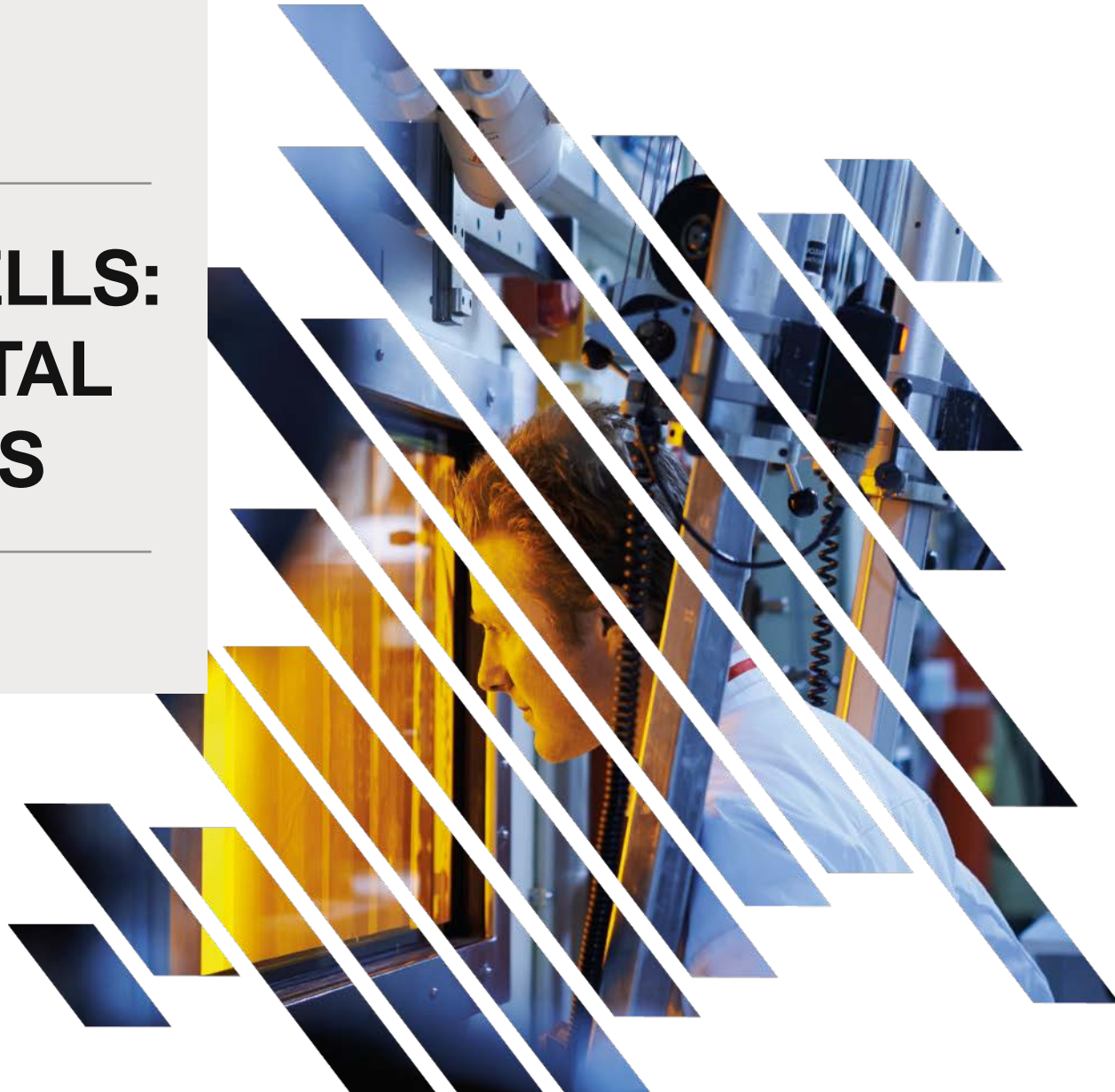




NRG HOT CELLS: EXPERIMENTAL CAPABILITIES

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S. Knol

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CONTENTS

Introduction NRG

Hot Cell facility overview

Experimental facilities + examples

NUCLEAR FACILITIES



**HIGH FLUX
REACTOR**



**HOT CELL
LABORATORIES**



**MOLYBDENUM
PRODUCTION FACILITY**



**DECONTAMINATION
& WASTE TREATMENT**



**RADIOLOGICAL LAB:
JAAP GOEDKOOP LABORATORY**



PRODUCTS AND SERVICES



ISOTOPES



TESTING
NUCLEAR
MATERIALS



RADIATION
PROTECTION



SAFETY &
RISK





ASSET
OPTIMIZATION








DECOMMISSIONING
& WASTE
MANAGEMENT

HOT CELL LAB LAYOUT

Concrete HA cells

-  Dismantling, NDE and radioisotope processing
-  Dedicated for historic nuclear waste processing

Lead cells

-  Alpha cell line, e.g. LM, SEM, EPMA, EBSD
-  Mechanical and physical material characterization
-  Boxed cells for chemical studies (dissolution, leaching)
-  Actinide lab, e.g. (MA-)fuel fabrication and characterization, fuel loading
-  Transport zone



NON DESTRUCTIVE (FUEL) PIE

Flexible setup allows reference testing and modifications outside the cell

Sample displacement with 3 DoF (2T,1R) and allows the testing of

- Plate-type (targets)
- Cylindrical (fuel pins)
- Spherical objects (HTR fuel pebbles)

Available analyses

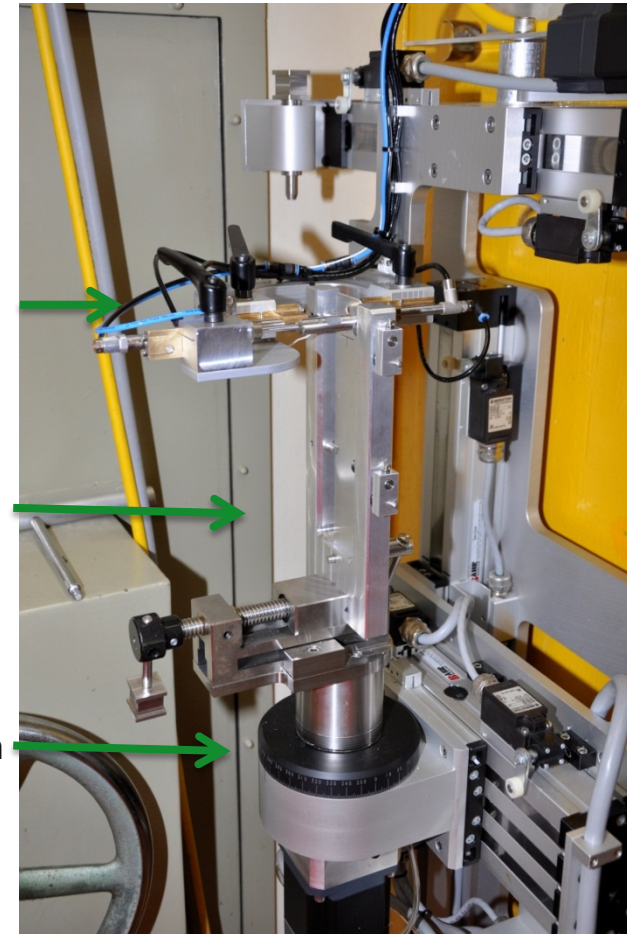
- Profilometry
- Oxide layer and surface analysis by eddy current measurements
- Gammaspectrometry

- Fission gas release

Probes

(dummy) target in holder

Displacement bench

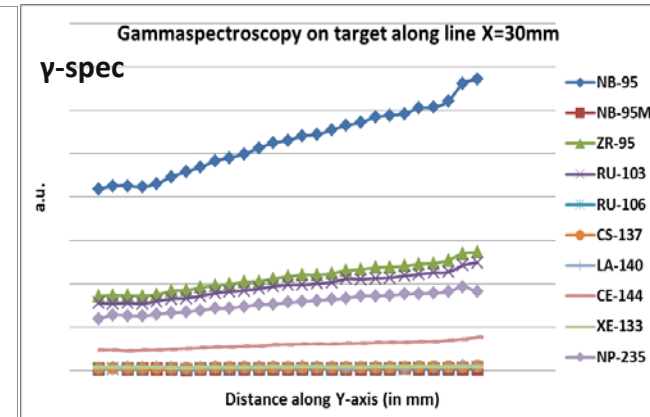
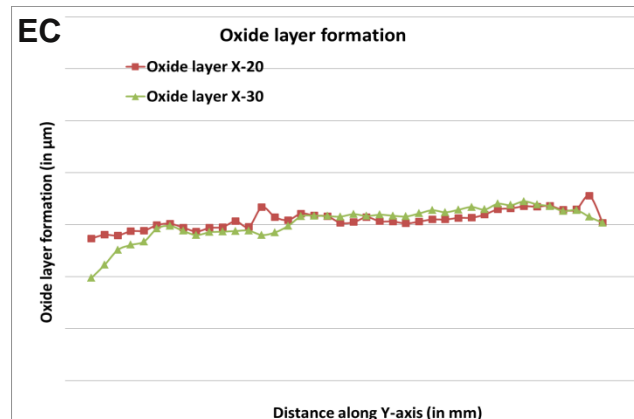
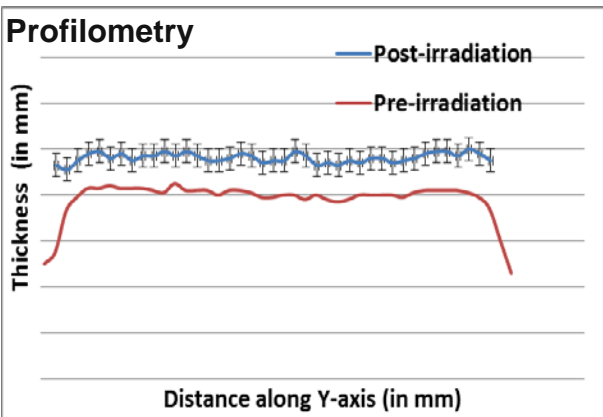


EXAMPLE LEU ^{99}Mo TARGETS

(Irradiation) Qualification of LEU targets for ^{99}Mo production

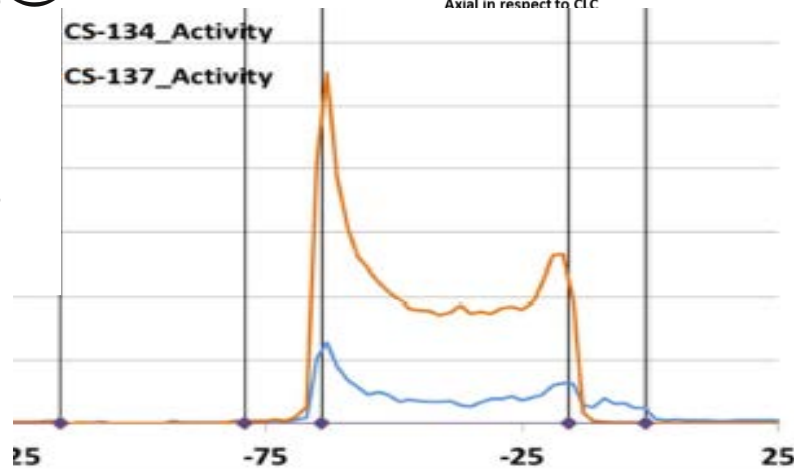
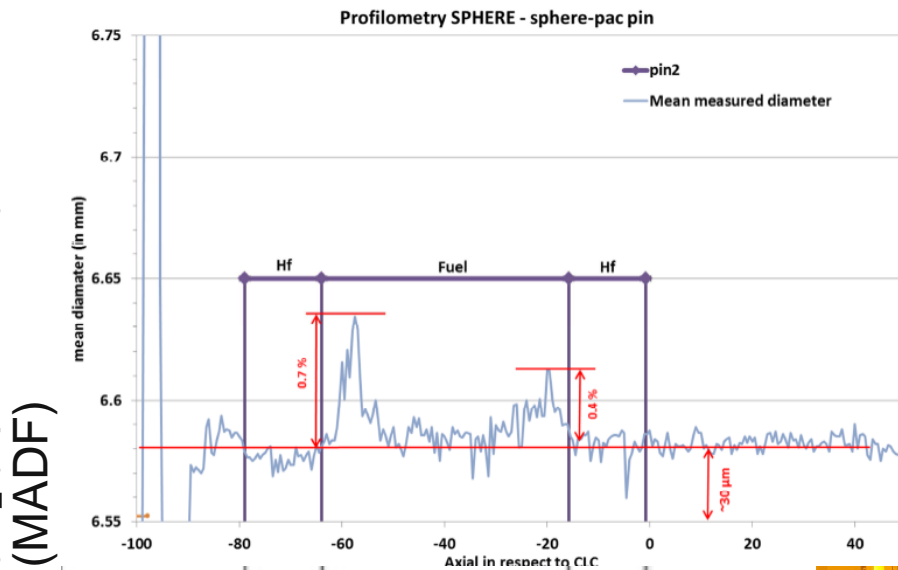
Batch of 12 targets with strict criteria on

- Swelling,
- Meat and fission product mobility
- Oxide layer growth (thermal insulation)

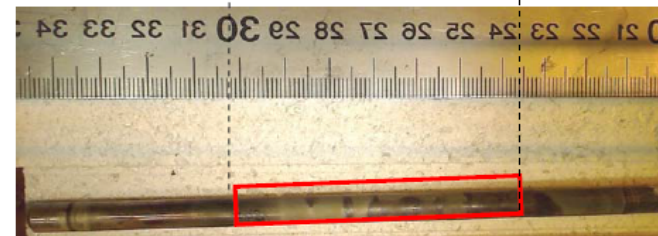
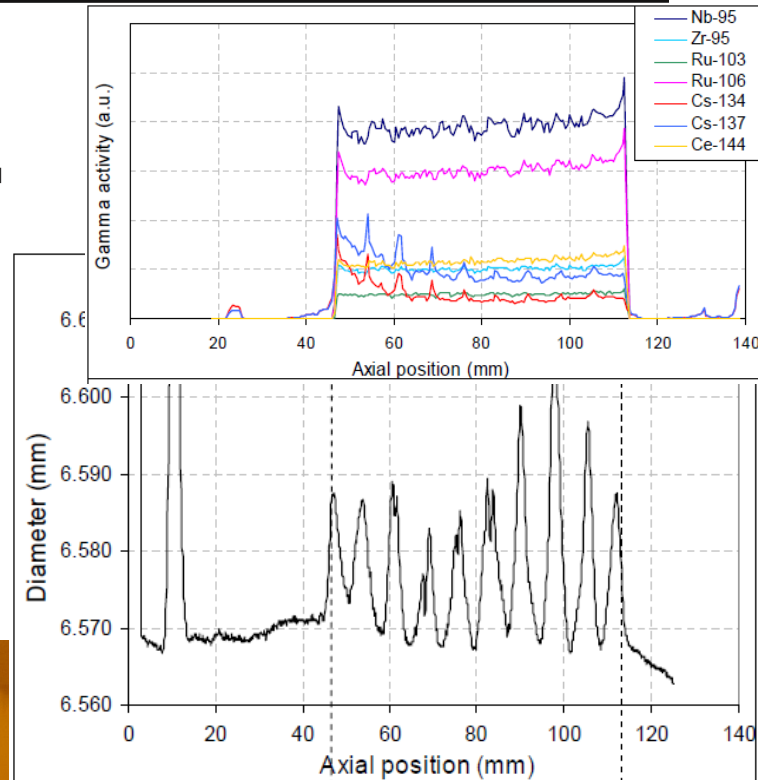


EXAMPLES ND PIE: GEN IV FUELS

(U,Pu,Am)O₂ (Sphere-Pac)



CERMET: (Pu,Am)O₂ + Mo



FISSION GAS RELEASE

- Sealed puncturing rig in cell
- Connected to vacuum system outside cell
- Fuel pin plenum pressure measured
- Gas composition analysis by QMS

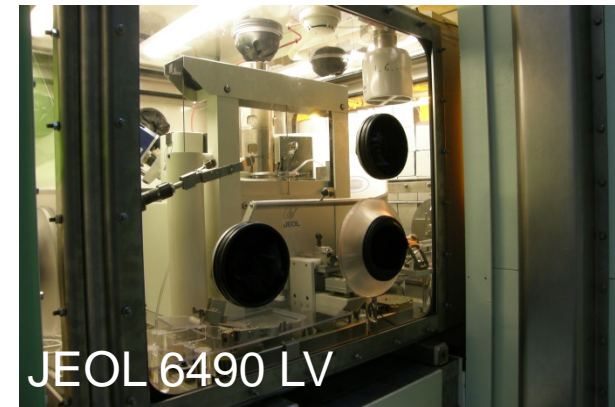
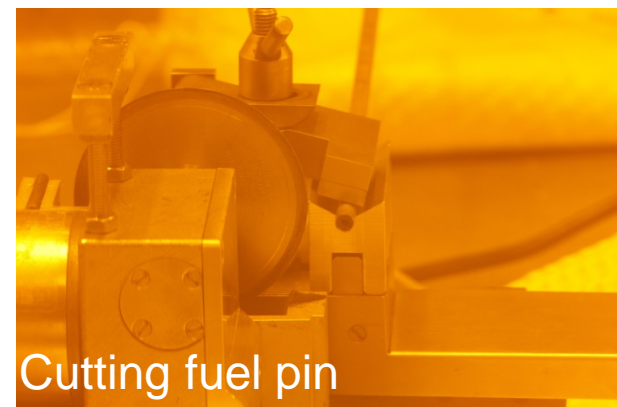
Started preparations for adaptation to perform fuel annealing in cell to study gas retention



MICROSCOPY LINE

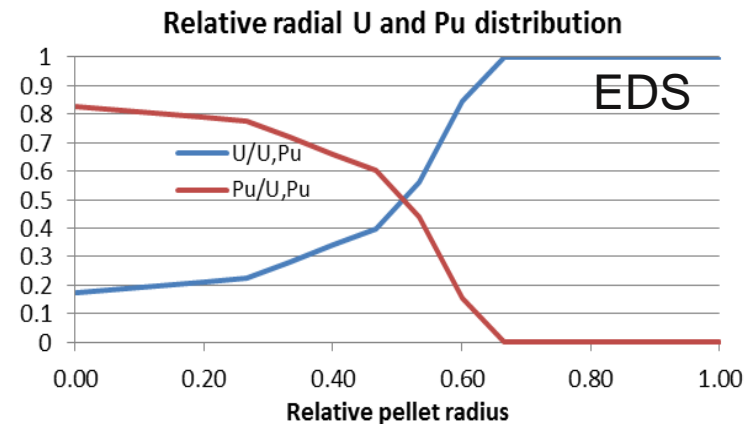
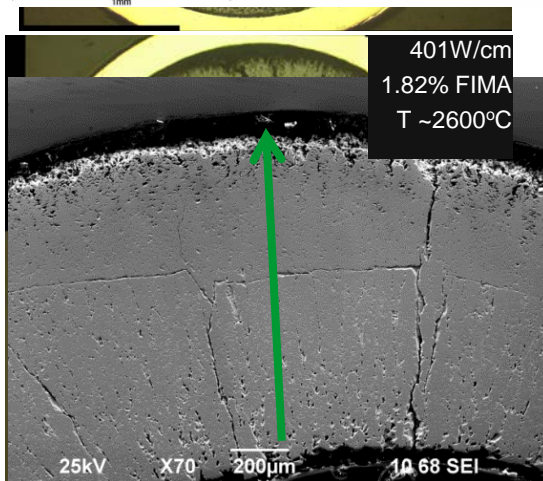
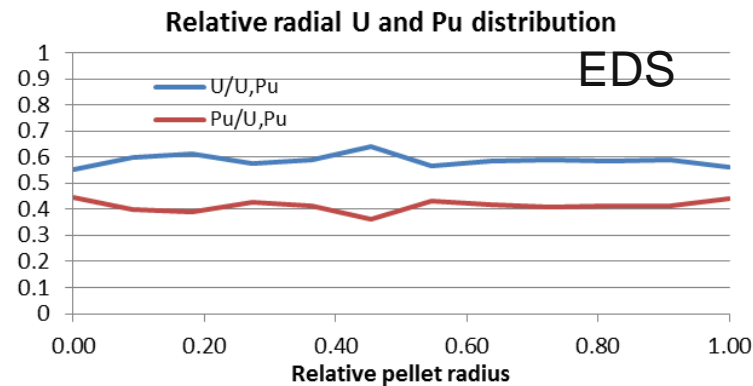
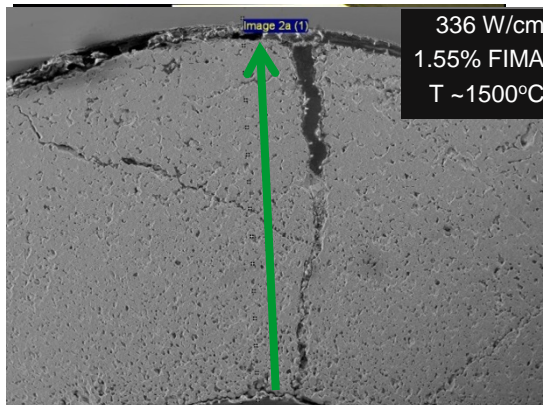
Alpha-tight hot cell line

- Cutting , Grinding and polishing of samples for LM, SEM and TEM
- Cathodic etching
- Conductive coating sputtering
- Leitz LM
- JEOL 6490 LV SEM (incl Oxford EDS, WDS, EBSD)
- TEM (other lab)



EXAMPLE FUEL CHARACTERIZATION

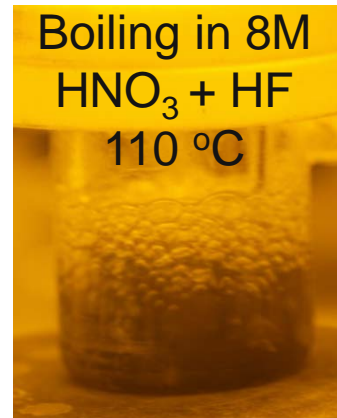
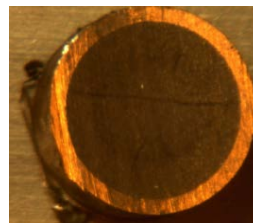
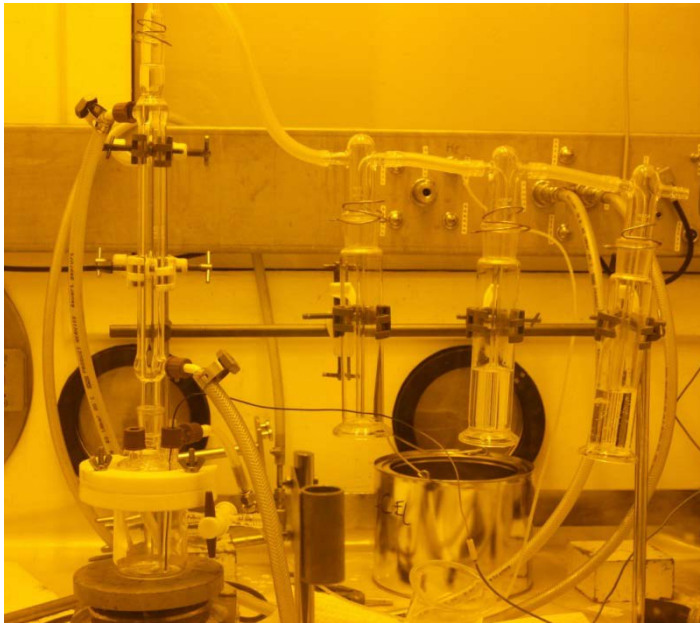
Gen IV MOX stability / redistribution study ($U_{0.55}Pu_{0.45}O_2$)



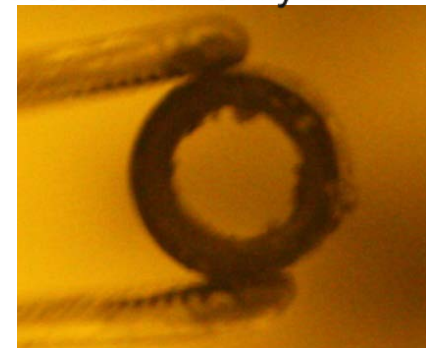
CHEMICAL STUDIES

Multiple boxed cells— allows (tailoring of) inert atmosphere

- Leaching studies C14 from steels
- Tritium retention/release in steels
- Fuel dissolution studies →
 - Dissolution of irradiated (oxide and) nitride fuels ($\text{Pu}_{0.3}\text{Zr}_{0.7}\text{N}$ (10%FIHMA))
 - Residue analysis by SEM
 - Isotopic analysis by TIMS (other lab)



Highest Burn-up in rim
Residue mainly ZrN



ACTINIDE LABORATORY

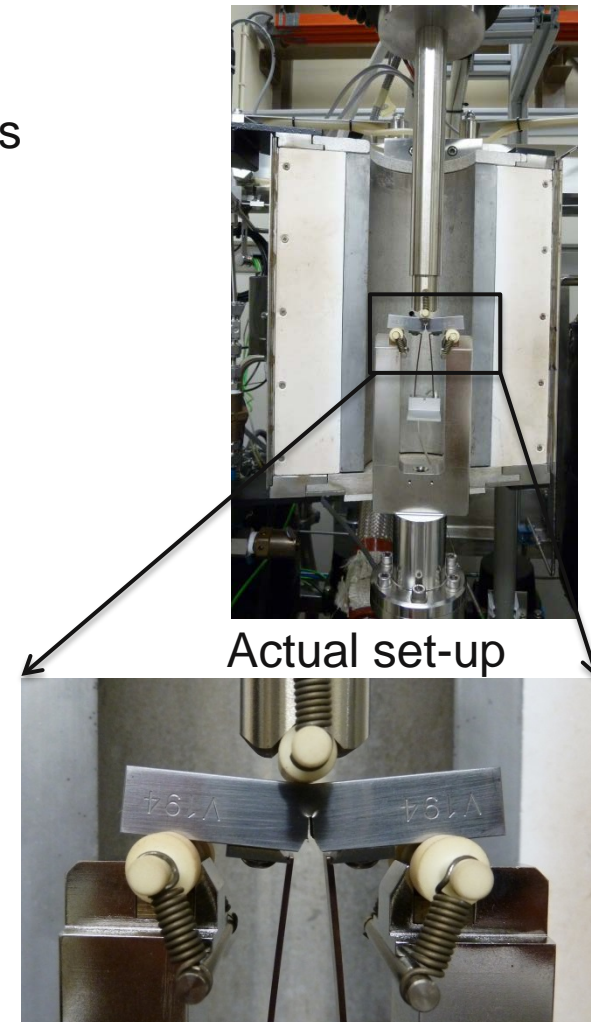
- Fabrication and characterization of CerMet and Oxide fuel
- Fabrication by powder metallurgy method
- Characterization by XRD (Bruker D2), density (immersion method) and/or DTA/TG
- Molten salt waste treatment for intermediate storage



IN-CELL FRACTURE MECHANICS SETUP FOR K_{IC} , J_{IC} AND T_0 DETERMINATION

- As a part of NRG's RPV Long Term Operation (LTO) research program (STRUMAT), a new fracture mechanics setup suitable for in-cell operation was installed in NRG hot cells.
- Accessible temperature range from -170 to + 300 °C.
- Possibility to perform ASTM K_{IC} , J_{IC} and crack extension measurements with integrated COD and DCPD systems.
- Suitable to perform 'Transition temperature, T_0 ' measurements by master curve approach on full size ISO-V charpy specimens (SNEB).
- Suitable for testing RPV surveillance specimens for its lifetime assessment based on T_0 shift measurements.

This setup is currently being used to investigate Armenian VVER-440 reactor steel thermally aged and irradiated for 27 years.



AGR LIFETIME EXTENSION

NATIONAL NUCLEAR
LABORATORY

edf
ENERGY

FRAZER-NASH
CONSULTANCY

Trepan Material from
AGRs

Shipment of material
from Windscale to
NRG

Decontamination of
material

Machining of
specimens

Pre-characterisation

Irradiation

Post-irradiation
measurements



- Young's modulus,
- Thermal expansion,
- Flexural strength (PIE only)
- Thermal conductivity,
- Electrical resistivity,
- X-ray tomography,
- Optical microscopy

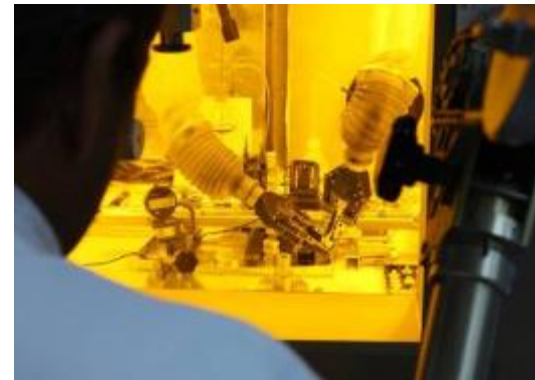


CREEP MEASUREMENT ROUTE

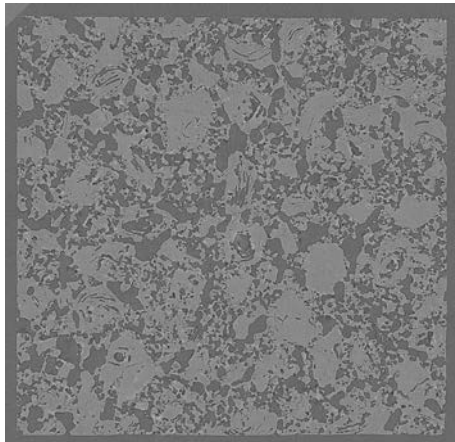
Pre-irradiation examination



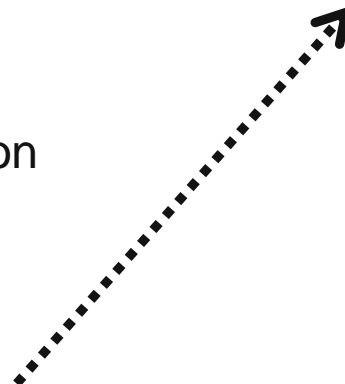
Experiment assembly



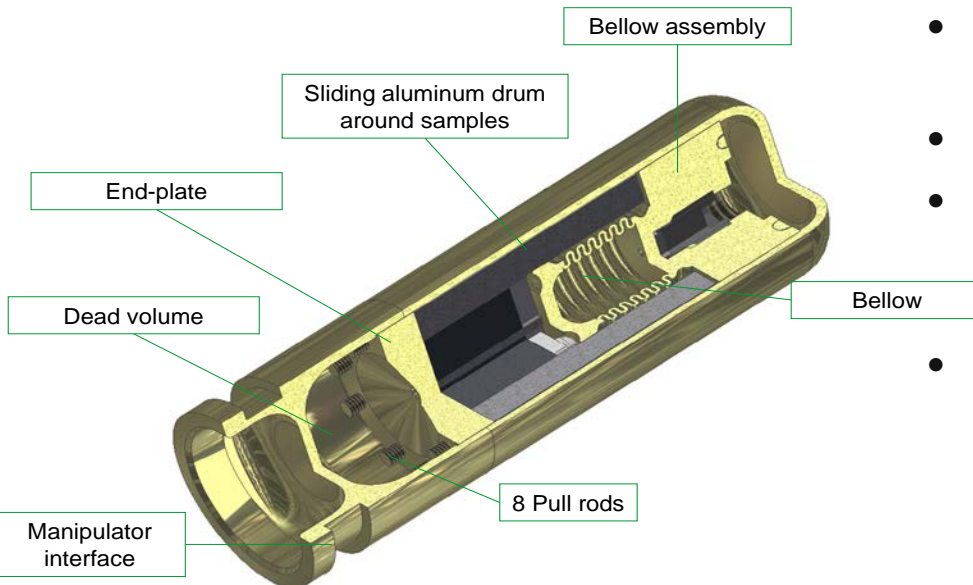
Post-irradiation examination



Irradiation



CREEP MODULAR DESIGN



Irradiation modules and measure material displacements post irradiation

- Multiple samples per module
- Online sample temperature monitoring by multiple-thermocouples
- Accurate online temperature control by gas gap mixture adjustment in radial gas gaps
- Online axial load control by externally pressurised bellow
- Total stack elongation measurement by LVDT
- Neutron activation monitoring sets for high accuracy post-irradiation neutron fluence measurement
- Constant sample flux by online facility positioning capability relative to HFR flux buckling profile

SUMMARY

NRG targets on operating the full irradiation chain with full cost recovery from the market

Increasing material characterizations/qualifications from nuclear industry/utilities (EdF, AREVA, INET, ITER, RWE, Mallinckrodt, ...)

Largely possible in combination with publically funded research projects to explore scientific and practical challenges (and due to its legacy)

Facility flexibility and planning are of increased importance, due to increasing pressure on HCL (more radioisotopes, cell reserved for waste treatment)

Besides established techniques, new hot cell techniques/procedures are developed to meet market and regulatory body demands

THANK YOU

For more information, contact me personally or at : vantil@nrg.eu