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**[Form 2 (<u>to be reported</u> to Committee on Countermeasures for Contaminated Water Treatment and to be disclosed to public)**

| Technology Information | |
|---|---|
| Area | Option 3 |
| Title | Removal of radioactive materials from the seawater in the harbor |
| Submitted by | Energy*Solutions* Services Inc. |

## 1.0 Introduction; Summary of the Problem

There is approximately 160,000 m3 of contaminated seawater impounded in the harbor at Fukushima Daiichi. This water is contaminated with radionuclides, principally fission product Strontium-90 (90Sr) and Cesium-134 and 137 (134Cs and 137Cs) at concentrations of up to 440 total beta Bq/liter of somewhat lower levels of Cs. The requirements are to remove the radionuclides to an acceptable level (30 Bq/liter for 90Sr or lower) and 60 Bq/l for 134Cs and 90 Bq/l 137Cs or lower. The principle challenge is to remove the 90Sr, removal of the Cs radioisotopes is also required. This is to be achieved in the presence of the natural minerals in seawater, principally sodium (Na), Magnesium (Mg) and calcium (Ca) and should be delivered by a simple process that does not generate significant secondary waste.

This proposal offers the IBC Advanced Technologies, Inc. (IBC) Molecular Recognition Technology (MRT) in a joint proposal, submitted by IBC and EnergySolutions (ES). IBC have extensive experience in removal and recovery of radionuclides from waste and separation of precious metals in the metallurgical and nuclear industries whilst ES have a detailed knowledge and experience of designing, deploying and operating equipment to clean up radioactive liquid effluent including the project at Fukushima to deploy their ALPS technology.

## 2.0 Overview of the technology

### 2.1 Features

The main features of this proposal are as follows:

- Uses the proven resins SuperLig® 605 for strontium removal and SuperLig® 644 for removing cesium.
- These resins have a high specificity for the target ions (Sr and Cs) and can be used in seawater in the presence of a large excess of the common seawater species.
- The resin can be regenerated by removal of the target ions at high purity by low volumes of simple solutions (dilute acid, base or water) and thus minimizes the volume of spent ion exchange resin
- The recovered solutions of Sr and Cs without the other seawater ions can be treated with existing or planned equipment at Fukushima, for example the ALPS multi-nuclide separation unit
- The spent resin is of low volume and can be dispositioned by many options including the planned incinerator, the HIC route or grouted.

The seawater will almost certainly require filtration prior to removal of Sr and Cs, to remove particulates that would blind the Ion Exchange resin and also to remove any particulates with sorbed radionuclides that would compromise the separation and add to the residual activity in the regenerated resin. We recommend a plastic tube cross flow ultrafilter as used on desalination plants. The recovered sludges can be disposed of along with the ALPS sludges.

The core technologies are ion selective resins based on Molecular Recognition Technology (MRT) whose complexing species is designed with a very high specificity for a particular ion.

ENERGYSOLUTIONS

The design, based on charge and ion size as well as preferred ligand binding geometry and other factors to more individually recognize the ion, can remove the target ion from chemically complex and challenging solutions. For example the Cs removal resin has been extensively tested for application in clean-up of HLW waste at Hanford (Tank Waste) which contains a wide range of radioactive and non-radioactive species and has an exceptionally high Na and K content. These resins have a high capacity for the target ion and the absorbed ions can be removed by simple acid, basic or neutral solutions to give a low volume high purity, in terms of the recovered ion, eluted liquid. The resin has a low residual retention of radioactive contaminants. The resins have been demonstrated to have a high chemical stability and a very high resistance to radiation, retaining the properties of the resin up to exposures of $10^8$-$10^9$ R.

These properties enable IBC with ES to offer a regeneration flow sheet with a resin that is capable of multiple recycles, and generating low volume products that can be treated in processes already deployed or planned on the site thereby avoiding any new disposition challenges.

### 2.2 Specification

IBC recommends two of its proprietary resins:

- SuperLig® 605 on a silica support for Sr which would be expected to demonstrate excellent selectivity for Sr in seawater at or near pH 8 and would be eluted with dilute hydrochloric acid.
- SuperLig® 644, has been exhaustively tested for Cs removal. This resin is on an organic substrate and gives a very high level of selectivity for Cs. This resin would be eluted with dilute HCl to recover the Cs.

### 2.3 Functions

The basis of this offering is a regeneration flow sheet, removing the Cs and Sr for further treatment, leaving a decontaminated seawater stream suitable for discharge.

The elements of this flow sheet are:

1. Filtration: Removal of any particulates in the seawater, if necessary to prevent blinding of the resin and retention of nuclides sorbed onto the particulates. We recommend a hollow fiber cross flow ultrafilter unit. These are available and have a history of seawater filtration as a pretreatment in desalination plants. Whilst it is difficult to be specific as to the volume of recovered sludge from this filtration, we estimate that volumes equivalent to approximately 5 8-120 HICs will be generated from treating 160,000 m3 of contaminated seawater, should the concentrate be exceed radioactivity limits for discharge back to sea.
2. Sorption of Cs and Sr: Using two separate trains of Cs and Sr resins (3 columns in series for each with breakthrough detection). It is estimated that the columns will contain approximately 8 $m^3$ and 23 $m^3$ of resin for Sr and Cs respectively for decontamination factors estimated to be between 10 and 100 respectively. This is well in excess of the DF implied by the measured concentrations in the seawater and the target limits.
3. Elution: Recovery of the sorbed Sr and Cs in low volume solutions (approximately 493 $m^3$ total for the Sr column and 4,514 $m^3$ total for the Cs column). The combined total of the Cs and Sr eluents equals 3% of the incoming volume.
4. Recovered nuclide treatment: We envisage these low volumes of relatively low concentration nuclides can be added to the ‘Blue Tanks’ for processing through the ALPS multinuclide removal system. The volumes are equivalent to approximately one day of arising of liquid waste from the reactor cooling, for the eluent from the SR column from the seawater and approximately 11 days arising for the Cs eluent.
5. Spent Resin: It is estimated for treating the entire 160,000 $m^3$ approximately 31 $m^3$ of

spent resin will be produced. The spent resin will be of low specific activity and can be dispositioned by routes that either exist or are planned at Fukushima. For example the 23 $m^3$ of organic SuperLig® 644 can be burned in the planned LLW incinerator and the 8 $m^3$ of silica resin dispositioned along with the ALPS inorganic resins.

IBC will provide the resin and operating data whilst ES will provide the plant design and any balance of plant.

### 2.4 Owners

IBC will manufacture and provide the resins whilst ES will be responsible for the plant design and specification. IBC routinely manufacture resins in quantity for their customers which include major mining and metal processing customers under stringent levels of Quality Assurance.

The details of the resins are proprietary and are provided together with recommendations and consultancy on the detailed operating conditions. The details of cost and charges will depend on the pre-installation testing required, quantities of resins and the level of input required from IBC/ES.

## 3.0 Technology Readiness Levels

No formal Technology Readiness Assessment has been carried out, as defined in the US DOE Technology Level procedure (Technology readiness Assessment Guide, DOE G 413.3-4A 9-15 2011), for either the IBC resin or the engineered process. The resins are a well proven and established product that have been extensively characterized (See notes below) for other applications. The resins are, however, available for this project and all that remains to do is to define the detailed design of the plant and the operating regime for this particular application. That indicates a formal assessment would place the resins as critical technology elements in the Technology Readiness Level 5-6.

The equipment train has also not been formally subject to a Technology Readiness Assessment but ES have extensive design experience in deploying the IBC products, through their involvement with design of the Waste Treatment Plant at Hanford and have experience of deploying ion exchange equipment at Fukushima Daiichi (The ALPS system). Therefore, the equipment can be rapidly deployed on site.

### Cases of Application

The IBC resin products, SuperLig® 605 (Sr) and SuperLig® 644 (Cs) have both been extensively tested in the nuclear industry. SuperLig® 605 has been tested with highly concentrated sea water matrix. Based on the test work, actual sea water (with lower Na, K, and Ca concentrations) will allow for even larger volumes of solution to be treated (see Appendix 3.1 and References). SuperLig® 644 has been extensively tested against the complex and challenging chemistry of the Hanford High Level Waste Tank solutions which are exceptionally high in sodium and potassium (see References). The SuperLig® Technetium removal resin has been tested against removal of Tc from secondary waste from the Hanford Tank Project (see References). IBC have used their manufacturing skills to produce the liquid phase complexant for treating sodium waste at Savannah River by solvent extraction (See Appendix 3.2). IBC products have a long history of deployment in the non-nuclear industry, for example, the precious and rare metals processing industries (See Appendices 3.3 and 3.4)

### Timeline for Application

For the IBC resins the deployment would be limited by the definition of the resin requirements and its manufacture. This would involve some confirmatory tests on the seawater or a simulant (2 months) and manufacture of the resin in operational quantities. IBC have extensive experience in resin manufacture and estimate that the resin can be supplied to the project in

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less than 6 months, subject to contract.

ES estimate that the design and installation of the equipment, together with commissioning, can be delivered on a similar schedule to a standard ALPS system.

### Challenges

The IBC products are a mature technology so there are no technical challenges to their use on this project. There are a number of steps in the process of deploying this and any technology, including confirmation of the composition of the seawater (radionuclide content, presence and contribution of particulates) and confirmatory tests with the resins. These would be features of any deployment of a mature technology in a project and would be used specify the filters, to fine tune the column sizes (and thus resin requirements) and operating regimes.

### Others

#### *Intellectual property*

The IBC resins are proprietary and trade secret products of IBC. IBC has extensive experience in supplying this product in bulk to customers whilst providing assurances concerning quality and performance of the resins. Energy*Solutions* will provide access to the IBC ion exchange media, and its application, using the same mechanism it gives access to technology in the existing ALPS system.

# Publically Available Reports on SuperLig 644 (Cs) and 639 (Tc)


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3. DE Kurath and JJ Wagner, Analysis of Spent Ion Exchange Media: SuperLig 639 and SuperLig 644, PNWD-3037 BNFL-RPT-028 Rev. 0
4. DJ McCabe, NM Hassan, WD King, JL Steimke, MA Norato, LL Hamm, LN Oji and ME Johnson, Comprehensive Scale Testing of the Ion Exchange Removal of Cesium and Technetium from Hanford Tank Waste, WRSC-MS-2000-00499
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### Trade Publications

www.ibcmrt.com
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