WTNA105 – Gas injection in a material quasi-saturated with standard clay describes by laws of Van-Genuchten/Mualem

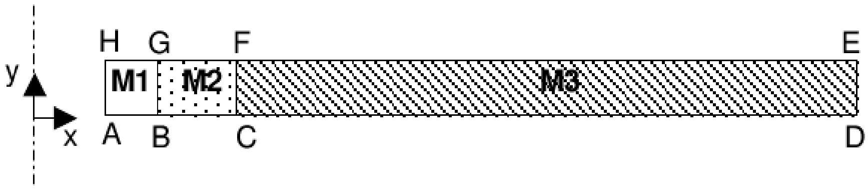
Summary:

This test represents the simulation of the gas injection in a geological medium. It is about a purely hydraulic calculation. The geometry represented corresponds to a radial cut around a parcel of storage. The medium, made up of a functional vacuum, a damaged zone and a geological barrier of type Callovo-Oxfordien (clay) is initially almost saturated. The medium is described by a model of Mualem Van-Genuchten. This test also enables us to test the hydraulic law called by `HYDR_VGM`.

1 Problem of reference

1.1 Geometry

The field is an axisymmetric slice:



Coordinates of the points:

Not	X	Y
A	0.3075	0
B	0.3375	0
C	0.5375	0
D	200	0
E	200	1
F	0.5375	1
G	0.3375	1
H	0.3075	1

The zone $M1$ represent the game and is made up by material $MATJEU$.
The zone $M2$ represent the damaged zone and is made up by material $MATZE$.
The zone $M3$ represent the clay of the ground and is made up by material $MATCOX$.

1.2 Properties of 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.

$MATJEU$		
Liquid water	Density ($kg.m^{-3}$) Viscosity ($kg.m^{-1}.s^{-1}$) Compressibilté (Pa^{-1})	1000 10^{-3} $0.5\ 10^{-9}$
Gas	Density ($kg.m^{-3}$) Viscosity ($kg.m^{-1}.s^{-1}$)	$2\ 10^{-3}$ $1.8\ 10^{-5}$
Dissolved gas	Coefficient of Henry ($Pa.mol^{-1}m^{3}$)	1870
Vapor	Density ($kg.m^{-3}$)	$18\ 10^{-3}$
Homogenized parameters	Permeability K (m^{2}) Porosity	$1{,}019\ 10^{-13}$ 0.3

	Fick gas ($m^2.s^{-1}$)	0.0015. ($Smax-S$)
	Liquid Fick ($m^2.s^{-1}$)	4.47 10 $^{-10}$. S
Parameters of Van-Genuchten	N	1.064
	Pr (Mpa)	4.91 10^{-3}
	Sr	0.08
	$Smax$	0.999
Initial state	Capillary pressure (Mpa)	$P_c^0=89\ (S=0{,}77)$
	Gas pressure (Mpa)	$Pgz=0{,}1$

MATZE		
Liquid water	Density ($kg.m^{-3}$)	1000
	Viscosity ($kg.m^{-1}.s^{-1}$)	10^{-3}
	Compressibilté (Pa^{-1})	0.5 10^{-9}
Gas	Density ($kg.m^{-3}$)	2 10^{-3}
	Viscosity ($kg.m^{-1}.s^{-1}$)	1.8 10^{-5}
Dissolved gas	Coefficient of Henry ($Pa.mol^{-1}m^3$)	1870
Vapor	Density ($kg.m^{-3}$)	18 10^{-3}
Homogenized parameters	Permeability K (m^2)	5,097 10^{-18}
	Porosity	0.15
	Fick gas ($m^2.s^{-1}$)	0.00075. ($Smax-S$)
	Liquid Fick ($m^2.s^{-1}$)	2.24 10 $^{-10}$. S
Parameters of Van-Genuchten	N	1.5
	Pr (Mpa)	4.91
	Sr	0
	$Smax$	0.999
Initial state	Capillary pressure (Mpa)	$P_c^0=0{,}1$
	Gas pressure (Mpa)	$Pgz=0{,}1$

MATCOX		
Liquid water	Density ($kg.m^{-3}$)	1000
	Viscosity ($kg.m^{-1}.s^{-1}$)	10^{-3}

	Compressibilté (Pa^{-1})	0.5 10^{-9}
Gas	Density ($kg.m^{-3}$) Viscosity ($kg.m^{-1}.s^{-1}$)	2 10^{-3} 1.8 10^{-5}
Dissolved gas	Coefficient of Henry ($Pa.mol^{-1}m^3$)	1870
Vapor	Density ($kg.m^{-3}$)	18 10^{-3}
Homogenized parameters	Permeability K ($m2$) Porosity Fick gas ($m^2.s^{-1}$) Liquid Fick ($m^2.s^{-1}$)	5.097 10^{-21} 0.15 0.00075. (Smax-S) 2.24 10^{-10} . S
Parameters of Van-Genuchten	N Pr (Mpa) Sr $Smax$	1.49 14.7 0.01 0.999
Initial state	Capillary pressure (Mpa) Gas pressure (Mpa)	$P_c^0 = 89\ (S = 0{,}77)$ $Pgz = 0{,}1$

The curves of saturation and permeabilities obey the Mualem-Van-Genuchten model (`HYDR_VGM`). It is thus necessary to define in materials the parameters N, Pr, Sr, $Smax$.
It is pointed out that these models are:

$$S_{we} = \frac{S - S_{wr}}{1 - S_{wr}} \text{ and } m = 1 - \frac{1}{n}$$

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

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

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

The permeability to gas is formulated in a similar way:

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

One recalls that for $S > Smax$, these curves are interpolated by a polynomial of degree 2 $C1$ in $Smax$.

1.3 Boundary conditions and initial

One imposes on the border of left a hydrogen flow and a water flow (modeling of corrosion):

$$Flux_{H20}=-2,13.10^{-10}\,kg/m^2 s$$

$$Flux_{H2}=2,37.10^{-11}\,kg/m^2 s$$

Initially, the initial capillary pressure is:

1) For the game $Pc=5,18\,Mpa$
2) For the damaged zone and Cox: $1\,atm$

The gas pressure is initially of $1\,atm$ everywhere.

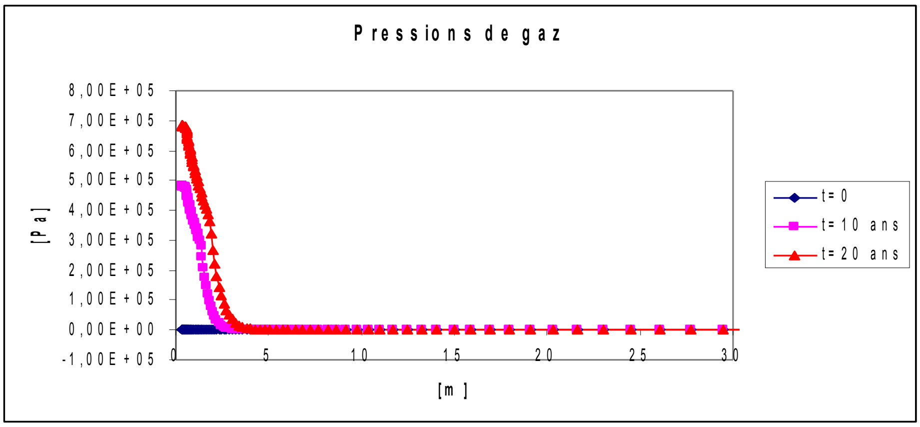
2 Modeling A

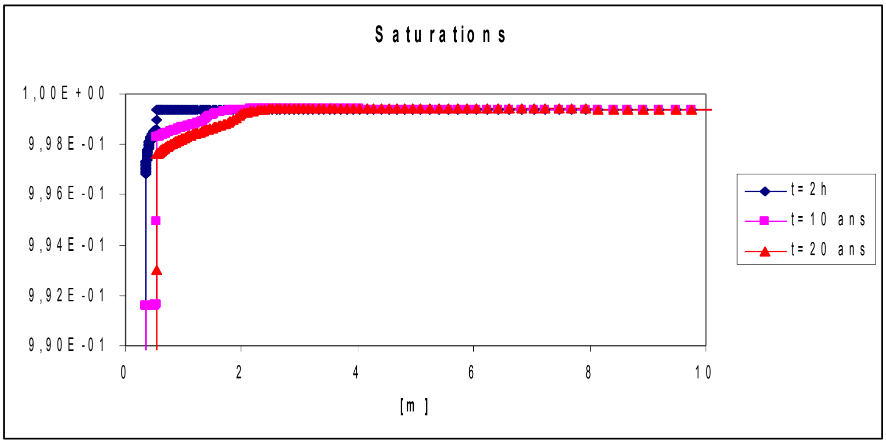
2.1 Characteristics of modeling A

Modeling HHS in plane deformations. Coupling LIQU_GAZ. 100 elements QUAD8

2.2 Results

One traces the profiles of pressure of gas and saturation (zoom) with 10 and 20 years:





One observes a rise of gas pressure well ($0{,}7\,Mpa$ at 20 years) in edge of parcel as well as very a slight decrease of saturation in the geological barrier. One sees the influence of the diffusion well by observing the unhooking of gas pressure corresponding to the projection of the face of saturation.

2.3 Values tested

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

One carries out tests on 4 values:

$X(m)$	**Time** (s)	**PRE2** ***Aster***	**Authorized relative error**
0.3075	10 years	4.81E5	0,001%
0.3075	20 years	6.83E6	0,001%
1.012	10 years	3.58E5	0,001%
1.012	20 years	5.36E5	0,001%

3 Summary of the results

This case test answers well one of its objectives: to test the functionality of HYDR_VGM. Moreover it makes it possible to have a classical problem of the digital modeling of underground storage: gas injection in a quasi-saturated medium. 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 nonregression.