SOLID RADIOACTIVE WASTE TREATMENT INITIATIVES FOR NUCLEAR SUBMARINE DECOMMISSIONING WASTES UNDER THE AMEC PROGRAM

Andrew Griffith
U.S. Department of Energy, Germantown, MD 20874
Thor Engøy
Norwegian Defence Research Establishment, Oslo, Norway
Alexander Diashev
Russian Navy, Moscow, Russia
Paul Krumrine
WPI, Germantown, MD 20874
Steinar Backe
Institute for Energy Technology, Kjeller, Norway
Steve Gorin
Los Alamos Technical Associates, Golden, CO 80401
Barry Spargo
Naval Research Laboratory, Washington, DC 20374

ABSTRACT

The volume of solid radioactive waste (SRW) generated from decommissioning Russia's nuclear submarines far exceeds existing SRW management capabilities of the Russian Northern Fleet. Inadequate management of this waste poses a substantial threat for pollution of the fragile Arctic environment. The Arctic Military Environmental Cooperation (AMEC) Project 1.3 has assessed waste treatment options, selected technologies, and is now designing and constructing a comprehensive SRW pretreatment system to meet this problem (1).

The chosen approach is to design, construct and deploy a novel Mobile SRW Pretreatment Facility (MPF). A key feature of the concept is the mobility aspect, which allows the system to be readily transported between the various shipyards and intermediate SRW storage sites on Russia's Kola Peninsula and in Severodvinsk. These sites either currently store or will generate the majority of the SRW in the region. Much of the existing waste storage is in poor condition. Based on consideration of potential accidents and resulting spread of pollution, it is often safer to bring the pretreatment facility to the waste source rather than transport the waste to the pretreatment facility. The proposed MPF can be set up in close proximity to the waste source and provide pretreatment unit operations of radiation monitoring, metal cutting/shearing, sorting/segregation, and low force compaction and repackaging. In advance of this facility, a set of hydraulically-operated hand-held metal cutting tools will be demonstrated and deployed. These will provide enhanced productivity and safety for size reduction of metal piping and conduit systems, and will ultimately support the operations of the MPF. This represents the first application and introduction of this equipment into Russia for this purpose.

This facility and tool system will achieve SRW volume reduction and stabilization at a rate of about 500 m^3/yr, thereby reducing a bottleneck to future ballistic missile nuclear submarine dismantlement. This paper highlights the progress on these two initiatives, and the cooperative

effort between the Russian Federation, Kingdom of Norway, and the United States of America to address this potential environmental threat.

INTRODUCTION

It is estimated that about 20,000 cubic meters of SRW has accumulated from prior decommissioning of nuclear submarines and other related military activities at Russia's Northern Fleet bases on the Kola Peninsula and in Severodvinsk (2). There is a significant backlog of submarines (~150 both ballistic missile and attack) awaiting accelerated decommissioning as part of Cooperative Threat Reduction activities or other multilateral cooperative programs that will significantly add to this SRW volume in the future.

The generation rate of SRW is about 1000 cubic meters per year (3) and is expected to increase as the rate of submarine decommissioning 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 Decommissioning of Nuclear Submarines (3)

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 wastes listed in Table I that are potentially subject to further pretreatment in the Mobile Pretreatment Facility (MPF) include:

3500 m^3	Metal SRW;
2800 m^3	Combustible SRW;
1000 m^3	Compressible SRW;
70 m^3	Activity Filters.

Some of the intermediate dose rate waste may be more than the 1.0 mSv/h limit for waste entering the MPF. It is expected that much of this can be detected and separated outside the MPF. The high activity metal and non-processible (non recyclable) SRW in Table I must be segregated and placed in concrete/metal matrix containers intended for storage and subsequent disposal, or in storehouses awaiting decay of short-lived radionuclides.

AMEC Project 1.3 entitled "Design and Construction of Treatment Systems for SRW Generated and Accumulated During the Decommissioning of Russian Nuclear Submarines" has undertaken two initiatives that will be deployed towards volume reduction and stabilization of this waste. The following discussion highlights the progress on these two initiatives.

EVOLUTION OF THE MOBILE PRETREATMENT FACILITY CONCEPT

In the early Technology Evaluation Phase of AMEC Project 1.3 several assessments were made of the SRW problem and the various technologies and commercial practices currently in use within Russia and the rest of the world. From these assessments, initial estimates for an integrated facility providing metal decontamination and recycling, super-compaction, vitrification, incineration, and cementation of wastes approached $100 M, which was beyond the financial capabilities of the program. Based on a report (4) provided under contract by the Russian technical support contractor, the scope was reconsidered and reduced, to include metal decontamination and recycling, super-compaction of non-metallic wastes, and cementation. A recommendation report on applicable technologies and an implementation approach was issued in August 1998, (5) which concluded the initial Technology Evaluation Phase.

The recommendation report laid out plans for a phased implementation – beginning with limited implementation to deploy cutting/shearing, waste handling, and low force compaction at a number of Russian shipyard sites. Each shipyard deployment was envisioned to include a skid steer tractor with various attachments including a hydraulic shearing implement and low force in-drum compaction to reduce waste volume. Estmated cost for each shipyard deployment was in the range of $250K assuming facilities already existed to house these operations. This was to be followed, pending funding availability, by full implementation. Plans for this consisted of metal decontamination, supercompaction of filled drums, and cementation of liquid and solid radioactive waste from these two operations entombing the compacted pucks from supercompaction. The estimated implementation costs were still in the $20 million range, and likely beyond the budget of the cooperating countries for this project.

The implementation options were further refined in March 1999 at a Joint AMEC 1.3/1.4 Project Officer Meeting held in conjunction with Waste Management 99, which provided an opportunity for Russian Ministry of Defence (MOD) and technical representatives to view US technologies and talk directly with a number of vendors. This new approach centered on design and construction of a mobile pretreatment facility (MPF) that was believed to be within the financial constraints of the project (6). Also included was the early deployment of a set of hydraulically operated metal cutting/shearing tools to demonstrate their capabilities for improving both D&D productivity and worker safety compared to current practices with mechanical saws and thermal cutting equipment.

The MPF concept is comprised of the basic unit operations of waste receipt/rejection, inspection, radiation monitoring, classification and segregation, size/volume reduction via cutting and compaction, and packaging into drums or other approved containers. These operations will result in a volume reduced and stabilized waste that can either be directly disposed or further processed at a central processing facility employing metal decontamination, supercompaction, grouting or other treatment options at a later time. To achieve mobility, the facility will be modular in design and based on ISO type containers and other readily assembled prefab building components. Although designed for mobility, it is expected that the facility would remain at each selected site for several years to treat existing volumes of waste and newly generated wastes. While in operation at a site, the modules could be situated within another structure or outside, but in either case would be securely anchored to a concrete pad. Prior to development of Russian Technical Requirements for the MPF, an early estimated cost for a simple facility consisting of three basic modules was in the neighborhood of $1.3M.

Shortly after the MPF concept was developed, an initial Request for Information identified over 12 firms or teams capable and interested in the design and construction of the MPF. Estimated costs spanned a broad range from a low of $380K to a high of $50M with a median of about $1.7M. Estimated time to complete construction ranged from a low of 3 months to a high of 37.5 months. The Russian Navy/MOD and ICC Nuclide further refined the MPF concept by compiling a set of Technical Requirements, which defined the design specifications for the facility to meet Russian regulations and needs. Several iterations followed in clarifying and refining the Technical Requirements to the satisfaction of MOD and to limit the expected cost. In a Request for Supplemental Information following finalization of the Technical Requirements, this list of capable and interested firms/teams was substantially shortened to only three, but estimated costs still ranged between $2.5 to $4.5M.

Further discussions on the scope for the MPF occurred at a Trilateral AMEC 1.3/1.4 Project Officers meeting in May 2000 and held in Moscow, Russia. The main issues for reducing the scope of the MPF were as follows:

- The maximum dose rate (whether 0.3 or 1.0 mSv/hr) of solid radioactive wastes that would be accepted and processed through the MPF. Higher dose rate wastes require more shielding and remote operations to protect workers and add significantly to costs.
- The required instrumentation for measurement of radionuclide speciation and level of information actually needed to satisfy regulatory requirements. Simpler instruments that provide gross alpha, beta and gamma and quantitative indications for only the most prevalent contaminants are more cost effective.
- The need to shred all the waste. Shredding waste does not add significant volume reduction benefit during compaction and adds mechanical complexity and cost.
- The need to dry the waste. Complete drying of waste adds extra steps and costs. It is not a necessary step to ensure drum containment integrity for a period of 7 years.
- The need to strictly adhere to use of ISO sized containers for the various modules versus achieving the transportability goal through other more flexible structural means.
- The processing rate of solid radioactive waste through the MPF. Previously the target was 1000 cubic meters per year, which was decreased to 500 cubic meters per year of incoming waste.
- Construction of a larger Project 1.4 waste storage facility and utilization of part of it to house the MPF and provide protection from the Arctic environment.

Several of these issues including vacuum drying of wastes and methods to prevent drum corrosion were studied in more detail by the technical contractors and it was later resolved to follow practices for similar wastes currently accepted in the US and Europe without drying.

Changes to the Russian Technical Requirements were successfully negotiated and a Request for Proposals (RFP) was issued in late June 2000. Only two of the three teams elected to respond to the RFP. Bids were reviewed and a final selection was made on a winning conceptual design and vendor team to deliver the MPF. It was determined that the most flexible and conforming design, and best value for the MPF were provided by the international team of Kvaerner & Zvezdochka JV consisting of Kvaerner Oil and Gas CIS a.s (Norway), FSUE SME Zvezdochka (Russia), and FSUE DB Onega (Russia). Kvaerner has since sold their share in the Kvaerner and Zvezdochka JV (KAZV) to the Norwegian company Storvik Co a.s.

Their conceptual design utilizes 4 standardized modules for waste processing, utilities, and worker service needs, plus 4 additional rooms to serve as the waste receipt and stabilized-waste shipping area, which provide adequate isolation and protection for these operations. The facility will be designed to handle wastes with dose rates up to 1.0 mSv/hr. Although this adds to the cost, it is required to address the bulk of the expected waste, and therefore has been jointly approved and funded by the US and Norway.

The MPF will be designated with three contamination control zones (a contaminated zone, a controlled zone, and a clean zone). The MPF utilizes separate ventilation and HEPA filtration systems for the clean and contaminated areas of the facility, which maintain negative pressure differentials between the three zones, helping to minimize and control the dispersion of any contamination.

Under typical operations, waste (after being pre-screened) will be brought into the facility by way of a forklift. The container will be monitored and opened by operators using appropriate personal protective clothing and equipment (PPE). If the contents of the container exceed the maximum acceptable activity level, the container will be rejected, closed, and removed from the facility. If found acceptable, the waste will be moved into a glovebox by use of a mechanical remotely operated tilter, dumped, sorted, and size reduced in the glovebox. One leg of the glovebox is used to handle the compressible waste, and the second leg the non-compressible waste. The glovebox is to be equipped with size-reduction equipment such as non-sparking chop saws, hydraulic nippers, hydraulic guillotines, and hand-held electric tools. A telpher (pulley support system) will be used to move the heavier pieces of waste within the glovebox. Non-compressible waste that is accumulated from the glovebox operations will be collected in drums for either later disposal or further treatment. Compressible waste will be collected in bags that will be fed into a press compactor with a 200-l disposal drum. Liquids that are collected from any of the waste handling operations will be collected in plastic drums for later disposal or treatment elsewhere. Decontamination will be carried out in a manner to minimize the generation of contaminated liquids.

The MPF facility will also be designed to incorporate all the appropriate support requirements for a facility handling nuclear waste such as shielding, fixed radiation area monitors, continuous air monitors, hand-held radiation detectors, alarms and alarm/data panels, decontamination solutions, contamination control check points, dosimeters, sanitary passages, (from contaminated zones to non-contaminated zones), smoke detectors, showers, intercoms, emergency lighting, uninterruptible power supplies (UPS), cranes, trolleys, PPE, some laboratory space, etc. It will also provide standard personnel requirements such as wardrobes, sinks, a lavatory, office space, computers, a utility room, etc. A conceptual layout for the MPF is shown in Figure 2.

In the figure, the "1" and "2" designate the waste processing modules where the waste sorting, size reduction, compaction, and repackaging occurs. Major equipment components within the processing module are the waste container tilter "9", the main sorting table "10", the sorting glove box for compactible waste "11", the sorting glove box for non-compactible waste "12", and the compactor "13". The utility module denoted by "3" contains the ventilation system and has various tanks for storing fresh water and preparing decontamination solutions. The service module denoted by "4" provides for worker sanitary needs and office space. These four modules would be based on a standard oil field module of the 1st oversize that can still be readily transported by truck, rail, and sea. The four rooms denoted by "5" through "8" constitute the waste receipt area, which would be fabricated as a light modular building. This module allows for receipt of waste in a variety of container sizes, decontamination of reusable containers, size reduction of breached/badly rusted containers, and repackaging of filled drums into large cylindrical transportation containers.

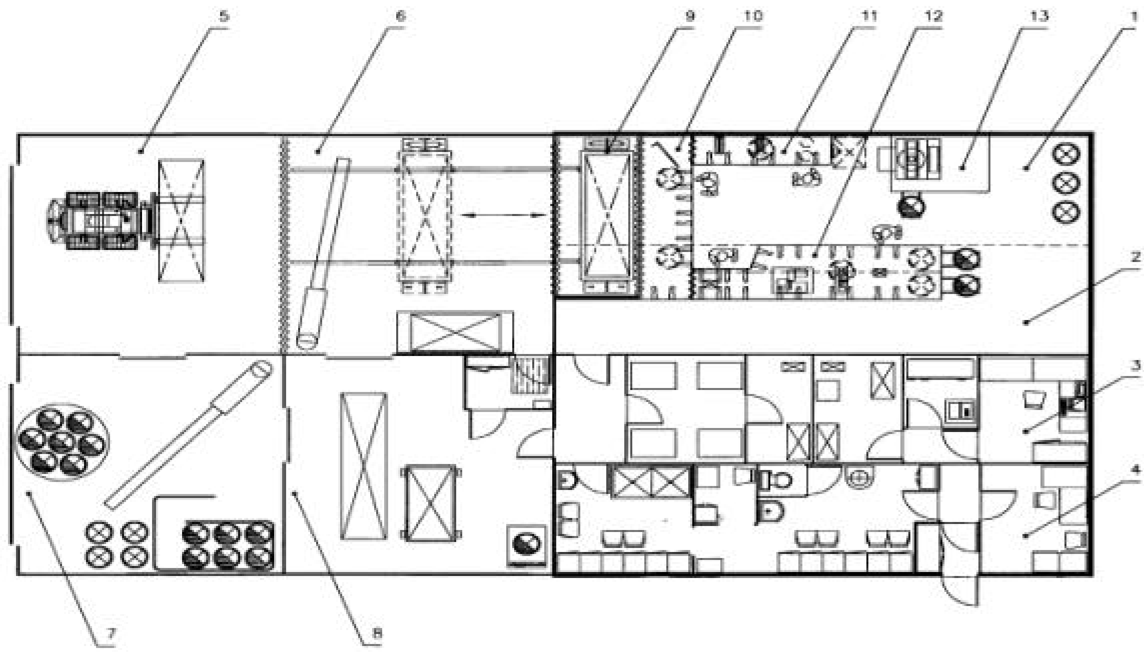

Fig. 2. Kvaerner &Zvezdochka JV Concept for the MPF.

Related AMEC Project 1.4 is providing these new cylindrical transportation containers (7,8). Current plans call for the facility to be built in 15 months and thereby be operational in early 2002.

METAL CUTTING AND SHEARING TOOL SYSTEM

An initial deployment of cutting and shearing equipment is planned under AMEC Project 1.3 as a pilot demonstration (9) preceding the actual deployment of the MPF. This provides an opportunity for Russian shipyard workers to develop first hand experience using these tools in actual D&D situations in the Arctic environment. The MPF will incorporate metal cutting and shearing operations for the sorting, size reduction, and volume reduction of metallic wastes. Therefore cutting and shearing equipment will support the overall strategy to pretreat such wastes at the various shipyards and storage points prior to final treatment and disposal at a future central processing facility.

Russian representatives to AMEC Project 1.3 briefly viewed the Mega-Tech Services product line of metal cutting tools at the Waste Management 99 Conference and Exhibition, and noted that there is no comparable equipment available within Russia. Such equipment could greatly facilitate ongoing D&D operations at their shipyards and complement the various thermal metal cutting techniques that they currently use. Key advantages noted for such equipment are that it limits spread of contamination due to its crimping action, and does not generate particulates that could possibly represent a health and safety hazard to workers. Also, portability and ease of use were seen to significantly increase productivity over traditional thermal cutting techniques. Such tools are in widespread use in US decommissioning projects, and are being deployed to other countries.

While similar hand-held equipment is used by fire and rescue teams, only Mega-Tech Services, has been identified that can provide such technology specific for D&D applications, and that can be used daily on an industrial basis. Typical fire and rescue versions of this equipment offered by other suppliers employ a scissors action where the cutting force is greatest at the notch and proportionally decreases further out on the blades. Therefore, in attempting to cut a large diameter pipe or piece of bar stock the actual cutting would occur far from the notch with resulting loss of cutting force. The fire and rescue equipment is better suited for cutting the thinner metal support structures and sheet metal found in automobiles and trucks.

Other competitive equipment might include saber saws and thermal torches, however, as mentioned previously these generate chips and particulates or potentially toxic and contaminated smoke/vapors. Saber saws are not efficient for cutting internal cabling as they often experience blade binding and are much slower per cut. Tools such as oxy/acetylene, oxy/gasoline, and plasma torches and various saws have been provided to the Russian Federation under the Cooperative Threat Reduction program for submarine decommissioning activities, therefore this planned deployment will provide for comparative evaluations in similar operating environments. Ultimately the tools will be used inside the MPF where space is expected to be at a premium, productivity a prime consideration, and fire hazards from combustible waste a concern.

Requirements and Differences in Operation

For nuclear power industry D&D applications, a significant component of an energy conversion system is contaminated piping and conduits associated with the various cooling loops and power generating equipment. The unique design of a blade action restrained by an anvil permits the blade plunging cutter tools to cut pipe and structural shapes that are well beyond the capability of any other contemporary device available or adapted from the fire and rescue service industry. The tool design firmly holds the piece to be cut in the blade jaws so that the cutting force is uniformly applied across the blade to cut and crimp in one action.

Existing commercially available models (10) provide cutting forces ranging from 34,100 kg (75,000 pound) for the smallest conduit cutter up to 227,000 kg (500,000 pound) for the 150mm (6 inch) blade plunging cutter. The tools can rapidly cut up to 150mm Schedule 40 carbon steel pipe and structural shapes or equivalent without generating chips, dross or significant heat. In addition, these tools are designed for industrial use with a design operating life of over 200,000 cycles with proper attention to periodic maintenance.

Complementary to the cutting and shearing application are spreading tools, which use hydraulic force to pry pieces apart such as piping from wall fasteners or brackets. This is similar to the spreading applications found in the fire and rescue field where this action is used to open vehicle compartments to extricate injured passengers. The tools for both applications have comparable spreading pressures. However, these are designed to operate in tandem off the same power unit with the cutting tools, therefore are not readily interchangeable with the fire and rescue tools.

The pointed nose of the spreader is inserted into an opening as small as 9.5mm and the spreading arms are forced outward by a hydraulic piston and mechanical translation of the force. The operator inserts the tool further into the opening as necessary to apply additional force and increase the opening size. It is necessary to create an opening approximately 25 x 25mm to insert the conduit cutter and make a cut, and 38 x 50mm to insert the pipe cutter.

Up to four tools can be connected to the cart and pumping unit at the same time by individual 138 MPa (20,000 psi) minimum burst pressure hydraulic supply hoses fitted with zero leakage quick disconnects. However, only two of the tools can be operated simultaneously. Thumb valves on the cart allow the operators to readily activate the various tools as needed. The applications/capabilities for the full line of available cutting tools are summarized in Table II.

Table II. Hydraulic Tool Cutting Capabilities (10)

Equipment Designation	Pipe or Conduit	Structural Shapes	Rod & Bolt Stock
38mm Conduit Cutter (CC-1.5)	Thin-wall Conduit up to 38mm OD, Small Tubing and 9.5mm Sch. 40 Pipe	Small Unistrut Hanger Material and Thin Angle Iron Structural Material	Up to 13mm Standard Rod and Bolt Material
100mm Pipe Cutter (BPC-4)	100 mm Sch. 40 C.S. Pipe & up to 100mm Conduit with wire loading	Medium Unistrut Hanger Materials, 50 x 9.5mm Angle Iron, 100 x 6mm I or H Beams	Up to 19mm Solid Bolt Stock (SS), and 19mm Reinforcing Bar
125mm Pipe Cutter (BPC-5)	125mm Sch. 40 C.S. Pipe and Conduit	All Unistrut Materials and Support Beams Equal to 125mm C.S. Pipe	Up to 25mm Reinforcing Bar
150mm Pipe Cutter (BPC-6)	150mm Sch. 40 C.S. Pipe and Conduit	150mm Light Support Beams, & 75 x 75 x 9.5mm Angle Iron	Up to 25mm Bolt Stock and Reinforcing Bar
Large Pipe Cutter	Special Purpose Tool for Cutting 150mm to 200mm Diameter Thin Wall Tubing / Piping.		

Tool Selection For Initial Deployment

The tools planned for initial deployment on the Russian project include the two smaller portable cutting tools and a spreader tool. These are a 38mm (1.5 inch) plunging blade conduit cutter, a 100mm (4 inch) plunging blade pipe cutter, and a 2500mm (10 inch) spreader (MS-10). As Russian workers gain experience with the tool capabilities and operations, a more detailed needs assessment will be performed to determine what additional tools and capabilities might be added to complement the MPF operations at a later point.

The 38mm conduit cutter is a small 6.4 kg (14 pound) tool designed to cut small (up to 40 mm diameter) thin wall conduit. The conduit cutter has recently been redesigned and strengthened to extend its capability for cutting small bore pipe up to 25mm Schedule 40 carbon steel.

The 100mm pipe cutter will be the workhorse for decommissioning applications. It cuts most materials that a typical operator encounters, which do not have to be handled with special rigging. The pipe cutter weighs approximately 12.8 kg (28 pound), but the effective weight is reduced to zero when the blade is embedded in the work. The 100mm tool is designed to cut pipe, conduit and structural shapes in 1 to 3 cuts depending on the tool orientation and particular blade. With this tool, heavy wall conduit can be cut with typical wire loads (less than 40% full), in place.

The other tool to be provided is a 7.7 kg (17 pound) pointed nose mini-spreader that exerts approximately 13,600 kg (30,000 pound) of force laterally to force pipe and conduit apart or away from walls. This permits entry of the larger cutting tool anvils for cutting, and facilitates rapid disassembly and removal of all materials in a facility on an areal basis. In many cases, and particularly in ship or submarine construction, systems are essentially built in place and must be cut out in place.

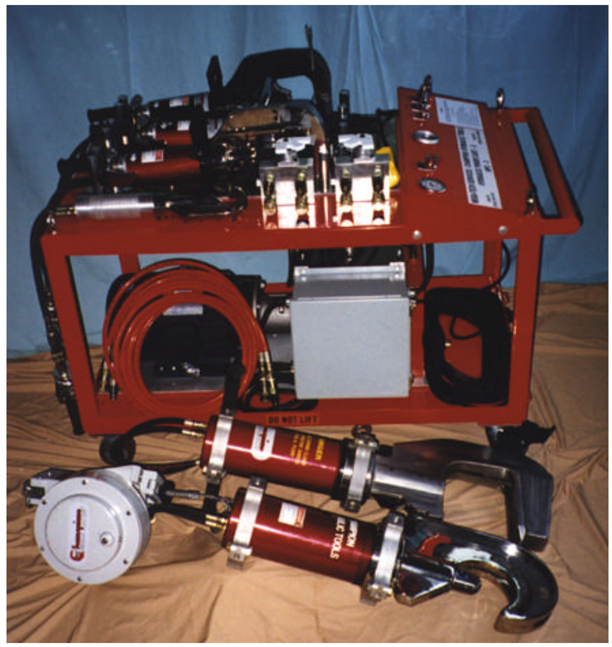

Fig. 3. Cart and cutting tool system.

The initial deployment is a pilot demonstration of the tool's capability, and part of a plan to integrate these operations into the MPF. The optimum integration of the hydraulic cutting tool system would be to make it fully functional within the MPF, operating immediately outside of the MPF, or operating some distance away from the MPF. Due to the configuration and size of the cart, shown in Figure 3, which is approximately 762mm wide by 914mm high and 1270mm long with a weight of approximately 160 kg (350 pound), the unit is sized to readily operate in typical power plant D&D environments. The MPF, however, is much more restrictive, and space is at a premium. Therefore, the hydraulic cart is envisioned to be mounted in a stationary position in the MPF with the hydraulic fluid piped via a small-bore high-pressure supply / return system to various operating stations within the MPF. For applications adjacent to and outside of the MPF, the hydraulic system can be extended through wall terminals. For applications remote from the MPF, the hydraulic cart and tools can be used as an independent system, much as it will be used prior to integration with the MPF operations.

Modifications For Arctic Use

This represents the first time such equipment will be deployed to an Arctic environment. Therefore, the tool system has been modified for start up and operation at temperatures reaching –40 ^{o}C. Mega-Tech Services has performed several tests in a dry ice cabinet at temperatures approaching –60 ^{o}C on selected components to ensure their functionality in Arctic conditions. They have performed cuts on various non-standard metal shapes to ensure blade functionality, tested hydraulic fluids, and tested the pre-heating devices, but not tested the system in its entirety.

Although these tools will be used in the Russian Arctic, it does not imply that the tools will be continually subjected to such conditions. In general the tools would be employed within the MPF, which will be heated to a comfortable operator working environment. However, on occasion the tools, taking advantage of their mobility feature, may be taken outside for disassembly of larger structural pieces. To meet this possibility, special modifications to the unit were made.

Two problems must be confronted with respect to low temperature operations. The first is maintaining the system (the cart, pumps, electrical supplies, oil in the system, and tools) fully operational at all times, and the second is maintaining the tools in a fully ready state (when they are off of or away from the cart) in low temperature conditions. The approach in the first case is addition of immersion heaters for the oil reservoir, customized insulating blankets, and electrical strip heaters (all automatically controlled) with an interlocked alarm system to notify the operator of problems in or failure of the heating systems. The second problem (dealing with effects of cold temperatures on the blade and anvil metal ductility characteristics) is solved through heaters under the tool storage brackets on the cart. Although the blade and anvil materials of construction are made from alloys not susceptible to brittle failure, they should be returned to the brackets to be kept warm. Also, this is a benefit to the operators in keeping gloved hands warm while handling and operating the tools.

To test the full system prior to sending the equipment to Russia a series of tests were arranged through the US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH. This facility has capabilities to simulate virtually any Arctic conditions on a large scale and perform engineering tests on a variety of materials including equipment, hardware, soils, road and bridge materials, etc. To simulate Arctic operation in Northwest Russia it was decided to test the tool system at –40 ^{o}C (-40 ^{o}F).

For the tests a variety of materials were selected including multi-strand electrical wire cables, conduit with cable inside, 2 and 3 inch Schedule 40 stainless steel, and 4 inch steel pipe. A generator was rented for the test that could simulate Russian electrical standards of 50Hz, 3 phase, and 380 volts. The equipment was first tested at ambient conditions near 20 ^{o}C. These results (11) are graphically plotted in Figure 4. Measurements were taken of the amperage drawn during the various cuts and operation of the spreader tool as the pump and motor were stressed. Also, qualitative observations were made of performance (e.g., number of cuts required to sever the piece, ease of handling, general operations) to establish a baseline for comparison to the cold tests.

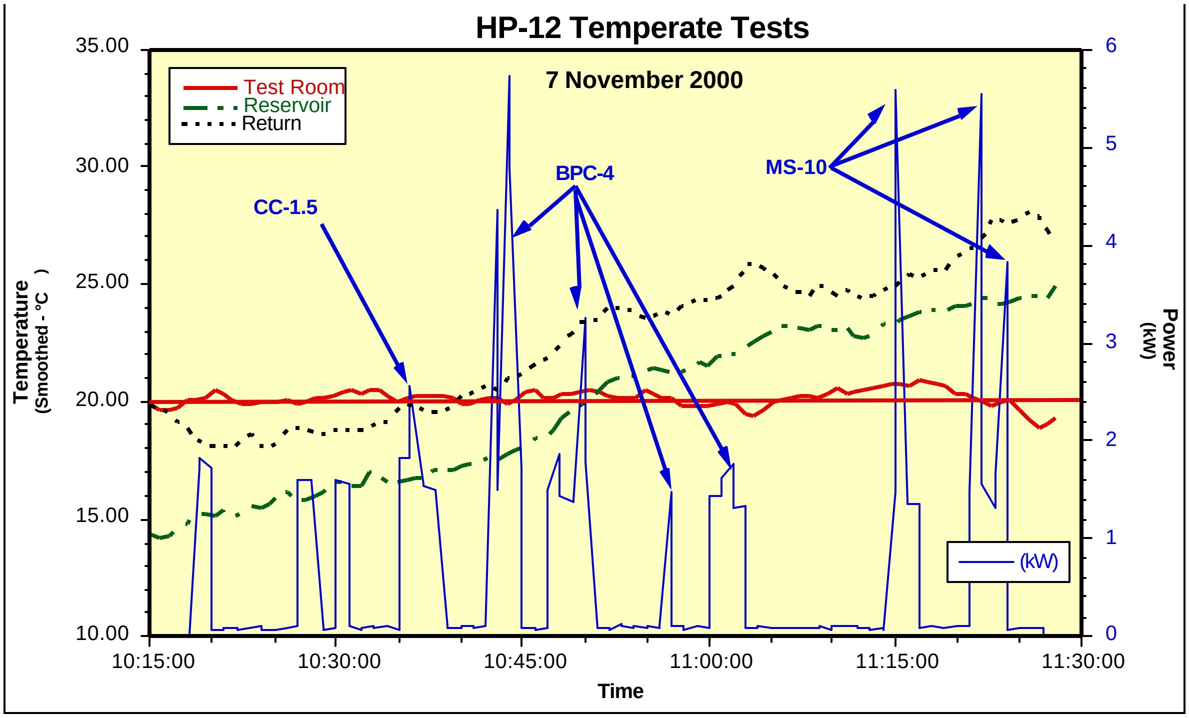

Fig. 4. Temperate performance testing results of cutting tools at 20°C.

At the conclusion of these baseline tests the chillers were turned on and the room and equipment brought down to –40 °C over night. The next morning the equipment and heaters were energized and allowed to warm up for about an hour as temperature measurements were made at various points on the cart and in the hydraulic fluid reservoir. A similar series of cuts were made on the various materials as temperature and amperage draw were again recorded continuously. These results (11) are graphically plotted in Figure 5.

There did not appear to be any deterioration in performance. The modifications were able to heat up the cart, pump, and tools within a reasonable time period and maintain the components within a desired operating range. Amperage draw was within the expected norms for the cart and tools and performance as measured by ability to cut the various pieces was not affected. Several of the metal pieces actually seemed easier to cut (the steel pipe experienced some brittle fracture). At the conclusion of the cold tests the room was allowed to return to ambient temperature and another series of cuts was performed to ensure no change in performance after a full cycle of simulated cold operation. The tests were videotaped and a final report has been generated for review by the Russian Navy as verification of performance.

Upon arrival of the tool system in Russia, training will be provided on proper operation and maintenance, and then the system turned over to a Russian shipyard for cold and hot testing on actual metal scrap. Ultimately, the tool system will be united with the MPF to support its waste pretreatment and volume reduction operations.

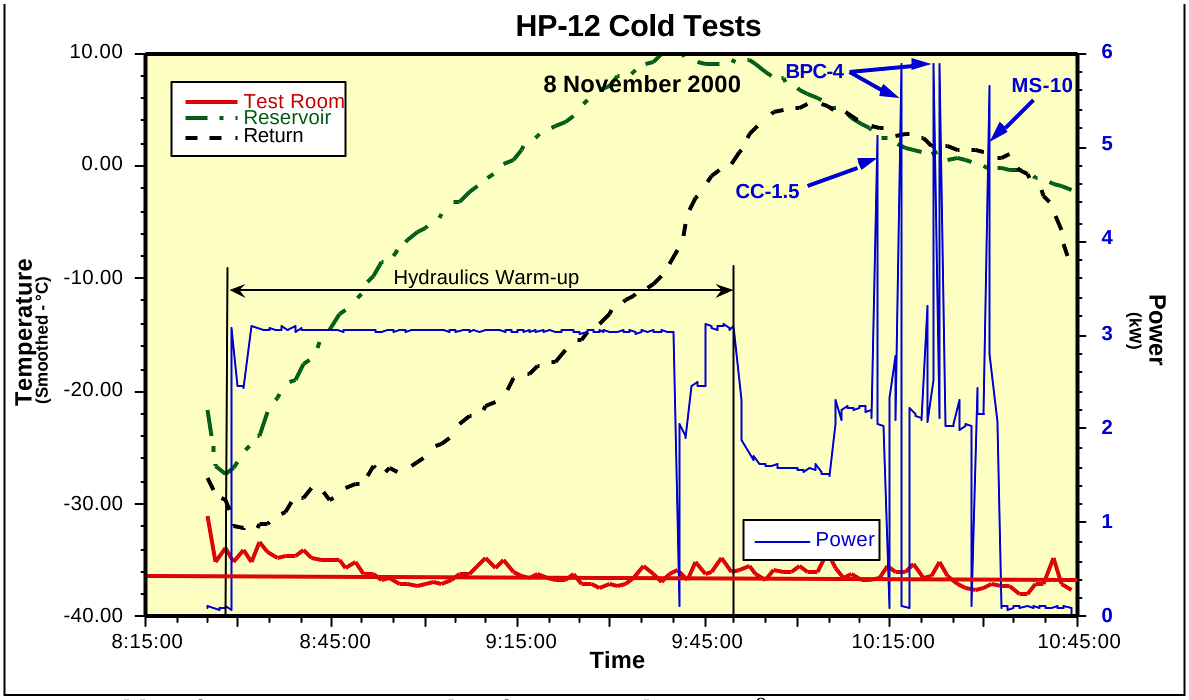

Fig. 5. Cold performance testing results of cutting tools at –40 °C.

CONCLUSIONS

1. Neither the MPF design/construction nor the cutting tool system procurement initiatives now in progress under AMEC Project 1.3 provide a total solution to the SRW problem. However, they do provide a cost-effective, comprehensive, and flexible pretreatment capabilities to begin stabilizing and reducing the volume of waste until a complete solution can be designed and implemented.
2. Through mutual cooperation and exchange of information, the MPF concept has evolved into a technically and economically viable plan to pretreat SRW on Russia's Kola Peninsula and in Severodvinsk. A well-qualified international collaboration between Norwegian and Russian firms is prepared to make this a reality.
3. The Mega-Tech metal cutting tool system is well suited to industrial applications and has been successfully modified and tested for operation in the Arctic environment.

REFERENCES

1. GRIFFITH, P. SCHWAB, A. NAZARIAN, P. KRUMRINE, and B. SPARGO, "Stabilization and Storage of Solid Radioactive Waste from the Russian Navy's Northern Fleet under the AMEC Program", **Waste Management 00**, Tucson, AZ, (2000).
2. N. BOHMER, "Measures for Securing Radioactive Waste and Spent Nuclear Fuel in Murmansk and Archangelsk Counties", published by Bellona Foundation, Oslo, Norway (1999).

3. ICC NUCLIDE, "Designing and Creation of Systems of Processing of Solid Radioactive Waste (SRW), Obtained and Accumulated as a Result of Utilization of Russian Nuclear Submarines", Project 1.3 Internal Report, (1998).
4. ICC NUCLIDE "The Design and Development of Systems for Processing Solid Radioactive Wastes Generated and Accumulated from Decommission of Russian Nuclear Submarines", Project 1.3 Internal Report, (1998).
5. B. SPARGO, "Recommendations for Solid Radioactive Waste Processing Technologies", Project 1.3 Recommendation Paper, (1998).
6. P. KRUMRINE, C. BUTLER, G. POLYANICHKO, and B. SPARGO, "A Mobile Solid Radioactive Waste Pretreatment Facility for Deployment in the Russian Arctic", **NDIA 26th Environmental Symposium & Exhibition**, Long Beach, CA, (2000).
7. V. PETRUSHENKO, E. BAAL, D. TZVETKOV, V. FORB, V. NIKITIN, and A. MIKHEEV, "Construction of Containers for Transportation of Solid Radioactive Wastes (SRW)", to be published **Waste Management 01**, Tucson AZ, (2001).
8. GRIFFITH, T. ENGOY, A. DIASHEV, P. SCHWAB, and A. NAZARIAN, "Storage of Solid Radioactive Waste from the Northern Fleet of the Russian Navy under the AMEC Program", to be published **Waste Management 01**, Tucson AZ, (2001).
9. P. KRUMRINE, B. SPARGO, C. BUTLER, and J. STOUKY, "Application of Advanced Hydraulic Cutting Tools for Russian Submarine Decommissioning", **International Decommissioning Symposium 2000**, Knoxville, TN, (2000).
10. Mega-Tech Services, "High-Efficiency Cutting & Volume Reduction Equipment for Low-Level Radioactive Waste Management and Decommissioning Waste Management" Product Information and Performance Data, 2804 Woodley Court, Jamestown, NC 27282.
11. M. WALSH, "Assessment Report: Mega-Tech Services Inc. HP-12 Hydraulic Metal Cutting System – Temperate and Cold Operations Tests", US Army COE, Cold Regions Research and Engineering Laboratory, Dec. (2000).

ACKNOWLEDGEMENTS

This work is funded tri-laterally by the U.S. Department of Defense, Ministry of Defence of the Kingdom of Norway, and the Ministry of Defence of the Russian Federation under the Arctic Military Environmental Cooperation program. This work was also supported by the U.S. Department of Energy, Office of Environmental Management, under Contract Number DE-AC21-96MC33241. The authors would like to thank Jon Stouky of Mega-Tech Services, Dr. Lev Tchernajenko and Vladimir Ilyin of ICC Nuclide (Russia), and Gregory Polyanichko of WPI, for their efforts in support of this project, and also acknowledge Michael Walsh and the fine work performed at CRREL.