CONF-9510108--18

DOE/MC/30170-96/C0580

Advanced Technologies for Decontamination and Conversion of Scrap Metal

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Contract Number:

DE-AC21-93MC30170

Conference Title:

Environmental Technology Development Through Industry Partnership

Conference Location:

Morgantown, West Virginia

Conference Dates:

October 3-5, 1995

Conference Sponsor:

U.S. Department of Energy, Office of Environmental Management,
Morgantown Energy Technology Center

DISCLAIMER

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Introduction

The Department of Energy (DOE) accumulated large quantities of radioactive scrap metal (RSM) through historic maintenance activities. The Decontamination and Decommissioning (D&D) of major sites formerly engaged in production of nuclear materials and manufacture of nuclear weapons will generate additional quantities of RSM, as much as 3 million tons of such metal according to a recent study (SC&A, 1995). The recycling of RSM is quickly becoming appreciated as a key strategy in DOE's cleanup of contaminated sites and facilities.

The work reported here has focused on recycle of the concentrated and high-value contaminated scrap metal resource that will arise from cleanup of DOE's gaseous diffusion plants located in Oak Ridge, TN, Paducah, KY, and Portsmouth, OH. An estimate of scrap metal streams from decommissioning of the DOE's gaseous diffusion plants indicates that nickel makes up less than 20 percent of the total expected scrap volume but may carry more than 80 percent of the total value based upon current scrap prices. Because of the abundance and high intrinsic value of the nickel in the DOE's existing scrap metal inventory, the team of Manufacturing Sciences Corporation (MSC), Colorado School of Mines (CSM), and Covofinish Co., Inc. has applied its efforts to the refining and recycle of contaminated nickel and alloying of nickel recovered from DOE scrap with chromium and iron to produce high-quality stainless steel intermediate and end products for restricted reuses.

[1] Research sponsored by the U.S. Department of Energy's Morgantown Energy Technology Center, under contract DE-AC21-93MC30170 with Manufacturing Sciences Corporation, 804 Kerr Hollow Rd., Oak Ridge, TN 37830; telefax: 423-481-3142.

Critical Recycle Issues

Two general approaches to RSM recycle are evident: 1) release to unrestricted commercial use after first removing contaminants from the surface or refining bulk contaminated metals; and 2) recycle to useful new products that would be restricted in end use. Removal of surface contamination and release is an economical approach in cases where there is no internal contamination and surfaces can be easily accessed. Unrestricted release of bulk-contaminated metals is presently not practiced in the U.S. due to the lack of an accepted standard for unrestricted release of these metals. Expense and difficulty of decontamination and quality assurance associated with unrestricted release make recycling of RSM into products with restricted end use attractive in many cases. Several critical issues surround the choice of recycle approach.

Technology

The DOE inventory of RSM includes some quantity of every engineering metal and alloy in common use. The technologies to produce these metals and alloys from ores and scrap metal feeds are well established and commonly practiced. However, conversion of these metals from their present contaminated state to a state suitable for restricted or unrestricted reuse requires adaptation of established techniques and development of new ones. Development and adaptation of technologies is central to this project and will be treated in more depth in a later section.

Economics

> First Law of Metal Recycle: "Economic viability of metal recycle increases in proportion to intrinsic value of the recycled metal"

> First Law of RSM Recycle: "Economic viability of RSM recycle increases in proportion to cost of disposal"

The market potential for recycling of RSM is the sum of the cost avoidance of disposal and the value of products that may be made from these metals. The comparative benefit of recycle for several metal types is shown in Table 1. The combined effects of intrinsic value of the metal and the cost of disposal are readily shown.

The current commercial price for disposal of radioactively contaminated scrap metals, not including any value that might be recovered, is a minimum of $1.50 per pound. The 1.5 million ton DOE RSM inventory therefore represents a $4+ billion disposal liability. All other sources of RSM, the nuclear utility industry being the largest among these, will create a disposal need of similar magnitude. When viewed as a business opportunity, including products that might be manufactured for restricted use, several businesses of moderate scale should be attracted to provide RSM recycle services and products.

Table 1. Economic Benefit of RSM Recycle

Metal Type	Cost of Commercial Sheet Metal	Cost to Produce RSM Sheet Metal	Cost of Disposal	Benefit of Recycle
Carbon Steel	$0.23	$1.80	$1.50	-$0.07
Stainless Steel	$1.32	$2.20	$1.50	$0.62
Stainless Steel (Ni Feed)	$1.32	$2.32	$1.50	$0.50
Nickel Alloy	$5.17	$2.60	$1.50	$4.07

Worker and Public Exposure

Workers and members of the public may be exposed to radioactivity resulting from contact with metals and contaminants during processing, direct contact with recycled RSM and contact with various effluents from the process. The project described here is actively generating data on actual exposures of workers and assessment of probable public exposures. Such data will be valuable input to future decisions concerning RSM recycle.

Liability

Environmental liability, both present and future, is a concern for both the generator and processor of radioactive scrap metal. Perceptions concerning legal exposure are often cited in decisions to pursue one course of action over another, for example, restricted versus unrestricted recycle. Responsible control of radioactive contaminants and understanding of the best processes to employ to assure metal recycling with minimum radiation exposure has been a key objective in the work reported here.

Current Work

The current work is directed toward development of several key technologies specific to recycle of RSM from gaseous diffusion plant origin. These technologies include 1) refining of contaminated nickel, 2) surface decontamination, 3) manufacturing, 4) detection and quantification of radioactive contaminants, and 5) assessment of worker exposures.

Metal Refining

Two methods of nickel refining are being undertaken. The primary refining approach is proceeding under subcontract with Covofinish Co., Inc. using a patent issued to that company entitled "Method for Removal of Technetium from Radio-Contaminated Metal. The method uses metal displacement reduction to remove Tc-99 from the electrolyte during electrorefining. Encouraging results have been observed in preliminary experiments. The current work will produce a bench-scale electrorefining cell that will identify conditions for later pilot-scale work.

A second approach being investigated is evaporative refining. Nickel contaminated with Tc-99 is being evaporated and collected on a substrate to quantify the degree of separation of the radio-contaminant. A several-order-of-magnitude difference in vapor pressure of the two metals is expected to result in a significant separation.

Surface Decontamination

MSC is pursuing development of chemical methods of surface decontamination as an aid for recycle of RSM. The chemical decontamination methods will be aimed at combinations of chemicals that will remove and prevent redeposition of radio-contaminants.

Gas phase decontamination using chlorine tri-fluoride ($C1F_3$) is being actively developed by Lockheed Martin Energy Systems at the K-25 site. MSC will coordinate its decontamination activities with the Lockheed Martin effort to provide maximum benefit from DOE expenditures.

Manufacturing

A principal activity within the project is development of manufacturing processes to produce prototype stainless steel vitrified waste containers starting from RSM characteristic of that arising from D&D of the gaseous diffusion plants. Manufacturing processes being developed and demonstrated include:

Precleaning of RSM. RSM may require precleaning prior to melting, depending upon the level of contamination from radio nuclides and other foreign material. Reduction of the level of radioactive contamination prior to melting can reduce the level of radioactivity in the final product and can benefit the overall process efficiency by reducing personnel exposure levels from the fabrication operations. It is possible that all operations subsequent to melting could be done with very minimal radiation safety concerns if most of the radio nuclide contamination is removed by precleaning combined with separation in the melt. Removal of other foreign materials before melting will greatly reduce the difficulties in maintaining control of the alloy chemistry of the final product. While it is possible to adjust the chemistry of the melt additions and reactions to achieve the desired alloy chemistry, MSC has demonstrated that stainless steel may be remelted to make new product within the same specification if careful precleaning and melting practices are followed.

Melting. All melting and alloying under this project is performed in an enclosed, gas-tight induction furnace under reduced pressure with an inert gas backfill. Such melting practice has two important advantages: 1) the vacuum or inert atmosphere prevents oxidation of the melt and thereby significantly reduces the secondary radioactive waste generated during the melting process, and 2) melting in a gas-tight vessel allows positive containment of volatile radionuclides such as tritium and cesium and provides the opportunity for treatment of a very low volume of off-gas to remove volatile radioactive constituents if found necessary.

Rolling. In a modem, high-volume commercial operation, stainless steel sheet metal would probably be produced as coiled hot-rolled product from a multiple-stand tandem mill and would be further cold reduced by a second multiple-stand rolling operation or on a reversing mill. Operations of this type produce large tonnage quantities of sheet metal on a commodity basis.

MSC's approach to rolling for metals recycle has been to use a 4-high reversing mill to produce plate or sheet to meet a specific product requirement. In other words, the objective of the rolling operation is different from commercial plate and sheet production in that the end product is not a commodity to be shipped for use in a variety of undefined products, but instead the plate and sheet is produced on a custom basis according to end use. The typical approach is to produce discreet pieces that are tailored in size to minimize waste and internal recycle.

Internal Recycle. A key issue in recycle of RSM is internal recycle of trimmings and other scrap. The overall objective of the processing is maximized process throughput, minimized secondary waste, and virtually complete consumption of the RSM in useful product. Internal recycle of RSM scrap and trimmings will be demonstrated within the project.

Detection and Quantification of Radioactive Contaminants

Work under the first phase of the project highlighted the need to accurately detect and quantify the specific isotopes and level of residual contamination in RSM and products that might be made from recycle of RSM. Determination of radioactive contamination by survey of radiation from the surface of RSM or products is limited in ability to differentiate by isotope and to detect low levels of contamination. Laboratory methods of radioanalytical and radiochemical analysis are expensive and impractical to apply to RSM streams of unknown origin. Methods of field survey, laboratory analysis, knowledge of scrap metal source, process knowledge, and quality assurance are being combined to provide an economical and accurate approach to contaminant characterization.

Worker Exposure Assessment

Personnel exposure data is being gathered from all operations encompassed within the project that involve handling of RSM or secondary waste from processing. The data will contribute to construction of likely worker exposure from large scale RSM recycle activities.

Related Work

Recycle of Stainless Steel to Drums and Boxes

MSC is engaged in demonstration of stainless steel RSM recycle under contract with Westinghouse Savannah River Company. This project includes melting, casting, rolling, and fabrication of boxes and drums in its plant in Oak Ridge, Tennessee. The technologies chosen for demonstration are directly relevant to the economical recycle of contaminated stainless steel on a small scale, dedicated basis and will be used to establish design and operating parameters for a commercially viable plant to recycle RSM.

Recycle of Copper Scrap

FERMCO recently awarded a contract to MSC for an engineering study and demonstration for removal of uranium and other trace surface contaminants from copper scrap to allow unrestricted release of the copper. The demonstration will process about 30 tons of copper and produce performance data and process information that will allow scale up for larger quantities.

New RSM Recycle Plant

MSC and British Nuclear Fuels, a world leader in nuclear fuel cycle service, have formed a joint venture to design and build the world's most advanced recycling plant for radioactive scrap metals. MSC will operate this exciting new facility. Ready to receive shipments of metal in November, 1995, the plant will allow nearly *100% RECYCLE* of scrap metal coming from commercial utilities, DOE sites, and other generators of radioactive waste. All incoming metal will be decontaminated. Metal that can be easily surveyed and verified to be clean will be recycled into the secondary metals market. Most other metal will enter a process of melting, casting, rolling and fabrication to produce useful products such as drums, boxes, and other containers for storage or disposal of radioactive waste and shielding components for research and nuclear industry uses. Scrap from in-house fabrication will be internally recycled. The small amount of metal not suitable for recycle will be melted into maximum density blocks for economical burial.

Summary

Recycle of RSM is unique in its promise of significant positive contribution to the cleanup of DOE's contaminated sites and facilities. RSM recycling offers the possibility of recovering the intrinsic value of the contaminated metals and reduction of future waste by reusing the contaminated metals in place of others that would become contaminated. Reuse of existing infrastructure on DOE sites to do RSM recycling in the future provides the opportunity for productive interim reuse of contaminated facilities and reemployment of displaced workers.

References

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Acknowledgments

The authors gratefully acknowledge the support of the U.S. Department of Energy's Morgantown Energy Technology Center, particularly the encouragement and cooperation of Jagdish L. (Jeet) Malhotra, METC Project Manager and COR, and Mary C. Spatafore, Contract Administrator. The contract was awarded September, 1993 under a Programmatic Research and Development Agreement (PRDA). Phase II of the contract was initiated in May, 1995.

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