WTNP120 - Appearance/disappearance of phase in a diphasic flow: Gas injection in a bar saturated with pure water

Summarized:

This test represents the simulation of the gas injection in a saturated geological medium.

It is a question of modelling and of simulating the appearance of gas and the evolution of a diphasic water/hydrogen flow in a porous environment initially saturated with pure water. One considers a situation “quasi” - 1D where the effects of gravity are neglected. The case test is presented in a configuration 2D but it can be treated in an equivalent way like a problem 1D.

It is about a miscible purely hydraulic computation. The geometry represented corresponds to a bar. The terms of transfer 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 Nets Centered Finished Volumes and the Mesh.

1 Problem of reference

1.1 Geometry

the field is a bar of size $[0\text{m},200\,m]\times[0\text{m},1\text{m}]$:

1.2 Properties of the materials

One gives only the properties here 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}	$0{,}4$
	S_{gr}	0
	$Smax$	$0{,}999$
State initial	capillary Pressure (Pa)	$P_c^0=-10^{-6}$
	gas Pressure (Pa)	$Pgz=0$

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 $n \quad Pr \quad Sr \quad Smax$.

It is pointed out that these models are:

$$S_{le}=\frac{S_l-S_{lr}}{1-S_{lr}} \text{ and } m=1-\frac{1}{n}$$

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

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

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

The permeability with gas is formulated in a similar way:

$$k_r^w=\sqrt{(1-S_{we})}(1-S_{we}^{1/m})^{2\text{m}}$$

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

1.3 Boundary conditions and initial

the limiting conditions are the following ones:

- conditions of Neumann on the top and the bottom of the field:

$$(F_l^w+F_g^w)\cdot n=0$$
$$(F_l^c+F_g^c)\cdot n=0$$

- conditions of Neumann on the left part of the field:

So $0<t<TSIM$ then $(F_l^w+F_g^w)\cdot n=0$

So $0<t<TINJ$ then $(F_l^c+F_g^c)\cdot n=Q$

So $TINJ<t<TSIM$ then $(F_l^c+F_g^c)\cdot n=0$

- of the conditions of Dirichlet on the right part of the field:

$$P_l(x=200,y,t)=10^{-6}\,Pa$$
$$P_g(x=200,y,t)=0\,Pa$$

the initial conditions are the following ones:

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

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

$$Q=1{,}76.10^{-13}\,kg/m^2\,s$$

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

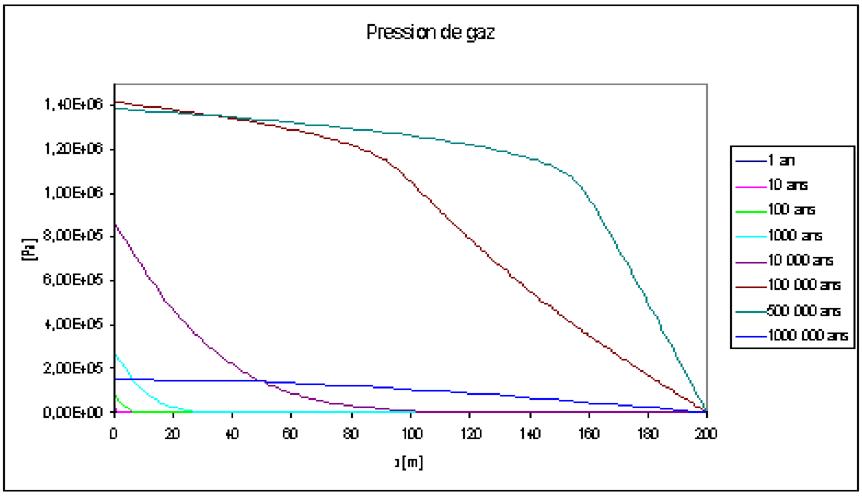
2 Modelization A

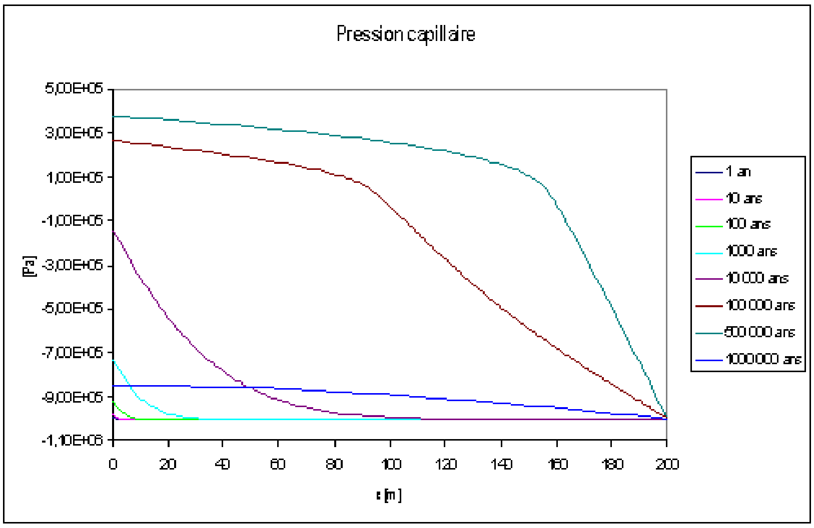
2.1 Characteristic of the modelization A

Modelization `D_PLAN_HH2SUDM`. This modelization corresponds to the modelization Eccentric Finished Volumes Nets (VFDM). Coupling `LIQU_AD_GAZ`. One uses a mesh made up of 200 elements QUAD8.

2.2 Results

One traces the profiles of pressure of gas and capillary pressures at various times:





It is noted that the gas pressure increases up to 100.000 years then decrease. It is also noted that the gas is diffused in the field in the course of time.

It is noted that one starts with désaturer from 100.000 years (when the capillary pressure becomes positive). That means that the gas is initially transported only by dissolution/diffusion.
The results are those until we wait.

2.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***
$(0,5 ; 0)$	1 year	-9.98E+005
	1000 years	-7.34E+005
$(0,5 ; 0,5)$	1 year	-9.97E+005
	1000 years	-7.34E+005
$(99,5 ; 0)$	1 year	-9.99E+005
	1000 years	-1.01E+006
$(99,5 ; 0,5)$	1 year	-9.99E+005
	1000 years	-1.00E+006
$(190,5 ; 0)$	1 year	-9.99E+005
	1000 years	-1.00E+006
$(190,5 ; 0,5)$	1 year	-9.99E+005
	1000 years	-1.00E+006

3 Modelization B

3.1 Characteristic of the modelization B

Modelization D_PLAN_HH2SUDA, this modelization correspond to the modelization Volume Finished Eccentric (VFDA) Edge. Coupling LIQU_AD_GAZ. One uses a mesh made up of 200 elements QUAD8.

3.2 Results

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

3.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***
$(0{,}5;0)$	1 year	-9.98E+005
	1000 years	-7.34E+005
$(0{,}5;0{,}5)$	1 year	-9.97E+005
	1000 years	-7.34E+005
$(99{,}5;0)$	1 year	-9.99E+005
	1000 years	-1.01E+006
$(99{,}5;0{,}5)$	1 year	-9.99E+005
	1000 years	-1.00E+006
$(190{,}5;0)$	1 year	-9.99E+005
	1000 years	-1.00E+006
$(190{,}5;0{,}5)$	1 year	-9.99E+005
	1000 years	-1.00E+006

4 Modelization C

4.1 Characteristic of the modelization C

Modelization D_PLAN_HH2SUC. This modelization corresponds to the modelization Centered Volume Finished. Coupling LIQU_AD_GAZ. 200 elements QUAD8.

4.2 Results

the results are identical that those obtained with the modelization Volumes finished eccentric on the mesh.

4.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***
$(0{,}5\,;0)$	1 year	-9.98E+005
	1000 years	-7.34E+005
$(0{,}5\,;0{,}5)$	1 year	-9.97E+005
	1000 years	-7.34E+005
$(99{,}5\,;0)$	1 year	-9.99E+005
	1000 years	-1.01E+006
$(99{,}5\,;0{,}5)$	1 year	-9.99E+005
	1000 years	-1.00E+006
$(190{,}5\,;0)$	1 year	-9.99E+005
	1000 years	-1.00E+006
$(190{,}5\,;0{,}5)$	1 year	-9.99E+005
	1000 years	-1.00E+006

5 Modelization D

5.1 Characteristic of the modelization D

Modelization D_PLAN_HH2S. This modelization corresponds to the modelization Conventional finite elements. Coupling LIQU_AD_GAZ. One uses a mesh made up of 200 elements QUAD8.

5.2 Results

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

5.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***
0	1 year	-9,95E+005
	1000 years	-7,22E+005
$(100{,}0)$	1 year	-9.99E+005
	1000 years	-1,00E+006
$(190{,}0)$	1 year	-9,99E+005
	1000 years	-1,00E+006

6 Modelization E

6.1 Characteristic of the modelization E

Modelization 3D_HH2SUDM. This modelization corresponds to the modelization Eccentric Finished Volumes Nets (VFDM). Coupling LIQU_AD_GAZ. One uses a mesh made up of 100 elements HEXA27.

6.2 Results

the results are very close to those obtained with the modelization volumes finished eccentric on the mesh.

6.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***	**PRE2** ***Aster***
$(-49{,}5 ; 0{,}5 ; 0)$ *NH4*	1 year	-9.96E+005	1,19E+003
	1000 years	-7,46E+005	2,55E+005
$(-1{,}5 ; 0 ; -0{,}5)$ *NH195*	1 year	-9.99E+005	4,96E-011
	1000 years	-1,00E+006	9,40E-006
$(-49{,}5 ; 0 ; 0{,}5)$ *NH1*	1 year	-9,99E+005	1,19E+003
	1000 years	-7,46E+005	2,55E+005

7 Modelization F

7.1 Characteristic of the modelization F

Modelization 3D_HH2SUDA. This modelization corresponds to the modelization Eccentric Finished Volumes (VFDA) Edge. Coupling LIQU_AD_GAZ. One uses a mesh made up of 502 elements HEXA27.

7.2 Results

the results are very close to those obtained with the modelization volumes finished eccentric on the mesh.

7.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***	**PRE2** ***Aster***
$(-49{,}5 ; 0{,}5 ; 0)$ *NH4*	1 year	-9.96E+005	1,19E+003
	1000 years	-7,46E+005	2,55E+005
$(-1{,}5 ; 0 ; -0{,}5)$ *NH195*	1 year	-9.99E+005	4,96E-011
	1000 years	-1,00E+006	9,40E-006
$(-49{,}5 ; 0 ; 0{,}5)$ *NH1*	1 year	-9,99E+005	1,19E+003
	1000 years	-7,46E+005	2,55E+005

8 Modelization G

8.1 Characteristic of the modelization G

Modelization 3D_HH2SUC. This modelization corresponds to the modelization Centered Finished Volumes (VFC). Coupling LIQU_AD_GAZ. One uses a mesh made up of 100 elements HEXA27.

8.2 Results

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

8.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***	**PRE2** ***Aster***
$(-49,5 ; 0,5 ; 0)$ *NH4*	1 year	-9.96E+005	1,19E+003
	1000 years	-7,46E+005	2,55E+005
$(-1,5 ; 0 ; -0,5)$ *NH195*	1 year	-9.99E+005	4,96E-011
	1000 years	-1,00E+006	9,40E-006
$(-49,5 ; 0 ; 0,5)$ *NH1*	1 year	-9,99E+005	1,19E+003
	1000 years	-7,46E+005	2,55E+005

9 Modelization H

9.1 Characteristic of the modelization H

Modelization 3D_HH2S. This modelization corresponds to the modelization Finite elements. Coupling LIQU_AD_GAZ. One uses a mesh made up of 100 elements HEXA20.

9.2 Results

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

9.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***	**PRE2** ***Aster***
$(-49\ ;-0{,}5\ ;0{,}5)$ *N6*	1 year	-9,99E+005	2,168E+003
	1000 years	-7,45E+005	2,55E+005
$(-47\ ;-0{,}5\ ;0{,}5)$ *N16*	1 year	-1,00E+006	2,322E-001
	1000 years	-7,91E+006	2,10E+005
$(-48\ ;-0{,}5\ ;-0{,}5)$ *N716*	1 year	-1.00E+006	7,86
	1000 years	-7,69E+005	2,32E+005

10 Modelization I

10.1 Characteristic of the modelization I

Modelization 3D_HH2MS. The purpose of this modelization corresponds to the modelization Finite elements and is just testing modelization 3D_HHMS with imposed flux. Displacements are blocked on edges of the field. Coupling LIQU_AD_GAZ. One uses a mesh made up of 100 elements HEXA20.

10.2 Results

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

10.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	Time (s)	PRE1 *Aster*	PRE2 *Aster*
$(-49\ ;-0{,}5\ ;0{,}5)$ $N6$	1 year	-9,99E+005	2,168E+003
	1000 years	-7,45E+005	2,55E+005
$(-47\ ;-0{,}5\ ;0{,}5)$ $N16$	1 year	-1,00E+006	2,322E-001
	1000 years	-7,91E+006	2,10E+005
$(-48\ ;-0{,}5\ ;-0{,}5)$ $N716$	1 year	-1.00E+006	7,86
	1000 years	-7,69E+005	2,32E+005

11 Modelization J

11.1 Characteristic of the modelization J

Modelization 3D_HH2MD. The purpose of this modelization corresponds to the modelization Finite elements and is just testing modelization 3D_HHMD with imposed flux. Displacements are blocked on edges of the field. Coupling LIQU_AD_GAZ. One uses a mesh made up of 100 elements HEXA20.

11.2 Results

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

11.3 Values tested

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

One carries out tests on 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***	**PRE2** ***Aster***
$(-49\ ;-0{,}5\ ;0{,}5)$ *N6*	1 year	-9,99E+005	2,168E+003
	1000 years	-7,45E+005	2,55E+005
$(-47\ ;-0{,}5\ ;0{,}5)$ *N16*	1 year	-1,00E+006	2,322E-001
	1000 years	-7,91E+006	2,10E+005
$(-48\ ;-0{,}5\ ;-0{,}5)$ *N716*	1 year	-1.00E+006	7,86
	1000 years	-7,69E+005	2,32E+005

12 Summary of the results

This test makes it possible to reproduce a classical case of the literature and modelization of storage: gas injection in a saturated medium. We do not have precise reference solutions with which to compare to us, however the values and the pace of the results are in conformity with those of the literature. We thus make of them a case test of non regression.

This case test makes it possible to test the various diagrams available for the modelization of diphasic flows in 2D and 3D:

- The conventional finite elements
- Eccentric Finished Volumes Edge (modelization * _HH2SUDA)
- Eccentric Finished Volumes Nets (modelization *_HH2SUDM)
- Centered Finished Volumes Mesh (modelization *_HH2SUC)

These diagrams give all of the very close results. In terms of performance and reliability, one will strongly privilege the diagrams Eccentric Finished Volumes Edge (*_HH2SUDA).