



Advanced Fabrication and Characterization of Gd Pellets for SMR Fuel in Argentina

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NUCLEAR ENERGY IN ARGENTINA



Unit	Power [MW]	Reactor type	Enrichment [%]	Commercial Operation
Atucha-1	362	PHWR	0.85 % U-235	1973
Embalse	656	PHWR-CANDU	Natural Uranium	1983
Atucha-2	745	PHWR	Natural Uranium	2015



CANDU-PHWR FUEL TYPES



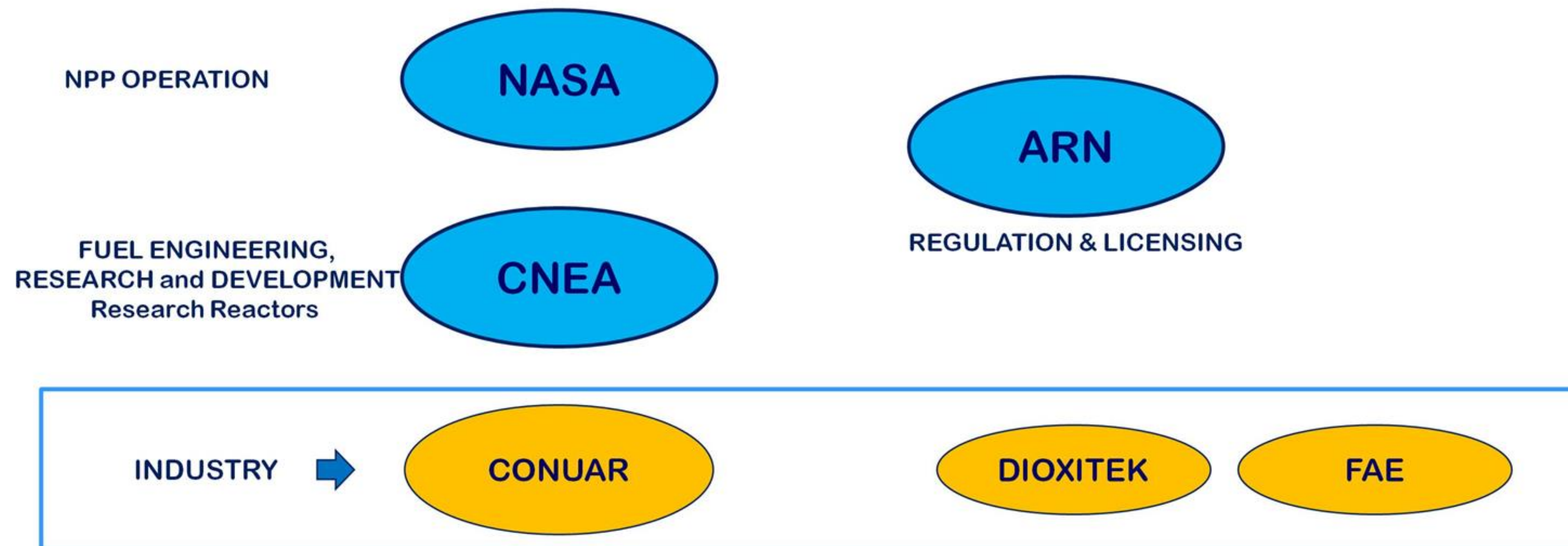
PHWR fuel assemblies →	Atucha I	Atucha II	Embalse CANDU
Array	Circular 37 Fuel Rods Rigid Spacer Grids	Circular 37 Fuel Rods Elastic Spacer Grids	Circular 37 Fuel Rods
Length	6 m	6 m	50 cm
Cladding material	Zry-4	Zry-4	Zry-4
Cladding coating	No	No	graphite
Collapsible cladding	No	No	Yes
Pellet material	UO ₂	UO ₂	UO ₂
Enrichment	SEU 0.85% U-235	Natural uranium	Natural uranium
Pellet density (nominal)	10.60 g/cm ³	10.55 g/cm ³	10.60 g/cm ³
Materials: structural components	Zry-4 - Stainless Steel and Inconel	Zry-4 - Stainless Steel and Inconel	Zry-4



ARGENTINE NUCLEAR FUEL NETWORK



Organizations – Power Reactor Fuels



ADVANCED FUELS PILOT PLANT



Ceramic research and development for nuclear fuels.

Location: Constituyentes Atomic Center (Buenos Aires)

CERAMIC CORES PILOT PLANT

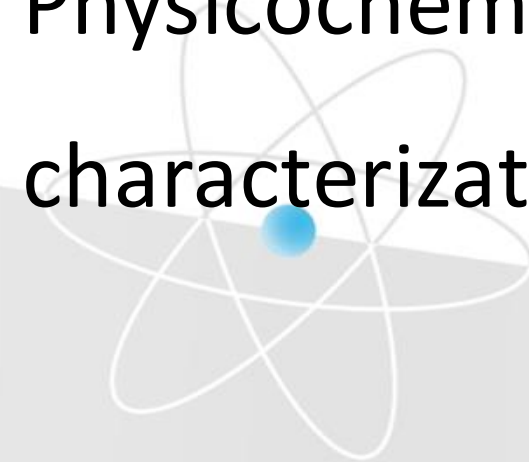
Research, development and pilot-scale manufacturing of natural and enriched UO_2 fuel pellets up to 3.6% U^{235} .

BURNABLE POISONS LABORATORY

Research, development and pilot-scale manufacturing of natural UO_2 fuel pellets with burnable poisons (Gd_2O_3 , Dy_2O_3).

CHARACTERIZATION AND NUCLEAR CERAMICS LABORATORY

Physicochemical characterization of samples of natural UO_2 and enriched up to 20% (powder and pellets characterization).



FUEL PELLETS DEVELOPMENT FOR A SMR



Development of fuel pellets for a SMR reactor, defining the characteristics, methodology and manufacturing parameters compatible with technologies already installed in local industry and controls to be carried out to obtain them uniformly and on an industrial scale.

ENRICHED URANIUM DIOXIDE PELLETS

URANIUM DIOXIDE– GADOLINIUM OXIDE PELLETS (UO_2 - Gd_2O_3)



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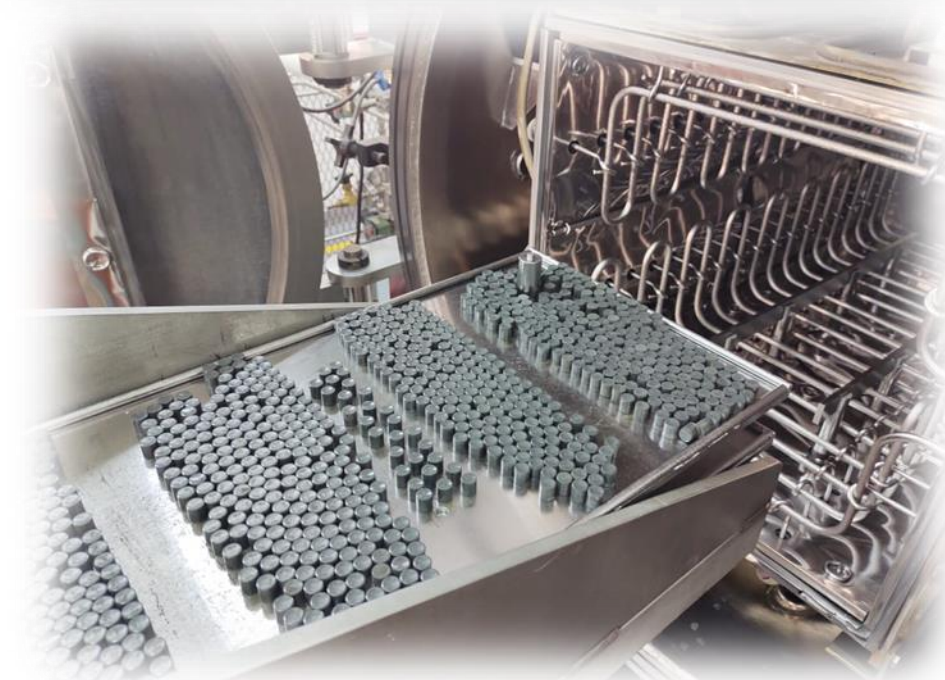
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ENRICHED UO_2 FUEL PELLETS FOR A SMR



3,1% ENRICHED UO_2 FUEL PELLETS WITH PORE FORMER

- FUEL PELLETS DEVELOPMENT
- DEVELOPMENT AND VALIDATION OF CHARACTERIZATION TECHNIQUES FOR POWDERS AND PELLETS
- FUEL PELLETS MANUFACTURE FOR IRRADIATION IN HALDEN REACTOR
- PILOT SCALE DEVELOPMENT
- TECHNOLOGY TRANSFER TO CONUAR



ENRICHED UO_2 FUEL PELLETS FOR A SMR



FUEL PELLETS DEVELOPMENT

Characterization of the UO_2 powder, study and selection of pore formers (OA) and lubricants, mechanical mixtures tests, study of pressing and sintering parameters.

DEVELOPMENT AND VALIDATION OF CHARACTERIZATION TECHNIQUES FOR POWDERS AND PELLETS

Characterization of raw materials, powders, intermediate products and fuel pellets in all stages of the process, according to the technical specifications. Survey of CNEA laboratories qualified to carry out the tests.

FUEL PELLETS MANUFACTURE FOR IRRADIATION IN HALDEN REACTOR

Manufacture of 3,1% UO_2 fuel pellets for irradiation in the Halden reactor (Norway).

PILOT SCALE DEVELOPMENT

Mixing system change of scale, dies and press automatic loading system adjustment, definition of manufacturing control parameters, definition of continuous sintering parameters, grinder adjustment.

TECHNOLOGY TRANSFER TO CONUAR

Technical meetings, assistance to CONUAR in preparing the manufacturing line. Preparation and delivery of documentation (manufacturing procedures, pilot scale manufacturing results reports and fuel pellets characterization).

$\text{UO}_2 - \text{Gd}_2\text{O}_3$ FUEL PELLETS FOR A SMR



NATURAL UO_2 PELLETS WITH Gd_2O_3 AS BURNABLE POISON

Developed in the Burnable Poisons Laboratory.

Currently the only facility with the capacity to manufacture fuel pellets with burnable poisons in Argentina.

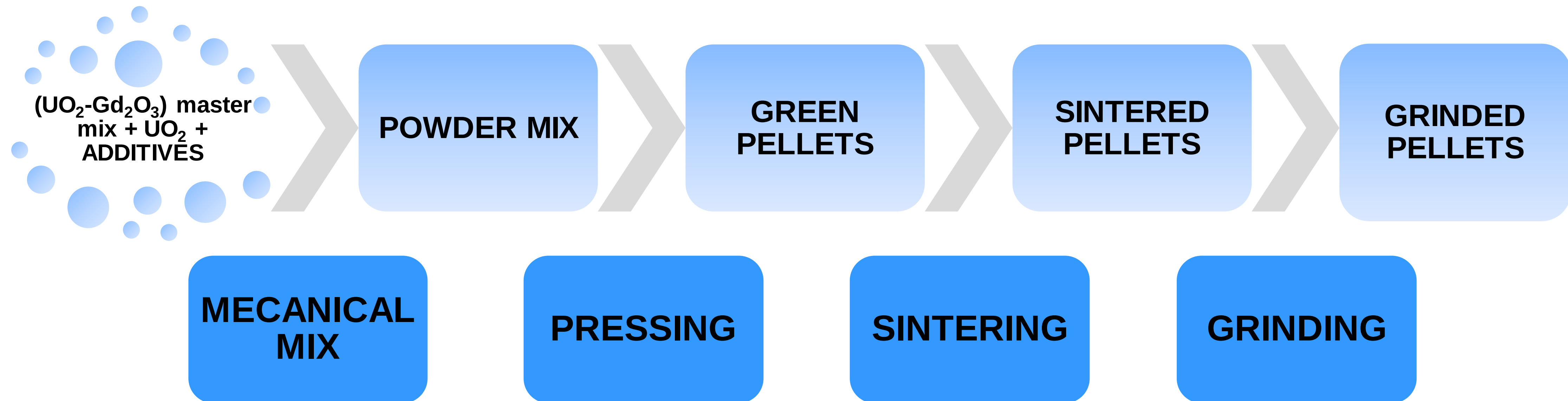
- **FUEL PELLETS DEVELOPMENT**
- **DEVELOPMENT AND VALIDATION OF CHARACTERIZATION TECHNIQUES FOR POWDERS AND PELLETS**
- **CHANGE OF SCALE AND SETTING UP EQUIPMENT**
- **QUALIFICATION AND MANUFACTURING OF FUEL PELLETS FOR A SMR**



$\text{UO}_2 - \text{Gd}_2\text{O}_3$ FUEL PELLETS FOR A SMR



MANUFACTURING PROCESS



UO₂ – Gd₂O₃ FUEL PELLETS FOR A SMR



FUEL PELLETS DEVELOPMENT

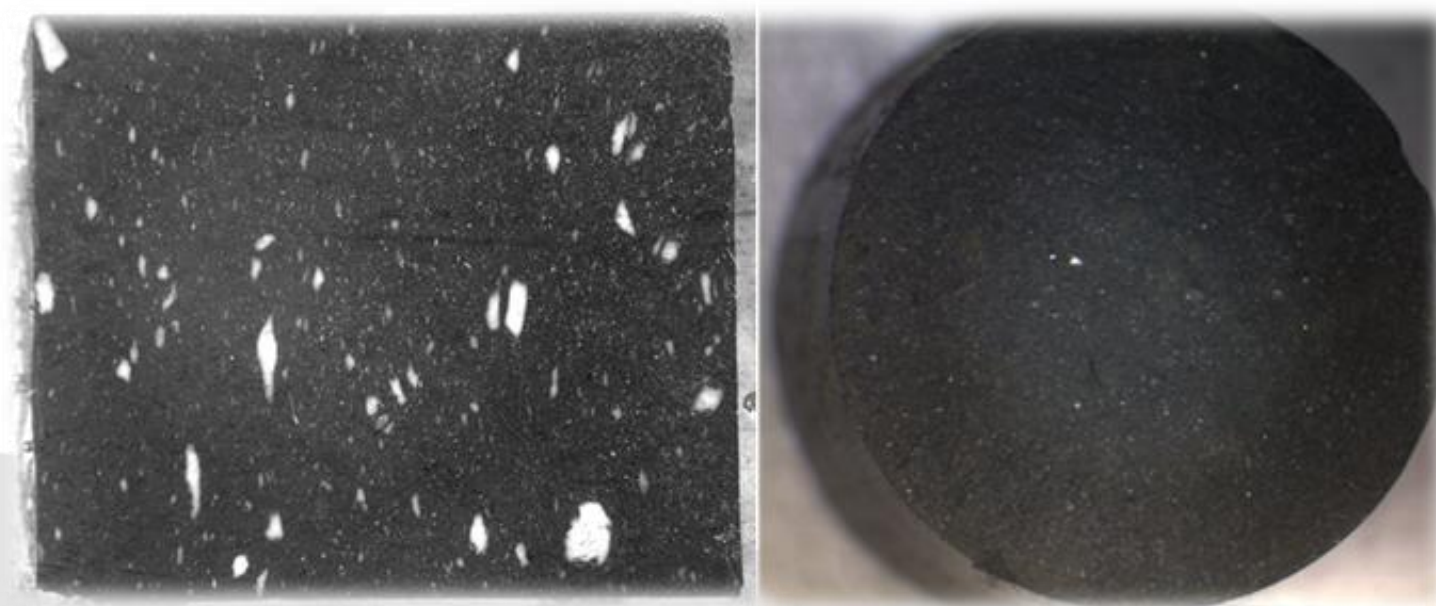
Objective: to obtain fuel pellets that meet specifications and can be manufactured on an industrial scale, compatible with Argentine technology.

First tests:

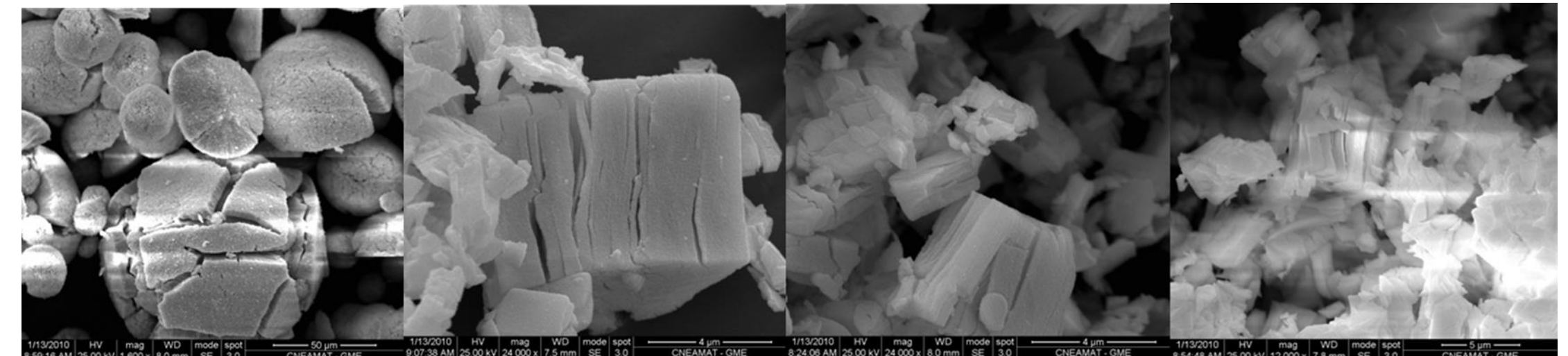
- Powders characterization
- Gd₂O₃ powder: characterization and suppliers selection
- Sintering at 1650°C for 2hs

Low densities

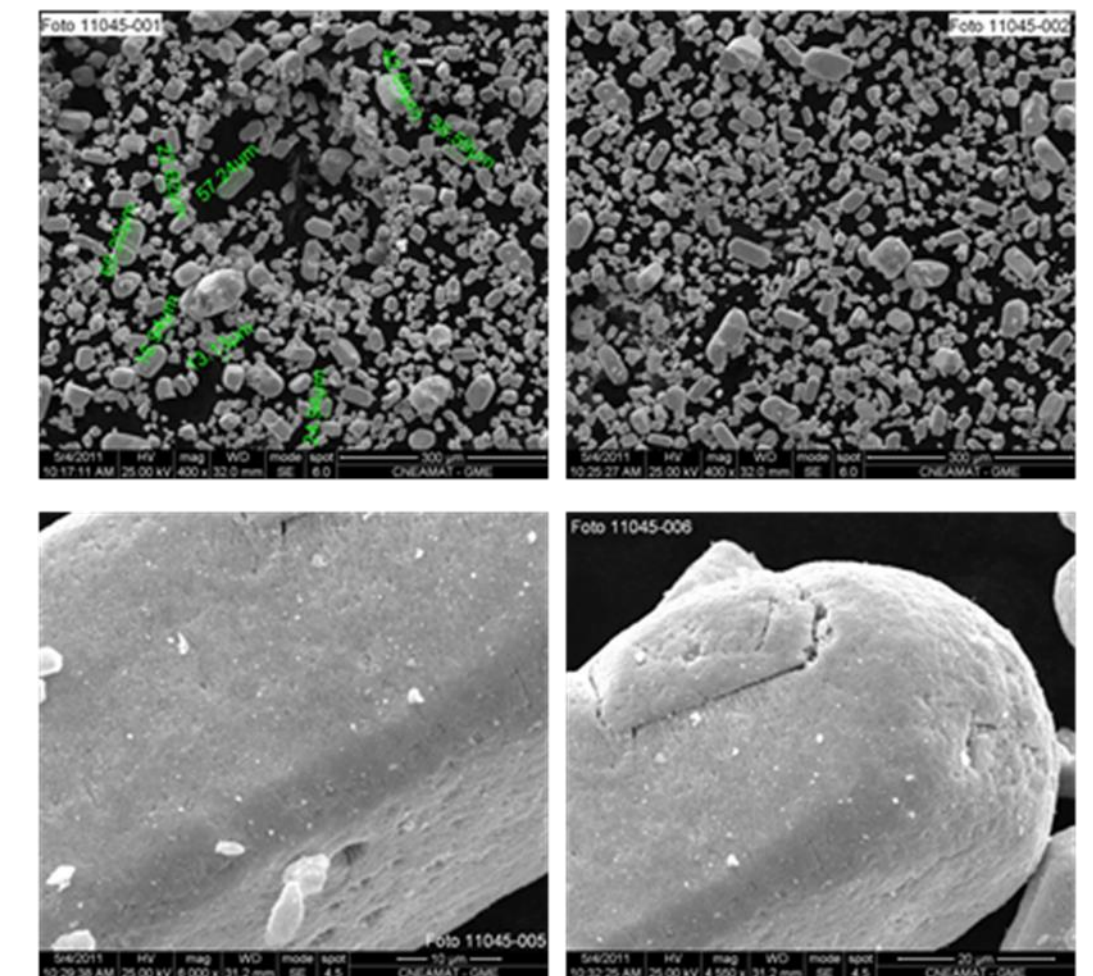
Gd islands



Gd₂O₃ powders



UO₂ ex AUC powder



UO₂ – Gd₂O₃ FUEL PELLETS FOR A SMR



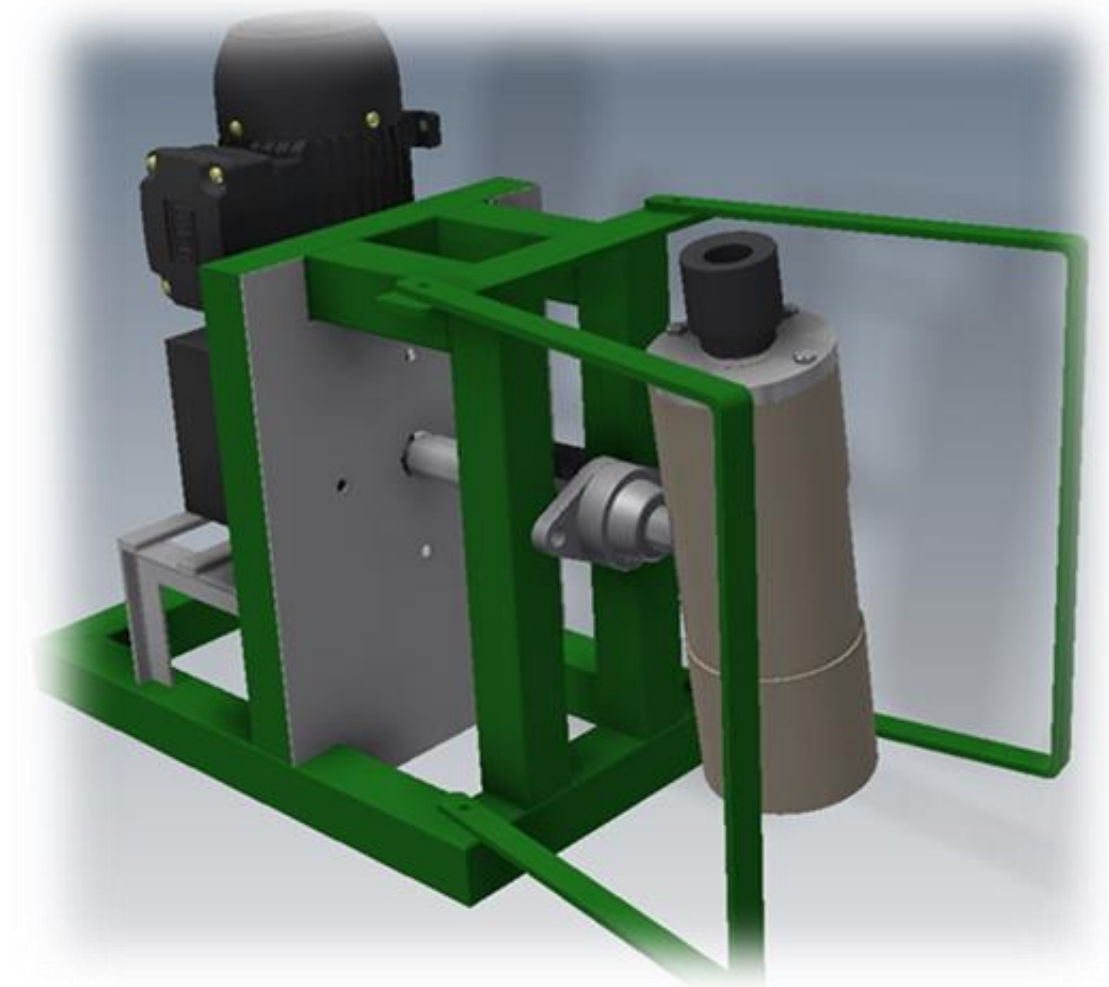
FUEL PELLETS DEVELOPMENT

- Mixing process optimization. Pellets without Gd islands
- Incorporation of Al in lubricant to improve microstructure
- Pellets contractions studies
- Preliminary tooling design
- Sintering in H₂ atmosphere up to 1750°C

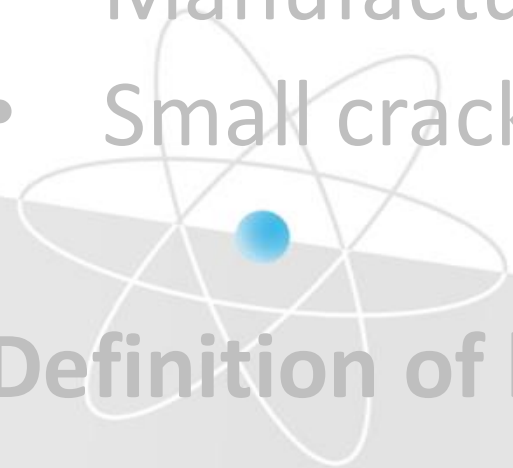


Homogeneous pellets with thermal stability

- Microstructural characterization. Study of the existing phases, distribution of grains and pores
- Manufacture of 200 UO₂-Gd₂O₃ fuel pellets for irradiation in the Halden reactor (Norway)
- Small cracks appear in the microstructure: sintering in a slightly oxidizing atmosphere



Definition of background technology for manufacturing



UO₂ – Gd₂O₃ FUEL PELLETS FOR A SMR



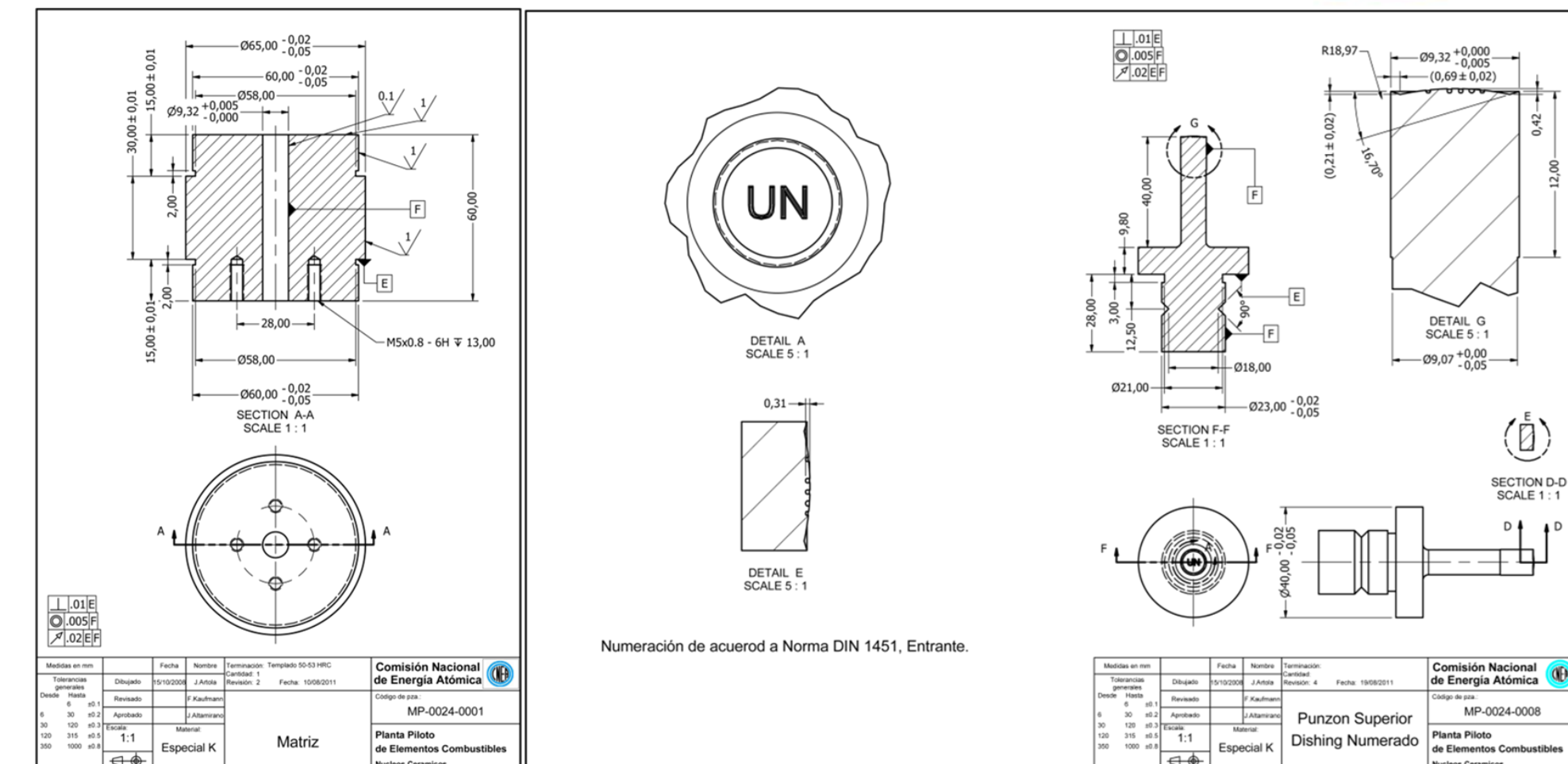
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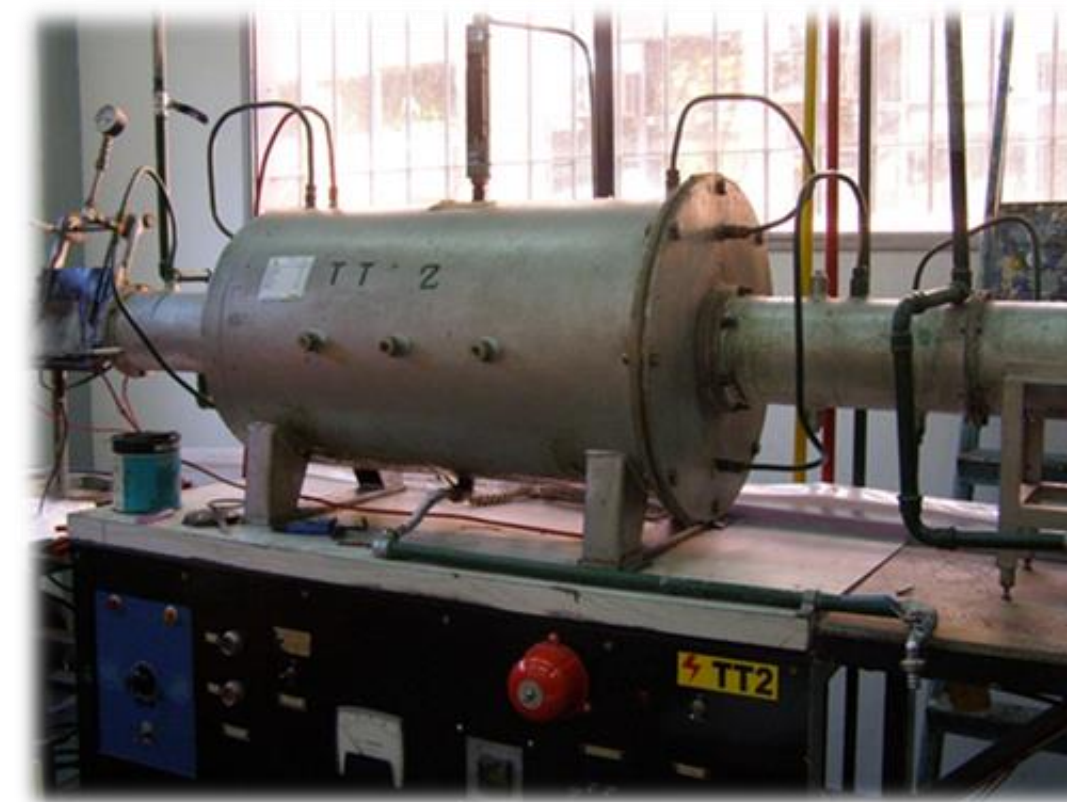


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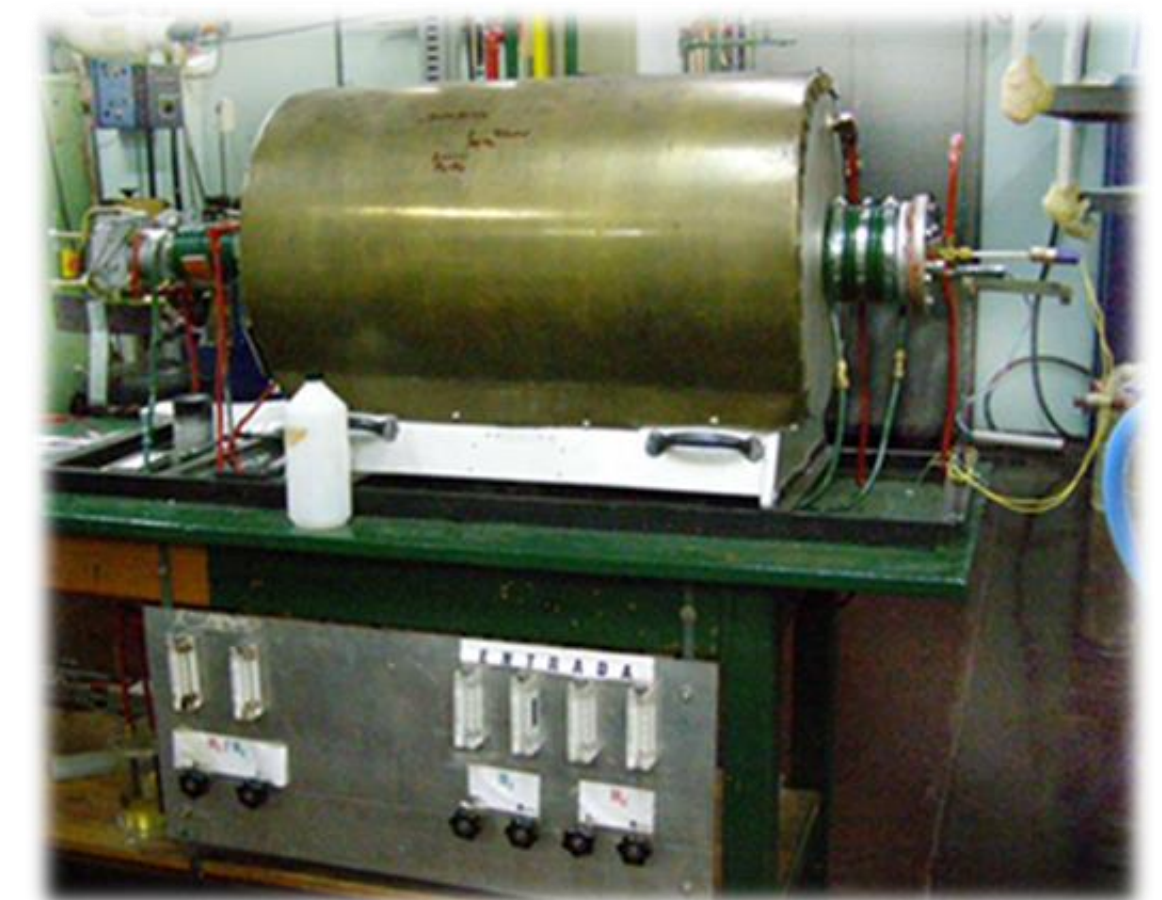
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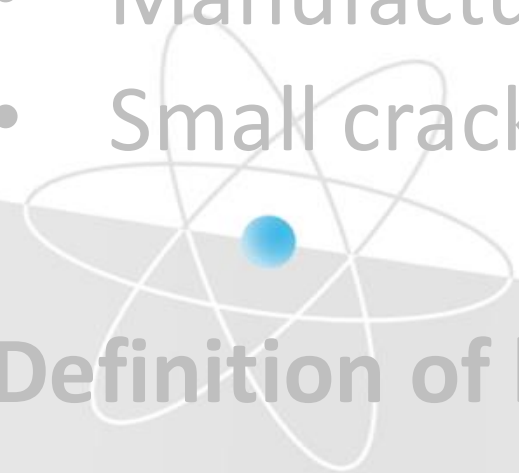


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$\text{UO}_2 - \text{Gd}_2\text{O}_3$ FUEL PELLETS FOR A SMR



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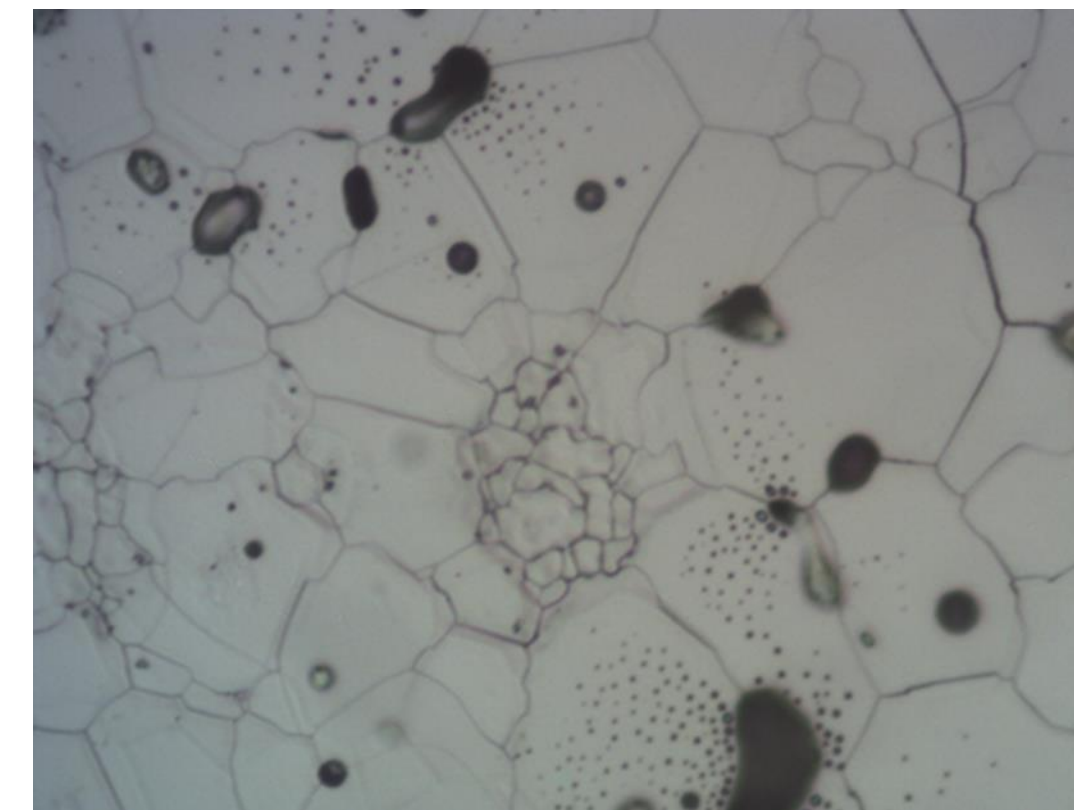
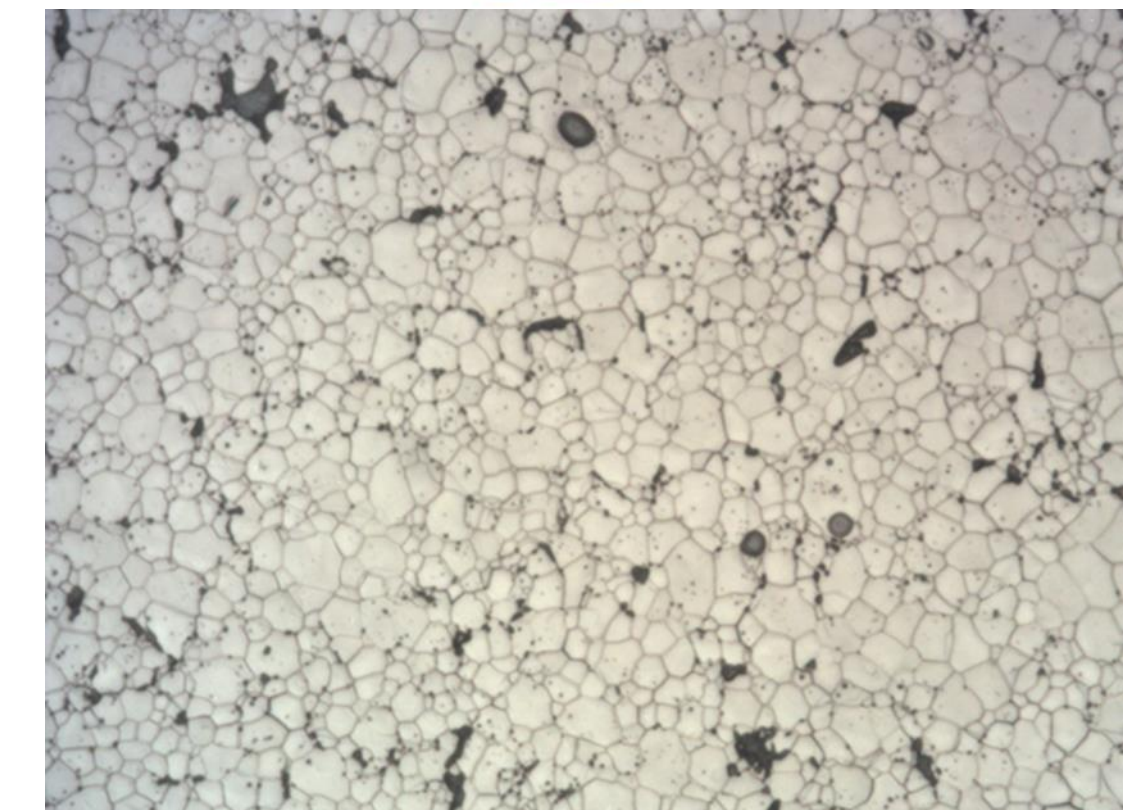
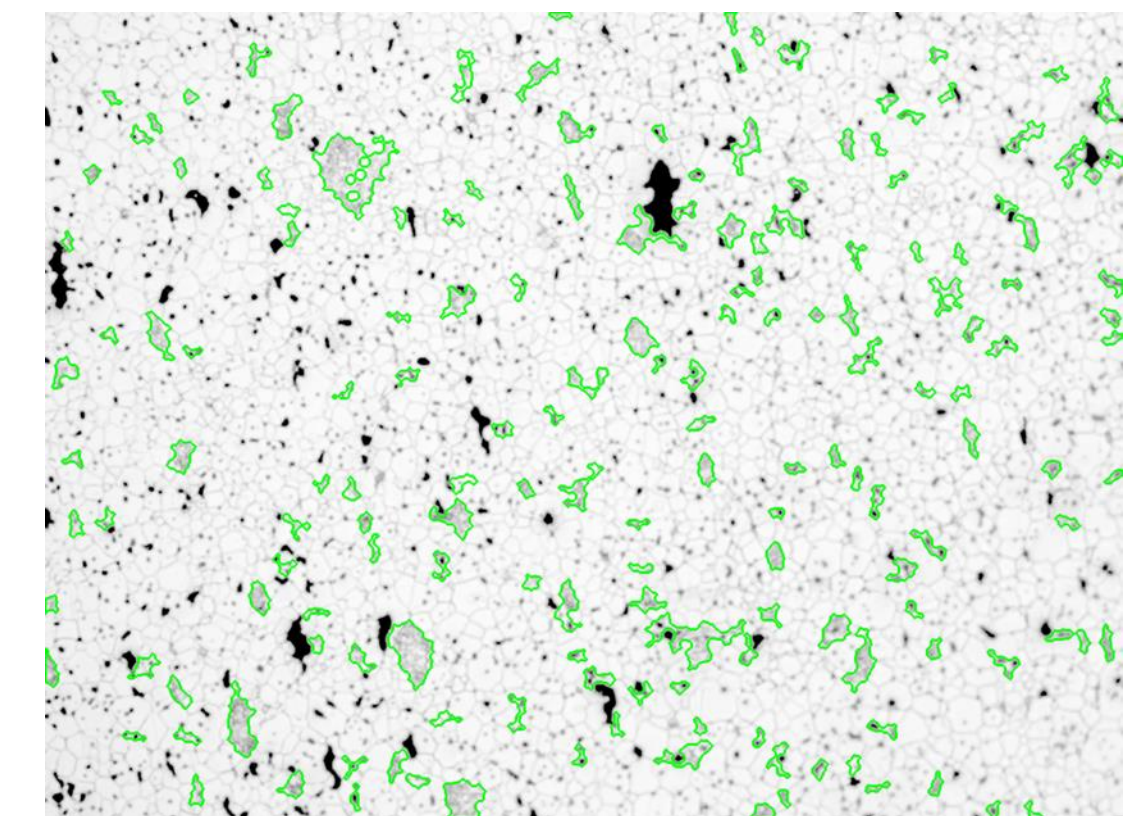


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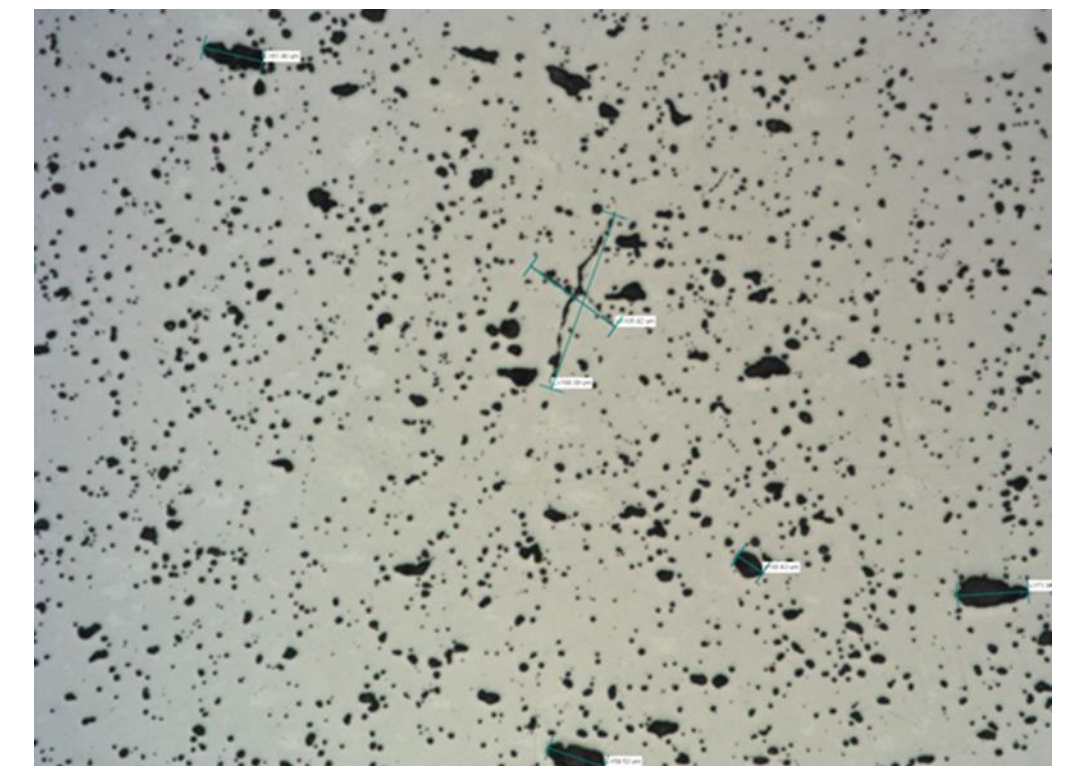


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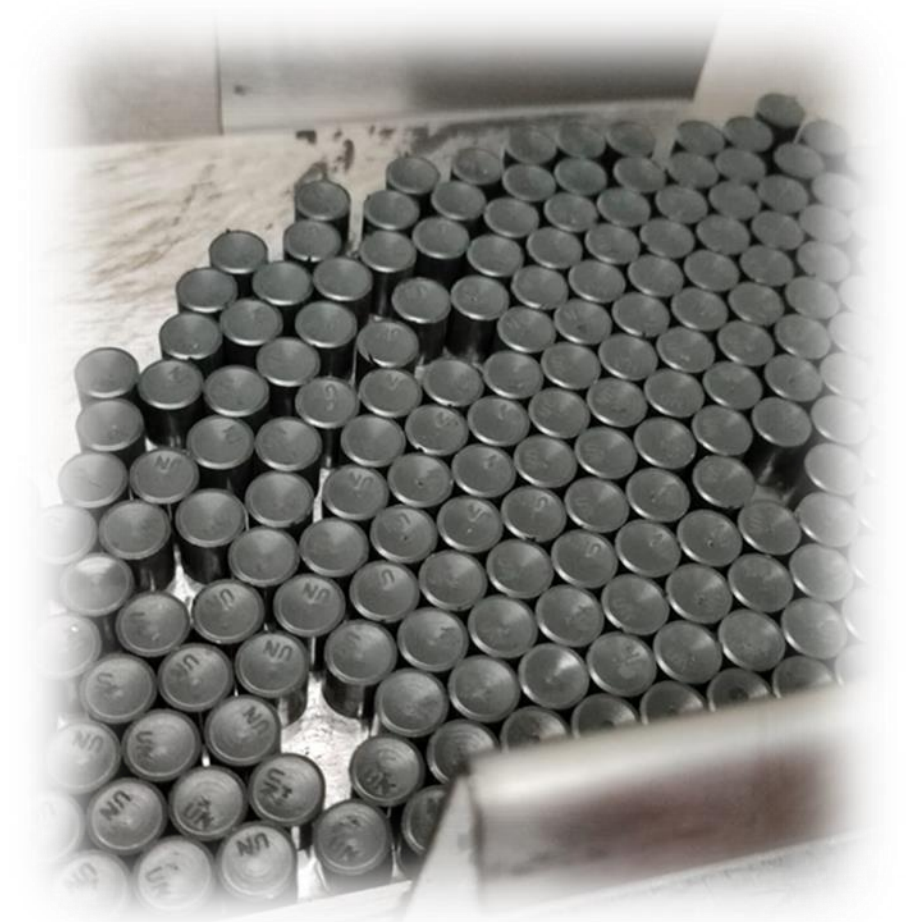


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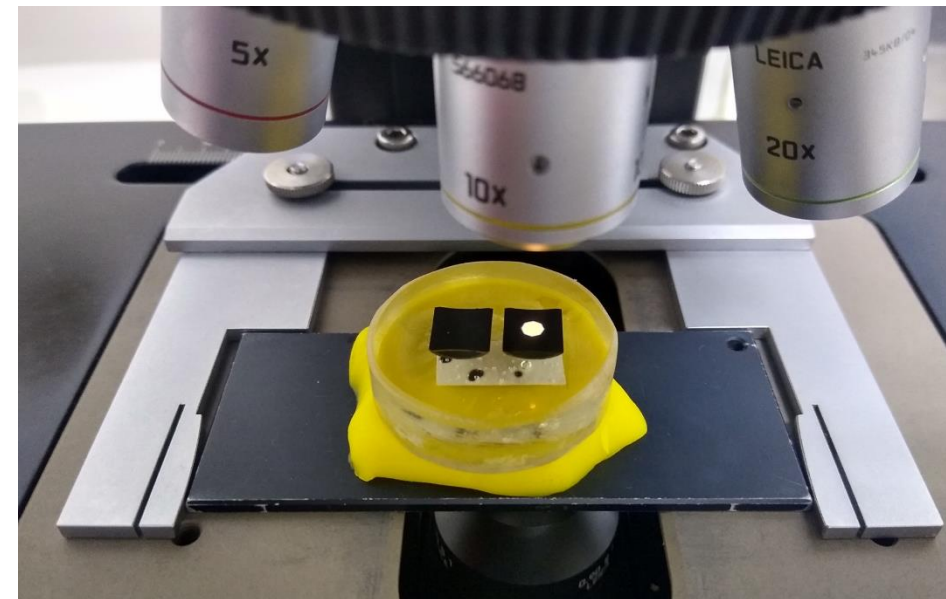
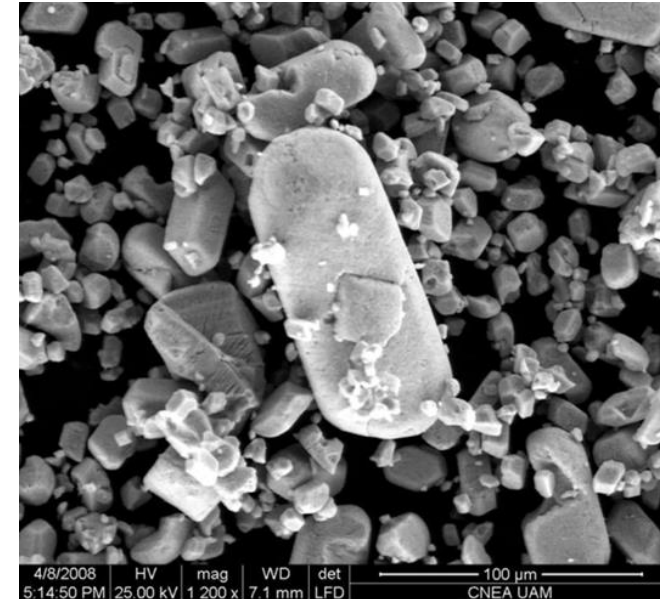
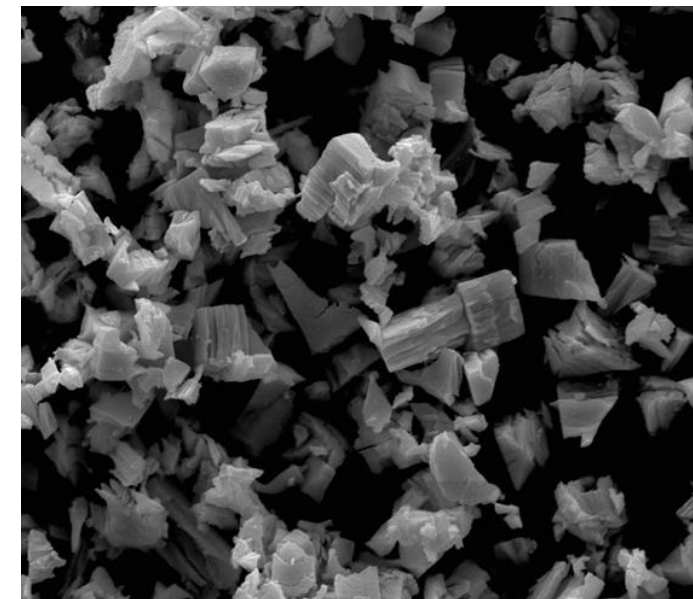
Definition of background technology for manufacturing

UO₂ – Gd₂O₃ FUEL PELLETS FOR A SMR



DEVELOPMENT AND VALIDATION OF CHARACTERIZATION TECHNIQUES FOR POWDERS AND PELLETS

- Raw materials reception controls: impurity content, isotopy, humidity, stoichiometry, specific area
- Semi-finished product controls: Mix powder homogeneity, green pellets dimensional control
- Final controls: chemical, mechanical, dimensional and microstructural controls



❖ Redensification tests on UO₂ – Gd₂O₃ fuel pellets



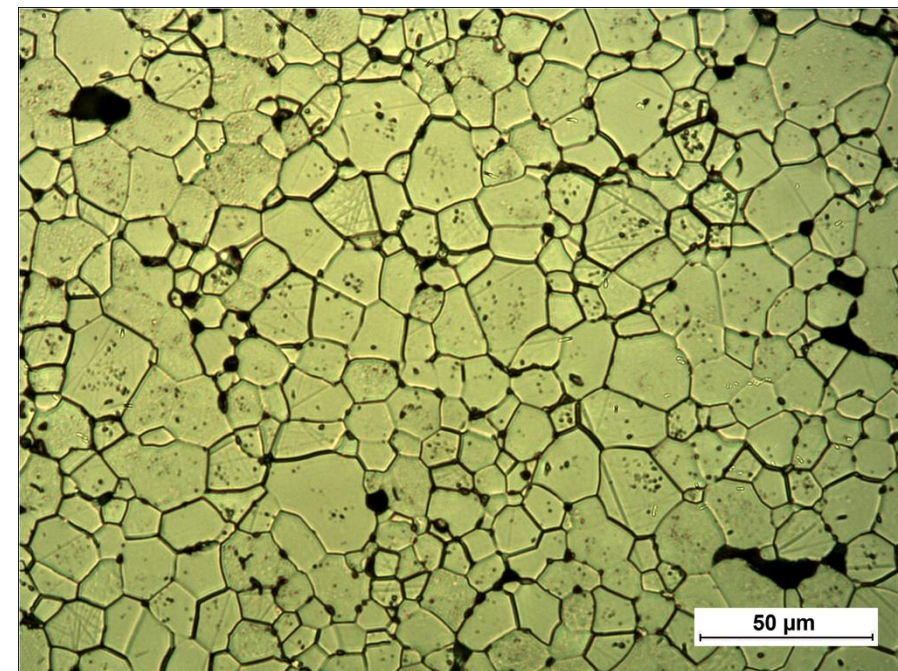
$\text{UO}_2 - \text{Gd}_2\text{O}_3$ FUEL PELLETS FOR A SMR



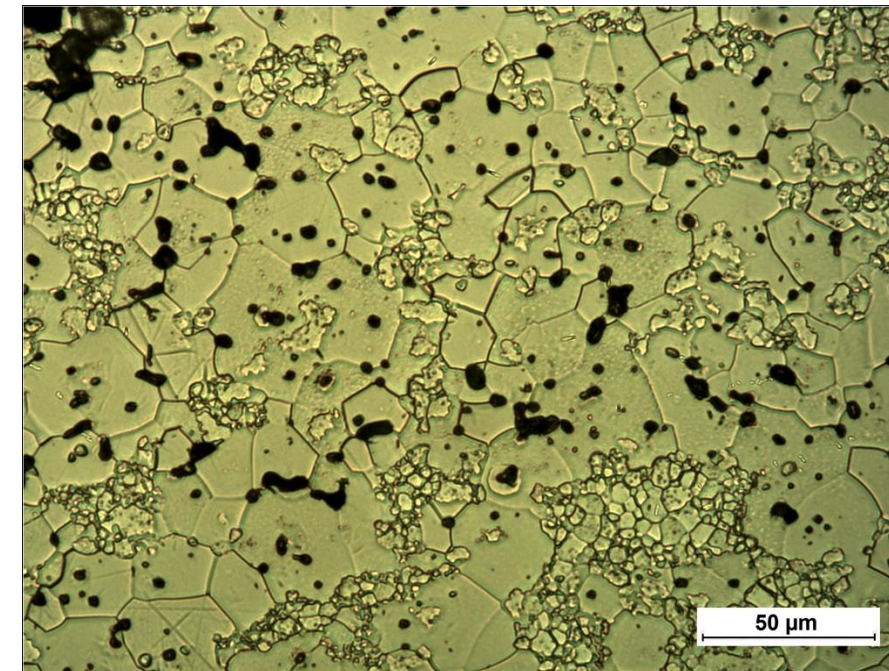
DEVELOPMENT AND VALIDATION OF CHARACTERIZATION TECHNIQUES FOR POWDERS AND PELLETS

- ❖ Homogeneity analysis in $\text{UO}_2 - \text{Gd}_2\text{O}_3$ fuel pellets by color etching ceramography

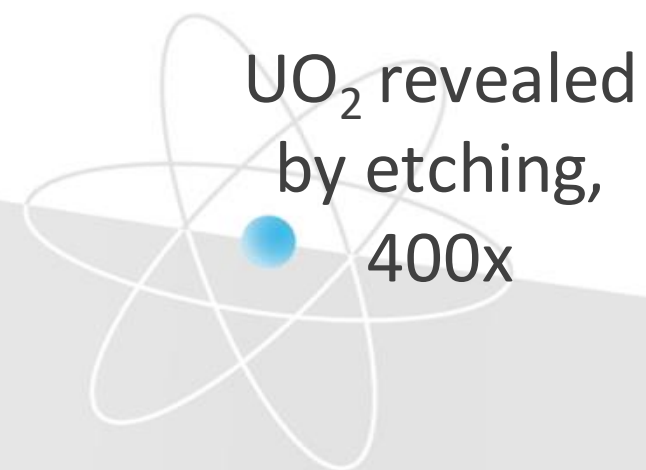
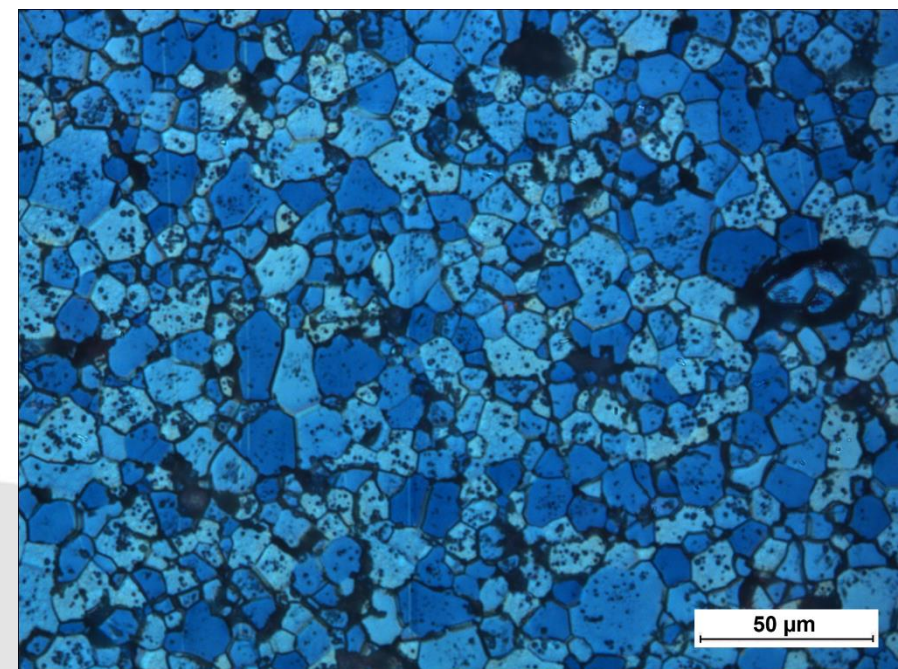
UO_2 grain
boundaries
revealed by
etching, 400x



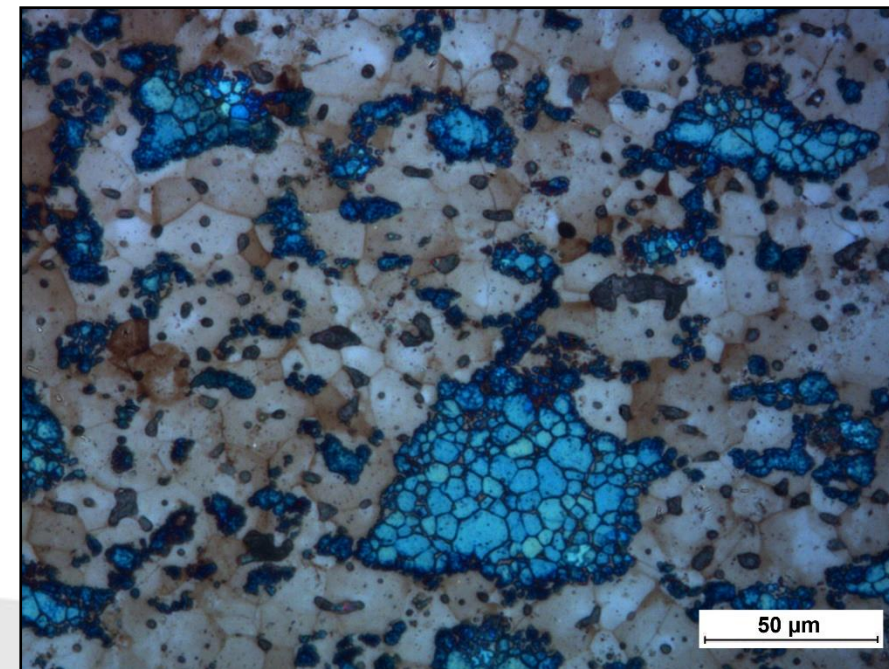
$\text{UO}_2 + \text{Gd}_2\text{O}_3$
grain boundaries
revealed by
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UO_2 revealed
by etching,
400x



$\text{UO}_2 + \text{Gd}_2\text{O}_3$
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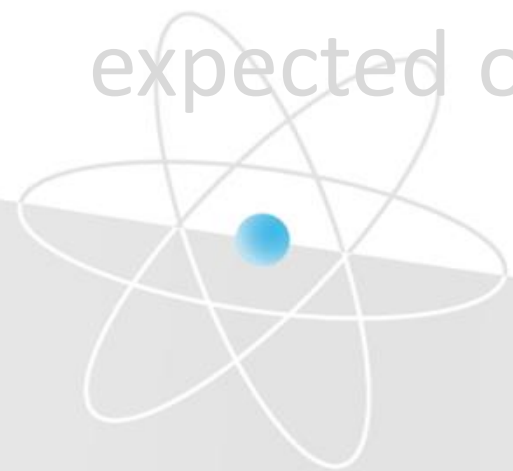
Non reactive UO_2 can be observed in blue

$\text{UO}_2 - \text{Gd}_2\text{O}_3$ FUEL PELLETS FOR A SMR



CHANGE OF SCALE AND SETTING UP EQUIPMENT

- Selection, acquisition, setup and adjustment of equipment
- Restructuring and refurbishment of facilities
- Change of scale, repeatability check of outcomes with respect to the development stage
- Definition of final parameters in the manufacturing and control processes
- Drafting of documents for qualification (working instructions, technical reports, etc.)
- Check of the installed capacity to produce —at required scale— fuel pellets according to specifications: manufacturing of prequalification batches with the expected outcomes.

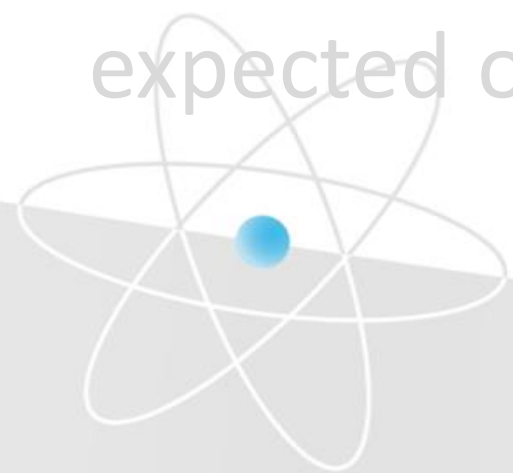


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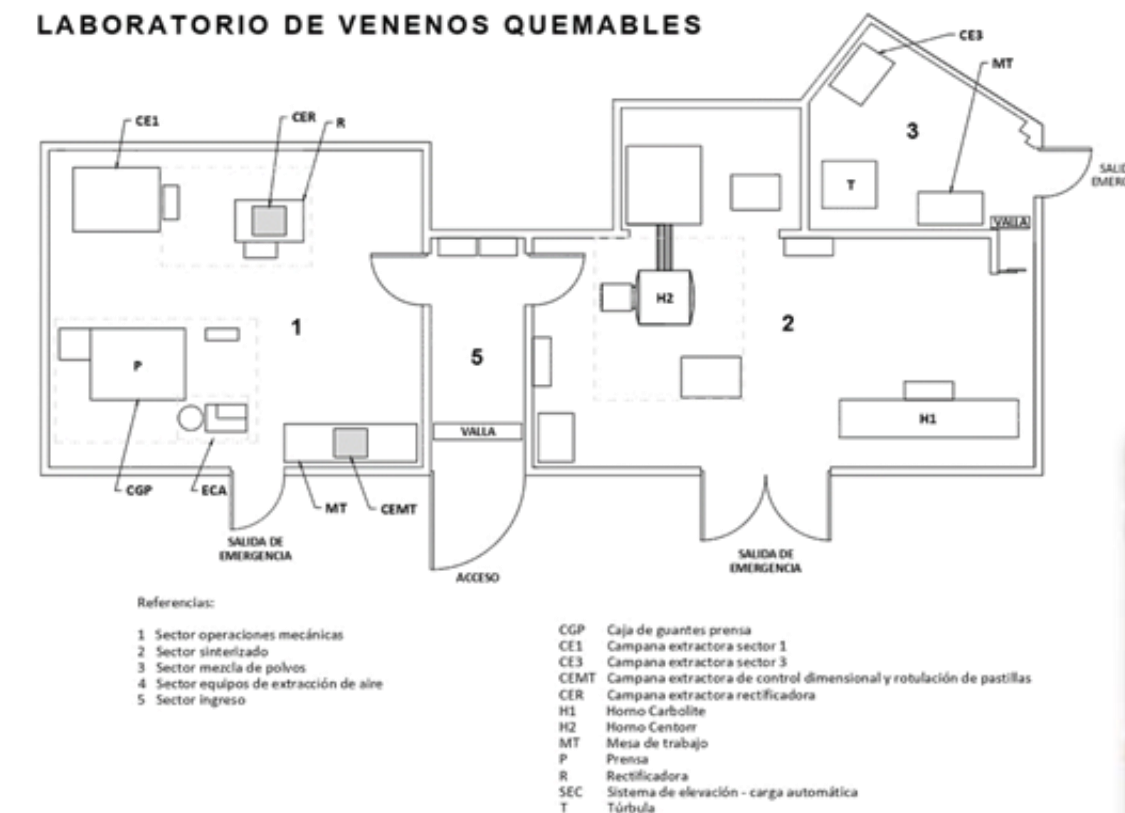
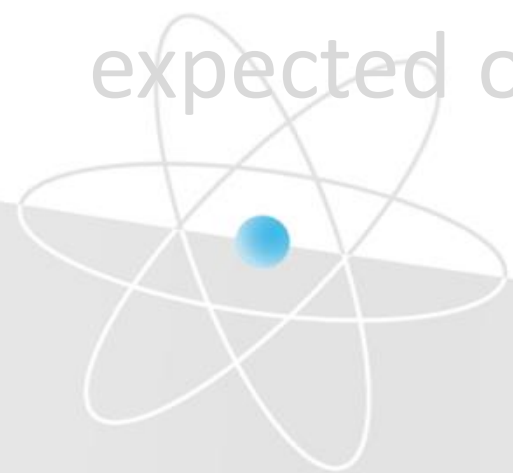


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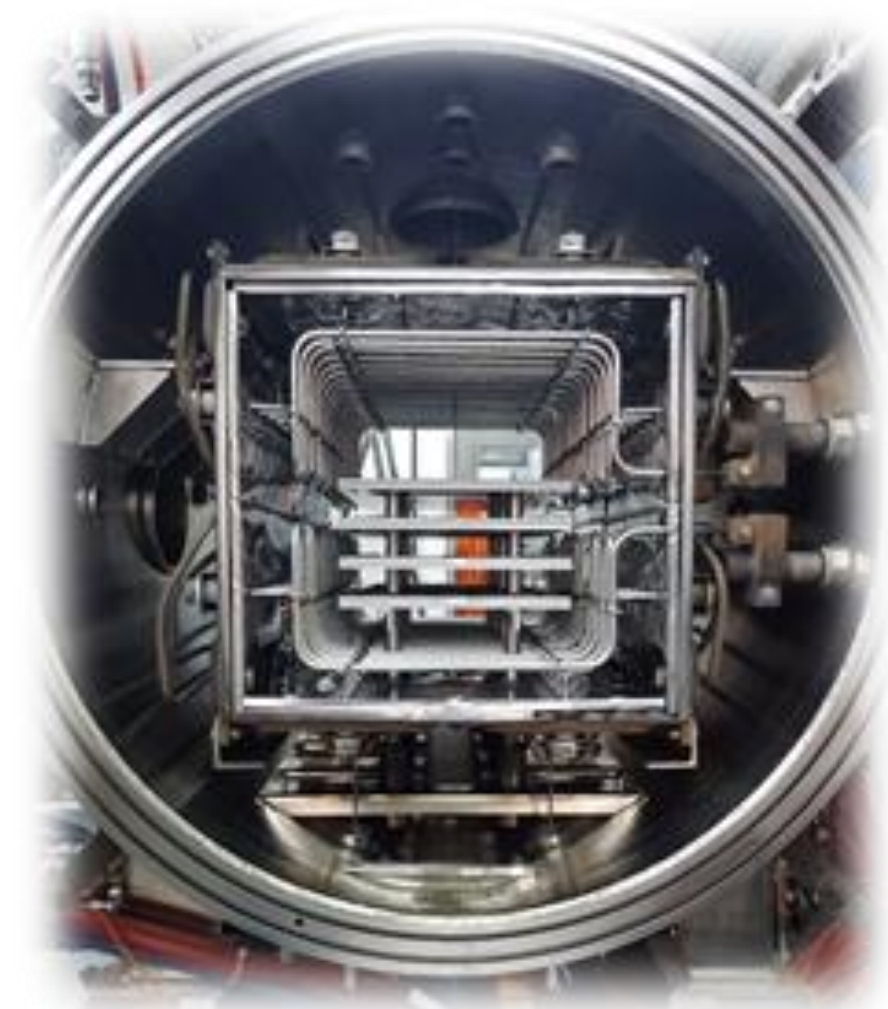
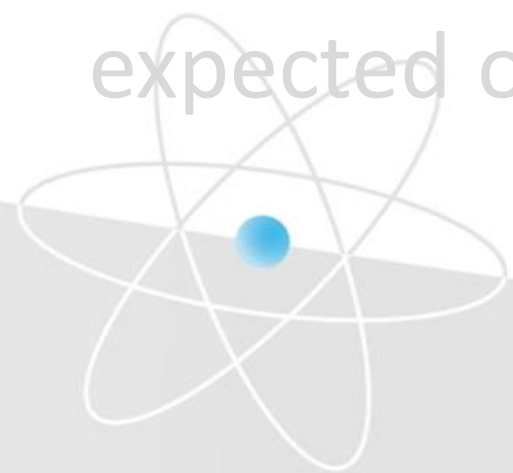


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UO₂ – Gd₂O₃ FUEL PELLETS FOR A SMR



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UO₂ – Gd₂O₃ FUEL PELLETS FOR A SMR



QUALIFICATION AND MANUFACTURING OF FUEL PELLETS FOR A SMR

- Refurbishment of facilities and equipment to qualify the manufacturing process of UO₂ – Gd₂O₃ fuel pellets after a period of inactivity as a result of the pandemic
- Survey and revalidation of analytic techniques, and dust and fuel pellets characterization
- Manufacturing of batch testing for the adjustment of operations. Characterization and analysis of outcomes. Evaluation and fitting of process parameters.
- Organization of resources for the manufacturing and characterization of fuel pellets
- Beginning of the process qualification stage



$\text{UO}_2 - \text{Gd}_2\text{O}_3$ FUEL PELLETS FOR A SMR



QUALIFICATION AND MANUFACTURING OF FUEL PELLETS FOR A SMR

Projections

- End of the qualification stage
- Beginning of the fuel pellets manufacturing stage, after the completion of the qualification stage





Comisión Nacional de Energía Atómica

Thank you for your attention!

M. Florencia Parrado
Advanced Fuels Pilot Plant

