THE UTILIZATION OF 10 MW RESEARCH REACTOR IN TASHKENT (UZBEKISTAN)

B. YULDASHEV *)

Stanford University, Stanford, CA 94305-6165, USA

U.SALIKHBAEV, S.BAYTELESOV, A.DOSIMBAEV, E.IBRAGIMOVA, A.KIST, Yu.KOBLIK, Sh.Makhkamov

Institute of Nuclear Physics, Ulughbek, Tashkent, 100214, Uzbekistan

M.ABDUKAYUMOV, P.CHISTYAKOV

Radiopreparat Enterprise of INP, Ulughbek, Tashkent, Uzbekistan

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*) On leave of absence from INP, Ulughbek, Tashkent, Uzbekistan

E-mail: byuldash@stanford.edu or yuldbekh@gmail.com

OUTLINE

- HISTORY
- FUEL (FRESH AND SPENT)
- OPERATION
- UTILIZATION:

- **BASIC RESEARCH**: NUCLEAR PHYSICS, NUCLEAR SPECTROSCOPY, FISSION PHYSICS, MATERIAL SCIENCES, RADIOCHEMISTRY

- **APPLIED RESEARCH**: ISOTOPES, ACTIVATION ANALYSIS, REACTOR MATERIALS AND FUEL ELEMENTS

- **PRODUCTS**: ISOTOPES FOR MEDICINE AND RESEARCH, COLORED GEMS, MODIFIED SEMICONDUCTORS

HISTORY

1 September 1959 – First criticality of 2 MW WWR-S reactor,
10% enrichment fuel

1972 -78 - Modernization, increase of thermal power up to 10 MW,
90% enrichment fuel

1990-97 - Upgrading cooling system, new additional cooling tower,
testing new types of fuel

1994-96 - New physical protection system

1997-98 - New type of fuel (36% enrichment)

2002-06 - Sending the spent fuel back to Russia

2007-08 - Full conversion to 19.82% fuel

Reactor WWR-SM INP AS RU

- **Maximal neutron flux – $3 \cdot 10^{14}$ neutrons / $cm^2 sec$**
- **Number of channels:**
  vertical – 44,
  horizontal – 10

TIME OF OPERATION

- **Nuclear Physics**
- **Radiation Material Science**
- **Activation Analysis, Radiochemistry**
- **Fission Physics**
- **Nuclear Spectroscopy**
- **Isotope Production**
- **Radiation Modification of Materials**

REACTOR PARAMETERS

- Thermal power: 10 MW, steady
- Coolant and moderator: Light water
- Core configuration: Cylindrical core of about 58cm diameter and 60cm height
- 10 Control rods: 3 safety rods (B_4C), 6 shim rods (B_4C) and one automatic regulating rod (AR)
- 44 vertical and 10 horizontal channels
- Neutron reflector: Be and Graphite.
- Thermal flux ~$2.0*10^{14}$n/(cm^2*sec)
- Fast flux ~$1.5*10^{14}$n/(cm2*sec)

Power 10 000 kW: 480 hrs/cycle, 1 cycle/month,
➔ 6000 hrs/year

At present reactor is operating for:

- Radioisotope production;
- Neutron activation analysis and radiochemistry;
- Basic and applied research;
- Research in reactor physics; thermohydraulics and materials;
- Testing of new types of reactor fuel;
- Material sciences;
- Personnel training and education;
- Irradiation of jewelry stones;

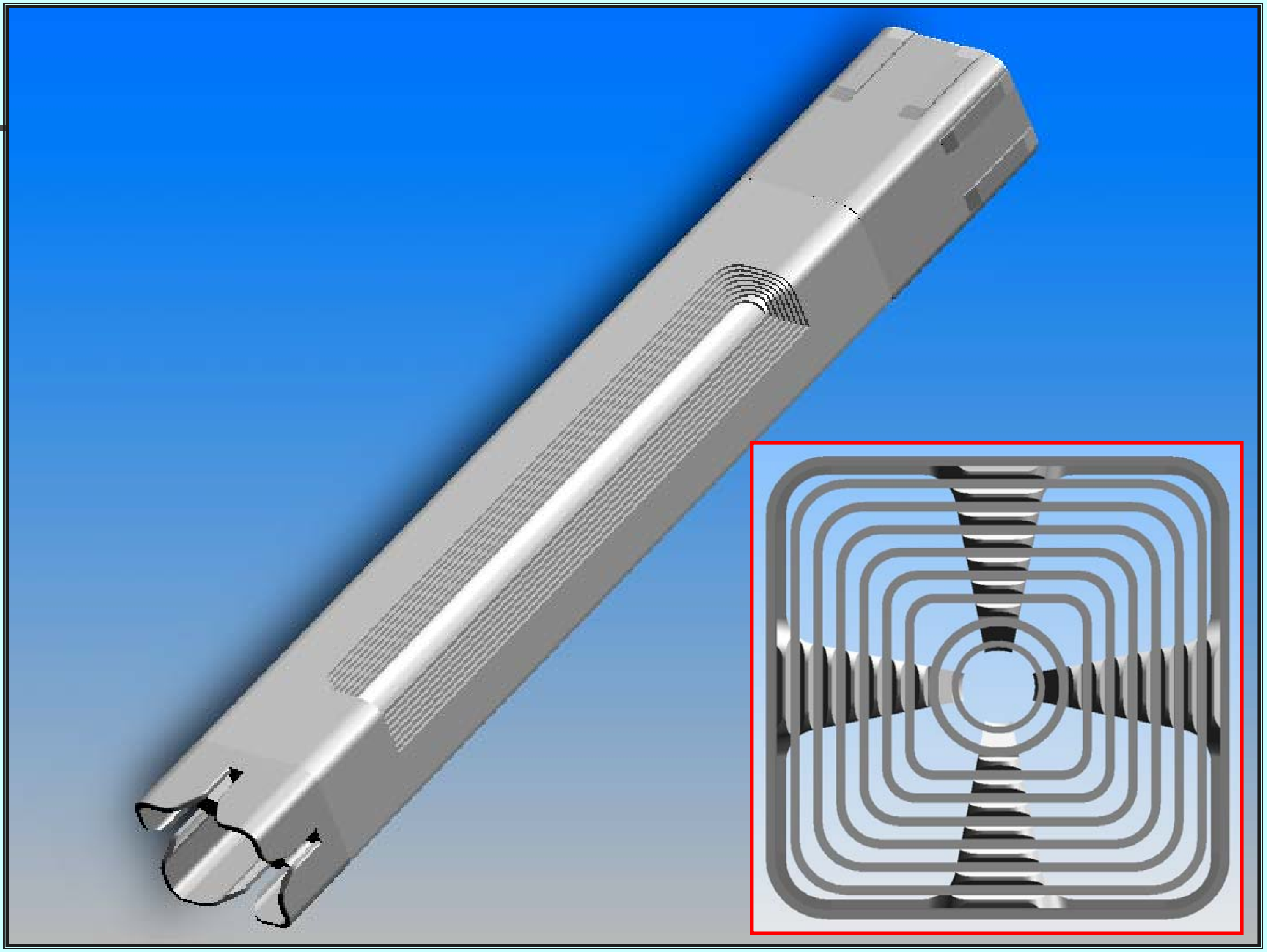
Upgrading Physical Protection System


STOP

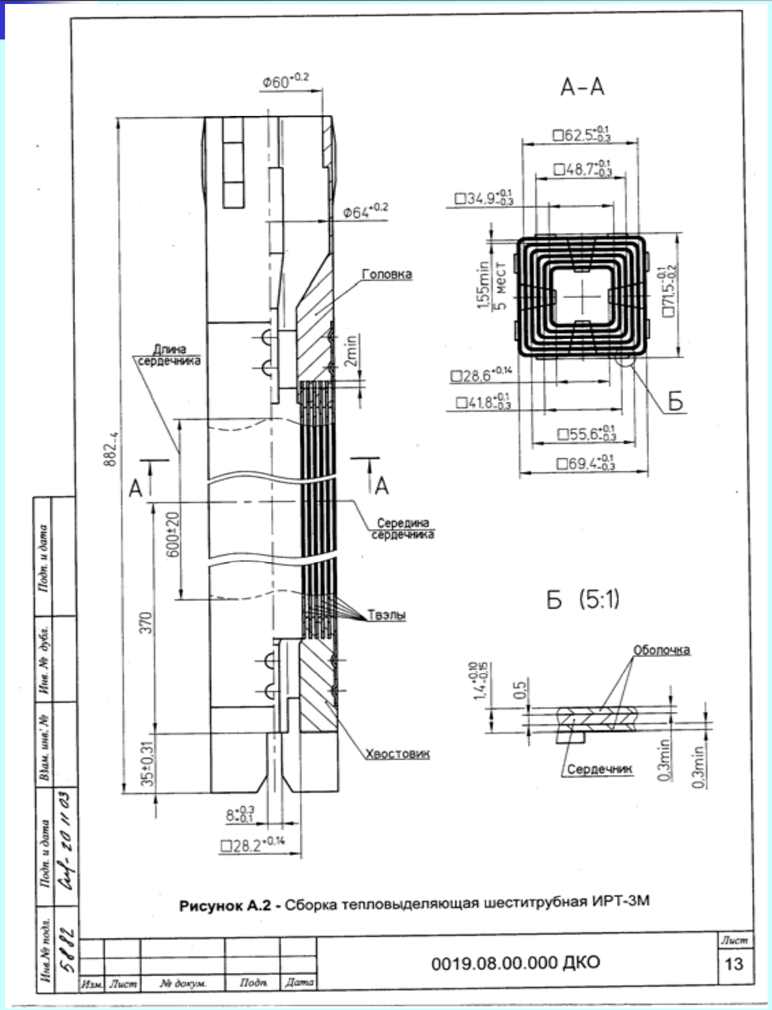
FUEL HISTORY

- **Since 1959 till 1970 nuclear fuel (type EK-10) with 10% enrichment has been used in the reactor operating at the power of 2MW.**
- **Since 1971 upon the end of reconstruction in 1977-1978 the nuclear fuel (IRT-2M type) with 90% enrichment was used. Power of the research reactor was increased up to 10 MW.**
- **Since 1979 the nuclear fuel of IRT-3M type with 90% enrichment has been used**
- **The conversion to 36 % enrichment FA (IRT-3M) started in late 1997 – fully completed in 1999.**
- **The end 2007 - 19.7% enrichment IRT-4M (plans).**
- **2002-2006 – sending spent fuel back to Russia**

FUEL ASSEMBLY IRT-3M (IRT- 4M)



FUEL ASSEMBLY



- ☞ Fuel assembly WWR-SM type: IRT-3M
- + Al-U alloy, 36% enriched on U-235
- + Total length: 880 mm
- + Fuel meat part length: 600 mm
- + 6 layers (5 square round tubes inside, 1 square round tube outside)
- + Fuel meat thickness: 0.5 mm
- + Cladding thickness: minimum 0.3 mm

FUEL TESTING

- **Since March 1987 till March 1989 for the first time the experimental life tests of 3 FA (fuel assemblies) of IRT-3M type (two 6- tube and one 8- tube) with 36 % enrichment were carried out in the core of our reactor. That was done as a first stage of the program on conversion to lower enrichment fuel of research reactors using Russian-made fuel. The tests of these FAs were successful and allowed, in particular, to exceed 60% in the burn-up of fuel.**

- **1998- starting to use full loads of IRT-3M fuel with 36 % enrichment.**

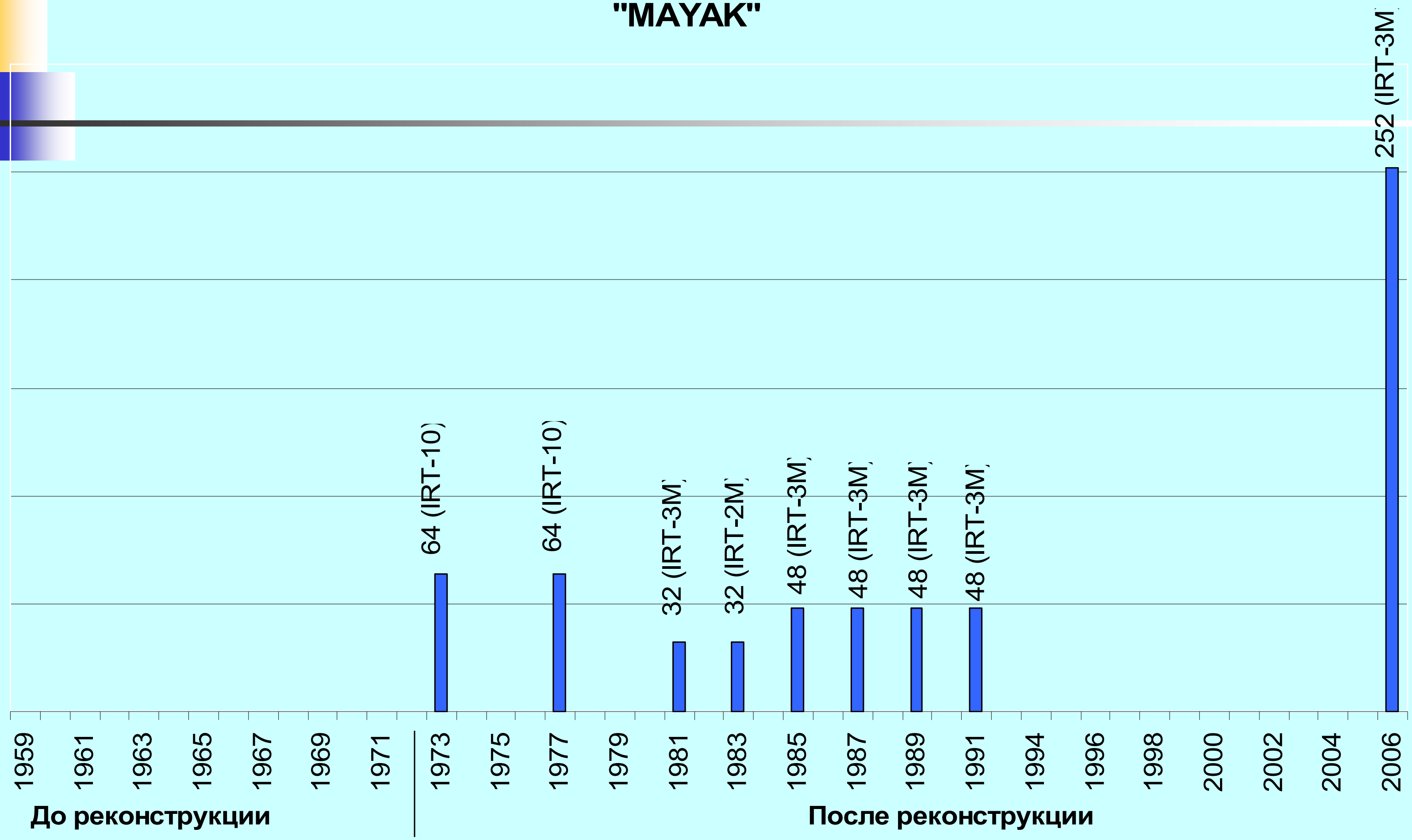
- **2001- 2002 - the life tests of fuel assemblies made of IRT-4M-type (two 6- tube and one 8- tube) with 19.82% enrichment. The tests of these FA have passed successfully with achievement of burn-out of fuel of more than 60 %.**

- **2002- starting project on the shipment of highly enriched spent fuel to the country-origin (Russia). Complete inspection of stored spent fuel**

- **2006- completion of the first stage of SF-shipment**

- **2007-2008 – full conversion to 19.62% enrichment fuel**

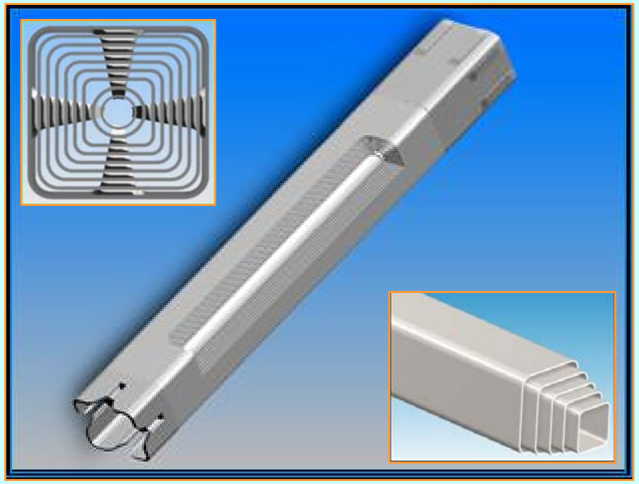
Shipment of used fuel assemblies to Russia^s reprocessing plant "MAYAK"



Spent Fuel Information

IRT-3M (by January 2005)

- 210 – 90% assemblies
- 42 – 36% assemblies
- Fuel meat: UO_2-Al
- Cladding: Aluminum
- 6 to 8 square tubes
- All intact, no leakage



Project Team

B. Yuldashev - INP
U. Salikhbaev – INP
A. Dosimbaev – INP

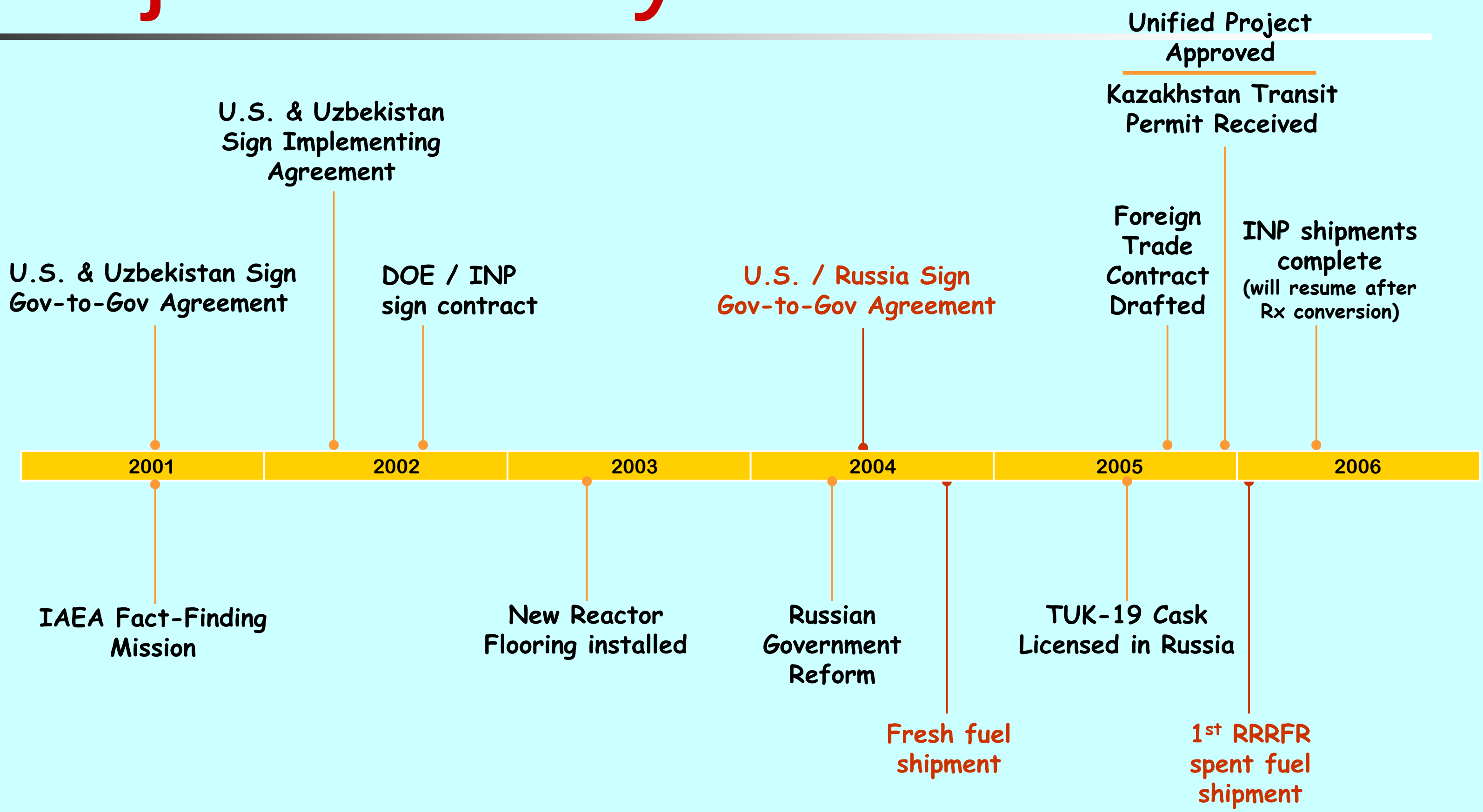
L. Yungerova, Rosatom
A. Lebedev, TENEX
M. Vybornov, TENEX
V. Tyazhkorob, Mayak
A. Takarenko, VNIPIET
V. Dorogov, IBRAE

I. Bolshinsky – INL/DOE/NNSA
J. Thomas – SRS/DOE/NNSA
M. Salome – DOE/NNSA

Y. Golyapo, KATEP
S. Lobova, KATEP

SHIPMENT OF UNUSED FRESH HIGHLY ENRICHED FUEL

Project History / Timeline



Facility Preparations

- **Reactor hall flooring**
- **Radiological monitoring & communications equipment**

- **Reactor hall lighting and remote cameras**
- **Self-releasing grapple**

- **Backup generator for emergency power**
- **TUK-19 transport racks for truck transport**
- **Trucks and crane**

THE SHIPMENT SCHEDULE

Date	No of FA	No of containers	Enrichm. %	No of FA
10.01.06	**64**	**16**	**90**	**64**
14.02.06	**64**	**16**	**90** **36**	**57** **7**
07.03.06	64	16	90 36	57 7
15.04.06	60	15	90 36	32 28

IN TOTAL – 252 FA

Shipment Details

TUK-19 Cask Information

Parameter	Value
Cask outer dimensions (mm)	910 OD x 2170 H
Cask cavity dimensions (mm)	220 D x 1400 H
Cask Weight (fully loaded) (kg)	4750
IRT capacity	4
Max. ^{235}U enrichment (%)	90
Max. decay heat (W)	112
Min. cooling time (year)	3
Number available for shipment	16
Transport method	TK-5 railcar; truck

Train arrival, 27 Dec. 2005

Loading fuel assemblies into containers

Shipment Details

Transportation

- **<u>4 trips total</u>**
  - Turnaround time ~ 3 weeks
  - 64 assemblies per shipment
  - No delays
- **<u>Coordination</u>**
  - Border Logistics (Physical protection forces exchange)
  - Customs
  - Dedicated rail

Lessons Learned Workshop

- **Held in Belgrade, Serbia, 4-7 October 2006**
  - Organized by the IAEA with support from the Serbian Ministry of Science, Technology and Environmental Management.
  - All RRRFR participating countries were represented
  - Shared experiences of SNF shipment

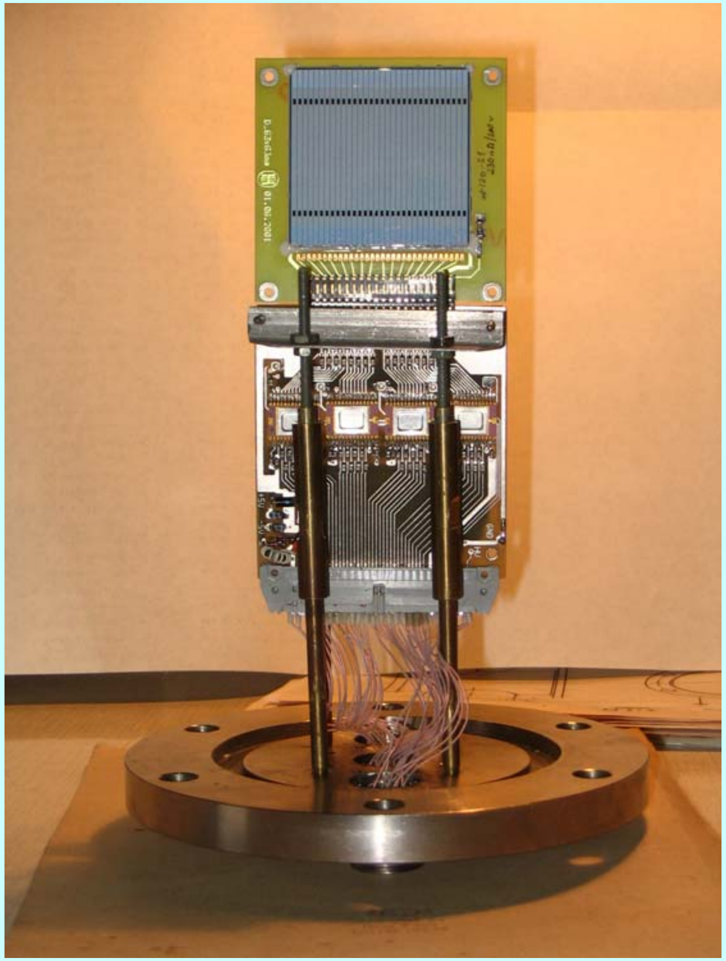
- **Lessons Learned**
  - Legal and technical requirements
  - Project Management
  - Mayak fuel inspections and acceptance

- **IAEA prepared draft of TECDOC – Guideline Document – Feb.2006**
  - Similar to TECDOC drafted for FRR shipments

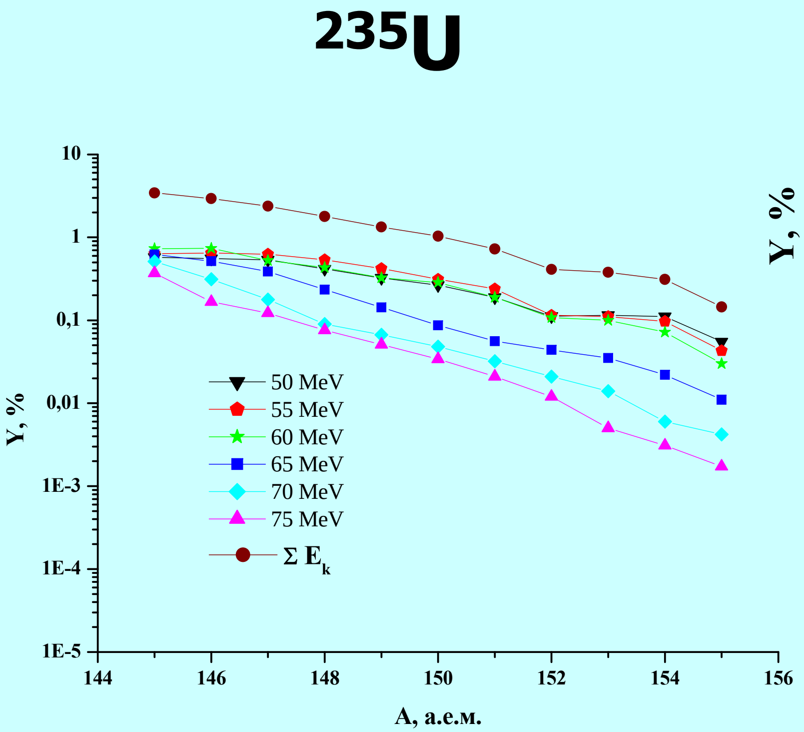
CLOSE PERSPECTIVES

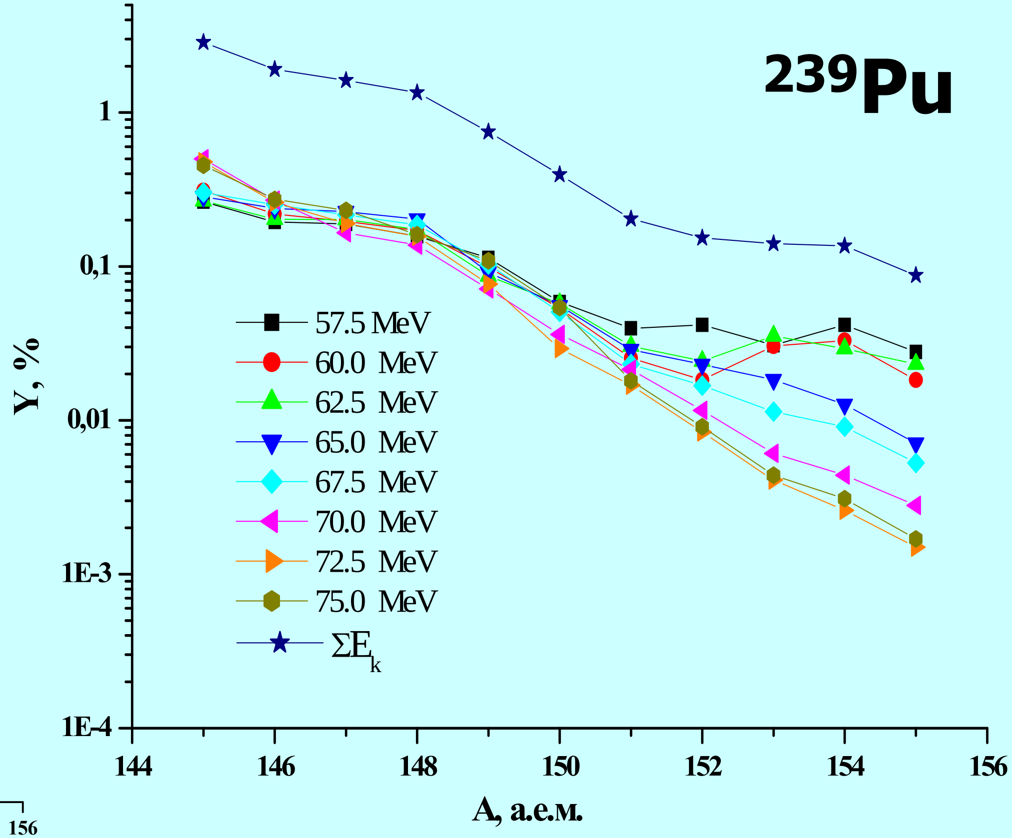
- **Upgrading of control system of reactor WWR-SM**
- **Full conversion of WWR-SM to low enrichment (19.7%) fuel. NEUTRON's SHORTAGE ???!!!**
- **Replacement and upgrading of some older parts**
- **Tests of new fuel elements.**

Mass-Spectrometer of Fission Products – Study of n ^{235}U and n ^{239}Pu Interactions with Thermal Neutrons



Relative Yields of Fragments from ^{235}U- and ^{239}Pu- Fission by Thermal Neutrons as a Function of Mass Number and Kinetic Energy of Fragment



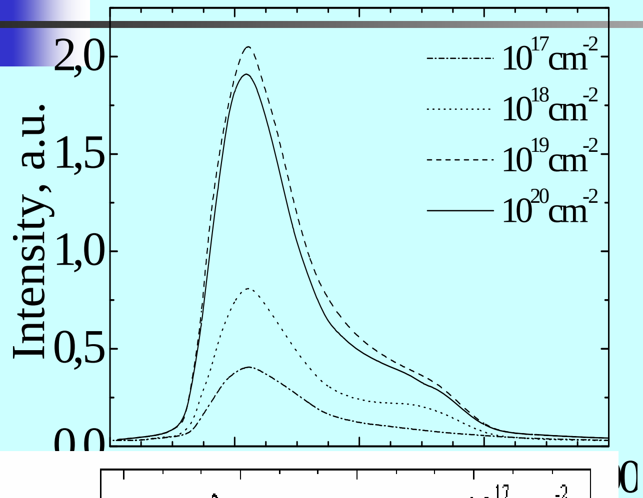


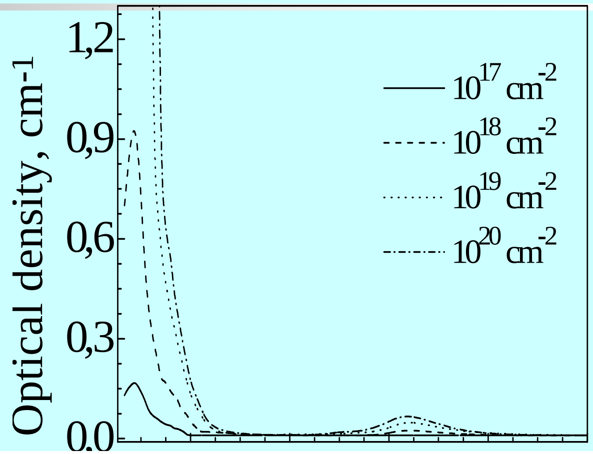
OPTICAL PARAMETERS OF QUARTZ AND SAPPHIRE AS A FUNCTION OF NEUTRON-GAMMA INTEGRATED FLUX (FLUENCE)

OPTICAL ABSORPTION

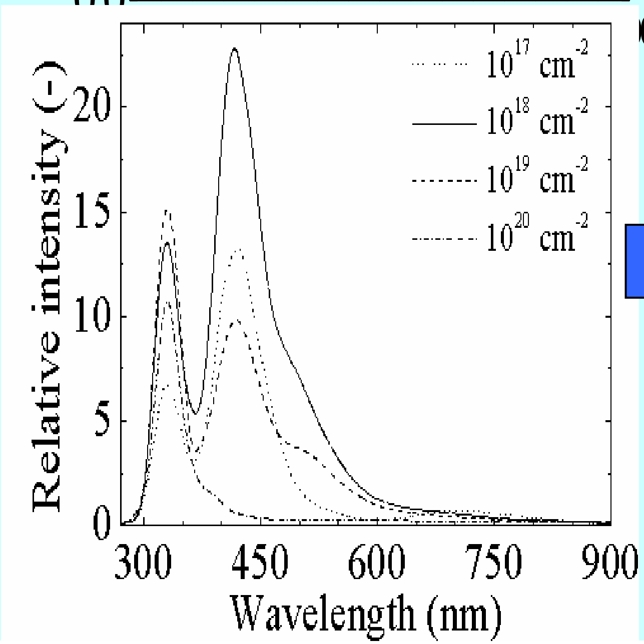
GAMMA – INDUCED LUMINESCENCE

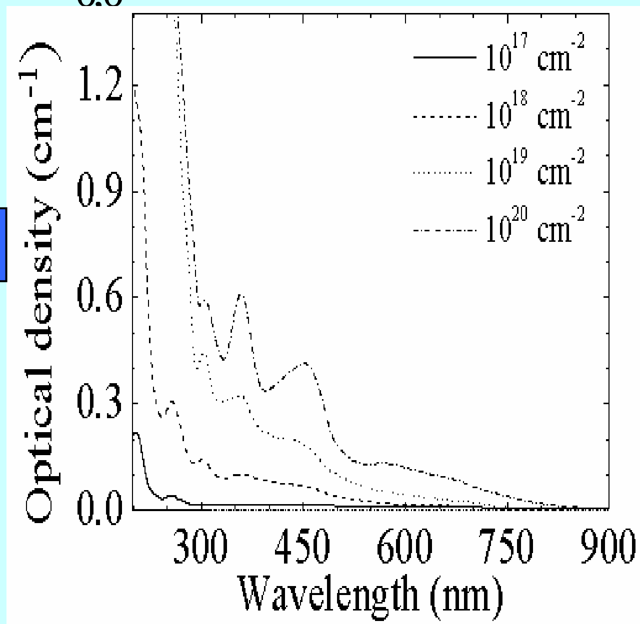
QUARTZ



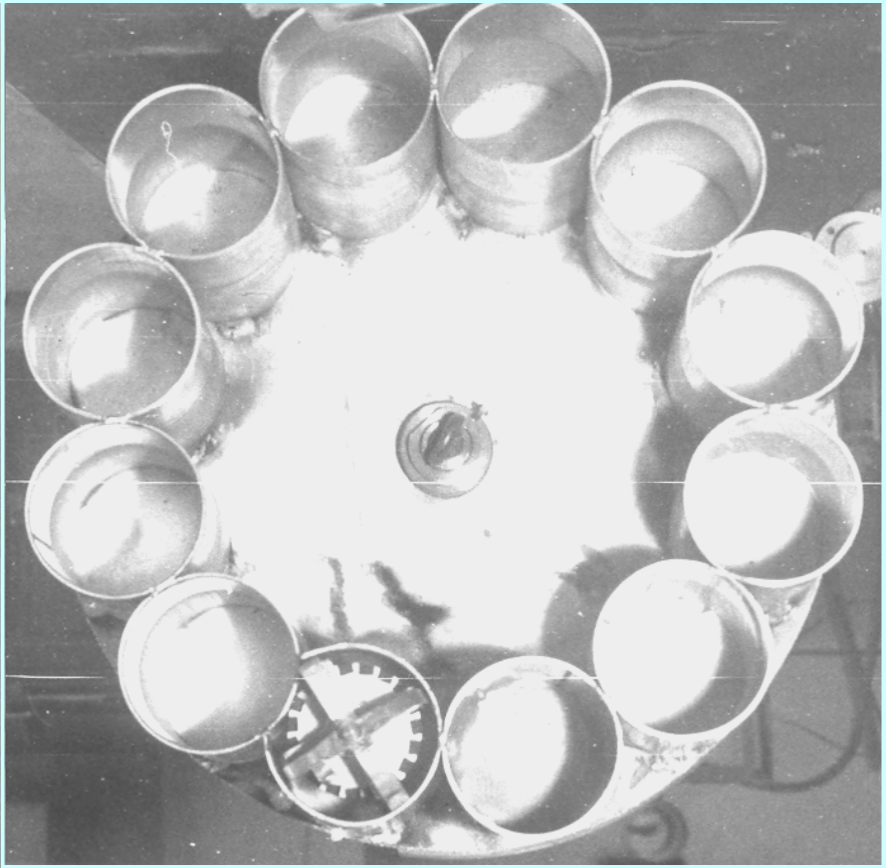


SAPPHIRE



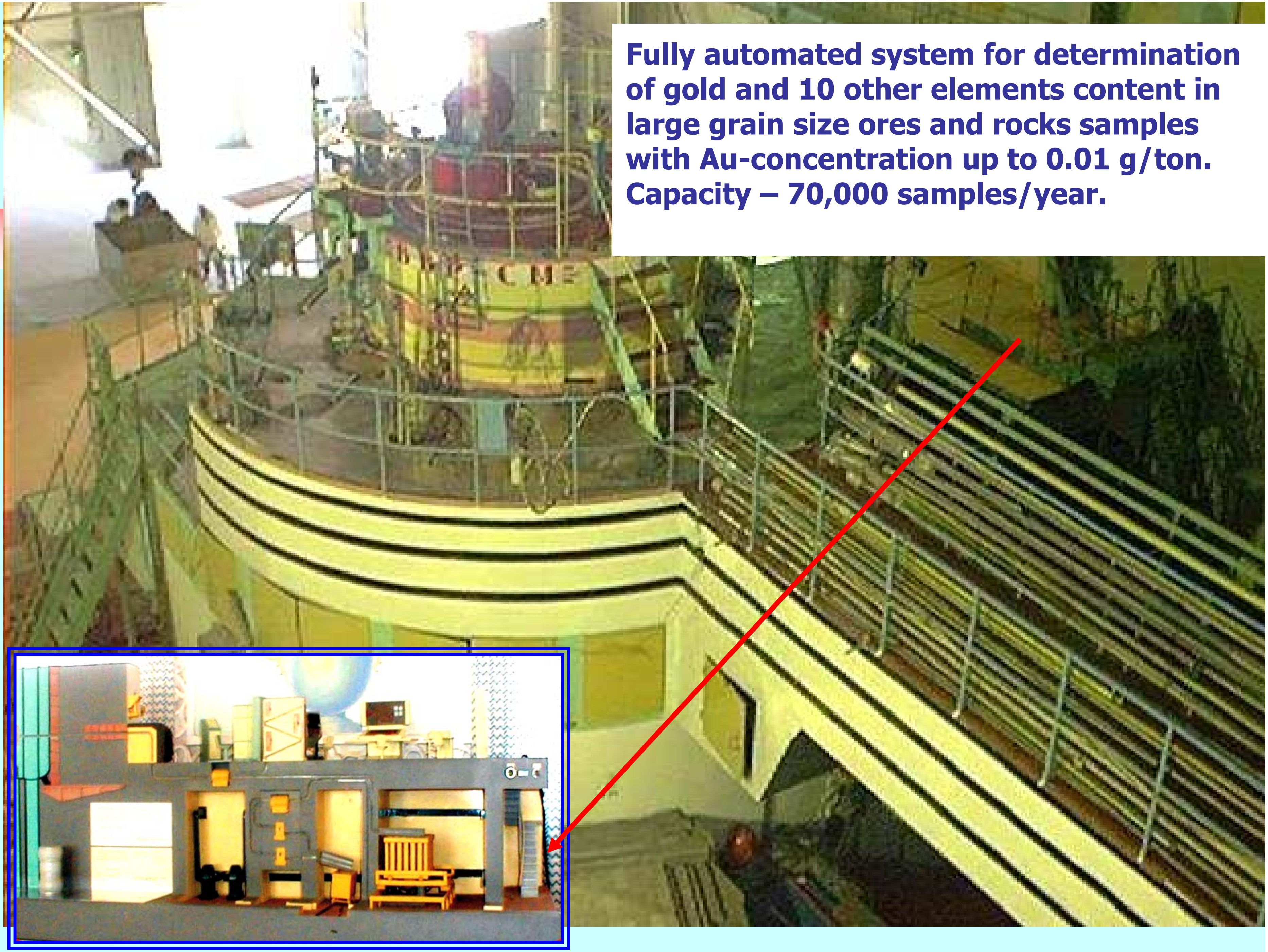


Neutron Transmutation of Silicon



Radiation Coloring of Optical Minerals

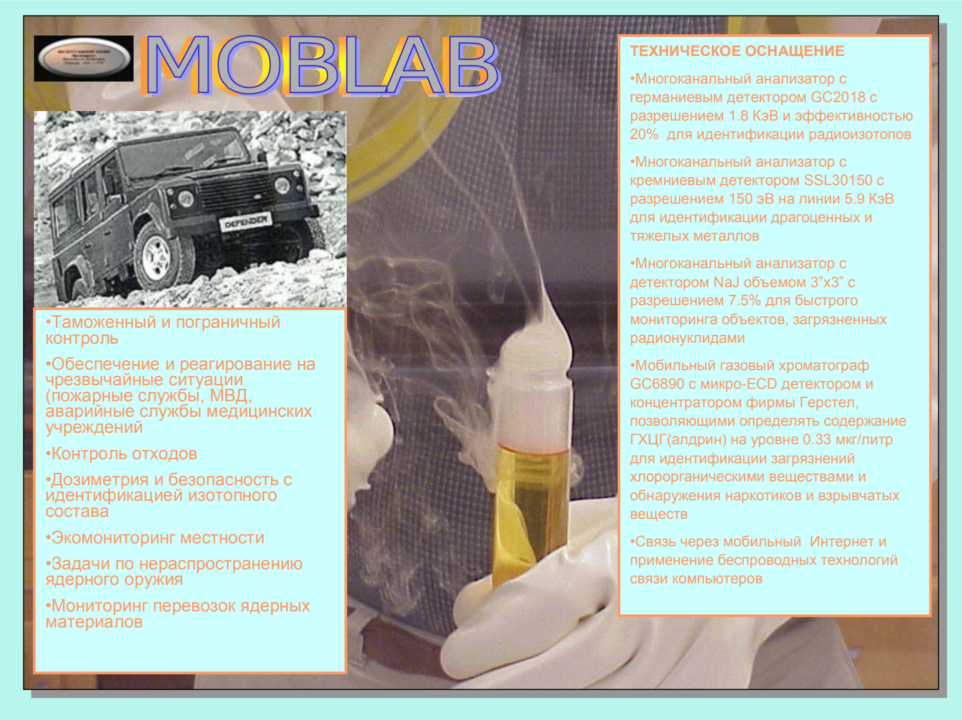
Fully automated system for determination of gold and 10 other elements content in large grain size ores and rocks samples with Au-concentration up to 0.01 g/ton. Capacity – 70,000 samples/year.



NEW RADIOANALYTICAL CENTER IS FOUNDED (Ge-, Si(Li)- and NaJ-spectrometers, alpha- and beta-detectors, Genie-2000 software, mobile laboratory etc.)

ONE OF THE MAIN TASKS OF THE CENTER IS DETERMINATION OF ELEMENTAL CONTENT OF VARIOUS SAMPLES INCLUDING IDENTIFICATION AND CHARACTERIZATION OF NUCLEAR, RADIOACTIVE, EXPLOSIVE AND OTHER DANGEROUS MATERIALS

MOBILE LABORATORY



Si-, Ge- and NaJ- Spectrometers, GO680- Gas Chromatograph

OBJECTS OF ANALYSIS	DETERMINED ELEMENTS	LOWER LIMITS OF DETERMINATION, IN % OF MASS
C*, Si*, SiC*	Na, Mg, Al, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Te, Cs, Ba, La, Ce, Pr, Sm, Eu, Gd, Tb, Dy, Ho, Yb, Hf, Ta, W, Re, Ir, Pt, Au, Th, U	$10^{-5} – 10^{-12}$
Ge	Na, K, P, Sc, Cr, Co, Cu, Zn, Se, Sr, Mo, Pd, Ag, Cd, Sb, Te, Cs, La, Ce, Pr, Sm, Eu, Gd, Tb, Dy, Ho, Yb, Hf, Ta, W, Re, Ir, Pt, Au	$10^{-5} - 10^{-10}$
Al	Mg, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Cs, La, Ce, Pr, Sm, Eu, Gd, Tb, Dy, Ho, Yb, Hf, Ta, W, Re, Ir, Pt, Au, Th, U	$10^{-5} – 10^{-10}$
Ti, V	Na, K, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Zr, Mo, Pd, Ag, Cd, Sn, Sb, Te, Cs, La, Ce, Pr, Sm, Eu, Gd, Tb, Dy, Yb, Hf, Ta, W, Re, Ir, Pt, Th, U	$10^{-5} – 10^{-11}$
Mn	Na, K, Sc, Cr, Co, Ni, Cu, Zn, Ga, As, Se, Sr, Mo, Ag, Cd, In, Sn, Sb, Cs, Ba, La, Ce, Pr, Sm, Eu, Gd, Tb, Dy, Ho, Yb, Hf, Ta, W, Re, Ir, Au, Th, U	$10^{-5} – 10^{-10}$
Mo*, $MoSi_2$*	Na, K, Ca, Sc, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Zr, Ag, Sn, Sb, Cs, Hf, Ta, W, Re, Ir, Au, Th, U	$10^{-5} - 10^{-8}$
W*, WSi_2*	Na, K, Sc, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Zr, Mo, Ag, Sn, Sb, Cs, Hf, Ta, Os, Ir, Th, U	$10^{-3} – 10^{-7}$
Cd	Na, K, Sc, Cr, Mn, Fe, Co, Ni, Zn, Ga, As, Sr, Cs, Ba, La, Ce, Pr, Sm, Eu, Gd, Tb, Dy, Ho, Yb, Hf,	$10^{-4} - 10^{-8}$
Te	Na, K, Sc, Cr, Mn, Fe, Co, Ni, Cu, As, Se, Ag, Cd, In, Cs, Ba, La, Sm, Eu, Gd, Tb, Dy, Yb, Hf, Re,	$10^{-4} – 10^{-8}$
Re, NH_4ReO_4	Na, K, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Zr, Mo, Ag, Cd, In, Sn, Sb, Te, Cs, Ba, La, Ce, Pr, Sm, Eu, Gd, Tb, Dy, Yb, Hf, Ta, W, Ir, Th, U	$10^{-4} - 10^{-8}$
Hg	Na, K, Sc, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, In, Sn, Sb, Cs, Ba, La, Sm, Eu, Gd, Tb, Ho, Yb, Hf	$10^{-5} - 10^{-8}$

ISOTOPE PRODUCTION

- **CYCLOTRON TYPE**
  - **Co-57, Zn-65, Ga-67, Ge-68, Pd-103, Ce-139**

- **REACTOR TYPE**

P-32, P-33, S-35, Cr-51, Mn-54, Fe-55, Co-58, Co-60, Mo-99,Y-90, I-125, I-131, Pm-147, Ta-182, W-188, Ir-192

GENERATORS

Ge-68 → Ga-68, Mo-99 → Tc-99m, Sn-113 → In-113m
W-188 → Re-188

Technetium-99m Generator

Technetium-99m generator is aimed for multiple preparations of **^{99m}Tc-Pertechnetate** sterile solution. The base element of the generator design is the glass column filled by aluminum oxide with absorbed [**^{99}Mo**]-Molybdenum oxide.

The ^{99}Mo-isotopes are produced by irradiation of enriched stable ^{98}Mo targets (wires) by thermal neutrons in reactor – the neutron-capture reaction **^{98}Mo(n,gamma)^{99}Mo**

.

- **The target material** – enriched (98%) molybdenum oxide(**MoO_3**)
- **Thermal neutron flux** is 1.0×10^{14} n/cm^{2}s-1.
- **Time of irradiation** is 7 days
- **Specific activity** - up to 74 GBq (2000 mCi) ^{99}Mo/g MoO_3

The column is connected with the system of communications for elution of [**^{99m}Tc**]-**Pertechnetate** by sterile solution containing 0.9% NaCl and 0.005% $NaNO_3$.

. It is applicable as radiopharmaceuticals and for preparing of radiopharmaceutical complexes with the special kits of reagents. **^{99}Mo** activities are **5550** MBq, **7400** MBq, **11100** MBq, **18500** MBq.

Specifications of ^{99m}Tc-Pertechnetate Solution

◈ **appearance: colorless, transparent solution** ◈

◈ **radioactive concentration: 74-1480 MBq/ml**

◈ **pH: 4.0-7.0**

◈ **Al_2O_5 admixture content: < 2.0 mg/ml**

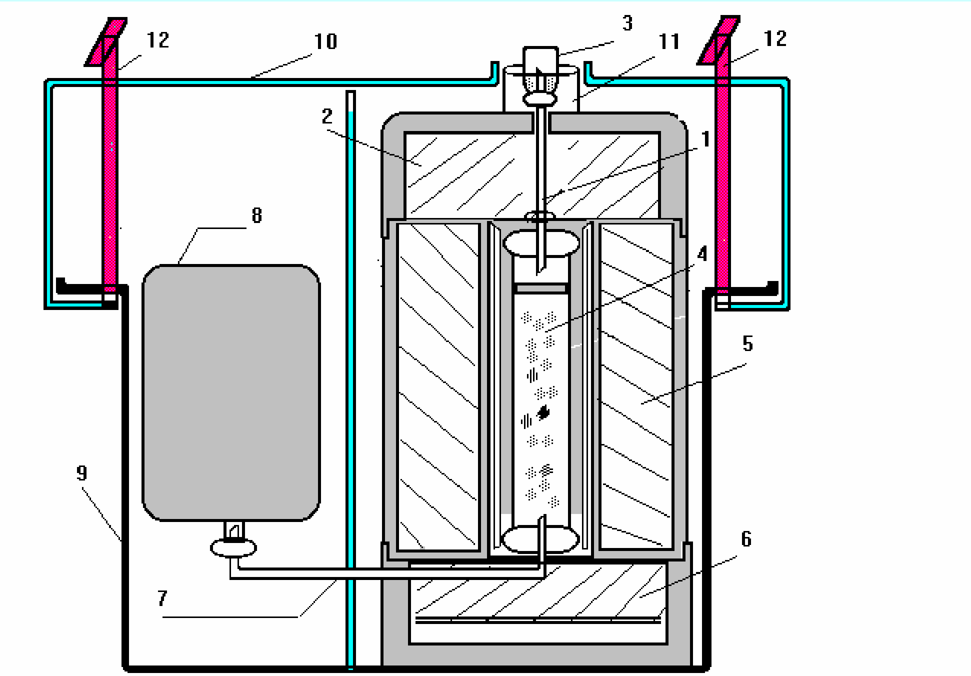
◈ **radiochemical purity: > 99.0%**

◈ **^{99}Mo radionuclide contamination: < 0.02% of total ^{99m}Tc radioactivity**

◈ **expiration: 14 days from the date of calibration**

At present time we are developing new design of protective lead cover (container) and plastic container.

Schematic view of the single needle Technetium-99m generator



1 – Eluate needle;

2 – Upper protective cover;

3 – Benzyl alcohol vial;

4 – Al_2O_3 column;

5 – The base of protective lead;

6 – Lower protective cover;

7 – Eluent line;

8 – Plastic container «Compoplast-300»;

9 – Plastic casing;

10 – Plastic cover;

11 – Guide bush;

12 – Transportation handles

Radioisotope Production Line of the Institute of Nuclear Physics

The radiochemical schemes for Sr^{89}, Y^{90} radionuclides production in nuclear reactor and Ge^{68}, Ga^{67} radionuclides production in cyclotron are developed.

The Sr^{89} radionuclide production technology is developed for synthesis of new pharmaceutical preparation "Metastron" used for medical treatment of malignant tumours in bone tissues.

These results can be used in the applied radiochemistry for development of radioactive production technologies and in nuclear physics for obtaining of radiodiagnostics and radiotherapeutical preparations.

DEPOSITORY FOR STORAGE OF RADIOACTIVE SOURCES

64 cells for sources and 15 holes for non-standard sources and large containers.

THE LIST OF RADIOISOTOPE PRODUCTS FOR GENERAL PURPOSES

/^{32}P /**Orthophosphoric Acid**, carrier free, in 0.04 M HCl,
specific radioactivity - 8500-9000 Ci/mmol,
volume radioactivity - 100-2000 mCi/ml,
radiochemical purity - more than 99% as orthophosphate,
radionuclide purity - more than 99%,
biological activity - not less than 95% in 10 minutes enzymatic conversion from ADP to gamma-/^{32}P/ATP.

/^{33}P /**Orthophosphoric Acid**, carrier free, in 0.04 M HCl or in water solution, specific radioactivity - 4500-5000 Ci/mmol,
volume radioactivity - 500-2000 mCi/ml,
radiochemical purity - more than 99% as orthophosphate, radionuclide purity - more than 99% (P-32 less than 0.5%),
biological activity - not less than 95% in 10 minutes enzymatic conversion from ADP to gamma-/^{33}P/ATP.

Sodium /^{125}I/Iodide, labeling solution, in 0.02-0.5 M NaOH,
pH 8-11, radioactive concentration: 300 - 1000 mCi/ml,
specific radioactivity: 13.0 - 17.4 mCi/mkg I,
radiochemical purity: more than 98%,
radionuclide purity: more than 99,99%,
^{126}I - less than 5x10^{-4} %,
other gamma impurities - less than 0.005%,
the lack of ^{134}Cs, ^{137}Cs is guaranteed by the production technology,
iodination efficiency: not less than 85% incorporation into ACTH by means of Chloramine T reaction.

/^{55}Fe/Iron Chloride, in 0.5 M HCl, radioactive concentration: 200-500 mCi/ml,
specific radioactivity - not less than 2 Ci/g,
radiochemical purity - more than 99%,
radionuclide purity - more than 99%.

Ammonium /^{35}S/Sulphate or /^{35}S/Sulphuric Acid, in water solution,
radioactive concentration: 100-1000 mCi/ml,
specific radioactivity – 1200-1600 Ci/mmol,
radiochemical purity - more than 99% as Sulphate,
radionuclide purity - more than 99%.

Sodium /^{131}I/Iodide, labeling solution, in 0.02-0.5 M NaOH,
reductant free, pH 8-11,
radioactive concentration - 100-200 mCi/ml,
specific radioactivity - not less than 600 Ci/mmol,
radiochemical purity - more than 95%,
Radionuclide purity - more than 99,99%.

THANK YOU !