JHR PROJECT- FRANCE

EU JHOP 2040

GAMMA DOSE TOLERANCE TESTS

FOR IRRADIATION LOOP INSTRUMENTATION

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CONTEXT REMINDER

- JHR Project (France) : Experimental Facility & Partners Consortium

https://jhrreactor.com/

- JHOP 2040 European Project

(roadmaps proposal of R&D activities in support of JHR)

https://www.jhop2040-h2020.eu/

- ADELINE irradiation fuel experimental loop
- Out of Pile instrumentation Behaviour

Fig.1a: JHR support building. v07.2019

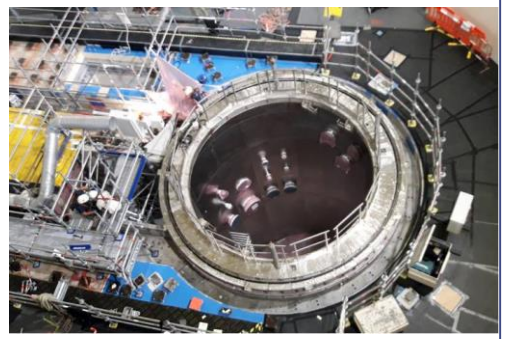


Fig.1b: JHR reactor pool overview. v09.2019

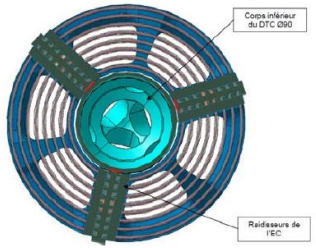
JHR EXPERIMENTAL REACTOR. OVERVIEW

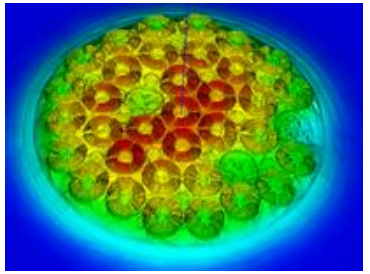
Material Testing Reactor designed at 100MWth (starting at 70MWth).

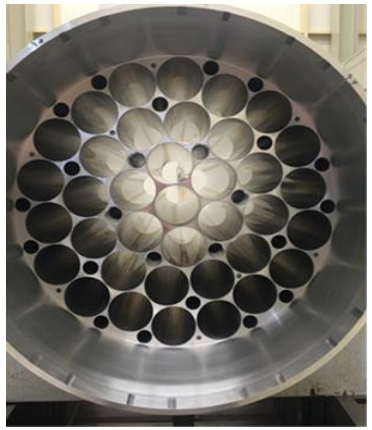
- Compact core geometry (60cm diameter),
- Reflector in Beryllium,
- Light water coolant

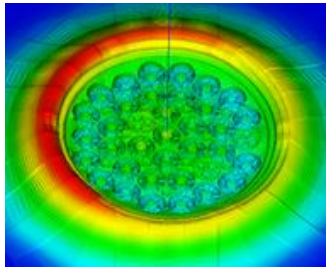
Closed primary circuit (12 bar pressurisation),

- High materials damages capabilities: 15 dpa/year (core),
- High thermal neutrons flux (reflector): 8 x PWR th.neutrons flux,









High experimental Platform: possibility to manage 20 irradiation devices (x10 in the core and x10 in the reflector),

Experimental and operation equipments integrated in the facility (NDE systems, FP laboratory, hot cells with specific one for failures rods conditioning).

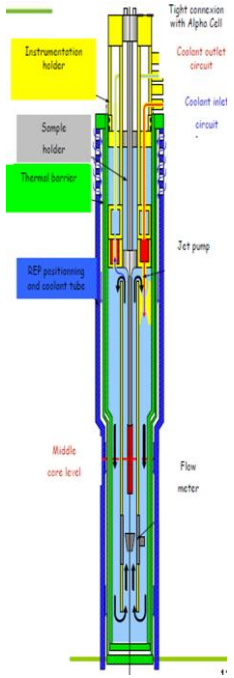
JHR EXPERIMENTAL DEVICE. ILLUSTRATION

ADELINE TYPE : FUEL IRRADIATION LOOP DEVOTED TO POWER RAMPS TESTS TRANSIENTS.

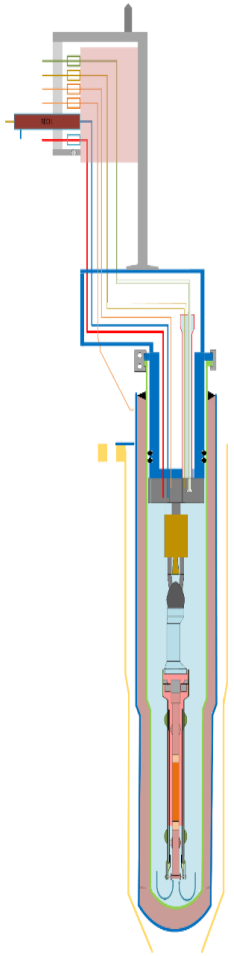
TH conditions : LWR

PWR : 155 bar , 320°C,

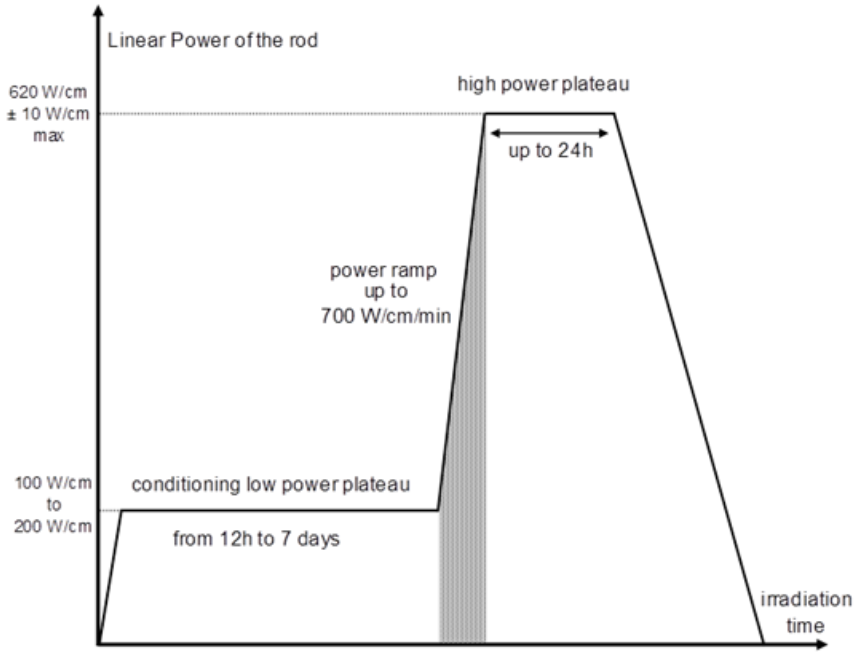
BWR : 75-80 bar,295°C.



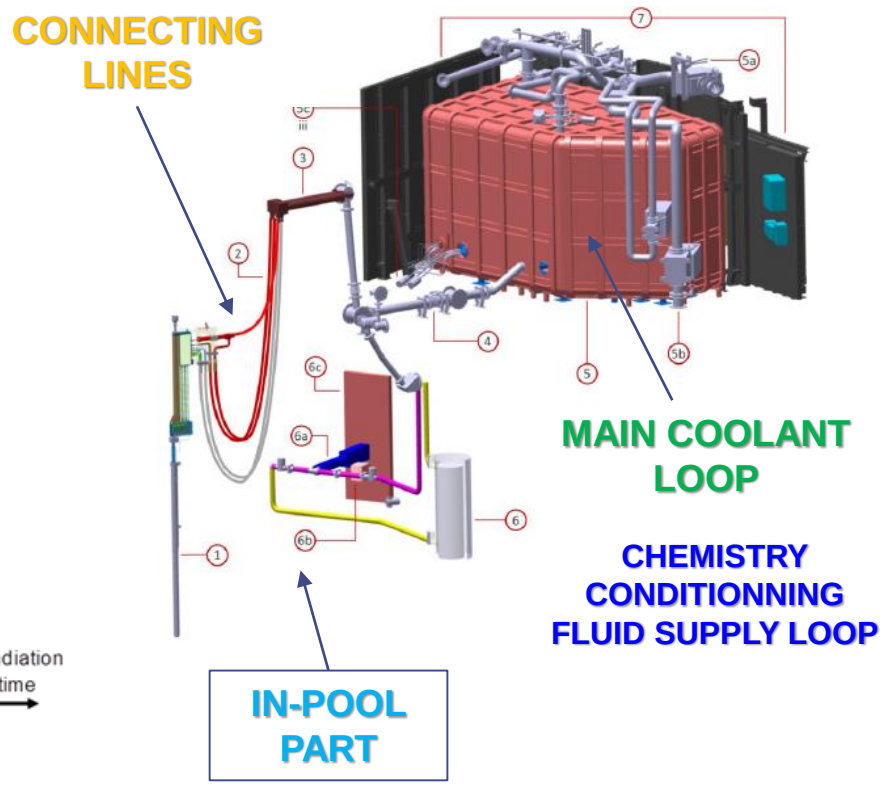
ADELINE V0 design



ADELINE V2 design



Typical Transient



JHR EXPERIMENTAL DEVICE. INSTRUMENTATION

- **Pressure sensors**
  - ✓ Process (pressurised water)
  - ✓ Flowmeter mesurement (Vcone technology)

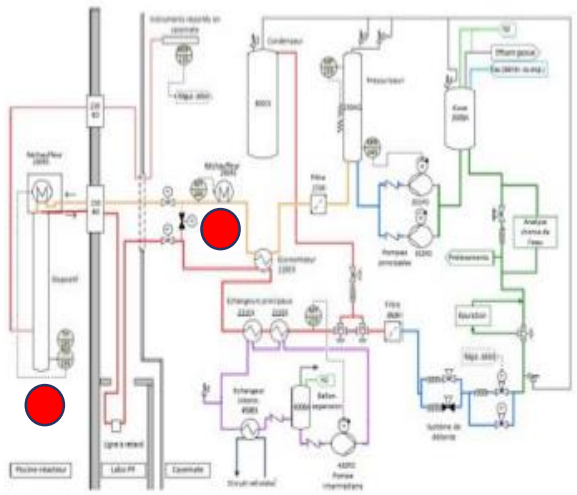


Figure 2a: simplified drawing of a fuel irradiation loop ("ADELINE type" device , TH loop, v 2021)

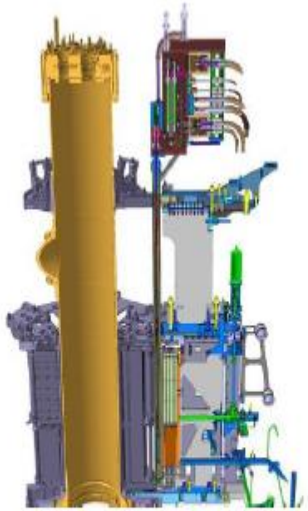


Figure 2b: overview of the "ADELINE type" device in-pile part in the JHR core environment.

sensor location	Fluid Process Pressure P In the circuit (Cubicle)	
sensor type	*Relative pressure P sensor analogical type Y*	*relative pressure P sensor numerical type K*
function	*test sensor*	*reference sensor*
nominal working pressure	*155 bar*	
maximal working pressure	*185 bar*	
sensor range	*0 - 250 bar*	
Acceptable dose rate	*To define during the test*	*50 Gy[1]*

sensor location	Delta P Flowmeter (VCone) Test Device	
sensor type	*Differential Pressure dP sensor analogical type Y*	*CVR calibration pressure sensor*
function	*test sensor*	*reference sensor*
nominal working pressure	*0 – 640 mbar*	
sensor range	*0 - 700 mbar*	
Acceptable dose rate	*To define during the test*	*Not precised*

INPUT DATA FOR THE TESTS

EXPERIMENTAL NEED (JHR)

In this case, the tests aim to qualify certain types of pressure sensors in the “ADELINE type” loop withstand irradiation in degraded situations.

By degraded situation is meant the consequence of rupture of the experimental rod embedded in the “ADELINE type” experimental device which leads to a transfer of radionuclides * from the rod to the coolant.

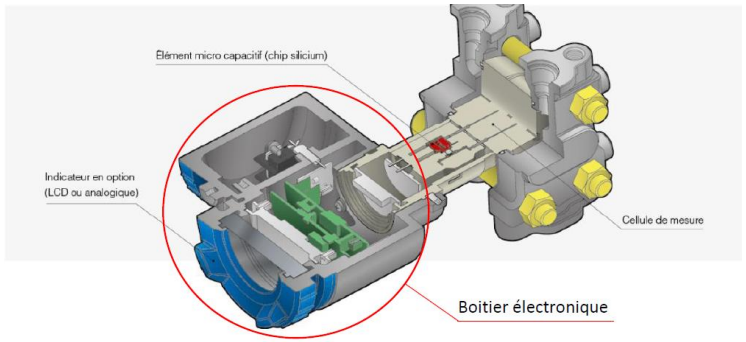
The dose absorbed by the sensors during a rod rupture has be estimated around 0.43 Gy/h.

Even if this value is considered as an envelope, it will still be used to determine an absorbed dose value over a year. The resulting value is equivalent to 3.77 kGy.

The test value has been fixed at 4 kGy.

INDUSTRIAL NEED (SUPPLIER)

The purpose of experimental program is to test a component under specific conditions in order to characterize its resistance over time and its ability to continuously **perform its functions & performance up to maximum gamma dose levels**.



EXPERIMENTAL CONFIGURATION

Two sensors used for each test :

1) Tested Sensor (Irradiated)
2) Reference Sensor (non irradiated)

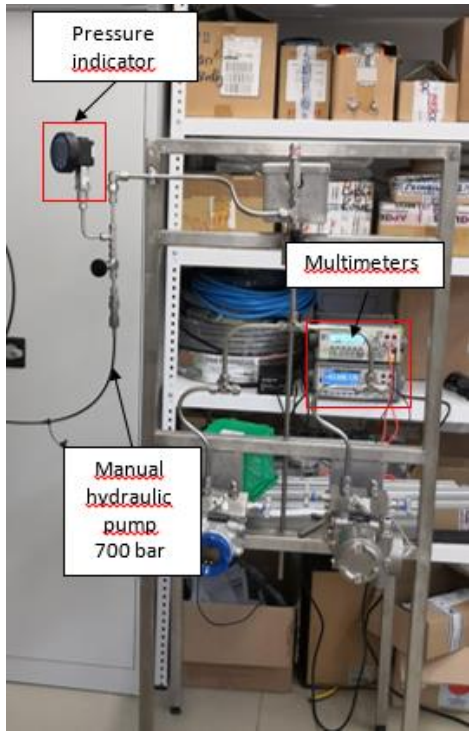


Fig.4a: Pressure sensors control bench (relative Pressure)

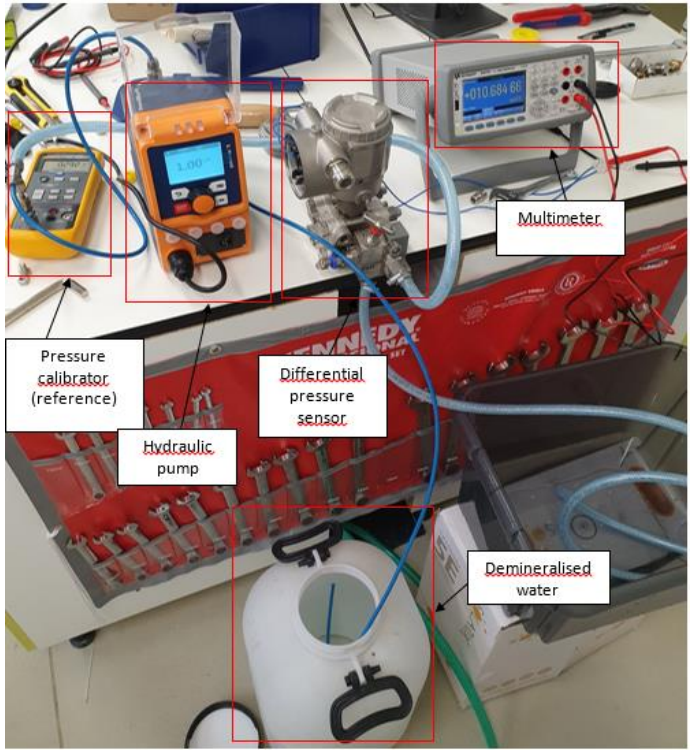
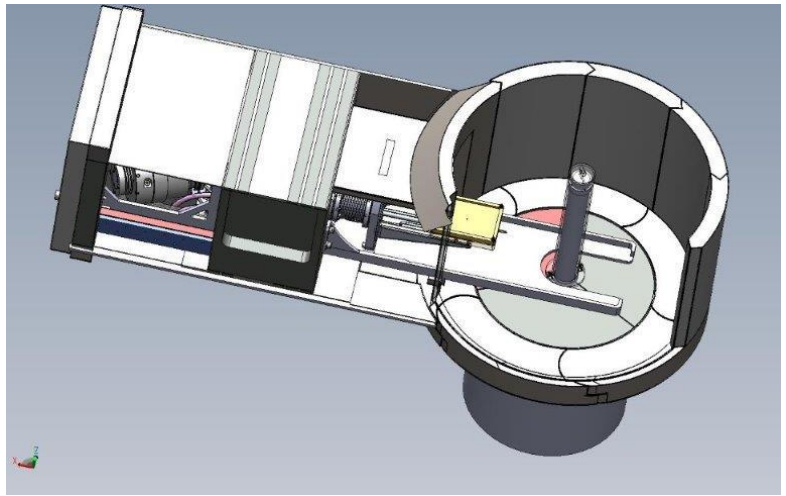


Fig.4b : Pressure sensors control bench (differential Pressure)

GAMMA IRRADIATION AT CVR (CZECH REPUBLIC)



Irradiation of small samples
^{60}Co Source: 180 TBq
Temperatures of -196 °C to 400 °C

THE IRRADIATION PLAN:

- **START IN AUGUST 2021**
- TO REACH 11 KGY WITH A STEP 3 KGY
- AFTER EACH STEP – TO MEASURE THE SENSOR AT A TESTING APPARATUS (PLACED AT DIFFERENT ROOM THAN THE GAMMA CHAMBER)
- AFTER REACHING 11 KGY IRRADIATION UP TO 70 KGY
- DEPENDING ON THE ACTUAL DOSE RATE, 11 KGY CAN BE DONE IN 1 WEEK

PREALABLE DOSIMETRY

Fig.6: The irradiation chamber with alanine detectors placed on the tested sensor from both sides and the same levels

Inside the sensor, a set of alanin detectors will be placed to measure the actual dose rate.

- The electronic part of the sensor will be used.
- The alanin detectors will be packed in some capsules that will be fixed by the Al-tape
- A pellet (cylinder) cca 5mm in diameter and 3mm in height
- The uncertainty of the measurement is cca 3%

IRRADIATION TEST PROTOCOL

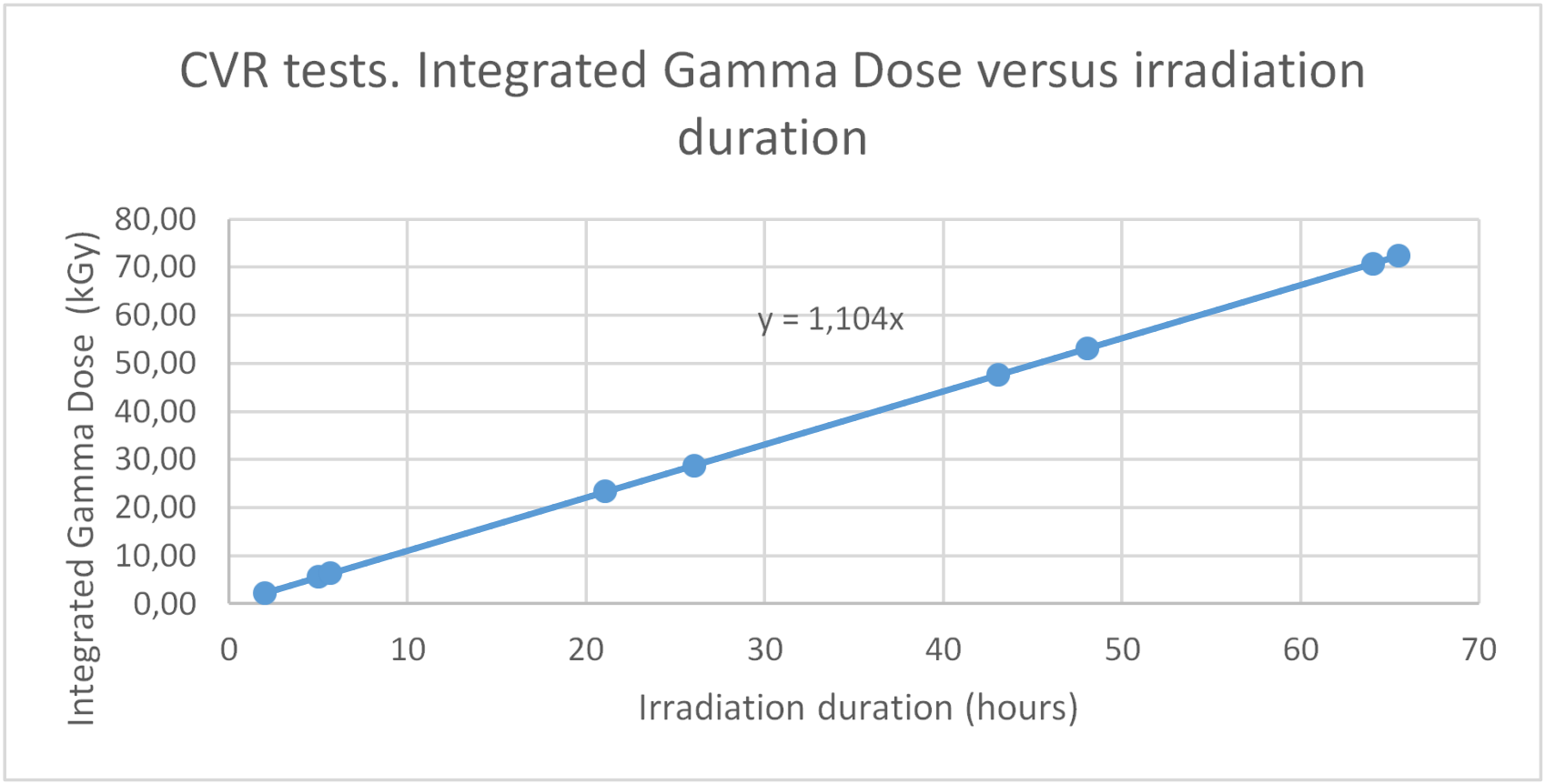


Fig.1: Gamma dose rate evolution (kGy) versus irradiation duration (h)

MAIN RESULTS OBTAINED (1/2)
RELATIVE PRESSURE SENSOR

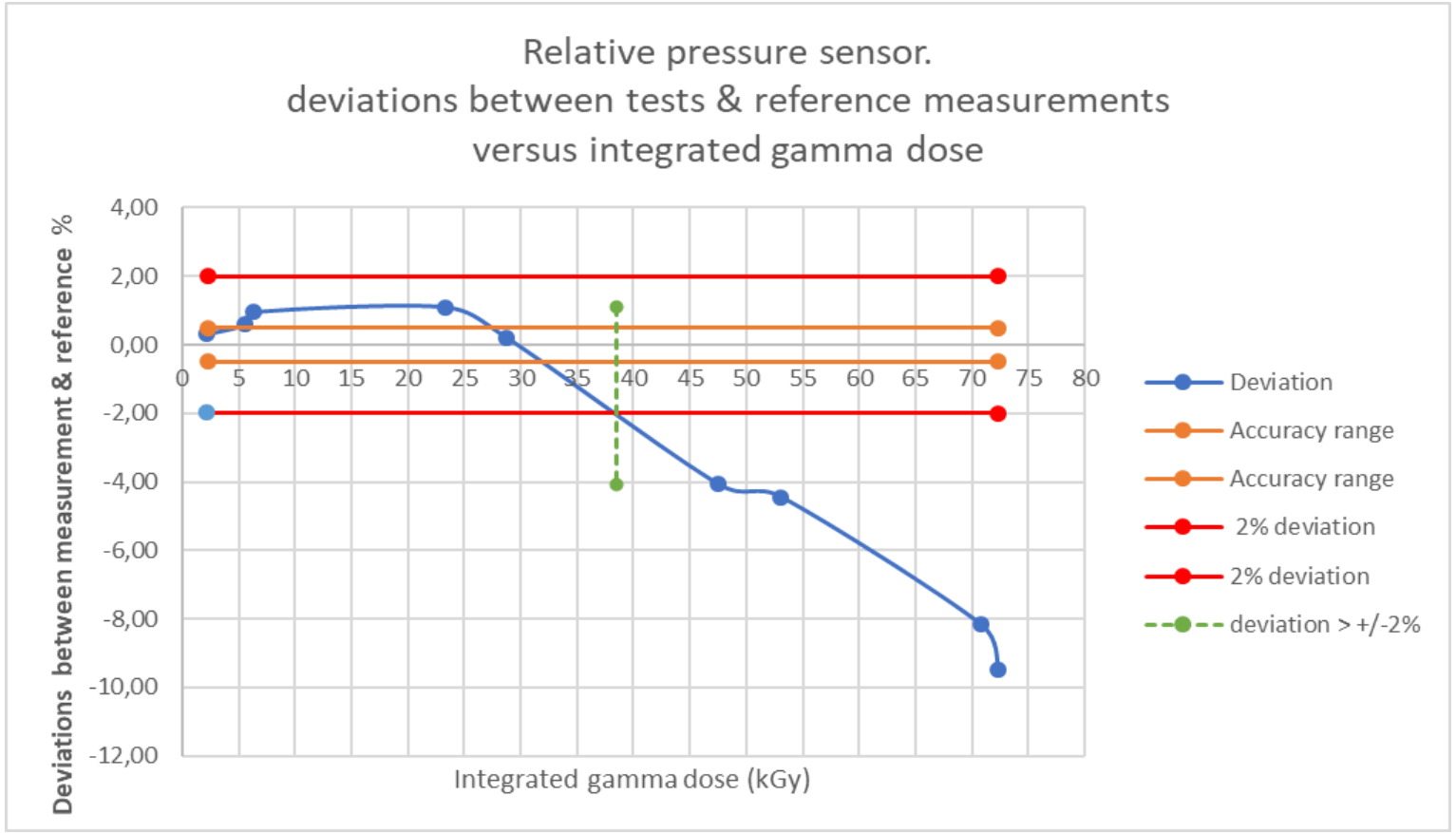


Fig.9: Relative pressure sensor P
Deviations observed between measurements (Y analogic)
& reference sensors (K numeric)
versus integrated gamma dose (kGy)

Three distinct stages observed :

A first step between 0 and 23.6 kGy where the measurements remain relatively constants,

A second step where, between 23.26 kGy and 70.75 kGy, the measurement deviations increase sharply and in a linear fashion
(from + 1.10% to -9.47%),

A last step from 70.75 kGy where the measurement deviation increases very strongly (vertical drop of the curve).

MAIN RESULTS OBTAINED (2/2)
DIFFERENTIAL PRESSURE SENSORS

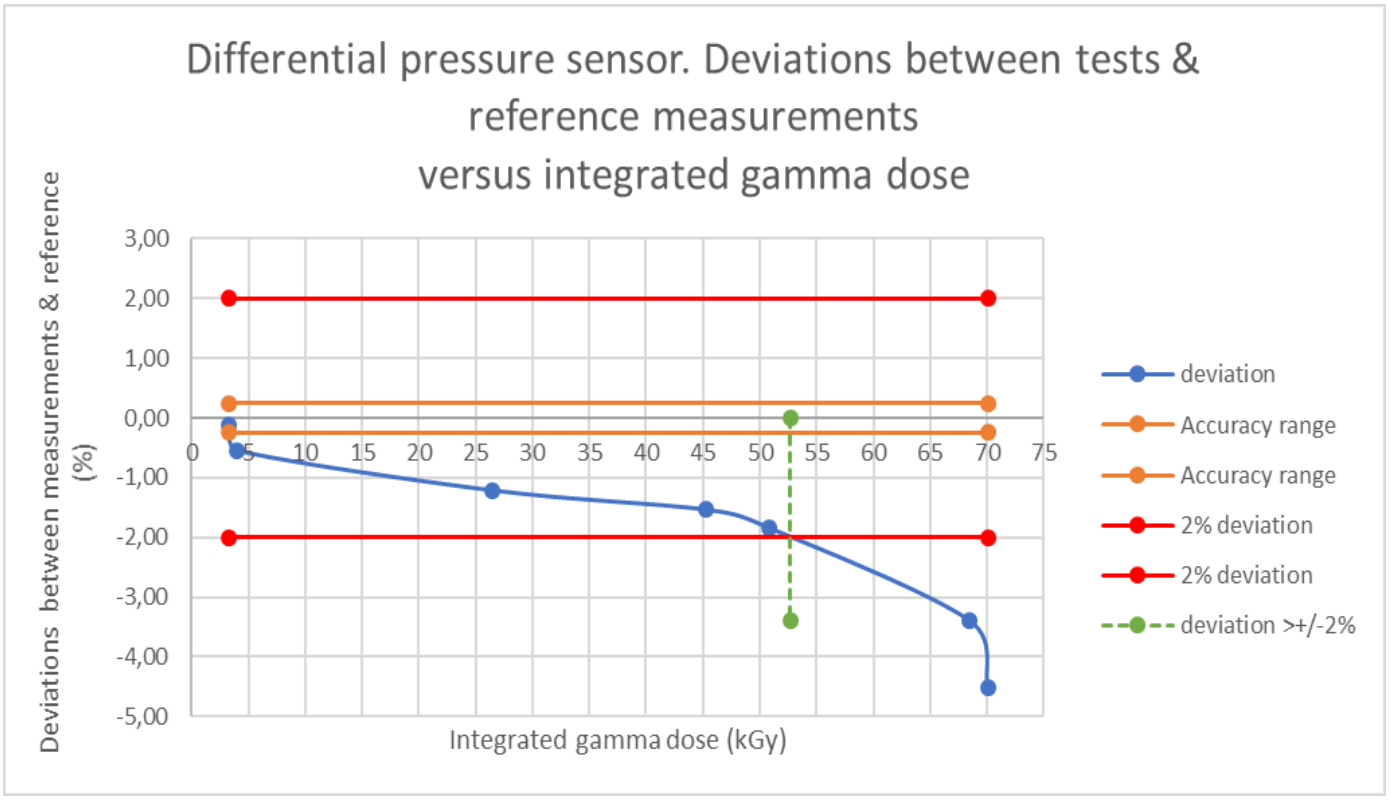


Fig.10: Differential pressure sensor P
deviations (after corrections) observed between measurements (Y analogic)
& reference sensors (CVR calibration module)
versus integrated gamma dose (kGy)

The results obtained show us three distinct stages:

- A first stage between 3.31 and 45.3 kGy where the differences increase slightly and in a linear fashion
- A second stage where, between 45.3 and 68.48 kGy, the measurement deviations increase more strongly, always linearly (from -1.53% to -3.39%)
- A last step from 68.48 kGy where the measurement deviation increases very strongly (vertical fall of the curve).

Note also that the point representing the plateau at 20.99 kGy was not taken into account to plot the curve in fig.10 because that did not correspond to the trend of the curve (hypothesis to be confirmed if necessary by further analyzes of the results).

CONCLUSION

The objective for these tests, corresponding to the irradiation of pressure sensors beyond a dose of 70 kGy within 5 days has been achieved.

The analogue and differential analogue relative pressure measuring sensors received 72 kGy and 70 kGy, respectively.

This overshoot has been observed

for analogue relative pressure measurement sensors from 39 kGy

and for analogue differential pressure measurement sensors from 53 kGy.

Following this experimental campaign,

- the results have been sent to the sensor supplier in order to carry out an expertise.
- At the same time, the results have send sent to the JHR ADELINE project team in order to decide on the conformity of these types of sensors with respect to the specifications and thus to validate or not the implementation of this type of sensors on the irradiation loop.

Thanks

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