DUTCH MOLTEN SALT IRRADIATION PROGRAM

ORNL Molten Salt Workshop

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Petten, The Netherlands
Amsterdam
JRC
EUROPEAN COMMISSION
curium
NRG
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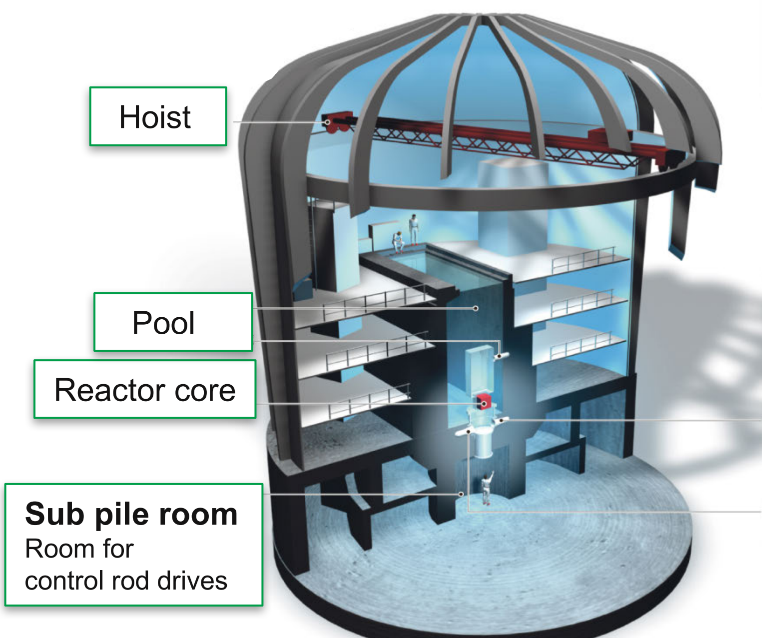
IRRADIATIONS IN THE HFR PETTEN

The High Flux Reactor in Petten is a 45 MW_{th} tank-in-pool reactor used for material research and isotope production (~275 full power days per year)



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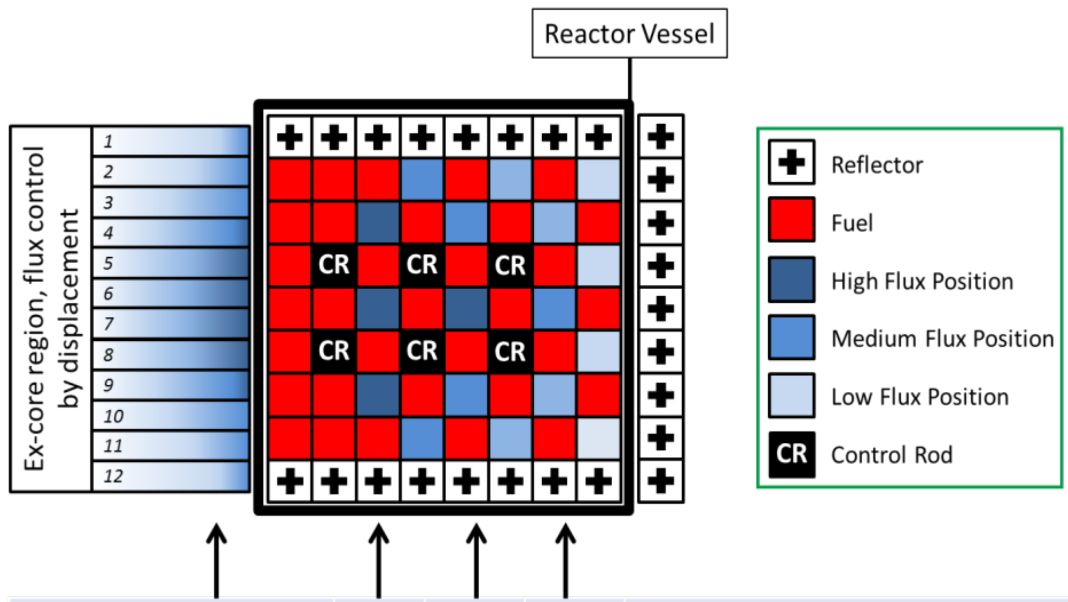


0-3, location dependent	5-8	3-5	1-3	Material DPA rate (DPA/year)
0-700, displacement controlled	n/a	500-700	300-400	Linear heat rate (W/cm fresh LWR fuel)

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

NRG'S MOLTEN SALT PROGRAM

Collaboration between NRG, JRC and TU Delft (soon also CVR Rez, FU Berlin)

- 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

1. Obtain operational experience
2. Confirm FP stability in the salt
3. Investigate FP management methods
4. Develop in-pile metal/graphite corrosion rig
5. Waste route for spent molten salt fuel
6. Experimental MS loop for the HFR Petten

TENTATIVE IRRADIATION SCHEDULE

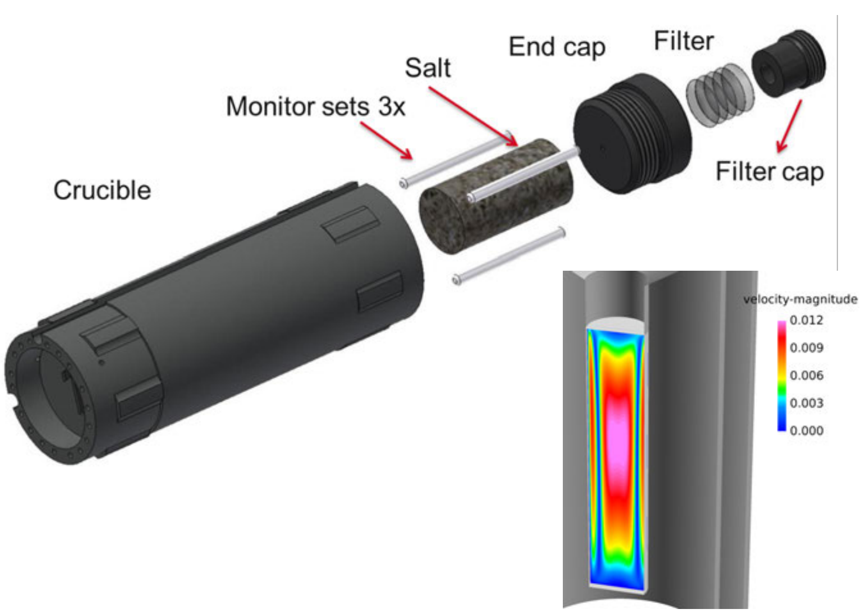
Item	Goal	Target date
SALIENT-01	fission product (FP) behavior	2017
SAGA	room temperature gamma irradiation / radiolysis	2018
SALIENT-03	in-pile alloy corrosion / FP behavior	2019
SALIENT-04	in-pile helium bubbling	2020
LUMOS loop	flowing salt experimental facility	

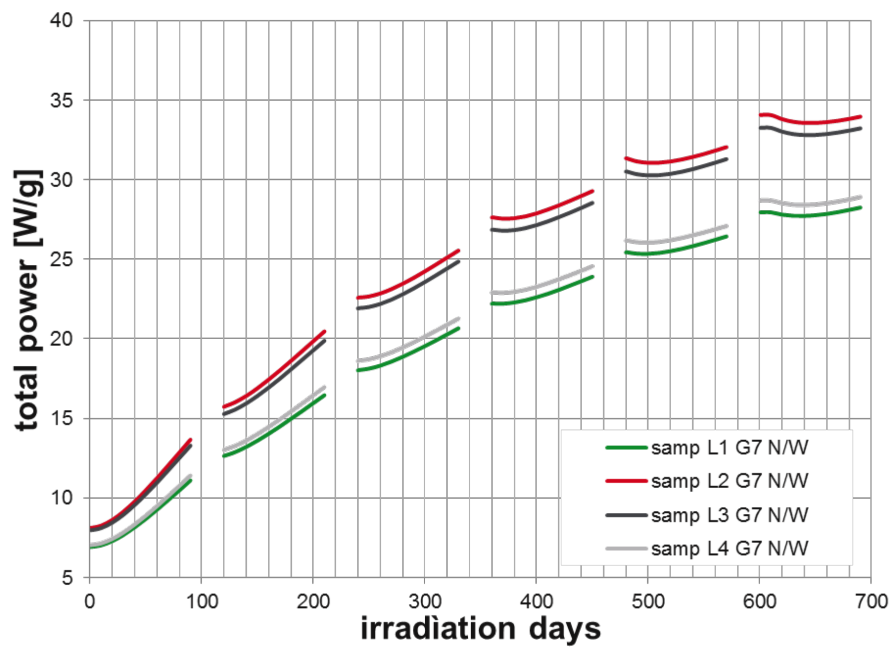
- SALIENT capsule irradiations in standard in-core HFR facilities
- SAGA facility in HFR spent fuel pool
- LUMOS loop in HFR pool (adjacent to core wall)

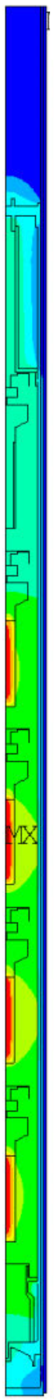
SALIENT-01 DESIGN

A stack of open crucibles is irradiated in a double containment:

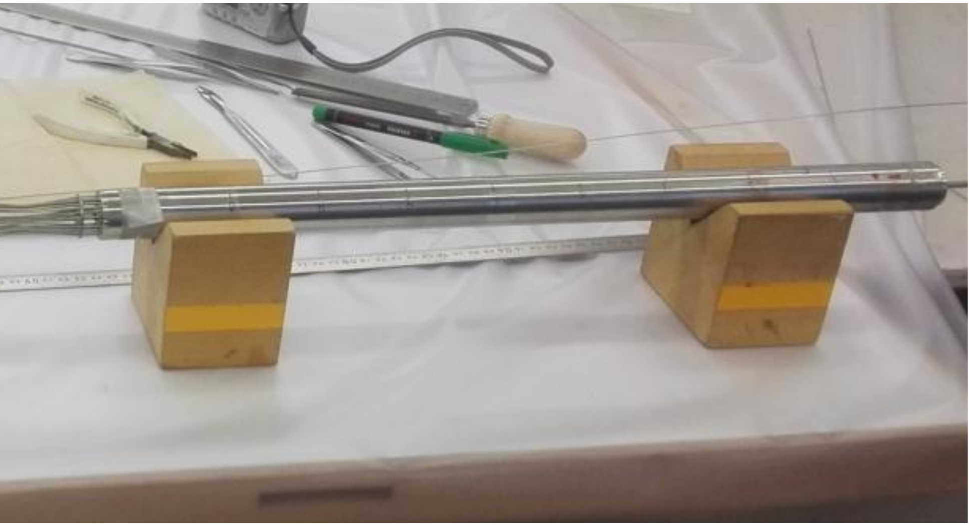
- Salt composition: **78LiF-22ThF$_4$**
- Single result on cover gas composition for multiple crucibles
- Fuel power rises during irradiation due to production of U-233
- Gas composition between containments is adjusted to maintain a **fixed crucible temperature (~600 ^{o}C)**

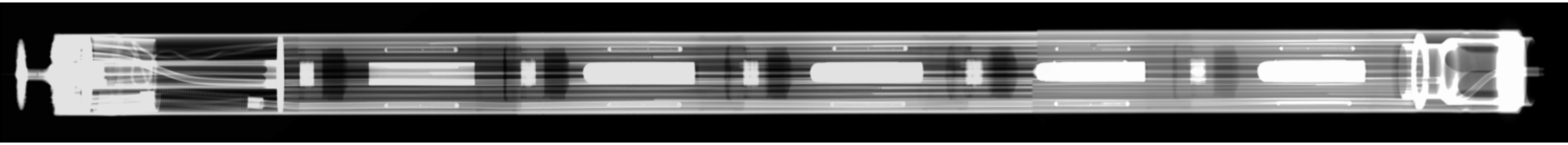






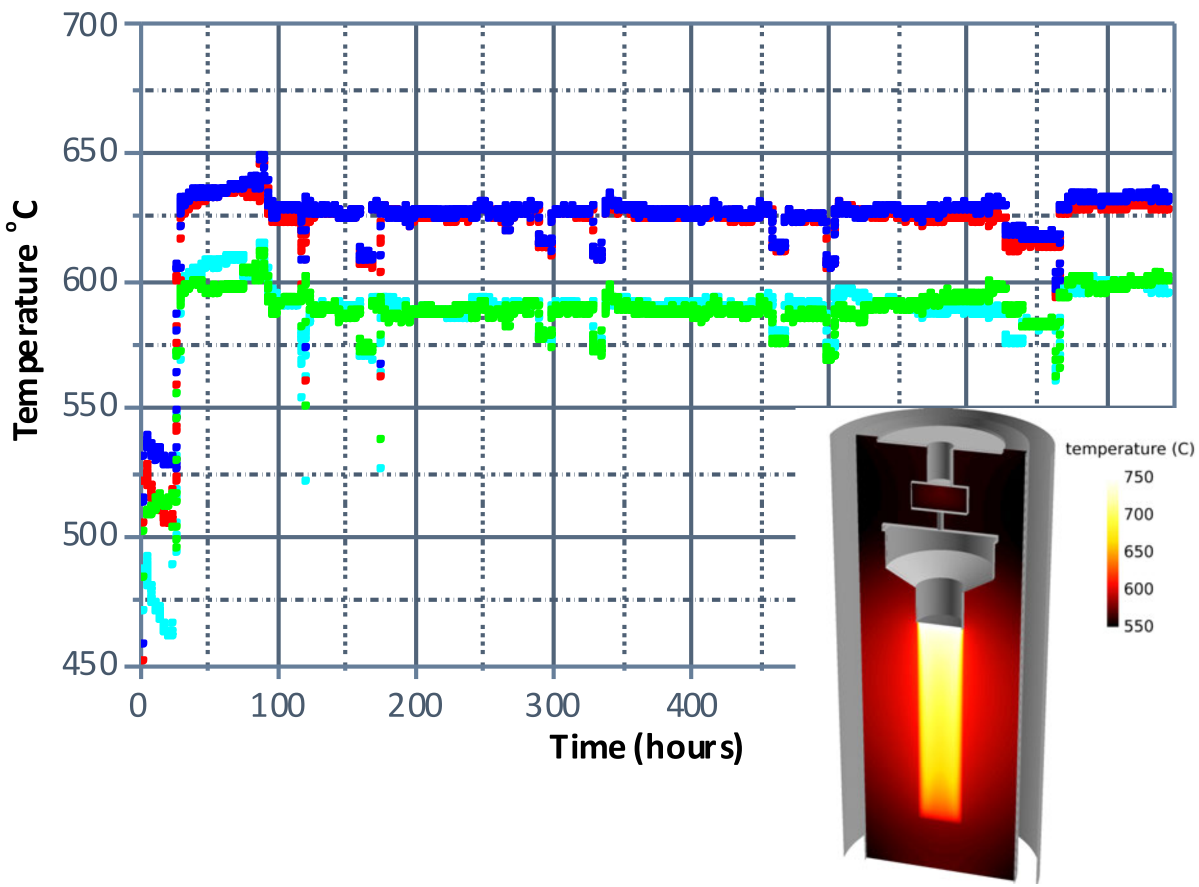
SALIENT-01 ASSEMBLY





CURRENT STATUS

- Start of irradiation: August 10
- First cycle completed according specifications
  - 31 FPD
  - Temperatures on target
- Average crucible temperatures:
  - 585 °C (L1, L4)
  - 620 °C (L2, L3)
- Max. # cycles: 18



POST-IRRADIATION EXAMINATIONS

Calibrated burn-up analysis
- Sample compositions

Neutron radiography of the sample holders
- Experiment overview, integrity after irradiation

Gamma spectrometry
- Indication of the spread of gamma-emitting species within sample holder

Puncture of the sample holder and gas analysis by mass spectrometry
- Fission gas release from samples through natural convection (Xe, Kr, He)

Electron microscopy / WDS:
- FP distribution over salt, metal filter, graphite wall
- Size distribution of metallic species
- Surface states of graphite, metallic species

Knudsen cell effusion:
- Determine salt stability, temperature at which FP species become volatile, Cs release

WASTE STRATEGY

- Conversion of salt to recognizable, acceptable chemical forms:
  - Oxide high level waste
  - Cemented intermediate level waste
  - Fluoride intermediate level waste (CaF_2 or fluorapatite)

- Route: aqueous processing
  - Can be performed at NRG hot cells with relatively little infrastructure changes
  - No complicated gas streams
  - Limited spreading of dust

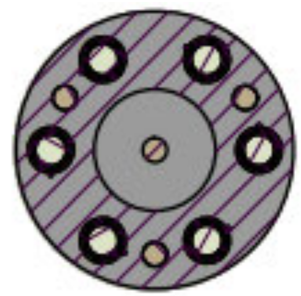
- Preliminary lab results:
  - Dissolution in nitric acid and removal of bulk lithium
  - Removal of the fluoride by metathesis in KOH
  - Precipitation of the fluoride using calcium (CaF_2)
  - Calcination of hydroxides to oxides
  - Cementation of remaining liquid waste

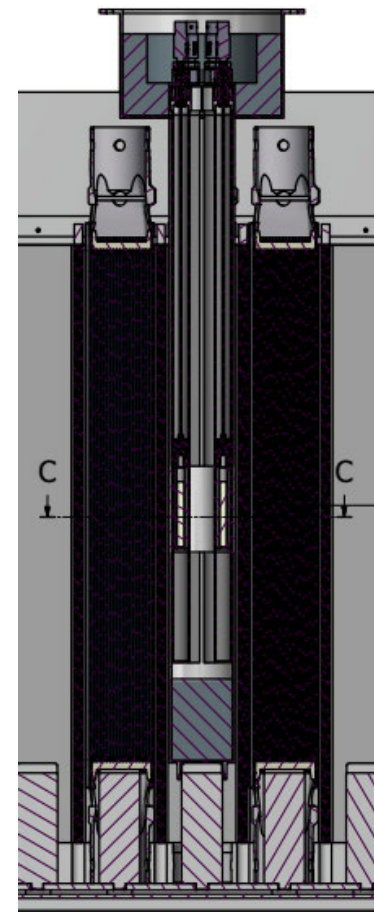
SALIENT-03 - CONCEPT

- A second capsule irradiation, but using Alloy N (or similar) crucibles
- Focus on in-pile corrosion → salt buffering (UF_4:UF_3) and electric heaters needed
  - Crucible corrosion from electron microscopy
  - Possibly: small samples of the crucible material for weight change measurements
- Materials:
  - Russian-developed formulation HN80MTY [Ignatiev2013 small batch produced by COMTES FHT in Czech Republ
  - **Other (modified) Alloy N types requested for direct comparison**
  - Possibly: SiC

SAGA GAMMA IRRADIATION FACILITY

- HFR Spent fuel used as gamma source (30-70 kGy/h)
- ~45 °C base irradiation (solid salt samples)
- Possibility for out-of-pool electric heating to 150 °C
  → recombination kinetics
- Samples provided bij CVR Rez and JRC Karlsruhe



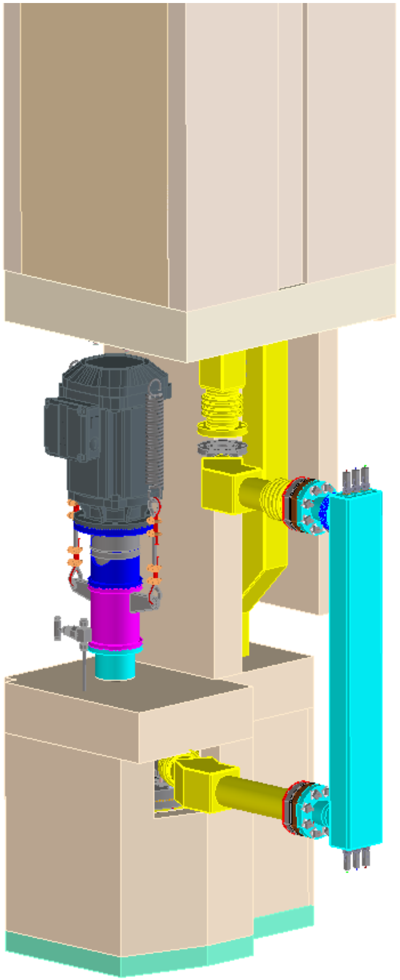


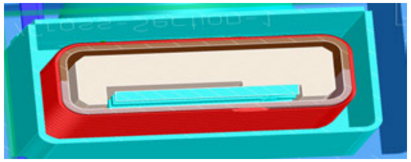
LUMOS LOOP CONCEPT DESIGN

In-pool loop positioned directly next to HFR core wall

Main parameters:

- Actinide bearing FLIBE salt (~20 L)
- Alloy N first containment
- Power: 125 kW (initial)
- Power density: 100-180 W/cc
- Flow rate: ≤3 m/s
- ΔT: ≤100 °C
- 5-6 operational years targeted





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RADIOLYSIS

- **Radiolysis** is the cleavage of chemical bonds by radiation (in the current context: alpha, beta and gamma radiation)

- From halide salts the halide gases are produced (**F_2** for fluorides)

- Radiolysis in cooled down irradiated fuel salt due to decay heat

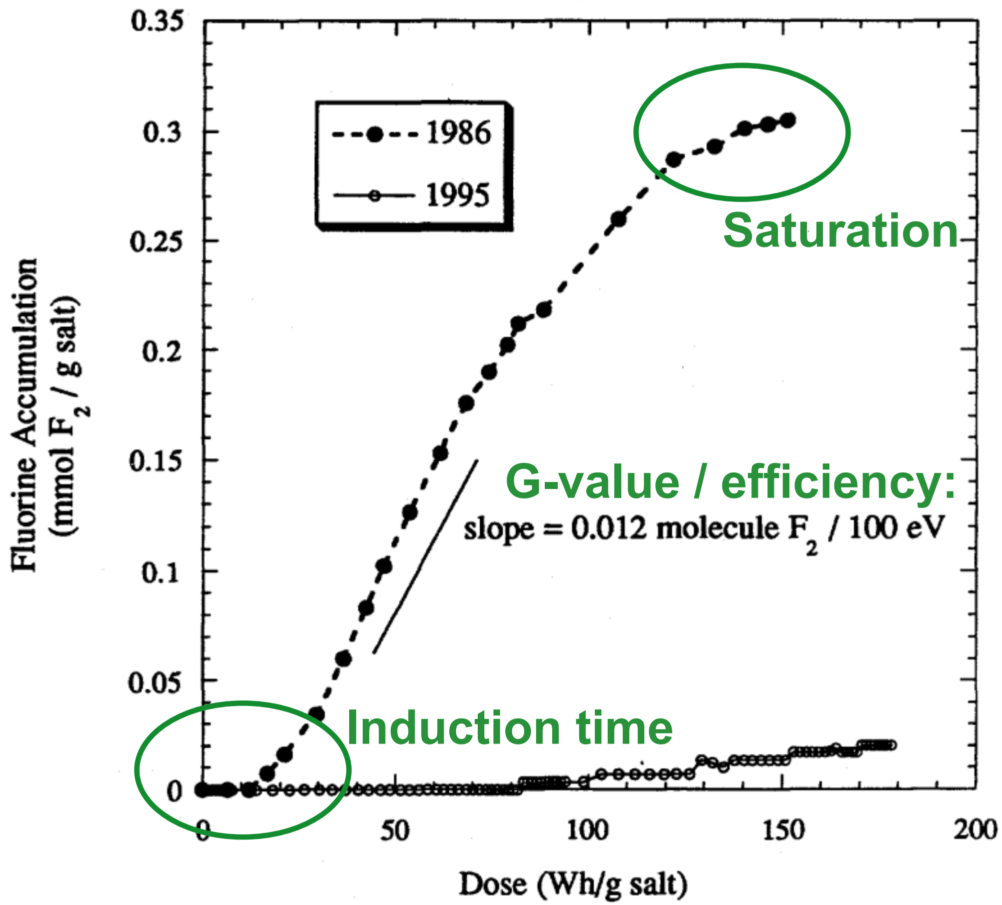

Fig. 3. Fluorine generation curves for 1986 and 1995 irradiation experiments.