Creating a broad acceptance for novel/advanced nuclear concepts

A report on relevant ISTC programs

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OUTLINE

- *INTRODUCTION*
- NUCLEAR SAFETY and NPP LIFE MANAGEMENT
- NOVEL REACTOR CONCEPTS
- ✓ MODELLING AND EXPERIMENTS
- NUCLER FUEL CYCLE WITH PARTITIONING AND TRANSMUTATION
- EXPERIMENTAL SUPPORT OF ENGINEERING FOR POWER SYSTEMS
- *SUMMARY*

Goals of this paper:

- ***the retrospective review and examples*** **of the ISTC activities in nuclear technology and in nuclear/reactor physics**
- ***the current status*** **of the ISTC programs, *and***
- ***perspectives***

What is ISTC ?

- A non-profit intergovernmental organization providing since 1994 *research grants* to former WMD scientists in civil oriented projects
- *A technology matchmaker* between Russian/CIS R&D institutes and Western partners
- *A tool* to integrate Russian/CIS scientists into the international research community
- *An insurance* against brain drain and proliferation of WMD

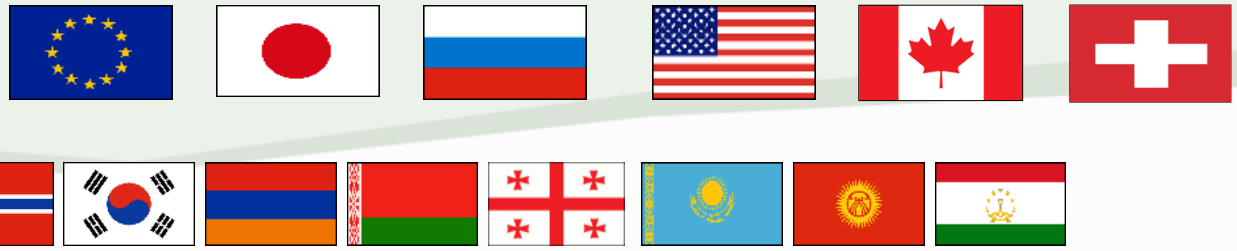
Introduction : The ISTC - Members. Mission
"Non-Proliferation Through Science Cooperation"

The ISTC is an Intergovernmental Organization with 37 member states and diplomatic status

Founded by *the European Union, Sweden, Norway, Republic of Korea, the United States of America, Japan and Russian Federation in November 1992*

Operations began in March 1994.
In 2004 Canada joined to ISTC as the Funding Party
In 2008 Switzerland joins ISTC

Headquarters in Moscow with Offices in
Armenia, Belarus, Georgia, Kazakhstan, Kyrgyz Republic, and Tajikistan



ISTC Core Programs and Services

***Regular Project* Program**

***Partner Project* Program**

Sustainability Program

Commercialization Support Program

Patenting Program

Competence Building Program

Workshops and Scientific Seminars

Travel Grants

Communication Support Program

Partner Promotion Program

ISTC – 15 years of operation

More than 2600 funded S&T projects

- 70 000 scientists and technicians working with ISTC projects and benefiting from other ISTC programs
- 800M$ support

In Nuclear Technology:

- More than 400 funded projects ($130 M) devoted to Nuclear reactor, Nuclear Fuel Cycle and Fusion problems

ISTC projects:

Who are performing the ISTC projects:

Scientists and engineers from:

- ✓ Nuclear centers from "closed" cities
- ✓ Institutions of nuclear and other industries
- ✓ Institutions of Academy of Science
- ✓ Universities

Who are managing the ISTC projects:

- ✓ Recipient institutions (Russia, CIS)
- ✓ ISTC
- ✓ Foreign Collaborators and Partners (such as IAEA, JRCs, FZK, FZR, ITU, CAE, AREVA, SCK-CEN, NUKEM, IRSN, CIEMAT, etc.)

Who are funding the ISTC projects:

- ✓ Governments of the ISTC Parties
- ✓ Partners
- ✓ Co-sponsoring collaborators

Turning toward Programmatic approach:

- **Call for Proposals** in ISTC Priority Programs – under preparation
- Preliminary phase : Targeted Initiatives (e.g. "Fuel cells")

- System of International **Contact Expert Group – (CEG):**
  - *pool of collaborators and on-going projects,*
  - *links with international and domestic programs*
  - *links with STCU (Ukraine), CIS and foreign collaborators*

CEGs particularily successful in nuclear field:

- CEG "RAW Partitioning and Transmutation"
- CEG "Severe Accident Management"
- CEG "Plant Life Management"
- CEG "Fusion"

– *Earlier: CEG "Pu Disposition – MOX" and CEG "GT-MHR"*

ISTC priority areas in nuclear:

- Nuclear and radiation safety of operating NPP;
- Novel reactor and Nuclear Fuel Cycle concepts;
- Nuclear material accounting and control;
- Nuclear science management;
- NPP decommissioning;
- Fusion;
- Other nuclear applications e.g. nuclear medicine, nuclear testing, isotopes etc.

Nuclear and radiation safety of operating NPP:

- **Plant life management (PLIM)**
  - ✓ Methods for VVER reactor vessel assessment and prediction of safe life-time – for operating NPPs with VVER in Russia, Ukraine, Armenia, Bulgaria, Slovakia, Hungary and Finland;
  - ✓ for operating PWR over the World

- **ISTC program Y2K (Year 2000)** : a very successful hardware and software update for 9 NPPs in Russia

- **Safety tools and systems** –

  New types of detectors, reactivity and vibration controllers, acoustic sensors, etc. – applied over NPPs in Russia (VNIIEF and Co)

Novel/advanced fast reactor concepts:

Advanced Sodium-Cooled Fast Reactors:

- Novel fuels : Nitride, carbide, metallic, MOX, ROX, vibro-packed
- Assessment of Plutonium and Minor Actinides burning in fast reactors (IPPE, RIAR, KIAE, Bochvar VNIINM, OKBM)

BFS-2 in IPPE:

Novel/advanced fast reactor concepts:

Gas-cooled Fast Reactors

Conceptual designs, nuclear and radiation safety – (KIAE)

Lead- cooled Fast Reactors (BREST project in Russia)

Conversion of unique Russian experience for civilian power reactors – about ten principal projects, including monographs:

- *" BREST-300 – Inherently safe fast neutron lead cooled reactor", and*
- *"Hydrodynamics and heat- and mass transfer processes in liquid metals"*

Novel/advanced fast reactor concepts: Pb/Pb-Bi Fundamentals

- *Hydrodynamics and Heat/Mass Transfer Processes*
- *Pb/ Pb-Bi Interaction with Structural Materials, Water, Air*
- *Improvement of Corrosion Resistance of Steels in Pb and Pb-Bi Alloys*
- *Laser Separation of Lead Isotopes*
- *Control of Oxygen Content in Lead Coolants*

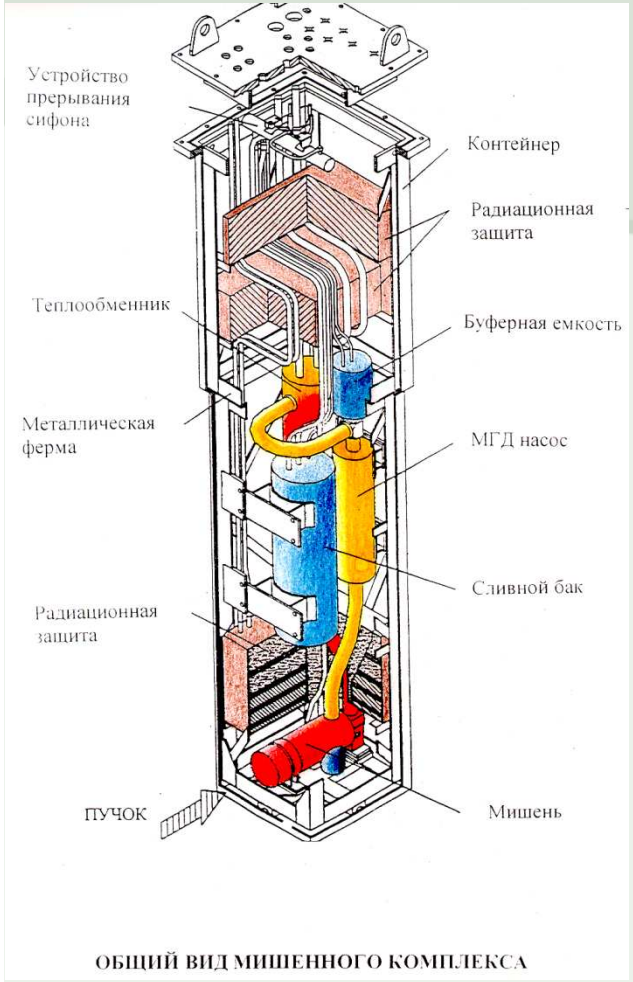
Russian institutes: **IPPE, NIIEFA, PROMETEY**
Foreign collaborators: **FZK, CEA, CIEMAT, ENEA, RIT, SCK-CEN, ANL, Mitsui**

Example: Pb/Pb-Bi coolant and Fuel Materials (Nitride fuel)

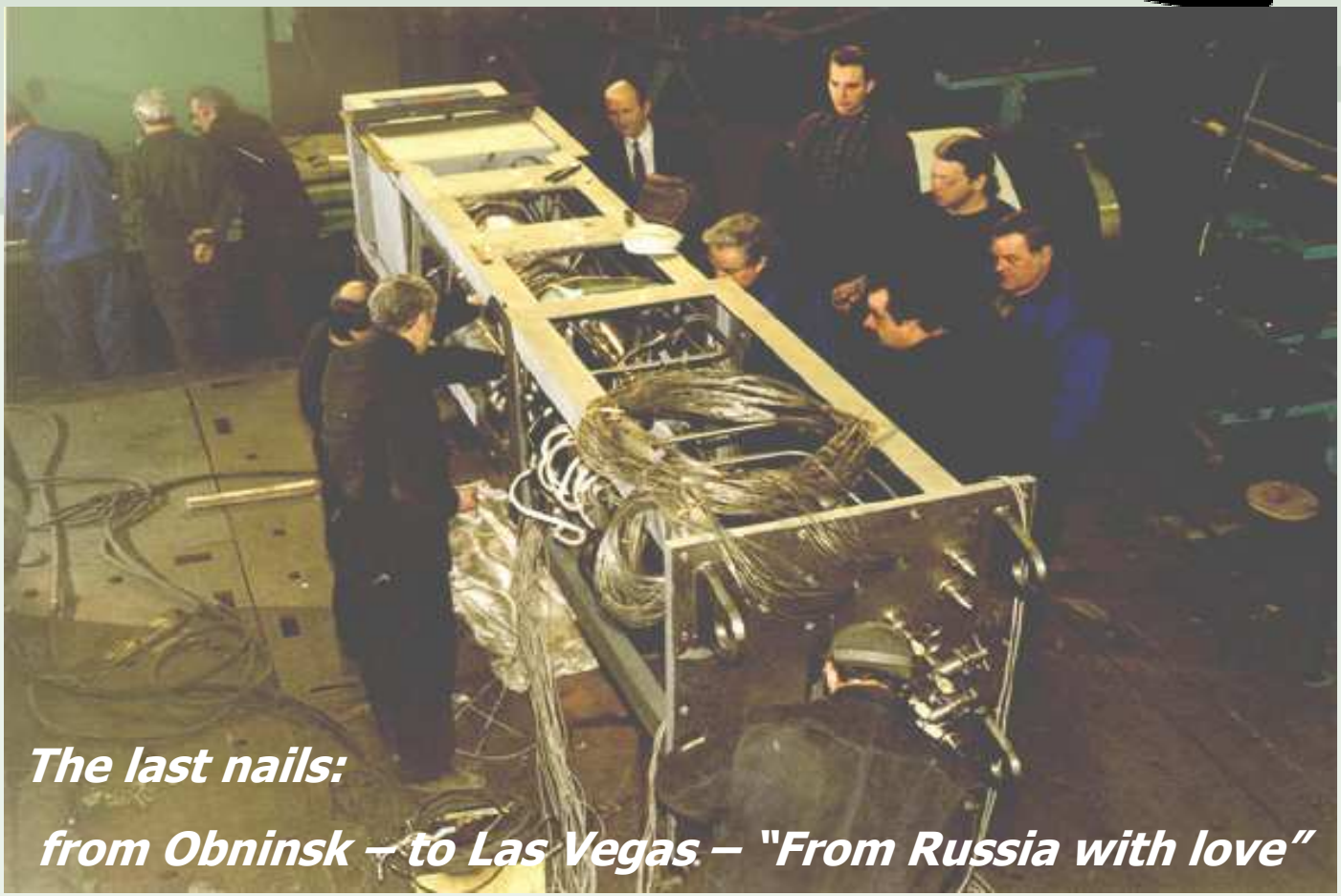
#2680 - Minor Actinide Transmutation in Nitrides Fuel Environment
IPPE, NIIAR

- ✓ Experimental study and modeling of basic properties of (Pu,Zr)N and (Pu,Am,Cm,Zr)N samples.
- ✓ Modeling of nitride fuel under irradiation up to high burn-up in fast neutron spectrum.
- ✓ Feasibility study of fabricating nitride fuels with inert matrix, containing curium

Example: Lead-Bismuth 1 MW SpallationTarget (#559- #2083)



ОБЩИЙ ВИД МИШЕННОГО КОМПЛЕКСА



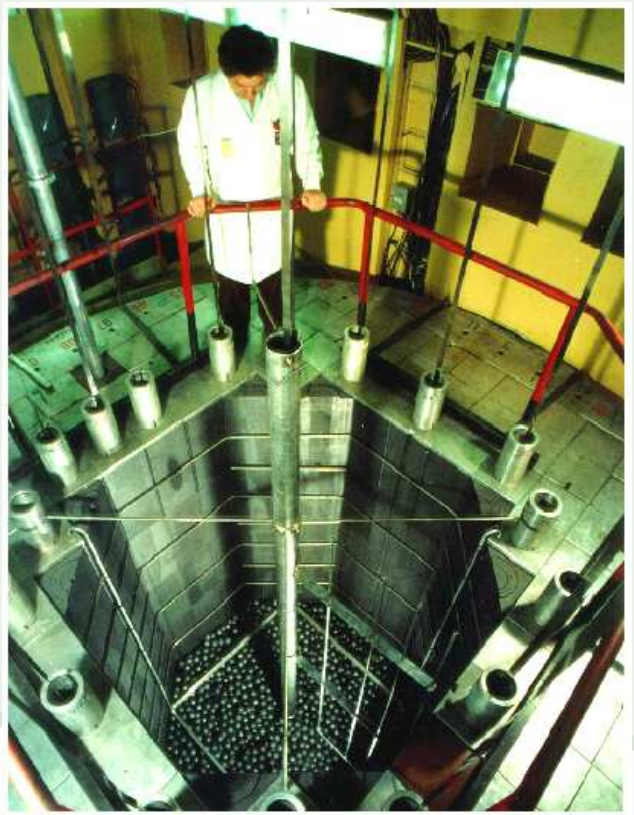
The last nails:

from Obninsk – to Las Vegas – "From Russia with love"

*This target has been a precursor to the **MEGAPIE Spallation target** at PSI*

Novel reactor concepts *(continued):* HTGR

- Reactor conceptual design - OKBM, KIAE;
- Experimental study of high-temperature components - OKBM;
- Recuperator design and testing - OKBM;
- ASTRA critical installation for HTGR modeling (Kurchatov KIAE):



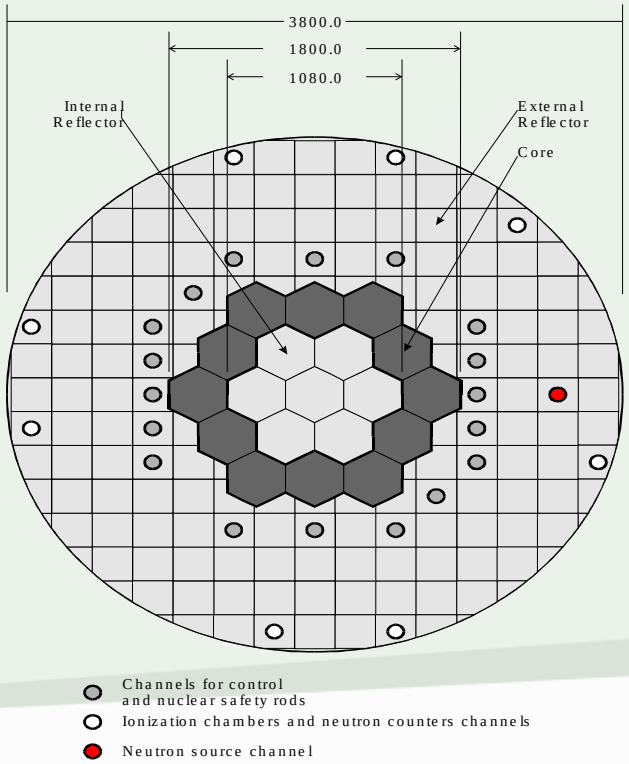


Figure 3. ASTRA Critical Assembly. Version 3.
Core - hexprisms.
Internal reflector - hexprisms.
External reflector - cuboids.

Novel reactor concepts *(continued):* Molten Salts

Links to FP-6/ FP-7 programs (MOST, MOSART, ALICIA, EUROPART)

Creation of unique experimental molten salt loop (VNIITF, KIAE):

- ✓ Experimental study of principal features of salts:
  - ✓ *Fuel compositions (Pu/ Th flibes)*
    - ✓ measurements of density, viscosity, thermal conductivity, heat capacity, free energy, etc.);
  - ✓ *Molten salts as a Coolant (Li,Be,Na/F salts);*
  - ✓ *Corrosion tests (Ni-Mo alloys)*

Novel reactor concepts *(continued):*
Molten Salts

Links to FP-6/ FP-7 programs (MOST, MOSART, ALICIA, EUROPART)

Actinides transmutation – Curium (NIIAR);

- *Thermodynamics of Curium in molten chlorides*
- *Formation of oxygen/ oxygen-free curium compounds*

Molten Salts for RAW treatment (Khlopin Radium institute)

- *Extraction and evaporation LL nuclides*
- *Concentrating of the liquid RAWs*
- *Production of solid mineral-like matrix*

Benchmarking, Verification:
ICSBEP Handbook of Critical Experiments

IPPE (Obninsk): BFS Family: BFS-1, BFS-2, COBRA, BR-1, MATR

#815 / #815.2 - Evaluation of Critical Safety Data and Uncertainty Analysis for the International Bank for Critical Experiments (ICSBEP)

#1483 Evaluation of K_{-inf} Experiments for Mixtures of HEU with Structure Materials (Stainless Steel, Steels with Molybdenum, Nickel, Chromium and Zirconium)

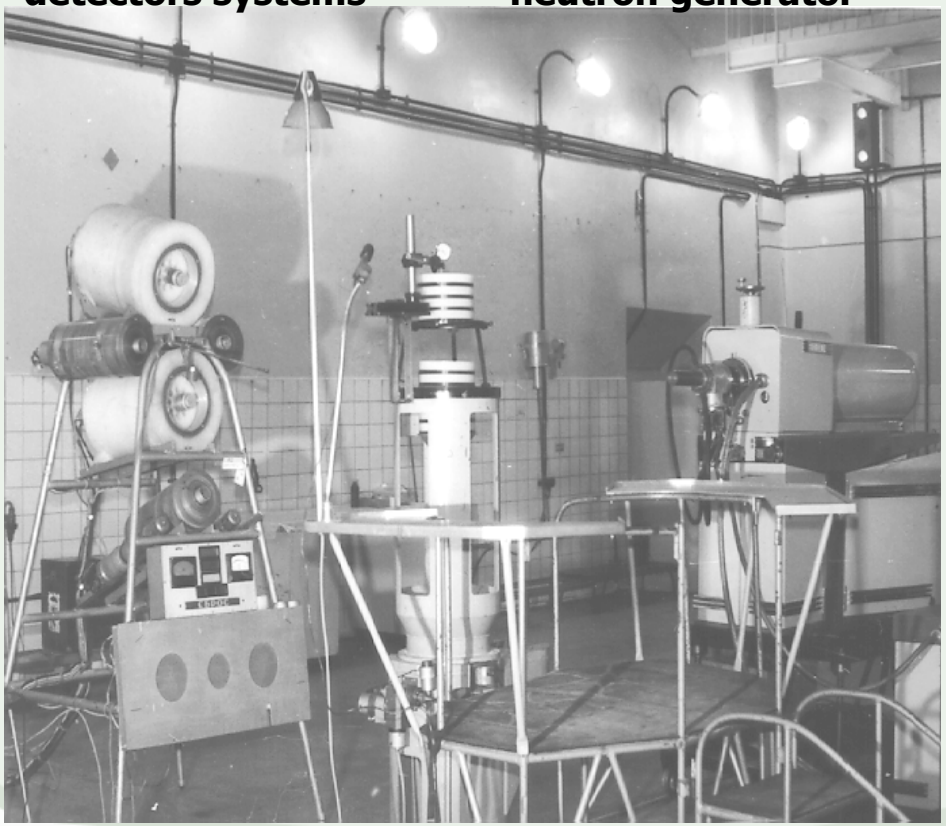
#1808 Analysis and Evaluation of Safety Criteria of Spent Fuel Underground Disposition via Critical Experiments

#2423 Benchmarking of Thorium Critical Experiments on the COBRA Facility

Benchmarking, Verification:
ICSBEP Handbook of Critical Experiments

VNIITF (Chelyabinsk-70)

detectors systems **neutron generator**



Critical stand FKBN-M / ROMB (VNIITF)

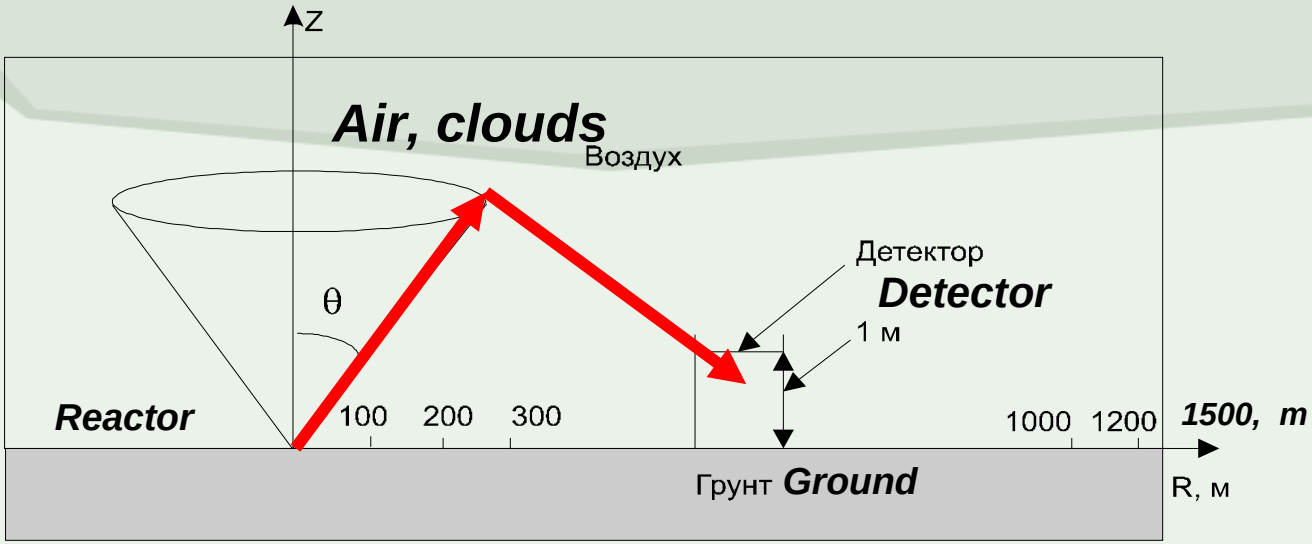
 # 0116 – "Verification of Reactor Data Bases" *(NIKIET, VNIITF):*

#3110 – "Experiments on the ROMB Critical Assembly for ICSBEP" *(VNIITF)*:

- beryllium moderator
- lead reflector
- unreflected, with HEU.

Benchmarking, Verification:

SKY-SHINE EFFECT



#0517 - Experimental Studies of Reactor Radiation Scattering (N, gamma) in the Atmosphere

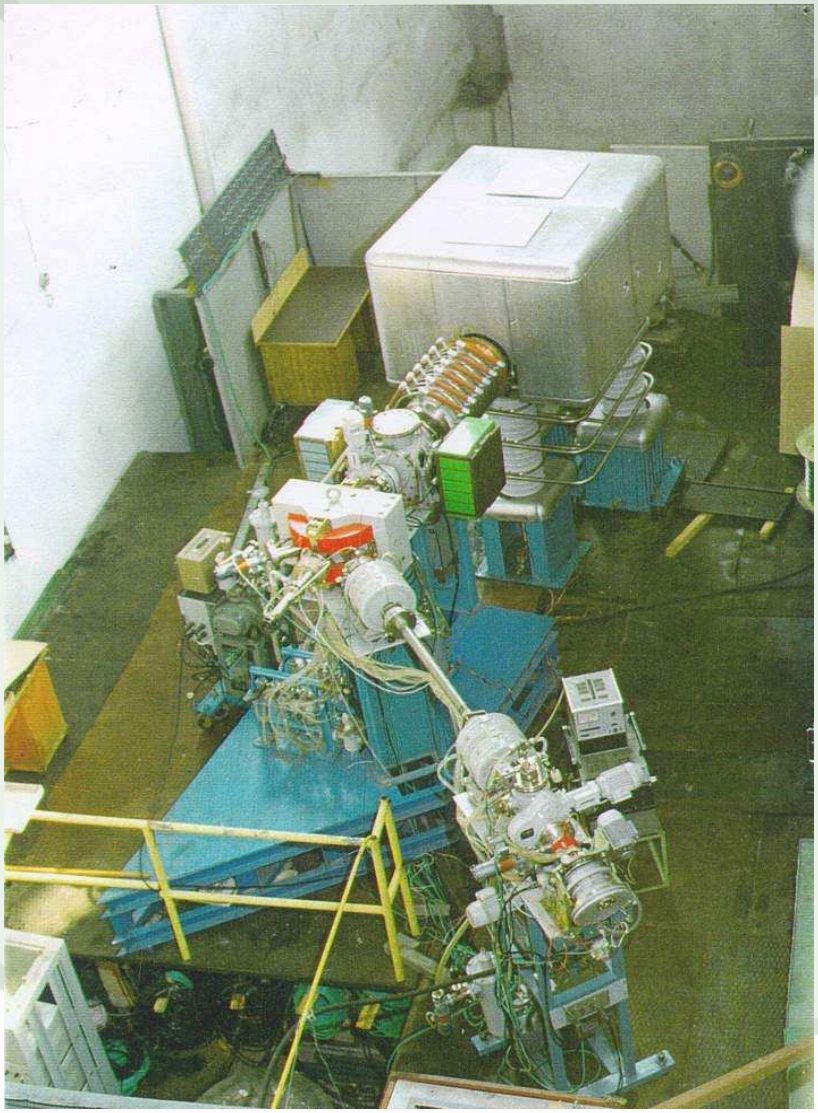
- *Dollezhal NIKIET, Moscow;*
- *Kazakstan National Nuclear Center / Institute of Atomic Energy, Kurchatov-city, Kazakstan*

Two special experimental reactors, located in desert area in Semipalatinsk, Kazakhstan, were used (IVG-1M and RA)

Minor Actinides Transmutation

- Conceptual studies
- Large-Scale Demo-Experiments
- Irradiation tests (by neutrons in-reactor, by accelerated particles beams)
- Nuclear data (neutron, spallation cascade, etc. – measures, libraries)
- ADS – Power target, Accelerator components
- Radio-Chemistry – Partitioning, Extraction
- Materials – Fuels, Construction materials

MA Transmutation (ADS)



B-070 : "YALINA" - Large-Scale Demo- ADS Experiment, Minsk, Belarus

- Neutron generator,
- Uranium (enriched) blanket
- Two international on-site workshops
- On-site technical training

Nuclear science

New methods, modeling, codes, nuclear data:

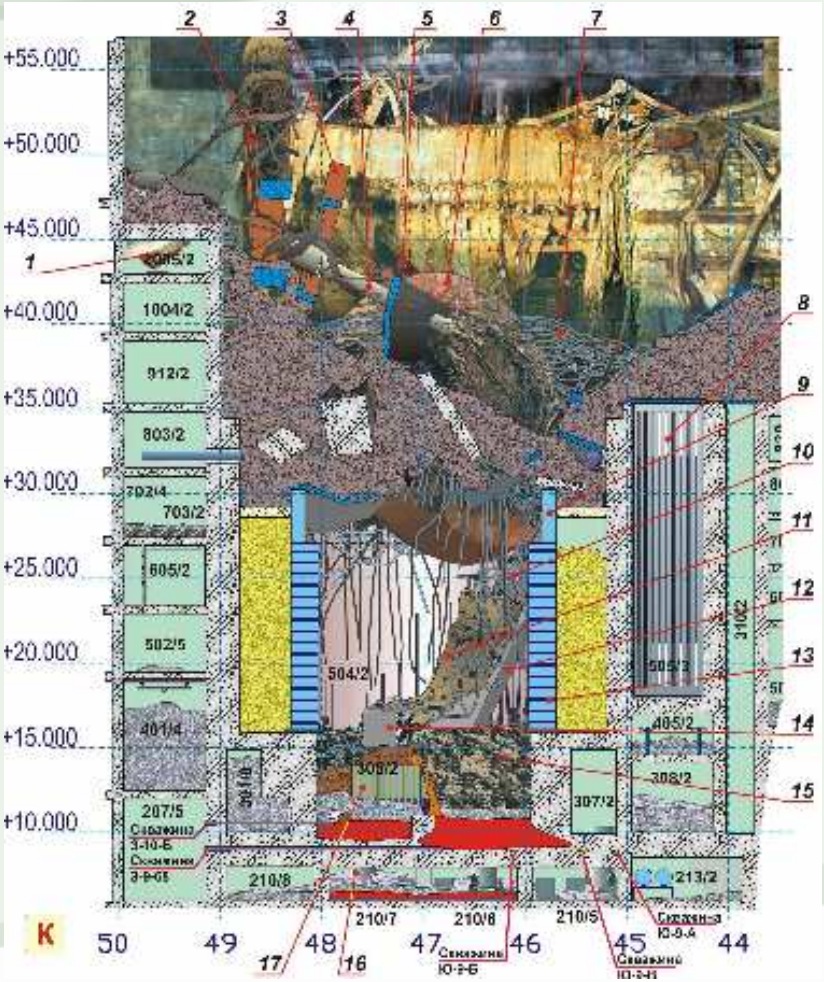
- Improvement of safety and efficiency of operating and designing NPPs (software was updated by dozens of new methods and codes);

- Update of nuclear databases and libraries
  - nuclear reaction data were updated by thousands in-reactor and in-accelerator experiments and measurements;
  - the Russian nuclear library ABBN has updated;

- Tens of projects were devoted to nuclear data measurements, evaluation and reevaluation, making international nuclear data libraries more reliable and more precise. Particular attention has been focused on Actinides and Minor Actinides, key components of spent fuel and nuclear wastes

Nuclear science:
Impact on Severe accident management

- **Chernobyl Lava Data-Base**
  - above 6000 measurements of corium state, modeling for "Shelter" improvement (*KIAE, IBRAE*)



Nuclear science:

Impact on Severe accident management *(continue)*

- **Protection materials – designing and study:**

- development of high-resistant materials and designs:concretes, ceramics and bricks for reactor containment, walls, catcher and other barriers;
- testing of candidates under severe conditions (shock loads, high temperatures, high pressure, chemical and radiation loads, steam explosion;
- data-bases with parameters

(IVTAN, VNIIEF, IBRAE, EREC, IChPh-Chernogolovka)

IVTAN: chamber for tests up to 1t TNT

Nuclear science:
Impact on Severe accident management *(continue)*

- **Corium study and modeling in-depth** - theoretical and experimental study of physical-chemical processes, interaction with reactor vessel

  (NITI &Co, S-P AEP, KIAE, IBRAE, Kazakhstan NRI, VNIIEF)

experiments with 5 – 10 – 50 –100 – 1200 kg of corium

- **QUENCH**: Experimental investigations of VVER-1000-type fuel behavior under accident conditions (*quench* regime)

  (*NIIAR (Dimitrovgrad), LUCH (Podolsk) and IBRAE jointly with EU collaborators)*

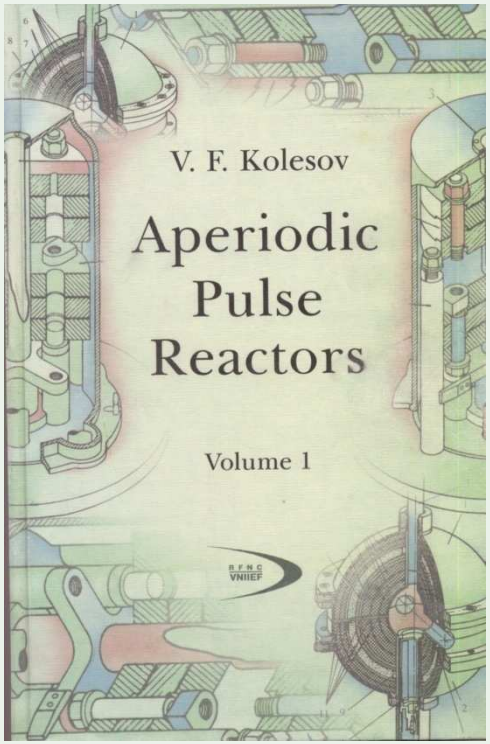
Tangible results: verification of models and codes, updated safety system for VVER-1000

Knowledge Management in Nuclear

Monographs

About twenty monographs have been written (both in-Russian and in-English), such as:

- *"Aperiodic Pulse Reactors", Kulichkova E., VNIIEF, Sarov*
- *"Shock Waves and Extreme States of Matter", Urlin V., VNIIEF, Sarov*
- *"Natural Safety Fast Neutron Lead Cooled Reactor for Large Scale Nuclear Power", V.Orlov, , NIKIET*
- *"Coupled Pulsed Reactor Systems" – A. Gulevich, IPPE, Obninsk*
- *"Pulsed Reactors in the RFNC-ITP", A.V.Lukin, VNIITF, Snezhinsk*



Knowledge Management in Nuclear:
International cooperation, *conferences, workshops*

NPP decommissioning

- Cut out and disposal of reactor compartments of nuclear submarines in *Zvezdochka*
- Disposal of radioactive *sodium and cerium* after decommissioning of sodium cooled reactors *BR-10* in IPPE, Obninsk, and *BN-350* in Aktau, Kazakhstan
- Measurements and analysis of contaminated reactor *graphite* by radioisotopes after decommissioning of plutonium production reactors in Ozersk Combinate
- New *"floating" concept* of removal of decommissioned NPP in the far site

Medical (nuclear) physics

➢ ***Cancer diagnostics –***

Fast diagnostic system on the basis of nuclear methods (designed initially for the nuclear fuel analysis) and computer visualization methods (MIFI, NIIIT, Cancer center)

➢ ***Cancer treatment –***

Methods of radiation cancer treatment (via reactor neutron and gamma, or accelerated electrons or charged particles) with relevant modeling and software (MIFI, ITEP, VNIIEF, IPPE, Budker, and others)

Synergy results:

✓MIFI (TU) started training specialists for "nuclear medicine" on the base of experimental reactor and other installations;

✓the cancer treatment center is operating in ITEP (Moscow).

➢ ***Radioisotope methods for treatment,*** particularly – production of specific radio-nuclides and preparations – IPPE, MAYAK, NIIAR

Radioactive Waste Treatment & Transport

Storage Cask (Based on Depleted Uranium - DU)

- Design of DU Container for Spent Fuel Transportation (#0963)
- Shielding Concrete *DUCRETE* on the Base of DU (#2691)
- Cast Uranium Cermet for Shielding Casks (#2693)
- Investigations of Sorption Capture of Long-lived Radionuclides from Underground Waters by DU Oxides (#2694)
- Cask Prototype on the Base of DUCRETE (#3693-P)

VNIIEF (Sarov), Bochvar VNIINM, VNIIKhT , Institute of Physical Chemistry RAS with US collaborators: ORNL, SANDIA

Perspectives

- Challenge of the World Nuclear Community is *to prove* to Public over the World, that *newly proposed nuclear concepts are safe and effective.*
- The only acceptable method is *a basic demonstration-type Experiment*, in advance of computer or paper-type arguing.
- Important, that results of these experiments are to be *available for international analysis and verification*.
- Nuclear experiments are very complex, it requires special licensing, long time preparation, high-skilled personnel, purchasing of special materials and tools, and consequently – very expensive.

Perspectives

- **In this sense the ISTC clients (first of all – nuclear and "nuclear weapon" centers in Russia and CIS) have unique nuclear installations:** *well-reputed, all set, well equipped, ready-for-service, licensed, provided by high-skilled personnel and good cooperation.*

- **At the same time the ISTC :**
  - Projects are being managed *internationally;*
  - Technical plans and results are *available for international collaborators;*
  - Results may be shared with international centers (IAEA, OECD/NEA and/or others) for *further international joint validation and benchmarking.*

Priorities

- **Activate Contacts**
  - Among PROJECTS, COLLABORATORS and SPONSORS
  - Contacts with Foreign Partners
- **Valorization of on-going projects**
- **Utilization of Completed Project Results**
- **Coordination of Projects with Russian/CIS Programs**
  - ROSATOM, KIAE- IPPE, Nuclear Safety Center, etc.
- **Coordination with International Organizations**
  - IAEA, OECD, etc.
- **Organize and Promote Meetings**
  - ISTC Seminars, Workshops, Conferences

- **THANK YOU !**
- **MERCY!**
- СПАСИБО !

Information:

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