

Disposition of Paducah Gaseous Diffusion Plant Nickel

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ACRONYMS

ALARA	As Low As Reasonably Achievable
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
BNFL	British Nuclear Fuels Limited
BWXT	BWX Technologies
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CVMR	Chemical Vapor Metal Refining, Incorporated
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EOI	Expression of Interest
EU	European Union
HPS	Health Physics Society
IAEA	International Atomic Energy Agency
KRCEE	Kentucky Research Consortium for Energy and the Environment
MIRC	Metals Industry Recycling Coalition
MSC	Manufacturing Sciences Corporation
NCRP	National Council of Radiation Protection and Measurements
NEPA	National Environmental Policy Act of 1969
NiDU	Nickel Development Institute
NRC	Nuclear Regulatory Commission
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
PACE	Paper, Allied-Industrial, Chemical, and Energy Workers Union
PACRO	Paducah Area Community Resource Organization
PGDP	Paducah Gaseous Diffusion Plant
PRS	Paducah Remediation Services
PRSM	Potentially Radioactive Scrap Metal
RCRA	Resource Conservation and Recovery Act
RFP	Request for Proposals
RSM	Radioactive Scrap Metal
SAIC	Science Applications International Corporation
SEG	Scientific Ecology Group
TEDE	Total Effective Dose Equivalent
UDS	Uranium Disposition Services
UK	University of Kentucky
USGS	United States Geological Survey
⁹⁹ Tc	Technetium-99

EXECUTIVE SUMMARY

The purpose of this document is to summarize the history of the issues surrounding the disposition of the 9700 metric tons of nickel ingots volumetrically contaminated with primarily ⁹⁹Tc currently stored at the Paducah Gaseous Diffusion Plant. Following the scientific and regulatory history of the nickel, potential paths forward for disposition of the nickel with potential benefits to the Paducah community are considered from an economic context. Technical, regulatory, and political constraints are considered with strategies suggested for overcoming these barriers.

Based on previous studies, the possible alternatives for disposition of the contaminated nickel are:

- Continued open storage on Department of Energy (DOE) grounds
- Disposal into an appropriate landfill
- Recycling at licensed, dedicated facility and reuse within DOE/Nuclear Regulatory Commission (NRC)/Department of Defense (DOD)
- Cleansing to background levels for general clearance for release

Continued storage fails to meet As Low As Reasonably Achievable standards. Disposal abandons the significant economic and strategic value of the nickel. Recycling using currently validated technologies would not allow clearance and release due to the DOE moratorium and lack of U.S. standards for volumetric contamination. Consequently, the following action is recommended:

- Obtain proposals from companies capable of processing the nickel into a state suitable for restricted use within the government nuclear sector, including DOE, NRC, and DOD
- If a company claims the capability of cleaning the nickel to background levels of activity, develop a protocol for pilot studies, involving the University of Kentucky (UK) or other independent, expert agency, to validate both the process and the product with suitable confidentiality agreements in place to protect proprietary technologies
- Identify potential internal users of the nickel and nickel-derived products, the processing required to produce usable products, and existing facilities capable of production
- Evaluate the most economical method of producing end-products for use in the government nuclear sector while minimizing new creation of radioactive scrap metal by contaminating processing equipment
- Involve representatives from the scrap metal industry and from affected labor unions in every step of the process from the current Expression of Interest (EOI) through contract award
- Inform the public and give opportunity for input at every phase from the current EOI through contract award
- Recommend that the processing occur at the location from which the most nickel originates, most likely the Paducah site

1. INTRODUCTION

The purpose of this document is to summarize the history of the issues surrounding the disposition of the 9700 metric tons of nickel ingots volumetrically contaminated with primarily ⁹⁹Tc currently stored at the Paducah Gaseous Diffusion Plant (PGDP). Following the scientific and regulatory history of the nickel, potential paths forward for disposition of the nickel with potential benefits to the Paducah community are considered from an economic context. Technical, regulatory, and political constraints are considered with strategies suggested for overcoming these barriers.

2. NICKEL BACKGROUND

2.1 HISTORY

2.1.1 Nickel Today

Nickel is primarily used as a component in metallic alloys, the most common being stainless steel. Worldwide, 60% of nickel is used for austenitic stainless. In the United States, that percentage drops to 46% due to the increasing use of specialty metals. Additional demand for nickel is caused by the use of nickel foam in manufacture of rechargeable batteries and in recent U.S. coinage issues dropping from circulation. Substantial increases in the price of nickel have caused a marked shift away from austenitic steels to other forms of stainless steel. Demand for nickel has been increasing since 2001, largely due to increased industrial construction requiring stainless steel in China and other developing industrial nations. The nickel industry is running at near-capacity levels. Further details of production and consumption are available in the U.S. Geological Survey (USGS) Minerals Yearbook (Kuck 2005).

2.1.2 Source of Nickel and Contaminants at the PGDP

The majority of nickel present at the PGDP was contaminated from its use in the diffusion process. During the enrichment process, compressed uranium hexafluoride gas is forced through nickel alloy piping. The porous nickel barrier allows uranium-235 to pass through while retaining the uranium-238 as waste. Some of the uranium sources processed in this system were contaminated with plutonium and other transuranics, resulting in the range of contaminants found in the nickel ingots (Malone 1999). The most recent analysis is given in Table 1. The nuclide consistently present in the highest concentration is ⁹⁹Tc.

Table 1 Results of analysis of 72 samples of Paducah nickel ingots performed in 1999/2000. From DOE 2007.

Nuclide	Sample Result (pCi/g)			Standard Deviation
	Minimum	Maximum	Average	
Alpha	4.60	4.60	4.60	N/A
Beta	3.970	11,400	6.980	2,650
²³⁷ Np	0.163	0.470	0.268	0.126
²³⁹ Pu	6.06	7.53	6.73	0.743
⁹⁹ Tc	8.77	23,500	13,800	5,990
²³⁰ Th	1.13	1.13	1.13	N/A
²³² Th	0.0000264	0.0118	0.000500	0.00196
²³⁵ U	0.000210	0.0184	0.00560	0.00770
²³⁸ U	0.00213	0.912	0.120	0.197
Np= Neptunium Th=Thorium Pu=Plutonium U=Uranium Tc=Technetium N/A=Not applicable; minimum, maximum, and average based on 1 sample result				

From 1977 to 1982, about 17 million pounds of nickel not contaminated with radiation were smelted at the PGDP and sold to private industry (Wyatt 2000). Following the processing of clean nickel, 20 million pounds of contaminated nickel were smelted from 1983-1986 (Walker 2001a). The products from the smelting process were formed into ingots, with the contaminated material placed in open storage on the PGDP site. According to one Department of Energy (DOE) report, some radioactive nickel ingots were “sold into commerce” (Malone 2000).

2.1.3 Nickel Holdings in the DOE Enrichment Complex

Currently, there are about 9700 t of volumetrically contaminated nickel ingots stored at the enrichment plant in Paducah, Kentucky. Decommissioning activities at Oak Ridge, Tennessee have generated 6000 t of shredded nickel scrap. An additional 20 000 t of scrap are expected from future decommissioning at Paducah, Oak Ridge, and Portsmouth, Ohio (Sheely 2005). A 1992 DOE survey classified the nickel as non-Resource Conservation and Recovery Act (RCRA) waste, held for further recovery (Casey and Heath 1992).

2.2 REGULATORY AND TECHNICAL BACKGROUND

A study performed by Westinghouse evaluated the electrorefining technique for processing radioactive scrap metals, including nickel. While it found it effective for removing uranium and other radioactive metals, it did not consider ^{99}Tc (Kessinger 1993).

DOE participated in a study with Argonne National Laboratory (ANL) to assess implications of recycling or disposing of contaminated metals. The study considered steel, iron, and copper. In the study, the most aggressive reuse involving consumers suggested that risks were orders of magnitude higher than general industrial reuse, but those risks varied substantially depending on the particular nuclide present in the scrap. The constraining exposure for ^{99}Tc in this study would occur during the melt process to the slag worker (Murphie, Lilly et al. 1993).

An Oak Ridge National Laboratory (ORNL) Technology Evaluation considered methods available to purify radionuclide contaminated nickel. Included in the report are smelt purification (effective on readily oxidized metals but not technetium), electrorefining (effective at the thermodynamic limit), leach/electro-winning, and the Mond process (high T deposition). The report cites a need for research on the Mond process while expressing concern about formation of non-volatile carbonyls (Fellows 1993).

Martin Marietta Energy Systems prepared a report summarizing the key decontamination and decommissioning needs for DOE facilities (Bundy and Kennerly 1993). Recovery of nickel obtained from porous barriers was cited as a priority, with electrorefining methods considered the most promising technology. Even if the recycling were for internal DOE reuse, recovery of the nickel was valued in the millions of dollars.

A 1993 DOE Program Summary cites previously mentioned drivers for recycling, but also discusses key obstacles, including lack of release standards, public understanding, and public confidence in DOE (Motl and Burns 1994). According to this summary, Manufacturing Sciences Corporation (MSC)/Chemical Vapor Metal Refining, Incorporated (CVMR) was expected to make decontaminated steel for use in storage of vitrified high-level nuclear waste (DOE 1994). There were significant concerns about the potential of economically fabricating containers from this material due to the non-standard sizes in use across DOE and Nuclear Regulatory Commission (NRC)-licensed facilities.

Compere reviewed industrial methods available for purification of nickel as of 1994 as part of a DOE study intended to lead to reduction of legacy wastes held by DOE (Compere, Griffith et al. 1994). Electrolysis processes were considered the most attractive.

ANL performed a study for DOE reported in 1995 assessing whether radioactive scrap recycling was a feasible alternative to disposal in the context of human health risk, environmental impact, and sociopolitical concerns (Nieves, Chen et al. 1995). The international standard of interest for release of radioactive materials at that time was from the International Commission on Radiological Protection. While the report focused on iron and steel scrap, much of the information contained in the report is relevant for nickel recycling. It limits its scope to two options: recycling and disposal. The report concludes that with a tiered release system, individual dose levels can be maintained at acceptable levels. In the 1995 report, volumetrically

contaminated materials were considered “Tier B” requiring melting prior to cleaning and release to a commercial facility. Resulting operations (assuming technical feasibility) were evaluated for radiative, chemical, and accidental health risks. Potential liabilities for harm caused by recycled materials released into the market in both in the USA and internationally were considered, with international liability considered significantly less than in the USA. The authors concluded that over time the public is becoming accustomed to “safe” radiation exposure (medical diagnostics, televisions, use of natural granite); but more recent attitudes that the government should protect the populace from all risks may preclude acceptability of radioactive scrap metal (RSM). This follows a 1994 study by the same group which concluded that recycling of RSM was preferred to disposal and replacement based on lower human health risks and environmental impacts (Nieves, Chen et al. 1994).

A study conducted by MSC in conjunction with the Colorado School of Mines considered the viability of recycling of RSM. Two economic “laws” were cited: 1) the viability of recycling contaminated metal increases with the intrinsic value of the metal to be recycled, and 2) “economic viability of RSM recycle increases in proportion to the cost of disposal.” The authors performed a simple analysis of the net benefit of recycling several metals, including nickel alloy. It assumed a cost of \$1.50/lb for disposal and subtracted this value from the cost of producing sheet metal from RSM. Comparing this value to the cost of commercially available nickel sheet metal indicated a substantial gain, even at 1995 prices. This analysis did not consider the cost of further decontamination of the metal, since the focus of the report considered means of remanufacturing for internal DOE use (Muth, Shasteen et al. 1995).

MSC, along with American Technologies Inc. and Science Applications International Corporation (SAIC), subcontractors for British Nuclear Fuels Limited (BNFL), were slated to receive rights to metals they cleaned as part of a contract to remediate three buildings at ORNL. The BNFL contract was awarded in a non-competitive process as part of the Clinton/Gore administration “reinventing government” initiative (Warrick 1999). This included some nickel in those buildings. One possible sale of the cleansed nickel was to a company for use in NiMH battery manufacture (Neal 1997). Demonstrations of the process indicated that it was an electrorefining process capable of reducing ⁹⁹Tc activity levels down to 1 to 10 Bq/g (DOE 2001). This project was not completed.

In preparation for a sale of the Paducah nickel ingots to Scientific Ecology Group, Inc. (SEG) in Oak Ridge, Oak Ridge Operations (ORO) prepared an Environmental Assessment evaluating impacts of that sale with eventual resale on the international market. The report found that the sale would not significantly affect the quality of the human environment as defined by the National Environmental Policy Act of 1969 (NEPA). Consequently, no environmental impact statement was required.

The sale would involve SEG building a dedicated facility in Oak Ridge to handle processing and decontamination, moving the ingots from Paducah to Oak Ridge, recycling the nickel, managing the resulting waste streams, shipping the recycled nickel to Spain, and transferring the residual waste back to DOE. Spanish regulations allowed acceptance of scrap with activity levels up to 74 Bq/g, but did not allow use of the scrap in consumer goods. The study found that use of stainless steel products manufactured in Spain using the contaminated nickel would at most result in an effective dose equivalent of 0.4 person-rem. The study concluded that the proposed action would

meet “As low as reasonably achievable” (ALARA) standards for risk while providing significant benefit to DOE. Leaving the material in Paducah would not meet ALARA standards, because of potential spread of contaminants from surface runoff after contact with the ingots and loss of the economic value of the nickel. Internal recycle, reprocessing for unrestricted release, improved storage, and direct disposal were considered and rejected due to lack of appropriate technologies, regulatory constraints, and economic considerations (Science Applications International Corporation 1995; Hall 1996).

The other options considered in the finding included no-action, which would not meet ALARA risk because spread of contaminants due to surface runoff or theft was possible; internal recycle; reprocessing for unrestricted release (domestic or foreign); improved storage; and direct disposal. These were declined due to lack of appropriate technologies, regulatory constraints, and economic considerations. The report also stated the contaminants are regulated by the NRC as implemented by the states, and not subject to RCRA because they are intended for recycle with that possibility existing. The report indicates that even if the processed nickel is allowed into unrestricted release with the worst case being some of the nickel being used to make a frying pan that the risk to human health is minimal. The report includes chemical analysis of the nickel ingot samples from Paducah (DOE 1995b).

A 1997 ANL study analyzed disposition alternatives for RSM, again summarizing the two likely alternatives (to develop a regulatory process for decontamination and recycling or to dispose of the material). The scope of the study considered the millions of tons of iron, steel, stainless steel, and copper expected to become available from decommissioned nuclear facilities. The study indicates an expectation that recycling RSM will create downward pressure on prices, though the impact may be lessened due to numerous factors including “local demand, logistics (transportation costs, timing, etc.), quality (grade), exchange rates, and trade barriers (if applicable).” The report also considers potential health and environmental risks associated with RSM processing (Nieves, Chen et al. 1997).

ELR Consultants was the only bidder on a contract to study ways of making a profit from reuse of contaminated nickel. One principal in the consulting firm was Jimmie Hodges, the PGDP manager during the contract bidding period (AP 2000). ELR facilitated the involvement of CVD Manufacturing as a potential contractor for nickel reclamation (Walker 2000a).

In 2002, DOE issued a call for proposals to purify contaminated nickel from DOE facilities (DOE 2002). This effort was to be restricted to reuse within the nuclear industry (Daniels 2002). DOE and the NRC permitted MSC to investigate restricted release scenarios including the use of recovered nickel in waste storage container manufacture and stainless steel sheeting for use in NRC-licensed repositories (Kuck 2002).

Even if the nickel were to be cleansed such that DOE believed residual radiation to be non-detectable, the metal would still need to be treated as potentially radioactive scrap metal (PRSM) until its final clearance. The National Council on Radiation Protection and Measurements published a report in 2002 prepared by a committee concluding a four year study of PRSM disposition. Its findings include

- Existing guidelines on pollution prevention provide a basis for PRSM management

- The current regulatory system lacks a range of viable options
- There is need for consistent national and international standards
- Both the metal industry and the public must be involved in the development of standards and approaches

The same report recommended a set of uniform clearance standards, and the use of a “licensed mill/brokerage as a ‘clearinghouse’ for recycling” (Chen, Dornsife et al. 2002).

The background levels of radiation and radionuclides naturally occurring in commercially available nickel have been measured and validated from two testing sources and multiple materials sources. These baseline measurements should facilitate evaluation of any purified nickel produced and possibly allow for DOE review for clearance (Hampson 2004).

CVMR-USA has proposed using a metal vapor-processing facility to clean the nickel to ultra-pure levels. CVMR has been very protective of their processes, preventing PACRO and other organizations from evaluating its effectiveness and applicability to the Paducah nickel. Should the DOE moratorium be lifted, CVMR has proposed an 8-employee plant similar to one constructed in Lynchburg, Virginia, to process 2000 ton/y of nickel (Walker 2004a). Two possible scenarios were identified as potential options in September 2000 if DOE were to agree to release the nickel for commercial use:

- Unrestricted release
- Industrial use on a lease basis

In all cases, DOE would be responsible for specifying and monitoring the performance of the reclamation process (PACRO 2004a). CVMR has claimed to be able to remove 99.99% of the ⁹⁹Tc from the nickel, but it is not clear what the resulting activity of the final product would be. A communication in 2004 indicated that the government was funding a project which would result in Paducah nickel being cleaned and released for intragovernment transfer to the Department of the Navy (PACRO 2004b). CVMR was scheduled to test a demonstration unit in February of 2005, in cooperation with BWX Technologies (BWXT) (PACRO 2005a). Uranium Disposition Services (UDS), the contractor currently converting depleted uranium hexafluoride at the PGDP, has expressed a need to use about 60 tons of the contaminated nickel (PACRO 2005b).

El-Azzami and Grulke from the University of Kentucky (UK) have proposed using vapor distillation as a means of effectively removing the ⁹⁹Tc from the nickel. The method has been shown to be thermodynamically feasible based on preliminary estimates of activities at infinite dilution. Questions regarding the process kinetics and phase equilibria remain, with design obstacles including the high temperatures required (El-Azzami and Grulke 2002).

Relocation of the nickel ingots was incorporated into the most recent Request for Proposals (RFP) for remediation at the PGDP. Specifically, the contracted firm would relocate all nickel ingots by mid-2007, with Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) documentation. Any other use, including cleansing and release, would require prior approval by DOE with net revenues returned to the government (DOE 2004). A subsequent amendment required the firm “develop and evaluate alternate uses of the Nickel ingots and

acquire competitive bids for its reuse” (DOE 2005). The current cleanup contractor, Paducah Remediation Services (PRS) was required to report to DOE by July 30, 2006 on alternatives for recovering the nickel (Walker 2006).

In March, 2007 DOE issued a request for Expressions of Interest (EOI) from companies interested in potentially becoming involved in the disposition of 15,300 tons of nickel scrap from uranium enrichment. This includes the Paducah ingots as well as Oak Ridge shredded nickel. This request does not obligate DOE to issue a solicitation for processing. The paper is explicit in stating that general clearance and release is not a consideration (DOE 2007).

3. OBSTACLES TO NICKEL RELEASE

3.1 TECHNICAL

As described in the previous section, there are currently no documented methods available to completely separate nickel from ^{99}Tc . Electrorefining processes, such as that proposed to be used at ORNL in the late 1990's, was shown to reduce activity levels down to 1 to 10 Bq/g. CVMR has more recently indicated that their vapor deposition method should remove 99.99% of ^{99}Tc present, but the imprecise meaning of that specification and lack of a validated demonstration preclude conclusions regarding the process. A company capable and willing to demonstrate the effectiveness of their process on contaminated nickel is required before any reclamation process can go forward. Ideally, the process would reduce activity levels to those naturally occurring in virgin nickel.

3.2 REGULATORY

There are currently no standards governing the release of volumetrically contaminated radioactive materials in the United States. The lack of formal standards combined with the DOE moratorium require that individual cases be considered by DOE and other authorities for potential release, making clearance and release unlikely at this time.

DOE Order 5400.5 describes requirements for control of residual radioactive materials. A document issued in 1995 described intended application of the rule in context of surface contamination, a relevant discussion since some have suggested that the same exposure standards be used for volumetric contamination. Three scenarios are considered for release of contaminated materials: release to a DOE landfill, release to a public or offsite landfill, or sale or transfer to members of the public. In the first case, DOE is required to use the ALARA Process to safely dispose of contaminated materials. For off-site disposal, DOE establishes suitable exposure limits and release protocols (using ALARA), subject to local and state requirements. For equipment and other real property, receivers are subject to licensing requirements for radioactive materials, and the following criteria are required to comply with DOE 5400.5:

- Doses to the public from all sources must not exceed 100 mrem in a year
- The exposure limits for the property must be approved in a manner consistent with the ALARA process
- The affected states and NRC should be involved in the release process

The approval process is also described, but does not address volumetric contamination (DOE 1995a).

Development of risk-based standards for safe release of contaminated materials is essential for unrestricted release. In 1994, Chen cited risk assessments performed using conservative model parameters, including International Atomic Energy Agency (IAEA) studies which suggested two basic criteria:

- Risks low enough to not warrant regulation
- Optimized radiation protection

The guidelines in effect at that time would result in risks less than 10^{-6} for an individual and 10^{-2} for society in general. It is not suggested that this risk is sufficient, only that it should be possible to derive risk-based standards for unrestricted release (Chen, Nieves et al. 1994).

Chen later reported on progress toward establishing “clearance” standards for releasing radioactive materials that pose negligible risk to the public. The trivial risk level was determined to be 10^{-6} to 10^{-7} for an individual, or an exposure of 1mSv/yr for the general public. As of 1999, release criteria in terms of activity levels for volumetric contamination in Europe ranged from 0.1 to 1.0 Bq/g for all types of nuclides. Both the IAEA and the European Union (EU) have proposed release criteria for specific nuclides, including ^{99}Tc . The proposed IAEA limit for volumetric contamination by ^{99}Tc was 300 Bq/g, while the proposed EU limit was 1,000 Bq/g (Chen 1999).

Some Congressmen raised opposition to the MSC plan to process and release nickel from ORNL, claiming the approval given by the state of Tennessee violated NRC regulations (Kelly 1999). The NRC was said to be supportive of the decision, which required the company to meet the “1.8 6 rule”, which would have limited to exposure to people to less than 10 millirems per year (Brass 1999b).

On January 12, 2000, then Secretary of Energy Bill Richardson placed a moratorium on the release of volumetrically contaminated nickel from DOE facilities. Concerns expressed by the scrap metals industry, consumer protection groups, and Congress were cited (Brass 2000b).

"I am making this decision," he (Richardson) declared, to assure American consumers "that scrap metal released from Energy Department facilities for recycling contains no detectable contamination from departmental activities"(WSJ Editor 2000).

The ban was expanded on July 13, 2000 to include all radioactively contaminated materials (Paducah Sun Editor 2001).

The Local Oversight Committee’s Citizen Advisory Panel in Oak Ridge, TN, issued a public letter to DOE commenting on the moratorium. It points out that scrap yards already have radiation detection equipment, that foreign countries allow recycling of RSM and those materials are likely imported into the U.S., and that the levels of radiation remaining in the recycled materials would be below detection limits of recycler’s equipment (Brass 2000a).

Changes to DOE Order 5400.5 were proposed in October 2000 to address the moratorium placed on release of contaminated materials from DOE sites. These changes were not adopted, so the moratorium remains in place (Volpe 2003).

A draft DOE guide released in 2002 suggests approaches for meeting requirements for release of property with residual radioactive material. The requirements were intended to meet three goals:

- Property was to be characterized and decontaminated, if possible, before release

- The residual levels were to be as near background levels as practical, following ALARA requirements and DOE limits
- All releases must be fully documented and reported, with public involvement and notification, and complete records maintenance

In the case of volumetric contamination, the guide continues to indicate case-by-case consideration, and provides guidance on how surface contamination standards might be applied to volumetric contamination. American National Standards Institute (ANSI) standards for volumetric contamination are presented as a potential option in place of DOE surface standards, but still require case-by-case approval (Smith 2002).

The NRC began a study considering standards for release of volumetrically contaminated metals in 1999 with the publication of an issues paper (NRC 1999). As part of this process, SAIC was awarded a contract to help create those regulations, but failed to disclose its work with BNFL in its contract to recycle nickel at ORNL (Brass 2000c). Four options were considered during the rulemaking process:

- Continued case-by-case review
- Recycling of slightly contaminated but safe solids
- Release of material for restricted use
- No release, requiring permanent disposal

The Health Physics Society (HPS) released a statement in conjunction with NRC consideration of release standards for volumetrically contaminated materials (Richard J. Burk 1999). The statement recommended:

“(1) we support regulations for radiation protection that are based on the National Council of Radiation Protection and Measurements’ (NCRP) recommendations for dose limits for individual members of the public;

(2) we recommend that constraints be applied to all regulated, non-medical, non-occupational sources of radiation exposure to the general public, excluding indoor radon, such that no individual member of the public will receive in any one year a total effective dose equivalent (TEDE) exceeding 100 mrem (1 mSv) from all such sources combined;

(3) we recommend that dose limits be applied only to individual members of the public, not to the collective dose to population groups.

Expansion and clarification of these recommendations specific to clearance of materials having surface or internal radioactivity further leads the Society to take the position that:

(4) we recommend that regulations for radiation protection be based on consensus standards of the American National Standards Institute (ANSI) issued by the Health Physics Society Standards Committee in keeping with the intent of Public Law 104-113 ‘National Technology and Transfer Act of 1995’ and OMB Circular A-119 ‘Federal Participation in the Development and Use of Voluntary Consensus Standards’;

(5) we recommend that primary radiation protection standards be all pathway TEDE standards with screening levels related to quantities that can be measured such that compliance with these levels will result in the primary dose standards being met for reasonable and likely scenarios;

(6) we recommend that these screening levels be derived with consideration of the principle of as low as reasonably achievable (ALARA); and,

(7) we support the adoption of ANSI Standard N13.12 (1999), “*Surface and Volume Radioactivity Standards for Clearance*”, which is consistent with positions (1) through (6) above” (Richard J. Burk 1999).

The National Academy of Sciences issued a report in 2002 critical of the NRC process leading to a proposed policy of free release of RSM from NRC-licensed sites. While neither opposing nor supporting free-release, the report indicated that metals processors and the public should have greater involvement in the rule-making process (Kelly 2002).

NRC officials state that it considered the 1 mrem/y standard endorsed by ANSI and the IAEA a starting point for their considerations (The International Radioactive Exchange 2002). In 2003, a request for comments was issued concerning the scope of rulemaking (NRC 2003). The draft proposal recommended a dose criterion limit of 1 mrem/year (0.01 mSv/yr) (Reyes 2005). The NRC disapproved publication of that rule, citing higher priority issues in light of delayed reactor decommissioning, concluding that the current case-by-case review is sufficiently protects the public (Vietti-Cook 2005).

The current regulatory standards for clearance of materials volumetrically contaminated with ⁹⁹Tc are given in Table 2.

Table 2. Current international standards for clearance of volumetrically contaminated metals given in Bq/g. Note the NRC value was proposed in a rule not adopted.

Radionuclide	IAEA	EU	NRC (not adopted)
⁹⁹ Tc	300	1000	50

3.3 POLITICAL

Both of Kentucky’s U.S. Senators, Mitch McConnell and Jim Bunning, along with 1st District Congressman Ed Whitfield have been supportive of the completion of the DOE study of the environmental effects of recycling the PGDP nickel, with the expectation that the study completion would facilitate the lifting of the DOE moratorium (Paducah Sun Editor 2003). The study results, originally expected in 2003, are still not available.

Ohio Congressman Ted Strickland proposed an amendment to the Energy Policy Act of 2003 which would have restricted release of radioactive scrap, requiring all solids originating at an NRC licensed facility to be disposed at a licensed low-level waste facility. The amendment was

not offered on the floor due to lack of support. The amendment had strong support from the metals industry (Kelly 2003).

3.3.1 Scrap Metal Industry

The American Iron and Steel Institute and the Metals Industry Recycling Coalition (MIRC) led opposition to release of nickel cleaned by MSC in Oak Ridge, citing concern that the public would not understand the concept of “safe” levels of contamination, nor distinguish between steel manufactured with cleaned nickel and metals inadvertently contaminated with other isotopes (Gravatt 2000). The Nickel Development Institute (NiDU), an industrial coalition, supports the MIRC position (Nickel Institute 2001). Ultimately, the concern was a damaged reputation for stainless steel products and supported markets. (Kuck 2002). As stated by the Nickel Institute, free-release should not be permitted of any materials containing higher-than-background levels of radioactivity, regardless of health impact (Nickel Institute 2001). The MIRC proposes instead that it remain within the nuclear industry “for reuse or recycling - under very stringent controls” (Nickel Institute 2002).

Nickel producers, represented by the Nickel Development Institute, the Nickel Producers Environmental Research Association, and INCO United States, have testified to the NRC in response to the NRC *Issues Paper on Release of Solid Materials at Licensed Facilities* issues paper (64 Fed. Reg. 25090, June 30, 1999) their opposition to an unrestricted release of contaminating metals, even if their radiation levels are below dose-based criteria issued by the NRC or other regulatory agencies. The primary concerns cited by the groups are potential impacts on marketability of metals in general, on marketability of recycled materials in particular, and on potential impacts on metal processors handling such materials. The statement cites media reports on radioactive materials “recycled all the way to your kitchen” and the “vision of consumers bringing a Geiger counter to the department store when they are planning to buy frying pans,” while acknowledging that such reports are not based in reality. The industry does support a “restricted-use” policy, and does not specifically address the free-release of metals with contamination below naturally occurring levels of radiation (Nickel Development Institute 1999).

Ninety “serious” incidents of radioactive materials entering scrap processing facilities have been documented since the early eighties, motivating processors to invest in radiation detection equipment. Several reviews of such incidents were published considering their impact on human health (Lubenau 1995; Lubenau 1998). One concern is that shielded sources may not be picked up by detectors and may enter the processing stream (Dunn 2005).

A 2001 comment on the DOE Programmatic Environmental Impact Statement of the Disposition of Scrap Metal went further in explaining the industry opposition to free release. The key argument was that recycle and free release would result in a net transfer of disposal costs to industry. Each incident where radioactive material enters the processing stream costs between \$10 and \$24 million to cleanup. Every alarm during delivery requires undesirable and expensive actions. The comments suggest that DOE include extended economic impacts resulting from decreases in demand due to public reaction to recycled materials from radioactive sources entering the source stream along with resulting impacts on employment, supplier and support businesses, and reduced tax revenues. The most promising alternative proposed by DOE, to

release only with radiation levels reduced to background levels, was rejected, citing numerous historical failures by DOE to prevent unintended releases of radioactive materials. Of particular concern was the use of private contractors with insufficient oversight. Three possible alternatives were proposed:

- Recycling at licensed, dedicated facility and reuse with DOE
- Use at NRC facilities with appropriate standards to prevent eventual release
- Disposal into an appropriate landfill

The preferred action was no change to the moratorium (Wittenbord and Parascandola 2001).

3.3.2 Labor Unions

During the approval process of DOE contracting with BNFL at Oak Ridge for process building cleanup, the union representing workers at those facilities sued DOE citing a failure to perform an environmental assessment of the process. The suit also expressed opposition to the release of contaminated metals processed at the site (Brass 1999a).

An ANL report concludes that over time the public is becoming accustomed to “safe” radiation exposure (medical diagnostics, televisions, use of natural granite); but more recent attitudes that the government should protect the populace from all risks may preclude acceptability of RSM recycling. The same report indicates that many environmental groups, while skeptical regarding RSM recycling, are open to the possibility in compliance with “adequate safety standards.” Trade unions are likely to support RSM recycling provided that worker safety is adequately addressed (Nieves, Chen et al. 1995). The Paper, Allied-industrial, Chemical and Energy Workers union (PACE) were amongst groups protesting the granting of a license for MSC to process contaminated nickel at ORNL in 1999 (Brass 1999d). This follows a PACE suit against BNFL and DOE in 1997 asserting that an environmental assessment and more public involvement should have been required. The suit was dismissed in U.S. District Court, citing the regulatory authority of the state of Tennessee (Brass 1999c). Others assert that issues with unions can be caused by the potential for recycled metals competing with the domestic steel industry (Paducah Sun Editor 2000).

3.3.3 Public Opposition

Perhaps a British newspaper expressed best the likelihood of public dissent by publishing an editorial containing the following:

"We are intrigued by some of the innovative uses British Nuclear Fuels Ltd have found for 100,000 tons of scrap metal from decommissioned nuclear plants in America. Despite claims in the Washington Post that traces of radioactive material can accumulate over decades in nickel plated pipes and other machinery, the US department of energy have given the go-ahead to a controversial recycling programme. Up to date this has led to little more than industrial machinery being produced from the low-level radioactive scrap. More recently, however, a contract between the Oak Ridge National Laboratory in Tennessee and our own BNFL looks set to transform 100,000 tons of radioactive metal - nickel, aluminum, copper and steel - into belt buckles, zippers, frying pans, forks, knives,

prams, intrauterine devices, dental fillings and braces. What an enterprising bunch they are at BNFL" (Guardian Editor 1999).

During a 2001 public meeting held by DOE on RSM recycling in Oak Ridge, TN, residents of the area and local environmental groups expressed concern regarding entry of recycled RSM into consumer product streams (Parson 2001). The same public opposition can be expected for any proposal involving processing of RSM, and possible clearance of PRSM.

4. IMPACT OF NICKEL RELEASE

4.1 PADUCAH

A non-technical regulatory consideration is the “Hall Amendment”, Section 3155 of the National Defense Authorization Act for Fiscal Year 1994. The law authorizes DOE to transfer title of property to any person determined to mitigate adverse economic consequences from closure of a DOE facility. The law requires that the property to be transferred be “excess to the needs of the Department of Energy” and that the replacement cost “does not exceed an amount equal to 110 percent of the costs of relocating the property or equipment to another facility of the Department of Energy”(U.S. Congress 1993).

DOE is on record as stating that “Economic development is not our job,” indicating a strong likelihood that any proceeds from eventual sale will not be placed in the community for use beyond any contractual commitments. The most likely use of such proceeds would be for further cleanup of the DOE site in Paducah (Walker 2005a). Note that the 1996 proposed sale to SEG in Oak Ridge would have directed revenues to further scrap metal processing, in keeping with the Hall Amendment.(Hall 1996). Area environmentalists claim that DOE promised in writing that revenue from recycling would only be used for cleanup (Walker 2000b).

These statements have not dampened hopes of Paducah and McCracken County officials, still looking to proceeds from eventual nickel sales to fund regional economic development (Thrower 2006a).

The Paducah Area Community Reuse Organization (PACRO), a DOE (Office of Worker and Community Transition) advisory body funded until 2006, lobbied extensively to move forward on nickel recycling. The motivation was the expected use of net revenues from the sale of the nickel to facilitate economic development, particularly in light of the scheduled closure of the PGDP (Fraser 2000). The justification for PACRO’s involvement was the aforementioned Hall Amendment. The last proposed role of PACRO in any nickel release was to act as broker, a role PACRO successfully carried out in the sale of fluorine cells. The organization was also opposed to making the nickel resolution part of the most recent cleanup contract, claiming it removed the community from the process (PACRO 2002). PACRO tried several approaches, including seeking Federal funding to investigate cleaning methods (Walker 2004b). In 2005, PACRO identified CVMR-USA as capable of cleaning the nickel to a state cleaner than commercial nickel containing natural radiation. The primary expected benefit was a processing facility employing displaced plant workers at pay similar to their past wages (Walker 2001b). By 2005, however, DOE had incorporated nickel scrap relocation into the scope of work for the new site cleanup contractor. CVMR planned to process 1000-2000 tons of metal per year, recovering 98% of the nickel (Walker 2005b). Following termination of Federal funding for all community reuse organizations, PACRO was reorganized into the Paducah Uranium Plant Asset Utilization Task Force (Thrower 2006b).

4.2 MARKET CONDITIONS

Using the CVMR projection of 98% recovery, nickel cleansing would potentially introduce about 9500 tons of nickel into the market from the ingots alone. The average cost on the London Metal Exchange in 2006 was \$23,871/t, for a potential market value of over \$200 million. As of March 9, 2007, the cash price of nickel was over \$45,000/t, with the 27-month contract price at \$31,150/t. Based on these values, the nickel has a potential value currently exceeding \$400 million. These prices are for virgin nickel and represent historical highs (London Metal Exchange 2007). Annual average cash prices on the London Metal Exchange for recent years are given in Figure 1.

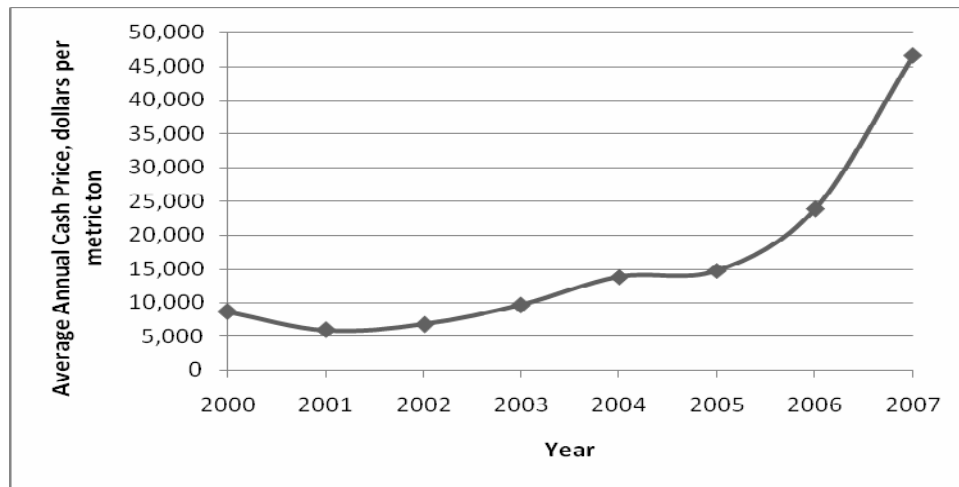


Figure 1. Nickel pricing trends. The 2007 value represents the cash price on March 12, 2007. Data from the London Metal Exchange Website, <http://www.lme.co.uk>

Since the DOE nickel would be recycled in any potential scenario, the value would likely be substantially less. Nickel-containing scrap has sold at about 50% of the price of virgin material. Potentially radioactive nickel would likely sell for less than that. If, however, a processor were able to produce an ultra-pure product, there may be a market for some of the material at a premium price. A conservative valuation would place the current market value of cleansed nickel at something on the order of \$100-\$200 million, minus the cost of processing.

Processing costs are unclear. The proposal to electrorefine nickel prior to export to Spain had an expected cost of \$43 million in 1995. In 2002, the expected net return on nickel reclamation was estimated between \$8 and \$12 million (PACRO 2004b).

A gradual release of nickel (<2,000 t/y) could have a noticeable impact on the value of the nickel. Consumption of nickel scrap domestically exceeds 80,000 t/y with a trend of decreasing product inventory (Kuck 2007). Regression analysis indicates that market prices over the past decade correlate reasonably well ($R^2=0.864$) with net consumption and the inverse of inventories, according to equation 1,

$$\text{Price} = 3.60292 \times 10^8 / (\text{Total Inventory}) + 0.26817 (\text{Total Consumption}) - 64485 \quad (1)$$

Figure 2 shows the regression on historical data. The recent trend of decreasing inventories and rising prices suggest that the impact on market prices of release of nickel in the event of clearance will be noticeable since the expected quantity represents a sizable fraction of inventory. Based on this regression, introduction of 1000 tons of recycled into the nickel market in 2006 would have reduced prices by around 8%. Obviously, markets are more complicated than the model equation implies, but it is reasonable to conclude that introduction of recycled nickel into the market in the quantities expected would affect its price.

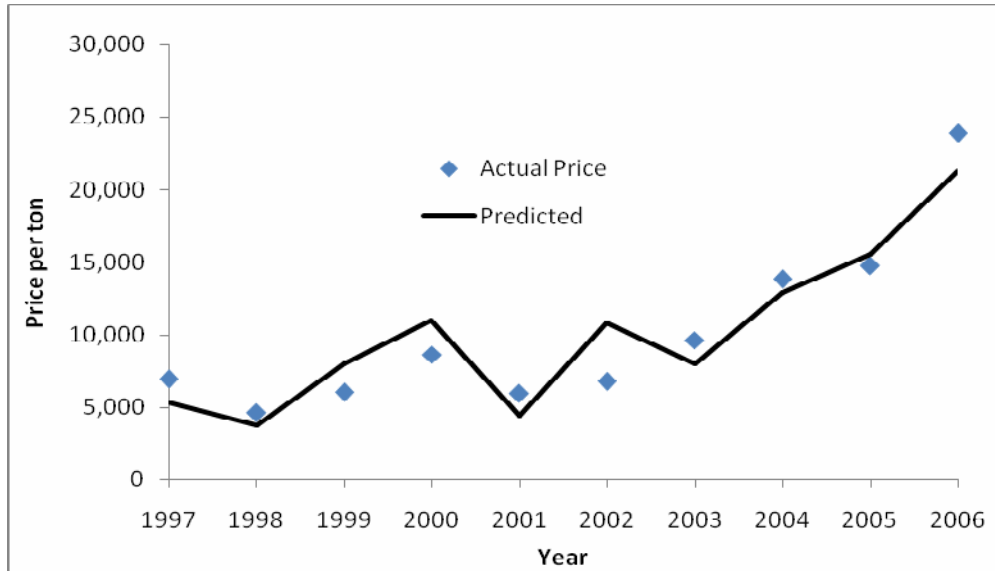


Figure 2. Regressed price data as a function of total consumption and inverse inventory.
Data from Kuck 2002, Kuck 2005, and Kuck 2007

In domestic use, increased scrap availability should result in decreased import of secondary nickel with some price depression combined with increased export of secondary nickel. Table 3 contains USGS data regarding the domestic nickel market.

Table 3. USGS data on nickel markets. From Kuck 2007.

Salient Statistics—United States:¹	2002	2003	2004	2005	2006^e
	W	W	W	W	W
Production, refinery byproduct					
Shipments of purchased scrap ²	114,000	119,000	113,000	117,000	107,000
Imports: Primary	121,000	125,000	136,000	143,000	161,000
Secondary	9,110	11,500	18,800	15,500	20,900
Exports: Primary	6,520	6,330	8,000	7,630	15,200
Secondary	39,400	47,300	48,300	55,600	48,600
Consumption: Reported, primary	88,200	87,300	98,900	96,800	102,000
Reported, secondary	83,900	83,500	83,300	77,300	79,300
Apparent, primary	121,000	117,000	128,000	137,000	147,000
Total ³	205,000	200,000	212,000	214,000	226,000
Price, average annual, London Metal Exchange:					
Cash, dollars per metric ton	6,772	9,629	13,823	14,738	23,871
Cash, dollars per pound	3.072	4.368	6.270	6.685	10.828
Stocks: Consumer, yearend	11,600	11,100	11,000	11,500	10,200
Producer, yearend ⁴	6,150	8,040	6,580	4,380	4,100
Net import reliance ⁵ as a percentage of apparent consumption	52	50	55	56	60

International markets mirror the domestic market as developing countries continue to increase their demand for nickel, hence the current trend of increasing prices. Possible pressures on price could come from reduced Chinese demand due to increases in interest rates by the People's Bank of China or success in recent exploration ventures in China. Internationally, nickel producers are consolidating. China in particular is leading efforts to develop future sources in partnership with international corporations. A move from use of NiMH batteries to lithium ion batteries may temper some nickel use, but limited availability of lithium may prohibit a near-term switch (Kuck 2005). The U.S. consumes 40% of the nickel produced worldwide, but only produces 10% (Walker 2005b).

5. RECOMMENDATIONS

5.1 OVERCOMING BARRIERS

5.1.1 Technical Barriers

Currently, the largest technical barrier is uncertainty in how effective the vapor deposition process proposed by CVMR would be in purifying nickel to activity levels below naturally occurring background levels. Data from isotope analysis of commercially available nickel is now available for comparison to CVMR samples; CVMR however has not allowed observation of their process working with Paducah nickel followed by independent analysis of the product activity. Validation of any process proposed to clean the nickel is essential prior to a proposal to DOE for possible clearance.

The method proposed by El-Azzami and Grulke involving metallic vapor distillation may also enable adequate cleansing of the nickel, but it is still at an early stage of development.

Currently validated technologies, in particular electrorefining originally intended for use at ORNL in the 1990's, should render the nickel in a condition suitable for reuse in applications within the U.S. nuclear complex, including DOE and the nuclear Navy. The recycling plant itself would likely produce significant quantities of RSM after decommissioning, making multiple facilities unadvisable. Potential operators should consider whether other RSM at the diffusion plants, including aluminum, might be economically recovered with the same equipment once initial capital costs have been recovered through nickel reclamation.

5.1.2 Regulatory Barriers

The ongoing moratorium on free release of PRSM from DOE facilities is unlikely to change, however exceptions may be possible on a case-by-case basis. The failure of the NRC to adopt a rule establishing a U.S. standard for clearance makes it unlikely any other agency will adopt standards. Work toward nickel reclamation should assume the moratorium will remain in place until a U.S. Government standard for volumetric contamination is adopted.

An effective argument can be made for an exception to the moratorium based on a process resulting in a product that upon testing by a method, when independently validated:

- Meets or exceeds all foreign standards (EU and IAEA)
- Meets or exceeds ANSI and HPS recommendations for standards
- Results in detection levels on the same order of magnitude of those naturally occurring in virgin nickel

Adherence to the last point may not be required, but achieving that level of activity will decrease the likelihood of objections from other constituencies.

5.1.3 Political Barriers

The metals industry will likely continue its opposition to free release of PRSM regardless of DOE assurances of monitoring delivered materials to minimal level of activity. The most likely successful mode of clearance will be contracting with a single facility to process all cleared materials with extensive monitoring in place. The product, regardless of specification, will likely command a significantly discounted price in the domestic market, but would likely find a foreign market where government standards for volumetric contamination standards exist ready to allow import into industrial use. Scrap metals industry representatives should be involved early in the planning phase of any reclamation plan in order to identify testing and verification protocols to ensure industry acceptance of any release or reuse plan.

The labor unions involved will be primarily concerned with worker safety in any reclamation process. The potential for reduced demand in the scrap metal market from existing facilities and associated industry employment is also an issue. Maintaining a limited capacity of any reclamation process to avoid affecting existing scrap metal processes in the wider market, engaging union representatives early in the planning processes for reclamation, and employing union workers displaced from diffusion plant closure in the recycling plant for a significant period should reduce objections to a nickel recycling plan.

The public at large is hesitant to accept the idea of recycling of PRSM in general and clearance in particular, a viewpoint that numerous environmental advocacy groups work to support. It is unlikely that public outcry (outside of environmental interest groups) would be significant if activity levels were reduced to background levels prior to release. Lack of domestic standards for clearance of volumetrically contaminated metals, however, likely precludes any release at levels above naturally occurring background radiation.

DOE is not likely to lift its moratorium, but the potential for exceptions to be granted does exist if a process is demonstrated to reduce activity levels below naturally occurring levels.

5.2 MOST LIKELY PATH FORWARD

Based on previous studies, the possible methods of disposition of the contaminated nickel are:

- Continued open storage on DOE grounds
- Disposal into an appropriate landfill
- Recycling at licensed, dedicated facility and reuse within DOE/NRC/Department of Defense (DOD)
- Cleansing to background levels for general clearance for release

Continued storage fails to meet ALARA standards. Disposal abandons the significant economic and strategic value of the nickel. Recycling using currently validated technologies would not allow clearance and release due to the DOE moratorium and lack of U.S. standards for volumetric contamination. Consequently, the following actions are recommended:

- Obtain proposals from companies capable of processing the nickel into a state suitable for restricted use within the government nuclear sector, including DOE, NRC, and DOD

- If a company claims the capability of cleaning the nickel to background levels of activity, develop a protocol for pilot studies, involving UK or other independent, expert agency, to validate both the process and the product with suitable confidentiality agreements in place to protect proprietary technologies
- Identify potential internal users of the nickel and nickel-derived products, the processing required to produce usable products, and existing facilities capable of production
- Evaluate the most economical method of producing end-products for use in the government nuclear sector while minimizing new creation of RSM by contaminating processing equipment
- Involve representatives from the scrap metal industry and from affected labor unions in every step of the process from the current EOI through contract award
- Inform the public and give opportunity for input at every phase from the current EOI through contract award
- Recommend that the processing occur at the location from which the most nickel originates, most likely the Paducah site

The location of the processing plant will determine where the primary benefit to the community will be returned in the form of construction jobs and operations jobs. Since the nickel ingots are primarily a PGDP property, the Hall Amendment suggests that any economic benefit be returned to the Paducah area. If the metal is processed for internal use, the location of the plant will meet the Hall Amendment's intent. The net gain from the reclamation should be used to enhance environmental remediation activities at the sites from which the nickel is obtained at amounts proportional to the quantity of materials obtained from each primary site. Additional economic benefit could be derived from production using the reclaimed nickel in the PGDP area and should be a focus for development in addition to the nickel cleansing. It is unlikely DOE would contribute cash proceeds to any other form of economic development unless there was a demonstrable benefit to DOE as well as the source community.

If a company does demonstrate the capability to clean the nickel to background radiation levels, clearance and unrestricted release becomes a possibility which maximizes the benefit to DOE and the source communities. While CVMR claims indicate this may be possible, the lack of independent validation makes it unlikely that clearance is possible in the near future.

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