INTEGRATED TREATMENT AND STORAGE SOLUTIONS FOR SOLID RADIOACTIVE WASTE AT THE RUSSIAN SHIPYARD NEAR POLYARNY

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ABSTRACT

Russian Navy Yard No. 10 (Shkval), near the city of Murmansk, has been designated as the recipient for Solid Radioactive Waste (SRW) pretreatment and storage facilities under the Arctic Military Environmental Cooperation (AMEC) Program. This shipyard serves the Northern Fleet by servicing, repairing, and dismantling naval vessels. Specifically, seven nuclear submarines of the first and second generation and Victor class are laid up at this shipyard, awaiting defueling and dismantlement. One first generation nuclear submarine has already been dismantled there, but recently progress on dismantlement has slowed because all the available storage space is full. SRW has been placed in metal storage containers, which have been moved outside of the actual storage site, which increases the environmental risks.

AMEC is a cooperative effort between the Russian Federation, Kingdom of Norway and the United States. AMEC Projects 1.3 and 1.4 specifically address waste treatment and storage issues. Various waste treatment options have been assessed, technologies selected, and now integrated facilities are being designed and constructed to address these problems. Treatment technologies that are being designed and constructed include a mobile pretreatment facility comprising waste assay, segregation, size reduction, compaction and repackaging operations. Waste storage technologies include metal and concrete containers, and lightweight modular storage buildings.

This paper focuses on the problems and challenges that are and will be faced at the Polyarninsky Shipyard. Specifically, discussion of the waste quantities, types, and conditions and various site considerations versus the various technologies that are to be employed will be provided. A systems approach at the site is being proposed by the Russian partners, therefore integration with other ongoing and planned operations at the site will also be discussed.

INTRODUCTION

The Polyarninsky Shipyard (sometimes called Navy Yard No. 10 or the Shkval Shipyard) has been designated as the recipient for Solid Radioactive Waste (SRW) pretreatment and storage facilities under the Arctic Military Environmental Cooperation (AMEC) Program. This shipyard is near Murmansk and it serves the Northern Fleet of the Russian Navy by servicing, repairing, and dismantling naval vessels. The integrated radioactive waste treatment and storage complex (abbreviated PPP RAO from the Russian language) is planned as a combination of AMEC Projects 1.2, 1.3, 1.4, 1.5, and 1.5-1.

It is estimated that about 20,000 cubic meters of SRW has accumulated from prior dismantlement of nuclear submarines and other related military activities at Russia's Northern Fleet bases on the Kola Peninsula and in Severodvinsk (1). There is a significant backlog of submarines (~150 both ballistic missile and general purpose submarines) awaiting dismantlement as part of Cooperative Threat Reduction activities or other multilateral cooperative programs that will significantly add to this SRW volume in the near future.

The generation rate of SRW is about 1000 cubic meters per year (2) and is expected to increase as the rate of submarine dismantlement increases. Existing storage containers and facilities are full and/or deteriorating. New waste is continuing to be generated and stored in an open-air environment, as shown in Figure 1, and will require stabilization. It is estimated that 25 to 30 percent of the SRW is presently uncovered and exposed to the elements. Much of this waste has not been well characterized, however, it is believed that from a third to a half of the waste is metallic. The metallic waste consists of equipment, piping, fittings, previously used containers, and other metal scraps. Table I provides a rough classification of SRW accumulated in the Murmansk area of Russia.

Fig. 1. Metal boxes with radioactive wastes at Zvezdochka

Table I
Classification of SRW Accumulated from
Dismantlement of Nuclear Submarines (2)

Waste Classification	Volume (m^3)	Activity[*]	Current Storage Mode
Combustible	2800	Low	Metal containers, bags
Compressible	1000	Low	Metal containers, bags
Activity Filters	70	Intermediate	Containers
Metallic	2100	Low	Containers, separate elements unpacked
	1400	Intermediate	Containers, separate elements unpacked
	600	High	Separate elements
Non-processible	500	High	Control sources, elements of reactors, control and protection assemblies
Total	**8500**		

[*] Russian radiation dosage transportation guidelines for each activity classification measured at a distance of 10 cm from the source are as follows:

Activity Classification	Guideline
Low Dose Rate	< 0.3 mSv/h
Intermediate Dose Rate	0.3 mSv/h – 10 mSv/h
High Dose Rate	> 10 mSv/h

Some SRW is stored loosely intermingled in large compartments, while other SRW has been placed in metal containers. Most of these containers are past their useful life and many contain free water; therefore, they must be considered part of the waste for pretreatment (i.e., cut up and volume reduced). Stabilization of this waste via removal of the free water, segregation, and repackaging into new containers is a prime objective for Russia.

The PPP RAO will have several elements, including a set of hydraulic metal cutting tools, the Mobile Pretreatment Facility for Solid Radioactive Waste (MPF SRW), the PICASSO system for radiation monitoring, the Mobile Treatment Facility for Liquid Radioactive Waste (MTF LRW), and a Waste Storage Facility. Each of these elements is discussed separately below. A paper on the design and fabrication of containers for transport and storage of solid radioactive waste is presented elsewhere in this conference (3).

HYDRAULIC METAL CUTTING TOOLS

The Polyarninsky Shipyard currently employs various mechanical grinding/cutting (disks and saws) and thermal cutting techniques (gas/plasma torches) to size reduce submarine components and structures. Such techniques readily generate dusts and particulates that can lead to spread of radioactive contamination or respirable hazards. Russian Navy representatives first became aware of the benefits of hydraulically operated metal cutting tools at the Waste Management 1999 Symposium and Exhibition. After discussions with the vendor as to the capabilities and expected productivity and safety aspects, it was agreed that a set of tools would be procured and deployed as an advance demonstration at the Polyarninsky shipyard for eventual operations to support the Mobile Pretreatment Facility. Such tools, however, had never been deployed in an Arctic environment before.

After an assessment of Russian shipyard needs, a set of Mega Tech Services metal cutting tools was procured, consisting of a motor and hydraulic pumping unit, a 38 mm conduit cutting tool, a 100 mm pipe cutting tool, and a spreading tool all mounted on a wheeled cart for ready deployment where needed around the shipyard. The tool system was modified by the vendor for Arctic operations and Russian electrical standards (2). Prior to shipment, it was then cold room tested at –40 ^{o}C at the US Army COE Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH (4). The modifications performed as anticipated and the tools were able to cut all test specimens. Some were actually easier to cut at –40 ^{o}C, due to brittle failure.

The tools were shipped to Russia, but were delayed in clearing customs for several months until complete documentation on the individual weight, function, purpose, and cost of all items on the manifest was provided. Also, documentation attesting to the U.S. military to Russian military nature of the assistance was required to obtain duty free import of the equipment under the AMEC and CTR programs. However, even so, the equipment was only cleared under a waiver from compliance from Russian standards, and does not hold a Russian Certificate of Conformance. This waiver only allows the equipment to be used for demonstration purposes, but does not allow it to be put into regular service on a continuing basis. Russian representatives stated that obtaining the Certificate of Conformance is a significant expense and can take up to 9 months, but this would then allow subsequent units to be procured and immediately deployed.

A Mega Tech Services representative conducted a training course on the operation, safety, and maintenance of the cutting tools, which was hosted at the RTP Atomflot facility in Murmansk. The course provided instruction and hands on operational experience to eight representatives from the Polyarninsky shipyard including the Chief Engineer. During training, the tools were readily applied to a variety of available materials. The tools successfully cut ¾-inch concrete rebar, 2-inch Schedule 40 carbon steel pipe, ¼-inch thick carbon steel angle bracing, 4-inch carbon steel I-beam, 3-inch Schedule 120 stainless steel pipe, and other stainless steel structural members. The tools with the supplied blades were not able to cut 1½ inch wire rope cabling due to flattening of the wire bundle in the tool jaw. However, additional notched blades will be supplied to address these types of materials. Also, the trainees expressed interest in the other larger tools in the Mega Tech line that can cut up to 6-inch pipes. They readily acknowledged that the tools will not universally replace their current techniques, but should enhance their productivity and safety on the types of materials for which it is best suited.

After the training, the tools were delivered to Polyarninsky shipyard, and will undergo an extended evaluation over the next several months as to their enhanced performance and safety compared to the baseline methods for size reducing pipe, conduit, cabling, and other small structural metal support scrap. Any decision on obtaining the Certificate of Conformance for these tools has been deferred until after the performance evaluations are completed.

MOBILE PRETREATMENT FACILITY FOR SOLID RADIOACTIVE WASTE

The MPF SRW has been designed and is in the process of being assembled. It will be a key element of the PPP RAO at the Polyarninsky Shipyard.

History

To initiate the development of the MPF SRW, a Technical Specification document and a Statement of Work (SOW) were released for an international competitive procurement. In addition to specifying waste parameters and bounding conditions for the MPF SRW feed streams, these documents also specified the technical requirements for the MPF SRW. Important design factors include the ability for the facility to be mobile to allow its movement between various sites within Russia, the capability for the facility to operate in a harsh northern Russian climate, the ability to meet the throughput and technical requirements (waste volumes, processing specifications, etc.), and the ability to provide a high degree of operational flexibility due to the uncertain nature and characterization of the SRW to be processed. A key to the mobility of the facility is its modular design and construction (i.e., the facility will be made up of eight modules that can be transported separately and reassembled at any site where submarine dismantlement SRW has been accumulated or will be generated).

The original Conceptual Design for the MPF was developed under a joint venture by a Norwegian and Russian team named Storvik & Zvezdochka (S&Z). This original design met the overall intent of the requirements specified during the procurement phase, but was sub-optimal in terms of radiological control, flexibility, and operability. Once selected as the design build firm for the MPF, S&Z expanded and modified the design and developed a Technical Design for the MPF, which improved upon the previous limitations. This Technical Design also provided optional features for the decontamination and free release of metals, for processing high dose material, and for the inclusion of an analytical laboratory within the MPF. While these optional features were requested by the Russian Navy, they were not included in the first phase of the project due to funding constraints and liability concerns related to free-release of metals. During this phase of the project, a critical issue was identified related to the development a Russian Statement of Work document called a Technicheskoye Zadaniye (TZ). This document, which is typically developed and approved at the start of any Russian project, is required by Russian regulations and is a key element in the review and approval cycle of the Russian regulatory bodies. To avoid a possible delay in the design approval process, a TZ was developed for the MPF project with input by the US, Norwegian, and

Russian parties. To date, the TZ for the MPF has undergone several changes and reviews and will be further modified to reflect the final design and as-built conditions of the MPF.

After review by the AMEC team, the Technical Design was expanded into a Detailed Design for use during the construction process (incorporating shop drawings, material lists, construction details, and other Detailed Design information). Further design modifications were incorporated into this Detailed Design to enhance the operability and functionality of the facility and to meet ongoing design and funding constraints within the AMEC program. During this phase of the project the Technical Design was provided to the Russian regulatory organizations for review and approval. Final approval of the Technical Design was obtained in the fall of 2001.

In preparation for the construction phase, the equipment procurement process began in early 2001 and the initial construction began in late 2001. Both were initiated in a phased approach to meet decision milestones and to support the AMEC funding profile. The frames for the first six modules were completed and inspected by the end of 2001 and the remaining two are scheduled for completion early in 2002. In addition, all long-lead-time equipment and a portion of the short-lead-time equipment have been procured, and work is underway on the specific construction elements for each of the eight modules. Construction of the facility is scheduled to be completed by the middle of 2002. Following this, the facility will undergo testing (equipment, systems, cold & hot testing), training, certification, and start-up. The timing and logistics for the deployment of the MPF are still under negotiation.

Current MPF Design and Capability

While the scope and specifics of the design have undergone a number of modifications, the major functionality of the facility has remained unchanged since its inception. The layout for the Russian-approved Technical Design is shown in Figure 2. This schematic shows the modules and rooms in which various activities take place as well as schematic representations of the incoming waste box and outgoing shipping container (with drums).

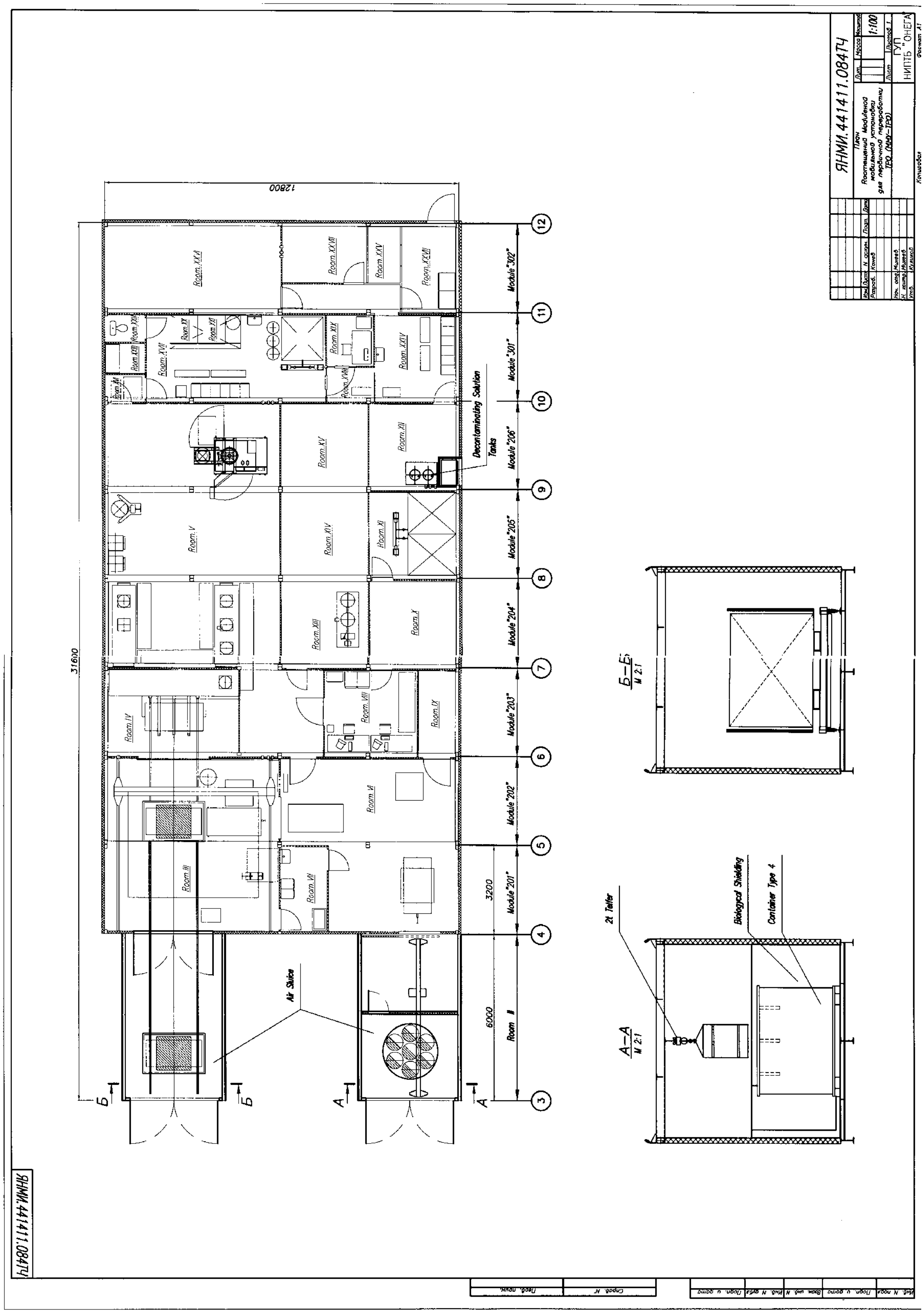

Fig. 2. Layout of the MPF SRW

The material flow through the MPF will be as follows. Material is brought into the MPF in metal waste containers using a forklift. These containers are brought one at a time into the airlock or air sluice and placed onto a trolley (shown at the top of Figure 2, in the area labeled Room II) where the initial dose reading can be obtained. This trolley can then be moved into Room III of Modules 201 & 202. Here additional dose measurements can be obtained from the waste box, the lid of the box removed (either unbolted or cut off), and the contents and internal dose levels of the container measured. Operators using the necessary personal protection equipment (PPE) and monitoring equipment perform all these operations. Acceptable processing criteria exist for the incoming waste containers and their contents (surface dose rates at or below 2 mSv/hr and 1-m dose rates at or below 0.1 mSv/h, no removable contamination present, fixed contamination levels below 10 particles/cm^2-min for alpha and below 100 particles/cm^2-min for beta, and design specified size and weight limitations for individual content items). If rejected, the waste box is closed and removed from the facility for continued storage pending treatment.

If the container is determined to be acceptable for processing, the waste box is moved via the trolley into Room IV and is placed onto a tilter (a device that lifts and tilts the waste box to allow the contents to be moved onto a glovebox sorting table for processing). The entire facility incorporates typical radiological and contamination control mechanisms (shielding, stepwise negative pressure gradients, multiple stage HEPA filters, PPE, dosimeters, hand held detectors, air monitors, stationary detectors, and access and material control). These controls are most restrictive for rooms in which waste is handled directly (Rooms III, IV, & V). Once the material is moved onto the glovebox sorting table (shown as part of Room V in Modules 203 and 204), each individual waste item is monitored and sorted into compressible and non-compressible streams. Waste items above the sorting table dose limit (gamma dose rates above 0.3 mSv/hr at 10 cm) are placed into a special shielded drum under the sorting table (via an access port at the lower end of the sorting table).

The acceptable non-compressible waste is moved into the bottom leg of the glove box while the acceptable compressible waste is moved into the top leg. Various workstations and equipment are available within each leg of the glovebox to allow the operators to inspect, dry & dewater (blowers & rollers), or size reduce (using chop saws, guillotines, and hand tools) the waste items. Liquid that is present in the waste box or generated from the processing operations is collected into drums underneath the glovebox line. Once full, this liquid is transferred to storage tanks within the MPF (shown in Room XI of Module 205). At the conclusion of processing, the SRW is bagged out of the glove box. Non-compressible waste is placed directly into waste drums while compressible waste is placed into a compaction unit for further size reduction (shown in Room V of Module 206).

Once full, both types of drums are moved via a drum dolly to the packaging area (shown in Room VI of Modules 201 and 202). Here the containers are checked, sealed, and labeled (contents, dose levels, waste streams, etc.) and then placed into a transportation container (shown in the lower air lock or air sluice in the section labeled Room II). The current design allows processed waste drums to be placed into Type 4 metal shipping containers (round, d = 2 m, h = 1.4 m). These are the PST 1A-6 containers described in detail elsewhere in this conference (3), which are the only containers presently certified for offsite transport of SRW in Russia. Other types of transportation containers may also be considered for use within the facility as long as their weight and dimensions can be accommodated within the facility.

In addition to normal processing, the facility is capable of handling some out-of-tolerance material. The facility has additional equipment (jackhammers and cutting and shearing tools) to allow oversized items to be size reduced and placed into either waste drums (in Room III) or Type 1 metal containers (1m x 1m x 2m). The facility also incorporates all necessary dose measurement equipment (personal dosimetry, hand held detectors, air monitors, stationary detectors) to maintain a safety envelop for the workers and control potential contamination within the facility. A decontamination solution distribution system has been incorporated into the design to allow the rooms, containers, and equipment to be decontaminated and the spent solution collected. In addition, water from the personnel showers and sinks will be collected and tested prior to release.

This facility includes several other rooms that allow the operators to perform tasks associated with waste processing. These include a changing room with showers, restroom facilities, and lockers (Module 301); rooms that house facility control, alarm, and electrical distribution panels (Module 302); HVAC equipment and filters, decontamination solutions, accumulated liquid radioactive waste (LRW), and storage areas (Modules 204, 205, 206); and an entrance area, offices, and work shop areas for the operational crew (Modules 202, 203, 204, 301, and 302).

The current version of the design incorporates a smaller storage area for processed material (Room VI of Modules 201 and 202) than previously proposed designs. While it may be preferable to have a larger area to stage and pack waste containers, project management considerations have required that the final design meet designated funding and project specific limitations. However, due to the modular nature of the current MPF design, any future desired modifications to the facility could easily be incorporated. This allows for any necessary future expansion to the facility for the incorporation of additional processing capacity/capability or for modifications to provide for additional functionality within the facility.

What's Next

Once construction and testing of the MPF is complete, the facility will be shipped to the Polyarninsky Shipyard for reassembly and for subsequent cold and hot testing. There are several issues associated with this phase of the project that are currently being addressed such as the transportation of the facility to Polyarninsky Shipyard, the specifics of testing at the construction yard and the operational site, the warrantee and spare parts & supplies to be provided, and the operational and maintenance requirements for the facility.

In preparation for its arrival at the Polyarninsky Shipyard, the AMEC team is currently evaluating the necessary site preparation work. Since the PPP-RAO processing complex at the Polyarninsky Shipyard will support multiple projects, an integrated approach is being taken to site preparation activities by incorporating the requirements for all the proposed PPP-RAO facilities. These activities will address both typical utility modifications and tie-ins (water, sewer, electricity, alarms, roads, drainage, etc.) and the site-specific requirements such as fencing, guard gates, cameras, personnel access control, building pads, and material accountability.

MPF SRW Summary

As a result of scope changes, budgets issues, and design considerations, the MPF project as a whole has undergone several changes and revisions since its inception. The current design has successfully gone through the Russian regulatory approval process and meets the technical and budgetary constraints of the AMEC program. Construction is underway and the specifics of the testing, site preparations, shipping, operations, and maintenance of the facility are currently under development. The MPF will be the focal point of the PPP-RAO and a key element in meeting the nuclear submarine dismantlement and waste processing needs of the Russian Federation.

PICASSO

The goals of AMEC Projects 1.5 (Cooperation in radiation and environmental safety) and 1.5-1 (Radiation control at facilities – application of the PICASSO system) are to enhance and improve the technical means of the Russian Navy for measuring and controlling radiation exposure of personnel, local population and the environment at sites involved in decommissioning and dismantlement of nuclear submarines.

An automatic radiation monitoring system, PICASSO-AMEC, has been developed and will be installed at Polyarninsky Shipyard as one of the elements of the integrated radioactive waste treatment and storage complex, PPP-RAO. There are also other radiation hazardous locations at the shipyard, which are relevant for deployment of the radiation monitoring system. This includes the existing open pad for interim storage of solid radioactive waste, laid-up submarines at the piers awaiting dismantlement, floating tanks with liquid radioactive waste and the floating docks where submarines are dismantled.

The radiation monitoring system is based on the software package PICASSO-3, developed by Institute for Energy Technology (IFE), Norway (5). This data presentation and visualization software is well suited when large amounts of data are to be stored, transferred to a user interface and be presented graphically in real-time in a user friendly and flexible manner.

Under the framework of AMEC, IFE programmers developed a prototype system for presentation of radioecological data, PICASSO-Environmental Monitoring System. Russian Naval officers and programmers from Nuclear Safety Institute (IBRAE) in

Moscow received training at IFE, and the software was transferred from Norway to Russia. The software was adapted to the Russian language and an operating model of a measuring unit based on the PICASSO-AMEC system was created and demonstrated to the AMEC principals and senior officials from the Russian Federation and Norwegian Kingdom Ministries of Defence and the U.S. Department of Defense on 14 August 2000. The model includes two types of radiation sensors, a smart controller, radio channel for data transmission, software for data acquisition and processing and adapted PICASSO-AMEC software. The sensors are of Russian manufacture, a gross gamma air detector and a submersible underwater scintillation detector.

The design for installation of the system at the Polyarninsky Shipyard has been completed, and the project is ready to enter the installation phase. The system will provide remote stand-alone radiation monitoring with presentation of the data in real-time with the option of comparison with historical data. Alarm limits will be defined. The computer network will consist of servers, working stations and sensor concentrating units. Eight gross gamma air detectors and one submersible detector are planned at the shipyard, including one gross gamma detector in the city of Polyarny. The exact placement of detectors in the vicinity of the PPP-RAO complex, including the MPF-SRW, will be decided when the final design and the exact layout of the complex has been approved.

The system will also be installed at RTP Atomflot in Rosta, north of Murmansk. During the spring of 2002 an interim storage pad for casks containing Naval spent nuclear fuel (SNF) awaiting transportation to the Mayak reprocessing plant will be commissioned at this site under the AMEC 1.1-1 project. The scope of the PICASSO monitoring system at this facility will include the SNF storage pad and the processing facility for liquid radioactive waste. Further installations of the system at other sites in northwest Russia will be considered.

MOBILE TREATMENT FACILITY FOR LIQUID RADIOACTIVE WASTE

Requirements

The MTF LRW under AMEC Project 1.2 was originally planned to treat stored LRW generated during dismantling of nuclear submarines. This is waste of very different and complex composition, stored at different sites. The total amount of accumulated LRW to be treated has been estimated to be about 6400 m^3. In addition, a generation rate of up to 1300 m^3/y is expected. (6)

The LRW has a complicated physico-chemical composition with high salt content, detergents, suspended solids up to 1 g/L, petroleum products up to 2 g/L and complexing agents and toxicants (6). In addition, this LRW is stored at a number of different Northern Fleet sites with difficult access for transportation to a central treatment facility.

Design

After reviewing a number of possibilities (6), a mobile treatment facility was selected to manage this waste because it could be transported to the different storage sites for complete treatment of the waste.

Due to the complex composition of the waste, a number of technologies must be used (7). The technological modules will include:

- Primary purification of LRW (to remove solid waste and petroleum products),
- Selective filters,
- A unit to remove organic mixtures (to remove hydrazine, ammonia, detergents, petroleum products, heavy metals and hydrolysable radionuclides),
- A reverse osmosis unit,
- A final purification unit,
- A solidification unit for mixing the concentrated waste with cement and pouring the cement matrix into 200-l metal drums, and
- A decontamination unit (for decontaminating the facility).

In addition, the facility will contain a power supply for self-contained operation, a control system, laboratory unit, a system of radiation and radioecological monitoring, a system for leakage control and a sanitary room.

The modules of the facility should have overall dimensions not exceeding a standard naval 20-foot container and maximum weight of 15 t to facilitate transport with standard transport equipment. A possible layout of the facility is shown in Figure 3.

The technical assignment for the facility (7) specifies a throughput of 1 m^3/h, and a continuous operation of at least 250 hours. The facility should be able to operate at ambient temperatures between +1 °C and +40 °C.

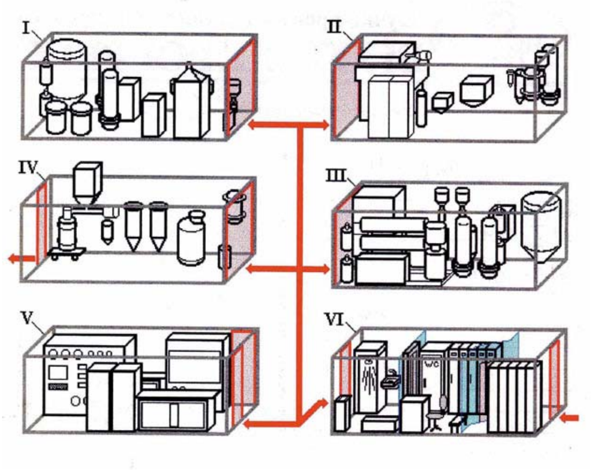

Fig. 3. Possible layout of MTF-LRW.
I: Primary purification and selective filters.
II: Removal of organic mixtures.
III: Reverse osmosis and final purification.
IV: Solidification. unit.
V: Laboratory
VI: Sanitary room

Operation at the Polyarninsky Shipyard

The above specifications assume operation in summer only. During the winter, the MTF LRW as currently planned would be inactive, but the PPP RAO may need to operate all year round. In order to use the MTF LRW at the Polyarninsky Shipyard in winter conditions, the facility must be able to operate at temperatures well below 0 °C. This could be solved by placing the units in a heated environment, or by providing the units and connecting pipelines with insulation and heating to withstand the low temperatures.

Not all modules may be needed at Polyarny, depending on the type of LRW generated and other available infrastructure. This might reduce the size of a heated environment or the number of modules needing insulation and heating, thereby reducing the increased cost due to operation in winter conditions.

WASTE STORAGE FACILITY

Treated waste from the MPF SRW and the MTF LRW will need to be stored safely and securely. AMEC Project 1.4 has investigated the feasibility of using lightweight steel structures on concrete pads for this purpose. Such structures are proven to be able to survive Arctic conditions and there is no Russian regulation that would prevent using them for storing treated radioactive waste. Thus, the plan for the integrated waste management complex at the Polyarninsky Shipyard includes one of these structures. This storage facility will have a net storage volume sufficient for 1,000 containers full of treated SRW.

CONCLUSION

As the Russian Navy dismantles more nuclear submarines, the need for radioactive waste management grows more and more acute in northwest Russia. The AMEC Program is working to meet this challenge by building an integrated waste management complex at the Polyarninsky Shipyard. Waste transport containers have been fabricated and certified, metal-cutting tools have been delivered, a solid waste treatment facility is being built, a liquid waste treatment facility is planned, and a treated waste storage facility is also planned. All these elements will have an integrated radiation monitoring system, built upon the PICASSO computer system.

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