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Conspectus of a report prepared for the Seminar to be held in the Institute of Heavy Ions (Darmstadt, Germany), February 17-18, 2004

The Laboratory of electromagnetic separation has been functioned in RFNC – VNIIEF since 1967.

The applied mass-separator is provided with radiation shielding what makes it possible to operate highly active materials: uranium, plutonium, americium and curium.

These materials are used to fulfill State Program of nuclear constants measurement where many Institutes of the former USSR took part.

During the last decade our products are open for foreign laboratories.

The basic characteristics are presented in Table.

Trichlorides of separated elements serve as working substance.

During the last three years much has been done to perfect the technology of electromagnetic separation and to achieve stable characteristics of S-2 mass-separator operation.

There were elaborated the technologies of producing pure trichlorides, technology of scattered material regeneration up to 85-90% for the purpose of its use in repeated cycles of separation, 100-% extraction and deep purification of accumulated isotopes from the collector boxes.

At our disposal we have equipment aimed at measuring isotopic composition of the produced isotopes.
The nomenclature of available isotopes is presented in Tables.
One can see that for the majority of isotope unique levels of enrichment are achieved.

A set of unique isotopes 239, 241, 243, 245 are obtained with the aid of double process of separation.

Of course, the quality of products depends on the composition of separated mixtures.

Within all these years there have been used isotopic specimens of uranium, plutonium, americium and curium produced as a result of long irradiation of original materials in the nuclear reactor with high density of neutron flux.

This reactor functions in the Institute of Nuclear Reactors (Dimitrovgrad). To study physical and chemical characteristics of isotopes in the experiments on heavy transactinium elements synthesis carried out in the JINR Laboratory of Nuclear Reactions, we have produced in recent years the materials for the targets used in these experiments.

U-233

Highly enriched uranium-233 has been produced and delivered to Dubna at the amount of up to 20mg (enrichment - 99,997%) (Table).

To produce this specimen the electromagnetic enrichment of original uranium containing 99,28% of uranium-233 was performed.

To produce the required amount of highly enriched uranium there was used the one-cycle separation at which up to 500mg of initial uranium was located in the ion source.

The works in uranium separation were carried out within a month and the required amount of material was consigned to JINR.

Pu-242

Within a short time period (about 2 months) the production of highly enriched plutonium-242 was performed (Table).

A mixture of plutonium isotopes containing about 90% of plutonium - 242 was used for electromagnetic separation.

Plutonium-242 (enrichment – 99,98%) has been produced and delivered to Dubna at the amount of up to 30mg to be used in the experiments.

Cm-245, Cm-246, Cm-247

The work dealing with production of the required for experiments amounts of curium-245, curium-246 and curium-247 turned out to be more complicated and laborious.

The original mixture of curium isotopes included about 25% of curium-245, 6.8% of curium-246 and 0.2% of curium-247.

Curium-244 constituted the basic mass of original material (about 70%) what defined complexity of radiation situation at all stages of the process of curium isotopes electromagnetic separation.

Particular measures were undertaken to shorten the time of performing operations in curium trichloride preparation and its fast positioning in the ion source of S-2 mass-separator.

The works in collecting scattered material from the internal surfaces of mass-separator vacuum chamber aimed at equipment decontamination and regeneration of highly expensive original curium material were of essential complexity (Table).

As a result of activities performed during 4 months there was produced and delivered to Dubna about 30mg of curium-245 (enrichment – more than 98%), more than 15mg of curium-246 (enrichment- more than 99%) about 3mg of curium-247 (enrichment – about 75%).

We consider maximum approachable curium mass for supplies to be approximately three times higher.

Now we are busy carrying out preparatory works to produce plutonium-244 enriched up to 99.5% and even up to 99.99%. We plan to use as original material a mixture of plutonium isotopes containing 17% of plutonium-244 that is provided by the USA.

Unfortunately, the process of negotiations dealing with transfer of this mixture of plutonium isotope oxides (5g) has covered about 2 years by now and there is still no end of this process.

We supply isotopes through JSC Techsnabexport (Tekhsnabexport) – that is an Organization subjected to MinAtom that possesses a license for export of radionuclides.

We coordinate technical requirements and price with the Customer, then, the Contract for supply is concluded through JSC Techsnabexport.

Usually the schedule for the specimens delivery from stock constitutes 3-6 months.

Our transport containers have international certificates.

We have no doubt that our science and technology potentialities make it possible for us to be active participants of the cooperation process with the Institutes occupied with the problems of heavy transactinium isotopes synthesis.

In our opinion the main difficulty in realizing this cooperation consists in the lack of required amounts of original materials, especially, isotopes of elements that are heavier than curium isotopes.

Finally, I would like to pay the audience attention to the activities dealing with the increase of efficiency of using highly expensive original materials at electromagnetic separation.

I have already mentioned that the today efficiency of using original material in the ion source of S-2 mass-separator constitutes approximately 5% (Table).

So, we are to develop a new ion source and power source to increase operation temperature of the source.

Unfortunately, such experiments performed in the seventies were not carried through.

High efficiency of the source will make it possible to use smaller amounts of original material for the production of the required mass of material and essentially improve radiation conditions of carrying out the works at separating highly active isotopic mixtures. According to our estimate 2-2.5 years of activities and 300 thousand dollars are required to create the new technology.

Now we are busy executing ISTC Project Proposal and we hope we get support of the Institutes interested in this problem solution. Multiple appreciations received from the leading foreign centers and distinguished scientists in response to brief information on the scheduled activities testify to this fact.

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Basic parameters of the S-2 mass separator

Magnetic field form	$H=H_0r_0/r$
Average trajectory radius, r_0	**1000 mm**
Average intensity of magnetic field, H_0	**4500 Oe**
Ion beam angle in magnetic field	**114,6° (2 rad)**
Total length of average trajectory	**6000 mm**
Accelerating voltage	Up to **45 kV**
Ion source type	Plasma-type with filamentary longitudinal cathode, bicrucible (10 g + 1 g)
Maximum temperature of crucibles	**1000°C**
Isotope receiver	Slit-type with a variable number of boxes
Power	50 kW

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Isotope Contents of Highly Enriched Uranium Samples

Isotope	Main isotope contents and impurities (as atoms. %)					
Uranium	**232**	**233**	**234**	**235**	**236**	**238**
U-233	$0.5 \cdot 10^{-3}$ act.	**99.97**	0.03	$0.1 \cdot 10^{-2}$	$<10^{-3}$	$0.1 \cdot 10^{-2}$
U-234		15.3	**84.52**	0.13	$1.3 \cdot 10^{-3}$	$4 \cdot 10^{-2}$
U-235		$1.7 \cdot 10^{-4}$	$2.6 \cdot 10^{-3}$	**99.9923**	$4.5 \cdot 10^{-3}$	$4.3 \cdot 10^{-4}$
U-236			$< 1.27 \cdot 10^{-2}$	1.41	**97.81**	0.763
U-238		$< 1.8 \cdot 10^{-4}$	$<1.58 \cdot 10^{-4}$	$<4.03 \cdot 10^{-4}$	$<2.82 \cdot 10^{-4}$	**99.999**

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Isotope Contents of Highly Enriched Plutonium Samples

Isotope	Main isotope contents and impurities (as atoms. %)					
Plutonium	**238**	**239**	**240**	**241**	**242**	**244**
Pu-238	**99.6**	0.4	0.015			
Pu-239		99.5 **99.997**	0.5 $2 \cdot 10^{-3}$	$2 \cdot 10^{-4}$	$1 \cdot 10^{-4}$	
Pu-240		$4 \cdot 10^{-3}$ $3 \cdot 10^{-2}$	**>99.9** 90.7	$6 \cdot 10^{-2}$ 0.2		
Pu-241		$<10^{-3}$ $<10^{-4}$	0.17 $3 \cdot 10^{-4}$	99.6 **99.998***	0.23 $1.6 \cdot 10^{-3}$	$<10^{-3}$ $<10^{-4}$
Pu-242		10^{-3} $5 \cdot 10^{-4}$	0.1 $5 \cdot 10^{-4}$	2.0 0.04	97.8 **99.99**	$7 \cdot 10^{-4}$ $5 \cdot 10^{-4}$
Pu-244		$5 \cdot 10^{-2}$ $3 \cdot 10^{-4}$	0.4 0.3	$5 \cdot 10^{-2}$ $7 \cdot 10^{-3}$	1.8 0.7	**97.8** **98.9**

*Produced by double separation process.

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Isotope Contents of Highly Enriched Neptunium Samples

Isotope	Main isotope contents and impurities (as atoms. %)	
Neptunium	**236**	**237**
Np-237	<0.01	**99.99**

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Isotope Contents of Highly Enriched Americium Samples

Isotope	Main isotope contents and impurities (as atoms. %)		
Americium	**241**	**242m**	**243**
Am-241	**99.99**		
Am-242m	30.5 13.0	**55.1** **85.6**	18.2 1.6
Am-243	0.7 $1.6 \cdot 10^{-3}$	0.1 $4 \cdot 10^{-4}$	**99.2** **99.998**

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Isotope Contents of Highly Enriched Curium Samples

Isotope	Main isotope contents and impurities (as atoms. %)					
Curium	**243**	**244**	**245**	**246**	**247**	**248**
Cm-243	**93.3** **99.99***	0.6 $8\cdot10^{-3}$	$4\cdot10^{-4}$ $5\cdot10^{-5}$	0.6 10^{-4}	$<10^{-2}$ $<10^{-4}$	$<10^{-2}$ $<10^{-4}$
Cm-244	$1.5\cdot10^{-2}$	**99.3**	$6\cdot10^{-2}$	$4\cdot10^{-3}$	$<10^{-3}$	$<10^{-2}$
Cm-245		1.3 $6\cdot10^{-3}$	**98.4** **99.998***	0.3 $2.5\cdot10^{-3}$		
Cm-246		$<10^{-2}$ $<10^{-2}$	6 $8\cdot10^{-3}$	**98.0** **99.8**	$<10^{-2}$ $<10^{-2}$	$<10^{-2}$ $<10^{-2}$
Cm-247	0.5	12 2.7	7 0.8	7 5	**72.3** **90.2**	1.4 0.5
Cm-248	0.1 0.1	2.8 1.7	0.04	1.24 0.7	0.1	 **97.5**

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U-233

- Mass of original material - **500 mg**
- Isotopic enrichment of original U-233 - **96,3%**
- Mass of produced material - **20 mg**
- Isotopic enrichment of the produced U-233 - **99,99%**

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Pu-242

- Mass of original material - **600 mg**
- Isotopic enrichment of original Pu mixture - **90%**
- Mass of produced material - **30 mg**
- Isotopic enrichment of the produced Pu-242 - **99,98%**

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Cm-245, Cm-246, Cm-247

- Mass of original material - **4500 mg**
- Isotopic content of original material
  - Cm-244 - **~70%**
  - Cm-245 - **~25%**
  - Cm-246 - **~6,8%**
  - Cm-247 - **~0,3%**
- Mass of produced material
  - Cm-245 - **~30 mg**
  - Cm-246 - **~30 mg**
  - Cm-247 - **~2 mg**
- Isotopic enrichment of the produced material
  - Cm-245 - **>98%**
  - Cm-246 - **>99%**
  - Cm-247 - **~75%**

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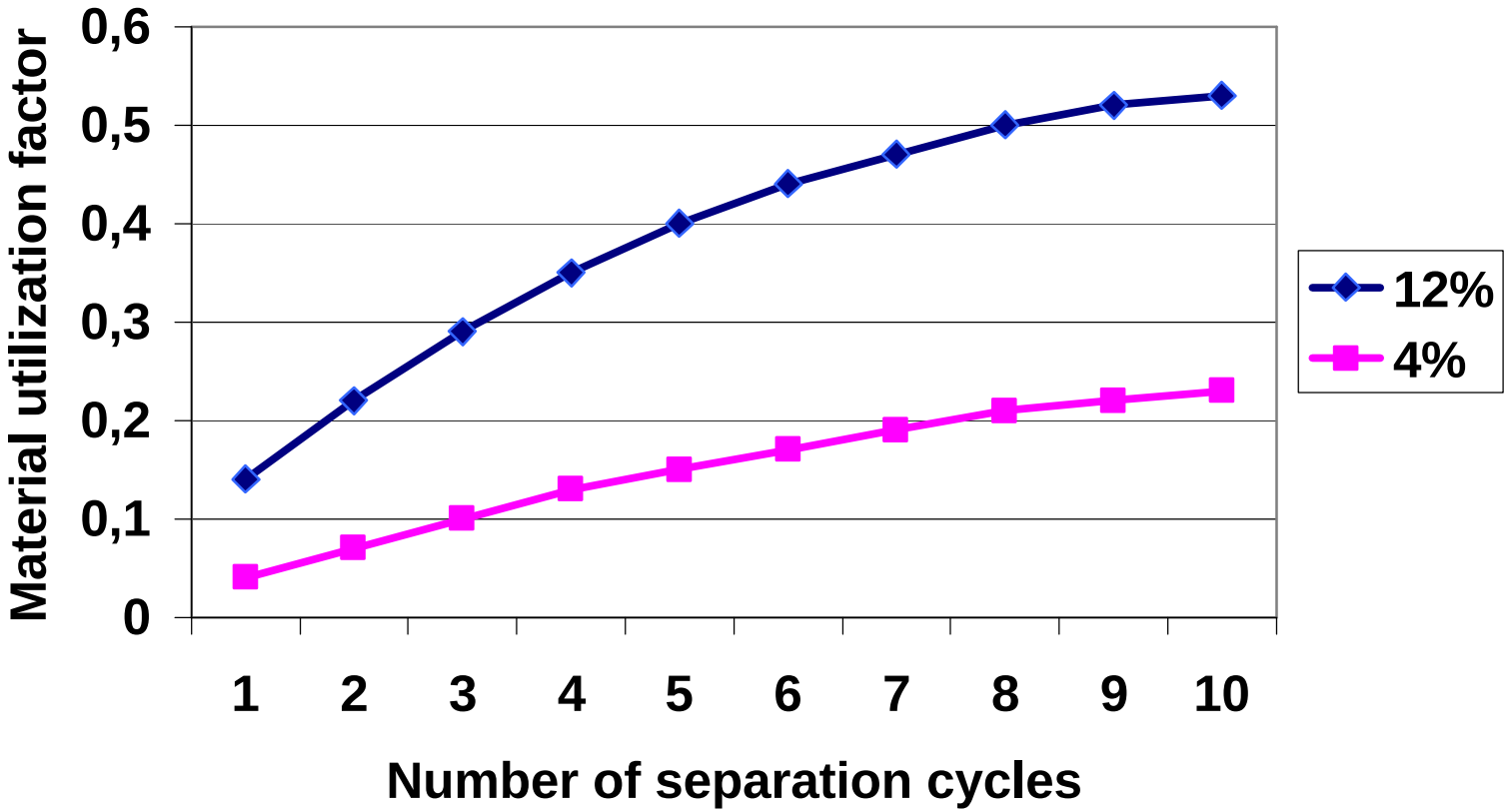
Working characteristics of the S-2 mass separator during isotope separation

Material utilization factor during separation	**~5%**
Material extraction factor from the isotope collector box	**100%**
Regeneration of the scattered material factor	**90%**

Isotope yiedls as function of material utilization factor



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