

#/s RRFM 2004

# TRANSACTIONS

## Session 4

8<sup>th</sup> International Topical Meeting

# Research Reactor Fuel Management

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in cooperation with the  
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## Session 4

# Spent Fuel Management, Back-end Options, Transportation



# **BACK-END OF THE RESEARCH REACTOR NUCLEAR FUEL CYCLE: INTERNATIONAL STATUS AND PERSPECTIVES**

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## **ABSTRACT**

The back-end of the research reactor (RR) nuclear fuel cycle is not only a technical issue. Non-proliferation, physical security and environmental concerns are just as important, if not more so, as technical concerns such as: safe management of spent nuclear fuel (SNF), storage capacity, availability of qualified high-density reprocessible fuel and national self-sufficiency to deal with the domestic turnover of RRSNF.

International activities in the back-end of the RR nuclear fuel cycle are dominated by two important undertakings. The first is the Reduced Enrichment for Research and Test Reactors (RERTR) program, and the second is the acceptance of RRSNF by the country where it was originally enriched. While RERTR focuses on conversion of RRs from HEU to LEU and qualifying high-density reprocessible fuel to facilitate it, a major goal of the separate take-back programs for US origin and Russian origin fuels is to eliminate inventories of HEU. Eventually, however, when these programmes have achieved their goals and there are no more HEU inventories at RRs and no more commerce in HEU for RRs, it is almost certain that the take-back programmes will cease. Many countries with one or more RR and no nuclear power programme will have to face the problem of final disposition for relatively small amounts of spent fuel or permanently shut down their RRs before the termination of the take-back programmes. Regional or international solutions would seem to be only chance of survival for the RRs in those countries.

## **1. Introduction**

International activities in the back-end of the RR nuclear fuel cycle are dominated by two important undertakings. The first is the Reduced Enrichment for Research and Test Reactors (RERTR) program, and the second is the acceptance of RRSNF by the country where it was originally enriched. While RERTR focuses on conversion of RRs from HEU to LEU and qualifying high-density reprocessible fuel to facilitate it, a major goal of the separate take-back programs for US origin and Russian origin fuels is to eliminate inventories of HEU.

RR spent fuel inventories worldwide can be summarized as follows:

- 62,027 fuel assemblies in storage;
- 45,108 in industrialized countries;
- 16,919 in developing countries;
- 21,732 HEU assemblies;
- 40,295 LEU assemblies.

Thus, even after 25 years of RERTR, over a third of all stored fuel assemblies are HEU. In addition, there are 24,338 fuel assemblies still in the cores of RRs, and if the large inventory of natural uranium assemblies are discounted, the current cores are roughly equal in numbers of HEU and LEU assemblies.

There are 12,850 spent fuel assemblies of US origin (enriched in the US) still at RRs abroad and most of them are eligible to be returned under the US acceptance program.

There are 24,803 assemblies originally enriched in the former Soviet Union, at RRs abroad. Although there is a Tripartite (IAEA, Russian Federation, US) Initiative to repatriate this fuel, so far the first shipment of spent fuel, scheduled to be from Tashkent, Uzbekistan, has yet to take place. In contrast, fresh HEU fuel has been repatriated from the former Yugoslavia, Romania and Bulgaria; all these shipments were funded by the US with IAEA involvement.

The present status of development and qualification of high density reprocessible fuel [1], [2]; progresses in the US [3] and Russian [4] take back programmes and reprocessing issues of RR fuel [5] will be reported in other presentations to this meeting. Consequently, this paper focuses mainly on the long-term perspectives of the back-end of the RR nuclear fuel cycle. Emphasis is put on the discussion of regional and international options (hereinafter referred to as multinational options).

## **2. Need for Multinational Solutions to the Back-end of the RR Nuclear Fuel Cycle**

In order to ensure consistency, the terminology used throughout this presentation follows the definitions of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [6].

After discharge from the core, RRSNF is stored under water, usually in at-reactor (AR) facilities, for a period of time to allow for cooling. This wet storage can be extended, in AR or away-from-reactor (AFR) facilities, in some cases over long periods (~50 years), or the RRSNF may be transferred to dry storage (AR or AFR) sites and stored dry for even longer periods. None of the above-mentioned strategies for RRSNF management can be considered as the end-point of the RR fuel cycle. Regardless of how long this extended interim storage is drawn out; the resolution of the back-end problem will remain, and proliferation, safety and physical security concerns will continue.

Considering current technologies, the end-point of the RR nuclear fuel cycle is attained (at least for the generating country) when the RRSNF is:

- a) returned to the country of origin;
- b) reprocessed, the HL and long lived wastes disposed of in a geological repository, and the useful isotopes reused; or
- c) directly disposed, or disposed of after conditioning, in a geological repository.

The main characteristic of options b) and c) is the irretrievability of the disposed materials.

Perpetual postponement of a final decision is not ethically or technically reasonable considering that after achieving their goals the take-back programmes will certainly cease. Then every country with a RR will face the necessity to develop a national strategy for disposal of RRSNF. For several countries with a small nuclear power programme or one or more RRs the expensive construction of away-from-reactor extended interim storage facilities and/or geological repositories for the relatively small amounts of spent fuel accumulated is obviously not practicable. Unfortunately, for many of these countries the option of reprocessing the fuel abroad is unlikely to be affordable. Moreover, if the fuel is shipped abroad for reprocessing, the problem of the final disposal of any returned HLW will have to be addressed anyway. Sooner or later, every country with at least one RR, which continues to operate beyond the termination of acceptance programmes of the countries of origin, will need a final solution for spent fuel and/or HLW waste. Clearly, access to a multinational long-term interim storage facility and eventually a multinational repository is the ideal solution.

The preamble of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management addresses multinational solutions in article (xi):

“Convinced that radioactive waste should, as far as is compatible with the safety of the management of such material, be disposed of in the State in which it was generated, whilst recognizing that, in certain circumstances, safe and efficient management of spent fuel and radioactive waste might be fostered through agreements among Contracting Parties to use facilities in one of them for the benefit of the other Parties, particularly where waste originates from joint projects”.

International interest in the multinational solutions was expressed recently in two major events:

1) One of the conclusions of the International Conference on Storage of Spent Fuel from Power Reactors, held in Vienna, 2-6 June 2003, organized by the IAEA in co-operation with the OECD Nuclear Energy Agency, was that: “Representatives of Member States with smaller nuclear programmes informally expressed continued interest in regional storage initiatives, as well as topic-specific workshops and training courses”.

2) In his Statement to the Forty-seventh Regular Session of the IAEA General Conference 2003, the Director General of IAEA Dr. Mohamed El Baradei said: “Our consideration should also include the merits of multinational approaches to the management and disposal of spent fuel and radioactive waste. Not all countries have the appropriate conditions for geologic disposal and, for many countries with small nuclear programmes for electricity generation or for research, the financial and human resource investments required for research, construction and operation of a geologic disposal facility are daunting. Considerable economic, safety, security and non-proliferation advantages may therefore accrue from international co-operation on the construction and operation of international waste repositories. In my view, the merits and feasibility of these and other approaches to the design and management of the nuclear fuel cycle should be given in-depth consideration. The convening of an Agency group of experts could be a useful first step”.

### 3 Conceptual Multinational Solutions

The term “multinational facility” means a facility in a country (host country or host), which serves several countries (partner countries or partners) [7]. This definition applies to storage facilities, geological repositories and reprocessing plants.

Different options for the services provided by the multinational facilities might be conceived [8]. The one presented here (Fig. 1) is a fully integrated approach that considers the classical alternatives for the RRSNF back-end (reprocessing or direct disposal). After transportation from the partner country, the spent fuel is stored for a specified (or unspecified) period in the multinational storage facility, after which it is transferred either to a multinational disposal facility (after appropriate conditioning) in the hosting country or to a reprocessing plant (also multinational?). The HLW from the reprocessing plant is finally disposed of in a multinational repository. Needless to say, the convenience of locating all the necessary facilities (storage, reprocessing and repository) in the same host country and even in the same site would be logical and economically desirable.

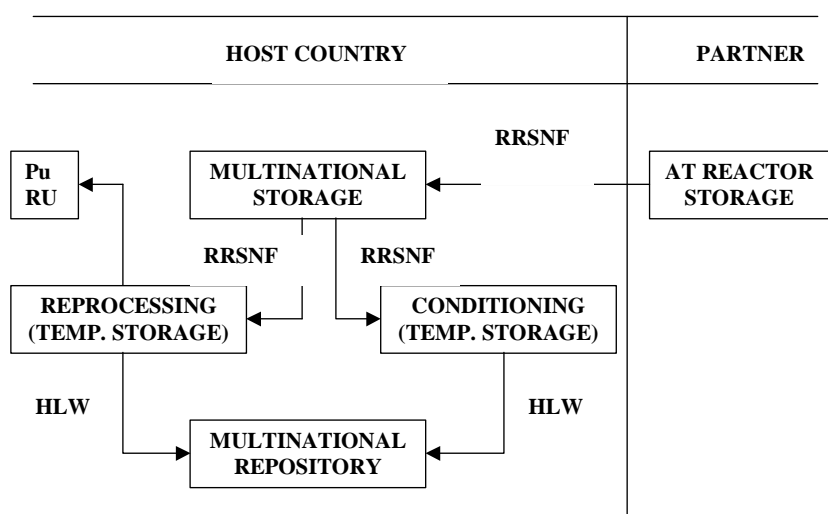


Fig. 1 Multinational Back-end System

Typical situations from which a multinational approach might develop are:

- Several industrialized countries with relatively small nuclear energy programmes decide to cooperate in the management of the back-end of the nuclear fuel cycle.

- A country with a large nuclear energy programme offers back-end services to other countries with a limited production of RRSNF.
- Countries with small nuclear energy programmes in varying stages of development seek assistance from each other. Among other issues would be to develop a suitable and common back-end option.

Countries likely to function as hosts are those with existing reprocessing facilities, advanced disposal programmes and/or favourable geological sites that see the tremendous commercial opportunities.

Partners would be countries with small nuclear power programmes or just research reactors that cannot realistically develop a national final solution and countries that see an economic and/or political advantage (despite likely high costs) in joining a multinational undertaking.

#### **4. Important Issues to be considered in a Multinational Approach**

##### **4.1. Legal Aspects**

The legal and regulatory situation in countries willing to consider a multinational solution should be harmonized among the partners. Mature and stable regulatory frameworks should be developed and, where existing regulations are inadequate or insufficient, the use of existing international conventions, e.g. the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [6] would help in bridging the gaps.

##### **4.2. Safety Principles**

Safety criteria should comply with international standards. A key advantage of the concept of the multinational approach is to reduce the number of locations at which radioactive materials are stored and disposed of. A thorough risk assessment has to be performed.

##### **4.3. Technical Issues**

Current inventories of all RRSNF available for management must be established before serious consideration can be given to establishing a multinational undertaking. There should be agreement between the host country and its partners as to acceptance criteria and QA/QC. The characterization and selection of a site as well as the design, construction and operation of the required facilities should be agreed upon. The application of well established technologies should be preferred.

##### **4.4. Economic Issues**

Multinational approaches will have a main economic impact in reducing the expenditures of the partners and increasing the resources of the host country. Many particular concerns should be taken into account. The costs and liabilities to all affected partners must be weighed against the benefits. As cost sharing will extend over many years, long lasting financial arrangements are thus unavoidable whether the project will be run and financed jointly or whether the non-host partners only play the role of customers. Financial provisions for future liability of the host country have to be considered seriously.

##### **4.5. Institutional Aspects and Political Continuity**

The considerations about cost, liability, safety regulations, etc. are closely linked to the institutional character of the project that involves national and multinational relations among regulatory and licensing bodies, as well as with contractual partners. Since a multinational undertaking may extend over decades or centuries, it may be run under an international convention or agreement. The political stability of the host and the partners is again a vital element.

##### **4.6. Ownership of RRSNF**

Ownership of RRSNF requires early negotiations between the countries participating in a multinational project. There is a strong interrelation between ownership of RRSNF and liability. Partners involved have to agree when (if ever), in the process, ownership is transferred to the host country operating the multinational facilities and on the full implications of the transfer.

#### **4.7. Ethical Aspects**

The ethical considerations are embodied in the IAEA's Safety Fundamentals [9], in particular with regard to the protection of human health and the environment, with emphasis for the protection of future generations, the protection of third countries/parties beyond national borders, and the principle of avoiding undue burdens on future generations. Equity must apply amongst the partner countries, that is, a fair balance must exist between the burden transferred and the compensation received through the multinational agreement.

#### **4.8. Public Acceptance**

The public acceptance issue is inevitable and crucially important for multinational projects, serving several countries or communities. High safety standards, quality assurance on conditioning and disposal, cost sharing, transparency with regard to coverage of potential future costs, clear and convincing answers with regard to ethical concerns, etc. are thus essential in the process of obtaining public acceptance of a multinational project.

#### **4.9. Safeguards**

As RRSNF contains fissile materials that, under the terms of the Treaty on Non-proliferation of Nuclear Materials [10], are subject to national and international safeguards regulations. Well-defined national and international safeguards regulations will have to be applied in the country of origin. Maintenance of long-term controls should be assured. One obvious advantage is that there will be fewer facilities to be safeguarded and physically secured.

### **5. Conclusions**

It is assumed that any multinational facility will be subject to international Conventions and internationally accepted standards involving safety, safeguards, physical security and environmental protection. Consequently, gathering together weapons-usable materials and radioactively hazardous wastes that are the inevitable products of the RR fuel cycle in preferably one (or a very small number) multinational, long-term interim storage facility and eventually final repository, compared with the current situation where hundreds of locations are involved, has obvious benefits to all mankind. First and foremost among these will be nuclear threat reduction through reductions in proliferation risk and opportunities for theft of materials that could be used in radioactive dispersion devices. Real advantages can be identified also for the host country and participating countries. The only obvious drawback would be an increase in the transportation of fuel and HLW from the participating countries to the multinational facility.

The IAEA should take the lead in initiating serious discussions of multinational solutions. The United States and Russian Federation, as the main suppliers of enrichment services to RRs, should also play important roles.

There are some effective multinational spent fuel storage facilities for RRSNF existing at present: RBOF and L-Basin at Savannah River Site hold foreign research reactor fuel (originally enriched in the U.S.) from all over the world pending a decision on final disposition. Similarly holding pools at reprocessing plants in France and Russia, store RR fuel from foreign countries pending reprocessing and eventually, Idaho National Engineering and Environmental Laboratory will be storing TRIGA fuel from up to 19 countries. Clearly, the technical problems of transportation and storage have been solved. Nevertheless, the most difficult obstacles – political willingness, legal issues of cost sharing and liability and, of course, public acceptance – have yet to be addressed. Now is the time to start serious discussions.

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# UMo SPENT FUEL ACCEPTANCE FOR TREATMENT AT LA HAGUE PLANT

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## ABSTRACT

Beside the Foreign Research Reactor Acceptance Program managed by the US DOE, the RTR spent fuel treatment program managed by COGEMA is continuing to provide full benefit of the long term spent fuel treatment program dedicated to the Light Water Reactors. The situation is marked currently by the US DOE decision to accelerate the Reduced Enrichment Research Test Reactor program, as a result of the terrible events of September, 11, 2001 and the end of the Foreign Research Reactor Acceptance Program on May, 13 2006. On the other hand, it is unlikely that the high-density UMo fuels will be qualified, licensed and manufactured in series within this remaining time window. For some RR operators the impending termination of the Foreign Research Reactor Acceptance Program can signal the premature closure of their reactor. The COGEMA solution, confirmed by its commitment to maintain an industrial solution, ensuring the treatment of the RTR UAlx and UMo type spent fuels and even some silicide spent fuels during a limited period, can be more than ever a sustainable answer to the Research Reactor Community for the RTR spent fuel back-end management. This is why, on the basis of the proven RTR spent fuel treatment French demonstration, COGEMA has initiated a Research and Development program on the RTR treatment process optimisation of UAlx, UMo and silicide spent fuels in its La Hague treatment Plant. COGEMA La Hague plant is legally authorized in La Hague treatment plant through a decree emitted by the French government to perform the reception, the interim storage, the treatment of the Research Test Reactor spent fuels, the conditioning and the return of the radioactive residues generated by the spent fuel treatment. For each Research Test Reactor spent fuel type, COGEMA has, however, to submit to the French safety authorities a safety demonstration in order to obtain a specific authorization. This essential step answering to the French authority requests time to be implemented namely between 6 months to one year. It was performed successfully by COGEMA for the aluminide type spent fuels and recently for the silicide type spent fuels. We conclude therefore that there is no doubt about the UMo Research Test Reactor treatment solution as a back-end management.

## 1. Introduction

Beside the challenge of the United States Foreign Research Reactor Spent Nuclear Fuel acceptance program to progress considering the expiration in 2009 of the acceptance Policy (fuel must not be irradiated after May 12, 2006) or even to extend the termination date, the French back-end Program through COGEMA has also many challenges to progress in its proposal to the Research Reactor Operators of a sustainable industrial back-end RTR Spent Fuel Management.

With the knowledge of the UMo fuel development situation, COGEMA has reviewed its back-end spent fuel offer and has the will to adjust it taking into account the difficulties met by the UMo development program.

In actual fact, it is unlikely that the high-density UMo fuels will be qualified, licensed and manufactured in series within this remaining time window.

For some RR operators the impending termination of the Foreign Research Reactor Acceptance Program can signal some brakes in the reactor operating.

COGEMA confirms by its commitment to maintain an industrial solution, ensuring the treatment of the RTR UAlx and UMo type spent fuels and even silicide spent fuels during a limited period.

It leads to continue the follow-up of French R&D UMo development Program and to strengthen the R&D  $U_3Si_2$  (silicide) fuel treatment-conditioning.

## **2. Treatment solution as back-end management**

### **2.1. Proven industrial experience**

COGEMA has already gained experience in the reprocessing of the RTR spent fuels, about 20 tons have been treated in the UP1 COGEMA plant proving the industrial feasibility to treat this type of fuels.

This feed back experience gained during the treatment of UAl has allowed to guide the treatment development program of the  $U_3Si_2$  and UMo spent fuels.

Actually, COGEMA La Hague plant has received successfully 14 tons of RTR Spent fuels. RTR Spent fuels have been delivered from France, Belgium and Australia.

The start-up of the RTR Spent Fuel Treatment Program is scheduled during the year 2005.

The French reprocessing of spent fuel has clearly as objective to minimize the waste volume and reduce the radio-toxicity of the ultimate waste to be disposed of (30 to 50 time volume reduction as compared to long term interim storage and 99% of activity encapsulated into stable residues).

### **2.2. La Hague plant: Process lines**

The French solution for RTR spent fuels back-end management is Treatment-Conditioning which could be performed in the COGEMA La Hague plant in France comprising several industrial process lines. The treatment is based on an advanced Purex process considering the dissolution of the UAl, UMo and  $U_3Si_2$  in nitric acid. The fissile material is separated in the reprocessing plant and the final waste can be encapsulated in a glass matrix.

At La Hague complex uses the RTR reprocessing process includes the following steps:

- Transport of the fuel to the plant and cooling in interim storage pools.  
The cooling or deactivation decreases the radioactivity of the fission products substantially
- Dissolution of the fuel followed by clarification of the liquor generated  
Depending on the fuel type, it is possible that some insoluble products may remain after dissolution.

At the end of the operation of dissolution, the insoluble fall into a perforated basket.

In addition, the remaining insoluble particles in the solution which would hamper further process steps, are removed by centrifugation. A centrifugal clarifier has been selected for La Hague because it provides good efficiency with high throughput.

- Uranium and plutonium splitting and purification by liquid-liquid extraction process  
Several extraction cycles of the clarified liquor, in pulsed columns, mixer-settler banks, or centrifugal extractors are necessary to meet the end-product specifications.

At the end of these cycles, different kinds of solutions are generated:

A solution containing specifically the uranium

A solution containing specifically the plutonium

Raffinates containing the fission products and the minor actinides

The solvent which is generated by a treatment with sodium carbonate followed by caustic soda and then recycled

- Final conversion of uranium and plutonium to end-products  
The uranium solution is concentrated by evaporation, stored and eventually converted to UF<sub>6</sub> for a new isotopic enrichment.  
The plutonium is precipitated as an oxalate salt by the addition of oxalic acid. This salt is then filtered, dried and calcinated to form the PuO<sub>2</sub> oxide or can be especially for the Research Reactor incorporated in the Glass Matrix of the residue container
- Management and treatment of HA process waste  
The high activity (HA) liquid waste are concentrated and generate the HALW concentrates which are treated in vitrification facility to form a glass matrix suitable and safer packaging for long term storage.

The process includes first converting the HALW solutions to a solid form in a rotary calciner and then vitrifying the solid in an induction-heated metallic melter. Characteristics and specifications of final stable residues are very known, approved internationally, and readily disposable.

### **2.3. RTR UAl, U<sub>3</sub>Si<sub>2</sub> and UMo treatment specificity**

RTR spent fuel reprocessing at La Hague would require some modifications, since the plant had been primarily designed to reprocess fuel from Light Water Reactors (LWR).

The shearing step is not used for the RTR UAl, U<sub>3</sub>Si<sub>2</sub> and UMo spent fuels.

The RTR UAl and UMo spent fuels will be introduced directly without shearing step in the continuous dissolver.

To be reprocessed, RTR fuels must be diluted in power UO<sub>2</sub> spent fuel to lower the <sup>235</sup>U content to a maximum acceptance of 2% in a main process flow.

### **2.4. R&D programs for optimisation of UAl, UMo and U<sub>3</sub>Si<sub>2</sub> treatment**

This feed back experience gained during the treatment of UAl has allowed to guide the treatment development program of the U<sub>3</sub>Si<sub>2</sub> and UMo spent fuels.

COGEMA defines the following methodology: Definition of the RTR treatment method on the UAl spent fuels, then to adapt the method for the U<sub>3</sub>Si<sub>2</sub> and UMo.

The treatment conditions are established on the basis of feed back experience of Marcoule

- Main process parameters to be optimised are:
- Solubility of Aluminium in the nitric acid
- Cinetics of dissolution with various Al alloy
- Gas produced during the dissolving
- Behavior of silicide in dissolution solution and extraction cycles (optimisation of the silicide incorporation in the process y dilution).

## **3. Conclusions**

The RTR operators have to select a sustainable and efficient back-end management for their spent fuels assemblies and to clarify their solutions to safety authorities by anticipating the change of the environment and of acceptance Programs.

Due to the specific nature of the RTR fuel, long term interim storage or direct disposal would require extensive R&D programs. The reprocessing seems to be the most operational management scheme in terms of safety, environmental and sustainable solution for the future generations, offering an industrial proven RTR spent fuel management.

This is why, the reprocessing aspects have to be imperatively examined in the same time of the development and qualification phases of the new generation of RTR fuel.

The COGEMA solution, confirmed by its commitment to maintain an industrial solution, ensuring the treatment of the RTR UAlx and UMo type spent fuels and even U<sub>3</sub>Si<sub>2</sub> spent fuels during a limited period, can be more than ever a sustainable answer to the Research Reactor Community for the RTR spent fuel back-end management.

On the basis of the proven RTR spent fuel treatment French demonstration, COGEMA has initiated a Research and Development program on the RTR treatment process optimisation of UAlx, UMo, U<sub>3</sub>Si<sub>2</sub> spent fuels and wants to strengthen this program for U<sub>3</sub>Si<sub>2</sub> spent fuels.

For each Research Test Reactor spent fuel type, COGEMA has, however, to submit to the French safety authorities a safety demonstration in order to obtain a specific authorization. This essential step answering to the French authority requests time to be implemented namely between 6 months to one year. It was performed successfully by COGEMA for the aluminide type spent fuels and recently for the U<sub>3</sub>Si<sub>2</sub> type spent fuels.

We conclude therefore that there is no doubt about the UMo Research Test Reactor treatment solution as a back-end management.

# DECOMMISSIONING THE MATERIAL TEST REACTOR FUEL CYCLE

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## ABSTRACT

The UKAEA Dounreay site, in the North of Scotland, has been involved in the UK, European and World research reactor fuel cycle since the late 1950's. Some of the early facilities on the site were a Dido type research reactor, a test reactor fuel reprocessing facility, a uranium treatment facility and a test reactor fuel fabrication plant. The entire research reactor fuel cycle within a single site.

The reactor and the reprocessing facility are now being decommissioned. The fabrication facility is completing its' final elements and will shortly start its 'clean-out' and early decommissioning phase. The last facility associated with the research reactor fuel cycle to operate will be the uranium treatment facility, which is being prepared for operation to enable the remaining site inventory of enriched uranium to be prepared for re-use elsewhere.

This paper sets out the integrated approach being taken by UKAEA at Dounreay to decommission the different facilities in a way that minimises the impact on the environment. It also highlights the importance of a clear policy on waste conditioning and storage for the decommissioning process.

## 1. Introduction

In the mid 1950's the UK Government decided to research the development of the fast reactor and commenced an extensive building programme at the site of a wartime dispersal airfield, Dounreay in the North coast of Scotland.

The development of civil nuclear power systems in the UK was entrusted to the United Kingdom Atomic Energy Authority (UKAEA) who were the operators of the site at Dounreay and other sites at Harwell, Winfrith, Risley, Windscale and Culham in England.

As part of the research and development of civil nuclear power systems, the UKAEA quickly identified the need for Material Test Reactors and built three Dido type reactors, Dido and Pluto at Harwell and DMTR at Dounreay. The fuel for these MTR reactors was enriched uranium, as was the fuel for the Dounreay Fast Reactor (DFR). Separate but adjacent fuel fabrication facilities were installed at Dounreay for the production of the Uranium Molybdenum alloy DFR fuel and the uranium aluminium alloy MTR Fuel. Enriched uranium supplies for the programme were obtained from the US and from within the UK.

UKAEA also recognised at an early stage, the benefits of recycling the remaining  $U_{235}$  from irradiated fuel, to reduce the need for fresh HEU. Reprocessing facilities were established for both the fast reactor and MTR fuels. Uranium recovery and metal production facilities were also installed to allow both the recycle of reject fuel from fabrication and the re-use of reprocessed uranium, raising the enrichment when required by blending with fresh high enriched uranium.

The MTR facilities at Dounreay have serviced both the UK and a number of other countries MTR cycles for the past 30 – 40 years. In 1969 DMTR was shutdown as the Dounreay Fast Reactor (DFR) provided a higher flux for fast reactor fuel and material experiments. In 1990 Dido and Pluto were closed as the UK's need for irradiation work and research reduced. Those shutdowns removed the base load work from the workplan for the facilities at Dounreay and although a number of external contracts were secured for reprocessing, uranium recovery and fabrication the business could not sustain the investment necessary to upgrade the facilities to meet the exacting standards of the 21<sup>st</sup> century. The reprocessing facility was shutdown in 1996 and with it the irradiated MTR fuel elements

receipt facility. The fuel element fabrication facility has continued to operate, at reduced output, to complete element order commitments. This facility will close on 31 March 2004.

The last facility associated with the MTR cycle in operation will be the uranium recovery facility. This will be utilised to process the remaining unirradiated enriched uranium on the site to a form that is useable by others within the research reactor fuel cycle. On completing this duty this facility will also be closed and decommissioned.

Each of the MTR facilities at Dounreay pose a number of individual problems for decommissioning - these are covered in the subsequent sections.

## **2. Decommissioning DMTR**

### **2.1 Reactor Containment**

#### Introduction

The Dounreay Materials Testing Reactor (DMTR) was fuelled with high enriched uranium, moderated and cooled by heavy water and it had an initial power output of 10 MW (th). The heat generated was dissipated to atmosphere via 8 cooling towers. Virtually a twin of the PLUTO reactor at Harwell, DMTR was designed as a facility to enable research work to be carried out in high neutron fluxes.

#### Construction

Construction work started in the summer of 1955 and continued until the reactor was taken critical on 24<sup>th</sup> May 1958. Commissioning and calibration work was carried out with the power being steadily raised until full power was achieved on 15<sup>th</sup> December 1958.

#### Operations

Utilisation was of a fairly high order throughout the working life of the reactor. The experimental research work carried out was mainly in support of power reactor system, in particular fast reactor systems. As operations progressed, the power was increased to 22 MW with the introduction of the Mk IV fuel elements. The reactor continued to run until 12 May 1969 when it was shut down for the last time. The decision to close the reactor was taken following a reduction in the need for reactor space for irradiation work and the availability of the Dounreay Fast Reactor as a test facility.

#### Stage 1 Decommissioning

On shutdown of the reactor in 1969 Stage 1 decommissioning was commenced. All the irradiated fuel was removed from the reactor and reprocessed and the absorbers removed. The Internal Fuel Element Storage Block, which was used for interim storage of both spent and new fuel elements, was emptied, cleaned out and painted. All experimental rigs were disposed of along with their handling facilities. The heavy water was cleaned by fine filtration, drained from the circuit and transferred to Winfrith for use in SGHWR. The heavy water circuit was then thoroughly washed out, drained and the Reactor Aluminium Tank was blanked off. The three main heavy water circulation pumps were removed from the system and sent to Harwell as spares for DIDO and PLUTO. With the exception of ventilation and power for lighting, all services to the reactor shell including drainage were disconnected and blanked at their entry points. The work was completed by 1971 and the reactor was then left under a minimal care and maintenance regime, expect for periodic entries to remove components for reuse elsewhere, until the mid 1990's. At this time the situation in DMTR was reviewed and a decision taken to progress the decommissioning of the reactor to a stage where the building could be justified for periodic entry and inspection. The environmental monitoring stations and the electrical systems were reconfigured to permit future dismantling of the reactor block and to permit environmental monitoring before entry. Further strip out work was also carried out to remove circulation paperwork and instrumentation. The system is now in a monitored condition. Decommissioning will recommence once further ILW conditioning and storage facilities are available.

### **2.2 Fuel Receipt Pond**

The D9814 pond is a small fuel storage pond with a total volume of 131.6m<sup>3</sup> located at the extreme western end of the DMTR complex. The pond is reinforced concrete construction and is lined with

stainless steel. It is 5.5 metres long, 4.6 metres wide and 5.3 metres deep. It contains no fuel or other items beyond redundant fuel storage racks, pumps, filters and lights, the pond currently holds some 125 m<sup>3</sup> of contaminated water. Historically the pond was used for MTR fuel receipt and storage. During the 1960s some fuel cropping and milling took place within it. The pond was thoroughly cleaned in the late 1960s and since has only been used for receipt, storage and transfer to the reprocessing facility. The last fuel elements to be held there were the Georgian fuel elements. These were removed from the Pond in 2001.

This pond will be decommissioned in three stages. Stage One will be concerned with the removal and size reduction of redundant items from the pond and the surrounding area. Stage Two will treat and dispose of the water in the pond and clean down the pond surfaces. Stage Three will remove the pond liner, decontaminate the pond walls, and remove all remaining operational equipment used in connection with the pond.

The demolition of the building will be held until the remaining areas of the DMTR complex have been cleaned. An important part of this final stage is the availability of segregation and monitoring units, to allow the bulk of the waste to be utilised as landfill.

### **2.3 Post Irradiation Examination Facilities**

The Post Irradiation Examination (PIE) Cave was constructed to support the Dounreay Materials Test Reactor (DMTR) programme in the late 1950's, was modified in 1972 and again in the 1980's to deal with irradiated Prototype Fast Reactor (PFR) components.

The cave contains both radioactive and toxic/hazardous materials.

- Radioactive materials, as stored non-fissile items
- Cans which contain in-cell process waste arisings
- Sodium contained inside the control rod pins in two control rod assemblies.
- Zinc Bromide liquid in the shielding windows
- Oil in the hydraulic systems

The decommissioning of the cave will involve the removal of all the stored items and all chemical and service items until the concrete monolith is left. (in a clean condition) This will remain until as the rest of the building is dismantled and facilities are available for the sentencing, segregation and disposal of the demolition rubble.

### **3. Decommissioning the MTR Fuel Reprocessing Facility**

The MTR reprocessing plant at Dounreay operated between 1958 and 1996. In this time the facility reprocessed nearly 13000 elements and recovered more than 2 tonnes of enriched uranium for re-use in the MTR fuel cycle. In 1998 the UKAEA board and the UK Government announced this facility would be decommissioned.

The reprocessing facility consists of a receipt pond where elements were cut and fed by elevator to one of two dissolvers. The dissolved fuel was then conditioned and fed through two cycles of solvent extraction to permit the separation of re-useable uranium from the fission products and other impurities. The fission products were sent in solution to storage tanks for future treatment. The uranium product was fed to the recovery plant.

Since 1996 the facility has been held under care and maintenance with upgrades being implemented to the electrical, ventilation and environmental monitoring systems. The intention is to undertake the decommissioning work in few distinct stages.

#### **Stage 0 - Enabling work**

The principal aim of the enabling stage will be to confirm the complete radiological waste inventory of the plant. Only when the total waste liability is confirmed can detailed assessments of the disposal options be considered and the decommissioning activities programmed in detail. The project methodology will be developed to ensure safe practical methods, and cost-effective solutions are identified. During this stage existing building services will be upgraded in preparation for the removal of non-active plant. New change room facilities will be installed and redundant inactive plant and equipment will be removed. A Decommissioning Safety Case will be prepared as an overview safety assessment

of all the proposed decommissioning activities to allow commencement of decommissioning stages 1 to 3.

#### Stage 1 – Activity Reduction

Stage 1 involves the removal and safe disposal of selected active plant and known contamination which will reduce the radiological hazard in the plant. The main decommissioning tasks to be undertaken are; 1, the removal and disposal of the fuel pond water and residual solid fuel debris and 2, an aggressive chemical washout of the high active cell dissolver process vessels and pipework systems.

#### Stage 2 - Removal of Active Plant

Stage 2 will include the removal of all remaining contaminated plant, equipment or structures. This work requires packaging, conditioning and storage facilities to be available to process the active items to a conditioned waste form. All redundant building services will be isolated and removed on completion of the decontamination and removal activities. All known contamination will be removed from the building structure to permit declassification of the building in preparation for demolition. There may be a requirement to delay the demolition stage until adjacent facilities are at the same stage as there is limited access around the facility and some building services are shared with adjoining plants.

#### Stage 3 - Restoration

Stage 3 involves the careful dismantling of the remaining reinforced concrete fuel pond and process cell structures and the demolition of the building steelwork frame and fabric. Completion of this final stage will be confirmed by the radiological declassification of the area within the building perimeter boundary to allow unrestricted use of the concrete foundation slab which will be left insitu.

### **4. Decommissioning the MTR Fabrication Facility**

The MTR Fabrication Facility at Dounreay started to produce fuel plates for use in the UK MTR reactors in 1958, and will have produced approximately 10,000 elements when it shuts down on 31 March 2004. More than 9500 elements have been of the alloy type with most of these irradiated in Dido type reactors. With the link to the reprocessing facility and uranium recovery the plant also demonstrated the use of a reducing enrichment in fuel elements, recycling the fuel. The UK Dido reactors started life with a uranium enrichment of 93% and went through a series of enrichment reductions 93% to 80% to 60 % to 55 %. Recycle of reprocessed uranium has also been demonstrated with dispersed fuel, with the successful production of 72% enriched elements for SCK/CEN's BR2 reactor, following the reprocessing of SCK/CEN fuel in 1994.

Decommissioning of the fabrication facility does not pose the same challenges as facilities handling irradiated fuel and will involve clean-out of glove boxes, preparation of nuclear material for recovery and the strip out of both radioactivity clean and contaminated items. It is UKAEA's intention to make available any equipment that could be utilised by other fabricators rather than dispose of all items to the low level waste stream.

Following removal of the active equipment, ventilation system and connections to the active drain systems, the building will be held, to be demolished with other adjacent buildings in the complex at Dounreay.

### **5. Decommissioning the Uranium Recovery Facility**

The uranium recovery facility will be the last of the Dounreay MTR cycle facilities to be operated. Although the facility was extensively modified in the late 1980's it is currently being upgraded and modified to permit its operation and decommissioning under current license standards. This will involve many upgrades, including improvements to environmental monitoring, electrical infrastructure, replacement of the dissolvers and replacement of the plant ventilation system.

The recovery plant will be utilised to process the remaining inventory of enriched unirradiated uranium on the Dounreay Site to allow the material to be returned to its owners for re-use or for transfer to other licensed enriched uranium users. The focus during the plant operation will be to produce as much 20% enriched uranium which complies to fabrication standards as possible, reducing the amount of fuel which will require treatment as waste.

As the final part of the operating phase the plant will be progressively washed out, until the bulk of the equipment can be considered for disposal as low level waste.

Following the strip out and size reduction of all active equipment this building will also be demolished, along with other adjacent buildings.

## **6. Integrated Approach**

The main focus of UKAEA has changed since the mid 1990's. There is no longer a focus on the support and development of power producing fission reactors, the organisation is now focused on the safe restoration of our sites, identifying best practice in decommissioning projects.

For the MTR facilities this has involved a review of the status of the facilities, checks on the building infrastructure required for decommissioning and in most cases the renewal of environmental monitoring, ventilation and electrical systems, replacing the system installed in the late 1950's. Decommissioning is a multistage process. The Dounreay site has many waste and fuel facilities that were designed to support the operation of two complete fuel cycles, in most cases these facilities are not suited to the support of the complete decommissioning process. Decommissioning poses new challenges and there is a need for new facilities which, will not store radioactive waste in a raw form, but will condition it to meet the requirements of a future national storage or disposal facility.

It is the availability of such facilities which determine the stages and rate of decommissioning of the MTR facilities.

In general the approach taken involves:

- Assessment of the complete building inventory
- The removal of fuel material and waste materials - post operational clean out
- Upgrading of building services for the decommissioning process
- The removal of active plant – when conditioning and storage facilities are available
- Co-ordinated demolition of buildings, segregation of contaminated material from general building rubble.

## **7. Summary**

The Dounreay involvement in the MTR cycle will end when the uranium recovery facility has completed its recovery work and the enriched uranium product is transferred for use elsewhere. Different decommissioning challenges are posed by each MTR facility necessitating a need for review of the facility status and the waste conditioning requirements, before commencing the decommissioning process.

Where there are chemical or radiological issues these are generally tackled, utilising existing facilities to deal with any waste arising. Further decommissioning is then carried out in a structured way, allowing similar wastes from many facilities to be conditioned and stored awaiting future consignment to a national facility. Groups of buildings will then be demolished in a progressive manner, minimising the generation of radioactively contaminated material.

For Dounreay the closure of the research reactor facilities is the end of an era, it also has heralded the start of a complex and challenging decommissioning project.

# THE FUEL SITUATION AT RESEARCH REACTORS IN AUSTRIA

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## ABSTRACT

In the past decades Austria operated three research reactors, the 10 MW ASTRA reactor at Seibersdorf, the 250 kW TRIGA reactor at the Atominstitut and the 1 kW Argonaut reactor at the Technical University in Graz. Since the shut down on July 31<sup>st</sup>, 1999 and decommissioning of the ASTRA reactor only two reactors remain operational. The MTR fuel elements of the ASTRA reactor have been shipped in spring 2001 to Savannah River under the DOE fuel return programme.

## 1. Introduction

The TRIGA reactor Vienna is used intensively for students education and training, all reactor systems are in excellent condition, spare fuel elements are available to operate this reactor for another 10 to 15 years and at present there is no indication whatsoever that this reactor should be closed down in the coming years.

The Argonaut reactor Graz however is planned to be shut down and decommissioned in 2004. Although its plate type fuel elements are almost inactive due to the low power level and infrequent operation the fuel shipment procedure and the costs are almost equal to other shipments. The financing of the shipment and the transport route is still under discussion presently.

This paper will discuss the experience with the completed fuel shipment of the ASTRA reactor, with one planned shipment with the Argonaut reactor and give an outlook of possible options for the TRIGA reactor.

## 2. Historical survey:

In the period between 1959 to 1965 three research reactors were built and operating until 1999. The first reactor was the MTR type ASTRA reactor at the Austrian Research Centre Seibersdorf (ARCS [www.arcs.ac.at](http://www.arcs.ac.at)) which for a long period was the main research facility for nuclear research in Austria as well as the planning centre for a nuclear power plant. As it is well known this nuclear power plant at the site of Zwentendorf (730 MWe BWR) was never put into operation due to a public negative referendum in 1978. This also effected the further development of nuclear research and in particular the programs at the ARCS. For several non-technical reasons the 10 MW ASTRA reactor was finally shut down on July 30, 1999 and immediately decommissioning started.

The second reactor was planned as typical university training and education reactor, a TRIGA Mark II reactor was selected and first critical on March 7<sup>th</sup>, 1962. This reactor is well maintained and utilized and is in operation without any specific deadline for shut down.

The third reactor was a Siemens ARGONAUT reactor to be also used for university training and education at the Technical University of Graz, it became critical for the first time in May 17<sup>th</sup>, 1965, the maximum licensed power is 1 kW but it is operating only at 10 W. The reactor is still in operation but discussions are going on to shut down and start decommissioning this reactor by 2004.

### **3. Present situation:**

#### **3.1. The ASTRA Reactor in Seibersdorf:**

After 39 years (1960 to 1999) of successful operation, the 10 MW multipurpose MTR research reactor ASTRA [1] at the Austrian Research Centers Seibersdorf (ARC) is now in the state of decommissioning [2]. An immediate dismantling to stage 1 of the IAEA technical guide-lines [3] [4] (storage with surveillance, final shipment of spent fuel and thus complete removal of high-level waste from the site) followed immediately by dismantling to stage 2 of these guidelines (restricted site use) was decided.

##### **3.1.1. Conditioning and radioactive waste management:**

A preliminary evaluation of the expected amount of radioactive waste was performed which showed that it would amount to approximately 320 kg of intermediate-level waste (ILW), about 100 t of activated low-level waste (LLW) and about 60 t of contaminated LLW.

The high-level waste (HLW) and ILW could be removed under the valid operating license of the reactor. According to EU-law, for the removal of the rest of the activity (which amounts to less than 0.001 % of activity one week after the final shutdown) an environmental impact assessment (EIA) was required. The option to start work on stage 1 under the existing operating license allowed for the necessary time to prepare and carry out the EIA.

Apart from standard methods for the treatment of low-level wastes, some new procedures to handle and store special materials had to be developed. For instance, material that will have to be conditioned and stored includes approximately 10 tons of reactor-grade graphite from the inner and outer thermal columns as well as from old-type reflector elements as used between 1960 and 1970 and moderators from late experiments. Over the 40 years of reactor operation, some of the graphite had been exposed to an estimated integrated fast-neutron flux of  $2.2 \times 10^{21}$  n/cm<sup>2</sup>. Since the temperature of the graphite never exceeded 100 °C, annealing of lattice defects did not occur and the accumulation of significant amounts of Wigner energy is to be expected.

##### **3.1.2. Review on work under stage 1:**

The 54 MTR-fuel elements (310.5 kg of HLW) were shipped to US-DOE Savannah River Plant for ultimate disposal in May 2001. In immediate succession and still under the operating license, all experimental facilities and components of the reactor within the vicinity of the core or in intermediate storage within the building e.g. old beam-tube-inserts, 492 kg of ILW and 5212 kg of LLW were removed and treated. In the course of this procedure custom-designed, remote-controlled equipment had to be built and three GNS-Mosaik containers were filled, partly under water, with the remaining material. Also the task of clearing the reactor building from remaining experimental equipment, obsolete storage facilities and the transfer of the structures of the industrial source services including a 21-ton-lead-cell to NES Hot Cell Laboratories were accomplished to 90 % under this stage. Work under stage 1 ceased by May 2003.



Fig 1. Conditioning of ILW – Under water loading of GNS-Mosaik Container

### 3.1.3. Status on work under stage 2:

During 2002 the EIA [5] was prepared. The public hearing was held on December 19<sup>th</sup>, 2002 and was followed by a license to decommission on April 8<sup>th</sup>, 2003.

Preparing stage 2 was well under way during stage 1, nevertheless, actual work could only be started after May 2003. It comprises the dismantling of the primary and secondary cooling facilities and the removal of the biological shield (roughly 1600 tons of LLW). A major part of stage 2 is the “clearing” of the remaining buildings, which are to be used for other purposes, e.g., as interim LLW storage facility. It is intended to take down the structures of the biological shield (400 m<sup>3</sup> reinforced Barite-concrete totaling approx. 1400 tons) by cutting blocks of between 7 and 9 tons (limited by the 10-ton-capacity of the crane) from the inactive zones using wire-cut techniques, and to obtain clearance for the material by measuring the surface activity and by additional internal probing. For surface activity measurements we prepare the use of an available Canberra ISOCS device. A validation of the method under ASTRA conditions is just being carried out with promising results so far.

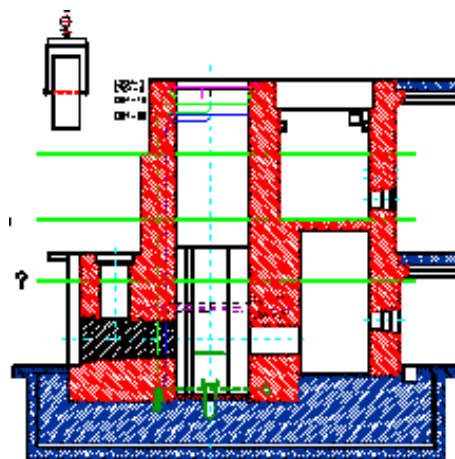


Fig 2. Biological shield – Concept of block cutting

A building directly attached to the reactor was erected to give ample room for clearance measurements and procedures. It was almost completed by end of 2003. Actual cutting is supposed to start in January 2004. The primary water was finally drained from all systems directly connected with the tank and the lower hot cell (usually filled with primary water), the surfaces of the liners were cleaned and stabilized to prevent continuing oxidation and hence occurrence of dust. The liner of the tank was removed to a level 3 meters below the upper floor. The concrete surfaces of the upper hot cell (designed for dry use) were cleaned of contamination. All connections e.g. electricity, pressurized air, primary water supply were disconnected from the shield, wires and tubes were removed. In preparation of the intended cutting work on the first section of the biological shield working platforms were installed in the pool

and in the upper hot cell. Additional measures were taken to control the drain of the cutting fluid and to remove concrete and steel particles from the solution. Calculations show that about 8 tons of cake is to be expected which should be inactive waste by definition. Therefore careful collection and preparations to achieve clearance is essential.

### 3.1.4. Work in progress under stage 2 in 2004

Work planned for 2004 are the dismantling of the inactive parts of the biological shield, radiological clearing of the removed materials, dismantling of the primary and secondary water installations in the pump room, cleaning and radiological identification of the metal parts for further conditioning and decision about methods to be applied for dismantling the active zones of the biological shield. The project's final goal is the release of the buildings for unrestricted use and immediate dismantling was chosen to be the optimum decommissioning strategy. From today's view the estimated completion of the project is expected around June 2006, which is about 6 months later than the original planning predicted.

### 3.2. The TRIGA reactor at the Atominstitut Vienna [6]

The operation of the reactor since first criticality averaged 220 days per year, without any long outages. The TRIGA-reactor is purely a research reactor of the swimming-pool type that is used for training, research and isotope production (Training, Research, Isotope Production, General Atomic = TRIGA). Throughout the world there are around 50 TRIGA-reactors in operation, Europe alone accounting for 8 of them. The reactor core consists presently of 81 fuel elements (3.75 cm in diameter and 72.24 cm in length), which are arranged in an annular lattice. Two fuel elements have thermocouples implemented in the fuel meat which allow to measure the fuel temperature during reactor operation. At nominal power (250 kW), the centre fuel temperature is about 200 °C. Because of the low reactor power level, the burn-up of the fuel is very small and most of the fuel elements loaded into the core in 1962 are still there. A summary of the fuel situation is shown in table 1.

Number of FE	Location	Cladding		Enrichment	Remarks
		Al	SST		
80 + 2 stor.	core	57	25	70 FE 20% 9 FE 70 %	2 instr. FE
13	fresh fuel storage	-	13	20 %	2 instr. FE
8	spent fuel storage	8	-	20%	1 instr. FE
1	hot storage facility	1	-	20 %	cut into 3 pieces
total: 104		66	38		

Tab 1. Fuel element situation at the TRIGA Vienna as of 1. 1. 2004

The TRIGA reactor is heavily used for training and education of students in the nuclear field but also used for national and international training courses with the IAEA and with neighbour countries (Germany, Czech Republic, Slovak Republic, European Nuclear Engineering Network –ENEN). Many cooperation projects exist with the IAEA as the TRIGA reactor Vienna is the closest nuclear facility to the IAEA and the irradiation services has increase since the shut down of the ASTR reactor although in many service requests the TRIGA cannot offer the requested power and neutron flux. At present there is no indication from the government that an imminent shut down of this facility is taken into consideration.

### 3.3. The ARGONAUT Reactor in Graz

The Reactor Institute Graz, attached to the University of Technology Graz, Austria, operates a low power Siemens-ARGONAUT Type reactor (10 W) for education and training in the academic field.

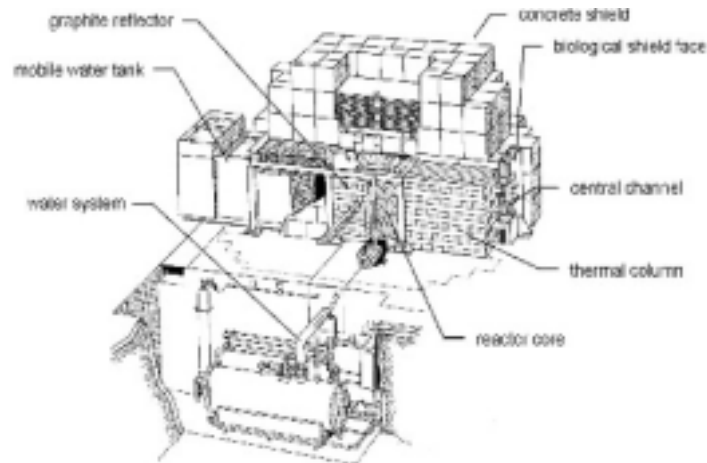


Fig 3. Pictorial view of the Siemens-Argonaut-Reactor Graz.

From May 1965 to April 1985 the Siemens-ARGONAUT Reactor (SAR), located in Graz, was driven alternately by an annular core with 234 low enriched (20% U 235 fuel plates and an asymmetrical one-slab loading with 125 high enriched (90 % U 235) fuel plates. From 1979-1985 a research project in collaboration with the KFA Jülich was performed. This project was directed to investigate the water ingress in systems with pebble-bed high-temperature gas-cooled reactor fuel. Since 1985 all low enriched fuel plates have been located in a dry storage because on 50% of the plates the aluminium claddings were damaged by corrosion. During the reactor operation from 1965-1985 the average reactor power was 1-10 W ( $10^7$ - $10^8$  neutrons/cm<sup>2</sup>s). Presently the core is composed of 108 fuel plates (90% enrichment) from the second delivery at 1969. While 17 fuel plates, also enriched at 90 %, are stored in the fresh fuel storage. It is planned to shut down the SAR-Graz in 2004. All fuel plates (low and high enriched) should be returned to USA. Therefore Graz is involved in negotiations with DOE, to identify a company for the transport of the fuel elements and to discuss details of financing with governmental organizations in Austria. Alternatively the fuel plates (they have a burn-up of only  $10^{-5}$  %, FIFA definition) could also be reprocessed in Europe and the fissile material could be used in a EURATOM member state.

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# STORAGE OF FUEL ELEMENTS COMING FROM DUTCH RESEARCH REACTORS AND LABORATORIES HABOG A NEW MULTI-PURPOSE STORAGE FACILITY

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## ABSTRACT

In the Netherlands, COVRA is in charge of radioactive waste management. COVRA currently operates a high level waste facility (HABOG) in Borsele. HABOG facility has been designed by SGN, AREVA Engineering Business Unit, to receive, condition and store in safe conditions, for a period of approximately 100 years, different types of waste coming from COGEMA and BNFL reprocessing plants as the result of fuel elements reprocessing (coming respectively from Borssele and Dodewaard Nuclear power plants), or used fuel elements from Dutch research reactors or laboratories. The fuel elements, coming from research reactors, are High Enriched Uranium fuel elements located in a MTR2 transport cask. This paper describes the operations conducted in HABOG to encapsulate the fuel elements in a canister (from the cask unloading to the fuel elements canister welding) and the way the fuel elements canisters are stored in HABOG facility in storage wells.

## 1. Introduction

In the Netherlands, COVRA is in charge of radioactive waste management. Besides the high level waste facility (HABOG), COVRA also operates a low level waste treatment facility (AVG), a low level waste storage facility (LOG), a storage facility for TENORM waste and a storage facility for depleted uranium (VOG) at her site in Borsele.

HABOG facility has been designed by SGN, AREVA Engineering Business Unit, to receive, condition and store in safe conditions, for a period of approximately 100 years. It is composed of one building with a possible future expansion of the storage capacity.

The HABOG facility is designed for the following purposes:

- Reception and unloading of transport cask from railway wagons or road trucks,
- Unloading of waste packages from transport cask,
- Checking of waste,
- Encapsulation of High Enriched Uranium (HEU) fuel elements,
- Storage of high thermal release waste in wells cooled by natural air convection:
  - Vitrified waste coming from COGEMA and BNFL reprocessing plants as the result of fuel elements (coming respectively from Borssele and Dodewaard Nuclear power plants) reprocessing, in canisters
  - Fuel elements, coming from the Dutch research reactors CGO and ECN (PETTEN) and IRI (DELFT) in a transport cask, encapsulated in canisters in HABOG facility.
- Storage of low thermal release waste (HAVA) in bunkers:
  - compacted hulls and end-pieces in canisters,
  - cemented technological waste from fuel reprocessing,
  - bituminized waste from fuel reprocessing,
  - miscellaneous waste from research reactors, coming from Dutch laboratory ECN (PETTEN),

At the end of the storage period, the waste will be retrieved in the reverse way to be sent to a final repository or to a reprocessing plant.

The paper aims at :

- Describing the operations conducted in HABOG to encapsulate the fuel elements in canisters (from the cask unloading to the fuel elements canister welding).
- Describing the way the fuel elements canisters are stored in HABOG facility in storage wells.

## 2. Characteristics of fuel canisters to be stored

HEU fuel elements arriving in HABOG facility are encapsulated into fuel canisters. The table below gives the characteristics of the fuel canisters to be stored in HABOG facility.

Origin	PETTEN			DELFT
Site facility	GCO	ECN	ECN	IRI
Waste type	HFR Fuel elements 93,2% U235	LFR Fuel elements 93,2% U235	Miscellaneous U, Pu	HOR Fuel elements 93,2% U235
Number of fuel elements to be stored	1400	29	/	139
Canister content	33 fuel sections	33 fuel sections	33 fuel objects	33 fuel sections
Number of canister to be stored	42	1	3	5
Heat release (W/canister)	693	693	Negligible	693

Tab.1: Fuel Canisters characteristics

## 3. Description of the facility

### 3.1 Building description and features

The HABOG facility is composed of one building with a roughly parallelepiped form, which can be extended later to increase the storage capacity. The building is approximately 75 m long, 46 m wide and the maximum height is 18 m. An annex is installed south-east to receive the trucks and railway wagons carrying the casks. Three stacks are provided on the roof for cooling air discharge to the atmosphere. A fourth stack is designed for building ventilation air discharge.

The building has three main levels. The general arrangement is the following:

- In the north part of the building, HAVA waste is stored,
- In the south part of the building, the vitrified waste and fuel elements are stored,
- In the east part of the building, reception operations are performed.

### 3.2 Implemented functions for HEU fuel elements conditioning

The main functions performed in the HABOG Facility are:

- Transport cask reception, preparation and shipping

HEU fuel elements arrive in HABOG facility located in a GNB-MTR2 transport cask. The transport cask arrives in vertical position on a trailer and is transferred and placed onto the cask transfer trolley. After reception of the cask in the reception hall, the cask is prepared at the preparation station and then transferred and tightly docked under the hot cell.

For empty transport cask shipping, the same operations are performed as for reception but in the reverse order. Before cask reshipment, non contamination checking is performed.

- **HEU fuel elements encapsulation**  
An encapsulation unit is implemented in the hot cell for HEU Spent Fuel to be stored in the Facility. Fuel elements have to be conditioned in tight canisters which have to be filled with helium to prevent any corrosion and guarantee their containment during storage.  
The HEU fuel elements are unloaded out of the cask by means of a transport basket which is directly transferred into the canister. The basket accommodates 33 fuel elements. The canister lid welding is then operated (large lid). The conditioning operations (vacuumization and helium filling of the canister) are performed, before welding the small canister lid. Then the canister tightness test is performed into a tank and finally the fuel canister is decontaminated, using high pressure water, prior to transfer to the storage vault.
- **Handling and storage of fuel canisters**  
Once transferred by the in-cell trolley to the storage hall, fuel canisters are rehandled to their storage well by means of a remote controlled nuclearized crane. Interlocks prevent personnel entering the hall during canister handling operations.  
Fuel canisters and vitrified waste are stored in two identical vaults, each vault containing dedicated wells for vitrified waste and for fuel canisters (not the same size). Each vault has 7 wells for fuel canisters, 27 wells for vitrified waste, 2 wells for overpacks of fuel canisters, and 2 wells for overpacks for vitrified waste. In addition, a third vault, identical to the others, is available as a spare. This vault may only be used for unloading one of the other vaults, i.e. the license allows COVRA only to use two of the three vaults. COVRA must always be able to unload a complete vault for inspection.
- **Auxiliary functions**  
Building ventilation  
Electric power supply and distribution  
Instrumentation and control Utilities

#### **4. Storage process**

Packages stored in HABOG facility are divided in two categories:

1. “Heat-producing packages”: an efficient cooling is necessary to guarantee the integrity of the first containment barrier. These packages are:
  - the spent Highly Enriched Uranium (HEU) fuel canisters,
  - the vitrified waste canisters.
2. “Non-heat producing packages”: the low quantity of heat produced means that a simpler storage process can be used.

The cooling process is selected according to the maximum allowable temperatures in normal and abnormal situations.

The selected storage and cooling processes are:

- For heat-producing packages: storage in vertical wells cooled by natural convection. A vertical airflow circulating between the external wall of the storage well and a double jacket cools the canisters. This process is implemented in numerous facilities in France, the most recent one being EVSE in La Hague reprocessing plant.
- Non-heat producing waste is stored in bunkers. The heat and the radiolysis gases are removed by mechanical ventilation. In case the mechanical ventilation fails, the decay heat is released by conduction through walls and the slab of the bunkers.

#### **Specific process issues for fuel and vitrified waste canisters storage**

The storage area for these canisters consists of three dry vaults, separated by a wall ensuring radiological shielding. The modularity of the storage vault structure allows a further extension of the

storage capacity. Fuel canisters and vitrified waste canisters are stacked on five levels in vertical stainless steel wells cooled by natural convection.

External double jackets are installed around the wells to improve cooling efficiency. In addition, they reduce heat radiation to the concrete walls and consequently reduce the temperature of these walls. This process requires a horizontal plate to distribute the airflow between the vertical wells and the double jackets.

The air inlet and outlet are designed to maintain concrete walls and stored package temperatures below maximal allowable values. These are summarised in the table below for the heat-producing waste storage:

	Heat produced*	Max. allowable temp. (° C)		Calculated temp. (° C)	
		In normal conditions	In accident conditions	In normal conditions	In accident conditions
Vitrified waste canisters	2000 W/canister (2500 W max.)	500	610	475	495
Fuel canisters	693 W/canister	250	425	215	250
Concrete	95	(105 locally)	180	90	130

\* these values are design values. The actual heat load will decrease with time.

Tab.2: Maximum allowable temperature for canisters and concrete

However, decay heat from fuel canisters and vitrified waste is significantly different. Therefore thermo-aeraulic studies were carried out to check that these two types of canisters could be stored in the same vault.

The design of the facility takes also into account the following features:

- Expansion of the storage wells due to temperature rises: the storage wells are hang from the top slab and guided on the bottom of the compartment, enabling free expansion,
- Load drop absorption: proper shock absorbers are implemented at the bottom of each well,
- Prevention from corrosion of storage wells:
  - the storage wells are tightly closed and placed in inert atmosphere of Argon to prevent possible corrosion risk due to corrosive gases produced by the air radiolysis.
  - austenitic stainless steel with Molybdenum is used for the storage wells, in order to reduce tendency to pitting corrosion, taking into account the salt content of the air due to the proximity of the sea..
  - electrostatic filters are installed at air inlets.
  - Moreover, it is possible to remove the storage wells and replace them by new ones. The wells are actually hanging from the slab through sleeves and are guided at the bottom. They can be removed upwards after the canisters have been relocated in the spare vault. New wells can be installed.
- First barrier monitoring for Fuel canisters: periodic inspections of the well by sampling the well atmosphere cavity to detect any canister leakage.

## 5. Main design issues

As for any nuclear facility, safety is the major issue for HABOG design:

1. The design complies with the rules of the American Standard ANSI-ANS 57-9, with minor adaptations due to specific aspects.
2. Two containment barriers are required between the radioactive materials and the environment.
3. The design external events considered are:
  - Flooding up to level + 2.71 m above the finished ground floor (i.e. +9.96 m above the sea level) Regarding flood protection two means are implemented:
    - A special waterproof concrete (special mix and cooling of concrete during pouring) is used for the storage compartments,
    - The building may be flooded without any consequence (diesel above the flooding level).
  - Earthquake; a horizontal free-field peak acceleration of  $1 \text{ m.s}^{-2}$  is considered.

On the basis of ground acceleration, a spectrum was drawn up for each floor level of the building. This spectrum was used for designing items of equipment located in the area involved (obviously a seismic design applies to equipment ensuring the integrity of at least one containment barrier).

- Aircraft crash: the General Dynamic Falcon Fighter F16-1 is the characteristic design aircraft (direct and indirect effects).

Ten impact perpendicular points on the building were considered. They generate an acceleration, and a spectrum is calculated. As for earthquake, this event has to be considered for numerous pieces of equipment. Therefore the most stringent of both spectrums – earthquake and aircraft crash – is considered when designing equipment.

Aircraft crash is also considered as a possible cause of disturbance of the cooling airflow: blockage of air inlet up to 95% or breakage of exhaust stacks.

- Pressure wave resulting from an external explosion: a pressure of 0.3 bar is considered. The building may be submitted to an external overpressure in case of an explosion around the facility (in case, for example of an accident of a gas transport ship in the Westerschelde, nearby the site). The building design as well as the design of the metallic containment barrier for the heat producing waste takes into account such pressure wave. A gas detection system at the site border allows ignitors to burn any gas cloud before entering the building.

- Whirlwinds: a maximum wind velocity of  $125 \text{ m.s}^{-1}$  is considered.

4. The operational requirements are also a major issue for design; they can be summarised as follows: HABOG is designed for at least 100 years of operation and the consideration of the existing AVG facility on the same site.
5. The last major issue results from the range of “waste suppliers” and consequently the numerous types of packages to be received, handled and stored in one facility (for every type of waste different handling means and tools are necessary).

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# **SUCCESSFULLY SHIPPING FRESH FUEL FROM ROMANIA TO RUSSIA: THE EXPERIENCE**

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## **ABSTRACT**

In September 2003, a shipment of fresh fuel containing highly enriched uranium (HEU) was successfully transported from the Institute for Nuclear Research in Pitesti, Romania to the Novosibirsk Chemical Combine in Russia. This was the first fresh fuel shipment carried out under the Russian Research Reactor Fuel Return (RRRFR) Program and was a result of the cooperation between the International Atomic Energy Agency, the Romanian Government, and the Russian Federation. The RRRFR Program is managed by the U.S. Department of Energy's National Nuclear Security Administration and has as its primary mission to prevent the theft or diversion of Russian-origin fissile material by eliminating stocks of HEU at Russian-supplied research reactors outside of Russia. This paper will describe the experiences gained from the shipment including: facility preparation; regulatory documentation; security; and schedule.

## **1. Introduction**

Since December 1999, the United States along with the International Atomic Energy Agency (IAEA) and the Russian Federation have been working together on the Russian Research Reactor Fuel Return (RRRFR) Program. The goal of this program is to support the return to the Russian Federation of fresh and irradiated high-enriched uranium (HEU) fuel, currently stored at foreign research reactors, that was originally supplied by Russia or the former Soviet Union. As an integral part of the program, participating countries have agreed to either convert their research reactors from high enriched to low enriched fuel when a suitable low enriched fuel had been qualified or shutdown the reactor. In return, the U.S. offers assistance on the removal of the fresh and spent fuel giving highest priority to the return of the high enriched uranium.

Romania had 200 assemblies/rods containing 14 kg of fresh HEU in storage in Pitesti and Bucharest. A meeting attended by representatives from the IAEA, the National Commission for Nuclear Activities

Control of Romania (CNCAN), the Institute for Nuclear Research (INR) in Pitesti, the Russian R&D Company SOSNY, and the U.S. was held in June 2003 to discuss the accelerated return of the fresh fuel. The schedule and critical path were developed in July with all parties working in parallel on the required contract and regulatory documentation. On August 21, 2003, the contract for the return of the fresh fuel was signed by the IAEA, SOSNY, and Romania and in September 2003, the shipment of 14 kg of fresh HEU fuel was successfully transported from Romania to Russia. This was an important milestone as it not only was the first repatriation of fuel under the RRRFR program but also defined the legal process for future shipments. This paper will identify the participants, briefly describe the fuel, discuss the regulatory documentation required, and summarize the transportation of the fuel to the Novosibirsk Chemical Concentrates Plant (NCCP) in Russia.

## 2. Shipment Participants

Contractor	International Atomic Energy Agency
Consignor	Institute of Nuclear Research, Pitesti, Romania
Consignee	Novosibirsk Chemical Concentrates Plant, Novosibirsk, Russia (End User)
Operator	R&D Company "SOSNY" plc, Dimitrovgrad, Russia
Carrier	Aircraft Company "Volga-Dnepr", Ulyanovsk, Russia
Assisted by	U.S. Department of Energy RF Minatom

## 3. Description of HEU fuel

There were two types of fresh Russian origin HEU fuel in Romania. First, IRTM-H type fuel, 80% enrichment, was imported in 1973 from the former Soviet Union for the refurbishment of the 2 MW, VVRS research reactor at the Institute for Atomic Physics in Bucharest. The refurbishment was never completed and the total existing amount of 50 IRTM fuel assemblies was transferred from the Institute for Atomic Physics in Bucharest to the INR in November 1984. The assemblies were to be used in a multi-zone zero power reactor designed and constructed in Pitesti for CANDU fuel testing and qualification. These tests were later renounced as unnecessary and the multi-zone zero power reactor project was stopped prior to placing in operation. The second type, C-36 B type fuel, 36% enrichment, was to be used in the VVRS research reactor at the Institute for Atomic Physics. It was similar to the original nuclear fuel of the VVRS reactor and consisted of 150 thin fuel rods. The reactor was permanently shutdown in 1997 for reasons linked to the aging of reactor components. As part of the shipment logistics, the fuel was transferred to the INR in Pitesti in August 2003.

Each IRTM-H fuel assembly consisted of four concentric tubes with adequate spacing for cooling. The tubes have rounded edges, active lengths of 580 mm and total lengths of 882mm. The square cross section measures 67 mm x 67 mm. The tube walls, 2 mm in thickness, were made from aluminum having a core, 0.4 mm thickness, of uranium - aluminum alloy with a uranium content of 37%. C-36 B fuel type is a cylindrical rod 10mm in diameter and 588 mm long. The following table describes additional fuel characteristics.

Fuel unit type	C-36 B (fuel rods)	IRTM-H (fuel assemblies)
U total / <sup>235</sup> U mass in one fuel unit, kg	0.0258 / 0.00945	0.20593 / 0.16571
Mass of one unit, kg	~0.13915	~3.3794
Outer diameter, m	0.01	NA
Height, m	0.588	~0.88
Cladding material	Al	Al
Fuel composition material	U-Al alloy	U-Al alloy
Fuel units number	150	50
U total / <sup>235</sup> U mass in all fuel units, kg	3.8700 / 1.41750	10.29658 / 8.28554
Total mass of all units, kg	20.8721	168.97

#### 4. Regulatory documents and process in Romania

Government approbation was required to return the fresh fuel due to the fact that it was public property. Based upon this, a government injunction, creating the legal framework for returning the Russian-origin fresh HEU fuel from Romania to the Russian Federation, was issued stipulating the: (1) return of Russian-origin fresh HEU fuel free of charge to the Russian Federation; (2) return based on the contract between the IAEA, Russian Federation and CNCAN; and (3) delivery of fuel based on protocol from the INR to CNCAN.

The tripartite contract stipulated in Article 2 that the work was to be performed in accordance with the norms, standards and regulations valid in Romania and the Russian Federation taking into account the relevant IAEA Safety Series. The Romanian regulations taken into consideration were:

- Law on safe deployment of nuclear activities (Law no.111/October 1996)
- Fundamental norms for safe transport of radioactive materials
- Norms for transport of radioactive materials - authorization procedures
- Safeguard norms in nuclear field
- Physical protection norms of special nuclear materials and nuclear installations

Under law on safe deployment of nuclear activities, the export of nuclear fuel (Article 2) requires an authorization issued by the Commission with observance of the specific authorizing procedure and fulfilling certain conditions as: *The applicant of the export authorization obtains from his external partner the necessary guarantees from which it shall follow that aforesaid partner will not use it for purposes that would be prejudicial to the international obligations assumed by Romania or to the national security. Likewise he shall have to prove that the export complies with the provisions under the law and specific regulation.*

Based on this Romanian regulatory framework INR had to apply for:

- Export authorization from CNCAN
- Shipment authorization from CNCAN for road transport
- Export license from National Agency for Export Control

Shipment authorization required the official application to contain essential information concerning: legal person (consignor, consignee), address, type and number of packages, description of the transported radioactive material (identification, physical and chemical form, uranium mass, fissile mass), package data (identification marks of each package, gross weight, dimensions), shipment data (total transport index, criticality index, category of the package, radiation level on the surface (packages), route, end destination, transport means, estimated date of the transport), assigned category, label for radioactive content, United Nations number for the consignment, list of applicable procedures, person responsible and competent authority certificate of approval for the package design.

In order to receive the export license from the National Agency for Export Control the official application was required to be accompanied by: the export authorization from CNCAN, the import license for nuclear materials from the Competent Authority of the Russian Federation and End User Certificate from the Novosibirsk Chemical Concentrates Plant of the Russian Federation.

SOSNY representing its subcontractors had to apply for:

- Validation of type approval certificate for packages transported by air
- Air shipment authorization of radioactive materials involving Romanian territory
- Air transport authorization applied for by Volga-Dnepr (Russian carrier company)

In order to get the validation of the type approval certificate from CNCAN the official application was accompanied by the following: copy of the type approval certificate issued by the Competent Authority from Russia covering air transport, technical description of the package, the safety report issued by the Russian Competent Institute which contains the criticality calculation for the consignment to be performed by air according to IAEA TS-R-1, including article 680, "Procedures for loading and transport listed in the Russian authorization".

In order to get air transport authorization from CNCAN the official application contained the following: legal person, address, copy of the air operator license issued by the Competent Authority on the air

transport, copy of the transport license for the transport of radioactive materials issued by competent authority in nuclear field from origin country, and the responsible person.

Following an evaluation of information provided by each participant in the above activities the Romanian authorities (National Commission for Nuclear Activities Control and National Agency for Export Control) issued the legal documents.

## **5. Regulatory documents and process in the Russian Federation**

Russia, being an IAEA member, acted as the project executor and guaranteed the program implementation from the position of the peaceful usage of nuclear materials. Minatom supported the necessity and expediency of importing the fresh fuel. The responsible organization selected to carry out the work from the Russian party was the R&D Company "SOSNY".

In accordance with the Russian Laws, the special license for nuclear material import was required. The import license was issued after of the coordinating documents concerning responsibility for the consignment, technical and economical issues and relations between interested parties had been legally implemented.

The main document that substantiates the shipment safety is the certificate of approval for package design and shipment, which is devoted to the following aspects:

- Assurance of nuclear and radiation safety
- Transport vehicles and route
- Operating conditions of transport packagings
- Safety assurance under accident conditions
- Quality assurance during the shipment

Certificate of approval RU/3040/IF-96T (Rev.0) was issued for the shipment. In accordance with this certificate, the nuclear and radiation safety of the package under normal and emergency conditions was assured according to the "General Rules of Safety and Protection at Transportation of Nuclear Materials" (GRSPTNM-83) requirements and the IAEA ST-1 regulations. The Russian Special-purpose Services (Transportation Management, Emergency Situation Centre and Accident Technical Centre of Minatom, dispatcher services of the involved enterprises, Government Civil Aviation Service of Ministry of Transport of RF, authorities of Ministry of Internal Affairs) provided the emergency preparedness measures during the shipment in Russia.

The "Special Requirements for Shipment by Air" document was issued to ensure fulfillment of the international and Russian requirements for the safe shipment of fissile materials by air (ICAO-DOC 9284-AN/905 rev. 2003-2004, ICAO-DOC 9481-AN/928 rev. 2003-2004, "Rules of transportation of nuclear materials by air".

## **6. Shipment**

The shipment was carried out in three phases. In the first phase, the fuel was transported in the TK-C16 containers by truck to the Otopeni Airport. It was transported by air to Novosibirsk as part of phase 2. The last phase was the transport of the containers by truck to the Novosibirsk Chemical Concentrates Plant. Air transportation was chosen for the longest phase although it was possible to use a truck and rail transport. Air transportation offered the following advantages: (1) simplified procedure and reduced costs of boundary passing; (2) reduction of costs for ensuring physical protection of the consignment; and (3) acceptable costs in comparison with the other transport types taking into account transit and guard costs.

The obligations of the INR (Consignor) were to:

- Deliver the fresh fuel as one lot in accordance with the Free Carrier (FCA) to Bucharest Otopeni Airport using the containers provided by SOSNY
- Clear the containers with fresh fuel through Romanian customs and put them at the disposal of the Carrier at Bucharest Airport

- Provide the following documents:
  - Packing list
  - Commercial invoice for the goods
  - Commercial invoice for the containers
- Provide copy of export shipping Customs' Declaration with customs labels of Romania
- Provide the items, equipment and facilities for the removal of the fuel from storage containers and its placement in the shipping containers
- Obtain the necessary import permits for empty containers of the SOSNY for the loading and transportation of the fresh fuel and for their re-export at the end of the work.

The TK-C16 containers were delivered one week prior to the shipment and have an Industrial Package Type 2 (IP-2) certification. Other important characteristics of the containers according to the container certificate are:

- |                                 |                                     |
|---------------------------------|-------------------------------------|
| • Dimensions (mm): 740x655x1200 | • Radioactive content type: LSA-III |
| • 7 fuel positions              | • UN classification: UN 3325        |
| • Channel diameter (mm): 110    | • Safety criticality index: 2       |
| • Full container mass (Kg): 250 |                                     |

In agreement with SOSNY the fuel was loaded into eight containers. The first seven had 7 IRTM-H fuel assemblies each, while the last contained all 150 C-36 B fuel rods (in 6 bundles of 25 rods each) and one remaining IRTM-H fuel assembly. The IAEA inspectors for documentation purposes assayed an assembly from each container. Two IAEA safeguards seals were placed on each container prior to removal from the storage facility. Radiation dose rates from the containers during the shipment did not exceed  $2.5 \times 10^{-3}$  mSv/h on the outside surface of the vehicle and  $7.5 \times 10^{-4}$  mSv/h at 2m from the vehicle surface.

Two detailed procedures, "Handling and Loading of Fresh HEU Fuel Existing in INR for its Transportation to Bucharest Otopeni Airport" and "Radiation Surveillance During Transportation of Unirradiated Fuel", were prepared based on the specifications of the fuel, containers, and equipment. The physical protection of materials during transportation was done by the organization empowered by law under contract. The physical protection plan during transportation was made by the representative of the counterpart and accepted by INR. The containers were transferred from the truck to the aircraft using the hoists and monorails on the aircraft as representatives of the Carrier Company implemented the assignment of responsibility for the consignment. For security and cost reasons, the time the aircraft was parked in the tie-down area was kept to a minimum. The total actual time on the ground was only three hours. At the Novosibirsk airport the transport packages were delivered to the Customs Carrier and then to the Customs storage of the Consignee (JSC "NCCP"). After issuing Customs documents the Goods were transmitted to the End User. The following was performed during the acceptance:

- Removal of the IAEA seals by the authorized representative of RF Minatom
- Acceptance inspection of the Goods

The removed seals were transmitted to IAEA for integrity test. Acceptance inspection of the consignment confirmed that consignment characteristics complied with the shipment documents.

## 7. Conclusions

Due to the excellent coordination between the INR, CNCAN, MinAtom, Sosny, IAEA and the U.S., the first shipment under the RRRFR program was not only planned and executed in an accelerated period of nine weeks, but also completed on schedule and without incident. It proved to be a fine example of how the international community works together to strive to achieve the goals of the non-proliferation programs.

# **THE UNITED STATES FOREIGN RESEARCH REACTOR (FRR) SPENT NUCLEAR FUEL (SNF) ACCEPTANCE PROGRAM: 2004 UPDATE**

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## **ABSTRACT**

The United States Department of Energy (DOE), in consultation with the Department of State (DOS), adopted the *Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* in May 1996. As of March 2004, the Foreign Research Reactor (FRR) Spent Nuclear Fuel (SNF) Acceptance Program has completed 27 shipments. Over 5,900 spent fuel elements from eligible research reactors throughout the world have been accepted into the United States under this program. Shipments are continuing on schedule, although a climate of increased security now exists following the terrorist attacks of September 11, 2001. Shipments of all types of radioactive material, both internationally and within the United States, are encountering greater public scrutiny and generally increased security and physical protection. The Acceptance Program has now passed the approximate midpoint of its duration; the current Acceptance Policy will expire in 2009 (fuel must not be irradiated after May 12, 2006). As the Acceptance Program draws closer to its termination date, an increased number of requests for program extension have been received. At the recent Reduced Enrichment for Research Test Reactors (RERTR) Conference in Chicago, Illinois in October 2003, research reactors signed a petition requesting extension of the Acceptance Policy. The extension question is under consideration by DOE senior management. A decision is expected soon; however, eligible reactor operators interested in participating in this program are strongly encouraged to evaluate their inventory and plan for future shipments as soon as possible.

## **1. Introduction**

The Foreign Research Reactor (FRR) Spent Nuclear Fuel (SNF) Acceptance Program, now in the eighth year of implementation, has to date completed 27 shipments safely and successfully, and another is expected to be completed very soon. Twenty-seven countries have participated so far, returning a total of 5,915 spent nuclear fuel elements to the United States for management at Department of Energy (DOE) sites in South Carolina and Idaho, pending final disposition in a geologic repository. 22 of the 27 shipments, containing aluminum-based spent nuclear fuel from research reactors, went to the Savannah River Site (SRS) in South Carolina. The most recent shipments were completed without incident, arriving at the Savannah River Site (SRS) on December 3, 2003 and the Idaho National Engineering and Environmental Laboratory (INEEL) on September 28, 2003. This last was the fifth shipment containing Training, Research, Isotope, General Atomic (TRIGA) spent nuclear fuel. During the next year (March 2004—March 2005), the program is planning a potential four shipments of fuel from reactors in Europe and Asia.

The FRR SNF Acceptance Program focuses on the planning and implementation of these shipments of research reactor spent fuel to the United States in support of worldwide nuclear nonproliferation efforts. Along with shipment logistics, the Department continues to address many other issues of importance to the program. As we pass the approximate midpoint in the duration of the current Acceptance Policy, we continue to address and resolve issues that may impose barriers to program success. The most critical issue associated with the program remains early scheduling and coordination of planned shipments. As DOE programs refocus their priorities on mission-critical goals, it becomes even more important that the Department clearly understands each Reactor Operator's plans and intentions so planning can be well integrated and supported.

The FRR SNF Acceptance Program works closely with federal, State and international contacts during planning for each shipment, thus ensuring that when the time comes for shipment, the transports occur smoothly and without incident. Open and responsive communication among international participants is essential, especially with regard to cask licensing. The Acceptance Program enjoys a very good working relationship with Nuclear Regulatory Commission (NRC) staff and, as such, wishes to take every measure possible to respect this relationship by ensuring that cask applications are timely and complete. In the past, the Acceptance Program may have been able to rely on NRC to readjust its workload to accommodate a special request for package review and certification under less than optimum deadlines. However, the post-September 11 environment now has U.S. federal staff weighted down with evaluations into safeguards practices and preventive measures. Beginning in early 2004, DOE has been meeting periodically with NRC to discuss planned shipments and forecasted support required to meet Acceptance Program needs. DOE and NRC are working now to finalize a new Inter-Agency Agreement that will support certificate reviews and other key activities.

Over the past year, DOE programs that ship SNF have been working to better integrate their planning. DOE works with States and Tribes to plan for shipments—some shipments to DOE sites are subject to NRC regulations, and others are subject to DOE requirements. States have requested DOE handle both kinds of shipments the same way for consistency. Although this is already done in most areas of logistical operations, some practices do differ slightly and DOE is working toward a more uniform approach. Although this is not an issue specific to shipments of SNF from reactor operators abroad, it should be understood that The Department, other Federal agencies, and State, Tribal and local governments have complex planning relationships on the receipt end, and are not yet at the point where shipments are considered “routine.”

Security issues continue to occupy a central focus as a result of the September 11, 2001, terrorist attacks. The DOE, working in conjunction with international, Federal, State, Tribal and local authorities, is reexamining procedures and requirements for transport of radioactive material, particularly commodities such as spent fuel. A temporary halt on all DOE-owned shipments of radioactive material in the U.S. was ordered by senior DOE management immediately after the 9-11 attack, and again in October 2001 after commencement of the air campaign over Afghanistan. This action was taken in conjunction with other security measures throughout the DOE weapons complex and the nation at large. However, DOE was allowed to continue a shipment that arrived on October 18, 2001, from Europe and Asia, primarily due to the ability of the Acceptance Program and participating Reactor Operators to react quickly. DOE was, and remains, in close contact with the Federal Bureau of Investigation, the Department of Defense, the NRC and other federal agencies responsible for transportation and infrastructure safety. The NRC implemented a series of Compensatory Measures for its licensees to follow in enhancing security for SNF shipments; the measures were later incorporated into an NRC Order. These new measures are not expected to impact the FRR SNF Acceptance Program adversely; in fact, many of the proposed measures are based on additional security measures the Program has been following since its inception. While the changed security climate requires additional time and resources to coordinate among different law enforcement agencies, we are confident they will continue to ensure that these are among the safest and most secure shipments undertaken throughout the world.

Historically, spent nuclear fuel shipments have not been considered attractive targets for terrorist attack or sabotage. However, across the globe spent fuel shipments are a matter of high concern for public officials due to the perception that spent fuel transportation presents a heightened risk as compared to transport of other hazardous materials (e.g., propane and liquid natural gas). In addition, inspection, escort and other enforcement duties related to safe, routine transport can burden law enforcement and emergency response assets which may be needed elsewhere. Recently, a planned barge shipment of a decommissioned commercial reactor vessel was postponed, in part because of concerns raised by countries along the route. As with other recent campaigns such as the transport of mixed-oxide fuel and related wastes between Japan and France, the United States continues to strongly believe that lawful shipment of nuclear cargoes on the high seas should not be impeded, either by nations along potential routes or by non-governmental organizations. Fuel shipments related to the FRR SNF Acceptance Program have experienced localized controversy from time to time, but have

not encountered opposition of this magnitude, perhaps because the ultimate goal of the Program is to support nonproliferation efforts. DOE will, however, continue to follow shipping campaigns of other types of nuclear material with interest.

Within the United States, discussions and advances concerning the Yucca Mountain permanent geologic repository have renewed and invigorated ardent support, both pro- and anti-nuclear. Congress ultimately voted to continue the siting process at Yucca Mountain, and a repository there may become operational as early as 2010. The public has voiced opinions on both ends of the anti-nuclear spectrum; they are not comfortable with transport of nuclear material across interstate roadways, nor are they comfortable with having spent fuel and other high level radioactive waste stored at the 131 temporary storage facilities across the United States. The contentious debate over SNF transportation safety can be expected to continue, and likely increase, as the licensing process continues. Proposals of varying complexity have been made in Congress to enact additional measures related to SNF transport; however, none have been enacted to date and it is impossible to determine at this time what effect, if any, such measures may have on current shipments of SNF. Like others interested in permanent disposition of spent fuel, the Program continues to monitor closely developments on this issue.

The Acceptance Program has now passed its approximate midpoint in duration. More than ever before, DOE and reactors need to work together to schedule shipments as soon as possible, to optimize shipment efficiency over the remaining five years of the program. Countries interested in participating in the Acceptance Program should express their interest as soon as possible so that fuel and facility assessments can be scheduled and shipments may be entered in the long-term shipment forecast. New and current Acceptance Program participants should also coordinate with DOE approximately 18 months in advance to ensure DOE can meet the Reactor Operator's plans and needs. Accelerated schedules are possible if there are no significant issues over past shipments. However, decreasing resources and coordination requirements with other agencies such as the NRC and Department of Transportation have the potential to limit DOE capability to support these accelerated schedules. Additionally, the Acceptance Program may not be able to accommodate a large number of requests at the end of the program, particularly from geographically isolated regions.

DOE expects about two dozen shipments will take place between now and the end of the program in May 2006 (May 2009 for SNF irradiated before May 2006). Under current feedback from many participants, DOE Acceptance Program personnel do not believe there will be any delays toward the end of the program. The schedule is becoming more limited, however, and if eligible reactors are still evaluating whether to participate, the Department strongly recommends they step up as soon as possible. DOE will try to accommodate everyone wishing to participate, but last-minute requests may not be able to be met.

A primary goal of the Acceptance Program is to support worldwide nonproliferation efforts by shipping fuel containing high enriched uranium (HEU) enriched in the United States for management and disposition. Integral to this process is the U.S. assistance offered in helping reactor operators convert their cores to low enriched uranium (LEU) as the reduced enrichment fuels become qualified and available. In addition, DOE plays a strategic role in ensuring a supply of enriched uranium for fuel fabrication. In the Acceptance Program, we realize our primary goal is intertwined with the missions of the Reduced Enrichment for Research and Test Reactors (RERTR) Program and the Enriched Uranium Operations group from DOE's Y-12 plant in Oak Ridge, TN. DOE Acceptance Program staff remain committed to working with staff in these other program offices within DOE to do whatever we can to assist in smooth transitions of core enrichment level and a reliable supply of fuel.

Some reactor operators and contractors have voiced support for extension of the program expiration date beyond 2006 (2009 for shipments of fuel irradiated prior to May 2006). DOE appreciates and is seriously considering the recommendations provided in a petition from reactor operators involving eligible participants during the last RERTR Conference held in Chicago, Illinois in October 2003. The Department understands that research reactors perform critically important medical and other research and testing work throughout the world, and that some reactors for a variety of reasons, may be forced

to curtail operations if an extension is not granted. A decision on extension is expected soon; however, the potential ramifications of an extension, and what form an extension might take, are by no means certain. Fuel acceptance and eventual geologic disposal have been contentious issues in Congress, among States hosting fuel management facilities, and in the court of public opinion. Even if a renewal of the policy were to be undertaken, there could be substantial delays while requisite environmental studies, and the litigation that may result, are completed. Therefore, DOE strongly suggests that eligible participants, who desire to disposition their SNF through the DOE FRR SNF Acceptance Program, ship all eligible material within the currently authorized window of opportunity.

One thing remains certain: the United States is committed to supporting worldwide nonproliferation goals such as those for which this program was designed. Accepting eligible fuel sooner rather than later is a goal toward which we are striving. We hope to work with all remaining eligible research reactors to plan for shipments of their eligible spent fuel. The DOE continues to support research reactor operators' needs and would be happy to meet any interested parties to discuss the program. The Acceptance Program is preparing to send cables to eligible countries through the US Department of State, to request they consider participating if they are not already doing so.

## **2. Conclusion**

We will have many challenges as we continue to plan for shipments during the remainder of the Acceptance Program. The United States, and the international nuclear transport community, will have a more watchful public. Some of the issues DOE and other agencies are examining now include impacts for State, Tribal and local resources should shipments be halted again, or additional requirements imposed. As the FRR SNF Acceptance Program works toward accomplishing its mission over the next five years, we strongly encourage reactor operators to work closely with our technical points-of-contact to ensure shipping schedules are accurate and achievable.

# A GLOBAL CLEANOUT PROJECT

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## ABSTRACT

Once upon a time there was a great dream of a atomic age for mankind. The technically advanced nations of the world promised amazing opportunities for all and promoted their materials and equipment often by supplying them throughout the world in the race to gain market share. For a time, the dream was fulfilled, as many countries embraced the new technologies initially for research and later for medical, power and even transport opportunities. In due course, the demand subsided and in some countries has even been reversed with plans to terminate outdated or unneeded facilities. This brings up the issue of nuclear waste disposal.

It was not until post “Sept 11”, that the US and other countries and NGOs began to seriously think about the larger implications of terrorist use of ‘Dirty Bombs’. This has led to the potential of a wider program aimed at the possible return of a larger amount of “abandoned” materials. Thus the “GLOBAL CLEANOUT PROJECT” was borne. Many in the nuclear fuel cycle will have a stake in this and can play a role in an international community to deal with the issue and it has to be started now.

### 1. Historical considerations

In December 1953, fifty years ago, the US president Dwight D. Eisenhower announced the ‘Atoms for Peace’ program at a United Nations conference. Under this program, the US started to supply enriched uranium and research reactor technology to nations that agreed not to produce nuclear weapons. The commercial atomic age was born. At that time, the experts expected that atomic power would be used for a myriad of applications besides electricity production and naval propulsion for military and civilian vessels.

While many military vessels are nuclear powered, e.g. aircraft carriers and icebreakers in the Russian fleet, only three nuclear powered commercial vessels were built. These were the ‘N.S. Savannah’ (US), the ‘N.S. Otto Hahn’ (Germany) and the ‘N.S. Mutsu’ (Japan). However, each of them had been shut down after some years of operation, as they were financially not viable.

Governments financed programs for air transport and space applications. Optimistic scientists even believed that peaceful nuclear explosives could dig canals. Of course, the world needed to see demonstrations of the potential before people could rely on it. The US and other countries including Britain, Canada, France, Russia and later China had new technologies and sought commercial advantage for their industrial concerns. The university system of the US became training ground for students from the US and abroad virtually without restrictions, which is no longer the case today. Trade exhibits around the world including those in Geneva, New York and Chicago would display

nuclear technologies. However, to really capture the attention of the potential customers, real examples of the technology had to be provided.

Therefore, the US and other countries began to export small research reactors. The reactors were designed for teaching and training purposes, physical experiments and medical isotope production as well as to familiarize countries with nuclear power. The idea, that this concept would lead to the purchase of larger dedicated power reactors came true in many cases.

Countries competed in selling facilities and providing assistance to get close relationships with different countries, especially during the time of the Cold War. The US leased and later on sold the uranium for fuelling the reactors to the operators of the facilities. This included highly enriched uranium (HEU) and plutonium. NUKEM and EDLOW cooperated in the late 1960's to move both plutonium oxide and plutonium nitrate to Europe for use in advanced reactor programs. The US and mainly Canada exported heavy water together with their reactors. More and more technology, materials and equipment was distributed to more and more countries.

In 1973, the first oil shock accelerated the process to replace fossil by nuclear power plants. However, at the same time the demand of electricity began to decline accompanied with the worldwide economical recession. In 1979, the accident at the 'Three Mile Island (TMI-2)' power reactor in the US contributed to a number of cancellations of contracts for constructing nuclear power plants, as did the latter Chernobyl-4 accident in the Ukraine in 1986. These facts led to the major decrease in the perceived future for the nuclear industry. Orders declined, prices fell, inventories increased. The major industrial players began to seek exit strategies.

One decade later, the Soviet Union collapsed and the Cold War ended. It was no longer necessary to court friends around the world. Today we find ourselves in a new situation. Materials have been spread around the world, often with no place to go for chemical treatment and/or final disposal. There are some programs, like the US based RERTR and the 'Foreign Research Reactor Spent Nuclear Fuel (FRR SNF) Take-back Program'. There are special cases like the Taiwan fuels return program. Now we have a few programs for materials originating in Russia, but so much material remains around the world.

Remember Sept 11. Many things are changing. Including the view of many experts that nuclear materials around the world can now be used in weapons of terror. They could be WMD ('Weapon of Mass Destruction') but they also could be 'Dirty Bombs' or as we now call them, RDD ('Radioactive Dispersal Devices'). So now, it is time to cleanup, collect or return these materials. However, the question is how and where should this be done? Who should do it?

There is no doubt that the governments that facilitated, fostered and even promoted the dispersal of these materials have the ultimate responsibility. But can they or will they do what is necessary and will it be done in time? To quote, former Senator Sam Nunn, now the Chairman of NII ('Nuclear Threat Initiative'), "I don't want to wake up the day after someone has used these materials in an attack on one of our cities, and say, 'We should have done something about that when we could'. We should do it now!"

And so we propose a partnership between the governments and the companies of the nuclear industry from around the world. This includes developing and industrialized partners. The problem **belongs** to all of us, so the solution must **include** all of us. These ideas are discussed in the following paragraphs.

## **2. Public Private 'Global Cleanout Fund':**

Whether for reasons of authority, influence, or political sensitivity, removing or securing certain holdings of at-risk fissile material may not be achievable through purely government efforts. The creation of a private-sector mechanism to supplement US Government-led programs with information, relationships, and shipping and processing capability would, therefore, be a key element of the successful implementation of a Global Cleanout and Secure Policy.

Funding these private sector activities would likely, however, require a new source of revenue. Several options for funding exist. One approach would be to take advantage of the willingness of industrialized countries to contribute funds to establish a dedicated, non-profit fund supporting cleanout and security for at-risk fissile material.

Some countries with a commitment to securing vulnerable weapons usable materials might be persuaded to donate funds strictly based on their commitment to the mission. Other countries may be persuaded to contribute to the fund in exchange for the disposal of so-called "stranded" nuclear materials they have in their inventories by the US and other countries. In the latter case, several industrialized countries with mature nuclear programs lack indigenous capabilities to manage or dispose of certain types of nuclear materials they have created or inherited over time.

These countries, or commercial entities within them, are willing to pay significant fees for disposition services well beyond the actual cost of disposing of those materials in the US nuclear complex, estimated by some to be as much as USD 200 million. Most of the materials in this category do not themselves raise concerns from a proliferation perspective, but rather offer opportunities to collect significant resources beyond the cost of disposal, which normally would be absorbed by the US Treasury.

The goal of a Global Cleanout Fund would be to capture the difference between payments offered by the sending country and the costs of storing or disposing of the material in question in a way that would allow them to support nonproliferation priorities. In many cases, these foreign-owned materials are identical to materials for which the US is otherwise responsible for managing. One example is fuel from the US Elk River reactor, half of which was purchased by Italy based on certain plans that have now changed. Italy is reportedly prepared to pay generously for its removal and disposal; since DOE is already responsible for managing the other half of the Elk River fuel, the marginal costs of treating the fuel currently owned by Italy are likely to be small, leaving significant resources that could be applied to other priority activities.

Another example is HEU spent fuel from the South African Safari-1 research reactor. The majority of this spent fuel (~480 assemblies) is of non-US origin and, therefore, not currently eligible for return to the US under the existing FRR SNF program. But, South Africa began their program with US origin fuel and about 50 such spent fuel assemblies are in need of disposition. The South African fuel assemblies are technically identical to the US-origin fuel, but are not currently eligible for return owing to the foreign origin of the material. Other similar instances are known, and others may yet be identified.

Other 'stranded material's lack of 'twins' within current US holdings, but should nonetheless be easily manageable by US or other processing capabilities.

For example, the Japanese Hitachi Training Reactor, shut down in 1975, retains spent medium-enriched uranium fuel. Whether either of these to be imported to the US for processing and disposition, a NEPA analysis would be required. Such analysis could be accomplished in the context of similar requirements associated with the global cleanout mission in any case; incorporating provisions for materials unrelated to nonproliferation missions except as moneymakers would maximize the value of such changes. The political manageability of such changes should be increased by their linkages, through this mechanism, to nonproliferation and national security.

The Global Cleanout Fund would initially be capitalized by a combination of outright donations from countries, or from earnest money offered by owners of 'stranded material' such as those mentioned above. The staff and advisors to the Fund would work with industry and government officials as necessary for each material type to design and arrange for a disposition pathway, and to assemble the necessary contracts.

Once a path had been determined and the necessary financial and regulatory steps have been taken, the 'stranded material' would be transported from current storage locations to the processing/disposition facilities, and final payments would be made.

It is important to note that ownership of the 'stranded material' would only transfer from the current owner to the processing/disposal entity at the time of shipment; at no point does the Fund carry any ownership or liability for the 'stranded material'. The operations of the Fund are paid for initially out of interest from the invested earnest money and ultimately by the difference between the fees paid by the current owners of 'stranded material' and the costs of their processing/disposal.

Simultaneously with the negotiation of disposition pathways for 'stranded material', the Fund can begin working with the task force described above to identify candidate sites for urgent removal of at-risk fissile material, likely at comparatively low-cost. Therefore, revenues associated with a single instance of 'stranded material's may be able to cover multiple actions to address at-risk fissile material. Accordingly, only a limited number of the most lucrative and technically straightforward 'stranded material' would need to be addressed to support the nonproliferation goals of a Global Cleanout and Secure Policy.

The US or any other government's direct role in the Global Cleanout Fund would by necessity be limited in order to maintain the value of the Fund's arm's-length status and associated independence of action. The Global Cleanout and Secure Task Force would work with the Global Cleanout Fund to share information and establish a division of labor between government and private efforts. DOE would also have to be prepared to support discussions with contractors operating government-owned facilities about their ability and costs to process/dispose of 'stranded material', and to carry out (based on cost recovery from the owners of the 'stranded material') any necessary NEPA ('National Environmental Policy Act') work.

### **3. Appeal**

We call on all of you to consider seriously this concept and to help us by providing us with your thoughts and ideas. We need all the help we can get to deal with the issues we raise, as quickly and as completely as possible.