SSC Research Institute of Atomic Reactors. RUSSIA

ПРЕДПРИЯТИЕ ГОСКОРПОРАЦИИ «РОСАТОМ»

Vibropac MOX-fuel for fast reactors

V.A.KISLY, O.V.SHISHALOV, M.V.KORMILITSYN, Yu.M.GOLOVCHENKO

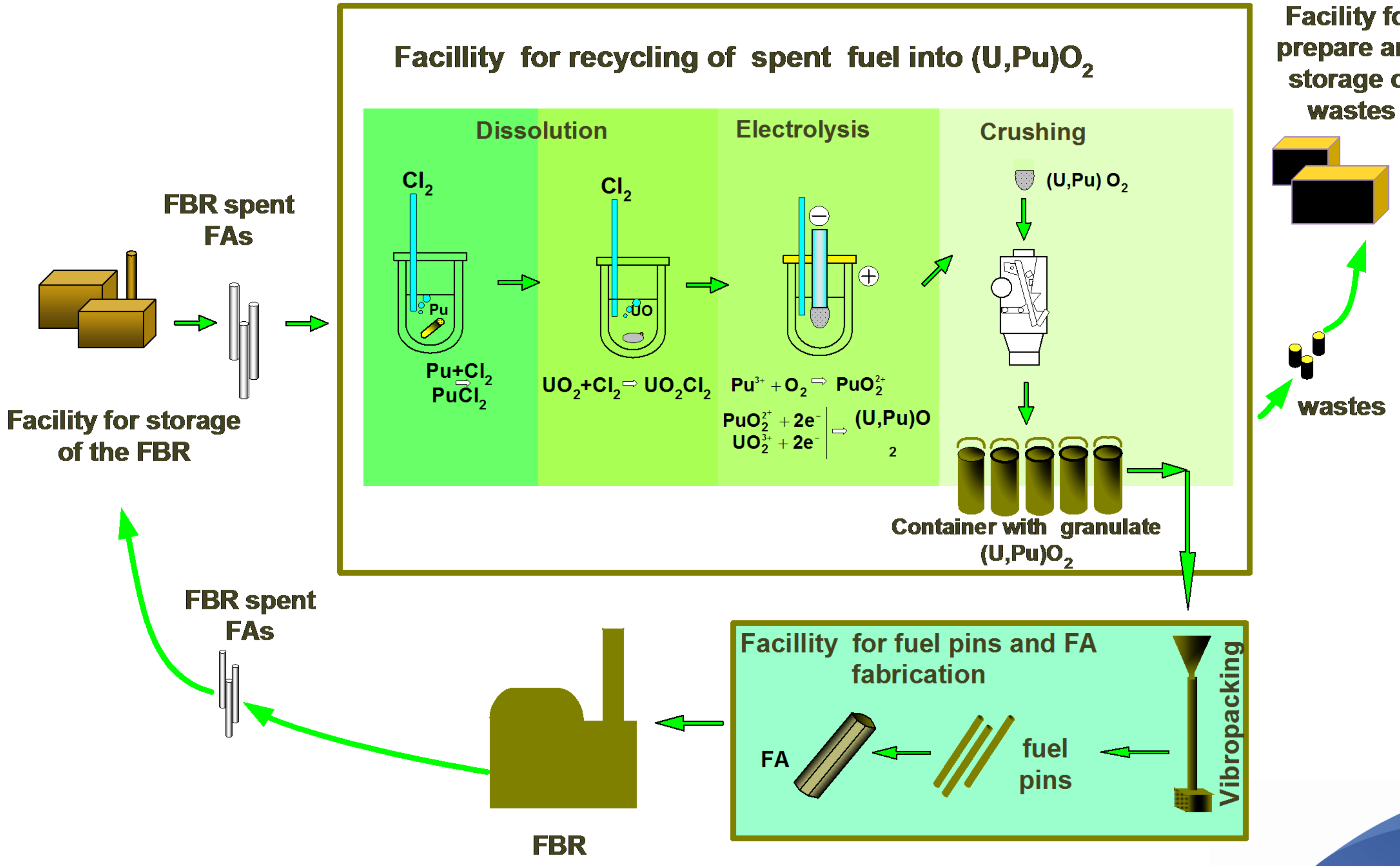
Main tasks

- **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**

2

Power-generating plutonium as a first stage of Closed Fuel Cycle for Fast Reactors creation

Fuel Cycle for Fast Reactors



First steps, 70-s

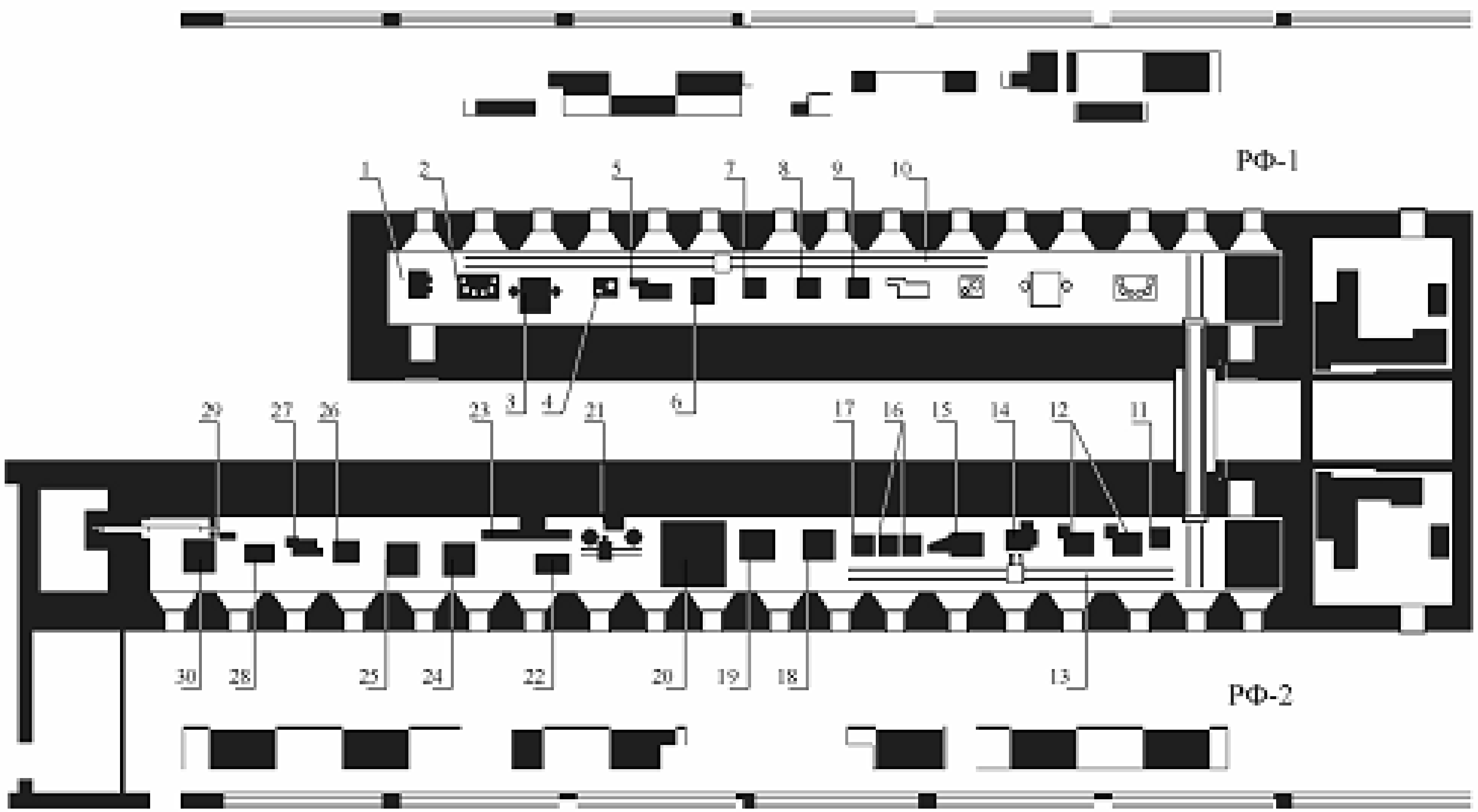
- Laboratory facilities for granulated fuel production and fuel pins manufacturing
- Requirements for fuel pins formalization
- Irradiation tests of vibropac fuel in different reactors
- Start of the OREL facility construction for BOR-60 fuel production

4

History, 70-s…80-s

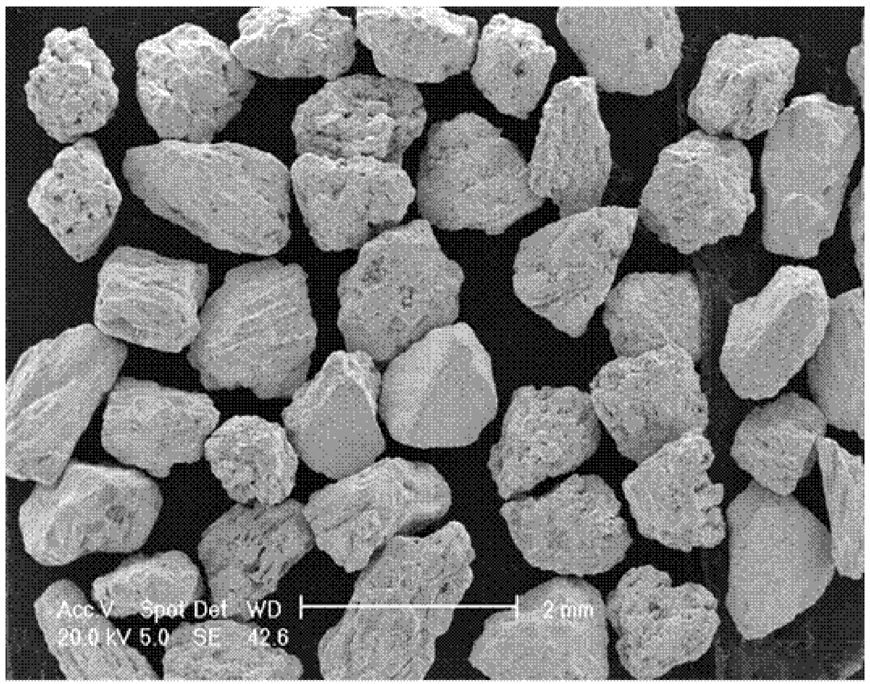
- **OREL facility: start-up;**
- **Vibropac fuel is a standard fuel for the BOR-60 reactor;**
- **Vibropac fuel irradiation in the BN-350 reactor;**
- **Substantiation of vibropac MOX-fuel for fast reactors is completed.**

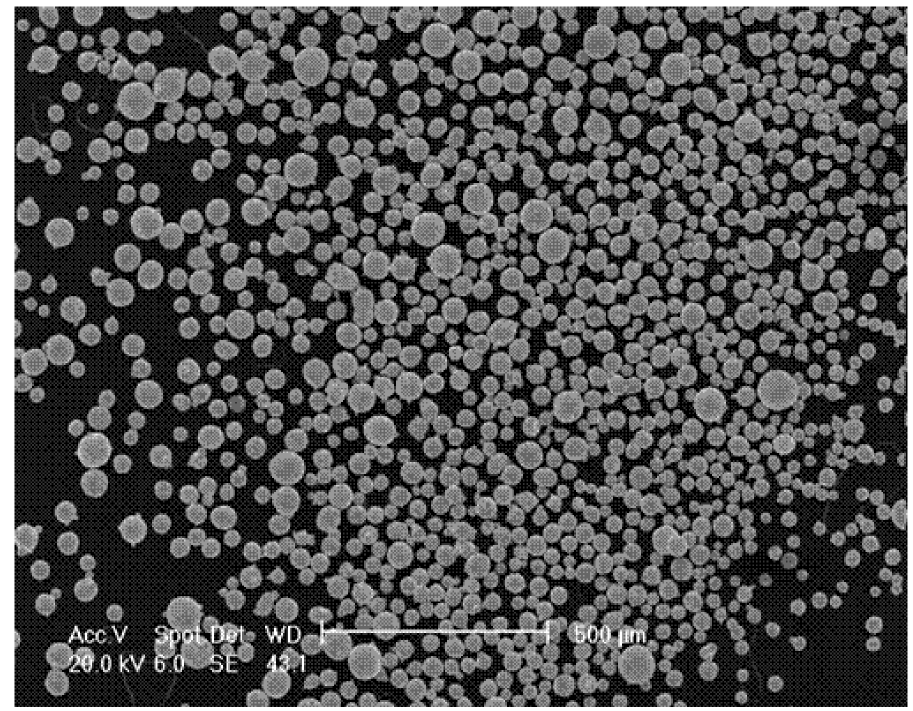
OREL facility

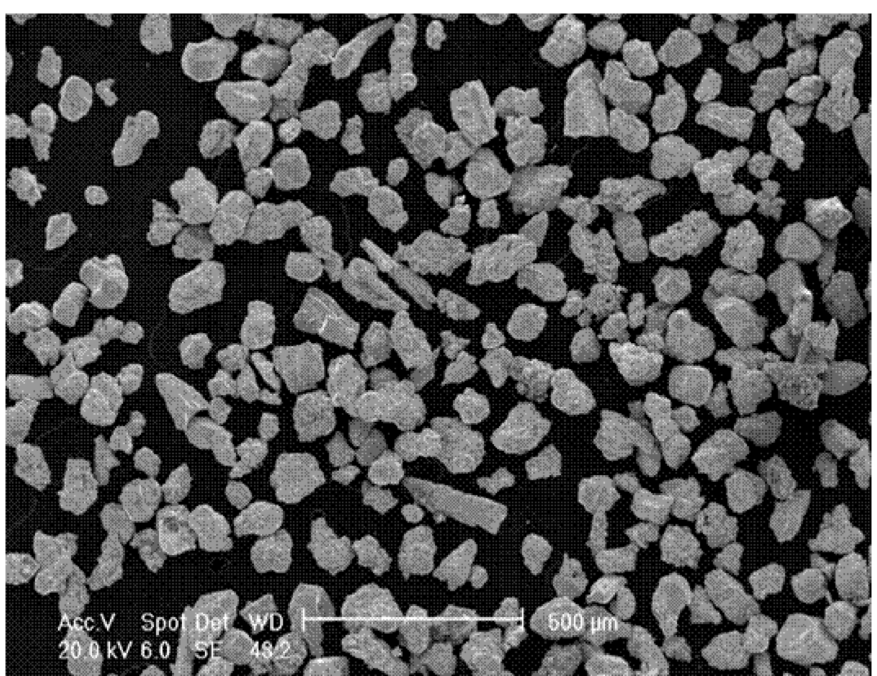


. Схема расположения оборудования для изготовления твэлов и ТВС в условиях защитных камер РФ-1 и РФ-2
1- бокс разделки твэлов; 2- подготовка гранулята; 3- виброуплотнение гранулята;
4- загрузка экрана; 5- загрузка верхней заглушки; 6- герметизация твэла;
7, 8, 9, 11, 16, 17, 18, 19, 20- хранение твэлов; 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.

Granulated MOX-fuel





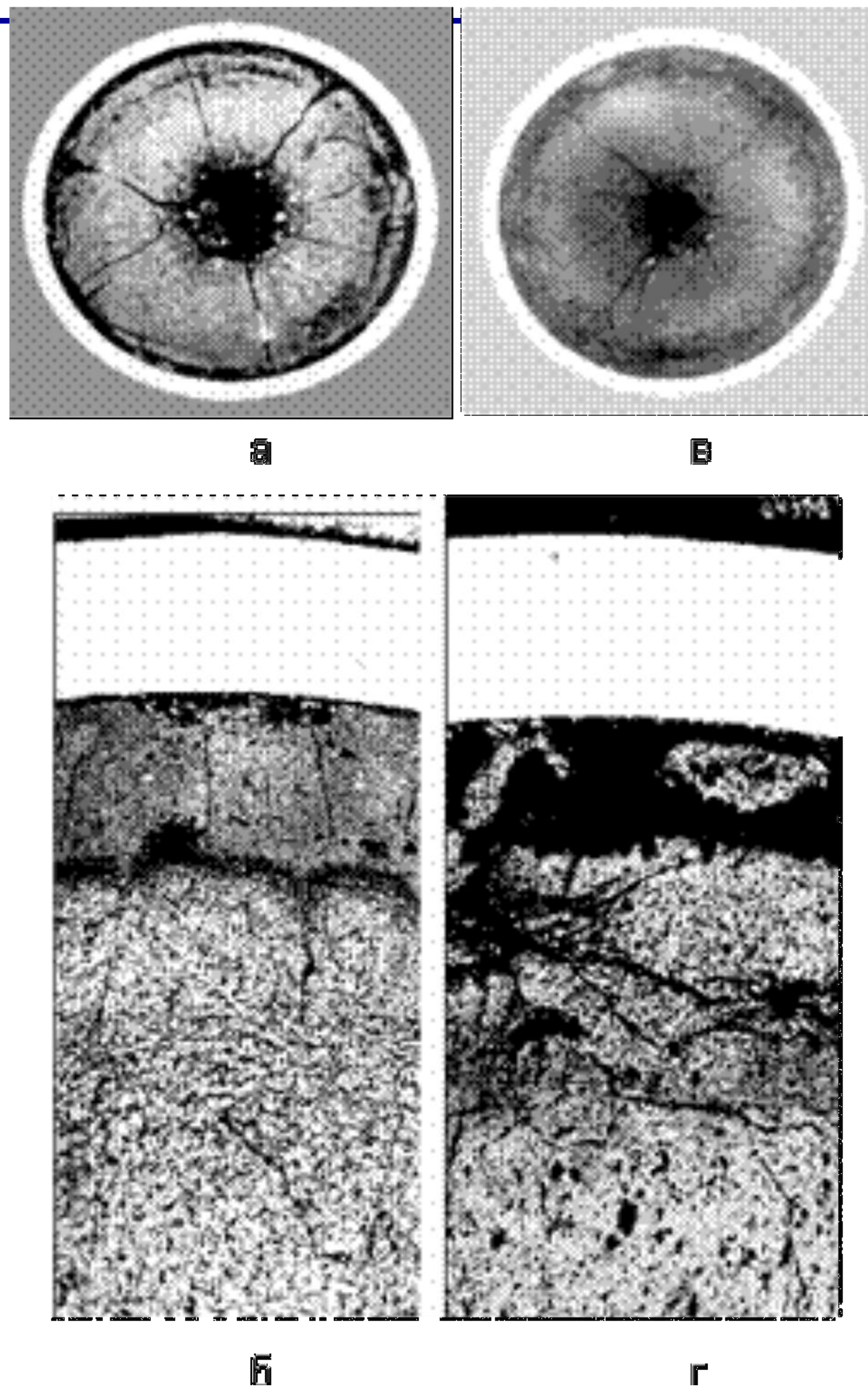


Metal content, %	**87,75**
Pycnometric density, g/cm^3	**10,7**
O/M ratio	**$2.00^{\pm 0.01}$**
Impurities, %	
-chlorine-ion	**0.005**
-Carbon	**0.015**

BOR-60 Vibropac fuel

- About 1000 standard and experimental FA irradiated
- Different cladding and wrapper materials used
- Different types of vibropac fuel
  - UO_2, $UPuO_2$, UO_2+PuO_2,
  - MOX-fuel with 45 PuO_2 %,
  - Fuel with 5 % of 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 % and 30%h.a.:

а, б) - fuel 78 % UO_2 + 22 % PuO_2

в, г) - fuel 95 % UO_2 + 5 % PuO_2

BOR-60 vibropac fuel

- **Maximum parameters**

  Cladding temperature – 722℃

  Linear power –up to 502 W/cm

  Burnup – 32 % h.a.
- **No corrosion internal surface of cladding. No limit burnup. Limit of lifetime – damage doze for structural material**

BOR-60 vibropac fuel

- **Maximum parameters**
  Cladding temperature – 722 ℃
  Linear power – 502 W/cm
  Burnup – 32 % h.a.

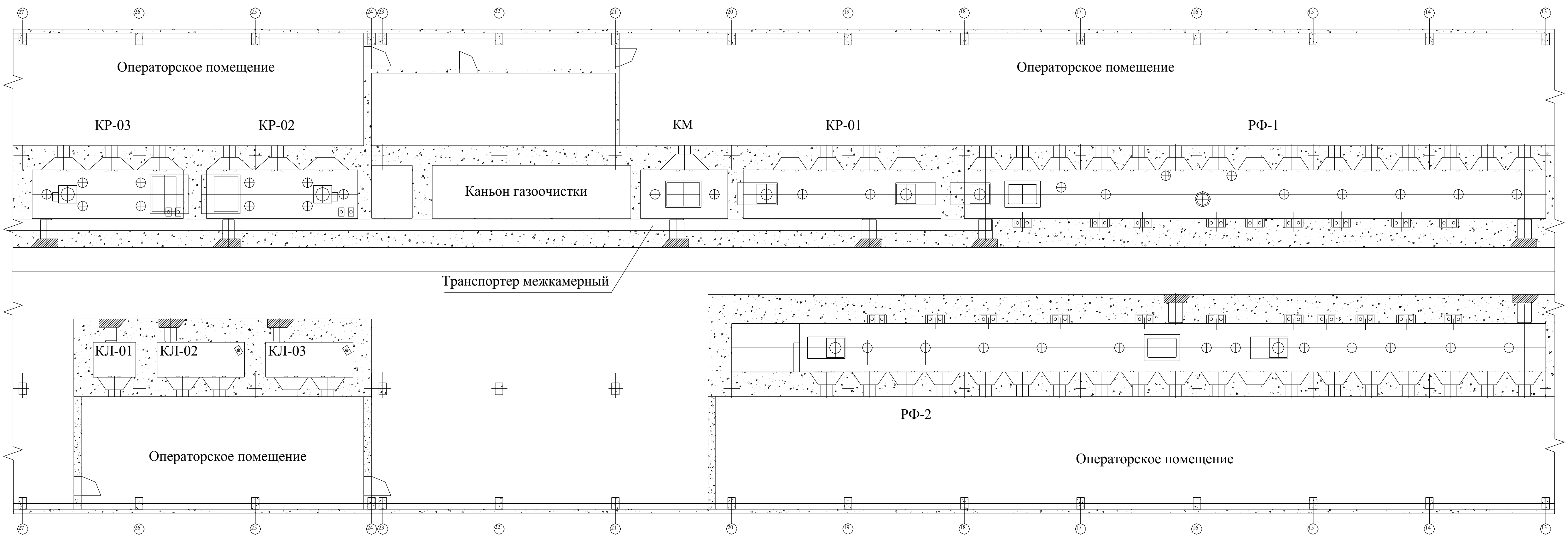
- **No corrosion internal surface of cladding. No limit burnup.**

- **Limit of lifetime – damage doze for structural material**

History, 80-s

- 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



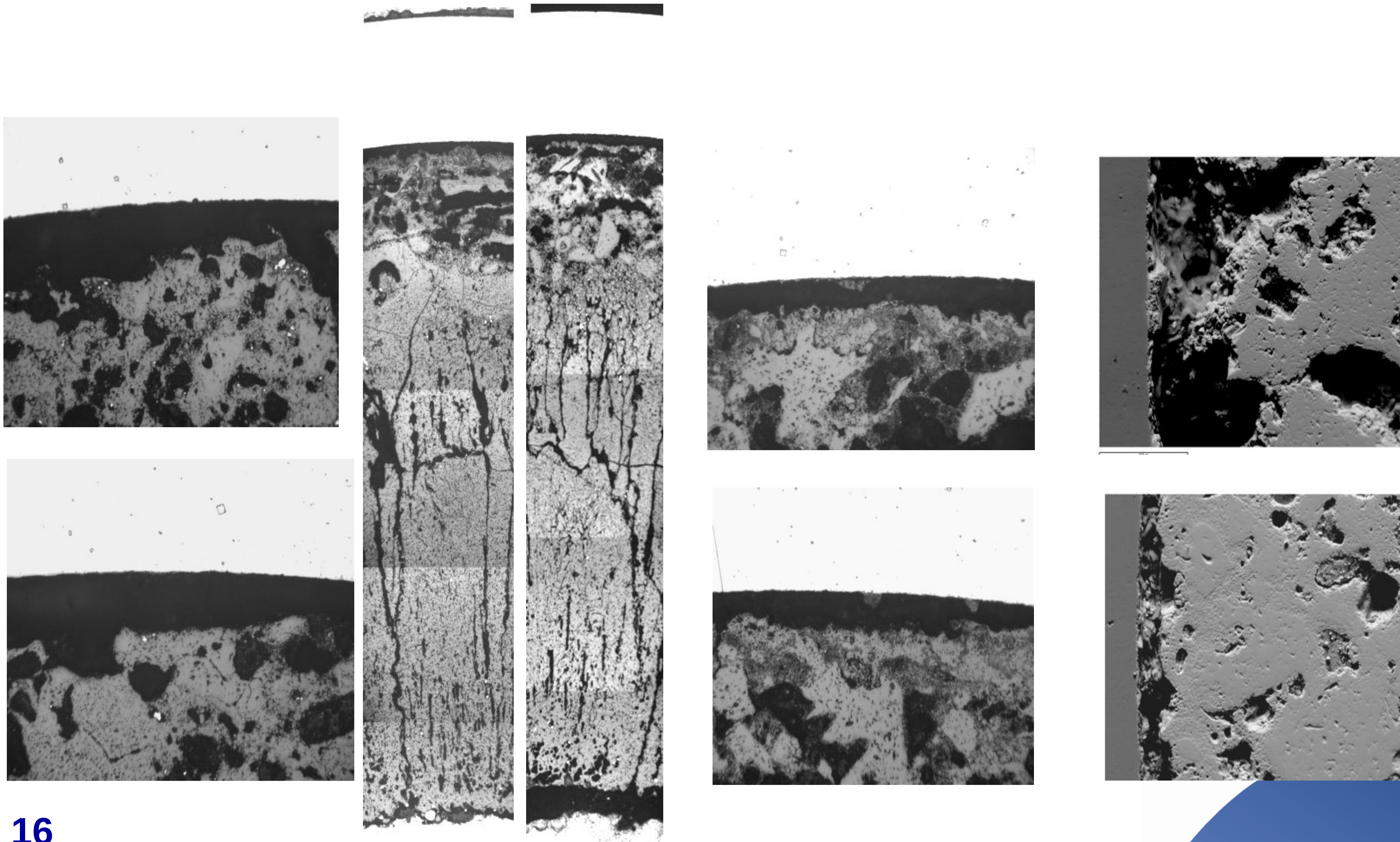
Vibropac MOX-fuel in BN-600. First stage

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/cм^3	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	04.01 – 06.02	07.03 – 09.03	10.05 – 12.05	01.05 – 03.05	04.06 – 12.06
Year of fabrication	1999	2001 – 2002	2003	2005	2005	2006
Getter content, %	7					
Plutonium content, %	23…25					
Effective density, g/cм^3	8.9…9.2					
Cladding material	ChS-68					
Cladding size, mm	6.6				6.9	
Wrapper material	EP-450					
Maximum linear generation,W/cm	401– 423	439 – 453	406 – 424	395 – 407	401 – 441	296 – 374
Maximum cladding temperature, ^{o}C	670 – 680	679 – 694	658 – 675	652 – 700	690 – 703	608- 687
Maximum fuel burnup, % h.a.	10,2 – 10,5	8,6 – 8,9	9,9 – 10,6	10,0 – 10,1	9,3 – 10,0	7,1 – 8,7
Maximum damage dose	74,2 – 77,0	60,3 – 62,3	71,8 – 77,7	74,1 – 75,5	75,3 – 80,9	59,4 – 74,4

Vibropac fuel in BN-600



Vibropac fuel in BN-600

- No specific differences in radiation-thermal effects in fuel pins and FA tested in BOR-60, BN-350 and BN-600 were observed.

Current Status

Up to date SSC RF RIAR has performed an extensive scope of research and developmental activities to validate vibropac oxide fuel pin application in fast reactors of BN-type.

These activities resulted in validation for mass fabrication and standard application of vibropac MOX fuel pins in the BOR-60 reactor, for expanding their application in BN-600 and in BN-800 ("hybride" core).

At the same time undoubtedly favorable results of the performed activities requires additional confirmations, statistical validations, more extended research of peculiarities found during fuel production, fuel rod fabrication, irradiation and PIE of fuel rods and FA.