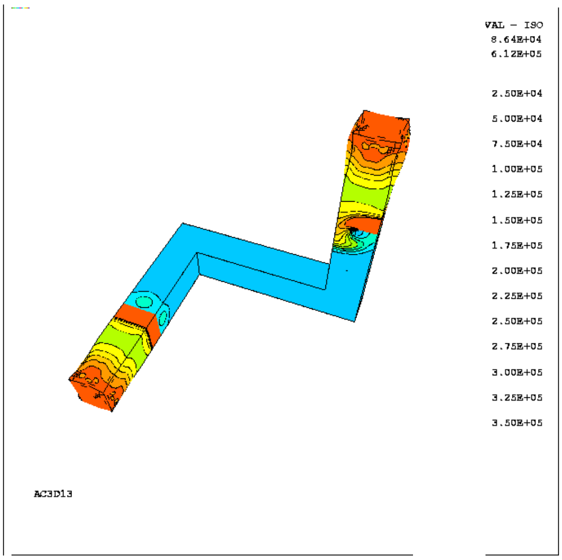
AC3D13

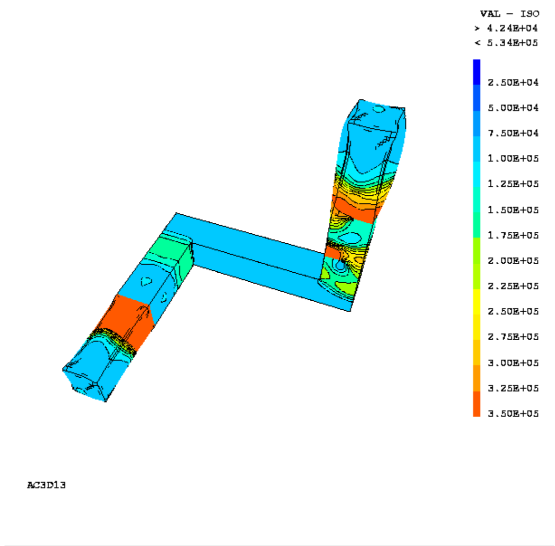
We use the FSA directive to prescribe the boundary conditions at the complex 3D surface of the fluid domain. The input file is:

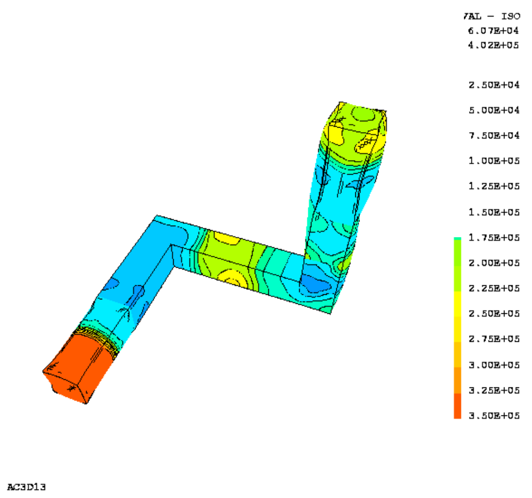
```
AC3D13
ECHO
 CONV win
CAST mesh
TRID NONL ALE
DIME
  PT6L 21956 PT3L 104983 FL38 93312 Q4GS 21996 ZONE 2
  NALE 7527 NBLE 1
  ECRO 5678928
  NEPE 232
  mtpo 3 mtel 4
  ndvc 494238
TERM
GEOM FL38 flui Q4GS stru TERM
COMP EPAI 0.010 LECT diap1 TERM
     EPAI 0.015 LECT diap2 TERM
     EPAI 0.015 LECT diap3 TERM
     EPAI 0.012 LECT tube  TERM
GRIL LAGR LECT stru TERM
     EULE LECT fsan TERM
     ALE  LECT flui TERM
     MEAN AUTR
OPTI REZO MVRE MODU LIAI
MATE VM23 RO 8000 YOUNG 2.E11 NU 0.3 ELAS 4.E8
          TRAC 3 4.E8 2.E-3 2.4E9 1.002E0 2.4E9 10.
          LECT stru TERM
     FLUT RO 10. EINT 2.5E5 GAMM 1.4 PB 0 ITER 1 ALF0 1
          BET0 1 KINT 0 AHGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 1
          pref 1.e5
          LECT expl TERM
     FLUT RO  1. EINT 2.5E5 GAMM 1.4 PB 0 ITER 1 ALF0 1
          BET0 1 KINT 0 AHGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 1
          pref 1.e5
          LECT gas TERM
OPTI FSCR
LINK COUP
     FSA LECT fsan TERM
ECRI DEPL VITE ECRO TFRE 10.E-3
     POIN LECT tpln TERM
     ELEM LECT tple TERM
     TRAC TPLO DESC 'AC3D13' TFRE 51.E-6
               POIN LECT tpln TERM
               ELEM LECT tple TERM
     fich alic temp TFRE 51.E-6
               POIN LECT tpln TERM
               ELEM LECT tple TERM
     FICH FORM spli K200 TFRE 0.5E-3
          POIN TOUS
          VARI DEPL VITE ECRO ECRC LECT 1 3 TERM
OPTI NOTE
  CSTA 0.5D0
  MOMT 2
  LOG 1
CALCUL TINI 0. TEND 50.E-3
*
SUIT
Post-treatment
ECHO
*
RESU ALIC TEMP GARD PSCR
*
SORT GRAP
*
AXTE 1000.0 'Time [ms]'
*
COUR 1 'dy_d1' DEPL COMP 2 NOEU LECT d1 TERM
COUR 2 'dz_d2' DEPL COMP 3 NOEU LECT d2 TERM
COUR 3 'dz_d3' DEPL COMP 3 NOEU LECT d3 TERM
COUR 4 'p_e1'  ECRO COMP 1 ELEM LECT e1 TERM
COUR 5 'p_e2'  ECRO COMP 1 ELEM LECT e2 TERM
COUR 6 'p_e3'  ECRO COMP 1 ELEM LECT e3 TERM
COUR 7 'p_e4'  ECRO COMP 1 ELEM LECT e4 TERM
*
trac 1 2 3 axes 1.0 'D [M]'
trac 4 5 6 7 axes 1.0 'P [PA]'
*
*QUAL VITE comp 1 lect 51 term REFE 8.25539E+2 TOLE 5.E-3
*     ECRO comp 1 lect 50 term REFE 3.41392E+5 TOLE 5.E-3
FIN
```

Some results: global deformed mesh views with fluid pressures:

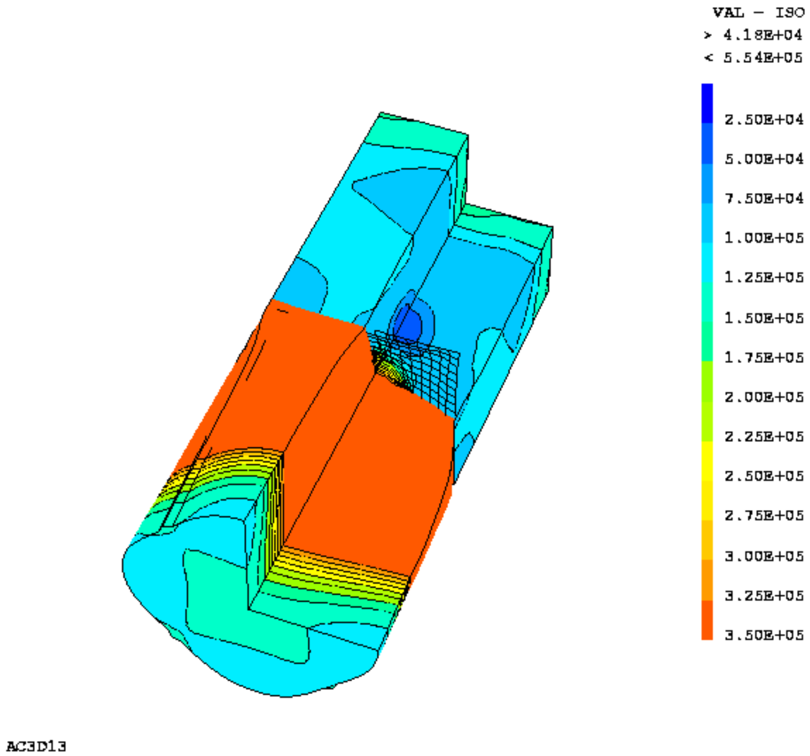








Detail of first diaphragm:



Detail of second and third diaphragms: