COPPER CABLE RECYCLING SYSTEM DEMONSTRATION PROJECT

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ABSTRACT

The United States Department of Energy (DOE) continually seeks safer and more cost-effective technologies for the deactivation and decommissioning (D&D) of nuclear facilities. The Deactivation and Decommissioning Focus Area (DDFA) and the DOE’s Office of Science and Technology (OST) sponsor Large Scale Demonstration and Deployment Projects (LSDDPs).

The increasing number of deactivation and decommissioning (D&D) activities at nuclear facilities can generate hundreds of tons of electrical cables per facility consuming valuable resources such as disposal space and the wasted value of the recycled copper. Driven by increasing environmental concerns as well as economical pressures there is a developing need for the recycling of the uncontaminated copper.

As part of the LSDDP program the NUKEM Copper Cable Recycling System (CCRS) was demonstrated in November of 1999 at the Idaho National Engineering and Environmental Laboratory (INEEL). This process allows recovering and recycling the uncontaminated copper contained within the surface contaminated cables.

A total of 13.5 tons of non and surrogate contaminated cables in a wide variety of sizes were successfully processed during the technology demonstration at INEEL. The assessment has demonstrated the mobility and flexibility of this new process.

The NUKEM CCRS was originally developed in Germany for use during the D&D of commercial power plants. To date, the CCRS has successfully processed more than 200 metric tons of contaminated cables in Germany resulting in virtually 100% free release of copper in accordance with German standards.

ORIGIN OF CONTAMINATED CABLES AND THE BENEFITS OF COPPER RECYCLING

During the maintenance, upgrade, repair, and especially the decommissioning of nuclear facilities, a wide variety of contaminated cables are generated. This cable can be coated with rubber, PVC, or polyethylene. The copper cable can vary in diameter and may be rigid or flexible. Usually, the cable is partially contaminated and typically in the past it is either

(1) decontaminated for unrestricted release using labor intensive measures, or

(2) packaged and shipped for contaminated disposal.

The volume of disposable cable is expected to rise dramatically in the future and with this increase both of these options are costly and the demand for an efficient alternative processing method will be needed to save time and money.

Non-nuclear industries have utilized several different mechanical processes to recycle the copper from cables. However, none of these processes has to take into consideration the special requirements for the processing of contaminated materials that are processed and released from nuclear installations. An intensive engineering review of the technologies that are available worldwide clearly indicated that a new and innovative approach was needed to meet the nuclear safety and handling needs.
The newly developed Copper Cable Recycling Technology had the following strategic goals:

1. Separate cable into contaminated and non-contaminated materials and maintain possible cross contamination of the non-contaminated copper below free release limits.

2. Accept all commercially used and different cable insulation types such as rubber, PVC, or polyethylene. The system must be able to process cable sizes ranging from telephone size wire to multi conductor heavy gauge power cable.

3. Allow efficient assay of the processed materials and if possible, enhance handling to prepare contaminated materials for disposal.

4. Consistently follow ALARA principles for safe handling and processing.

5. Incorporate the design of a mobile system that can be shipped and deployed at various D&D locations.

As a result, the patented Copper Cable Recycling System (CCRS) was developed and successfully deployed at several nuclear power plant decommissioning projects in Germany. The deployment of the CCRS demonstrated the ability to separate the feed stream into contaminated and non-contaminated end products, achieve a substantial volume reduction, granulate the cables into homogeneous materials for better assay and obtain a high purity of individual material fractions for increased value in recycling of the copper.

In the United States the DOE has made plans in the foreseeable future to deactivate and decommission about 5,000 facilities that have been identified as surplus. They no longer support the mission of the DOE to reduce its cost to monitor and maintain the facilities, decrease the potential for release of radioactive and hazardous materials to the environment and decrease the risk for safety accidents due to continued deterioration of the aging facilities. Many of these facilities contain miles of insulated copper cable to supply electrical power and control systems for operation of the equipment in the facilities. These copper cables are either uncontaminated or contaminated only the external sheathing. The copper wire inside the cable is uncontaminated and is not activated unless it has been exposed to neutron radiation (1).

Recovery of the uncontaminated copper inside electric cables has multiple benefits. These include the resale of clean copper to the scrap metal market, eliminating the cost of disposing of clean copper as low-level radioactive waste, avoiding the cost of sending clean materials in disposal facilities for low-level radioactive waste (LLW) and unnecessarily depleting available space for disposal of LLW.

THE COPPER CABLE RECYCLING SYSTEM DEMONSTRATION PROJECT AT INEEL

The field demonstration of the NUKEM Copper Cable Recycling Technology is part of a larger series of demonstrations executed under the Large Scale Demonstration and Deployment Project (LSDDP) funded by the Department of Energy (DOE) Office of Science and Technology (OST). The primary purpose of the LSDDP is to demonstrate innovative technologies on a large-scale basis in conjunction with Decontamination and Decommissioning (D&D) activities. The innovative technologies demonstrated are compared against DOE’s baselines and/or industrial baseline technologies in the relevant areas. The outline below describes the results of this technology demonstration that are documented in more detail in OST’s “Innovative Technology Summary Report, Copper Cable Recycling Technology” (2).
The current baseline technology used for the disposal of contaminated cables at the INEEL is to remove contaminated cables from a facility being decommissioned, size and package cables in waste storage boxes or soft-sided containers, and transport it to the Remote Waste Management Complex (RWMC) for disposal as low-level waste.

The main goal of the demonstration was to provide sufficient technical and economical benchmark information against this baseline.

**Demonstration Goals and Objectives**

The objective of the LSDDP is to identify existing technologies unproven in DOE D&D applications that address the defined problems or needs of DOE D&D activities. The second objective is to quantify and document the benefits that can be realized from a side by side comparison of the innovative and baseline technologies. Possible benefits include reduced cost, reduced exposure, increased safety, and ease of application and reduced schedule. This direct comparison provides an opportunity to assess the impact of the innovative technology against the baseline and validate the benefits to be gained.

The scope of this demonstration project was to demonstrate the NUKEM Copper Cable Recycling technology for processing and recycling of radioactively contaminated and non-radioactively contaminated copper cable at the Idaho National Engineering and Environmental Laboratory (INEEL) and compare it with the existing baseline technology.

The purpose of this field demonstration was to assess the effectiveness of the NUKEM Copper Cable Recycling Technology in separating uncontaminated copper from its contaminated insulation and providing separate output streams for uncontaminated copper, contaminated insulation and contaminated dust products. Subsequently the NUKEM process was evaluated in an Innovative Technology Summary Report (2) for efficiency, reliability and potential for cost and schedule savings compared to the current baseline of direct disposal at the INEEL.

**Description of the Technology Demonstration**

The NUKEM Copper Cable Recycling System (CCRS) was transported from Germany to the INEEL where it was setup to demonstrate the recycling of non-radioactively contaminated cable as well as cable with a surrogate contaminate applied.

The Copper Cable Recycling System is a D&D proven mobile system that is housed in two containers with the dimensions of a standard 20ft Sealand container. The system can process a wide variety of cables ranging from telephone wire with 0.5 cm or less to 6.5 cm with all available insulation materials. The typical set up time after arrival is two days or less.

The CCRS produces three distinct individually collected waste streams:

- clean copper,
- potentially contaminated insulation, and
- contaminated dust.

A total of thirteen and one-half tons of cable containing various sizes of copper conductors was available at the demonstration site for the demonstration. The total was divided into two parts to allow individual demonstrations using non-contaminated cable and demonstrations using surrogate contaminated cable. This sizing and segregating process was completed prior to receipt of the NUKEM equipment.
System Setup and Operation

The NUKEM Copper Cable Recycling Technology was shipped via Sea and Land transport to the INEEL where it was setup to recycle non-radioactively contaminated cable as well as cable with a surrogate contaminate applied.

All activities and operations taking place during the demonstration of the surrogate contaminated wire/cable were treated as if it were radiologically contaminated including generation of appropriate documents, personal protection equipment (PPE), monitoring, environmental and air controls. All personnel associated with operations of the equipment were assumed to be radiation worker trained to the level commensurate with the radiation levels typically experienced.

Pre-job and post-job debriefings were conducted to collect observations, concerns, and opinions of operators, sampling personnel, industrial and safety personnel, and other support personnel.

The NUKEM Copper Cable Recycling Technology Operational Procedure was reviewed by all personnel involved in the setup and operation of the equipment. NUKEM personnel held a thorough review with the INEEL and Bonneville County Technology Center (BCTC) personnel and covered each step of the procedure as required during the pre-job briefings. These operational steps were followed during setup, operation and disassembly of the equipment. Personnel were briefed with the procedure and followed all safety guidelines established in the INEEL Jobs Safety Analysis (JSA).

The key components of the CCRS consist of a conveyor to feed the cable scrap into the system, a pre-shredder, and a shredder with several blades that will cut the cables into 3 to 5 mm nodules. These nodules are transported to an air separation table that separates the insulation/dust material from the copper. Fig. 1 shows the simplified process diagram.

![Copper Cable Recycling System PROCESS FLOW DIAGRAM](image)

The cables were placed on the conveyor to feed into a pre-shredder (cables can be fed as rings or as individual pieces). The larger cables were cut into approximate 1 m lengths to facilitate ease of handling and provide a constant feed into the Copper Cable Recycling System. The speed at which the cables were fed into Copper Cable Recycling Technology was determined by the amperage draw of the shredder/grinder motors. An amperage meter located on the side of the conveyor was observed.
continually by the operators during the process to regulate their feed rate. If the current exceeded the system limit, it was necessary to reduce or stop the feed until the amperage lowered back within the operating range.

The grinder is a horizontal shaft with grinding blades placed on the circumference of the shaft. The grinder granulates the copper wire, filler/strengthening fibers and the insulation material covering the copper wire. During the grinding process, most of the contamination is removed from the insulation due to strong mechanical sheer tension in the grinder.

The processed cable is separated into contaminated and non-contaminated material fractions in an air-separation chamber. Fig. 2 shows pure copper and insulation as a result of processing. The contaminated portion is the outer covering or cable insulation and dust materials associated with the inner fillers and strength fibers used in the makeup of multi-conductor cables. The non-contaminated portion (which is the copper wire) is recovered from the inside of the insulation/covering. The relatively lighter insulation and dust granules float on a layer of air above the sieve, while the heavier copper fraction is separated by control of the sieve. Obtaining high volumes of uncontaminated copper for recycling and high volumes of materials that can be used as void fillers in low-level radioactive waste containers was one of the objectives of the technology demonstration.

The Copper Cable Recycling Technology processed approximately 13.5 (US) tons of insulated/coated copper cable. Data was collected during training, setup, operations, maintenance, decontamination, and demobilization activities. Granulated copper and surrogate contaminated cable insulation and dust materials were collected in 55-gallon drums or plywood waste boxes.

Large volumes of virtually pure uncontaminated copper were collected, which demonstrated that contaminated insulation material can be successfully and with high purity separated from the uncontaminated copper wire so the non-contaminated copper can be recycled or reused. Data was collected for surrogate contaminated cable and non-contaminated cable using 55-gallon drums as the collection containers for the copper.

The insulation that is collected separately is a grainy, non-sticky, easily flowable material. Although experience shows that most of the insulation leaving the CCRS is uncontaminated and can be free released, the remaining contaminated fraction can easily be used to fill the void spaces of other waste boxes. Thus allowing virtually free disposal and maximization of disposal space. If the free release of insulation must be maximized as an option the cables may be wiped down prior to processing in order to remove loose surface contamination. Tests conducted in Germany have demonstrated an approximately 20% increase of free releasable insulation if wiped prior to processing. This step was naturally not performed for the demonstration.
Contaminated dust generated by the grinding process is filtered through a three-stage process to prevent the release of airborne contamination. A special design inherent to the NUKEM Copper Cable Recycling Technology prevents the re-binding of contaminated dust to the insulation material. The dust filters and the off-gas filter are encapsulated and monitored for particulate buildup and cleaned or replaced as required. The dust filters did not require replacement or cleaning during the processing of 13.5 tons of cable. Larger amounts however, would require changing the filters and this frequency would depend on the amount and types of cables being processed.

The dust was collected on standard waste boxes and is a fluffy material. Since the dust generally contains the majority of the contamination its handling should be limited. However if volumes need to be minimized it can be used as a void filler or can be compacted minimizing the volume.

The CCRS operated very well over a period of approximately five days. Twenty-one 2’x4’x8’ waste boxes containing 27,100 pounds of copper cable were processed during the demonstration. The demonstration generated 9.5 individual 55-gallon drums of clean copper (17,250 lbs.), five 2’x4’x8’ waste boxes of granular insulation and four 2’x4’x8’ waste boxes of dust.

The unit was capable of processing up to a maximum of six tons of insulated copper cable per day, ranging from small individual strands of wire up to large (two inches in diameter) power cables, in random lengths or coils.

An average throughput during the entire demonstration was 847 lbs. per hour. This included the time required for setting up the equipment at the beginning of the day and shutting down and cleanup at the end of the day. The overall run-time for the demonstration was 32 hours.

The demonstration provided sufficient data to develop a cost benefit analysis for fair and independent comparison of the potential benefits of the NUKEM Copper Cable Recycling Technology over baseline technologies at end-user sites. These benefits can be re-evaluated by the end-user based on the changing value of copper and changing costs of alternative disposal methods.

**Economical Benchmark**

Based on the data collected during the demonstration, it is estimated that the innovative CCRS can save $350,000 if processing 50 ton of cables designated for the INEEL Remote Waste Management Complex (RWMC) landfill for disposal (see Fig. 3) (2). Influenced by the cable sizes generally such a quantity could be processed in less than 15 single shift processing days. With increasing project size these cost savings will significantly increase over the baseline.

![Fig. 3: Job Cost as a Function of Job Size (2)](image-url)
Large decommissioning projects of commercial power plants and DOE facility decommissioning will generate several hundred tons of contaminated cables. The cost savings received will be clearly visible over the baseline technology of direct disposal. For such projects the handling, packaging, transportation and disposal costs can be significantly reduced using the NUKEM CCRS and could even upset other necessary D&D costs.

**Issues Discovered and Lessons Learned During the Demonstration**

Each time the CCRS is shut down and restarted, a total of approximately 2 hours is required to balance the air movers at the beginning of the day and to allow the copper to clean out of the system at the end of the day. This time may vary but needs to be considered each time the CCRS is started and stopped. The CCRS is more cost effective if it can run continuously for as long as possible to avoid the startup and shutdown procedures associated with balancing the air movers and removing the remaining copper from the system. Double shifts or around the clock operation will allow even more cost-effective operation than demonstrated.

A large portion of the CCRS costs are mobilization and demobilization, which remain relatively the same irrespective of the quantity of cable processed. Consequently, the CCRS compares differently with the baseline technology for different size jobs. For jobs that are larger than 25,000 lbs. of cable, the CCRS will be more cost effective than the baseline technology at INEEL.

**CCRS PROCESS EXPERIENCE GAINED DURING D&D PROJECTS IN GERMANY**

During several D&D projects performed in Germany, the CCRS successfully separated the contaminated insulation/dust from the clean copper in the cable. The system has processed cables that were collected during the decommissioning of a fuel manufacturing plant (primarily alpha contaminated) as well from the decommissioning of commercial power plants (primarily gamma contaminated).

Thus far, the CCRS has successfully processed more than 120 metric tons of various sized contaminated cables, as well as approximately 100 metric tons of alpha-contaminated cables at a fuel fabrication plant. With a total of more than 200 metric tons successfully processed cables the process can be considered proven and mature.

Use of the CCRS at various German commercial power plants resulted in the unrestricted release (by German standards) of 74% of the initial cable scrap mass (100% copper, 65% of insulation). A total of 8% of the insulation was disposed at a regular landfill utilizing the unrestricted release limits. Only 18% of the cables processed (insulation and dust) remained and had to be treated as radioactively contaminated waste. *Fig. 4* summarizes the typical ratios after 97 ton processing.

![Fig. 4: Processing Results for Contaminated Cables in Germany](image-url)
This very efficient separation of contaminated materials resulted in significant cost savings for the decommissioning project (3). The copper with its exceptionally high purity was free released and subsequently recycled and sold to a melter of electrolytic copper. The cost savings due to reduced disposal costs and revenue from this sale of copper contributes positively to the reduction of decommissioning costs for the nuclear facility.

DOES RECYCLING HAVE A FUTURE?

The worldwide increasing number of nuclear facilities that reach the end of their 40 year design life will generate increasing and high volumes of waste associated with their decommissioning. The unconditional disposal of these wastes without considering the currently available technologies to minimize and recycle will rapidly deplete the disposal volumes available and will result in increased decommissioning costs.

The CCRS demonstration project has demonstrated that there are already cost savings producing solutions available that are not only supporting tight budgets but also recycle valuable materials for reuse in the industrial materials cycle. The CCRS has its immediate application at DOE sites where facility D&D is planned or underway.

The mobile system is able to support relatively small and large copper recycling projects as the demand develops on the individual sites thus eliminating extra handling, storage, container and transportation costs. The CCRS has demonstrated the enormous potential to significantly reduce costs for many D&D projects throughout the United States.

FOOTNOTES

* References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with the Idaho National Engineering and Environmental Laboratory.

REFERENCES:

