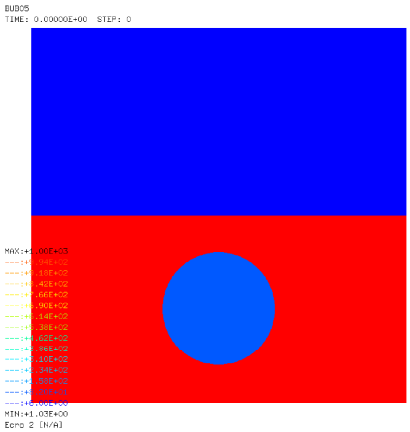
Exercise 7 – Gas bubble expansion in liquid



Solution with structured mesh (method of Despres, Lagoutière et al.)

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Geometric data:
Compressed gas bubble expands in a liquid with free surface. A structured mesh is used.
Boundary conditions:
Rigid boundary.
Initial conditions:
High pressure in the bubble.
Materials
The various fluids are modelled by the ADCR material model: this material models a mixture of gases and liquids.
Solutions
Solutions are obtained with either FE or CCFV, without and with anti-diffusion according to the Despres-Lagoutière method.

NODP02

This solution uses a coarse mesh of Finite Elements without anti-diffusion. The mesh generation file is:

```
opti echo 1;
opti dime 2 elem qua4;
opti sauv form 'nodp02.msh';
opti trac psc ftra 'nodp02_mesh.ps';
*
p0 = 0 0;
p1 = 1 0;
p2 = 1 1;
p3 = 0 1;
*
n = 50;
*
c1 = p0 d n p1;
c2 = p1 d n p2;
c3 = p2 d n p3;
c4 = p3 d n p0;
*
flui = dall c1 c2 c3 c4 plan;
*
blox = c2 et c4;
bloy = c1 et c3;
*
mesh = flui et blox et bloy;
tass mesh noop;
sauv form mesh;
*
trac qual mesh;
*
fin;
```

The input file is:

```
NODP02
ECHO
!CONV win
CAST mesh
DPLA EULE
GEOM CAR1 flui TERM
COMP GROU 3 'gazz' LECT flui TERM COND YB GT 0.5
            'bull' LECT flui TERM COND SPHE XC 0.5 YC 0.25 R 0.15
            'liqu' LECT flui DIFF gazz bull TERM
     COUL roug LECT bull TERM
          bleu LECT liqu TERM
          turq LECT gazz TERM
MATE ADCR ! Bulle
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 2.E6
          CAR 0. CBU 1.
          LECT bull TERM
     ADCR ! Eau
```

```
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 0.
          LECT liqu TERM
     ADCR ! Couverture
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 1.
          LECT gazz TERM
LINK COUP BLOQ 1 LECT blox TERM
          BLOQ 2 LECT bloy TERM
ECRI VITE TFRE 1.2E-2 NOPO NOEL
     FICH ALIC TFRE 1.E-4
OPTI PAS AUTO CSTA 0.5 AMOR QUAD 4.
     LOG 1
CALC TINI 0. TFIN 1.2E-2
FIN
```

DPLG02

This solution uses a coarse mesh of Finite Elements with anti-diffusion according to the Despres-Lagoutière method. The input file is:

```
DPLG02
ECHO
!CONV win
CAST mesh
DPLA EULE
GEOM CAR1 flui TERM
COMP GROU 3 'gazz' LECT flui TERM COND YB GT 0.5
           'bull' LECT flui TERM COND SPHE XC 0.5 YC 0.25 R 0.15
           'liqu' LECT flui DIFF gazz bull TERM
     COUL roug LECT bull TERM
          bleu LECT liqu TERM
          turq LECT gazz TERM
MATE ADCR ! Bulle
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 2.E6
          CAR 0. CBU 1.
          LECT bull TERM
     ADCR ! Eau
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 0.
          LECT liqu TERM
     ADCR ! Couverture
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 1.
          LECT gazz TERM
LINK COUP BLOQ 1 LECT blox TERM
          BLOQ 2 LECT bloy TERM
ECRI VITE TFRE 1.2E-2 NOPO NOEL
     FICH ALIC TFRE 1.E-4
OPTI PAS AUTO CSTA 0.5 AMOR QUAD 4.
     DPLG
     LOG 1
CALC TINI 0. TFIN 1.2E-2
FIN
```

NODP03

This solution uses a coarse mesh of Cell-Centred Finite Volumes without anti-diffusion. The input file is:

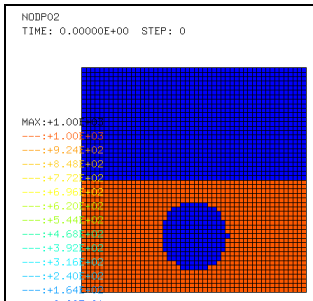
```
NODP02
ECHO
!CONV win
CAST mesh
DPLA EULE
GEOM CAR1 flui TERM
COMP GROU 3 'gazz' LECT flui TERM COND YB GT 0.5
           'bull' LECT flui TERM COND SPHE XC 0.5 YC 0.25 R 0.15
           'liqu' LECT flui DIFF gazz bull TERM
     COUL roug LECT bull TERM
          bleu LECT liqu TERM
          turq LECT gazz TERM
MATE ADCR ! Bulle
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 2.E6
          CAR 0. CBU 1.
          LECT bull TERM
     ADCR ! Eau
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 0.
          LECT liqu TERM
     ADCR ! Couverture
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 1.
          LECT gazz TERM
LINK COUP BLOQ 1 LECT blox TERM
          BLOQ 2 LECT bloy TERM
ECRI VITE TFRE 1.2E-2 NOPO NOEL
     FICH ALIC TFRE 1.E-4
OPTI PAS AUTO CSTA 0.5 AMOR QUAD 4.
     LOG 1
CALC TINI 0. TFIN 1.2E-2
FIN
```

DPLG03

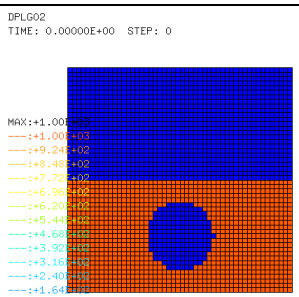
This solution uses a coarse mesh of Cell-Centred Finite Volumes with anti-diffusion according to the Despres-Lagoutière method. The input file is:

```
DPLG02
ECHO
!CONV win
CAST mesh
DPLA EULE
GEOM CAR1 flui TERM
COMP GROU 3 'gazz' LECT flui TERM COND YB GT 0.5
           'bull' LECT flui TERM COND SPHE XC 0.5 YC 0.25 R 0.15
           'liqu' LECT flui DIFF gazz bull TERM
     COUL roug LECT bull TERM
          bleu LECT liqu TERM
          turq LECT gazz TERM
MATE ADCR ! Bulle
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 2.E6
          CAR 0. CBU 1.
          LECT bull TERM
     ADCR ! Eau
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 0.
          LECT liqu TERM
     ADCR ! Couverture
          RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 1.
          LECT gazz TERM
LINK COUP BLOQ 1 LECT blox TERM
          BLOQ 2 LECT bloy TERM
ECRI VITE TFRE 1.2E-2 NOPO NOEL
     FICH ALIC TFRE 1.E-4
OPTI PAS AUTO CSTA 0.5 AMOR QUAD 4.
     DPLG
     LOG 1
CALC TINI 0. TFIN 1.2E-2
FIN
```

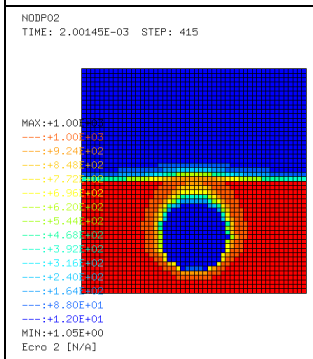
The computed densities at some selected instants for the Finite Element solutions are shown below:



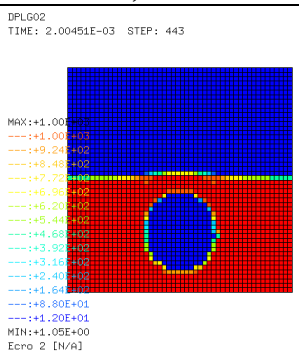
t = 0



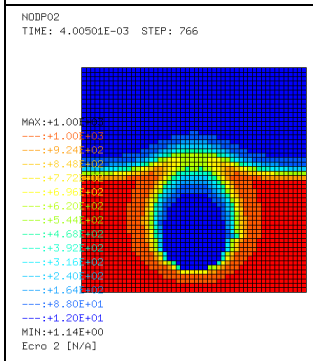
t = 0, anti-diffusion



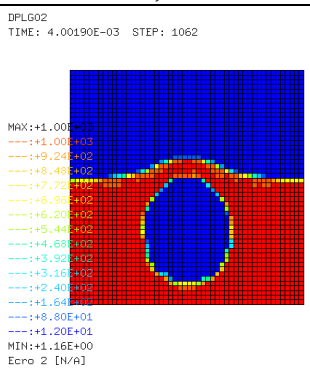
t = 2.E-3



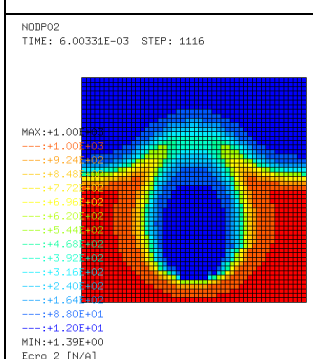
t = 2.E-3, anti-diffusion



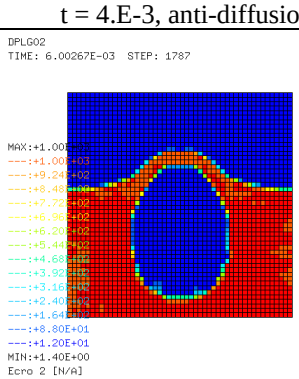
t = 4.E-3



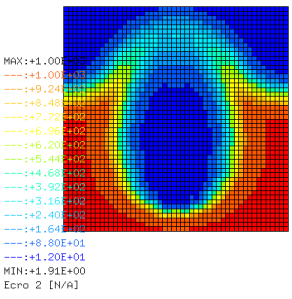
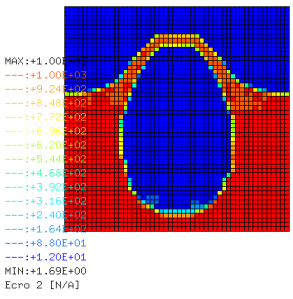
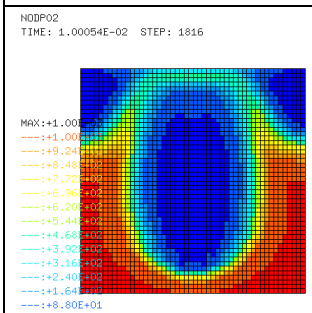
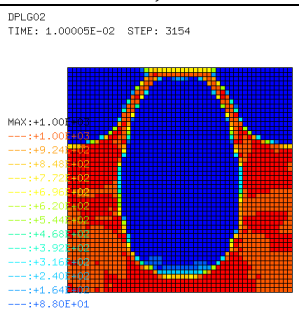
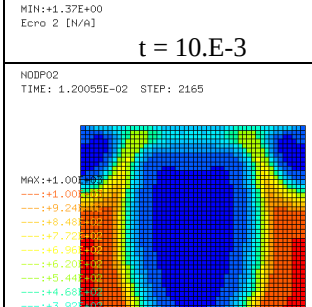
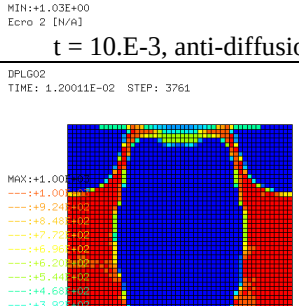
t = 4.E-3, anti-diffusion



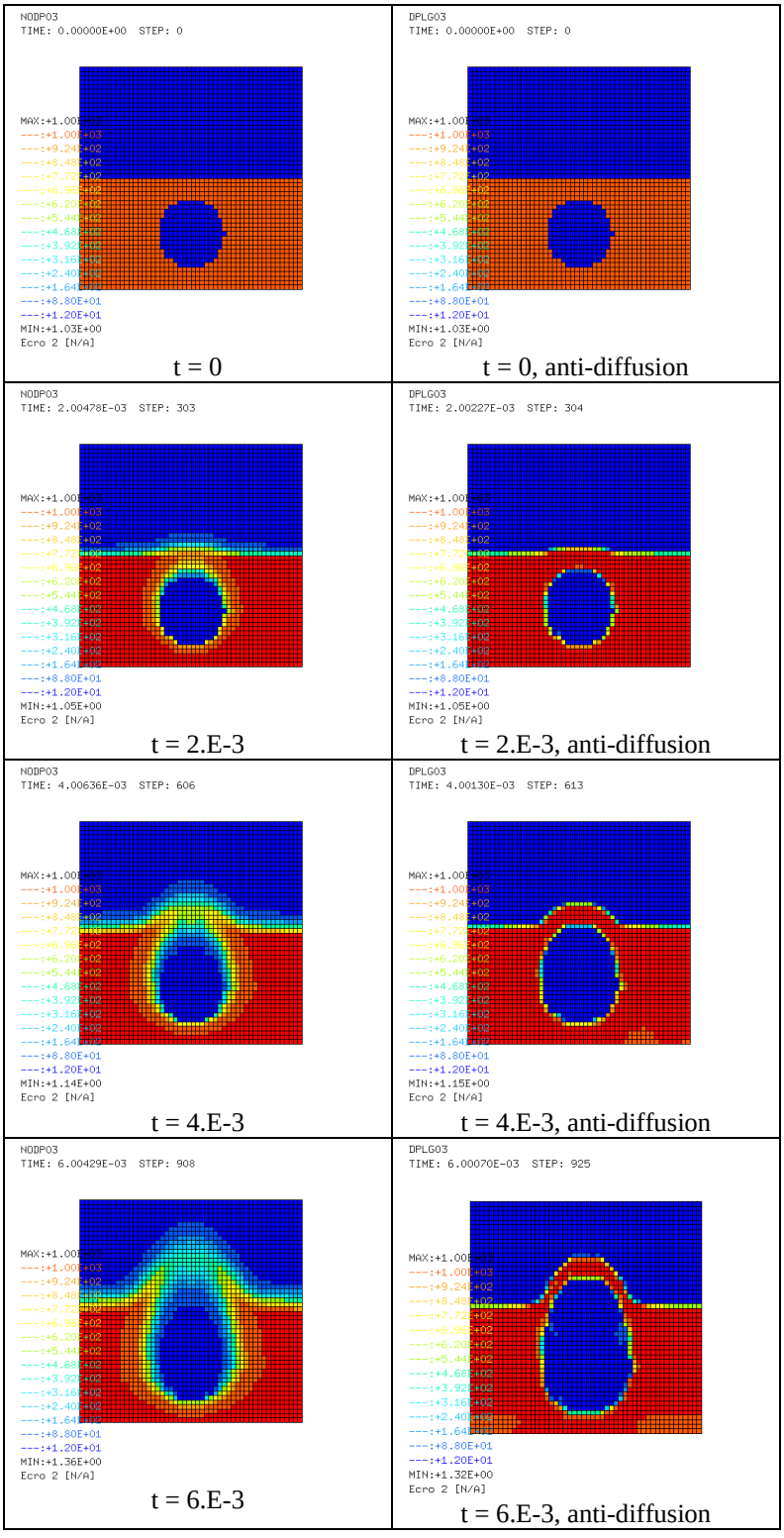
t = 6.E-3

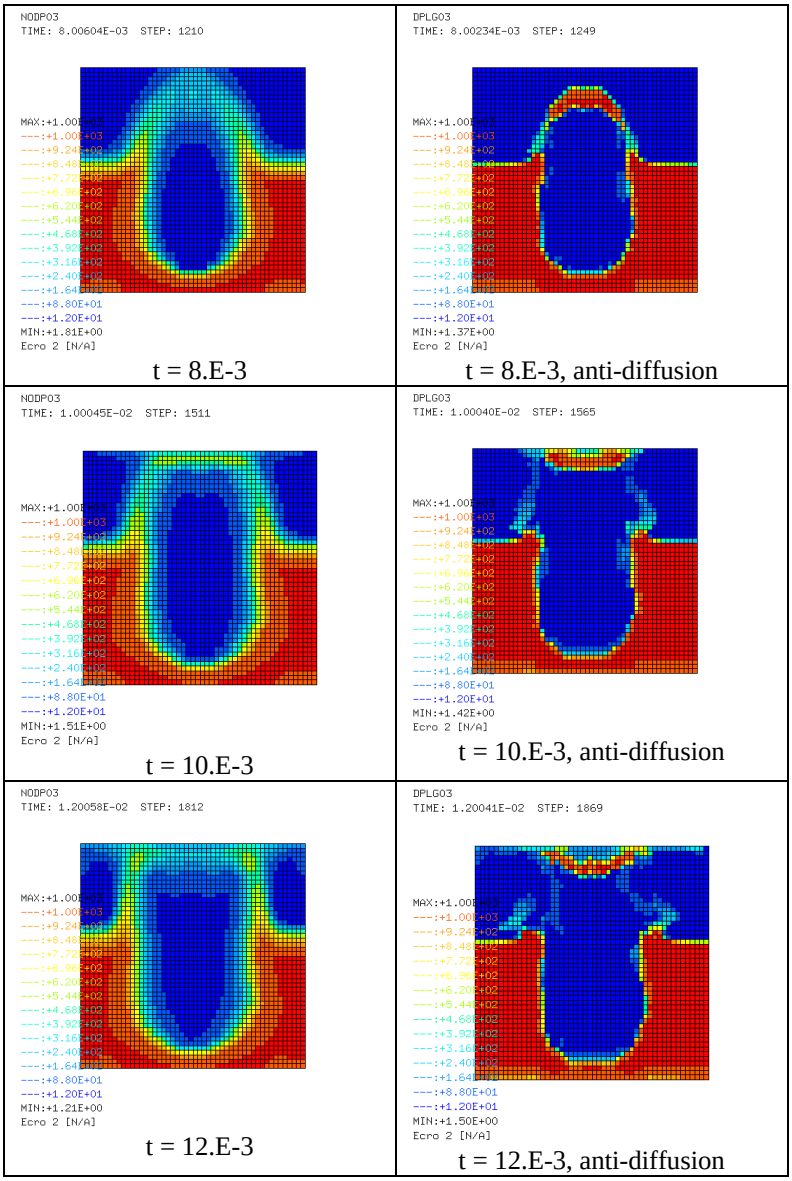


t = 6.E-3, anti-diffusion

 t = 8.E-3	 t = 8.E-3, anti-diffusion
 t = 10.E-3	 t = 10.E-3, anti-diffusion
 t = 12.E-3	 t = 12.E-3, anti-diffusion

The computed densities at some selected instants for the Cell-Centred Finite Volume solutions are shown below:





BUB05

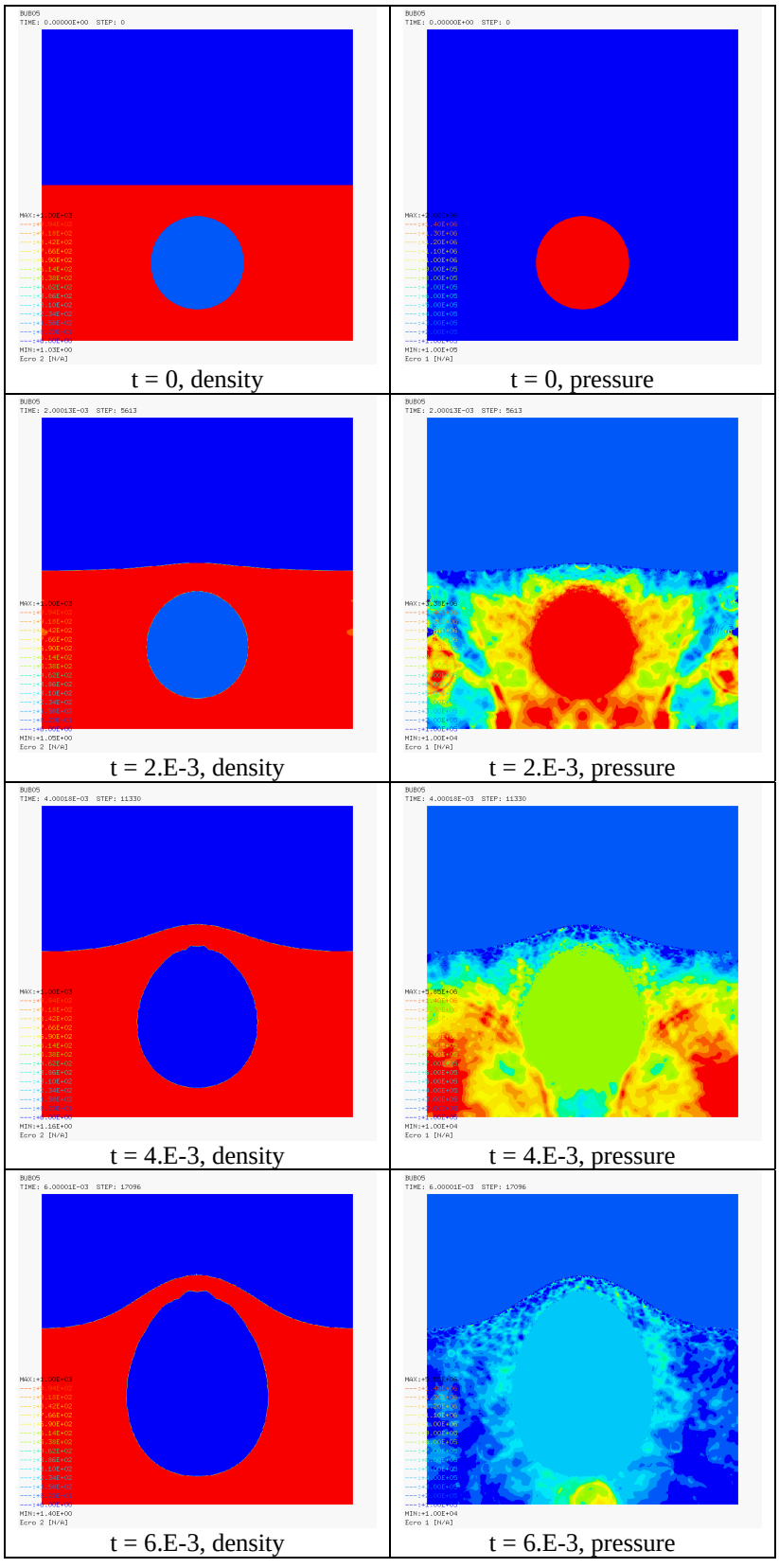
This solution uses a fine mesh with anti-diffusion.
The mesh generation file is:

```
opti echo 1;
opti dime 2 elem qua4;
opti sauv form 'bub05.msh';
opti trac psc ftra 'bub05_mesh.ps';
*
p0 = 0 0;
p1 = 1 0;
p2 = 1 1;
p3 = 0 1;
*
n = 800;
*
c1 = p0 d n p1;
c2 = p1 d n p2;
c3 = p2 d n p3;
c4 = p3 d n p0;
*
flui = dall c1 c2 c3 c4 plan;
*
blox = c2 et c4;
bloy = c1 et c3;
*
mesh = flui et blox et bloy;
tass mesh noop;
sauv form mesh;
*
trac qual mesh;
*
fin;
```

The input file is:

```
BUB05
ECHO
!CONV win
CAST mesh
DPLA EULE
GEOM CAR1 flui TERM
COMP GROU 3 'gazz' LECT flui TERM COND YB GT 0.5
           'bull' LECT flui TERM COND SPHE XC 0.5 YC 0.25 R 0.15
           'liqu' LECT flui DIFF gazz bull TERM
     COUL roug LECT bull TERM
          bleu LECT liqu TERM
          turq LECT gazz TERM
MATE ADCR RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 2.E6
          CAR 0. CBU 1.
          LECT bull TERM
     ADCR RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 0.
          LECT liqu TERM
     ADCR RONA 1000. CNA 1500. PNA 1.E5 PSAT 1.E4 ROSAT 0.1
          ROBU 1. GBU 1.4 PBU 1.E5 NBU 1.4
          ROAR 1. GAR 1.4 PARG 1.E5 PREF 1.E5
          BETA 5E-3 PTOT 1.E5
          CAR 0. CBU 1.
          LECT gazz TERM
LINK COUP BLOQ 1 LECT blox TERM
          BLOQ 2 LECT bloy TERM
ECRI VITE TFRE 1.2E-2 NOPO NOEL
     FICH ALIC TFRE 1.E-4
OPTI PAS AUTO CSTA 0.5 AMOR QUAD 4. DPLG
     LOG 1
CALC TINI 0. TFIN 1.2E-2
FIN
```

The computed densities at some selected instants are shown below:

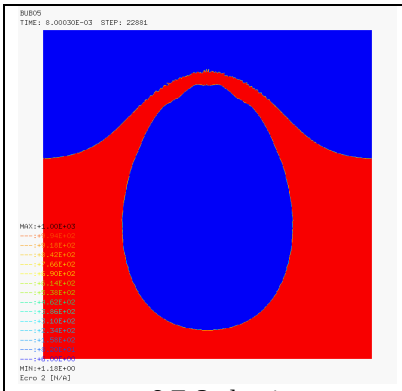


t = 0, density | t = 0, pressure

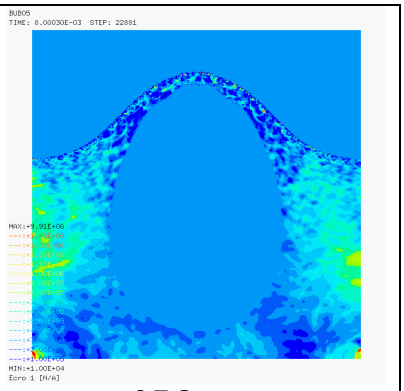
t = 2.E-3, density | t = 2.E-3, pressure

t = 4.E-3, density | t = 4.E-3, pressure

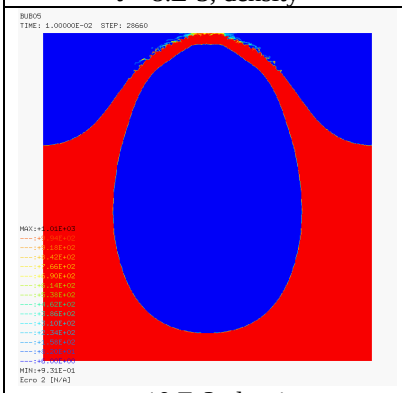
t = 6.E-3, density | t = 6.E-3, pressure



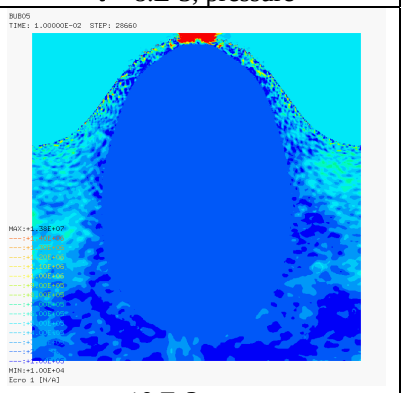
t = 8.E-3, density



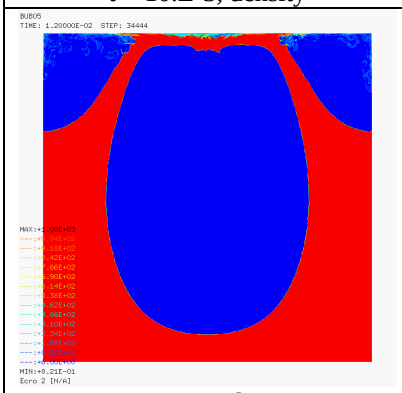
t = 8.E-3, pressure



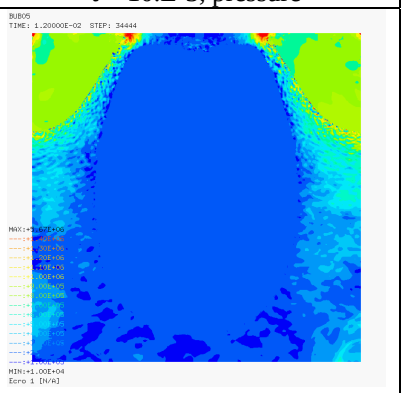
t = 10.E-3, density



t = 10.E-3, pressure



t = 12.E-3, density



t = 12.E-3, pressure