

# Decontamination and Conversion of Nickel Radioactive Scrap Metal

Industry Programs



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# Decontamination and Conversion of Nickel Radioactive Scrap Metal

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Industry Programs

*Demonstrated at*  
Manufacturing Science's Facility  
Large-Scale Demonstration and Deployment Project  
Oak Ridge, Tennessee  
(Using Contaminated Nickel from Paducah Gaseous Diffusion Plant)

# **INNOVATIVE TECHNOLOGY**

*Summary Report*

## ***Purpose of this document***

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at <http://ost.em.doe.gov> under "Publications."

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# SECTION 1 SUMMARY

## Technology Summary

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### Problem

The deactivation and decommissioning (D&D) of Department of Energy (DOE) gaseous diffusion plants (GDPs) will generate large quantities of scrap metals, including nickel. The source of the nickel is the gaseous diffusion barrier. This nickel is contaminated with uranium compounds and with fission products including technetium #99 ( $^{99}\text{Tc}$ ). This nickel has a particularly high scrap value, but will require decontamination before it can be sold as scrap or recycled.

Decontamination of this nickel is challenging for two primary reasons:

- Radioactive contamination includes  $^{99}\text{Tc}$ , which can not be removed by conventional metal purification technologies such as melt refining and conventional electrorefining.
- The contamination is present throughout the volume of the nickel, and can not be removed by surface-decontamination methods.

The DOE is responsible for the D&D of GDPs, located in Oak Ridge, TN, Paducah KY, and Portsmouth, OH. The D&D of GDP at the Oak Ridge's East Tennessee Technology Park (ETTP), formerly the K-25 site, is currently underway. The Paducah and Portsmouth GDPs are slated for future D&D.

### Solution

Manufacturing Sciences Corporation (MSC) has developed an innovative electrorefining process that is capable of removing  $^{99}\text{Tc}$  from nickel. This process is capable of reducing volumetric  $^{99}\text{Tc}$  contamination to levels between 1 and 10 Becquerels per gram (Bq/g).

### Summary of Technology

MSC's unique electrorefining process utilizes an electrorefining cell in which a permeable, ion-selective membrane is positioned between each anode and cathode. In this process, contaminated nickel is dissolved electrolytically (as an anode) in sulfate-based electrolyte. Nickel cations ( $\text{Ni}^{2+}$ ), driven by electrokinetic forces, migrate toward the negatively charged cathode. The permeable membrane allows nickel ions to pass through, but prevents  $^{99}\text{Tc}$  contamination from reaching the cathode. Purified nickel is deposited, or "plated," on the cathode in its metallic state.  $^{99}\text{Tc}$  contamination is removed from the electrolyte by recirculating the electrolyte through a filtration/cementation process. A simplified schematic of the basic electrorefining cell is provided in Figure 1. The system is capable of semi-continuous operation and is stopped only to remove and replace anodes and cathodes.

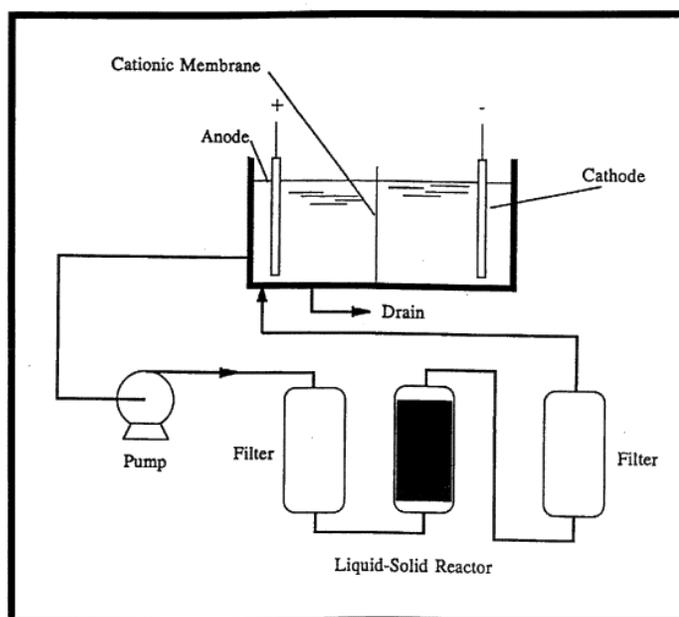


Figure 1. Schematic of electrorefining process.

## Advantages Over Baseline

The baseline technologies for purification of nickel are melt refining and conventional electrorefining. Both melt refining and conventional electrorefining are capable of removing uranium and transuranics from nickel, but neither is able to significantly reduce  $^{99}\text{Tc}$  contamination. With regard to conventional electrorefining, a study by Westinghouse/SEG showed that when  $^{99}\text{Tc}$  was present in the electrorefining electrolyte,  $^{99}\text{Tc}$  always co-deposited with the nickel at the cathode (DOE RAPIC 1987).

MSC's innovative electrorefining process, with the ion-selective membrane, is capable of removing volumetric  $^{99}\text{Tc}$  contamination from nickel. The technology offers the following advantages:

- Capable of removing  $^{99}\text{Tc}$  from nickel to a concentration below 1 Bq/g
- Economic recovery of a valuable resource
- Decontamination and recycle to useful new products

## Markets

The primary market for MSC's electrorefining process is the contaminated nickel from the GDPs at ETTP, Paducah, and Portsmouth, which has been estimated at 40,000 tons (MSC, Inc. 1999). BNFL, Inc. is currently under contract with the DOE for the D&D of three buildings at ETTP. MSC was purchased by BNFL, Inc. to aid in the decontamination and recycle of more than 126,000 tons of metals including 6,000 tons of gaseous diffusion barrier nickel. Construction of a large-scale MSC electrorefining system was planned to process the nickel from this project.

## Regulatory Issues

Regulatory and policy issues play a significant role in the implementation of MSC's electrorefining technology. Most of the issues are associated with National policy on the recycling and end use of RSM rather than MSC's electrorefining technology. Since these issues do affect the need and ultimate implementation of this technology, they will be summarized briefly below.

During the development of this technology, which began in 1993, there was no national standard regulating the release of volumetrically-contaminated RSM. For design purposes, MSC set forth a standard of 1 Bq/g as the stated goal for decontamination of the nickel. This concentration was based on a standard proposed by the International Atomic Energy Agency (IAEA) for release of recycled of RSM.

On January 12, 2000, Secretary of Energy Bill Richardson placed a moratorium on the free release of any "volumetrically" contaminated material from Department facilities. Later on July 13, 2000, Richardson expanded the scope of the moratorium to include all radioactively contaminated scrap metal. The moratorium was enacted in order to "give the Nuclear Regulatory Commission (NRC) time to develop national standards for volumetrically contaminated materials...allow the public opportunity to weigh in on the development of a national policy..[and allow] DOE to examine alternatives to free release" (Weapons Complex Monitor, 2000).

At the time of the writing of this report, the moratorium on the release of recycled RSM from the DOE complex remained in effect. As a result of the moratorium, the construction of the full-scale electrorefining system for the decontamination nickel from ETTP has been suspended. Although MSC's technology is commercially ready, implementation will be delayed until the regulatory issues regarding the release of this material are resolved. MSC continues to investigate alternative uses for RSM that may be allowable under a "restricted" release scenario. Such uses include sanitary drums and waste containers or other products that are needed within the DOE complex.

## Demonstration Summary

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MSC demonstrated their full-scale electrorefining technology between June 1998 and May 1999 using nine contaminated nickel ingots from Paducah, weighing a total of 18,000 lbs. The demonstration was

conducted at MCS's processing facilities in Oak Ridge, Tennessee. The nickel used for the demonstration had been previously melted during the Cascade Improvement Program/Cascade Upgrade Program (CIP/CUP) from the late 1970's to the early 1980's. The full-scale demonstration system, designed to process 160 lbs. per day of contaminated nickel, included a 2,000-gallon main tank, ten anodes, and 11 cathodes. Each electrode had approximately 20 square feet of surface area.

Over the course of the demonstration, over one ton of barrier nickel was processed through the electrorefining cell and more than 30 days of actual operation time was logged. Some technical problems were encountered in the early stages of the demonstration, but were addressed with design modifications. After modifications were made, the electrorefining system demonstrated the capability to reduce <sup>99</sup>Tc contamination to levels below 1 Bq/g. Initial <sup>99</sup>Tc contamination in the nickel ingots ranged from 226 to 627 Bq/g. The system was able to produce approximately 140 lb/day of purified nickel during the demonstrations.

## **Contacts**

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### **Other**

All published Innovative Technology Summary Reports are available on the OST Web site at <http://ost.em.doe.gov> under "Publications." The Technology Management System (TMS), also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST/TMS ID for Decontamination and Conversion of Nickel Radioactive Scrap Metal is 234.

## SECTION 2 TECHNOLOGY DESCRIPTION

### Overall Process Definition

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MSC's electrorefining process is designed to remove radioactive contaminants, including  $^{99}\text{Tc}$ , from nickel to a level between 1 and 10 Bq/g. Conventional electrorefining is not capable of removing  $^{99}\text{Tc}$  to desired levels.

Conventional electrorefining is an electrochemical process that produces a purified metal from a less pure metal. The metal to be purified becomes the anode in an electrolytic cell. The anode is then dissolved into an acidic, aqueous electrolyte by the application of an electric current. Under the proper conditions the pure metal is electroplated on the cathode while most impurities will either precipitate as "sludge" or remain dissolved in the electrolyte. Copper and nickel are metals that are often electrorefined.

Conventional electrorefining is effective in reducing the concentration of transuranic elements in metal to below detectable levels, but is not able to significantly reduce the amount of  $^{99}\text{Tc}$ . A study by Westinghouse/SEG showed that when  $^{99}\text{Tc}$  was present in the electrorefining electrolyte,  $^{99}\text{Tc}$  always co-deposited with the nickel at the cathode (DOE RAPIC 1987).

MSC's electrorefining process utilizes a permeable, ion-selective membrane positioned between the anode and cathode, in conjunction with a  $^{99}\text{Tc}$  removal system to prevent the  $^{99}\text{Tc}$  from being transported to the cathode chamber. A Nafion<sup>TM</sup> permeable cationic membrane, allows passage of positively charged nickel ions (cations) from the anode to the cathode, but prevents passage of negatively charged  $^{99}\text{Tc}$  ions (pertechnetate ions). The pertechnetate ions, contained in the anolyte (solution surrounding the anode) are removed by circulating the anolyte through a cementation chamber. The combination of the Nafion<sup>TM</sup> membrane and  $^{99}\text{Tc}$ -removal system prevents the  $^{99}\text{Tc}$  from plating on the cathode and results in a decontaminated nickel product.



Figure 2. Top view of electrorefining cell.

The full-scale electrorefining system was designed with a capacity to decontaminate 160 lbs. of nickel per day. A photograph of the top of the electrorefining cell is provided in Figure 2.

Major elements of the full-scale system are described below:

*Main Tank* - The full-scale cell (used for demonstration) was a 2,000-gallon tank made of polymer concrete. Eleven cathodes and 10 anodes were installed in the tank, alternating anode and cathode. Each electrode measures 38 in. by 38 in. by 2 in. thick. A membrane frame is used to support a cationic membrane surrounding each cathode. The cationic membrane separated the contaminated anolyte from the clean catholyte (solution surrounding the cathode).

*Metal Impurities Recovery Unit (MRU)* - Solution exiting the main cell is sent to the MRU for additional impurities removal. The MRU includes one anode and two internal cathodes. Cationic membranes surround the cathodes.

*Electrolyte Solution* - The solution used in the full-scale cell was a Watts-type electrolyte containing nickel sulfate, nickel chloride, and boric acid at a pH level of approximately 3.0.

*Temperature Controls* - The electrolyte is heated using five immersion heaters located inside the main cell. The temperature of the electrolyte is monitored by a sensor and displayed on the operators control panel. The temperature control is set between 145 and 155°F and is programmed to automatically shutdown if the temperature exceeds 170°F.

*Cementation Chambers* - Solution exiting the MRU is sent to the cementation chambers. Four cementation chambers, arranged in series are used for removal of <sup>99</sup>Tc from solution. The cementation chambers utilize a liquid-solid contact process by which <sup>99</sup>Tc is removed from solution using nickel powder. Each chamber is 8 in. in diameter and 54 in. tall.

*Power Supplies* - Electricity is provided to the 10 anodes at a current density of 15-20 amps/ft<sup>2</sup>. The main cell is operated at 1800-3600 amps at approximately 6 volts.

*Hoist* - A one-ton hoist is utilized to lift the anodes and cathodes, and for handling materials over the cell.

*Ventilation System* – Fumes from the main cell and the MRU are treated by an intermediate acid scrubber. The scrubbed air is directed through the building's HEPA filtration system prior being discharged to the atmosphere.

*Phone Dialer* - A phone dialer is utilized to automatically contact operators in case of problems with the system. This allowed continuous 24-hour, 7-days-per-week operation of the cell.

## **System Operation**

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Prior to electrorefining, the contaminated nickel is pre-processed by melting. The melting serves two primary purposes: 1) melting is done to declassify the material with respect to shape, and 2) melting removes some impurities prior to electrorefining. The nickel must also be cut into the appropriately sized anode sheets to fit into the electrorefining cell. The design size for the nickel anode is 38 in. by 38 in. by 2 in. thick.

The contaminated scrap uranium diffusion plant barrier typically must be melted and cast into a different shape, such as an ingot, because the original shape of the metal is classified information. Melting the material and re-casting it into a new shape declassifies the material.

MSC investigated the direct dissolution of contaminated nickel barrier that had not been previously melted. This was investigated on a lab-scale. The results of this investigation found direct dissolution to be a promising, but further scaled up experiments would be required to confirm feasibility and cost-effectiveness. Other issues such as increased process waste and effects on cationic membrane require further investigation.

The Watts nickel electrolyte solution is made up from nickel sulfate and nickel chloride in liquid form. The electrolyte is mixed in small batches and transferred to the main cell.

The electrorefining process has potential safety hazards for which operational safeguards are required. The primary hazards are chemical burns from the heated acidic solutions and electric shock from the applied current. MSC has addressed the potential hazards with procedural and engineering safeguards. Procedural safeguards include safety plans and operator training for all job duties. Operators are given extensive training on the safe operation of all components and machinery associated with their job descriptions. Engineering safeguards are also built-in to the process equipment.

Accurate and economical measurement of the radioactivity in the decontaminated scrap metal is a critical step in the overall decontamination process. Measuring contamination in volumetrically contaminated materials (as opposed to surface-contaminated materials) is challenging. Shielding, blocking, and self-absorption of the energies make it difficult to quantify the contamination levels. After evaluation of several radiological assay techniques, the method of choice for quantifying low levels of <sup>99</sup>Tc in nickel was determined to be liquid scintillation. The accuracy of the liquid scintillation process was verified by Inductively Coupled Plasma Mass Spectrometer (ICP Mass- Spec) on a random sample basis.

## SECTION 3 PERFORMANCE

### Demonstration Plan

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MSC demonstrated its electrorefining process at their facilities in Oak Ridge, Tennessee using contaminated nickel ingots from Paducah. MSC obtained nine ingots with a total weight of 18,000 lbs. This nickel had been previously melted during the CIP/CUP in the late 1970's to early 1980's. Contamination levels in this nickel ranged from 226 Bq/g to 627 Bq/g <sup>99</sup>Tc. These nickel ingots were sliced into anode sheets, mounted on hangers, and placed directly into the electrorefining cell.

The demonstration utilized the full-scale electrorefining cell with a design capacity of 160 lb/day as described in the previous section. The primary goal of the demonstration was to test a full-scale refining cell for the removal of <sup>99</sup>Tc from bulk contaminated nickel to a concentration of between 1 and 10 Bq/g. Other objectives were to optimize system parameters and improve system efficiency and cost effectiveness in the production mode. Previous lab-scale and pilot scale testing had confirmed that <sup>99</sup>Tc could be removed from nickel using the electrorefining process.

Performance evaluation included measurement of <sup>99</sup>Tc concentration in the anolyte, catholyte, and purified nickel product. The rate at which the nickel was processed was also measured.

Demonstration of the full-scale system was initiated in June of 1998. After one day of operation, the system was shut down due to design problems. The design was modified, tested, and the system was restarted on October 6, 1998 and operated successfully through October 16. The cell underwent additional modifications, was restarted in February 1999, and operated intermittently through May 1999.

### Results

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Samples of the anolyte and catholyte were taken daily to track levels of <sup>99</sup>Tc in solution. These levels are indicators of potential contamination reaching the final product cathode. The concentration of <sup>99</sup>Tc in the catholyte was maintained at lower level than in the anolyte, indicating that the cationic membrane is an effective barrier between the anolyte and catholyte.

The <sup>99</sup>Tc levels in the decontaminated nickel product (the cathode) were also tracked over time. As parameters were optimized, contamination was reduced to levels in the range of 1-2 Bq/g. The concentration of <sup>99</sup>Tc in the cementation units, where the <sup>99</sup>Tc is removed, was measured as high as 2,315 Bq/g. Approximately 14 lb/day of nickel was plated onto each cathode, which equates to 154 lb/day for the 11 cathodes in the main cell.

### Conclusions

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Once the process parameters were stabilized and optimized, the full-scale electrorefining system worked as anticipated. Nickel was decontaminated to levels between 1 and 2 Bq/g. The cementation units contained high levels of <sup>99</sup>Tc as expected. As of May 20, 1999, in excess of one ton of barrier nickel was processed over one month of actual operation time.

## SECTION 4 TECHNOLOGY APPLICABILITY AND ALTERNATIVES

### Competing Technologies

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MSC's electrorefining technology can be considered an "enabling" technology for the removal of <sup>99</sup>Tc from nickel. Existing metal purification technologies, such as melt refining and conventional electrorefining are not capable of removing <sup>99</sup>Tc to desired levels.

In melt refining, the contaminated nickel is melted, usually in an induction furnace, in the presence of an oxidizing flux; the mechanism of the purification is that of liquid-liquid extraction. Melt Refining using a vacuum induction furnace is capable of removing uranium and transuranic elements from nickel, but <sup>99</sup>Tc becomes bound to the nickel and is difficult to separate. Technetium contamination is also problematic for conventional electrorefining because it tends to co-deposit with nickel on the cathode.

### Technology Applicability

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The current design of MSC's technology is applicable to the removal of <sup>99</sup>Tc contamination from scrap nickel. The technology specifically targets contaminated nickel that was used as gaseous diffusion barrier in GDPs. Typically, this material is volumetrically contaminated, meaning that it is contaminated throughout its volume. The nickel must be pre-melted prior to electrorefining. Pre-melting serves two purposes, it declassifies the material with respect to shape and it removes other contaminants and impurities prior to electrorefining. MSC's electrorefining technology could also be used on surface-contaminated metal, but other more cost-effective technologies exist for this application.

### Patents/Commercialization/Sponsor

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MSC's development of their electrorefining technology has been supported through DOE's NETL, formerly the Federal Energy Technology Center (FETC) under a Program Research and Development Announcement (PRDA) Contract No. DE-A-C21-93MC30170. MSC subcontracted with Covofinish, Inc. of Providence, Rhode Island, the initial developer of the electrorefining process for the removal of <sup>99</sup>Tc from nickel. Covofinish developed a process for the decontamination of radioactively contaminated nickel diffusion plant barrier (U.S. Patent 5, 458, 755) in which <sup>99</sup>Tc is removed from the electrolyte by a displacement reaction with nickel.

MSC has successfully commercialized its electrorefining technology, as evidenced by its role in BNFL's \$238 million contract for D&D of three buildings at ETTP. Although the technology is commercially ready, the recently enacted moratorium on the free release of recycled RSM has delayed its implementation. MSC continues to investigate alternative uses for RSM that may be allowable under a "restricted" release scenario. Such uses include sanitary drums and waste containers or other products that are needed within the DOE complex.

# SECTION 5

## COST

### Methodology

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The economic value of MSC's electrorefining technology lies in its ability to convert a material that would otherwise be a contaminated waste, with an associated disposal cost, into a valuable resource.

The economic viability of MCS's process is dependent on the following factors:

- Disposal cost avoidance (by recycling the nickel rather than disposal)
- Nickel decontamination cost; and
- Scrap value of decontaminated nickel.

The cost savings to the DOE is calculated by the following equation:

$$\text{Cost Savings} = [\text{Disposal Cost Avoidance}] - [\text{Decontamination Costs}] + [\text{Market Value of Scrap Nickel}]$$

The costs presented below were obtained from various sources. The disposal cost are based on published estimates for disposal of the nickel from the ETPP project (Weapons Complex Monitor, January 17, 2000). The costs for MSC's electrorefining process are conceptual in nature and are based on independent, unpublished estimates. MSC considers their cost projections for their full-scale electrorefining process to be proprietary. The scrap value for nickel is based on market values from the London Metals Exchange (London Metals Exchange, 2000). Cost are provided on a cost per pound basis and total costs are also calculated based on the estimated 40,000 tons of nickel diffusion barrier from ETPP, Paducah, and Portsmouth.

### Cost Analysis

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#### Disposal Cost Avoidance

If the contaminated nickel were not decontaminated, it would be considered a LLW and would require disposal accordingly. Based on DOE documents, if the 6,000 tons of nickel from ETPP is kept as a classified material and disposed of at the Nevada Test Site, the cost the DOE would be \$19.5 million. If the material is put into a declassified form (melted) and sent to a private site such as Envirocare of Utah, the costs would be \$31 million project (Weapons Complex Monitor, January 17, 2000). These costs are summarized below:

- \$1.62/lb if disposed of at the Nevada Test Site
- \$2.58/lb if the material was sent to Envirocare

The total costs for disposal of the 40,000 tons of nickel from ETPP, Paducah, and Portsmouth based on the unit costs above are summarized below:

- \$129.6 million if disposed of at the Nevada Test Site
- \$208 million if the material was sent to Envirocare

#### Decontamination Costs

Conceptual costs for MSC's electrorefining process have been estimated by independent sources to be in the range of \$1.80 to \$2.50 per pound. The cost for pre-melting the nickel has been estimated at approximately \$0.75 to \$1.50 per pound (MSC, 2000). These costs are summarized below:

- \$2.55- \$4.00/lb to pre-melt and decontaminate nickel using MSC electrorefining technology
- \$204-\$320 million to pre-melt and decontaminate 40,000 tons of nickel

## Scrap Value of Recycled Nickel

The scrap value for primary nickel, based on a London Metal Exchange, 15 month mean price per metric ton from September, 2000 is \$6,9783.86/ metric ton (\$3.16/lb). For reference, the average price for August 2000 was \$8,006.70/metric ton (\$3.63/lb).

- \$3.16/lb market value(15 month average).
- \$252.8 million market value for the 40,000 tons of nickel

## Total Cost Saving to DOE

The total cost saving to DOE from decontaminating the nickel and selling it as scrap, instead of disposing the material as a LLW, is provided below. Since some of the cost components were provided as a range, a high estimate (best case) and low estimate (worst case) are provided.

Cost Savings = [Disposal Cost Avoidance] – [Decontamination Costs] + [Market Value of Scrap Nickel]

**Table 1. Total Cost Savings Calculation**

<b>Cost Component</b>	<b>High Estimate (Million \$)</b>	<b>Low Estimate (Million \$)</b>
Disposal Cost Avoidance	\$208.6	\$129.6
Decontamination Cost	-\$204	-\$320
Market Value Scrap Nickel	\$252.8	\$252.8
<b>Total Cost Saving (Sum):</b>	<b>\$257.4</b>	<b>\$62.4</b>

## Cost Conclusions

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Based on the cost estimates presented here, decontamination of the diffusion barrier nickel, and sale for recycling, as opposed to disposal as a LLW will result in a cost savings to the DOE of \$62.4 to \$257.4 million. This calculation is based on 40,000 tons of scrap nickel, generated from D&D of the GDPs at ETPP, Paducah, and Portsmouth.

## SECTION 6 REGULATORY AND POLICY ISSUES

### Introduction

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When evaluating the regulatory and policy issues related to this process, one must look at two different aspects - those pertaining to the release and use of the final recycled nickel product, and those regulations regarding the actual electrorefining process. MSC's electrorefining process to remove radioactive contaminants from classified nickel does not have extraordinary regulatory or policy issues compared to other processes that treat radioactive materials; however, there are significant issues related to the potential free release of RSM.

### Regulatory Considerations – Nickel Recycling/Re-Use

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At the time of the writing of this report, national regulations governing the free release of volumetrically contaminated nickel were under consideration by the NRC. On January 12, 2000 Secretary of Energy Bill Richardson placed a moratorium on the free release of any "volumetrically" contaminated material from Department facilities. Later on 13 July 2000, Richardson expanded the scope of the moratorium, to suspending the release of all radioactively contaminated scrap metal, including surface contaminated scrap metals. The moratorium was enacted in order to "give the NRC time to develop national standards for volumetrically contaminated materials....allow the public opportunity to weigh in on the development of a national policy..[and allow] DOE to examine alternatives to free release" (Weapons Complex Monitor, Vol. 11 No 2, 2000).

The overall purpose of the moratorium is ensure that recycled nickel is not released into general commerce until a national standard for such material is issued by the NRC. Presently, none of the volumetrically contaminated nickel has been sold or released. The timetable for development of national standards by the NRC is indefinite and could be a multi-year project.

Prior to the moratorium, the Tennessee Department of Environment and Conservation (an NRC agreement state) had granted MSC an amendment to their license, allowing the free release of volumetrically contaminated nickel after decontamination. The following release standards were included in this amendment:

- Maximum average <sup>99</sup>Tc concentration in a single shipment: 3Bq/g
- <sup>99</sup>Tc concentration in a single ingot in the shipment not to exceed 6 Bq/g
- Maximum average total U concentration in a single shipment: 0.3 Bq/g
- U concentration in a single ingot in the shipment not to exceed 0.6 Bq/g
- Single shipment not to exceed 20 tons

### Regulatory Considerations – Electrorefining Process

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*Permitting:* MSC's Oak Ridge Facility operates under two Radioactive Materials Licenses (RML) issued by the State of Tennessee. At federal facilities, a National Environmental Policy Act (NEPA) review is required. Work performed related to this technology demonstration was given a NEPA Appendix B Categorical Exclusion (CX-B) after a review of project information and examination of Subpart D, Appendix B classification in 10 CFR 1021. Therefore, approval was granted for a CX-B categorical exclusion of the demonstration proposed action from further NEPA review and documentation. A full NEPA assessment is likely needed for full-scale operation. Air permits and wastewater permits may be required based on full-scale operation conditions.

All related processes must be carried out in full compliance with all applicable federal, state, and local environmental, health, and safety regulations, including but not limited to the following:

- Clean Water Act (CWA)
- Clean Air Act (CAA)

- Resource Conservation and Recovery Act (RCRA)
- Occupational Safety and Health Administration (OSHA)
- Atomic Energy Act (AEA)
- Low Level Radioactive Waste Policy Act

During the demonstration work, all of the following were completed regarding the affected environment and should be applied to full-scale operations:

- Plant air was passed through a four-stage high efficiency particulate air (HEPA) filtration system prior to being exhausted through a stack;
- Air exiting stacks was continuously monitored for radioactive emissions;
- Water used within the controlled area of the plant was treated and stored until analysis verified it was below release limits;
- Contaminated solid waste was disposed of by burial in an approved low-level repository; and
- Soil and water surveys were performed periodically to verify compliance with applicable regulations.

*Process Waste:* Secondary waste generated is in the form of wastewater, nickel particulate emissions, and spent filters contaminated with <sup>99</sup>Tc from the cementation unit. The wastewater generated results from neutralizing sulfuric acid with calcium hydroxide. This water is neutralized with lime and discharged to a sanitary sewer after sampling for release limits. The concentration of the nickel particulate emissions will depend on the nickel content in the radioactively contaminated scrap metal and will be controlled and collected by particulate filters with a 99.999 percent efficiency. AEA and RCRA regulate the mixed waste filters.

*Worker Safety:* Potential hazards exist in the following major areas: electrical, power lifting equipment, thermal, and chemical (solids and fumes). Employees were given extensive training on the safe operation of all components of machinery associated with their job descriptions as it related to work in the electrorefining production area. All workers were properly trained in HAZWOPER courses, lockout/tagout procedures, personal protective equipment (PPE), and other applicable areas. For full-scale operation, the hazards listed in Table 2 may exist:

**Table 2. Potential Work Hazards**

Type of Hazard	Hazard Description
Electrical	Maximum 15 volts D.C., 3600 amps
Chemical/Burns	Heated nickel sulfate, nickel chloride, boric acid. PPE required as well as restricted access to certain work areas.
Fumes	Mainly water vapor, potential for chemical fume, however, results from samples taken by independent source revealed no fumes from cell that are potentially harmful. Ventilation system in place as a precaution.
Material Handling	Potential for cuts, drops, etc. PPE required. Special handling devices were designed and implemented.

## Safety, Risks, Benefits, and Community Reaction

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Public opposition to the recycling of radioactive scrap metal from DOE facilities is a significant issue. Public opposition is not necessarily directed at MSCs process, but broad policy issues related to recycling of radioactive scrap metals. Negative media reporting regarding radioactive metals becoming a part of household products across the nation is partly responsible for the lack of community acceptance. The public fears that exposure to radioactive metal will result in increased cancer incidences, death, birth defects, and other radiation-related illnesses. Opposing groups include Nuclear Information and Resource Service, the Paper, Allied-Industrial, Chemical & Energy Workers Unions (PACE), and the Natural Resources Defense Council (NRDC).

## SECTION 7 LESSONS LEARNED

### **Technology Limitations and Needs for Future Development**

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Though, MSC's electrorefining technology worked as designed, there is room for improvement in efficiency. Direct dissolution of the nickel into the electrorefining cell without pre-melting was investigated and the process was found to be promising. Additional development is needed before direct dissolution could be integrated into the current process. Direct dissolution adds complexity to the process because additional impurities are introduced to the system. Direct dissolution of the raw nickel would save a pre-processing step and streamline the process. The cost of preprocessing ranges from \$0.75 to \$1.50 per pound. This is a significant portion of the overall processing cost and area for potential cost savings. Since the melting step also declassifies the material, security issues would also have to be addressed if the melting step were eliminated.

Pre-processing the diffusion plant nickel currently requires melting and casting. The presence of fluorine compounds in the nickel causes corrosion of oxide refractories used to contain the molten nickel. Replacing deteriorated refractories is expensive and also results in a radioactive waste that requires disposal. MSC explored using a corrosion-resistant graphite refractory to address this problem. A result of using a graphite refractory is high carbon nickel. The tolerance of carbon in the cast nickel anodes was tested, but further testing is needed. Other options, such as removing fluorine prior to melting could also be explored.

### **Technology Selection and Implementation Considerations**

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The value of decontaminated/recycled nickel on the free market is a primary driver behind the development of this technology. The current moratorium on the free release of recycled RSM subsequently impacts the economic viability of the process. If the moratorium is resolved and free release is allowed, MSC's process will be economically viable. If the free release of the RSM is restricted indefinitely, other uses for the decontaminated nickel must be identified that are economically feasible.

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## APPENDIX B ACRONYMS AND ABBREVIATIONS

AEA	Atomic Energy Act
Bq/g	Bequerels per gram
BNFL	British Nuclear Fuels Limited
CIP/CUP	Cascade Improvement Program/Cascade Upgrade Program
CWA	Clean Water Act
CAA	Clean Air Act
D&D	Decontamination and Decommissioning
DOE	Department of Energy
ETTP	East Tennessee Technology Park
FETC	Federal Energy Technology Laboratory
HEPA	High Efficiency Particulate Filter
IAEA	International Atomic Energy Association
MRU	Metals Recovery Unit
NETL	National Energy Technology Laboratory
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Association
OST	Office of Science and Technology
PACE	Paper, Allied-Industrial, Chemical and Energy Workers Unions
PPE	Personal Protective Equipment
PRDA	Programatic Research and Development Agreement
RCRA	Resource Conversation Recovery Act
RSM	Radioactive Scrap Metal
<sup>99</sup> Tc	Technetium-99