THE SALIENT FLUORIDE FUEL SALT IRRADIATIONS

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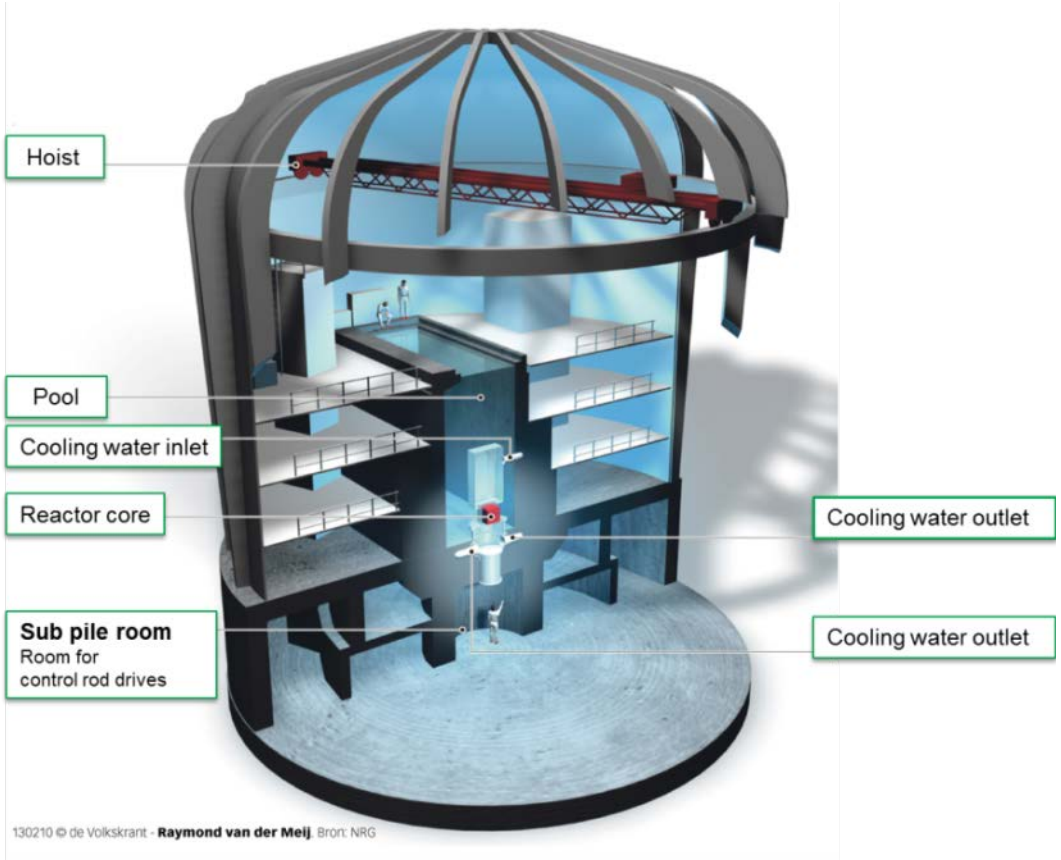
Mallinckrodt
NRG
ECN

COMPLETE NUCLEAR INFRASTRUCTURE

THE HIGH FLUX REACTOR (HFR)



- High flux
- 45 MW thermal power
- Stable and constant flux profile in each irradiation position
- Main applications
  - Isotope production
  - Nuclear energy irradiation services
  - R&D
- 31 operation days per irradiation cycle, 9 cycles a year

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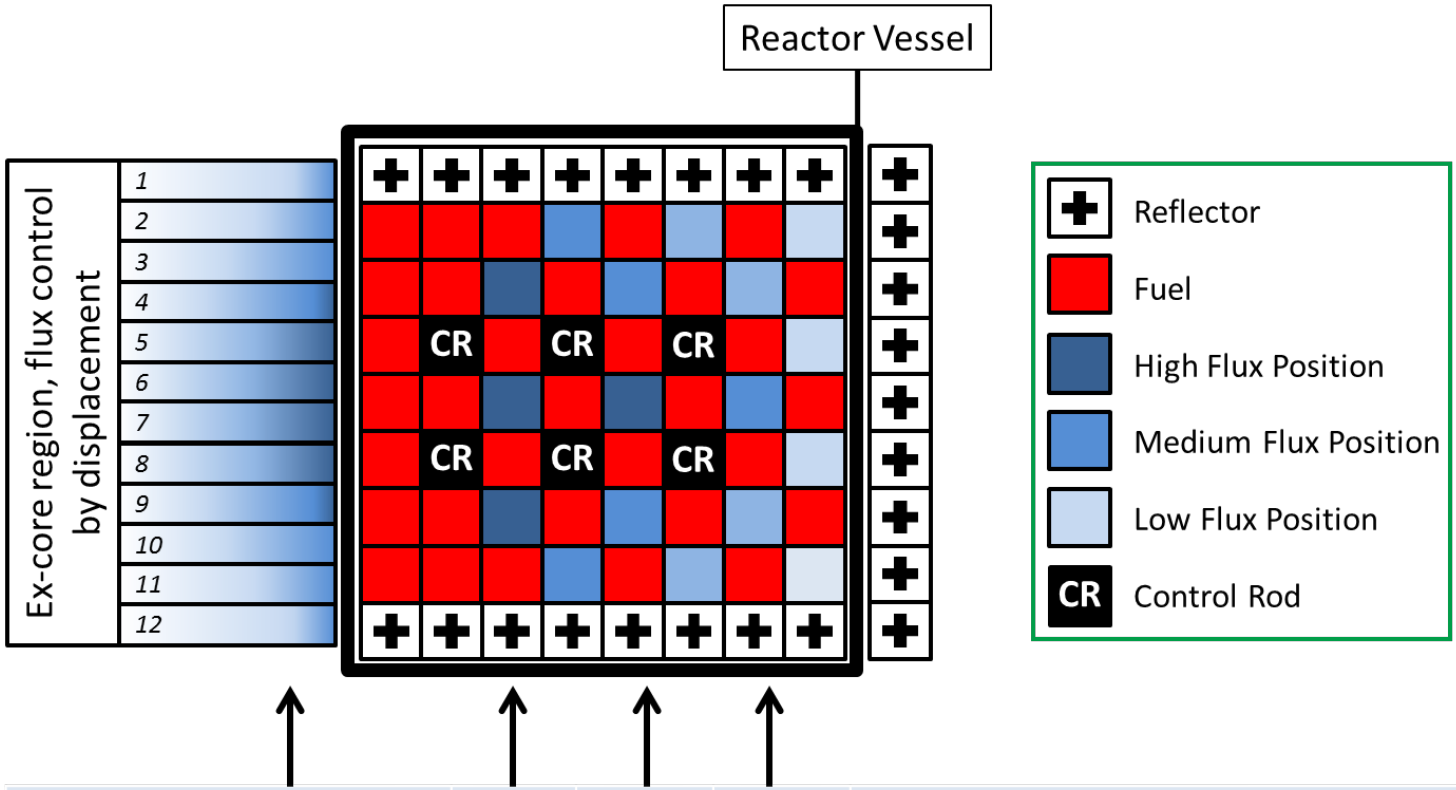


0-3, location dependent	5-8	3-5	1-3	Material DPA rate (DPA/year)
0-700, displacement controlled	n/a	500-700	300-400	Linear heat rate (W/cm fresh LWR fuel)

The stable and constant flux profile in each irradiation position is a unique HFR feature

THE DUTCH NUCLEAR R&D PROGRAM

R&D themes:

- Safe Reactor Operation
- Radiation Protection
- Decommissioning
- **Nuclear Technology for the future**
  - SMR
  - Fusion
  - **LUMOS (Learning to Understand MOlten Salts)**

LUMOS

Trilateral collaboration between NRG, JRC and TUD

- Complementary competences

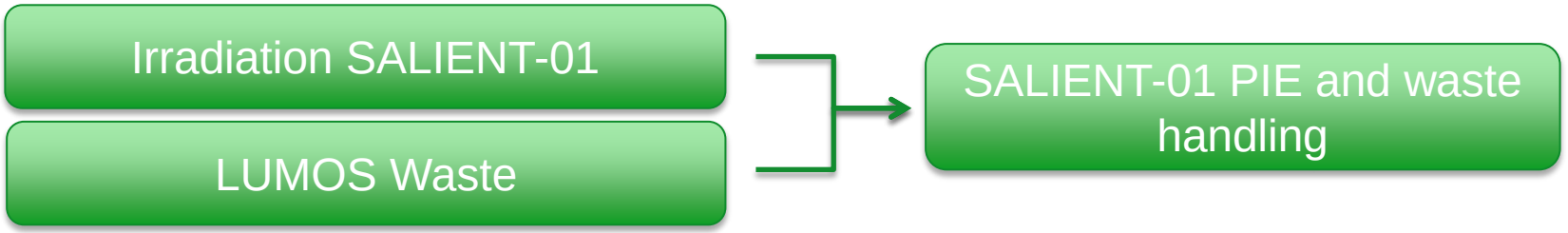
Molten Salt Technology fits well within R&D goals

- Improving safety
- Reducing use of resources
- Contributing to CO_2-free energy market

Program Objectives

- Obtain operational experience
- Confirm FP stability in the salt
- Investigate FP management methods
- Develop in-pile metal/graphite corrosion rig
- Waste route for spent molten salt fuel
- In-pile molten salt loop for the HFR Petten

SALIENT-01



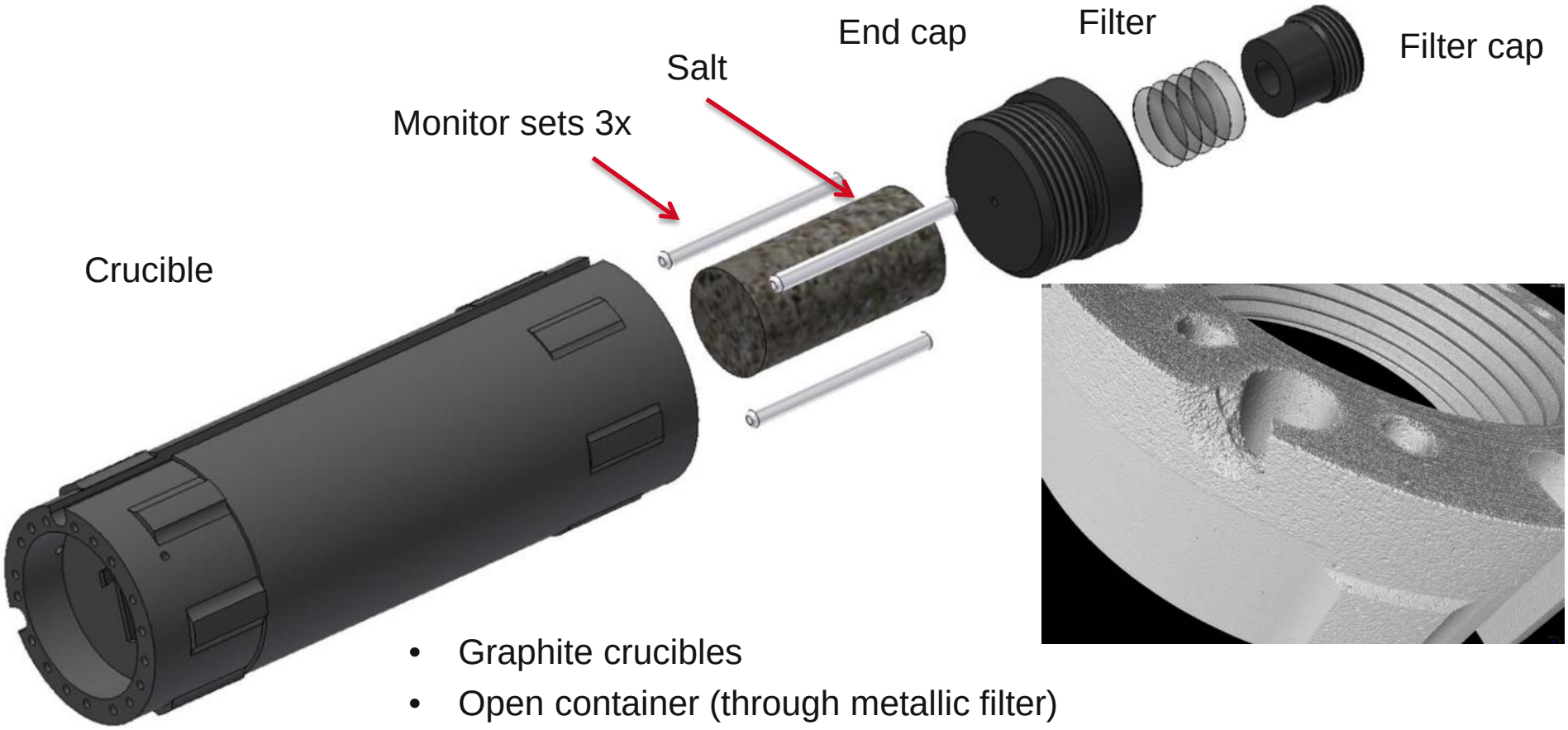
Goals:

- Handling experience
- Salt-graphite interaction
- Fission product stability / redistribution
- Metal particle size distribution

Issues:

- *Reduced salt condition → increased graphite interaction*
- *Radiolytic gas production*

SALIENT CRUCIBLES



- Graphite crucibles
- Open container (through metallic filter)
- Wall temperature maintained at ~610 ^{o}C (ThF_4-LiF), 24 TCs
- Neutron fluence monitored through activation sets

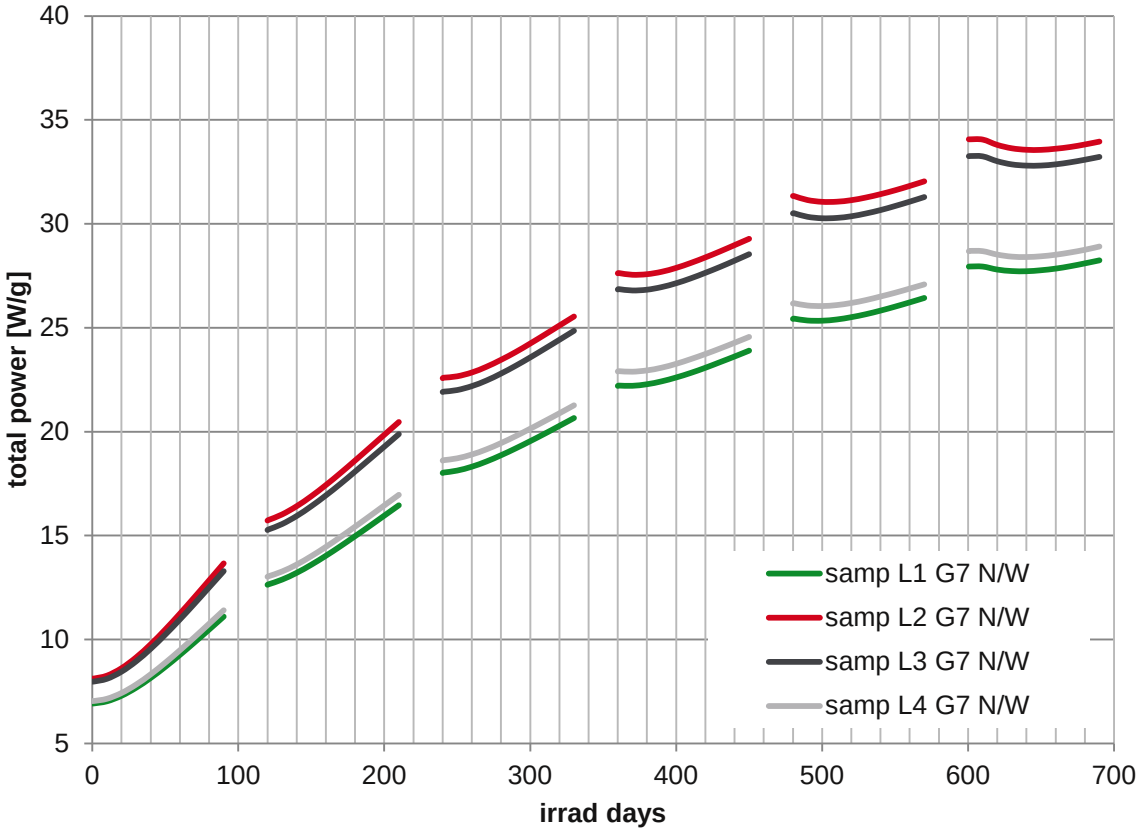
MATERIAL SAMPLES

SALIENT-01 (385-01)						
nr	mat crucible	Contents	øin (eff)	øin (crucible)	identifier	Metal samples
L5	PCIB	SS	8.0	8.0	EXP180-05	-
L4	T-950	LIF	7.6	7.8	EXP180-04	nickel (Ni-201) foil 0,1 mm
L3	PCIB	LIF	7.0	7.0	EXP180-03	-
L2	T-950	LIF	7.0	7.0	EXP180-02	-
L1	PCIB	LIF	7.6	7.6	EXP180-01	nickel (Ni-201) sponge

Nickel added to two crucibles:

- Foil
- Sponge

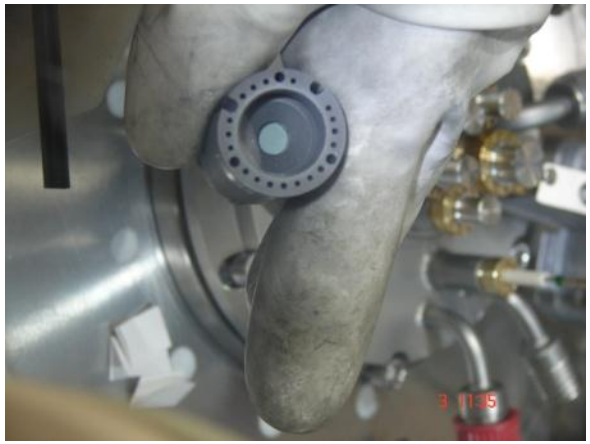
FUEL POWER VS. TIME (THF_4-LIF)



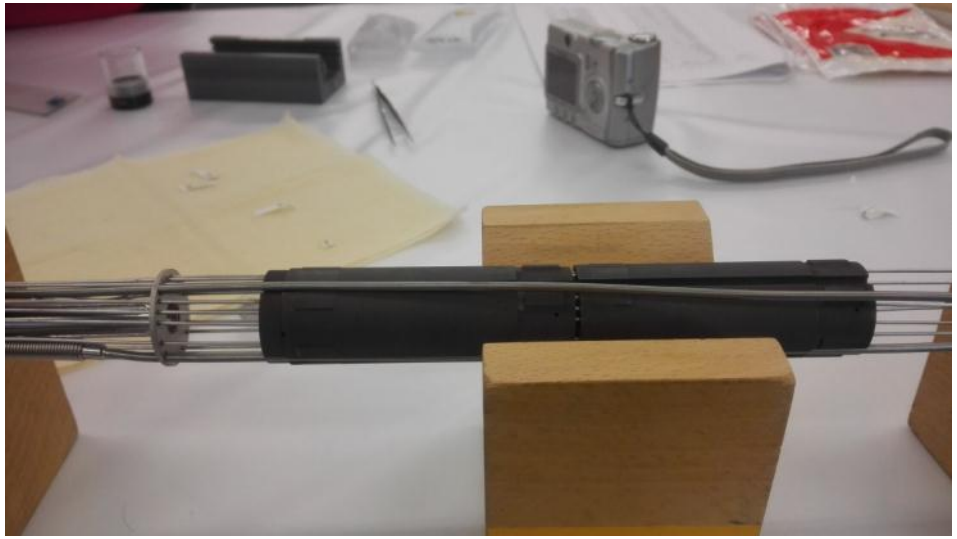
- Fuel power increases during the irradiation (U-233 production)
- Constant wall temperature by variation of gas mixtures

ASSEMBLY

Synthesis and crucible loading at ITU



Assembly of sample holder at NRG



FLUORINE EVOLUTION (RADIOLYSIS)

- Best estimate (maximum) G-value: 0.02 (0.045) F_2-molecules / 100 eV.
- Saturation at fluorine losses of 2-8 mol-%

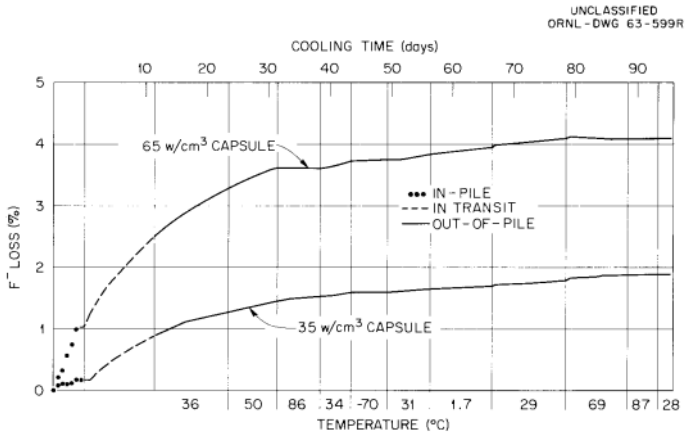


Fig. 2.3. Loss of Radiolytic Fluorine from MTR-47-5 Capsules.

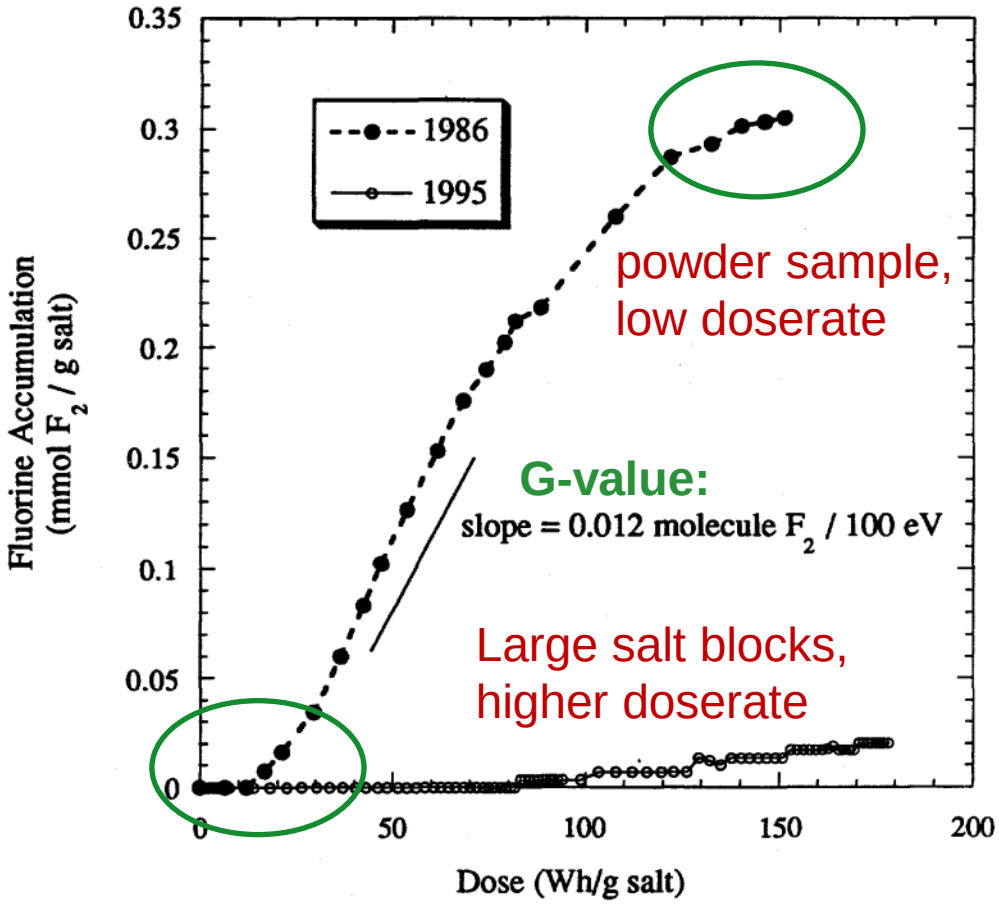


Fig. 3. Fluorine generation curves for 1986 and 1995 irradiation experiments.

BACK-END

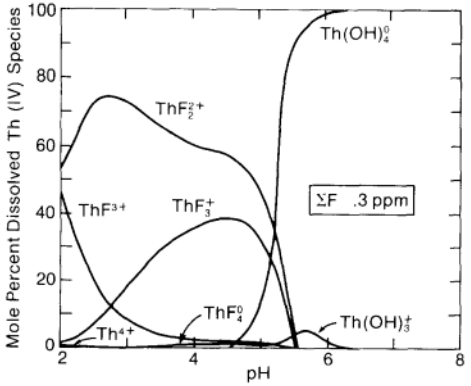
Fluoride salt is not an acceptable waste form (Corrosive and Unstable)

Temporary storage:

- Nickel-based container
- Inert gas
- F_2 / UF_6 adsorbent

NRG waste route to COVRA (government storage)

- Dissolution in strong nitric acid
- Precipitation of as hydroxides or nitrates after removal of fluoride
- Calcination to oxides
- Cementation of remaining liquid waste

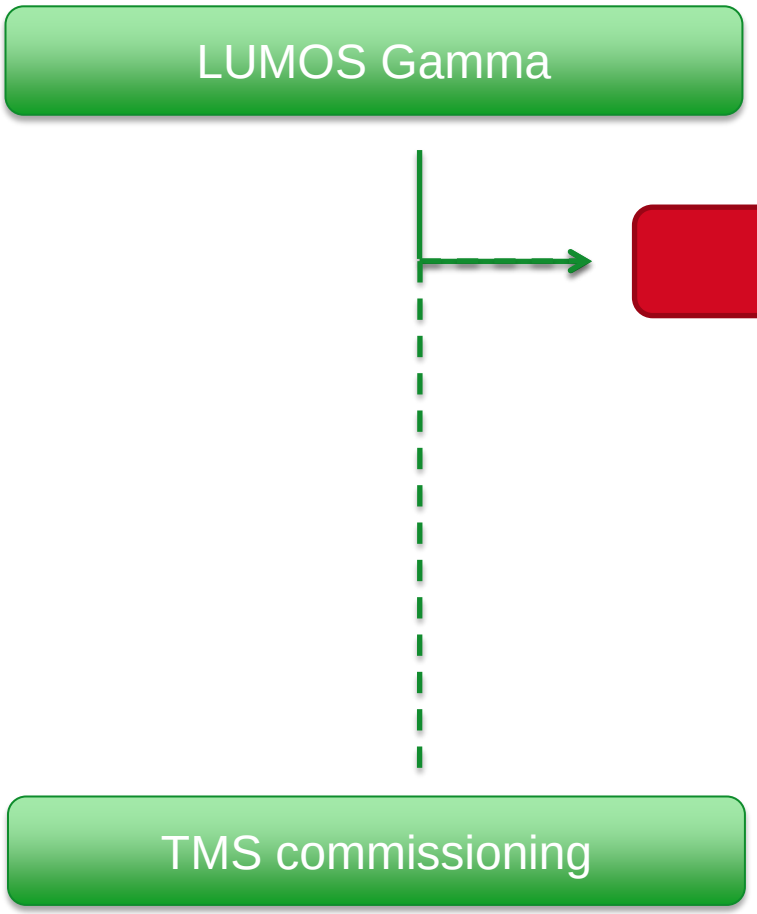


General MSR waste processing: vitrification?

SALIENT-02

- **Twin experiment to SALIENT-01**
  - LiF – BeF_2 – UF_4 eutectic
- **Not yet assembled**
  - On hold
- **May be rebuilt with pressure sensor**
  - on-line measurement of fluorine release

NEXT: SALIENT-03/-04



Goals:

- Quantify tradiolytic gas production

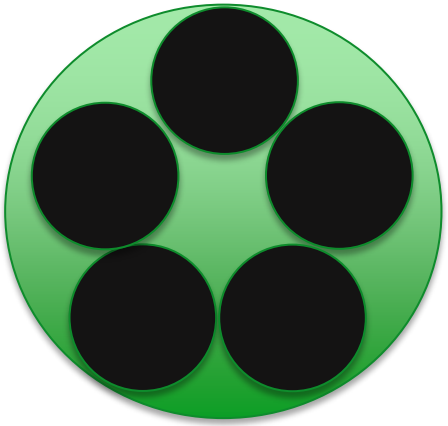
Irradiation SALIENT-03/-04

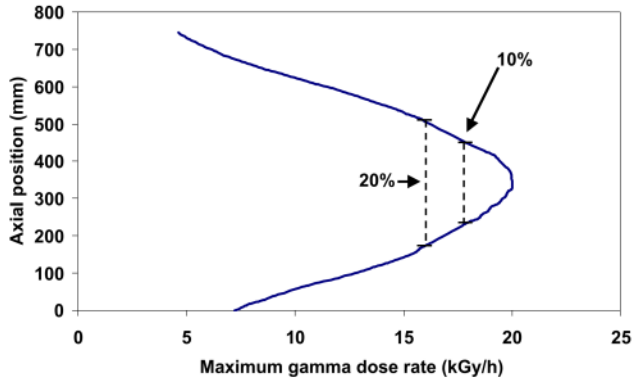
- Realistic chemistry (***salt buffering***, ***use of heaters***)
- Metal corrosion study (Ni-based alloys)
- Influence graphite on metal corrosion
- graphite-salt interaction
- Metal particle size distribution

- *'Tritium release measurements'*

GAMMA IRRADITION

- Space for 5 Salt capsules
- Pressure vs. dose
- Long-term experiment
- Sister experiment at TU Delft



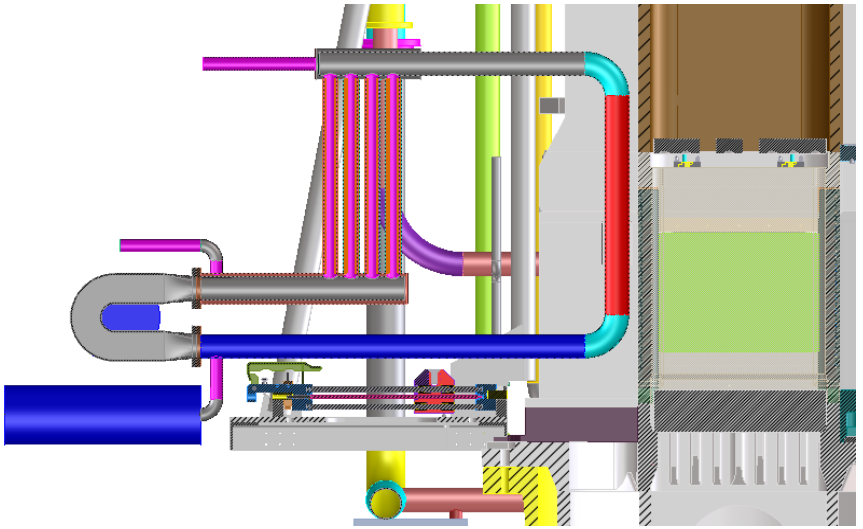


Axial distribution of the gamma radiation over the height of the container, for the large diameter container.

OUTLOOK

- We underestimated radiolytic F_2 release and related chemistry
  - SALIENT-01 now non-representative
  - Significant delays / time lost
  - Safety discussions before end 2016

- **2017 priorities**
  - Start of SALIENT-01
  - Start of gamma irradiations
  - Establish salt waste route to COVRA
  - First results helium bubbling @TU Delft
  - Safety Reports for SALIENT-03/-04
  - Design of the in-pile loop



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