DIRECTION
TECHNIQUE
DIPNN
LA GRANDE HALLE

VERCORS

Benchmark III

23/10/2020
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SUMMARY

- The French Nuclear Fleet
- Double Wall Containment
- Containment leakage (IRLT)
- Birth of VERCORS*
- Why a 1/3 scale ?
- What's inside the beast ?
- Data management ? What is CERVIN ?
- Why a 3rd Benchmark on VERCORS ?
- Global Planning
- Calibration challenge !

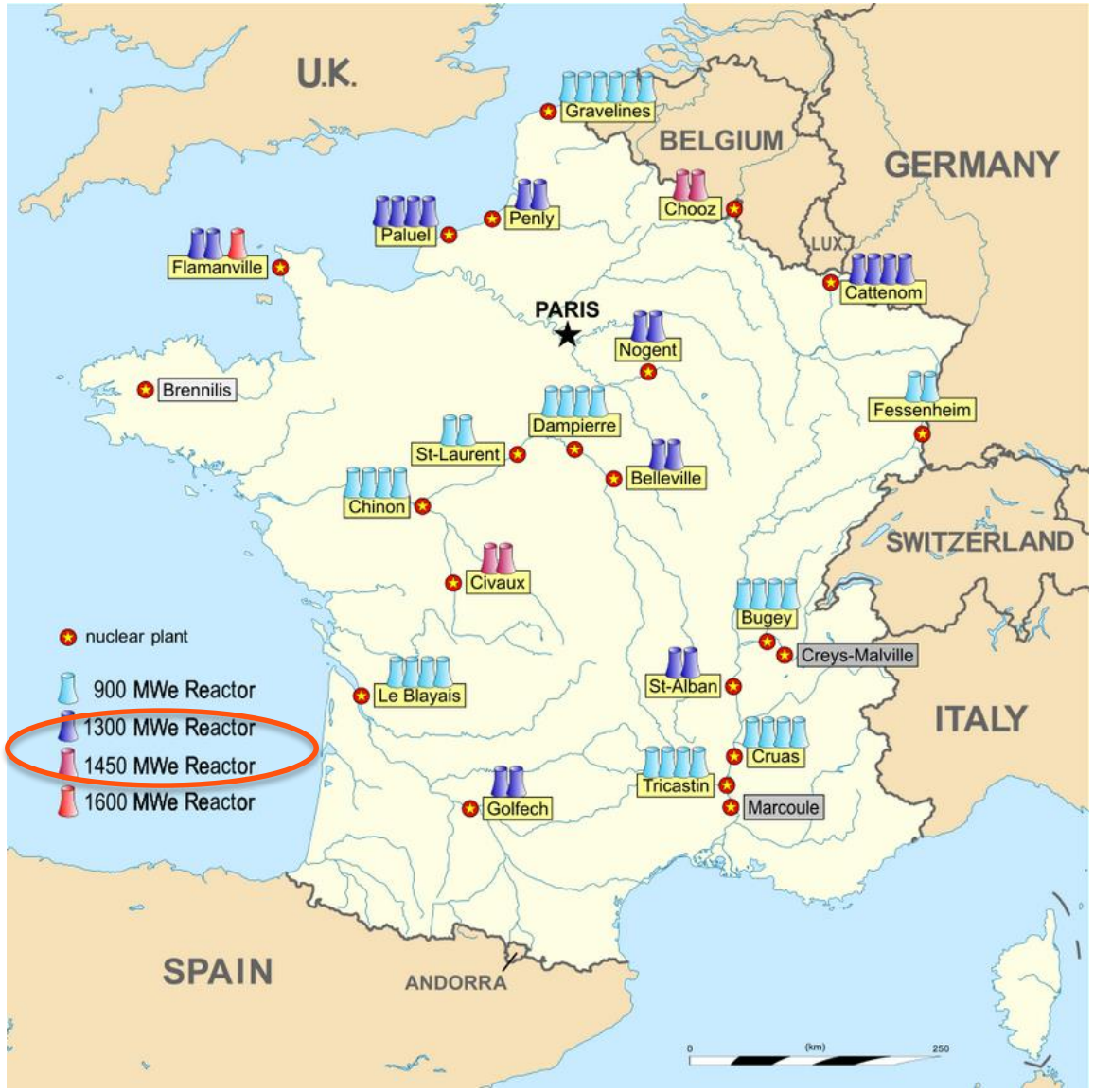
- F A Q : Funding
- F A Q : Modeling of VERCORS ? Code-Aster ?
- F A Q : global & local leakage ?
- F A Q : SUGTEN** method ?
- F A Q : In summary what will you have ?

This benchmark receives EU funding through a Euratom project named ACES, and is supported by OECD-NEA & ACI

*French acronym for **VE**rification **R**éaliste du **CO**nfinement des **R**éacteur**S**

French acronym for **SUivi en phase de **G**onflage du **T**aux de fuite de l'**EN**ceinte

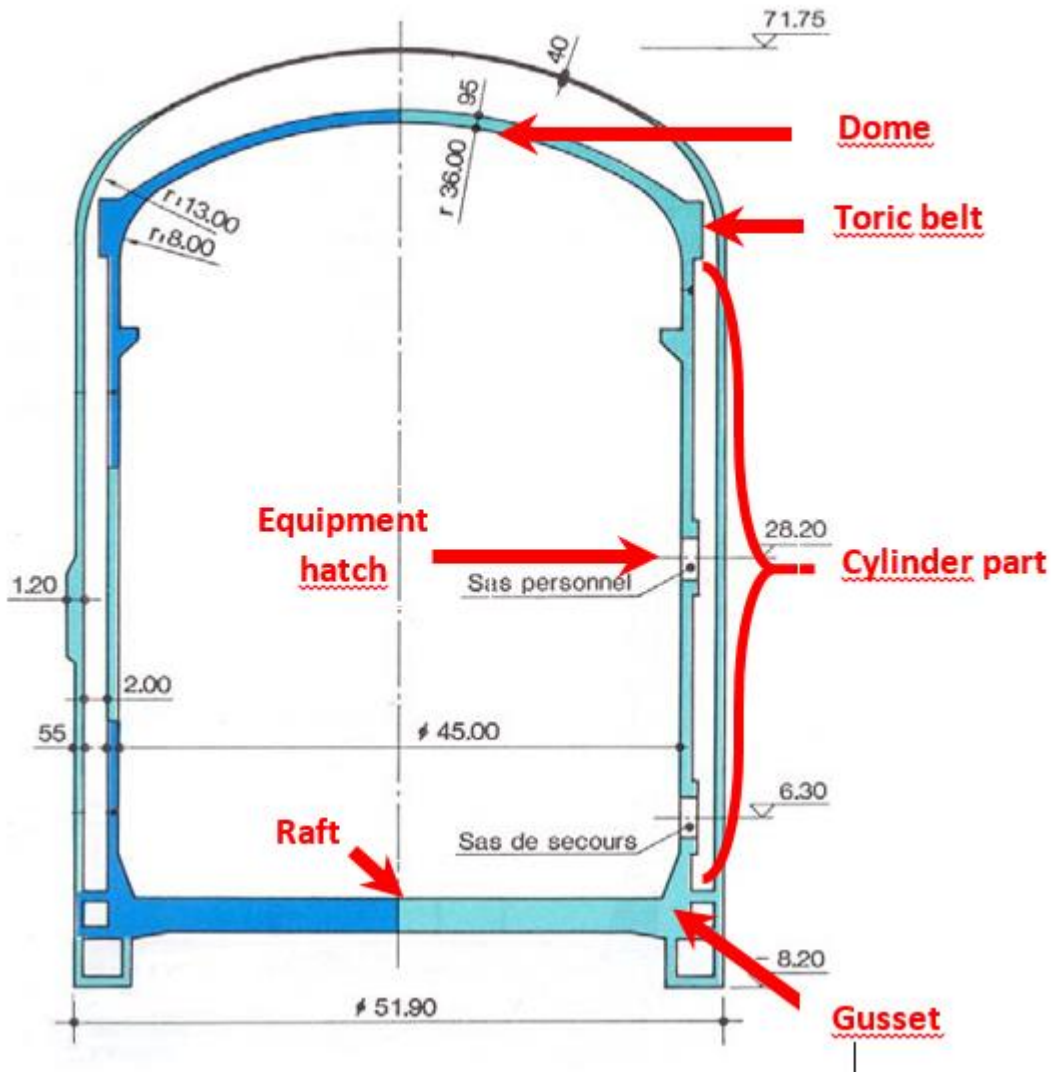
The French Nuclear Fleet ?



Electricité de France (EDF) operates a large fleet of nuclear reactors and is responsible for demonstrating the safety of facilities, including concrete containment buildings (CCB), which are non-replaceable components.

Choices made by EDF in early 70’ during the switch from 900 MWe nuclear power plant (NPP) to 1300 MWe NPP lead to a **drastic** change in the design of the containment buildings.

Double Wall Containment ?

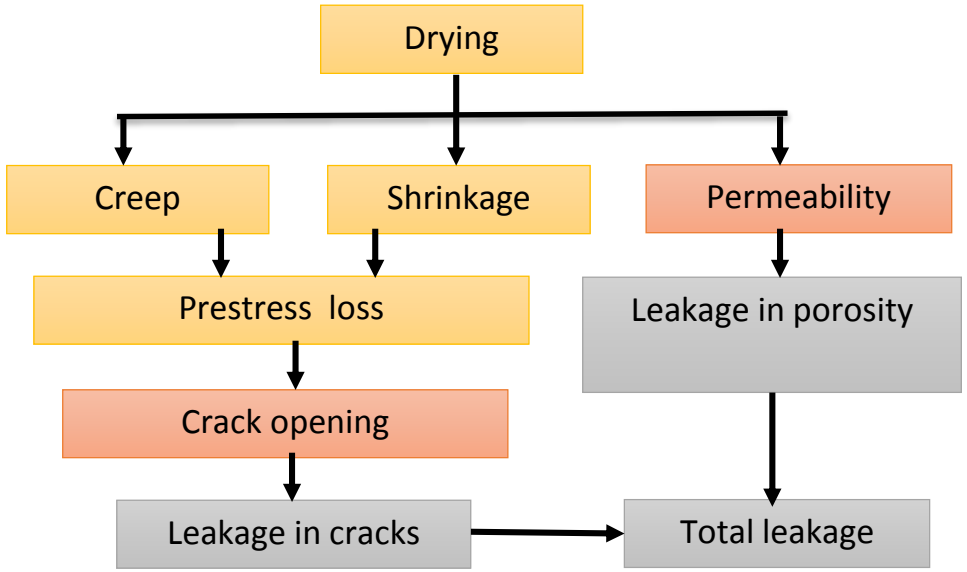


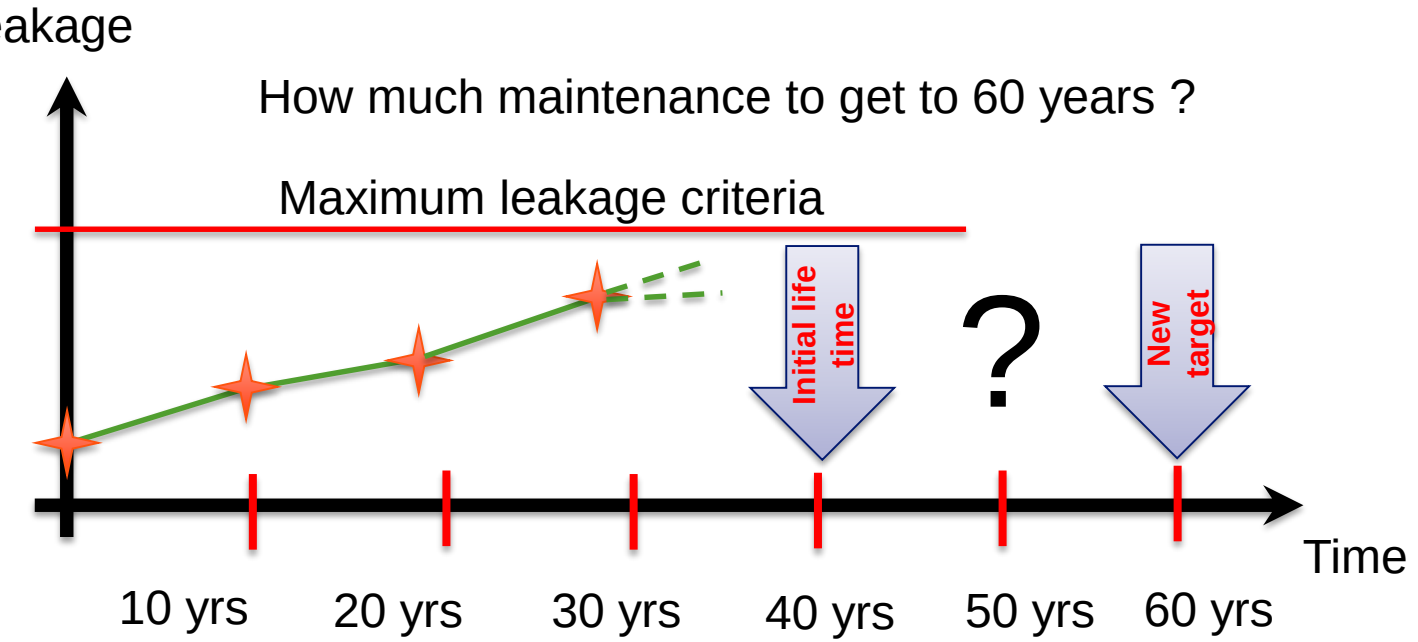
Instead of ensuring the leak-tightness of the single pre-stressed concrete wall with a steel liner, the leak-tightness is obtained thanks to the duplication of the containments, and with an active system that keeps the space between those containments under a constant depresuization (-60 hPa).

This system improved the nuclear safety of the NPP in a way that the potential radiological elements due to accidental situations can be pumped up and filtered instead of being released in the atmosphere. In addition, the design provides better protection against aircraft impacts.

However, even if the leak-tightness function relies on both containments, there is still an allowed maximum leak criterion on the first pre-stressed containment which is **1,5 % of the dry air mass per day.**

Containment leakage (IRLT) ?





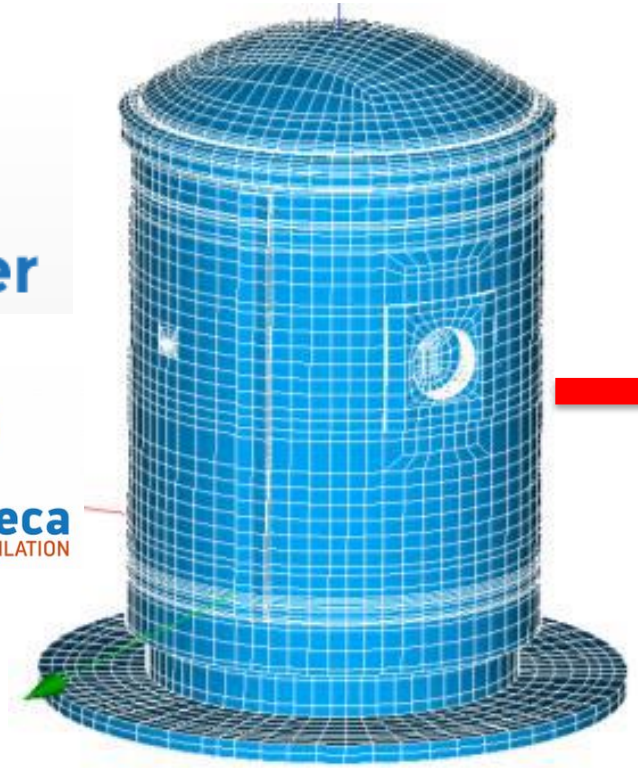
The leak-tightness of CCBs is assessed every 10 years during **I**ntegrated **L**eak-**R**ate **T**ests (IRLT). For double-wall containments, which have no metallic liners, the leak-tightness is strongly influenced by the degree of cracking of concrete and opening of the cracks, which mostly depends on (a) the prestress decrease due to the delayed strains of concrete, and (b) the saturation degree of the concrete wall.

Therefore, to **optimize** the maintenance programs on CCBs, it is important to **predict** the evolution of drying, creep shrinkage strains of concrete to be able to correctly assess the pre-stress losses, and finally the air leak-tightness at a structural level during pressure tests or under accidental loadings.

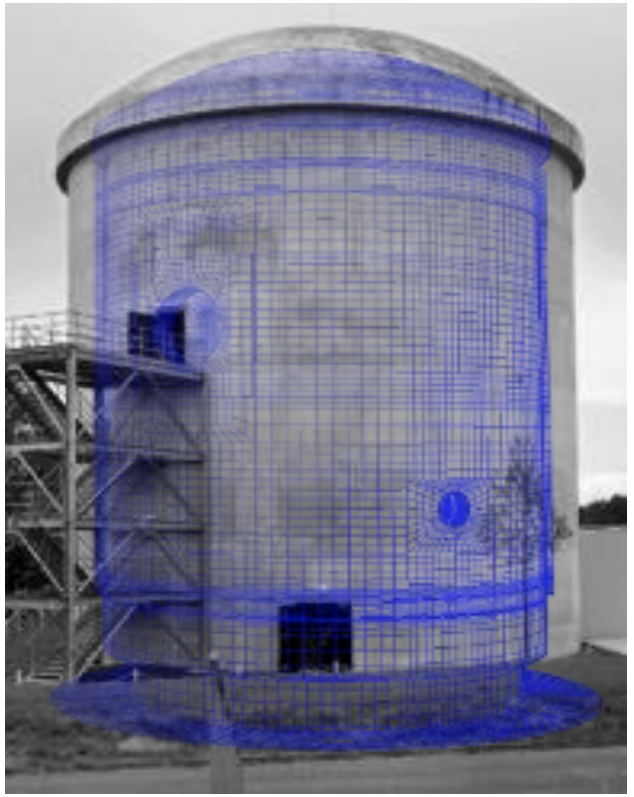
A new tool for the owners !

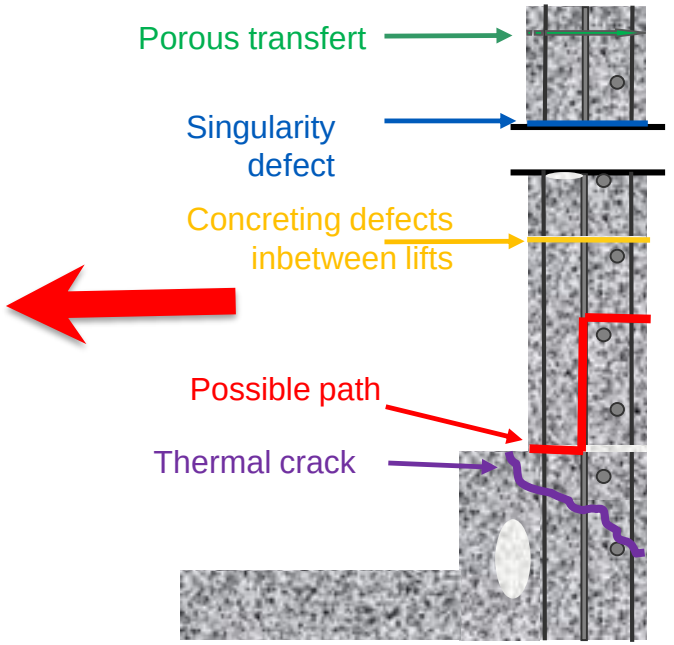
code_aster

salome_meca
EXPERIENCE OPEN SIMULATION



Numerical difficulty

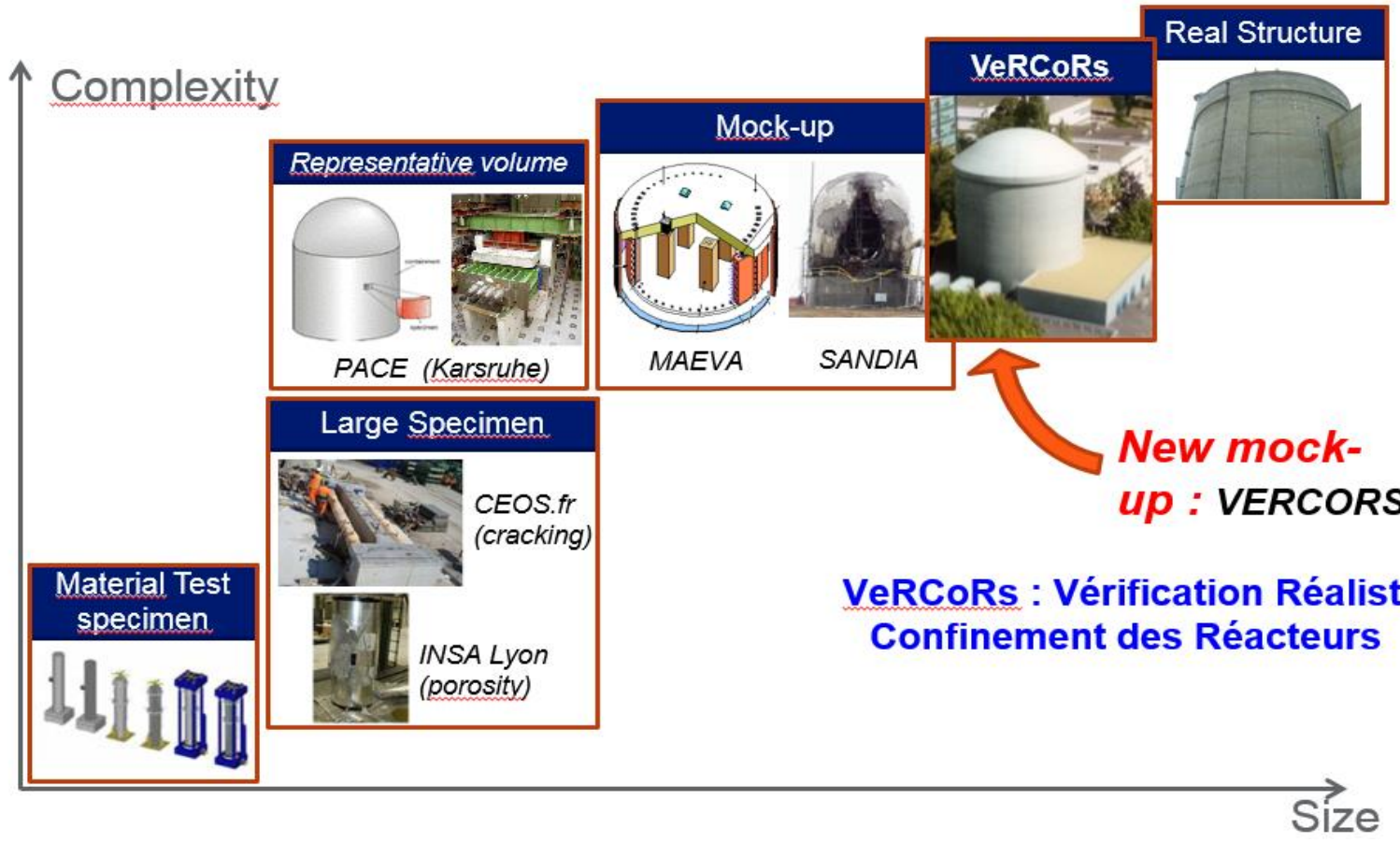




Physical complexity

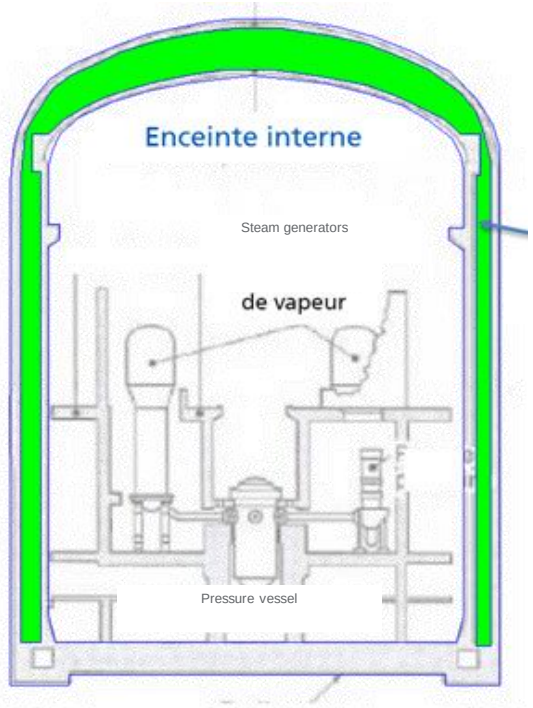
To strengthen its approach, EDF performs numerical simulations with Code-Aster® in order to assess the safety margins of the containments on the long term (60 years) regarding the mechanical and the leak-tightness behaviours.

Birth of VERCORS* from the international feedback !

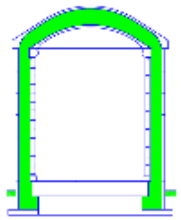


REAL CCB !

P'4 : 1300 MWe CCB



VERCORS



To improve our understanding and identify the best modelling practices on this issue, a large experimental program called VERCORS was launched in 2014. VERCORS is a **1/3 mock-up** of a 1300 MWe nuclear reactor CCB. It is widely instrumented, and its concrete thoroughly studied. A specific attention has been paid to ensure it is consistent with real CBBs features in EDF's nuclear fleet.

*VERCORS : **VE**rification **R**éaliste du **CO**nfinement des **R**éacteur**S**

How does VERCORS' mock up look now ?

This is how it looks with a good weather

This is how it looks with a bad weather

In both case it looks nice !

Why a 1/3 scale ?

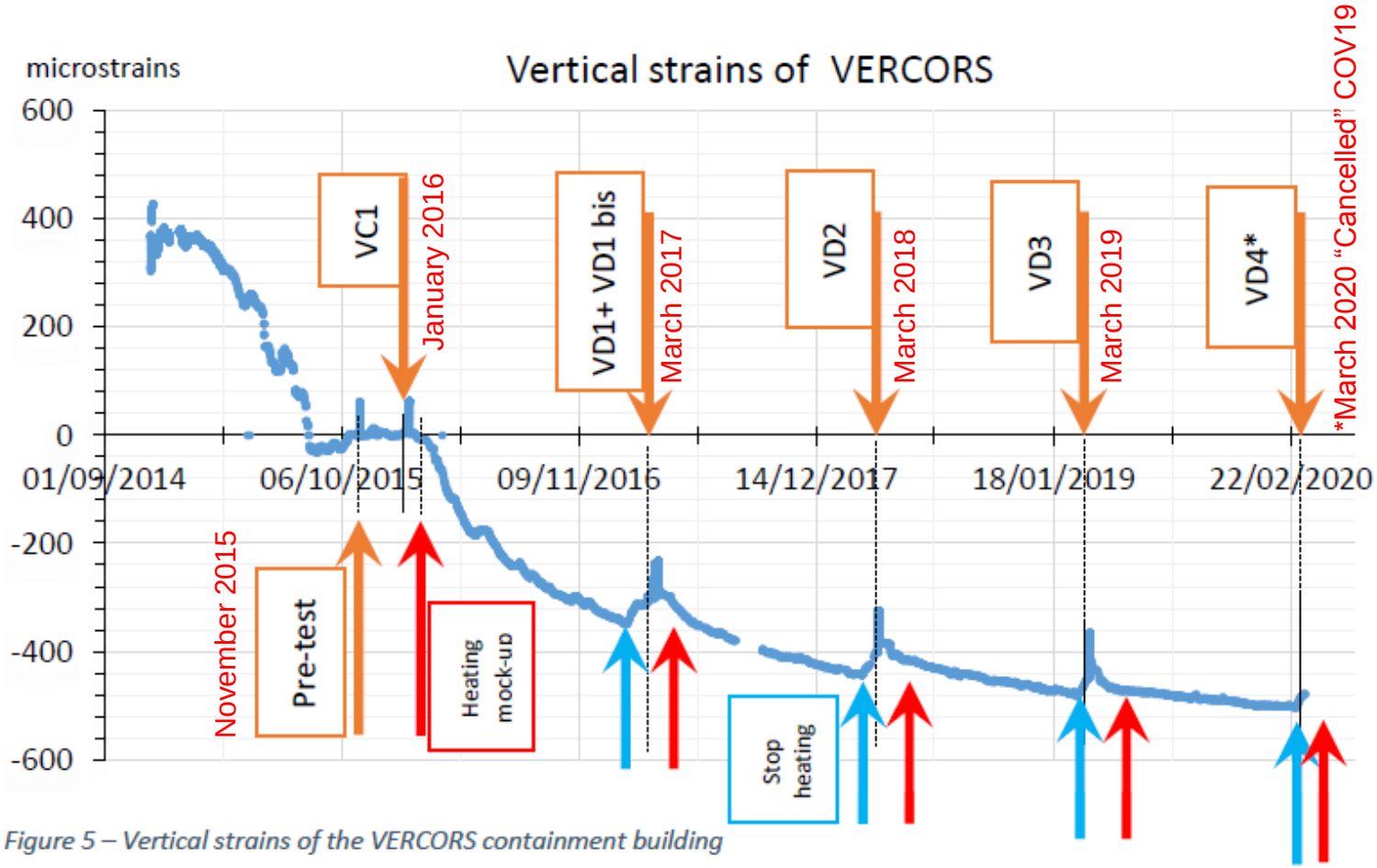
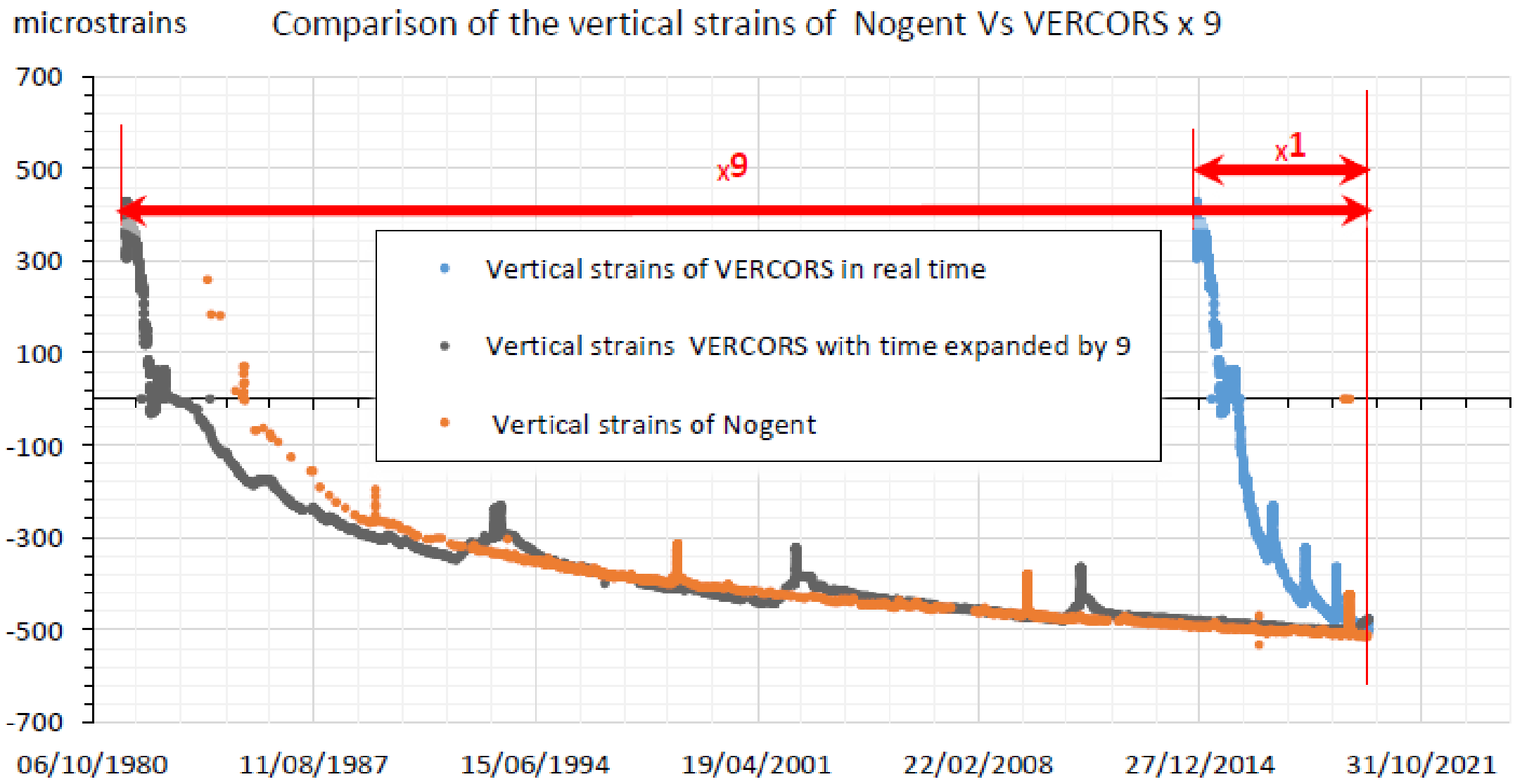


Figure 5 – Vertical strains of the VERCORS containment building

This ratio of 1/3 has been decided as it is considered to represent an optimum between **representativity** of the mock-up (at this scale, it is possible to represent the main features of a real CCB) and **acceleration of drying**, and hence, ageing of the mock-up.

Based on diffusion theory equations, EDF estimated that thanks to its 1/3 scale the acceleration of drying would approximately be speeded up by a **factor of 9** in comparison with the real CCB.

Why a 1/3 scale? And how does it look today from the real CCB?



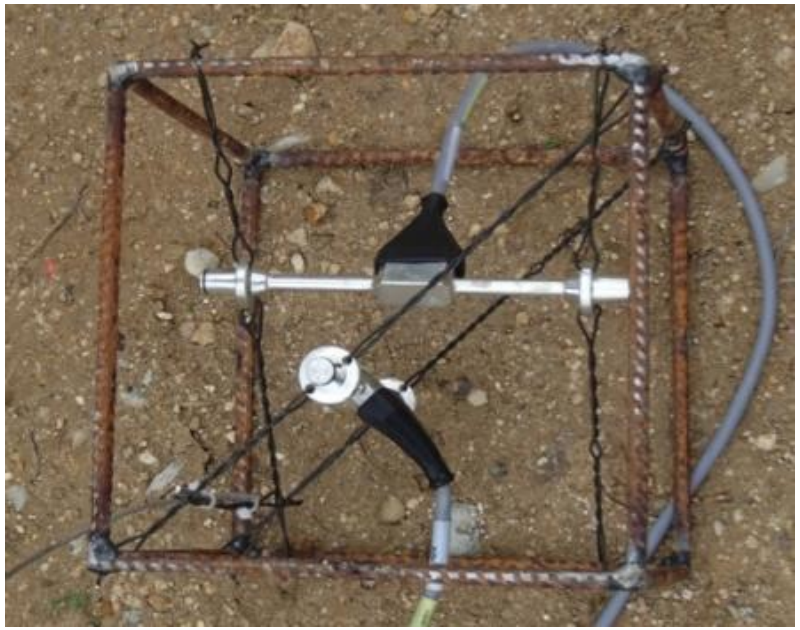
What’s inside the beast ?

12 Pendulums

6 Dynamometers for instrumented tendons (VW6 + GLOTZL)

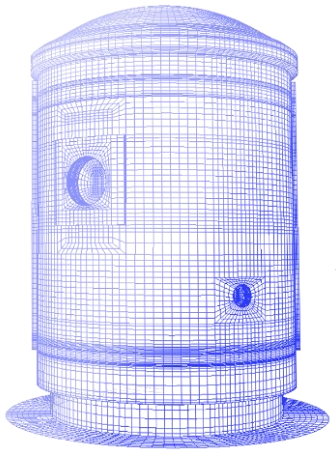
Temperature PT100 (211)

- 1 meteorological station
- For the ambient air measure : 10 thermometers, 10 relative humidity sensors,
- 1 atmospheric pressure gage,
- 1 flow meter
- 2 km of optic fiber
- 31 TDR (Time Domain Reflectometry) sensors
- 30 « pulse » sensors (permeability measurement)
- 160 strain gauges on rebars



Embedded strain sensors (326)

How do we deal with so much data? And what to do with it?

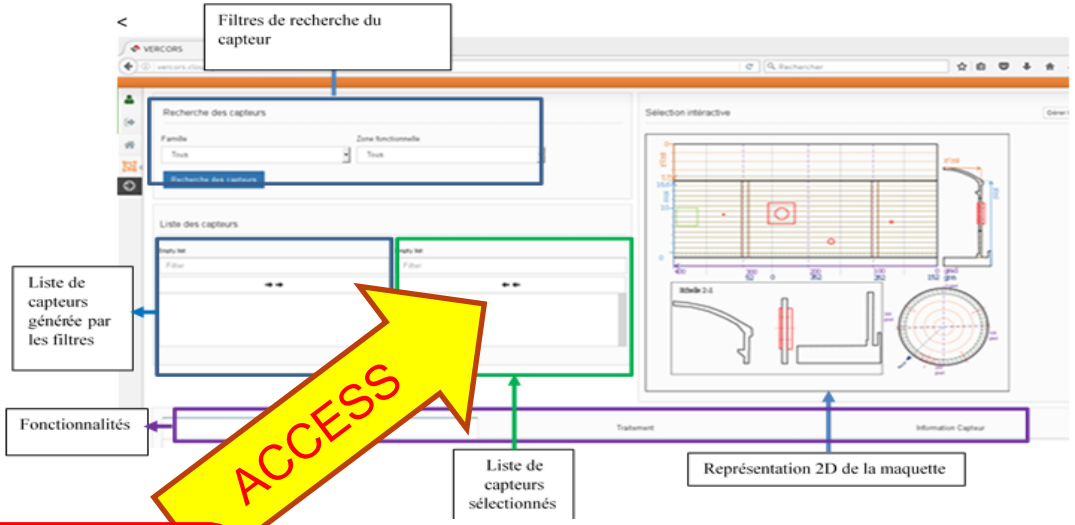


MODEL

R&D

Salome-Meca

Code_Aster



ACCESS

Direction Technique R&D

ARMORIC

CERVIN

Ingénieurs terrain
Direction Technique
R&D

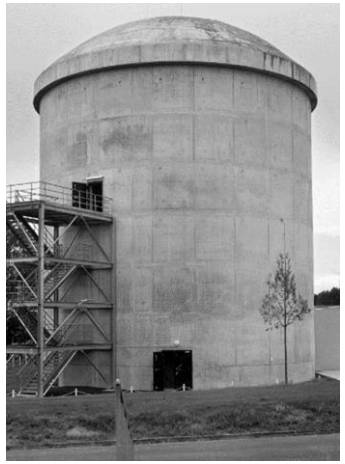
DTG

KOALA

SAV

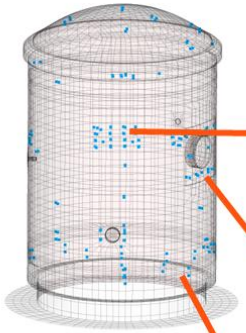
Direction Industrielle R&D

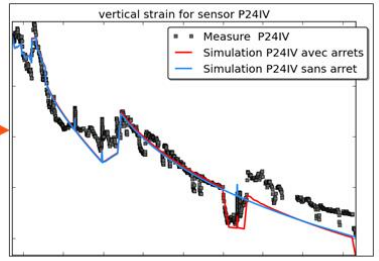
CADEEX



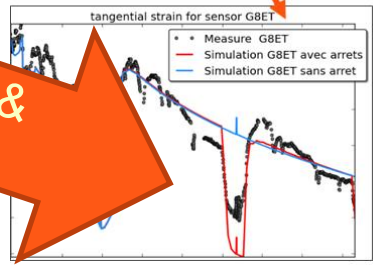
BENCHMARK 3

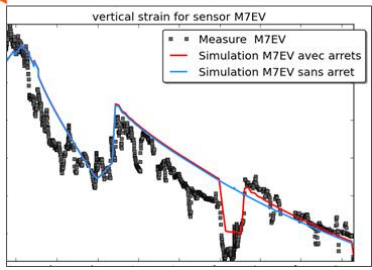
DATA





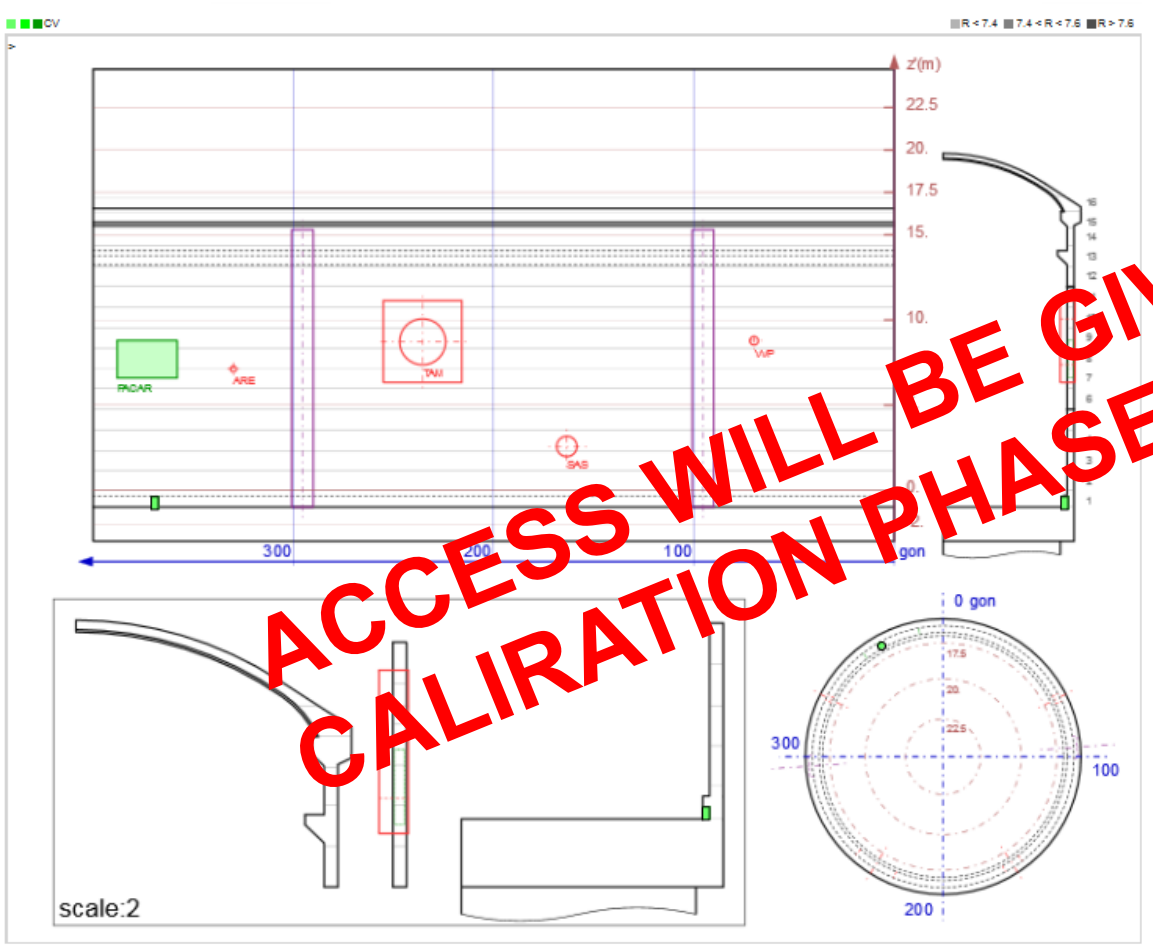
COMPARE DATA & MODEL

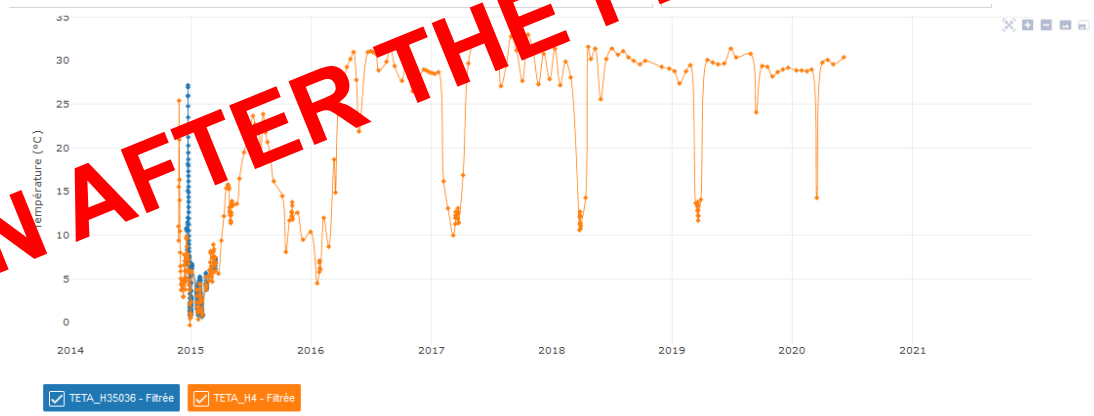


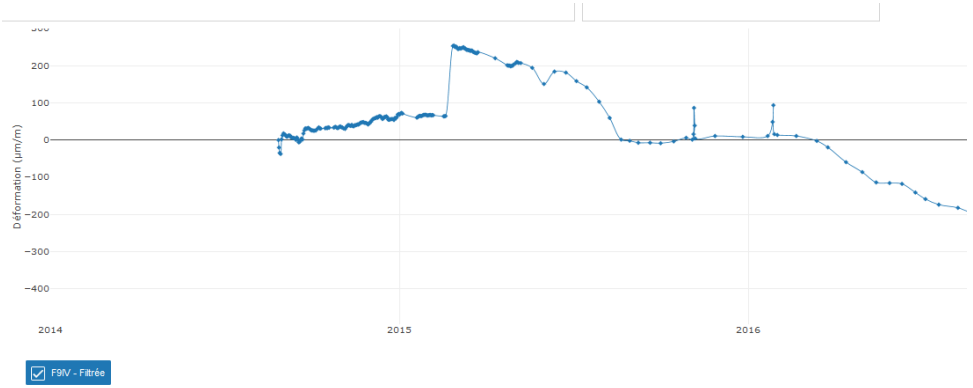


What is CERVIN ?

To make it simple CERVIN is a platform which allows you to access easily to all the data collected on VERCORS.







ACCESS WILL BE GIVEN AFTER THE FIRST CALIRATION PHASE !

Why EDF is proposing a 3rd Benchmark on VERCORS ?

EDF thinks the best way to address this challenge was to perform a series of benchmarks where each participant had the same data and the same given objectives to answer.

There have been already 2 benchmarks organized :

- The first one in 2015 (early-age behavior and leak-tightness),
- The second one in 2018 (Creep modeling - Micromechanics and/or Multiphysics approaches; Mechanical behavior of the containment during pressurization test; Air leakage).

This 3rd benchmark is mainly financed by **EDF**, however supported by Euratom project named **ACES**, and also cosponsored by **OECD-NEA** & **ACI**

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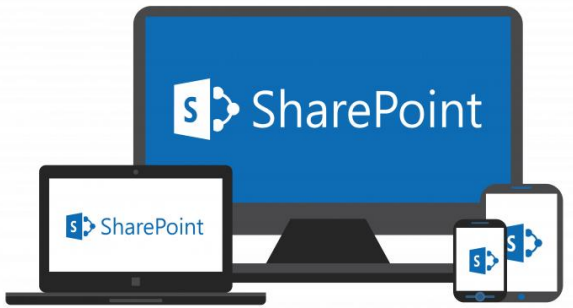
Benchmark III

VERCORS' 3rd Benchmark Time Frame

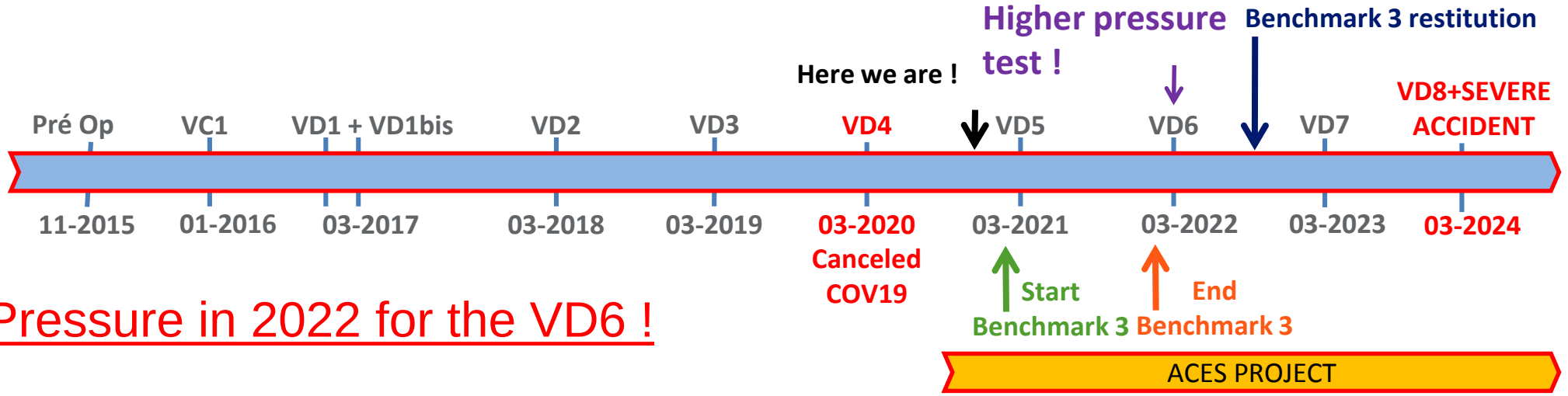
Communication with **EDF** :



- SharePoint access for all the data not available in CERVIN
- Forum on SharePoint to share ideas; tips from the participants; help from EDF.
- E-mails to julien.niepceron@edf.fr if necessary (and only if :) .
- *To give you **an access to this SharePoint**, in addition of your e-mail address, I will need your **date of birth** & **place of birth** please copy / paste in your explorer the following link :*

https://edfonline-my.sharepoint.com/:x:/g/personal/julien_niepceron_edf_fr/ESENEguC161Ouk68pe-D94sBnJvPeEe6U4Jmt6FdiR6bPw?e=ltvggK

Global Planning : Vercors / Benchmark 3 / ACES



Higher Pressure in 2022 for the VD6 !

EDF is currently investigating on increasing the nominal value of the pressure test which is currently 4,2 bars.

The maximum applied pressure is today **unknown**, however it is certain that the maximum will **not be over 6 bars (7 bars abs)**. The limiting criteria will be based on the evolution of the global leakage rate and the test will be stopped if the global leakage rate going beyond a certain threshold of the nominal value. The participants will have to propose results on both the mechanical behavior and the leakage at different pressure values.

Benchmark 3 : Themes of Benchmark 3

In the end, the themes, will be the following on :

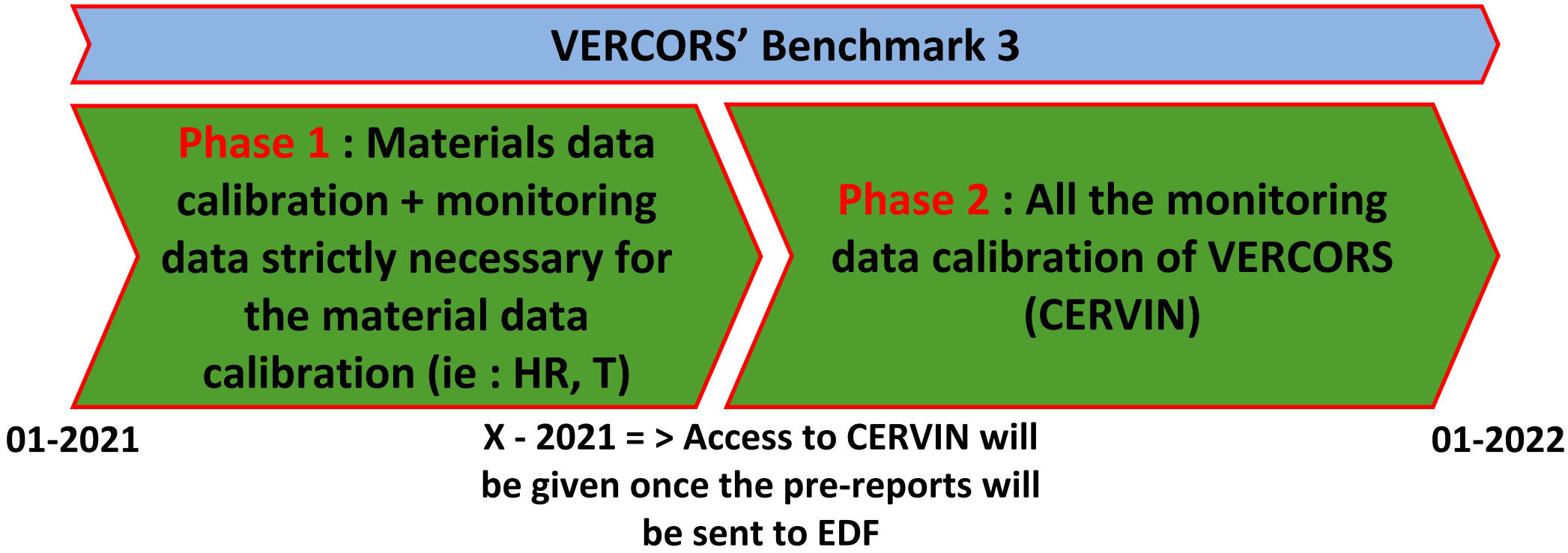
- Theme 1 : Mechanical behaviour (Linear & Non linear).
- Theme 2 : Leakage at Local & Global scale.
- Theme 3 : Open subject

All details about how to address and answer those themes will be given by EDF in January 2021. “Formatting & Sample File imposed by EDF”

Calibration : Material versus Monitoring calibration methods ?

The **calibration methods** has been fully discussed during our meetings, and we have concluded in order to clearly distinguish how you have improved your predictions to give only the material data first and then the monitoring data.

Data given will be up to VD4 (March 2020)



Frequently Asked Questions

- Will EDF provide some funding to perform this benchmark?

  - No, EDF will not provide any funding to the participant. However, in order to limit your costs, EDF will provide for the Benchmark restitution in 2022 the accommodations and the catering. Travel expenses will not be reimbursed neither.

No promises on this point but we will try our best to improve it.

Frequently Asked Questions

- Will EDF gives the mesh models of VERCORS ?

  - Yes, EDF has been working on 3 grades of modelling (Fine, Average, Coarse) modelling for mechanical & thermal. It will be given to the participants as for the previous benchmarks (formats: .med, .unv , .stl). Geometry files will also be given (formats: .brep, .iges, .xao).

From now, the format .med, .unv are working just fine and include everything (the tendons), however we still have some issues with the .stl format.

Thanks to your feedback improvements will be made on the .stl format.

Frequently Asked Questions

- If I don’t use the software of EDF : “Code-Aster”, can I still use some constitutes laws from EDF.

  - Yes, EDF will give you the opportunity to use some of our constitutive laws that can be implemented on your own FE software (Cast3M, Code-Aster, Abaqus Standard, Abaqus Explicit, CalculiX, ZeBuLoN, Eureoplexus) through MFront.

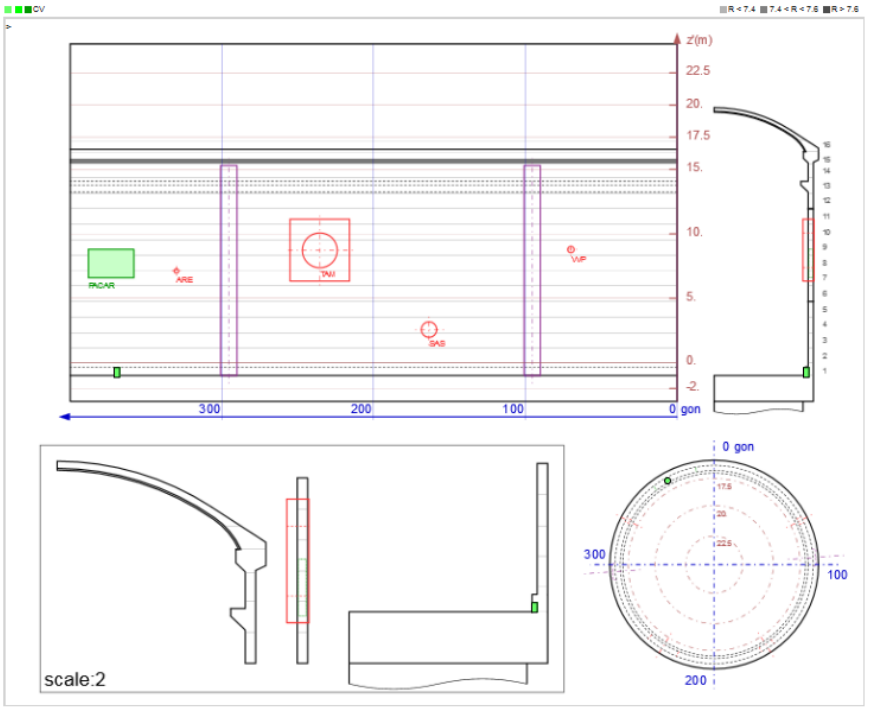
For more information about “Code-Aster” : https://www.code-aster.org Free open source software.

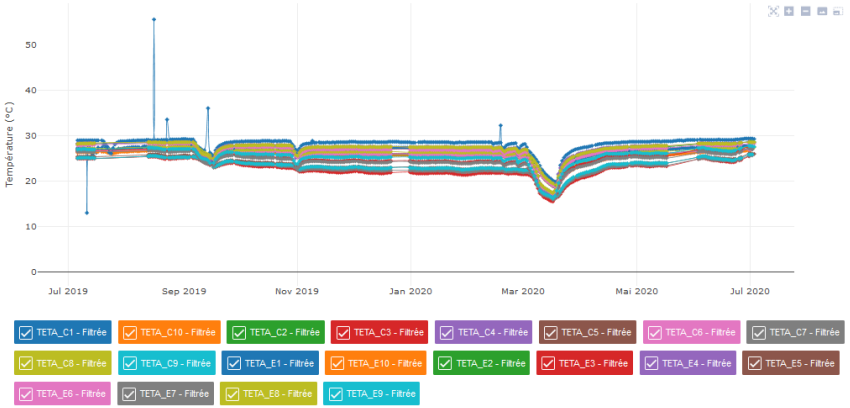
For more information about “MFront” http://tfel.sourceforge.net/ Free open source software.

Frequently Asked Questions

Which data will be available on CERVIN ?

- Strains in the concrete
- Strains on the rebars
- Pendulum + invar wire
- Temperature in the concrete
- Temperature, Pressure & Humidity in the annular space & inner containment containment
- Tendons (only some of them are instrumented)
- Concrete Saturation (“TDR” Time Domain Reflectometry sensor)





Frequently Asked Questions

How is measured the global leakage rate ?

The global leakage rate measurement consist in measuring the mass decay of the pressurized air contained in the CCB, then the global leakage rate is deduced from the ideal gas law.

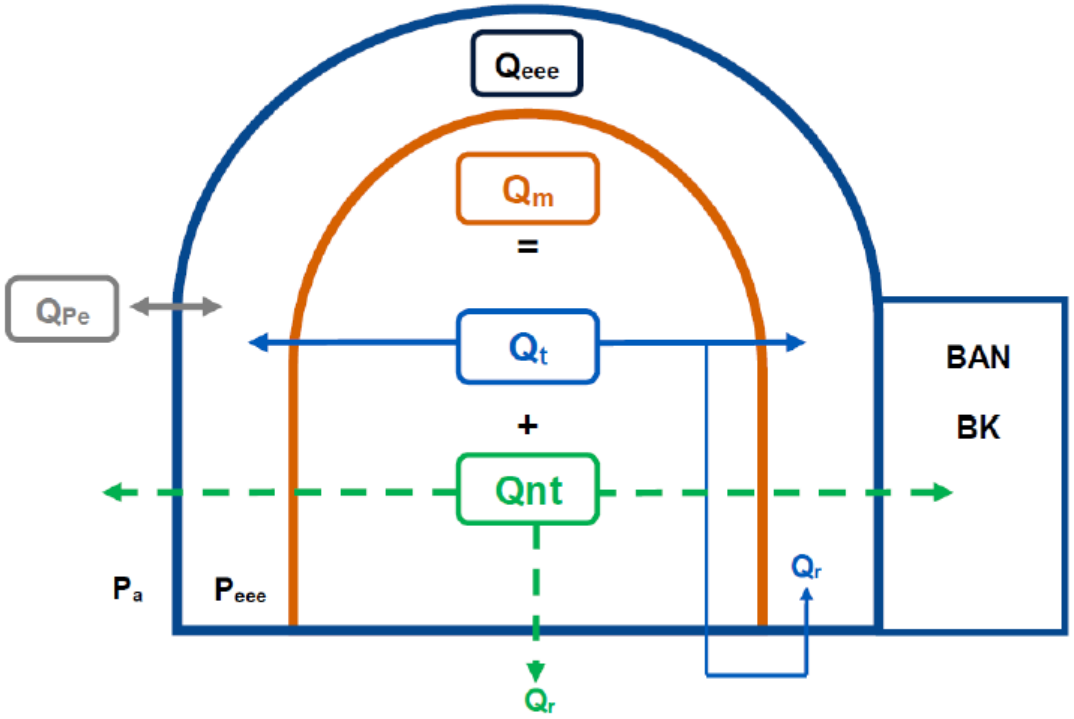
This measure takes about 12h to be perform with EDF standards in order to limit as much as possible the uncertainty. Indeed the longer we wait the better is the mass stability in CCB. (Temperature, Humidity).

The average accuracy of the global leakage rate is about **± 2%.**

With this method you have the global leakage rate only at the nominal pressure Pnom = 4,2 Bars.

Frequently Asked Questions

How is measured the global leakage rate with SUGTEN* method ?



Only on double-walled containments, the global leakage rate can be estimate with the SUGTEN* method. The SUGTEN method gives you the containment leak rate during the inflation phase of the pressure test.

Indeed, thanks to some previous calibrations tests performed previously to determine the leakage rate of the outer containment it is possible to deduct the global leakage.

***** It's a french acronyme for **: « SU**ivi en phase de **G**onflage du **T**aux de fuite de l'**En**ceinte » = « Monitoring during the inflation phase of the containment leak rate ».

Frequently Asked Questions

How is measured the local leakage rate ?

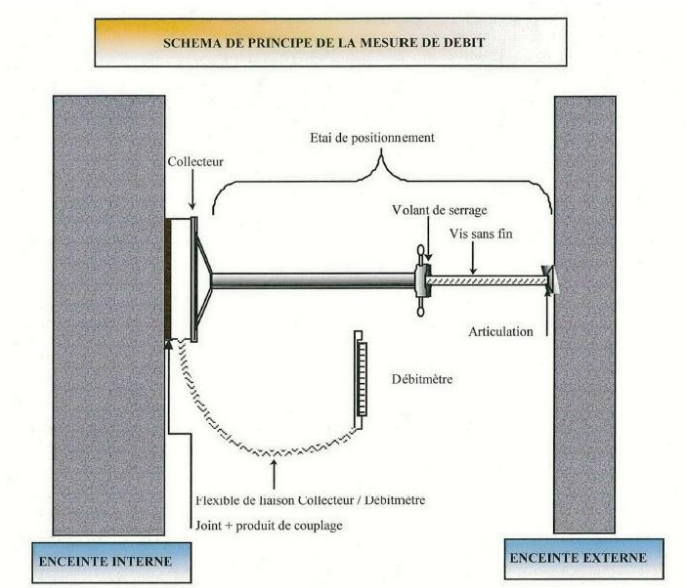
The local leakage rate is measured through a very traditional method.

First step : once the inner containment is at 4,2 bars (nominal value), a soapy water is applied on the outer surface of the inner containment in order to visually detect the local leakage.

Frequently Asked Questions

How is measured the local leakage rate ?

Second step : a collecting box is applied on the visually detected location (bubbles), and the leakage is measured with an float type flow meters and sometimes numerical flow meter.

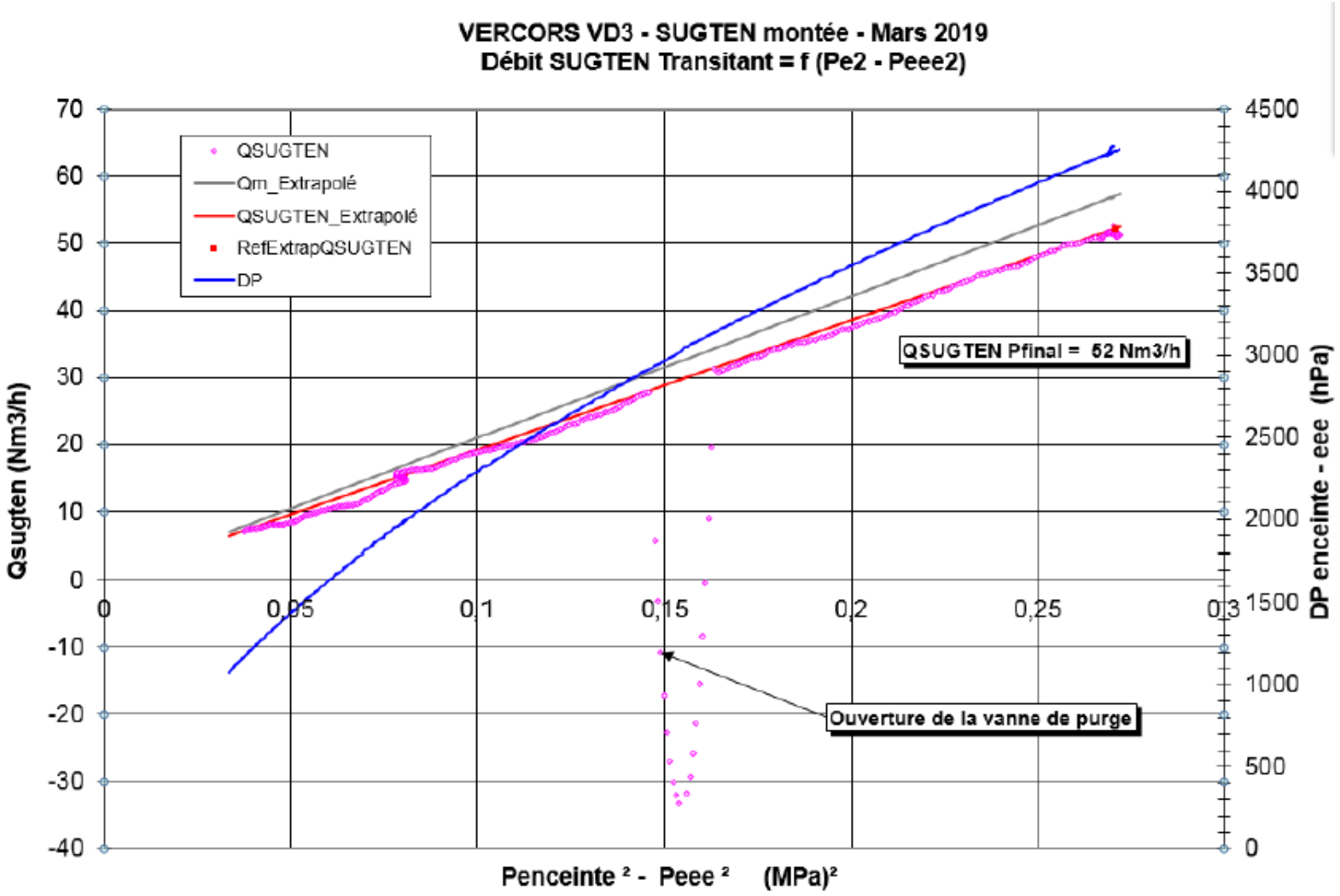


Frequently Asked Questions

How is measured the global leakage rate with SUGTEN* ?

In the end, you obtain such graphs which gives you the evolution of the global leakage rate at any pressure level.

The average accuracy of the global leakage rate with SUGTEN is about **± 10%.**

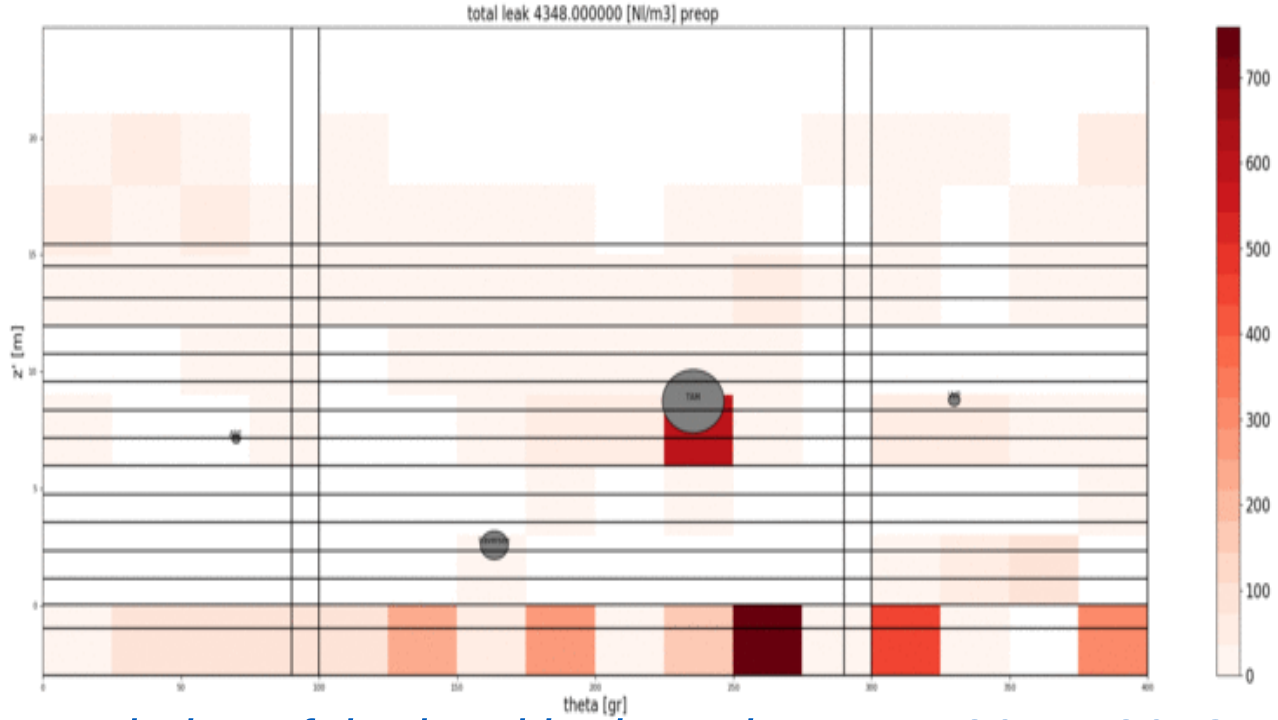


Frequently Asked Questions

- Which information EDF will give about the local leakage of VERCORS?

  Yes, EDF will give information about the local leakage of the mock-up. However in order to avoid having too much information only a “simplified local leakage” map will be given. Each “square” will distinguish the local leakage from vertical, horizontal cracks and porosity area.

Here is an example of what could be given for the local leakage



Evolution of the local leakage between 2015 -2018

Frequently Asked Questions

- In summary what does the participant will have from EDF ?

First phase of data

- All the information that were given for the previous Benchmarks 1 & 2.
- Concrete and reinforcement drawings of VERCORS.
- Reports & Presentations from Benchmark 1 & 2.
- Some communication such as pictures & videos.
- Local leakage (As explained before a simplified form only).
- Global leakage (As explained in forme with SUGTEN method, and the official method).
- Material data (Young's modulus, Porosity, Strength, Fracture energy , Desorption isotherm, Mass loss, concrete creep & shrinkage, etc)
- Some constituve laws of EDF (Through M.Front).
- Continuous evolution of the local leakage with only one crack.
- Continuous evolution of the local leakage on a porous area (no cracks).
- Summary of the Benchmark III + Formatting & Sample File imposed by EDF

Second phase of data

- Monitoring data will be given up to VD4 (See calibration slide).

VERCORS IT'S A TEAM !

- Laurent Charpin (EDF R&D General project manager & ACES contact for EDF)
- Alexis Legrix (EDF R&D Site manager of Vercors)
- Benoit Masson, Julien Niepceron (EDF DT EDF's strategic coordination)
- Jean Marie Hénault, Frédéric Taillade, Vincent Guihard, Pauline Laviron (EDF R&D : Experts in NDT & NDE)
- Solenne Desforges, Mathieu Galan (EDF DTG : Pressure tests & NDT/NDE)
- Floriant Escoffier, Sylvie Michel-Ponnelle (R&D ERMES : Modelling)
- Jean Luc Adia, Charles Toulemonde (EDF R&D : Structural & Material behavior)
- Guillaume Boulant, (EDF R&D : Data & IT)