

**AMEC 1.2 “A MODULAR MOBILE TREATMENT FACILITY FOR LIQUID
RADIOACTIVE WASTE – PROJECT DESCRIPTION AND COMPARISON OF LIQUID
LOW-LEVEL RADIOACTIVE WASTE TECHNOLOGIES “IN USE” OR PLANNED FOR
NORTHWEST RUSSIA”**

Carl Czajkowski
Brookhaven National Laboratory, Building 830, Upton, NY 11973, USA

Stephen R. Gorin, Jerry V. Fox
Los Alamos Technical Associates, Inc., Golden, CO 80401, USA

Robert S. Dyer
US Environmental Protection Agency, 401 M Street S.W., Washington, DC 20460, USA

ABSTRACT

A number of sites have been identified in remote coastal locations in the Russian Northwest Arctic where complex liquid radioactive wastes (LRW) have been stored. These radioactive wastes are mostly stored in tanks under environmentally unsafe conditions within close proximity to the Arctic coast. The LRW are the result of nuclear submarine decommissioning activities related to arms reduction during the post-Cold War period. The conditions of storage and general circumstances of the remote coastal naval facilities prevent the off-loading from these storage tanks onto surface ships for transport to the fixed liquid radioactive waste processing facility at Murmansk, Russia. In addition, some of the radio-nuclides, the extremely high salinity content and specific organic contaminants present in some of the LRW are outside the design capabilities of the existing low-level liquid radioactive waste (LLRW) processing capabilities in Russia. Also, the tanks containing the LRW were not intended for long-term storage of such wastes, and many are now in a rapidly deteriorating condition, threatening the nearby marine environment.

In addition to the environmental concerns posed by the deteriorating conditions of storage of these LRW, the former Soviet Union routinely dumped LRW and other radioactive waste in the Arctic Seas. Its successor, the Russian Federation, also has dumped LLRW at sea. Although the Russian Federation has refrained from such actions in recent years, it has not yet signed the 1993 amendments to the London Convention that bans the ocean dumping of all radioactive waste, including LLRW that was not covered under the original convention. This prototype demonstration project (Project 1.2) will be developed under the Arctic Military Environmental Cooperation (AMEC) Agreement, a trilateral agreement between Norway, Russia and the United States. The overall objective of this project is to design, develop, construct and demonstrate a unique prototype LRW processing system that is mobile, so that it can be transported to the remote sites where the storage tanks are located and can be operated at those locations. The first phase of the project, of concern here, will address those activities resulting in the successful design of the prototype LRW processing system.

The prototype system will consist of specially designed modules that can be assembled in particular configurations to address the special chemical and radioactive characteristics of the LRW stored in the individual tanks. Many of the individual modules will be based on new state-of-the-art demonstration technologies developed by Russia, Finland and/or the United States. The paper will discuss the characteristics and operating parameters of the proposed AMEC 1.2 unit in addition to a having review on current LLRW facilities operating in this region of Northwest Russia (e.g. ECO-3, Murmansk, MOS-Radon) and a tabular listing of available LLRW technologies available in the USA.

INTRODUCTION

AMEC 1.2 - A Modular Mobile Treatment Facility For Liquid Radioactive Waste

A number of sites have been identified in remote coastal locations in the Russian Northwest Arctic where complex liquid radioactive wastes (LRW) have been stored. These radioactive wastes are mostly stored in tanks under environmentally unsafe conditions within close proximity to the Arctic coast. The LRW are the result of nuclear submarine decommissioning activities related to arms reduction during the post-Cold War period. The conditions of storage and general circumstances of the remote coastal naval facilities prevent the off-loading from these storage tanks onto surface ships for transport to the fixed liquid radioactive waste processing facility at Murmansk, Russia (1,2,3). In addition, some of the radio-nuclides, the extremely high salinity content and specific organic contaminants present in some of the LRW are outside the capabilities of the existing low-level liquid radioactive waste (LLRW) processing facilities in Russia. Also, the tanks containing the LRW were not intended for long-term storage of such wastes, and many are now in a rapidly deteriorating condition, threatening the nearby marine environment.

In addition to the environmental concerns posed by the deteriorating conditions of storage of these LRW, the former Soviet Union routinely dumped LRW and other radioactive waste in the Arctic Seas. Its successor, the Russian Federation, also has dumped LLRW at sea. Although the Russian Federation has refrained from such actions in recent years, it has not yet signed the 1993 amendments to the London Convention that bans the ocean dumping of all radioactive waste, including LLRW that was not covered under the original convention. This prototype demonstration project (Project 1.2) will be developed under the Arctic Military Environmental Cooperation (AMEC) Agreement, a trilateral agreement between Norway, Russia and the United States. The overall objective of this project is to design, develop, construct and operate prototype LRW processing system that is both modular and mobile. The prototype system then can be transported to and operated at the remote sites where the storage tanks are located. The first phase of the project, of concern here, will address those activities resulting in the successful design of the prototype LRW processing system (4).

The prototype system will consist of specially designed modules that can be assembled in particular configurations to address the special chemical and radioactive characteristics of the LRW stored in the individual tanks. Anticipating the formal initiation of the design process, technical representatives of the AMEC participating countries began discussions of process and technologies concepts while at the May meeting, Figure 1. Many of the individual modules will be based on new state-of-the-art demonstration technologies developed by Russia, Finland and/or the United States. The system will be unique both in its selection of technologies from various countries and in its ability to be configured specifically to process wastes of various characteristics.

Purpose of the facility

The mobile module facility will be used as a prototype for treatment of low level liquid radioactive waste in Northern Russia. These include wastes accumulated or generated from decommissioning of interim LRW/SNF storage facilities placed at shore or floating technical bases withdrawn from operation for the Russian Federation Navy and from dismantling nuclear submarines near the shore bases. As a prototype the facility will demonstrate the effectiveness of state of the art technologies.

Requirements for the facility

The design of the prototype facility will be based upon such criteria as:

- Capacity of facility – 1,000 m³/y
- Volumes of LRW to be treated:
- Accumulated waste, about 6,400 m³
- Operating constraints imposed by the Arctic climate

- Support systems available at the various sites
- Characteristics and production rates of the various wastes

Characteristics of LRW to be treated with the mobile module facility (5):

1. Salt-free LRW

Accumulated, about 1,600 m³

Expected generation, 200-300 m³/y

Salt content up to 50mg/l

Volume activity $3,7 \cdot 10^4 - 3,7 \cdot 10^5$ Bq/l [$1 \cdot 10^{-6} - 1 \cdot 10^{-5}$ Ci/l]

Main radionuclides ¹³⁷Cs (60%), ⁹⁰Sr (20%), ⁶⁰Co (10%), others (10-%)

pH 9,5 - 10,5

Chlorides up to 10 mg/l

Hydrazin-hydrate 20 mg/l

Ammonium 20 mg/l

2. Low-salted LRW

Accumulated, about 2,700 m³

Expected generation, up to 100 m³/y

Salt content up to 1 g/l

Volume activity $3,7 \cdot 10^4 - 3,7 \cdot 10^5$ Bq/l [$1 \cdot 10^{-6} - 1 \cdot 10^{-5}$ Ci/l]

Main radionuclides ¹³⁷Cs and ⁹⁰Sr at ratios from 2:1 to 1:2; ⁶⁰Co up to 1%

pH 6,8 - 7,4

Chlorides up to 300 mg/l

Polyphosphates up to 100 mg/l

Oxalates up to 200 mg/l

Suspensions up to 200 mg/l

3. Low-salted LRW containing petroleum products

Accumulated, about 500 m³

Expected generation - ? (should be specified annually as conditions of such LRW depend on technical condition of LRW handling means)

Salt content up to 3 g/l

Volume activity $3,7 \cdot 10^4 - 3,7 \cdot 10^5$ Bq/l [$1 \cdot 10^{-6} - 1 \cdot 10^{-5}$ Ci/l]

Main radionuclides ¹³⁷Cs (60%), ⁹⁰Sr (30%); ⁶⁰Co (up to 10%),

pH 6,6 - 7,6

Chlorides up to 2 g/l

Petroleum products up to 2 g/l (at most 50-100 mg/l)

Detergents 50 mg/l

Suspensions up to 500 mg/l

4. Trap water and decontaminated water

Accumulated, about 500 m³

Expected generation, 200-300 m³/y

Salt content 3 - 5 g/l

Volume activity $3,7 \cdot 10^3 - 3,7 \cdot 10^4$ Bq/l [$1 \cdot 10^{-7} - 1 \cdot 10^{-6}$ Ci/l]

Main radionuclides ¹³⁷Cs (70%), ⁹⁰Sr(20%), ⁶⁰Co (10%)

pH 6,8 - 7,4

Oxalates 1 - 2 g/l

Chlorides 0,2 - 1 g/l

Polyphosphates 0,3 - 0,4 g/l

Nitrates 0,2 - 0,3 g/l

Petroleum products, oils 20 - 100 mg/l

Detergents	100-200 mg/l
Suspensions	up to 100 mg/l

5. Salted LRW

Accumulated, about 800 m³

Expected generation, up to 100 m³/y

Salt content 5-15 g/l

Volume activity 3,7·10³ - 3,7·10⁴ Bq/l [1·10⁻⁷ - 1·10⁻⁶ Ci/l]

Main radionuclides ¹³⁷Cs (65-70%), ⁹⁰Sr (25-30%), ⁶⁰Co (up to 1%)
¹⁴⁴Ce (2-3%), ¹²⁵Sb- traces

pH: 6.1- 9,4

Chlorides up to 10 mg/l

Oxalates up to 1 g/l

Petroleum products, oils up to 20 mg/l

Detergents 10-20 mg/l

Suspensions 0,5 – 1,0 g/l

6. High-salted LRW

Accumulated, about 300 m³

Expected generation, 500 m³/y

Salt content up to 33 g/l

Volume activity 3,7·10³ - 3,7·10⁴ Bq/l [1·10⁻⁷ - 1·10⁻⁶ Ci/l]

Main radionuclides ³⁵S, ⁶⁰Co (up to 10%)

Oils 50-100 mg/l

Suspensions up to 1 g/l

In addition to these waste characterizations the facility must address other requirements associated with good engineering practices. As a precursor to developing conceptual design solutions, the US AMEC team reviewed certain technologies used in US treatment practices. A common technology is the use of ion exchange employing resins selected based upon specific waste characterizations. Table 1 presents a summary of these ion exchange practices. This experience coupled with that of the Russians provides a wide choice for application in the mobile modular facility. Additional process units under consideration include electro-chemical oxidation, reverse osmosis, and electro-dialysis among others. The design philosophy for the facility with its requirements for mobility in standard size sea containers, modularity, and variable process configurations poses some unique design situations. Table 2 presents other requirements for safety, constructability, and operability of the facility.

A conceptual process configuration representing all required modular units, developed at the meeting in Saint Petersburg, is presented in Figure 2.

ECO-3 Mobile Liquid Radioactive Waste Treatment System

In May 2000, the AMEC 1.2 technical team traveled to the Svezdochka shipyard in Severodvinsk (6) to inspect the ECO-3 mobile liquid radioactive waste treatment unit, manufactured by Radon, Moscow (MOSRADON).

MOSRADON has 40 years experience in monitoring, processing, and disposal of radioactive wastes, including 15 years experience with mobile units and are specialists in mobile processing. Their systems have been installed on truck trailers and in sea containers.

The ECO-3 system was designed to treat low saline; low activity liquid wastes using sorption and membrane unit operations. Three similar Radon-designed systems have been operating at 16 different sites since 1970.

The Phoenix (cyanoferrate-type) sorbent is used for selective removal of cesium; a strong acid cation resin, similar to KA-11, is used to remove strontium.

The electro-dialysis/electro-osmosis module concentrates dissolved salts to 120-200 grams/liter. The concentrated salt solution is solidified.

The most common operating problems experienced are inconsistent waste stream composition and fouling of electro-dialysis membranes.

The three most limiting factors for ECO-3 are 1) composition of the radionuclides, 2) the maximum dose rate for the operators, and 3) the deposition rate of solids.

Compared with the ECO-3 system, Radon's mobile LRW treatment system in Moscow is more suitable for lower salinity waste. However, both systems can treat up to 3 grams/liter of dissolved salts. The ECO-3 system is more rugged and is both mobile and modular. The Moscow system is mobile, but not modular.

If necessary, the ECO-3 unit could be moved to a remote site to treat waste. However, it does not have its own power supply.

The ECO-3 unit power requirement is not more than 25 kw. The electro-dialysis unit is probably the greatest consumer at not more than 10 kw.

To treat higher salinity waste streams, Radon would add reverse osmosis; for dissolved organic compounds and detergents, they would use electro-chemical oxidation; and for suspended solids, they would include micro-filtration.

In 1996-1997, the unit was used to treat slightly more than 400 m³ (105,600 gallons) of liquid waste from an on-shore storage tank. This allowed the tank to be taken out of service so that the liquid waste storage facility (Building 159) could be upgraded. The waste was processed in 800 hours at roughly 0.5 m³ /hr (2.2 gpm) and yielded 2.5 m³ of solidified treatment residuals.

A total of 820 m³ (217,000 gallons) of liquid waste from the tanker Osetia was processed in two campaigns in 1999. This allowed the tanker to be emptied and sent to dry-dock for repair. In the first campaign, 500 m³ of liquid waste was processed in 1,000 hours to yield 5 m³ of solidified residuals. In the second, 320 m³ of waste was treated in 650 hours to yield 3 m³ of solidified residuals. The treated effluent from ECO-3 was discharged to an industrial sewer. Radon specialists supervised the system operation by Zvezdochka personnel.

The system is currently located inside a building and is no longer installed in a sea container. Most of the process equipment is installed on four modular skids. Though the ECO-3 system was not viewed assembled for operation at the time of the visit, the operating configuration as presented to the team is as shown in Figure 3. The piping on the skids is primarily stainless steel. The interconnecting piping between the skids is primarily flexible rubber hose. There are three piping interface connections between the shipyard and the treatment system: raw waste influent, treated waste effluent, and tap water supply.

Raw waste enters the system through two 16-micron cartridge filters for removal of suspended solids. The filtered wastewater then passes through two 30-liter sorbent columns containing Phoenix sorbent for selective removal of up to 98% of the cesium content. These sorbent columns are shielded with lead and are not installed on skids.

The effluent from the two 30-liter sorbent columns flows to four larger sorbent columns. These four columns are installed on two skids. The sorbents used in these columns depend on the waste composition, but would typically include a strong cation resin for strontium removal. The sorption column effluent passes through two more 16-micron cartridge filters, which serve as resin traps.

The filtered effluent from the sorption skids flows to an ultra-filtration skid for removal of fine suspended solids and colloids. This skid includes a small tank, feed pump, and four ultra-filtration membrane housings. Each UF filtration housing is about 4 inches in diameter and 5 feet long. The system operates at a pressure of around 4 atmospheres (60 psig).

The effluent from the ultra-filtration module flows to an electro-dialysis unit on the fourth and final skid. The electro-dialysis unit separates the stream into treated effluent suitable for discharge and a concentrated salt solution. The electro-dialysis unit includes 150 membrane couples and two anodes and cathodes. It requires a 250-volt power supply. The unit operates at 40°C and requires cooling. The treated effluent is discharged to an industrial sewer. The unit can discharge into rubber bladder tanks of 25 m³ each for holding until certified for discharge.

The salt solution from the electro-dialysis unit is further concentrated in an electro-osmosis unit installed on the same skid. This unit requires a 90-volt power supply and concentrates the salts to 200 grams/liter. The concentrated salt solution is solidified. The dilute effluent from the electro-osmosis unit can be recycled back to the inlet of the electro-dialysis unit.

Treatment residuals from the ECO-3 system would include spent sorbents, spent filter cartridges, sludge from ultra-filtration, and concentrated salt solution from electro-osmosis. These residuals would be solidified, probably with cement. However, no solidification equipment was evident during the tour.

“The Murmansk Initiative - RF”

“The Murmansk Initiative - RF” was conceived to address Russia’s ability to meet the London Convention prohibiting ocean dumping of radioactive waste. The Initiative, under a trilateral agreement initiated in 1994, has upgraded an existing low-level liquid radioactive waste treatment facility, increased its capacity from 1,200 m³/year to 5,000 m³/year, and expanded the capability of the facility to treat liquids containing salt (up to 10 g/L). The three parties to the agreement, the Russian Federation, Norway, and the United States, have split the costs for the project. Russia conducted all construction activities at the facility. Construction is complete. Start-up testing has been completed both in manual phase and with automation controls in effect. These start-up activities have included processing of actual radioactive liquid waste from the Arctic icebreaker fleet, and incorporation of these wastes into a cementation process of Russian design. With the completion of these activities, the requirements of the tri-lateral agreement, known as the “Oslo Protocol” have been fulfilled. This paper will report on the results of the start-up testing activities in addition to the “acceptance testing” phase of the project. The acceptance testing requires the processing of 2000m³ of decommissioned submarine LLRW over a six-month time frame. This important phase of the project began on 01 October 2000. Progress of this phase of the project, including Russian licensing activities will be reported. Discussion will also report on any modifications to the proposed operational schedule for the facility. “Lessons Learned” will be evaluated and discussed, in addition to a discussion of potential follow-on activities for this unique region of the Russian Federation.

Zvezdochka/ Zvezda Facilities

Lockheed Martin Energy Technologies (LMET) was awarded a contract by the U.S. Defense Threat Reduction Agency in 1998 to design, develop, fabricate, test, a turn-key low-level radioactive waste (LLRW) volume reduction system at strategic submarine dismantlement facilities in the Russian Federation. The two sites chosen for this work were the Zvezdochka Shipyard in Severodvinsk and the Zvezda Shipyard in Bolshoi Kamen. These projects include construction of a building capable of storing 1500 m³ of processed waste at the Zvezda Shipyard. This project aids the Russian Federation in the volume reduction of LLRW generated from the dismantlement of strategic submarines under the Strategic Arms Reduction Treaties (START).

The project is intended to implement the following volume reductions 1) 4000 m³ per year of liquid/laundry LLRW and 200 m³ per year of SRW at the Zvezdochka Shipyard to less than 100 m³ per year and 2) 2500 m³ per year of laundry LLRW and 200 m³ per year of SRW at the Zvezda Shipyard to less than 50 m³ per year.

Four solution-types of liquid will be treated: Primary Loop Coolant, Biological Shielding Water, a mixture of organic-based decontamination solutions, and Radiological Laundry Wash/Rinse Water.

Renovation of the existing structures and the physical infrastructure at the Zvezdochka site was completed in February 2000. Process equipment installation at this site was completed in May 2000. Hydraulic and simulant cold testing were conducted between June and September, and hot testing will commence in early October 2000. It is anticipated that the Zvezdochka site will be ready to begin processing submarine dismantlement waste (i.e., hot tested and licensed by Russian certification authorities) by December 2000.

Activities at the Zvezda site have proceeded at a slower pace. Construction and renovation activities are continuing and are scheduled to be complete by September 2000. Installation of process equipment will be completed by December 2000 and hydraulic and simulant cold testing are scheduled to run from January to March 2001. It is anticipated that the Zvezda site will be fully operational by June 2001.

Summary/Conclusions

Based on Radon's presentation and the AMEC 1.2 technical team's inspection of the ECO-3 installation, the system appears to be suitable for treatment of up to 0.5 cu.M/hr of low salinity, low activity liquid waste. It is both mobile and modular and should be suitable for treatment of wastes in remote locations.

The system is not suitable for treatment of wastes with elevated levels of dissolved solids (salt), suspended solids, oil, and dissolved organic compounds and detergents. Additional unit operations which would permit treatment of the six AMEC 1.2 waste streams defined by Nuclide might include: cross-flow membrane filtration to remove suspended solids and oil, oxidation/adsorption of dissolved organics/detergents, and reverse osmosis to remove dissolved solids.

The ECO-3 system, as currently installed in Zvezdochka, is not a stand-alone system. Supporting equipment and systems which would be required for remote operation would include: a power supply, analytical/monitoring equipment, solidification equipment, treated effluent storage capacity, decontamination equipment, etc.

In the opinion of the technical team, it is not be cost effective to modify the ECO-3 system to treat the six AMEC 1.2 waste streams in remote locations, although elements of the system, or of the design, could be incorporated into an AMEC 1.2 system. The AMEC 1.2 project team is currently planning to procure the necessary components and expertise to re-design (taking into account lessons learned from ECO-3, Zvezdochka/ Zvezda Facilities) and construct a new mobile modular facility to treat low level liquid radioactive waste in northwestern Russia.

Table I. Review of U.S. Ion Exchange Treatment Practices for Liquid Radioactive Waste Streams					
Location/Sour ce of Feed Stream	Ion Exchange Resin	Resin Characteristic s	Contaminants of Concern	Decontaminati on Factor	Status/Remark s
Hanford/ N-Reactor Storage Basin Water	^a KCOHex, unmilled	Inorganic material produced by 3M on an experimental basis.	Cs-137	1.001E+01	From PNNL Study “Performance Evaluation of 24 Ion Exchange Materials for
	^a KCOHex, milled		Sr-90	1.090E+00	
			Cs-137	1.121E+01	
			Sr-90	1.099E+00	
			Cs-137	3.599E+00	

	Pharma-cosiderite		Sr-90	4.433E+00	Removing Cesium and Strontium from Actual and Simulated N-Reactor Storage Basin Water”, (PNNL-11711).
	Pharma-cosiderite		Cs-137	4.677E+00	
	Pharma-cosiderite		Sr-90	2.376E+00	
	Pharma-cosiderite		Cs-137	2.507E+00	
	Phlogopite (90% Na)	Chemically and thermally stable layered aluminosilicate micas modified from natural form. Highly selective for removing cesium and strontium from various waste matrices.	Sr-90	1.708E+00	
	Phlogopite (90% Na)		Cs-137	6.192E+00	
	Biotite (60% Na)		Sr-90	1.130E+00	
	Biotite (60% Na)		Cs-137	3.296E+00	
	Biotite (60% Na)		Sr-90	1.135E+00	
	Modified Biotite		Cs-137	1.097E+01	
	Modified Biotite		Sr-90	1.169E+00	
	Modified Biotite		Cs-137	8.738E+00	
	Modified Biotite		Sr-90	1.139E+00	
	Modified Biotite		Cs-137	8.194E+00	
	Modified Biotite		Sr-90	1.141E+00	
	Modified Biotite		Cs-137	6.234E+00	
	Modified Biotite		Sr-90	1.053E+00	
	IONSIV® IE-96		Cs-137	3.642E+00	
	IONSIV® IE-96		Sr-90	1.305E+00	
	IONSIV® TIE-96	Synthetic high-capacity aluminosilicate zeolite with relatively little selectivity for cesium over other alkali metals.	Cs-137	2.748E+00	
	IONSIV® TIE-96		Sr-90	1.296E+00	

^aPotassium cobalt hexacyanoferrate.

Location/Source of Feed Stream	Ion Exchange Resin	Resin Characteristics	Contaminants of Concern	Decontamination Factor	Status/Remarks
Hanford/N-Reactor Storage Basin Water	IONSIV® IE-910	Modified version of IE-96 capable of removing strontium, plutonium, and cesium from alkali solutions.	Cs-137	9.965E+00	From PNNL Study “Performance Evaluation of 24 Ion Exchange Materials for Removing Cesium and Strontium from Actual and Simulated N-Reactor Storage Basin Water”
			Sr-90	3.283E+00	
	IONSIV® IE-911	Powdered crystalline silicotitanate.	Cs-137	3.336E+00	
			Sr-90	2.103E+00	
	IONSIV® IE-911	Crystalline silicotitanate in engineered	Cs-137	2.541E+00	
			Sr-90	1.674E+00	
	IONSIV®		Cs-137	5.046E+00	

	IE-911	bead or pellet form.	Sr-90	2.390E+00	Water", (PNNL-11711).
	SuperLig® 644	Chemically and radiochemically stable polymer resin; highly selective for cesium even in the presence of excess sodium and potassium.	Cs-137	1.401E+00	
			Sr-90	1.015E+00	
	Duolite C-467	Organic cation exchangers	Cs-137	1.039E+00	
			Sr-90	1.057E+00	
	Amberlite IRC-76	containing aminophosphonic acid groups	Cs-137	1.043E+00	
			Sr-90	1.362E+00	
	Amberlite IRC-718	on a polymer backbone. Expected to have a greater affinity for strontium than cesium under most conditions.	Cs-137	9.847E+00	
			Sr-90	1.084E+00	
	Duolite CS-100	Commercially available	Cs-137	NA	
			Sr-90	NA	
	Resorcinol-formaldehyde	organic ion exchange resins. CS-100 is a granular phenol-formaldehyde condensate polymer resin. R-F exhibits a much greater selectivity for cesium and strontium over sodium and potassium than CS-100.	Cs-137	1.523E+00	
			Sr-90	1.162E+00	

Location/Source of Feed Stream	Ion Exchange Resin	Resin Characteristics	Contaminants of Concern	Decontamination Factor	Status/Remarks
Hanford/	Amberlite CG-120	Strong nonselective acid	Cs-137	1.047E+00	From PNNL Study

WM'01 Conference, February 25-March 1, 2001, Tucson, AZ

N-Reactor Storage Basin Water	CG-120	nonselective acid cation exchanger similar to IRC-76 and IRC 718 – should not pick up strontium or cesium.	Sr-90	1.419E+00	Study “Performance Evaluation of 24 Ion Exchange Materials for Removing Cesium and Strontium from Actual and Simulated N-Reactor Storage Basin Water”, (PNNL-11711).
	Clinoptilolite	Relatively inexpensive natural zeolite capable of removing strontium and, to a lesser degree, cesium from low sodium solutions.	Cs-137	1.823E+00	
			Sr-90	1.196E+00	
Oak Ridge – Melton Valley/ Storage Tank W-25 supernate	SRR Resorcinol – formaldehyde	See above. Specific type of R-F developed at Savannah River Site.	Cs-137		From ORNL Study “Evaluation of Selected Ion Exchangers for the Removal of Cesium from MVST W-25 Supernate” (ORNL/TM-12938).
	Duolite CS-100	See above.	Cs-137		
	Crystalline silicotitanate	Powdered inorganic ion exchanger for use in batch processes. Not suitable for use in ion-exchange columns.	Cs-137		
	KCoHex, granular	See above.	Cs-137		
	Hydrous titanium oxide/KCoHex composite	HTiO microspheres embedded with KCoHex powder by internal gelation process. Prepared in column-useable form; effectively removes strontium from alkaline solutions of high salt content.	Cs-137		
	Titanium monohydrogen phosphate/NaC oHex Composite	See composite characteristics above.	Cs-137		
Oak Ridge – Melton Valley/	Crystalline silicotitanate	See above.	Cs-137	Unknown	Engineering-scale

Storage Tank W-29					demonstration processed 31,000 gals. Demonstration began in '96 and produced 70 gals. of spent sorbent. High-pH, high-salt feed. Flows up to 9 bed-volumes/hr. Design basis concentration of $4.0-4.9 \times 10^{-5}$ Bq/ml.
-------------------	--	--	--	--	--

Location/Source of Feed Stream	Ion Exchange Resin	Resin Characteristics	Contaminants of Concern	Decontamination Factor	Status/Remarks
West Valley/ HLW Tank supernate	Zeolite	Not specified.	Cs-137	Unknown	Spent sorbent is vitrified. Sorbent must be ground (for size reduction) prior to vitrification. Zeolite fines management and handling a major challenge during column change-out. Significant operational and material handling modifications were required to account for heat of hydration during sorbent preparation and column change-out.
Hanford/ Tank 101-AW	Resorcinol-formaldehyde	See above.	Unknown	Unknown	Laboratory-scale tests using 8-millimeter column at 6 column-vols./hour. Initial and 50% breakthrough for crystalline silicotitanate were 330 and 660 column volumes; the 50% breakthrough for resorcinol-formaldehyde was 13.5 volumes.
	Crystalline silicotitanate				

Table II. Prototype LRW Facility Design Considerations	
Requirement Addressed	Comments and Potential Solutions
Suitability of the overall process concept, and of the specific unit operations selected, for treatment of the waste stream compositions identified.	A conceptual overall process configuration, as discussed in May, 2000, for treatment of the six waste streams would include the following. • primary purification; coarse mechanical pre-filtration followed by filtration with a centrifugal ceramic cross-flow membrane filter – a device designed specifically for high suspended solids and oil loadings without fouling and tested extensively at Los Alamos. • selective sorption filters; ion exchange columns for removing the bulk of the radioactive components – essentially cesium and strontium • destructor of organic admixtures; partial (electro-chemical) oxidation of organics and detergents followed by coagulation and a second filtration • reverse osmosis (RO); a concentration of the remaining dissolved solids, especially radionuclides • final purification; ion exchange polishing of the clean water before transferring to the holding tank for analytical verification of quality • solidification; cementation by mixing with cement in 200 L metal drums No details of the design have been developed beyond the conceptual stage. The technology of each of the units is stated to have been proven in Russian experience. Most, if not all, have had some development in the United States. The primary purification unit may also include activated carbon – following electro-chemical oxidation should it be included- for final protection of the ion exchange resin – a common and probably required process step in this situation. An electrodialysis unit and or an evaporation unit may be added to further concentrate the RO concentrate before solidification.
Cost and schedule factors	A definitive cost estimate and schedule cannot be made until the final design basis is agreed upon. A preliminary schedule and cost estimate is needed in order to ferret out any significant impacts attributable to a specific technology. Definitive confirmation of the estimates can then be made before authorizing mechanical design and construction
Adequacy of design criteria and scope definition	The design criteria must address site interface questions and product disposition in addition to the prototype facility itself.
Adequacy of plans for treatability testing	Extensive characterization of the waste streams has been done or plans are in place. No other treatability tests for these specific wastes have been presented and apparently none are intended. (Treatability tests on actual radioactive waste can be very difficult and expensive.) They, the Russians, apparently will rely on

	experience with other similar materials.
Logistical requirements	Logistical requirements have to be addressed specific to the various sites though they have been discussed in general with regard to the need to provide support for laboratory work, need to supply fuel, and quick access to maintenance supplies not in the on site inventory. Also, available operation consultation support must be addressed.
Definition of system interface requirements with existing facilities	The facility is to be designed as a stand-alone facility with capability to interface with on site utilities where they are available.
Requirement Addressed	Comments and Potential Solutions
Adequacy of plans for stabilizing and/or disposal of treatment process residuals	Process residuals will be solidified by cementation. Site and waste specific cement formulation criteria must be addressed.
Process flexibility including capability to reprocess effluent that does not satisfy discharge requirements	Process flexibility is being addressed through the selection of various process units. Off spec product recycling is addressed in the Technical Requirements document.
Provisions for the effluent monitoring and laboratory support	Effluent monitoring is more of an operating plan and procedure problem than a facility design and construct question. Except, of course, adequate provisions for sampling is required in the design and proper test equipment must be provided for.
System mobility	System mobility has been stressed throughout the technical meetings and in the Technical Requirements. All units and support equipment is to be contained in up to four (4) twenty foot sea containers,
Operational efficiency	Operational efficiency is addressed in the Technical Requirements. The requirements for minimum downtime for maintenance as a factor in limiting personnel exposure also serve to insure a high level of operational efficiency.
Ability to perform planned maintenance at remote sites	Provision for the ability to perform maintenance at remote sites is provided in the Technical Requirements. Ability to do this will depend upon availability of trained maintenance personnel.
Capability and limitations for winter operations at remote sites	The facility will not be capable of operation in below freezing conditions but will be designed for freeze protection to -50 degrees C when not operating. The facility may be moved indoors for winter operation if the site facilities permit.
Constructability	A design issue that should be addressed early in the design process. Inasmuch as the facility is composed primarily of manufactured items, constructability should not be a serious issue but does require the different unit suppliers communicate with each other on this subject.
Potential for accidental uncontrolled environmental releases	Prevention of uncontrolled releases will be a concern of the facility operating procedures and operator training. The design team must address this concern with the operating organization.
Operator safety	Operator safety is addressed through the Technical Requirements provisions for limited need of access by maintenance and operation personnel. Also, the order of units is being designed to the extent possible to remove the bulk of the radionuclides early in the process to minimize the hazard in the following process areas.
On-stream factor(what percent of the time it will be operating)	The design on stream factor is only about 11 percent. This takes into account the limited available time because of weather considerations and the need for transfer time between sites. If the facility is designed, operated and maintained in accordance with Technical Requirements, the design on-stream factor is conservative.

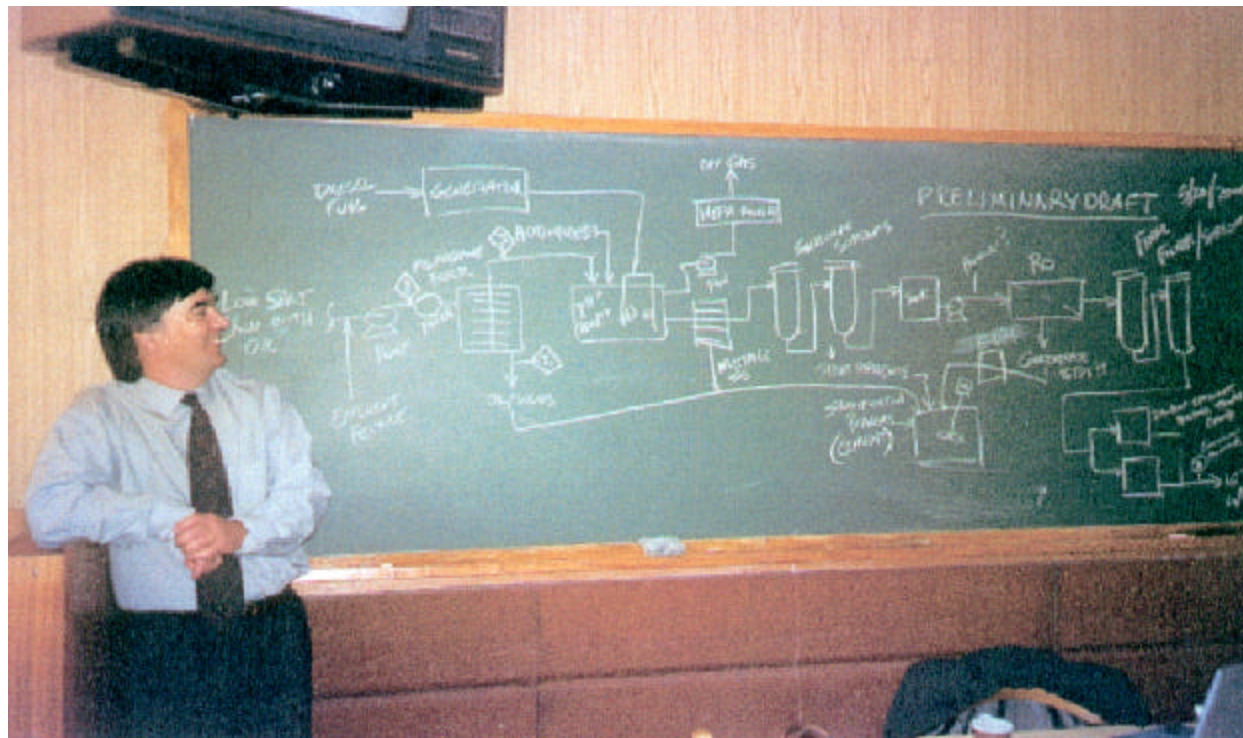


Fig. 1. Jim Findley, USA AMEC Engineer Leads PFD Development In St. Petersburg

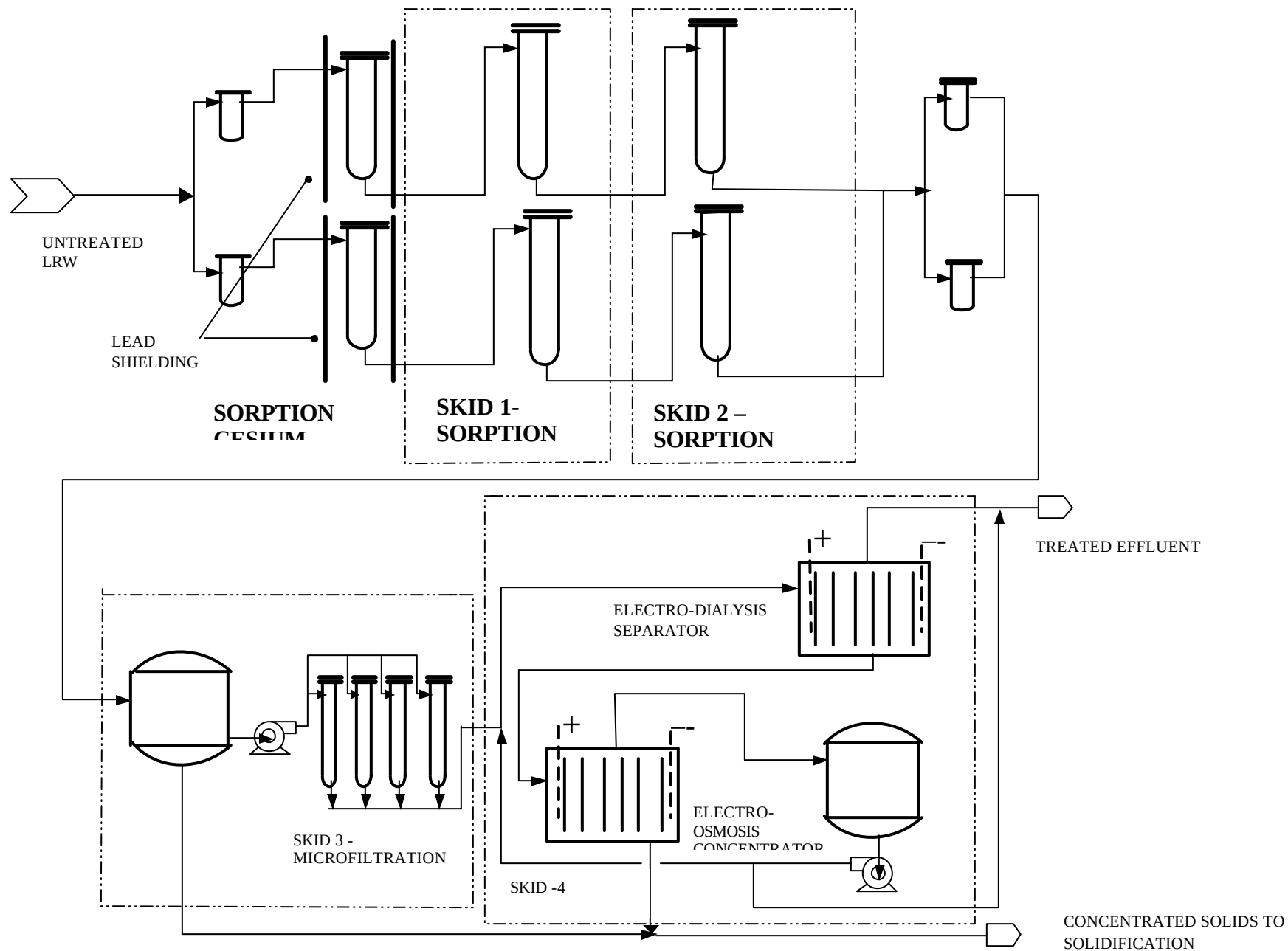


Fig. 2. The ECO – 3 Unit Was Presented At Svezdochka With This PFD Configuration

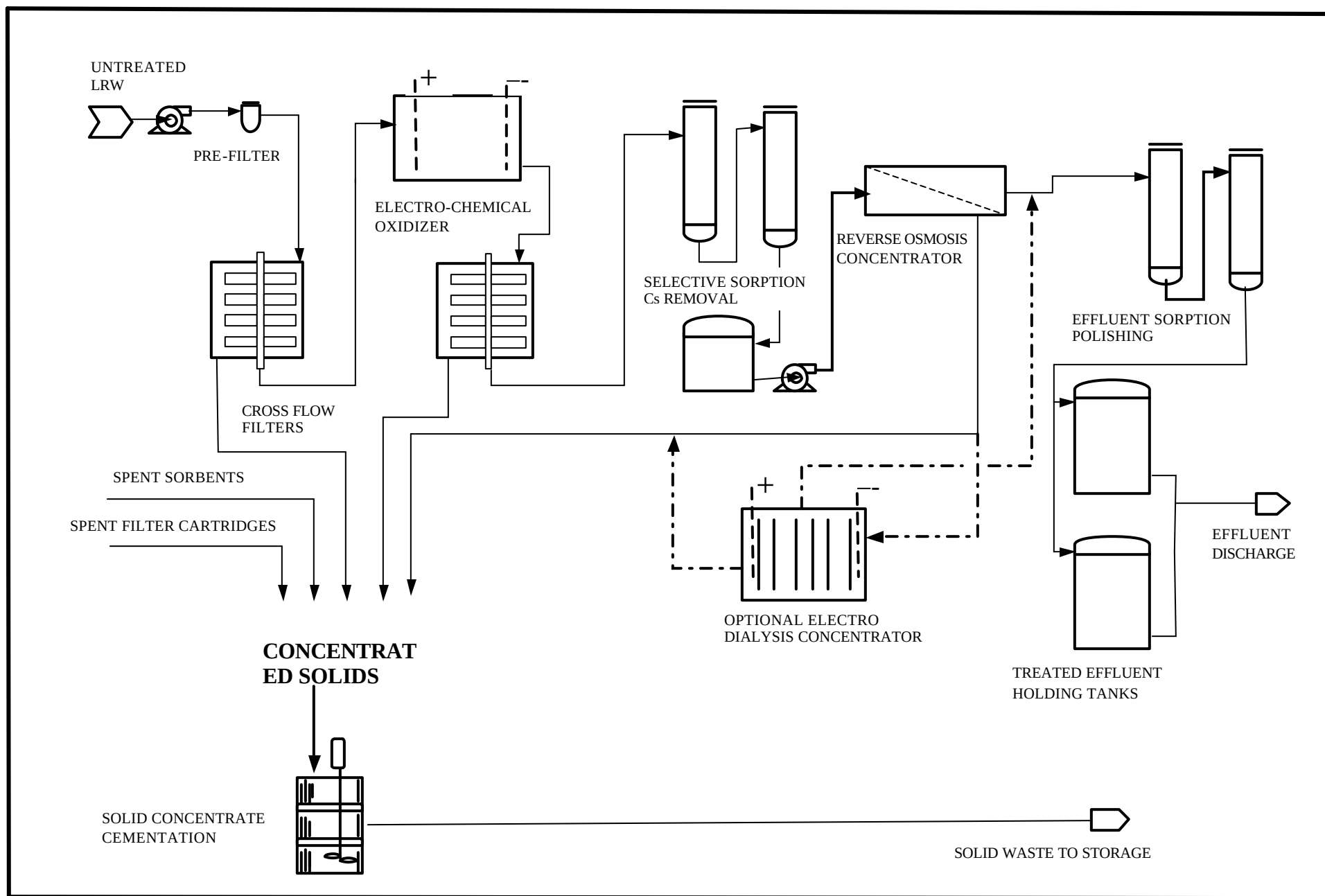


Fig. 3. The Conceptual Flow Diagram Includes Units For Treating All Presented Liquid Rad Waste Streams

REFERENCES

- 1 Belikov, Co. A.D., "The Radiation and Ecological Situation at Northern Fleet Facilities", Proceedings from the NATO Advanced Research Workshop "Recycling, Remediation, and Restoration Strategies for Contaminated Civilian and Military Sites in the Arctic Far North", Kirkenes, Norway, 24-28 June 1996.
- 2 Khitrov, Y.A., "Options for Storing and Processing Radioactive Wastes", Proceedings from the NATO Advanced Research Workshop "Recycling, Remediation, and Restoration Strategies for Contaminated Civilian and Military Sites in the Arctic Far North", Kirkenes, Norway, 24-28 June 1996.
- 3 Penzin, R.A., Sheptunov, V.S., Lesohin, B.M., Bulygin, B.K., Shvedov, A.A., "The Development of a Modular Plant for Processing Liquid Radioactive Wastes from the Nuclear Fleet: Korvet Project", Proceedings from the NATO Advanced Research Workshop "Recycling, Remediation, and Restoration Strategies for Contaminated Civilian and Military Sites in the Arctic Far North", Kirkenes, Norway, 24-28 June 1996.
- 4 Record of Discussion, "Meeting on AMEC PROJECT 1.2", St. Petersburg, Russia, 3-5 November 1999.
- 5 Report, "Implementation of Mobile Pretreatment Facility for Reprocessing of Liquid Radioactive Waste with Complex Physical and Chemical Composition", ICC Nuclide, St. Petersburg, Russia.
- 6 Record of Discussion, "The PROTOCOL of technical meeting under the question of creation, "Infrastructure of spent nuclear fuel unloading from the nuclear submarine with ballistic missiles reactors", at the FSUE MBE "Zvyozdochka", 29 May, 2000."