# WTN123 - Appearance/disappearance of phase in a diphasic flow: Gas injection around a gallery in a Summarized saturated

**field:**

This test represents the simulation of the gas injection in a geological medium. It is a question of modelling and of simulating the appearance and the evolution of a diphasic water/hydrogen flow in a porous environment initially saturated with pure water. One considers a situation $2D$ where the effects of gravity are neglected.

It is about a miscible purely hydraulic computation. The geometry represented corresponds to a square field whose zone was withdrawn. The terms of transfers are described by a model of Mualem Van-Genuchten. With the problem is dealt by the various diagrams available for the modelization of diphasic flows: the conventional finite elements, Eccentric Finished Volumes Edge, Eccentric Finished Volumes and the Nets Centered Finished Volumes.

This case test is an extension in $2D$ case test WTNP120.

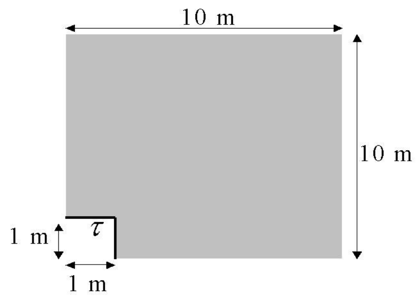
*Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.*

*Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)*

# 1 Problem of reference

## 1.1 Geometry

the field is a square of size $[0\mathrm{m},10\,m]\times[0\mathrm{m};10\mathrm{m}]$ with a hole of $[1\mathrm{m},1\,m]$ in bottom on the left.




**Appear 1.1-a: Representation of the Properties**

## 1.2 field of the materials

One gives here only the properties whose solution depends, knowing that the command file contains other data of material which do not play any part in the solution of with the dealt problem.

| | | |
|---|---|---|
| Liquid water | Density $(kg.m^{-3})$ | $1000$ |
| | Molar mass $(kg.mol^{-1})$ | $10^{-2}$ |
| | Viscosity $(kg.m^{-1}.s^{-1})$ | $10^{-3}$ |
| Gas | Density $(kg.m^{-3})$ | $8\,10^{-2}$ |
| | Molar mass $(kg.mol^{-1})$ | $2\,10^{-3}$ |
| | Viscosity $(kg.m^{-1}.s^{-1})$ | $9\,10^{-5}$ |
| dissolved Gas | Coefficient of Henry $(Pa.mol^{-1}.m^{3})$ | $130719$ |
| Vapor | Density $(kg.m^{-3})$ | $10^{-4}$ |
| homogenized Parameters | Permeability $k$ $(m^{2})$ | $5\,10^{-20}$ |
| | Porosity | $0.15$ |
| | Fick liquid $(m^{2}.s^{-1})$ | $0$ |
| | gas Fick $(m^{2}.s^{-1})$ | $0{,}45\,10^{-9}$ |
| Parameters of Van-Genuchten | $N$ | 1,49 |
| | $P_r$ $MPa$ | 2 |
| | $S_{rl}$ | 0 |
| | $S_{gr}$ | 0 |
| | $Smax$ | 0,999 |

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

| | | |
|---|---|---|
| State initial | capillary Pressure $(Pa)$<br>gas Pressure $(Pa)$ | $\begin{cases} P_l^0=10^{-6} \\ S_l=1 \end{cases} \Leftrightarrow \begin{cases} P_c^0=-10^{-6} \\ P_g^0=0 \end{cases}$ |

**Table 1.2-1 : properties of the materials**

the curves of saturation and permeabilities obey the model Mualem-Van-Genuchten (HYDR_VGM). It is thus necessary to define in the materials the parameters $n, Pr, Sr, Smax$ .

It is pointed out that these models are: $S_{le}=\frac{S_l-S_{lr}}{1-S_{lr}}$ and $m=1-\frac{1}{n}$

$$S_{we}=\frac{1}{\left[1+\left(\frac{P_c}{P_r}\right)^n\right]^m}$$

the permeability relating to water is expressed by integrating the model prediction proposed by Mualem (1976) in the model of capillarity of Van Genuchten.

$$k_r^l=\sqrt{S_{le}}\left(1-\left(1-S_{le}^{\frac{1}{m}}\right)^m\right)^2$$

The permeability with gas is formulated in a similar way by a model of Parker:

$$k_r^g=\sqrt{(1-S_{le})}\left(1-S_{le}^{\frac{1}{m}}\right)^{2m}$$

It is pointed out that for $S>Smax$ , these curves are interpolated by a polynomial of degree 2 $C1$ in $Smax$ .

For the modelization E, the model of Parker for the permeability relating to gas is replaced by a cubic model (me "HYDR_VGC"):

$$k_r^g=(1-S_l)^3$$

## 1.3 Boundary conditions and initial

the limiting conditions are the following ones:

- conditions of Neumann on the right-hand side and the left of the field:

$$(\boldsymbol{F}_l^w+\boldsymbol{F}_g^w).\boldsymbol{n}=0$$
$$(\boldsymbol{F}_l^c+\boldsymbol{F}_g^c).\boldsymbol{n}=0$$

- conditions of Neumann in hole $\tau$ :
  So $0<t<TSIM$ then $(\boldsymbol{F}_l^w+\boldsymbol{F}_g^w).\boldsymbol{n}=0$
  So $0<t<TINJ$ then $(\boldsymbol{F}_l^c+\boldsymbol{F}_g^c).\boldsymbol{n}=Q$
  So $TINJ<t<TSIM$ then $(\boldsymbol{F}_l^c+\boldsymbol{F}_g^c).\boldsymbol{n}=0$

- of the condition of Dirichlet on the part in top on the right of field:
  $P_l(9\leq x\leq 10, y=10, t)=10^6 \quad Pa$
  $P_g(9\leq x\leq 10, y=10, t)=0 \quad Pa$

The initial conditions are the following ones:

$$P_l(x, y, t=0)=10^6 \quad Pa$$
$$P_g(x, y, t=0)=0 \quad Pa$$

The hydrogen flux imposed on the left part $Q$ , is worth:

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

$$Q = 0{,}44.10^{-11}\, kg.m^{-2}.s^{-1}$$

The time of injection, $TINJ$ is $5.10^5$ years and the time of simulation is $10^6$ years.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

# 2 Modelization A

## 2.1 Characteristic of the modelization

Modelization `D_PLAN_HH2SUDM`. This modelization corresponds to the modelization Volume Finished Eccentric Nets. Coupling `LIQU_AD_GAZ`.

## 2.2 Characteristics of the mesh

One uses a mesh made up of 1632 elements `TRIA7`.

## 2.3 Quantities tested and results

One traces the profiles of pressure of gas and capillary pressure on the bottom of the field at various times:

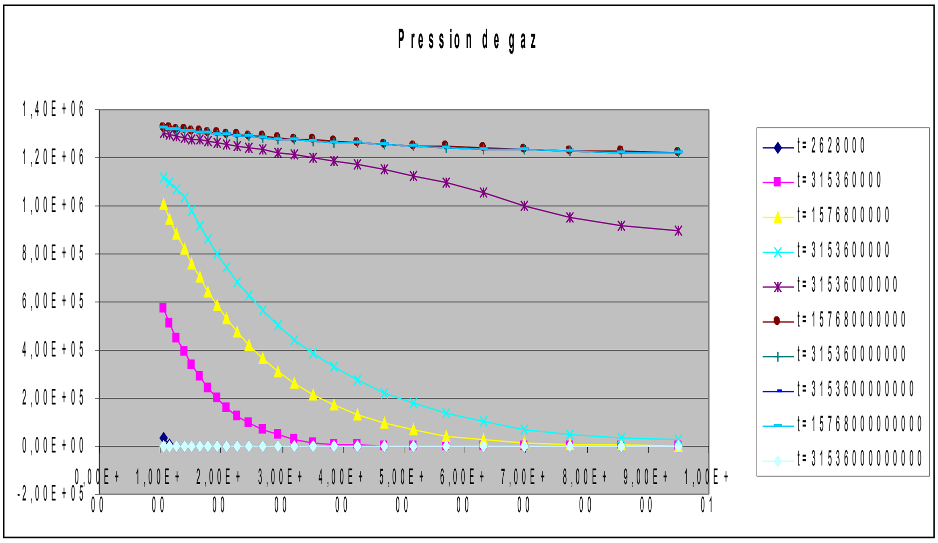



**Illustration 1: Profiles of pressure of gas,** $Y=0$

*Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.*

*Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)*

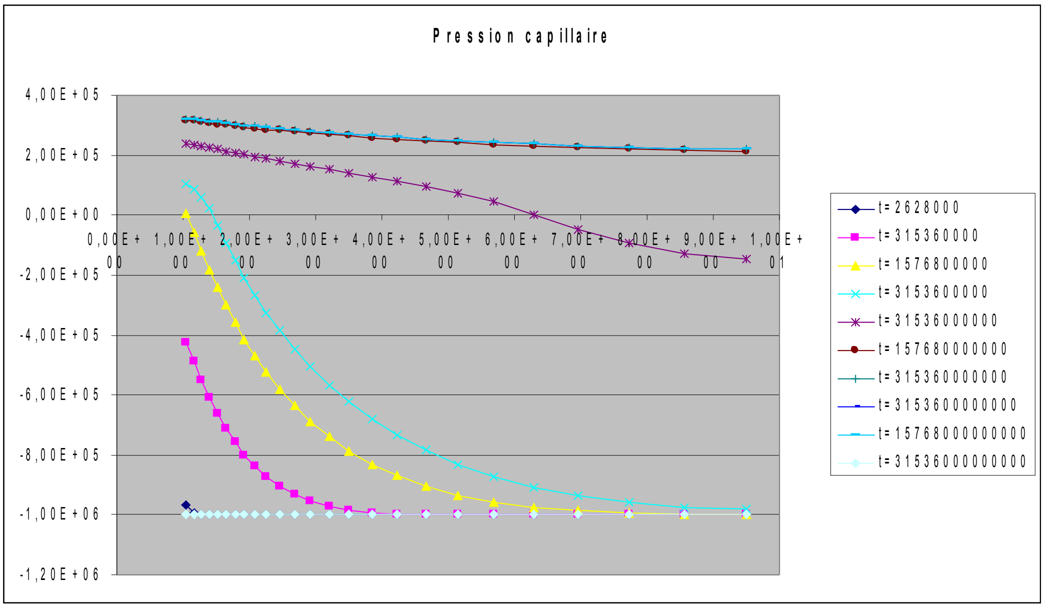



**Illustration 2: Profiles of capillary pressure, $Y=0$**

One initially notes a progressive increase in the gas pressure by dissolution (when the medium is saturated, i.e. when the capillary pressures are negative) then in gas form since the desaturation starts after 50 years. The medium goes then désaturé over all its length. Spent the time of injection, the resaturé medium and the gas pressure decreases. These results are in conformity with those expected.

This case test does not have a value of reference, one thus makes a case of non regression of them.

| Quantity | Points $(x, y)$ | Time $(s)$ | Reference | Tolerance |
|---|---|---|---|---|
| PRE1 | (1,02; 0,947) NT335 | 1 month | -9.55974E+05 | 0.01% |
| PRE1 | (5,05; 5,25) NT551 | 1 month | -9.99999E+05 | 0.01% |
| PRE1 | (9,86; 9,7) NT566 | 1 month | -9.99999E+05 | 0.01% |
| PRE2 | (1,02; 0,947) NT335 | 1 month | 44025.4 | 0.01% |
| PRE2 | (5,05; 5,25) NT551 | 1 month | 1.80789E-13 | 1.0E-12 |
| PRE2 | (9,86; 9,7) NT566 | 1 month | 4.66788E-14 | 1.0E-12 |

**Table 2.3-1: Values tested**

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

# 3 Modelization B

## 3.1 Characteristic of the modelization

Modelization D_PLAN_HH2SUDA. This modelization corresponds to the modelization Volume Finished Eccentric Edges. Coupling LIQU_AD_GAZ.

## 3.2 Characteristics of the mesh

One uses a mesh made up of 1632 elements TRIA7.

## 3.3 Quantities tested and results

the results are identical to those obtained with the modelization finished volumes eccentric nets,

This case test does not have a value of reference, one thus makes a case of non regression of them.

| Quantity | Points $(x, y)$ | Time $(s)$ | Reference | Tolerance |
|---|---|---|---|---|
| PRE1 | (1,02; 0,947) NT335 | 1 month | -9.55974E+05 | 1.0% |
| PRE1 | (5,05; 5,25) NT551 | 1 month | -9.99999E+05 | 1.0% |
| PRE1 | (9,86; 9,7) NT566 | 1 month | -9.99999E+05 | 1.0% |
| PRE2 | (1,02; 0,947) NT335 | 1 month | 44025.7 | 1.0% |
| PRE2 | (5,05; 5,25) NT551 | 1 month | 1.63287E-13 | 1.0% |
| PRE2 | (9,86; 9,7) NT566 | 1 month | 3.477E-15 | 0.010 |

**Table 3.3-1: Values tested**

*Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.*

*Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)*

# 4 Modelization C

## 4.1 Characteristic of the modelization

Modelization `D_PLAN_HH2SUC`. This modelization corresponds to the modelization Volume Finished Centered. Coupling `LIQU_AD_GAZ`.

## 4.2 Characteristics of the mesh

One uses a mesh made up of 1632 elements `TRIA7`,

## 4.3 Quantities tested and results

the results are identical that those obtained with the modelization Eccentric finished Volumes Nets.

This case test does not have a value of reference, one thus makes a case of non regression of them.

| Quantity | Points $(x, y)$ | Time $(s)$ | Reference | Tolerance |
|---|---|---|---|---|
| PRE1 | (1,02; 0,947) NT335 | 1 month | -9.55974E+05 | 1.0% |
| PRE1 | (5,05; 5,25) NT551 | 1 month | -9.99999E+05 | 1.0% |
| PRE1 | (9,86; 9,7) NT566 | 1 month | -9.99999E+05 | 1.0% |
| PRE2 | (1,02; 0,947) NT335 | 1 month | 44025.9 | 1.0% |
| PRE2 | (5,05; 5,25) NT551 | 1 month | 1.6546E-13 | 0.010 |
| PRE2 | (9,86; 9,7) NT566 | 1 month | 3.446E-15 | 0.010 |

**Table 4.3-1 : Values tested**

*Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.*

*Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)*

# 5 Modelization D

## 5.1 Characteristic of the modelization

Modelization D_PLAN_HH2S. This modelization corresponds to the modelization Finite elements. Coupling LIQU_AD_GAZ.

## 5.2 Characteristics of the mesh

One uses a mesh made up of 1632 elements TRIA6.

## 5.3 Quantities tested and results

the results are identical to those obtained with the modelization eccentric finished volumes nets.

This case test does not have a value of reference, one thus makes a case of non regression of them.

| Quantity | Points $(x, y)$ | Time $(s)$ | Reference | Tolerance |
|---|---|---|---|---|
| PRE1 | (1; 1) N6 | 1 month | -9.59793E+05 | 1.0% |
| PRE1 | (5,33; 5,30) N292 | 1 month | -9.99999E+05 | 1.0% |
| PRE1 | (9,6; 9,6) N577 | 1 month | 1.42195E-13 | 0.010 |
| PRE2 | (1; 1) N6 | 1 month | 40206.9 | 1.0% |
| PRE2 | (5,33; 5,30) N292 | 1 month | -9.99999E+05 | 1.0% |
| PRE2 | (9,6; 9,6) N577 | 1 month | 6.93178E-15 | 0.010 |

**Table 5.3-1 : Values tested**

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

# 6 Modelization E

## 6.1 Characteristic of the modelization

Even modelization that the modelization D but with a cubic model (“HYDR_VGC”) for the permeability relating to gas instead of a model of Parker.

## 6.2 Characteristics of the mesh

One uses a mesh made up of 1632 elements TRIA6.

## 6.3 Quantities tested and results

For short times when are carried out the test, saturation remains equal to one, also the choice of the model of permeability relating to gas does not influence the results which are identical to those obtained with modelization D.

This case test does not have a value of reference, one thus makes a case of non regression of them.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

# 7 Summary of the results

This case test makes it possible to have a classical problem of the numerical modelization of underground storage: gas injection in a medium saturated with $2D$. We do not have reference solutions with which to compare to us, however the values and the pace of the results are classical of this kind of problem. We thus make of them a case test of non regression. This test is treated with the 4 numerical diagrams available for the modelization of diphasic flows:

- the 3 diagrams finished volumes: centered, decentred edge, decentred mesh
- the conventional finite elements

the got results are the same ones. In term of performance and reliability, one will strongly privilege the diagrams Eccentric Finished Volumes Edge (*_HH2SUDA).

*Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.*

*Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)*