MANAGEMENT OF SPENT NUCLEAR FUEL FROM DECOMMISSIONED SUBMARINES OF RUSSIA'S NORTHERN FLEET

R. S. Dyer, U.S. Environmental Protection Agency, Washington, D.C., United States
R. L. Snipes, Oak Ridge National Laboratory, Oak Ridge, Tennessee, United States
E. Barnes, U.S. Environmental Protection Agency, Washington, D.C., United States
S. Høibråten, Norwegian Defence Research Establishment, Oslo, Norway
E. Foshaug, Institute for Energy Technology, Halden, Norway
T. Makarchuk, ICC Nuclide, St. Petersburg, Russia

ABSTRACT

Northwest Russia contains large quantities of spent nuclear fuel (SNF) that potentially threaten the fragile environment of the surrounding Arctic region. The majority of SNF from decommissioned Russian nuclear submarines is stored either onboard submarines or in floating storage vessels in Northwest Russia. The existing Russian transport infrastructure and reprocessing facilities cannot meet the requirements for moving and reprocessing the fuel from all of the decommissioned submarines as well as those awaiting decommissioning. Some of the SNF is damaged, stored in unsuitable conditions, or of a type that is not currently being reprocessed. These conditions require safe interim storage systems for the SNF. Some of the existing storage facilities being used in Northwest Russia for temporary storage are unsafe both from a health and safety aspect, as well as an environmental perspective. The removal, handling, interim storage, and shipment of the fuel pose technical and environmental challenges.

Norway and the United States are involved in a trilateral cooperative project with the Russian Federation (RF) with the objective of developing a prototype container and an interim transshipment/storage pad system that meets RF requirements for managing the SNF from their decommissioned nuclear powered submarines. This project is part of the Arctic Military Environmental Cooperation (AMEC) Program being implemented by the Defence Ministries of Norway and Russia, and the U. S. Department of Defense. The project has two major tasks. The first task involves the development of a prototype dual-purpose, metal-concrete 40-tonne container for transport and storage of the SNF. The second task involves the development of a suitable interim transshipment/storage pad for 19, 40-tonne SNF containers. The AMEC container and interim transshipment pad are designed for a performance life of not less than 50 years. Current plans are to store loaded casks, awaiting off-site transportation, on the pad for a period not to exceed two years—probably less than six months. After full certification of the prototype cask, sufficient numbers of these casks will be fabricated to allow removal and safe containment of the RF military SNF removed from decommissioned submarines. The project is designed to provide a safe and environmentally sound interim solution while increasing the capacity for removal and management of SNF from decommissioned RF submarines until permanent storage is attained.

INTRODUCTION

Northwest Russia is the location of the greatest number of nuclear powered submarines in the world. The fuel, if not properly managed, could release significant concentrations of radioactivity to the sensitive Arctic environment and become a serious global environmental security issue. Norway, Russia, and the United States are working together to address this concern in Arctic Military Environmental Cooperation (AMEC) Projects 1.1 and 1.1-1.

These projects address specific issues facilitating the transport and storage of spent nuclear fuel (SNF) from nuclear submarines being decommissioned in Northwest Russia.

AMEC Project 1.1 involves the development of a 40-tonne SNF cask suitable for both transportation and interim storage (up to 50 years) of the SNF being removed from the submarines. The specific objective of the project is to design, fabricate, test, and certify a prototype 40-tonne transport and storage cask for use in the RF. The Norwegian Defence Research Establishment for Norway, ICC Nuclide for the Russian Federation, and the Environmental Protection Agency for the United States initiated AMEC Project 1.1 in February 1997.

AMEC Project 1.1-1 involves the development of suitable facilities for interim storage of the dual-purpose casks. The objective of this project is to design, construct, and license a facility suitable for storing 19, 40-tonne casks containing SNF. AMEC Project 1.1-1, "Storage Pad Development," was initiated in July 1998.

THE NEED FOR ACTION IN NORTHWEST RUSSIA

Since the late 1950s, Northwest Russia has been the home for an increasing number of nuclear submarines, icebreakers, and other nuclear powered vessels. This geographic region has more marine nuclear propulsion reactors than any other place on the earth. As a result, there is a vast quantity of SNF in Northwest Russia.

Improper management increases the risk for and the potential environmental impact of this SNF. SNF, and other waste, from an estimated 380 submarine reactors are reportedly being stored in Northwest Russia. SNF from approximately 18 reactor cores are currently being stored on floating storage ships or barges. While awaiting removal, nuclear reactor fuel is also stored in-place in reactor cores, on-board decommissioned submarines. A quantity of SNF is also being stored on shore in dry storage facilities that do not meet current safety requirements.

There is a high potential for negative environmental impact caused by inadequate management of this SNF. Potential environmental impacts to the region includes: (1) the contamination of local and regional ground water, (2) the contamination of vegetation and wildlife throughout the entire region, and (3) ultimately contamination of the food chain for animals and humans.

The militaries of the Kingdom of Norway, the Russian Federation, and the United States are committed to protecting the environment, particularly a fragile ecosystem like the Arctic. The people who live in this region need an environmentally sound Arctic to ensure their health and, in some cases, their economic livelihood.

AMEC was formed to deal with these issues in a cooperative and constructive manner. Several AMEC projects were created to help ensure that the militaries of the three countries do their part to help assess, preserve, and restore the Arctic environment.

ARCTIC MILITARY ENVIRONMENTAL COOPERATION

On September 26, 1996, in Bergen, Norway, Jørgen Kosmo, Norwegian Minister of Defence; Igor Rodionov, Russian Federation Minister of Defence; and William J. Perry, U.S. Secretary of Defense launched a cooperative effort called the AMEC forum. The Ministers signed a historic Declaration

calling for contacts and cooperation among the parties to jointly address critical environmental concerns in the Arctic.

AMEC is a forum for dialogue and joint activities among the United States, Russian, and Norwegian military and environmental officials. This forum addresses Arctic environmental issues that are related to their military's unique capabilities and activities.

AMEC is led by top environmental officials from the Norwegian Ministry of Defence (MOD), Russian MOD, and U.S. Department of Defense (DoD) who are designated as the AMEC Principals. Major General Boris Alekseev is the Russian Principal for the Ministry of Defence, Russian Ferderation. Rear Admiral Ole-Gerhard Røn is the Norwegian Principal for the Ministry of Denfence, Kingdom of Norway. For the U.S. DoD, the Deputy Under Secretary of Defense for Environmental Security provides policy oversight. Rear Admiral L.C. Baucom, Director, Environmental Protection, Safety and Occupational Health Division, Chief of Naval Operations, has been designated as the U.S. Principal.

AMEC has seven active projects. The projects are primarily focused on "off the shelf" technology demonstrations. The five active projects that deal with radioactive waste technologies are:

- Development of a prototype dual-purpose cask for transport and interim storage of SNF from decommissioned submarines and a storage pad for the casks.
- Development of mobile technology for treatment of liquid radioactive waste at remote sites associated with nuclear submarine decommissioning.
- Implementation of technologies for solid radioactive waste volume reduction.
- Development of technologies for enhancement of solid radioactive waste storage facilities.
- Radiation safety training, monitoring techniques and equipment focused on nuclear submarine dismantlement.

The two additional active AMEC projects that deal with non-radioactive waste problems are:

- Demonstration of technologies for cleanup of hazardous waste on military bases in the Arctic (this project involves only Norway and Russia).
- Demonstration of "Clean Ship" technologies for the collection and processing of ship-generated waste.

The AMEC Program is discussed in further detail in a paper presented in Session 6 of this Symposium.

SUMMARY OF AMEC PROJECT 1.1

AMEC Project 1.1 Objectives

As previously stated, the primary objectives of AMEC Project 1.1 are to design, fabricate, test, and certify a dual-purpose transport/storage cask for handling of SNF from decommissioned Russian Navy submarines.

Table I. AMEC Project 1.1 Primary Participants

PARTICIPANTS	ROLE IN THE PROJECT
Norwegian	
Norwegian Defence Research Establishment	Norwegian AMEC 1.1 Project Officer and Project Management/Technical Oversight
Institute for Energy Technology, OEDC Halden Reactor Project	Technical Expert – Radiation Safety
Russian	
Russian Ministry of Defence – MOD	RF AMEC 1.1 Project Officer and the Ultimate Cask User
ICC Nuclide – Interbranch Coordination Scientific-Technical Centre of Nuclide Production	Project Manager for the Russian Federation
KBSM – Special Mechanical Engineering Design Office	Designer of the AMEC Cask – the TUK-108
IZHORA Works	Fabricator of the AMEC Cask
VNIPIET – The All Russian Design and Research Institute of Complex Power Technology	Cask Testing and Safety Assessments
VNIIEF – The All Russian Scientific Research Institute of Experimental Physics	Nuclear Design and Calculations
MOD Institute #26	Concrete Design
MINATOM – Ministry of Atomic Energy	Certifying Agent of the AMEC Cask for the Russian MOD
MOD- and Civilian- Minatom, Minzdrav, Mintrans	Military and Civilian Certifying Agents of the AMEC Cask
United States	
EPA – U.S. Environmental Protection Agency, Office of International Activities	U.S. AMEC 1.1 Project Officer/Project Management
ORNL – Oak Ridge National Laboratory	Integrating Project Manager/Lead Technical Expert
NAC International	Technical Experts in Cask Design, Fabrication, Testing and Certification

AMEC Cask General Description

The AMEC cask is a metal-concrete cask designed to contain 7 spent nuclear fuel canisters each holding up to 7 spent fuel assemblies, for a total of up to 49 fuel assemblies, from decommissioned Russian submarines. It is approximately 4.5-m high and 1.6-m in diameter. It has been designated as the TUK-MBK-VMF or TUK-108/1 by Russian authorities. When the AMEC cask is fully loaded with fuel, it will weigh approximately 40 metric tonnes. The empty cask (without the basket, fuel canisters, and spent fuel) will weigh approximately 35 metric tonnes.The AMEC cask is comprised of three concentric metal shells attached to a common forging (coaming) at the upper end and metal bottom pieces for each of the shells. The AMEC cask is shown in Fig. 1 with the outer and inner lids removed.

Heavy-duty, high-density concrete is poured between the metal shells to form two separate concentric concrete shells. The inner concrete shell is significantly thicker than the outer concrete shell and serves as the primary structural and shielding element for the cask. The outer concrete shell provides additional strength and shielding but also serves as a sacrificial shell in case of an accident.

The cask is sealed at its upper end by two separate metal lids. The inner lid serves as both a shielding and first containment barrier for the contents while the outer lid serves as structural protection for the inner lid and as an "impact limiter" or "damping device" during an accident.

The bottom portion of the cask and the outer lid of the cask both incorporate metal-rib damping devices as an integral part of their construction. Previous generations of metal-concrete casks have utilized removable damping devices bolted onto the cask. However, the AMEC cask incorporates the damping devices into the actual construction of the cask bottom and outer lid and therefore needs no additional bolt-on damping devices.

Fig. 1. AMEC TUK-108 prototype cask without lids with one fuel canister installed.

AMEC Cask Design Requirements

The AMEC cask is designed to be handled and transported by the existing infrastructure used by the Russian Navy for the all-metal TK-18 transport casks. The TK-18 casks were only designed for transportation of SNF. The TUK-108/1 AMEC casks will complement the existing TK-18 casks. The AMEC 40-tonne cask is designed for at least a 50-year life.

The AMEC cask is designed to meet all applicable Russian and International Atomic Energy Agency (IAEA) standards for storage and transport of SNF.

The AMEC cask will be certified/licensed by the appropriate Russian authorities to allow it to be used for transport and storage.

The AMEC prototype cask must be proven to meet or exceed all design and licensing requirements for fabrication and operation of the cask. It must also demonstrate, either through testing or analytically, the ability to survive, intact and without breach of containment, the normal and hypothetical accident conditions specified in Russian regulations and IAEA Standard ST-1. These hypothetical accident conditions include:

- 9-meter drop onto a flat unyielding surface;
- 1-meter drop onto a rigid upright 15-cm diameter, 20-cm high metal pin;
- complete entrainment within an 800^{o}C fire for 30 minutes; and
- submersion under water at a depth of 15 m for a period of eight hours.

Current Project Status

The design, fabrication, and design verification testing of the AMEC prototype cask have been successfully completed. The AMEC prototype cask has undergone successful in-plant testing. Successful 9- and 1-m drop tests, as defined by IAEA guidelines, were conducted on a half-scale model of the prototype cask. Testing has been completed at the RTP Atomflot site in Murmansk, the Mayak processing facility in Chelyabinsk, and a naval shipyard in Severodvinsk demonstrating that the full-scale AMEC cask effectively interfaces with existing fuel and cask handling equipment at the sites and can be safely and effectively loaded and unloaded with fuel. Figure 2 illustrates some of the testing conducted at the RF RTP "Atomflot" site in Murmansk, Russia. One of the first serially produced casks of the TUK-108/1 design was loaded with "real" fuel to test the shielding provided by the cask. All design parameters were successfully met.

The AMEC cask design will be certified by the Russian Federation Ministry of Defence, Minatom, Ministry of Health, and other appropriate Russian authorities. After certification, serial production of the AMEC cask is planned. The Russian Federation has stated that as many as 300-400 of the AMEC casks may be required to safely transport and store all of the SNF from decommissioned nuclear submarines and other applications in Russia.

Fig. 2. AMEC cask undergoing testing at the RF RTP "Atomflot" site.

SUMMARY OF AMEC PROJECT 1.1-1

Project Objectives

The objectives of AMEC Project 1.1-1 are to design, construct and license a transshipment/temporary storage pad for up to 19 AMEC casks. This pad will be designed and located to maximize the use of existing Russian cask and fuel handling equipment and facilities.

Table II. AMEC Project 1.1-1 Primary Participants

PARTICIPANTS	ROLE IN THE PROJECT
Norwegian	
Norwegian Defence Research Establishment	Norwegian AMEC 1.1-1 Project Officer and Project Management/Technical Oversight
Institute for Energy Technology, OEDC Halden Reactor Project	Technical Expert – Radiation Safety
Norwegian Defence Construction Service	Construction Expert
Russian	
Russian Ministry of Defense – MOD	RF AMEC 1.1-1 Project Officer and the Ultimate Pad User
ICC Nuclide – Interbranch Coordination Scientific-Technical Centre of Nuclide Production	Project Manager for the Russian Federation
VNIPIET – The All Russian Design and Research Institute of Complex Power Technology	Storage Pad Designer
RTP Atomflot/Murmansk Shipping Company	Operators of the Cask Loading and Unloading Facility in Murmansk
MOD Institute #26	Concrete Design
MOD- and Civilian-Gostatomnadzor (GAN)	Military and Civilian Certifying Agents of the AMEC Cask
United States	
EPA – U.S. Environmental Protection Agency	U.S. AMEC Project Officer and Project Management
ORNL – Oak Ridge National Laboratory	Integrating Project Manager and Lead Technical Expert
NAC International	Technical Experts in Cask Design, Fabrication, Testing, and Certification
Cold Regions Research and Engineering Laboratory/USCOE	Technical Experts in Cold Climate Construction
Dominion Power Nuclear Services	Technical Experts in Storage Pad Construction, Operation, and Licensing for the U.S. Team

AMEC Storage Pad General Description

The AMEC transshipment/temporary storage pad preliminary design indicates that the pad will be a reinforced concrete slab sized to hold up to 19 AMEC casks in a vertical position. Vertical concrete shield walls will be constructed around the outer periphery of the slab to minimize radiation dose to workers. These shield walls extend upward to about two-thirds of the cask's height. Together the concrete shield walls and the remainder of the cask enclosure will greatly facilitate the cask handling operation in inclement weather. Figure 3 provides a schematic drawing of the transshipment/storage pad being constructed at the RF FTP "Atomflot" facility in Murmansk, Russia.

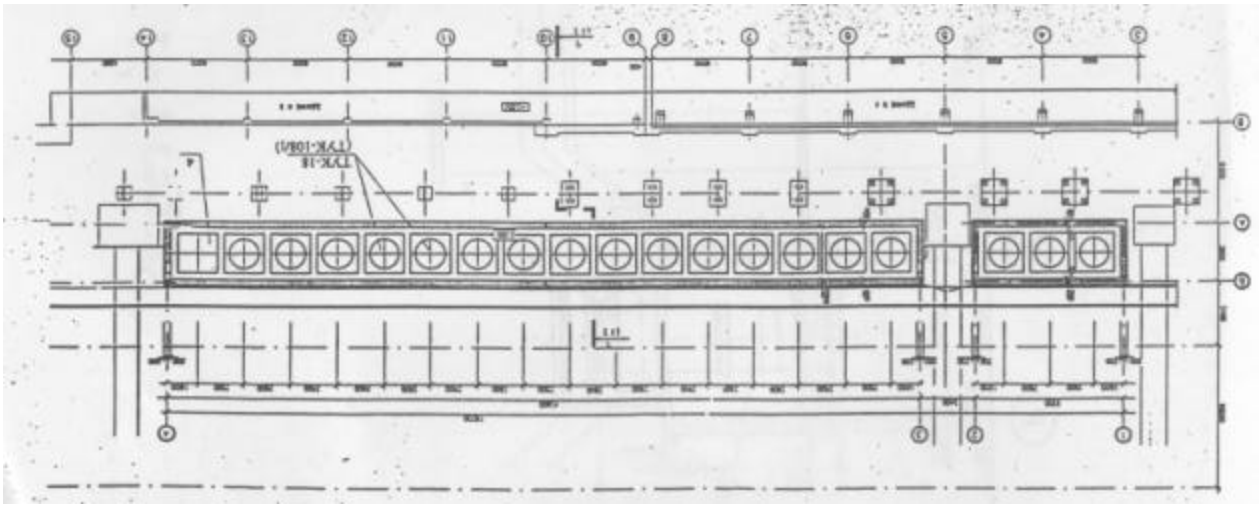

Fig. 3. Schematic of the AMEC 1.1-1 transshipment/storage pad.

AMEC Transshipment Storage Pad Requirements

The AMEC transshipment storage pad must meet or exceed all Russian codes and IAEA standards and guidelines for the design, construction, and licensing of a transshipment storage pad for SNF.

The AMEC storage pad must be designed and constructed for at least a 50-year service life.

The AMEC storage pad must be designed and constructed to withstand the extreme temperatures (-37^{o}C to +32^{o}C) of the Arctic.

The AMEC storage pad must withstand anticipated seismic activity (6 points on the MSK/Richter scale) in the area and remain intact and serviceable.

The AMEC pad must be located and designed to facilitate the use of existing equipment, railways, and facilities.

The AMEC storage pad must be designed and constructed to facilitate loading and unloading of both TK-18 and the new TUK-108 casks utilizing the existing cask fuel loading facilities (the floating service ships) and rail transport cars.

Current Status

The Russian Federation experts have completed the project's "Technical Assignment," "Declaration of Intent," "Justification of Investments," and design and construction documentation for the AMEC transshipment/temporary storage pad. These documents describe the basic functional and regulatory requirements for the storage pad and have been approved by the relevant Russian organizations.

Initial construction for the AMEC transshipment/storage pad began in late 2000. Construction is scheduled be completed by mid-2001.