




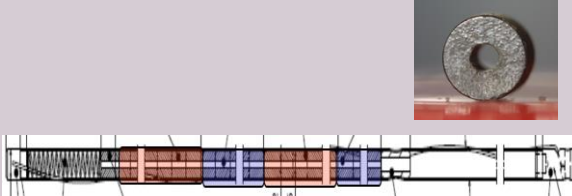
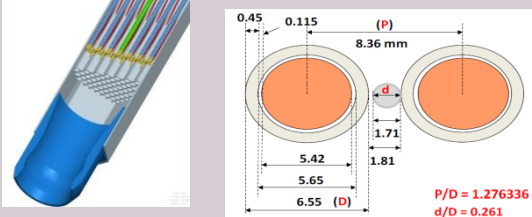
DE LA RECHERCHE À L'INDUSTRIE
cea den

**ESNII +
WP7 – Fuel Safety**

Nathalie CHAUVIN

CEA – Cadarache Fuel Studies Department

WP7 Fuel Safety – Fuel characteristics of 3 prototypes (starting cores)

<h2>ALLEGRO</h2> <p>Starting core 75 MWth</p>	<h2>ASTRID</h2>	<h2>MYRRHA-ALFRED</h2>
		
<h3>FUEL TYPE</h3>		
<p>(U,Pu)O₂</p> <p>25% Pu</p> <p>Fuel pin Ø 6.55 mm</p> <p>Clad: 15-15 Ti</p>	<p>(U,Pu)O₂</p> <p>20-25% Pu</p> <p>Fuel pin Ø 8,57 mm</p> <p>15-15 Ti</p>	<p>(U,Pu)O₂</p> <p>35% Pu</p> <p>Fuel pin Ø 6.55 mm</p> <p>15-15 Ti – T91</p>
<h3>IRRADIATIONS CONDITIONS</h3>		
<p>70 dpa</p> <p>~170 W/cm</p>	<p>70 then 130 dpa</p> <p>350-450 W/cm</p>	<p>60 dpa</p> <p><500 W/cm</p>

WP7 Fuel Safety – Updating of MOX properties

WP7 is devoted to update the European catalogue on the MOX fuel properties in the light of more recent data and then to complete with the realization of new measurements.

- 2014 → Task 7.1 State of the art
- 2014 → Task 7.2 Preparation of the experimental programme
- 2015 → Task 7.3 Characterisations of fresh and irradiated fuels MOX
- Task 7.4 Properties measurements on fresh and irradiated MOX
- Task 7.5 New catalog on MOX properties for fast reactors

WP partners: PSI, NRG, AREVA, SCK-CEN, NNL, JRC, MTA-EK, UJV, ENEA, CEA

Length: 48 months

Task 7.1 State of the art (task leader: CEA, JP. Ottaviani)

A state of the art report on (U,Pu)O₂ properties, including a work plan to acquire missing data

- ❑ List of properties needed for each conditions of the 3 prototypes and for each code that will be used for the fuel design of the prototype **done**
- ❑ Bibliographic work has been shared between several ESNI+ participants (CEA, ITU, ENEA, MTA-EK, AREVA, UJV, NRG, NNL, PSI, SCK) **done except 2 contributors which are undergoing**
- ❑ Work plan for future experimental work **done**

→ deliverable 711 : delayed from M12 to M18 (draft available but some contributions are missing, NNL, SCK).

ESNI+ - WP7 – TASK 7.1 : STATUS (2/2)

(U,Pu)O ₂	Parameters of influence / (Range of interest)							Topics included in the European catalog of UPuO ₂ properties in 1990
	Properties / models of interest	Temperature (293K - BP)	Pu/M ratio (15% - 35%)	O/M ratio (1,94 - 2,00)	Fract. porosity (0 - 40%)	Grain size (4µm - 30µm)	Stress (1MPa - 100MPa)	
Lattice parameter	X	X	X				X	Yes
Thermal conductivity (Sol. & Liq. ph)	X	X	X	X			X	Yes
Melting point (Solidus & Liquidus)		X	X				X	Yes
Specific heat Cp (Sol. & Liq. ph)	X	X	X				X	No
Enthalpy of fusion		X	X				X	No
Emissivity	X	X	X				X	No
Theoretical density	X	X	X					Yes
Thermal expansion (Sol. & Liq. ph)	X	X	X				X	Yes
Young modulus	X	X	X	X				Yes
Poisson's ratio	X	X	X	X				Yes
Yield stress	X	X	X	X				No
Ultimate stress	X	X	X	X				No
Thermal creep	X	X	X	X	X	X	X	Yes
Diffusion/migration of fission gas	X	X	X					No
Diffusion/migration of pores	X	X	X					No
Diffusion/migration of Oxygen	X	X	X					Yes
Diffusion/migration of U, Pu	X	X	X					Yes
Oxygen potential	X	X	X				X	Yes
Grain growth	X			X	X			Yes

CHOICE OF FUELS FOR MEASUREMENTS

Fresh fuel:

<i>NAME</i>	<i>GEOMETRY</i>	<i>Pu CONTENT</i>	<i>O/M</i>
MOX –fresh1	Phenix	~24,5w%Pu/(U+Pu with chamotte)	O/M = 1.976

Irradiated fuels;

<i>NAME INTEREST</i>	<i>GEOMETRY</i>	<i>Pu CONTENT</i>	<i>LINEAR HEAT RATE</i>	<i>BURN UP</i>
MOX-irr1 : NESTOR3 (pin n° 110) Irradiated in Phenix Intermediate LHR and %Pu ASTRID&ALLEGRO like parameters	Phenix	19.82%	377W/cm	12,5at%
MOX-irr2 : TRABANT2 (pin n°5 and 6) Irradiated in HFR High %Pu, MYRRHA like parameters	Phenix	40%	480 W/cm	6at%

Task 7.2 Preparation of the experimental programme (task leader: NRG, R. Hania)

- ❑ **Definition of samples geometries and numbers for each characterisation or measurement** . done
- ❑ **Organisation of the fuel samples transports** . Done for fresh samples (15 oct) and planed before mid 2015 irradiated samples (NESTOR, TRABANT2).

→ deliverable 721 : delayed from M12 to M20

SAMPLES GEOMETRIES CHARACTERISATION OR MEASUREMENT

NAME	task	Nature of charact./property	Number of sample	Geometry needed	
MOX-Fresh1 O/M=1.976	7.3	TEM-SEM	6	10 mg fragment	
	7.4	Melting temperature	3	disk e=2mm	
	7.4	Thermal diffusivity	3	e=1mm disk	
	7.4	Knudsen cell – vapour pressure	3	10 mg fragment	
MOX-Fresh1 O/M=2.0	7.3	TEM-SEM	3	10 mg fragment	
	7.4	Melting temperature	3	disk e=2mm	
	7.4	Thermal diffusivity	3	e=1mm disk	
	7.4	Knudsen cell – vapour pressure	3	10 mg fragment	
MOX-Irr1 <i>NESTOR</i>	Axial 1	7.3	TEM-SEM	2	10 mg fragment
		7.3	Knudsen cell – gas retention – vapour pressure	3	10 mg fragment
		7.4	Thermal diffusivity and Heat capacity	3	e=1mm L=2,5-3mm l=2,5-3mm
	Axial 2	7.4	Thermal diffusivity and Heat capacity	3	e=1mm L=2,5-3mm l=2,5-3mm
	Radial 1	7.3	TEM-SEM	2	10 mg fragment
		7.4	Thermal diffusivity and Heat capacity	3	e=1mm L=2,5-3mm l=2,5-3mm
	Radial 2	7.4	Thermal diffusivity and Heat capacity	3	e=1mm L=2,5-3mm l=2,5-3mm
	MOX-Irr2 <i>TRABANT2</i>	Axial 1	7.3	TEM-SEM	2
7.3			Knudsen cell – gas retention – vapour pressure	3	10 mg fragment
7.4			Thermal diffusivity and Heat capacity	3	e=1mm L=2,5-3mm l=2,5-3mm
Axial 2		7.4	Thermal diffusivity and Heat capacity	3	e=1mm L=2,5-3mm l=2,5-3mm
Radial 1		7.3	TEM-SEM	2	10 mg fragment
		7.3	Knudsen cell – gas retention – vapour pressure	1	10 mg fragment
		7.4	Thermal diffusivity and Heat capacity	3	e=1mm L=2,5-3mm l=2,5-3mm
Radial 2		7.3	TEM-SEM	2	10 mg fragment
	7.4	Thermal diffusivity and Heat capacity	3	e=1mm L=2,5-3mm l=2,5-3mm	

7.3 Characterisation

- **micro-analyse (SEM-SIMS-EPMA- XRD), composition, densité sur 1 combustible frais et 2 combustibles irradiés**

→ livrable 731 (combustible frais): diffusion effectuée le 24th oct.

→ 2015 : *livrables 732 & 733 (combustibles irradiés)*.

7.4 Propriétés de mesure

- **diffusivité thermique, expansion thermique, température de fusion, fluage thermique, pression de vapeur**

→ 2015-2016

7.5 Nouveau catalogue

- **Basé sur les mesures et sur le SOAR pour recommandations**

→ 2016-2017

CONCLUSION

- WP7 is undergoing with some delay for the transport
- Community around mixed oxide fuels for Fast Reactor driver fuel reconstituted.

Commissariat à l'énergie atomique et aux énergies alternatives
Centre de Cadarache | 13108 Saint Paul Lez Durance
T. +33 (0)442257000

Nuclear Energy Directorate
Fuel Studies Department

Etablissement public à caractère industriel et commercial | RCS Paris B 775 685 019

WP	TSK	STSK	D	Date	Content	Contributors
7	1		D711	M12	State of the art based on a literature review of the fuel properties and uncertainties - Workplan on properties measurements.	CEA, AREVA, ENEA, JRC, MTA-EK, NNL, NRG, PSI, SCK-CEN, UJV
7	2		D721	M12	Achievement of fuel transportation.	NRG, CEA
7	3		D731	M12	Characterisations of MOX fresh1 fuels	NRG, CEA, JRC
7	3		D732	M18	Characterisations of MOX irr1 fuels	NRG, CEA, JRC
7	3		D733	M18	Characterisations of MOX irr2 fuels	NRG, CEA, JRC
7	4		D741	M36	Measurements of MOX fresh1 properties	JRC, CEA
7	4		D742	M18	Measurements of MOX irr1 properties	JRC
7	4		D743	M36	Measurements of MOX irr2 properties	JRC
7	5		D751	M48	New (U, Pu)O ₂ properties catalogue	NNL, PSI, CEA, AREVA, ENEA, JRC, MTA-EK, NRG, SCK-CEN, UJV