

U.S. DEPARTMENT OF ENERGY'S "INITIATIVES FOR PROLIFERATION PREVENTION" PROGRAM: SOLIDIFICATION TECHNOLOGIES FOR RADIOACTIVE WASTE TREATMENT IN RUSSIA

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ABSTRACT

Large amounts of liquid radioactive waste have existed in the U.S. and Russia since the 1950's as a result of the Cold War. Comprehensive action to treat and dispose of waste products has been lacking due to insufficient funding, ineffective technologies or no proven technologies, low priority by governments among others. Today the U.S. and Russian governments seek new, more reliable methods to treat liquid waste, in particular the legacy waste streams. A primary objective of waste generators and regulators is to find economical and proven technologies that can provide long-term stability for repository storage.

In 2001, the V.G. Khlopin Radium Institute (Khlopin), St. Petersburg, Russia, and Pacific Nuclear Solutions (PNS), Indianapolis, Indiana, began extensive research and test programs to determine the validity of polymer technology for the absorption and immobilization of standard and complex waste streams. Over 60 liquid compositions have been tested including extensive irradiation tests to verify polymer stability and possible degradation. With conclusive scientific evidence of the polymer's effectiveness in treating liquid waste, both parties have decided to enter the Russian market and offer the solidification technology to nuclear sites for waste treatment and disposal.

In conjunction with these efforts, the U.S. Department of Energy (DOE) will join Khlopin and PNS to explore opportunities for direct application of the polymers at pre-determined sites and to conduct research for new product development. Under DOE's "Initiatives for Proliferation Prevention"(IPP) program, funding will be provided to the Russian participants over a three year period to implement the program plan.

This paper will present details of U.S. DOE's IPP program, the project structure and its objectives both short and long-term, training programs for scientists, polymer tests and applications for LLW, ILW and HLW, and new product development initiatives.

INTRODUCTION

Legacy liquid waste streams have been untreated through the decades as a result of inadequate, unreliable technologies and lack of funding by governments. Today, with political pressure for more effective environmental management, new technologies with high performance characteristics and attractive cost efficiencies are just beginning to enter the nuclear market. Through scientific research new methods of liquid waste treatment and advanced designs of treatment equipment are addressing the environmental issues of legacy waste management. One such technology is the advanced polymer system designed and manufactured by Nochar, Inc., USA.

With scientific evidence regarding the efficiency, performance and stability of the polymer systems, Khlopin and PNS have decided to enter the Russian nuclear market and apply the systems to a wide variety of user markets: weapons production sites and associated labs, nuclear power plants, research institutes, uranium mining industries, decommissioning sites including ships and submarines, land and lake remediation projects, medical waste generators and toxic waste generators.

One major challenge facing Khlopin and PNS is Russian market access and regulatory approval for the use of foreign technology. For this effort to proceed, additional partners and government support is needed. The inclusion of U.S. DOE and the Russian Federal Agency for Atomic Energy in the project provides an avenue for all parties to pursue common goals and objectives.

EXPERIMENTAL CONDITIONS AND RESULTS

The experimental programs began in 2002 when Khlopin and PNS began testing known and unknown waste compositions. Compositions included oil, aqueous, acidic and basic solutions with heavy metals, oil sludge, spent extractants, decontamination solutions, salt sludge and many complex streams. Different polymers were combined to enable complete solidification of an entire waste stream. Khlopin performed various tests on the solidification samples including leaching, compression and stability (irradiation).

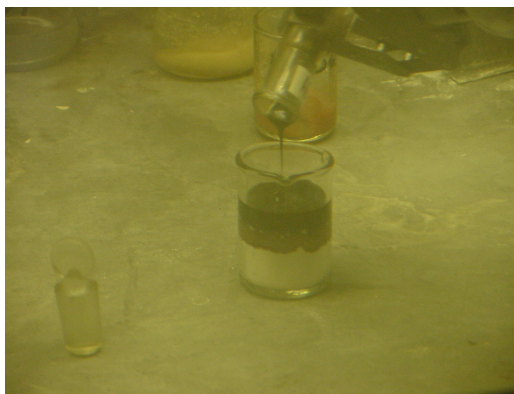


Fig. 1 Oil Sludge Sample

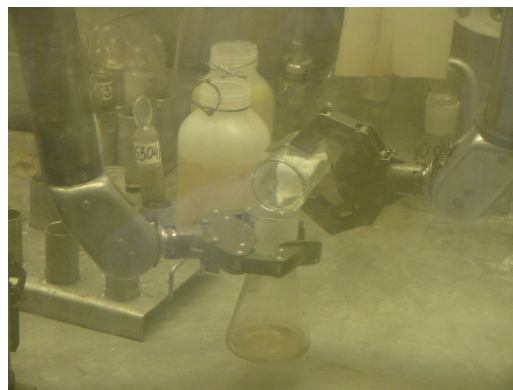


Fig. 2 Nitric Acid with Plutonium Sample

An important aspect of the test program was to evaluate leaching and stability of the solidified waste form. Gamma irradiation (Cobalt 60 source, at 30 rad per second) was applied to the solid waste forms and analysis proved that there was no polymer degradation and no leaching following high dose irradiation. After 30 days or 77,000,000 rad, the sample was hard and no liquid present. The ampoule was then placed into the irradiator for an additional 73 days of exposure for a total of 270,000,000 rad. The sample became brittle and broke into 2 pieces.



Fig. 3 Organic / Nitric Solidification
(Dodecane + di-2 ethyl, hexyl
phosphoric acid 0.25M)



Fig. 4 Irradiation at 77 Mega-rad

The research program has proven the effectiveness and viability of the polymer systems for use with radioactive liquids and for wide ranging applications.

PARTNERING WITH THE U.S. DEPARTMENT OF ENERGY

In 2006 Khlopin and PNS made a strategic decision to commercialize the polymer technology and offer it to the various waste generators in Russia. Four conditions would apply for market entry:

- Create a commercial avenue for distribution and sales of product to customers
- Obtain certification from Russian agencies to permit the importation and sales to customers
- Apply to the various nuclear sites for approval to use the polymer systems
- Obtain approval from the Russian repository authority for final disposal of the waste product

To assist with this effort, PNS and Argonne National Laboratory began discussions about possible U.S. Department of Energy participation under its Initiatives for Proliferation Prevention (IPP) program. Argonne's National Security and Non-Proliferation Department partners with several U.S. firms to promote the goals of the IPP program in Russia and new independent states.

IPP, established in 1994, is a non-proliferation program of the U.S. DOE / National Nuclear Security Administration and receives its funding each year through Congressional appropriation. The objectives of IPP are:

- To engage former Soviet nuclear weapons scientists, engineers and technicians, currently or formerly involved with weapons of mass destruction, in peaceful and sustainable commercial activities.
- To identify non-military, commercial applications for former Soviet institute technologies through cooperative projects among former Soviet weapons scientists, U.S. national laboratories and U.S. industry.
- To create new technology sources and to provide business opportunities for U.S. companies, while offering commercial opportunities and meaningful employment for former weapons scientists.

The achievement of these objectives reduces the risk of proliferation and pursues the application of technologies for peaceful purposes.

In 2007 the U.S. Department of Energy approved the joint project entitled, "Solidification Technologies for Radioactive and Chemical Liquid Waste Management", with Khlopin as the project manager for the Russian side, PNS as the project manager for the U.S. side. Argonne provides technical oversight and overall project management. The International Science and Technology Center (ISTC), Moscow, provides oversight, project management and is responsible for the distribution of funds to the participating scientists and staff workers in Russia.

PROJECT OBJECTIVES, EXPECTED RESULTS AND FUNDING

In addition to the IPP objectives stated above, the project will focus on the application of polymers for the purpose of immobilizing complex streams including organic, aqueous and mixed waste. Successful applications and methodologies will result in safer environmental conditions at waste generating facilities and will provide a pathway for safe transport and disposal of waste products. The technical work performed in the first phase of the project will validate the actual use of polymers in a variety of nuclear markets as well as confirm its application to HLW waste.

Another important objective of the project is to establish a viable commercial business that can employ a number of scientists that have worked on waste immobilization. It is the intent of the project leaders to sustain the project beyond the three IPP program years and build a

private sector business that can function within the Russian nuclear sector and service all nuclear markets. Daymos Co. and PNS will be responsible for market research and the commercial sales activity with the long-range plan of establishing technical distribution centers around Russia.

Market growth and use of polymer technology is dependent upon each government's funding priorities and its willingness to address environmental clean-up. The success of this project, like others, will be determined by the Russian government's allocation of resources for environmental safety.

The IPP project is funded by the U.S. Department of Energy. Funds are transferred by DOE to ISTC, whereby ISTC distributes pay checks to the participating scientists on a quarterly basis. Total project funding is based on the length of time and scope of the project. A detailed work plan is created by calendar quarter that outlines the number of scientists involved at each site and their expected work activity. Funding is also allocated for necessary equipment and travel.

U.S. participants are required to match, in kind, the total amount of funds contributed by DOE for the project. In kind match includes product and equipment contribution, travel expenses and time spent on project implementation. U.S. private industry partners do not receive any funding from DOE. As the technical liaison and DOE project manager, Argonne receives a portion of the funds allocated by DOE.

ORGANIZATION - PARTICIPANTS

The organization for the IPP project is wide-ranging and inclusive. The core of the project is to involve qualified nuclear weapons scientists, labs and institutes and production plants that will have a direct role in meeting the overall project objectives. Extensive project oversight is a key aspect of the project's implementation with the International Science & Technology Center in Moscow and Argonne National Lab in supervisory roles.

The International Science & Technology Center (ISTC) was established in 1992 by several governments as a non-proliferation program. The ISTC coordinates the efforts of governments, international organizations and private sector companies by providing weapons scientists in Russia and CIS with employment opportunities for peaceful purposes. The ISTC is the coordinating body for DOE's IPP in Russia.

The organization of the project can be described in three levels:

- Level 1: Governments and Non-governmental Organizations
- Level 2: Project Leaders - Overall Project Management
- Level 3: Site Participants

Level 1: Governments and Non-governmental Organizations

United States

U.S. Department of Energy

Global Initiatives for Proliferation
Prevention (GIPP)

Argonne National Laboratory

NGO

International Science
& Technology Center
(Moscow)

United States Industry
Coalition (USIC)

Russia

Federal Agency for
Atomic Energy

Level 2: Project Leaders - Overall Project Management

Pacific Nuclear Solutions
(Indianapolis)

V.G. Khlopin Radium
Institute (St. Petersburg)

Level 3: Site Participants

Nochar, Inc.
(polymer technologist/
manufacturer, Indianapolis)



Fig. 5 Solidification Tests at Gatchyna

Gatchyna - Khlopin
(technical center
- 26 scientists
- 22 support staff

MAYAK - PAM
(Ozersk)
- 10 scientists
- 3 support staff

Siberian Chemical Combine
(SCC - Seversk)
- 13 scientists
- 10 support staff

Mining Chemical Combine
(MCC - Zheleznogorsk)
- 15 scientists
- 1 support staff

Daymos Co., (St. Petersburg)
- Commercial / distribution

There will be a total of 64 qualified weapons scientists and more than 36 support staff involved with project implementation in Russia.

OPERATING PLAN

The project is structured with an activity plan by quarter for a three year term. Technical schedules are created by tasks assigned to each site location and the number of “person days” allocated to each task. Scientific and technical reports, conference reports and annual meetings are key management tools to ensure that the project is adhering to the original project objectives.

It is expected that the project will commence in March, 2008. To begin the process, a planning meeting will be held in St. Petersburg with project managers and site representatives. The meeting will lay the groundwork for the project’s Year 1 and will detail the activities and responsibilities of each participant. Discussion topics will include: budget review, confirmation of site personnel and designate job assignments, reporting guidelines, identify scientific research priorities, travel and conference participation, etc.

The following activities are scheduled for Year 1:

- Preparation of laboratories for test programs and procurement of equipment required for testing
- Training of scientists on the use and applications of the polymer technology
- Preliminary testing of simulant waste streams that are problematic at each site
- Test selective radioactive aqueous, organic and mixed waste streams for the purpose of investigating the suitability for final packaging and long-term storage
- Apply for government certification for the use of polymers at ROSTEHNADZOR, the supervising administrative authority
- Conduct market research on a national level and identify: possible users of the polymers, amount of radioactive liquid for treatment by market sector, and access and distribution channels for each sector

Although preliminary planning for Years 2 & 3 has been identified, the specific activities will be determined as the participants work through Year 1. The work schedule is somewhat flexible and can be changed as long as it adheres to the fundamental objectives of the IPP project.

NEW TECHNOLOGY DEVELOPMENT

One important aspect of the project’s research effort is the development of new technologies for commercial applications. It is the intent of Khlopin and PNS to identify, over time, prospective partners for joint research involving existing Russian waste treatment technologies and their possible combination or design with polymers for specific, complex treatment applications. Additionally, new technologies will be explored through applied science techniques for the purpose of creating commercial products for sale worldwide.

Some of the technology development programs may include:

- Coatings to apply to aqueous polymer solidification waste in order to block additional absorption of water, if grout / cement packaging is required for the final waste product
- New techniques to solidify complex waste in uncommon circumstances, such as reactor vessels or tanks with limited access
- Combination of technologies to immobilize waste streams that are currently un-treatable
- Filtration systems for land and water remediation and extraction systems that will reduce environmental hazards

To assist PNS, Argonne National Lab will provide technical assistance for newly created technologies. The School of Civil Engineering and Geological Sciences at the University of Notre Dame will participate in applied science research projects for filtration and other remediation related technologies.

Intellectual property (IPR) is protected under the terms of the IPP program and all participating organizations and sites will strictly adhere to existing IPR laws and regulations. Intellectual property law protects copyrights, patents, trademarks, trade secrets, industrial design rights, etc. For new product designs and joint work activities, the following IPR options will be available to the project leaders:

- Co-patents; for the development of new, commercially viable products by combining existing technologies or by utilizing one existing technology with a newly discovered technology
- New patents; for new products designed by the participants. Argonne will own the patent rights outside of Russia for newly created products. PNS will have the option to license the new products from Argonne for sales outside of Russia.

The primary objectives for research and development projects are to expand the involvement of the participants and eventually offer private sector employment opportunities to the scientists and to create viable technologies that can be applied in the global nuclear market.

CONCLUSIONS

Russia, and most other nuclear nations seek reliable, high performance waste treatment technologies that can be deployed safely and at low cost. Through previous research and test programs conducted in Russia, the polymers prove to be a viable waste treatment option. However, the polymer systems must conform to the Russian waste disposal regulations if they are to be considered for ILW and HLW treatment and final storage. The IPP program provides the Khlopin Radium Institute and PNS the vehicle to certify the polymers and to pursue regulatory approvals for final storage of immobilized waste.

The opportunity to engage weapons scientists in commercial nuclear activities and to offer long-term employment opportunities in nuclear and toxic-generating industries enhances

the notion that new technologies may be used for environmental safety as well as for profitable and peaceful purposes. The IPP program clearly establishes a pathway for achievement of the objectives; however, the challenges are many. An intensive and collective effort will be necessary for the program to be successful.

The integration of the newly established private sector commercial business into the Russian nuclear market may be a first of its kind, with the introduction of western business philosophy and techniques. It is the intent of Khlopin and PNS to set up a profit-making enterprise that can be self-sustaining as a business and employ scientists at a number of strategic locations.

Funding by the Russian government for the clean-up of nuclear waste and for water and land remediation sites is an unknown factor. The success of the private sector business will be determined, in large part, by the Russian government's allocation of resources to the waste generators.

It is the intent of these authors to document and present the results of this program to various conferences each year. The presentation will include technical achievements, program successes and failures, technology certification tests and results, market research and analysis of waste conditions, new product development programs, and the establishment of the private sector business.

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Initiatives for Proliferation Prevention, National Nuclear Security Administration, and United States Industry Coalition, Inc. www.nnsa.doe.gov and www.usic.net

Argonne National Laboratory, Nuclear Engineering Division, Initiatives for Proliferation Prevention (IPP) Program, David Ehst - Senior Engineer, Nuclear Engineering Division, www.ne.anl.gov/activ/programs/IPP/index.html



Figure 4.2. Russian Weapons Complex