

# Vibropac MOX-Fuel For Fast Reactors – Experience and Prospects



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A.V.BYCHKOV, A.A.MAYORSHIN, O.V.SKIBA,  
V.A.KISLY, O.V.SHISHALOV,  
M.V.KORMILITSYN, Yu.M.GOLOVCHENKO

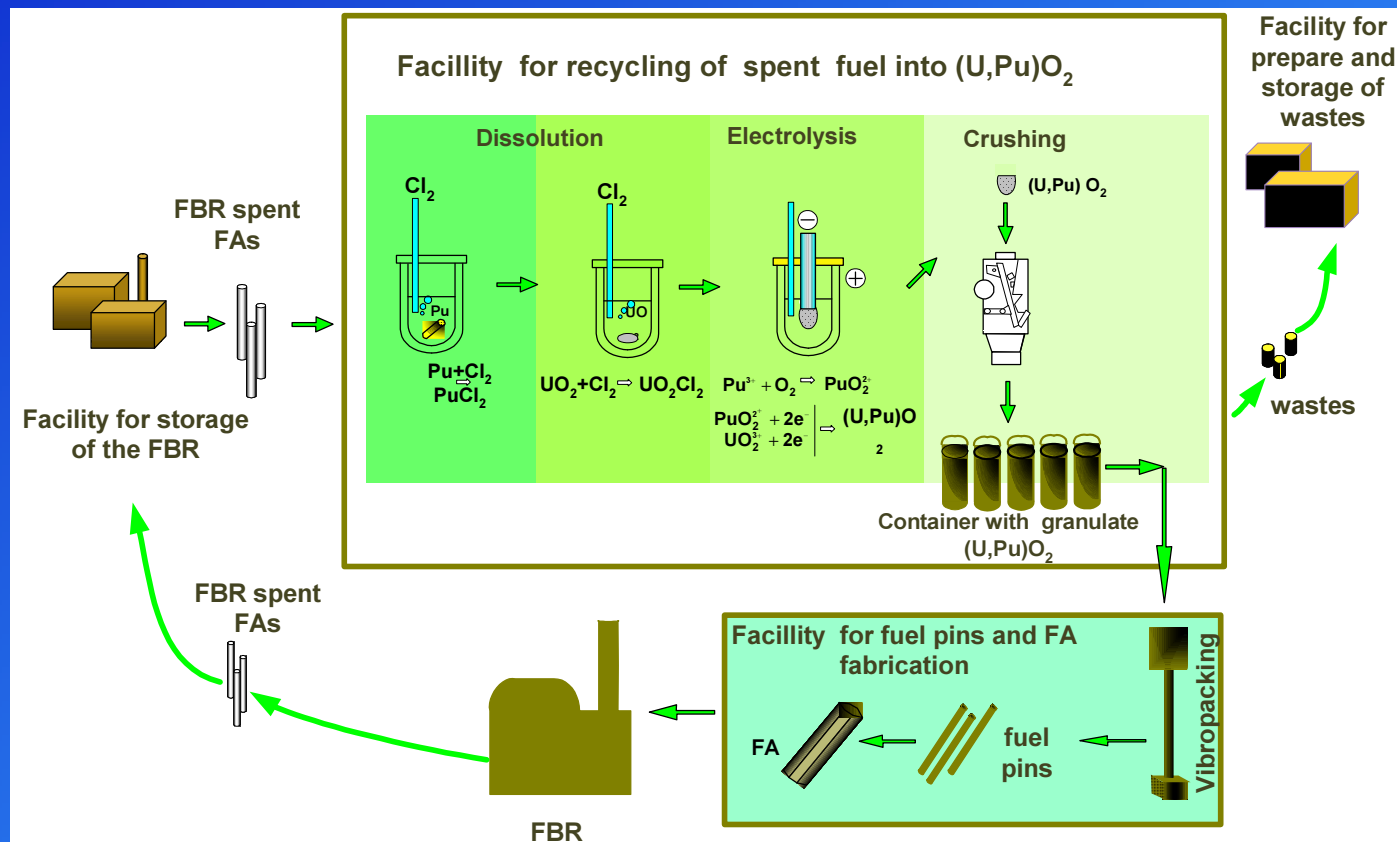


# Main tasks

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- In the USSR the activity in the field of vibropac fuel development and production started in late 60-s of the previous century as a logic end of Closed Fuel Cycle for Fast Reactors together with “dry” reprocessing
  - Power-generating plutonium as a first stage of Closed Fuel Cycle for Fast Reactors creation

# Fuel Cycle for Fast Reactors





## First steps, 70-s

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- Laboratory facilities for granulated fuel production and fuel pins manufacturing
- Requirements for fuel pins formalization
- Irradiation tests of vibropac fuel in different reactors
- Start of the OREL facility construction for BOR-60 fuel production



## History, 70-s...80-s

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- OREL facility: start-up;
- Vibropac fuel is a standard fuel for the BOR-60 reactor;
- Vibropac fuel irradiation in the BN-350 reactor;
- Substantiation of vibropac MOX-fuel for fast reactors is completed.



# Vibropac fuel in BOR-60

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- Problems of fuel pins serviceability during the initial period:
  - intercrystalline corrosion of the cladding
  - lower smear density
  - insufficient reliability of the welded joint "cladding –upper endplug"
- Solution of problems
  - Getter additives in the form of metal U particles- 5-10 wt. %
  - Granulated fuel improvement
  - special preparation of cladding and granulated fuel

# OREL facility

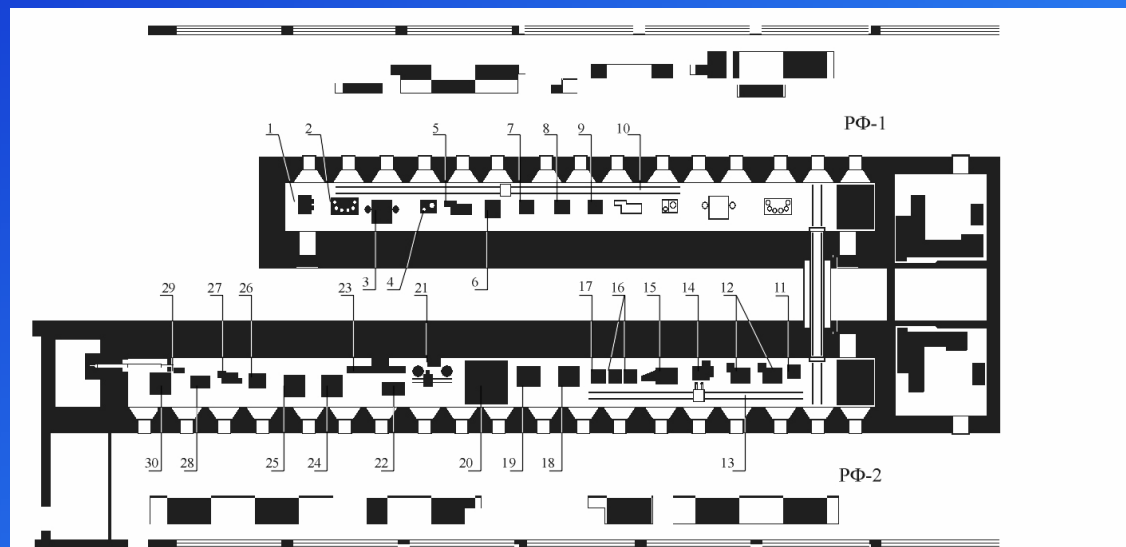
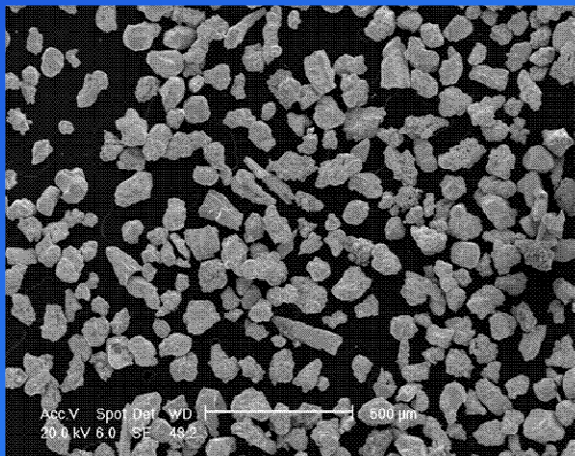
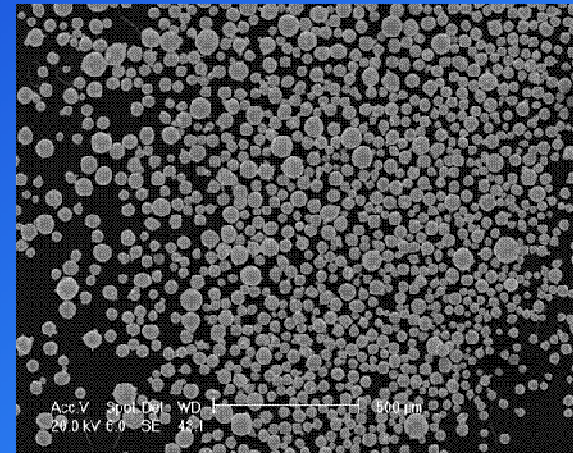
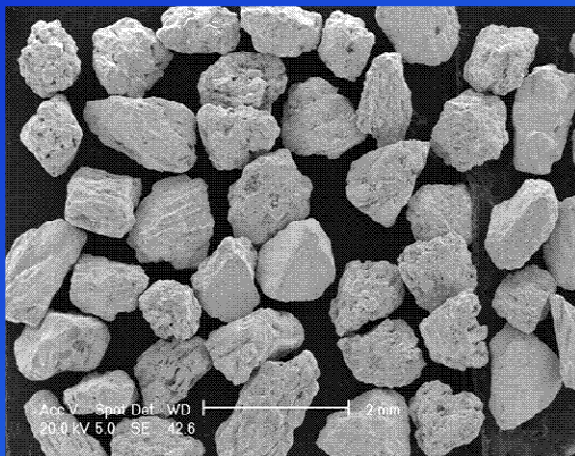


Схема расположения оборудования для изготовления твэлов и ТВС в условиях защитных камер РФ-1 и РФ-2

- 1- бокс разделки твэлов; 2- подготовка гранулята; 3- виброуплотнение гранулята;
- 4- загрузка экрана; 5- загрузка верхней заглушки; 6- герметизация твэла;
- 7, 8, 9, 11, 16, 17, 18, 19, 20- хранение твэлов; 10, 13- транспортная система твэлов;
- 12- контроль герметичности твэлов; 14- контроль распределения компонентов топливного сердечника твэлов; 15- контроль геометрических размеров твэлов и их визуальный осмотр; 21- сборка ТВС; 22- сварка ТВС; 23- кантование ТВС;
- 24- контроль герметичности твэлов в составе ТВС; 25- измерение гидравлических характеристик ТВС; 26- контроль сварного шва; 27- визуальный осмотр ТВС;
- 28- радиографический контроль сварного шва; 29- сварка контровочной гайки;
- 30- хранилище ТВС.

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# Granulated MOX-fuel



Metal content, %	87,75
Pycnometric density, g/cm <sup>3</sup>	2.00±0.01
O/M ratio	
Impurities, %	
-chlorine-ion	0.005
-Carbon	0.015



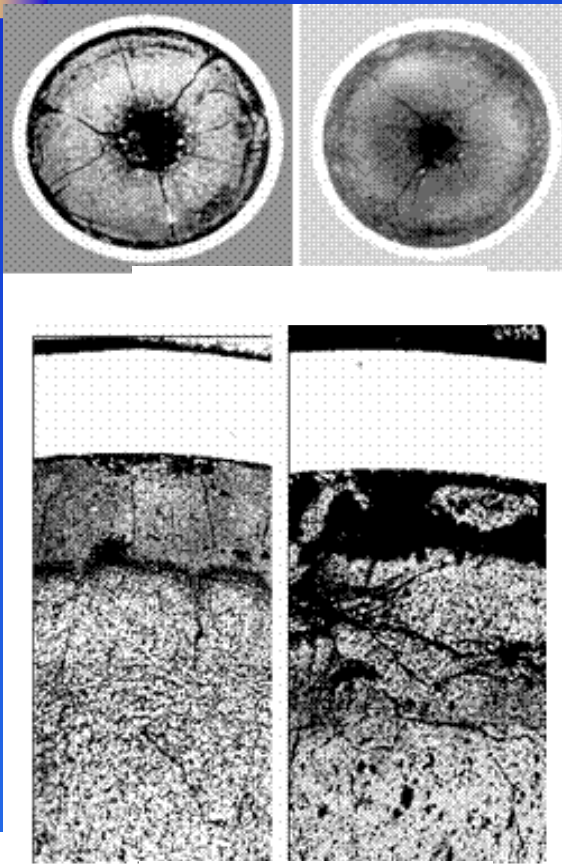


# BOR-60 Vibropac fuel

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- About 1000 standard and experimental FA irradiated
- Different cladding and wrapper materials used
- Different types of vibropac fuel
  - $\text{UO}_2$ ,  $\text{UPuO}_2$ ,  $\text{UO}_2+\text{PuO}_2$ ,
  - MOX-fuel with 45  $\text{PuO}_2$  %,
  - Fuel with 5 % of  $\text{NpO}_2$ ,
  - Recycled fuel with 8 % of FP

# BOR-60 experimental fuel



Macro- and microstructure  
of cross section of high-  
temperature part of fuel  
rod at a burnup of 32 %  
h.a.:

fuel 95 %  $\text{UO}_2$  + 5 %  $\text{PuO}_2$

fuel 78 %  $\text{UO}_2$  + 22 %  $\text{PuO}_2$





# BOR-60 vibropac fuel

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- Maximum parameters
  - Cladding temperature – 722 °C
  - Linear power – 502 W/cm
  - Burnup – 32 % h.a.
- No corrosion internal surface of cladding. No limit burnup. Limit of lifetime – damage doze for structural material

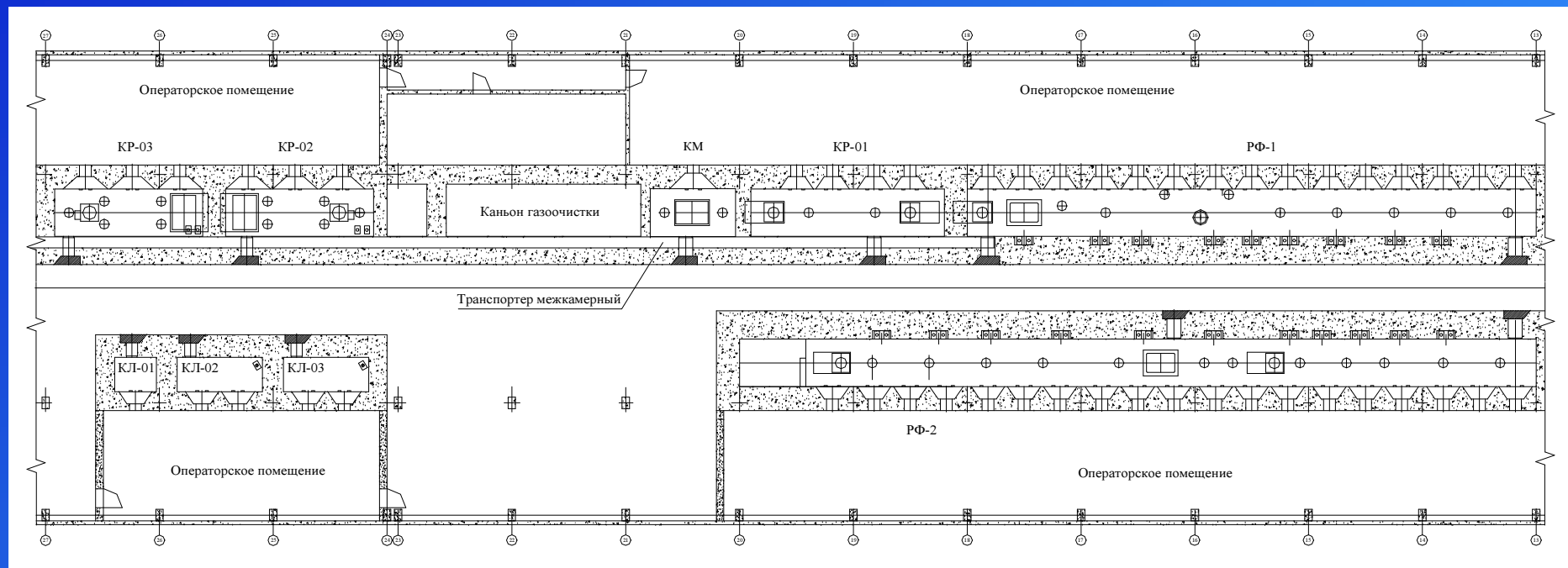


## History, 80-s

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- Optimization of fuel pins design and fabrication technology;
- Reconstruction of the OREL facility and creation of Semi Industrial Complex (SIC);
- Start of vibropac fuel irradiation in the BN-600 reactor.

# Semi Industrial Complex



# Vibropac MOX-fuel in BN-600

## First stage.

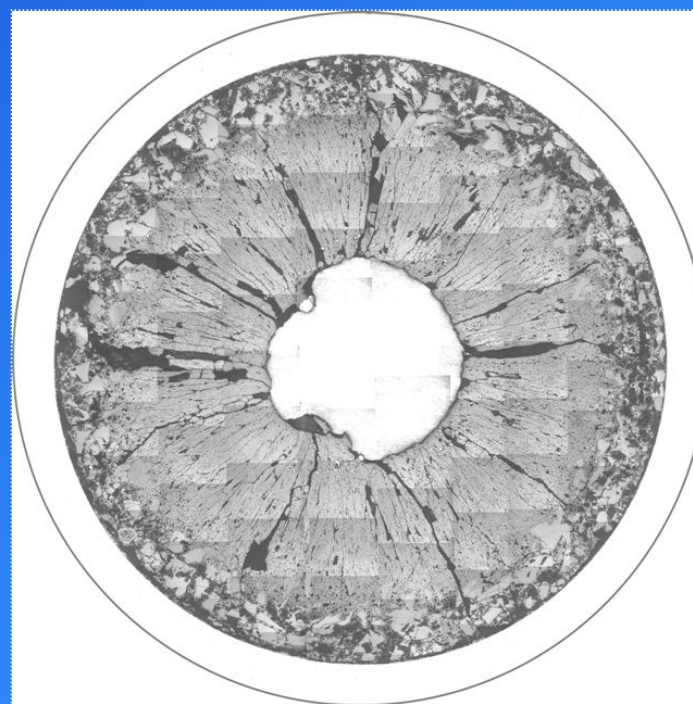
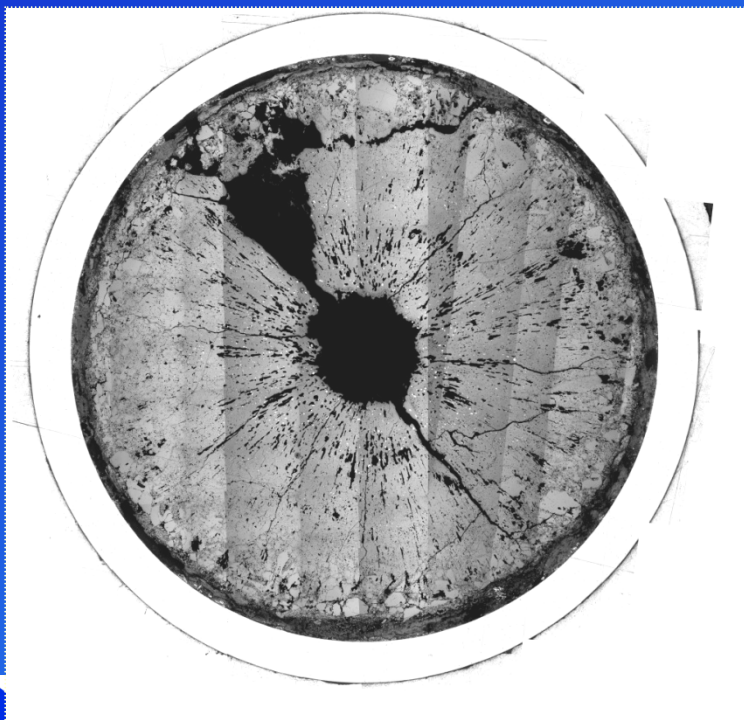
Serial number of FA	NF0187	NF0287	NF03...NF06
Year of production	1987		1989...1990
Getter content, %	10		
Plutonium content, %	22...28		~30
Effective density, g/cm <sup>3</sup>	8,9...9,1		8,8...9,2
Cladding material	Steel EP-172		Steel ChS-68
Wrapper material	08Cr16Ni11Mo3Ti		05Cr12Ni2Mo
Linear heat rate, kW/м	41		47
Cladding temperature, °C	670		680...698
Damage dose, dpa	52,3	77	64...70
Burnup, % h.a.	6,8	9,6	9,0...9,8

# Vibropac MOX-fuel in BN-600

## Second stage.

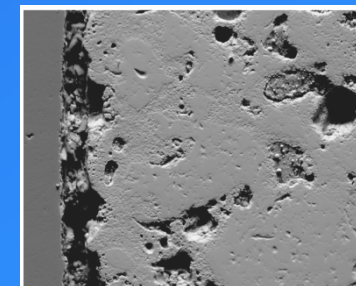
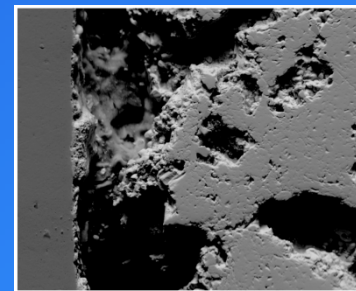
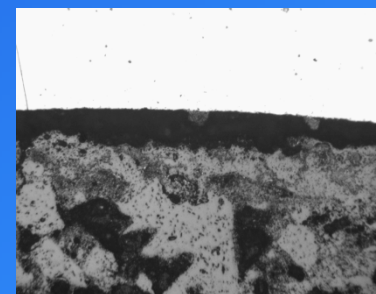
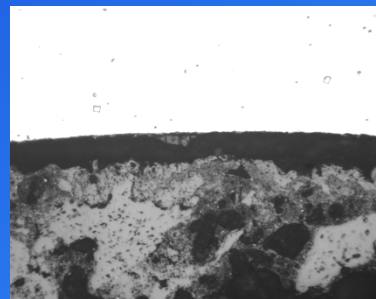
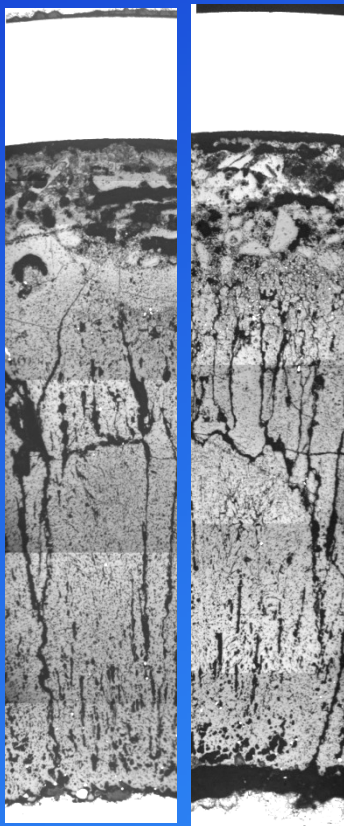
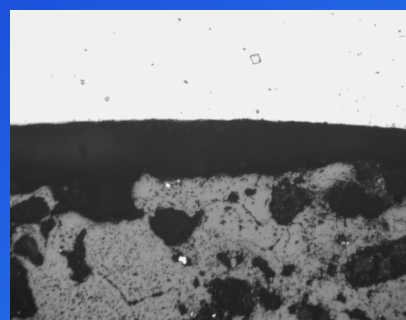
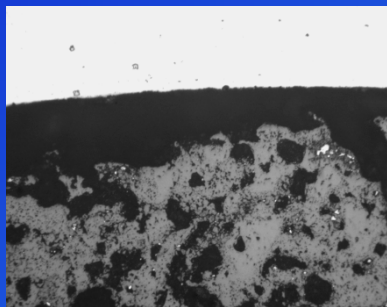
Serial number of FA	01.99... 03.99	04.02... 06.02	07.03... 09.03	10.05... 12.05	01.05... 12.06
Year of production	1999	2002	2003	2005	2006...2007
Getter content, %	7				
Plutonium content, %	23...25				
Effective density, g/cm <sup>3</sup>	8.9...9.2				
Cladding material	ChS-68				
Cladding size, mm	6,6				6,9
Wrapper material	05Cr12Ni2 Mo	EP-450			
Linear heat rate, kW/m	31,8...42,5	35,3...45,3	30,9...33,9	38,0...38,9	28,8...42,0
Cladding temperature, °C	661...705	643..694	613...659	647...694	660...700
Damage dose, dpa	73,6...77	60,3...61,7	71,8...77,1	75,5...76,1	59,4...81,4
% h.a.	10,1...10,5	8,7...9,0	9,9...10,6	10,1...10,2	7,1...9,8

# Vibropac fuel in BN-600





# Vibropac fuel in BN-600





# Vibropac fuel in BN-600

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- No specific differences in radiation-thermal effects in fuel pins and FA tested in BOR-60, BN-350 and BN-600 were observed;
  - More detailed information about second stage of vibpaced MOX-fuel irradiation is provided in another paper for this conference (IAEA-CN-176-07-16P)



# Current Status

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- Fuel pin design, technologies for granulated fuel production and fuel pins fabrication are ready for industrial application;
- RIAR technologies are main technologies for BN-800 fuel supply
  - Start of modernization of technological complex