Advanced Technologies for Decontamination and Conversion of Scrap Metal

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Introduction

On August, 25, 1997, the Department of Energy (DOE) signed a $238 million contract for the complete decontamination of three buildings in the East Tennessee Technology Park in Oak Ridge (formerly K-25). This effort will make available nearly five million square feet of building space for re-industrialization of the former gaseous diffusion plant. In support of that project, Manufacturing Sciences Corporation (MSC) will have the opportunity to disposition over 126,000 tons of potentially radioactive scrap metals. In most cases, the most environmentally friendly and cost effective means for disposition of the metals is through decontamination and recycle.

For the past few years, Manufacturing Sciences Corporation has maintained a vision to aid in the decontamination of radioactively contaminated scrap metals from government as well as commercial facilities. This included promoting the recycle of metals in lieu of expending the space and cost required for burial. As part of that vision, MSC operates a facility in Oak Ridge that decontaminates metals on a production scale. However, some contaminate and metals combinations are difficult to decontaminate using traditional means. In 1993, MSC entered into a Programmatic Research and Development Agreement with the Federal Energy Technology Center - Morgantown (FETC, formerly METC). The purpose of the research effort was to solve special technical problems associated with the decommissioning and decontamination of DOE's nuclear facilities. One of these problems involved the decontamination and reuse of the high value, technetium contaminated barrier nickel. The technetium proved tenacious and traditional mechanical and chemical decontamination processes were unsuccessful in separating the technetium from the nickel.

Objectives

The goals for phase I of the research project included testing a new vacuum induction melting process using various mixtures of slag for separating out technetium during nickel melting. This process, called inducto-slag was unsuccessful at removing technetium from the nickel. During phase I, however, efforts to make stainless steel and other alloys from the contaminated metal was highly successful and lead to further efforts producing useful products made from radioactively contaminated scrap metals (RSM).

Phase II goals included developing a method to separate nickel from technetium, developing a product made from RSM, and to research methods for quantification of radioisotopes in contaminated metals. Results from phase II included successful lab and pilot scale electro-refining experiments that removed technetium concentrations from approximately 250 Bq/g to below 1 Bq/g. Also, a stainless steel closed head (sanitary) drum was developed and fabricated made from RSM. This product is used by Savannah River to store D_2O (heavy) water. Finally, several methods for quantitative measurement of technetium in nickel were evaluated and a few of the best methods were chosen for further analysis.

Phase III of the research effort began January 30,1997. Tasks for Phase III include; develop and test a full scale electro-refining cell, test the feasibility of direct or chemical dissolution of nickel in the electro-refining cell, demonstrate the use of a NdYAG laser for size reduction of a diffusion plant converter shell, develop a new product made from RSM, and refinement of techniques to quantify technetium contamination in nickel on a large scale basis.

Laser Demonstration

In buildings K-33, K-31, and K-29 at the East Tennessee Technology Park (formerly K-25), over 102,000 tons of carbon and stainless steels must be dispositioned as part of the Three Building D&D project. Included in that number are over 1,500 process converter shell of various sizes. These shells, usually at least 1/2" thick must be size reduced into pieces small enough to be decontaminated.

MSC's recycling facility in Oak Ridge is capable of decontaminating steel pieces size reduced to 2'x 2' or smaller through an automated decontamination and recycling process. A robot is used in the sort and section area to separate incoming material. The operator, as shown, is isolated from the contaminated material. Most steel scrap is then conveyed to a tumble grit-blast unit for mechanical decontamination. A chemical decontamination facility is available for the decontamination of materials such as copper and aluminum.

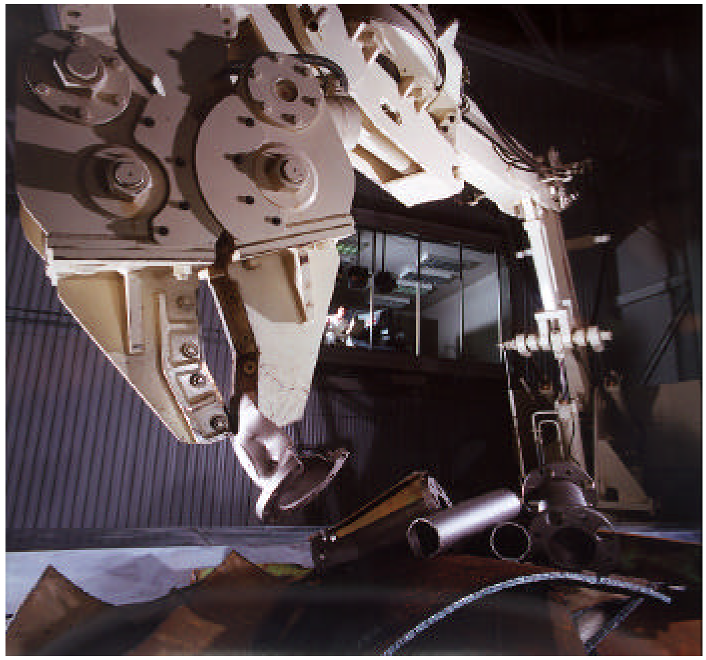


Photo 1 shows the sort and section robot

Size reduction of large components has historically taken place using cold cutting or thermal techniques such as plasma or oxy-fuel. Cold cutting technologies, such as band saws or pipe cutters, generally are time consuming both for set-up and the cutting operation. Plasma and oxy-fuel technologies often have the disadvantage of fumes, excessive heat, and increased waste due to the kerf (or width) of the cut. The worker required to perform the cutting in a radioactively contaminated environment must be suited with personal protective equipment which aggravates the problem of excessive heat from the procedure.

MSC, which currently size reduces RSM on a production scale using thermal and cold cutting technologies, was tasked with evaluating an NdYAG remote fiber optic delivery laser for the size reduction of one converter shell from ETTP. This would include size reducing the shell into pieces small enough for decontamination and recycle at MSC's Oak Ridge facility. The objective was to size reduce a number 2 converter shell using a remote laser cutting operation. The number 2 converter shell size is only one of many sizes on site. The converter shell used during the demonstration was actually used as a cooler in the diffusion process which alleviated any security issues associated with converter shells.

Approach

The Department of Energy worked with Lumonics in Detroit to allow the use of a 2 kW laser system for two demonstrations. The first demonstration with the borrowed laser took place at the Energy Technology Engineering Center (ETEC) in California. ETEC was able to successfully demonstrate the use of the laser with fiber optic delivery for the size reduction of contaminated fuel storage tubes. Approximately 300 16-gauge tubes, 5"diameter by 118" long were size reduced during this demonstration. This test required manual handling of the tubes during the demonstration. ETEC was willing to set all parameters required for operation of the laser and transfer all data and "lessons learned" to MSC.

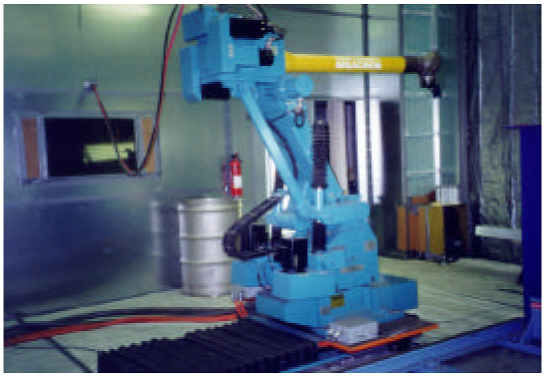


Photo 2 - Cincinnati Milacron Robot

When the demonstration at ETEC was complete, the borrowed laser was sent to MSC for the converter shell demonstration. In order to have the laser operate remotely, other equipment was required. A pre-owned Cincinnati Milacron robot was coupled with a Lumonics Auto-Focus head to enable the cutting beam to maintain a 1 mm distance from the cutting surface at all times. Automatic turning rolls and a part indexer were used to rotate and position the converter shell. A monorail box was positioned to capture the size reduced pieces after a cut is complete. These systems were placed in a lightproof room to ensure that the invisible laser light could not escape. Doors were interlocked and a blue light was turned on during laser operation. If someone entered the room during operation, the laser was automatically turned off. A programmable logic controller provided a means of communication between the laser, auto-focus head, robot, and turning rolls.

Photo 3 - Loading the converter shell

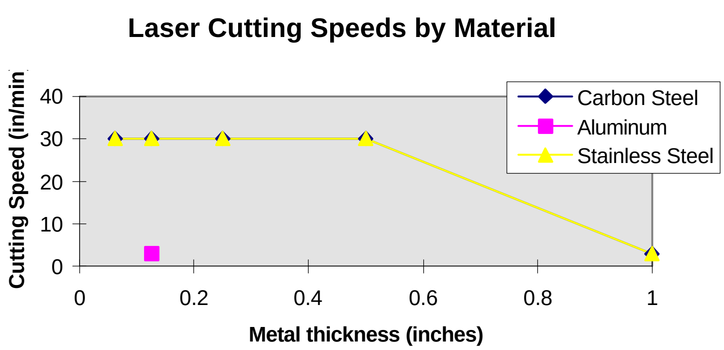
For the demonstration, the 6 ft. diameter converter shell was placed on the turning rolls and moved into the lightproof room. Laser power, assist gas and cutting speed were optimized during cutting trials. Other metals such as stainless steel, 1" thick carbon steel and aluminum were also size reduced during the practice cuts.

Results

Photo 4 - the laser demonstration

The 6 foot diameter, carbon steel converter shell was successfully size reduced at 1800 watts, 10 psi oxygen at a speed of 20 to 30 inches per min. The resulting pieces measured about 1' x 1'. The pieces were captured in a monorail box during the demonstration. The monorail box is the standard box for handling of scrap metal in MSC's recycling facility. This prevented double handling of the size reduced pieces. Kerf width for plasma was compared to that for laser cutting. The average plasma kerf measured 0.125" while the laser kerf measured 0.035" for the 1/2" thick material. This will result in savings due to the reduction of slag and the change-out of HEPA filters. The following chart shows the comparisons of cutting parameters for the various metals.

Carbon steel and stainless steel followed the same performance curve. Cutting of steels at ½" or less was performed at speeds around 30 in/ min. which rivals the speed of plasma cutting. The speed drastically reduced, however when cutting aluminum or 1" thick carbon steels. The three inches/ minute cutting speed for these materials is too slow to be feasible for production size reduction of scrap metals.



Advantages of laser cutting noted to date include improved worker safety due to the ability to cut remotely, reduce waste due to reduced kerf, and less fumes which results in HEPA system cost savings. Less heat generation during and after cutting and easier subsequent decontamination due to less slag generated were also noted. As phase III efforts are continuing, the effects of these results on the size reduction of metals for the three building D&D project will be evaluated.

Nickel Recovery

Approximately 6,000 tons of potentially high value nickel exists in the ETTP site. However, present contamination levels in the nickel make the nickel a liability instead of an asset. Past attempts to remove technetium using traditional mechanical, chemical or melting processes have failed to remove the tenacious contaminates. Phase II efforts under the FETC research contract produced exciting results from lab scale and pilot scale testing of a new electro-refining technology to separate technetium contamination from nickel.

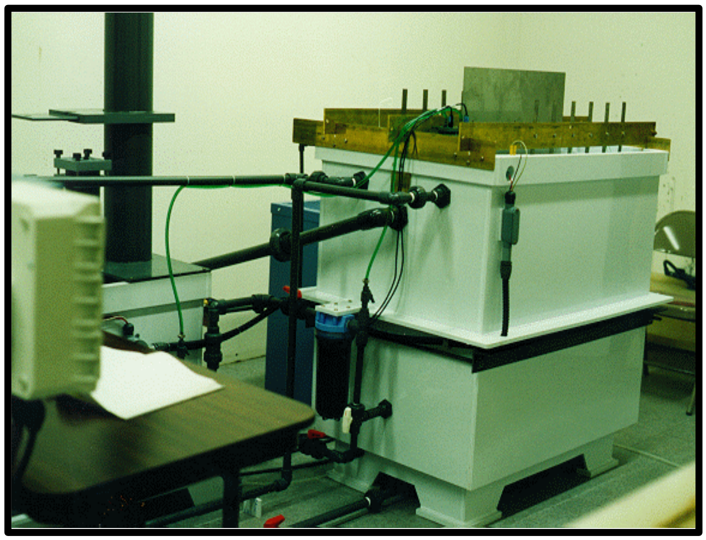


Photo 5 Pilot Scale Electro-refining cell

During phase II, lab scale and pilot scale electro-refining experiments were completed. Lab scale tests took place in a 500 ml cell. In this process, the contaminated nickel is prepared in the form of an anode and placed in the cell. The nickel is electro-deposited into the electrolyte, passed through the cationic membrane and plates out onto the cathode. The technetium contamination, trapped by the membrane, remains in the anolyte (solution surrounding the anode). The anolyte solution must be treated or the concentration of technetium in the anolyte would continue to build. The anolyte is passed through a regenerative process that removes technetium and other contaminates. This process was scaled up to a 200 gallon cell for the pilot scale testing.

The results met all expectations revealing a resulting activity of less than 1 Bq/g.

Objective

The objectives for phase III include building and testing one full scale electro-refining cell. This cell has a volume of approximately 2,000 gallons and will fit eleven cathodes and ten anodes. Preparation of the anodes will be developed during phase III. This will include researching mold designs, refractory options, and melting and casting techniques. Alternative techniques for electro-refining such as direct dissolution and chemical dissolution will help evaluate the possibility of bypassing the expensive melt and cast anode preparation step.

Approach

Traditional electro-refining of metals is not a new process. In fact, electro-refining plants have been in existence since the 1930's. What makes the system able to remove contaminates is the addition of the separation membrane and the anolyte regenerative loop. Instead of "re-inventing the wheel", MSC has researched existing electro-refining operations as "models" for the design of the full scale electro-refining cell. Many lessons learned from the existing industry are directly applicable to our system. Representatives from these plants, understanding our objective is the decontamination of nickel and our relatively low production rates, have been willing to work with us during the design phase. Using the knowledge gained from the phase II experiments and the advice from the existing electro-refining industry, design work is underway for full scale electro-refining.

In order to supply the 800 pound anodes required for operation of the cell, the contaminated nickel must be melted for declassification. Once the nickel is in molten form, it is cast into molds the shape of the anodes. Melting contaminated metals is optimized by melting in a vacuum induction furnace. Melting is vacuum allows capture of any volatiles containing radioactive contaminates, and reduces waste by minimizing oxides or slag during the melt. A six metric ton Vacuum Induction Degas and Pour (VIDP) furnace resides in MSC's recycling facility and will be used for melting and casting of the contaminated nickel. In order to fit the anode molds into the nine foot diameter mold chamber, the molds must be stacked as shown.

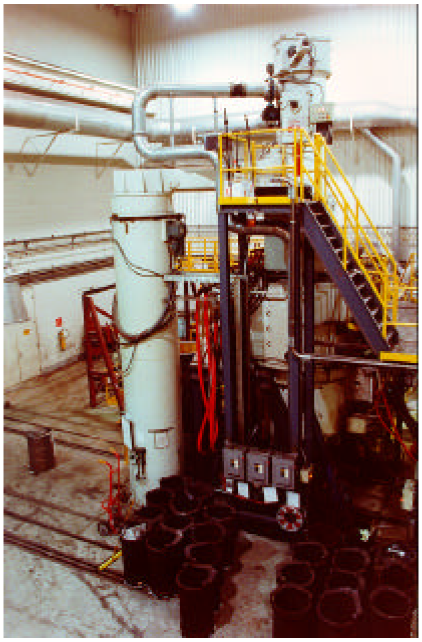


Photo 6 - VIDP Furnace

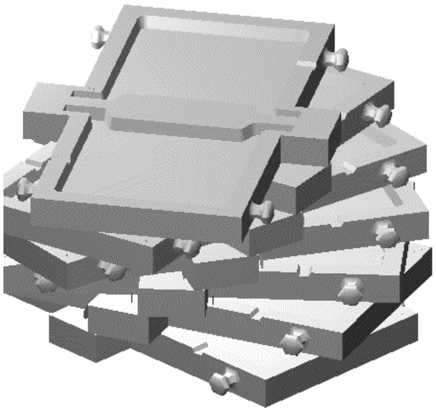


Figure 1 - mold stack

Casting will occur by pouring into the top mold and allowing the molten nickel to "cascade" down to the bottom molds. If for any reason the cascading flow is impeded, the molten nickel can be poured directly into the corner of each mold.

Application

Purchasing and installation of all major components for the one full scale cell is underway. Operation of the cell is expected by the end of the year. The research currently underway is directly applicable to the ongoing three building D & D project at the ETTP site. Electro-refining, as proven during pilot scale testing, will be the method to decontaminate approximately 6,000 tons of contaminated nickel at ETTP. A plant is anticipated to be built in just over a year that includes approximately 50 of these electro-refining cells.

Once the nickel is decontaminated several options exist for the final disposition of the material. The conversion of the nickel from a liability to an asset is not complete unless a suitable market can be found for disposition of the metal. The first option that was researched for nickel outlets was to use the nickel as feed in making stainless steel. In keeping with this vision, MSC has developed several useful products made from radioactively contaminated scrap metal (RSM) that have uses back in the DOE.

Photo 7 - containers

Stainless steel products have lately proven their worth within the DOE due to the corrosion resistance during storage. Many materials that were stored in carbon steel drums have been transferred to stainless steel because the original containers rusted and leaked. One of MSC's stainless steel products, the sanitary (closed head) drum, was developed during phase II FETC activities. Savannah River has issued a purchase order for 100 of these drums and has expressed an interest for 1,000 more.

The most promising outlet for the decontaminated nickel is for the production of nickel metal hydride batteries. Nickel metal hydride batteries are commonly used in portable computers, cell phones, and electric vehicles. Energy Conversion Devices/ Ovonic Battery currently holds all patents for nickel metal hydride batteries. An electric vehicle, powered by a nickel metal hydride battery recently won the distance record for miles traveled on a single charge. MSC and ECD/ Ovonic are currently discussing the possibility of using the decontaminated nickel for the nickel metal hydride market.

Having the possibility of a nickel source close by and the expertise available at ORNL has attracted ECD/ Ovonic to consider establishing a battery manufacturing plant in Oak Ridge. This paves the way for re-industrialization of decommissioned DOE facilities in Oak Ridge.

Photo 8 - scooter powered by nickel metal hydride batteries

Future Activities

Many activities underway in phase III FETC activities are directly applicable to contracted D&D work underway in Oak Ridge. The laser demonstration will be used as part of the evaluation of equipment to be installed by MSC to size reduce thousands of tons of metals at ETTP including over 1500 converter shells. The electro-refining system is expected to be upgraded from a full scale experimental cell to a full size operating plant in just over a year. This is direct implementation of a process developed during research activities for FETC. The upcoming year will prove to be an exciting and challenging time to progress to full scale D&D activities at the ETTP site.

Acknowledgments

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