November 19, 1997

Mr. James Kennedy
U. S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Washington, D.C. 20555-0001

Re: Shieldalloy Metallurgical Corporation (License No. SMB-1507)

Dear Mr. Kennedy:

On behalf of our client, Shieldalloy Metallurgical Corporation (SMC), enclosed is a copy of Report No. 94005/G-8154, "Technical Basis, Work Plan, and Health/Safety Plan for the Sale of East Pile Slag". If you have any questions or require additional information, please contact the Radiation Safety Officer for the Cambridge plant, Mr. James Valenti, at (609) 692-4200.

Sincerely,

Carol D. Berger, C.H.P.

cc (w/o enc.) J. Valenti - SMC
File 94005.15

Technical Basis, Work Plan, and Health/Safety Plan for the Sale of East Pile Slag

Submitted to:

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(609) 692-4200

by:

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Report No. 94005/G-8154
October 2, 1997

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EXECUTIVE SUMMARY

Steel manufacturers and service organizations (slag blenders) wish to purchase East Pile Slag (EPS) from Shieldalloy Metallurgical Corporation (SMC) for use as an additive (fluidizer) in steel-making. This product is in demand because it improves the quality of produced steel, its low melting point reduces the amount of energy required in the steel-making process, and its introduction reduces impurities in the end product.

The work plan for staging EPS for sale calls for excavating slag from the East Slag Pile and transferring it to a work area that has been temporarily restricted for radiological purposes. There, a preliminary segregation step will take place in order to remove foreign objects, if any, and slag pieces with significantly elevated exposure rates. Once the segregation is complete, the slag will be crushed, screened and staged for shipment. Confirmatory samples of the final product will be collected and analyzed prior to transport.

EPS contains low concentrations of uranium and thorium (i.e., less than 0.05 percent). Therefore, it is exempt from licensing pursuant to Title 10, Code of Federal Regulations, Section 40.13. In addition, the radiological impact on workers at the steel plant and on members of the general population is negligible, so EPS may be used without regard for its radiological constituents. In fact, the maximum possible increase in radiation dose incurred by workers or end users cannot be distinguished from the radiation doses incurred by these individuals every day from natural background radiation.

INTRODUCTION

Shieldalloy Metallurgical Corporation (SMC) owns a ferroalloy plant near the city of Cambridge, Ohio. Currently, ferrovanadium alloys and vanadium chemicals are manufactured at that facility. However, previous owners processed columbium (niobium)-containing ores which also contained thorium and uranium in quantities that were licensable by the U. S Nuclear Regulatory Commission (USNRC).

Because radioactive material occurs naturally throughout the earth's crust, any mineral extraction, operation or process may result in technological enhancement of certain elements in the byproducts of the process. Consequently, two non-essential elements are present in the slag that is produced from the metallurgical operation. These are uranium and thorium.[1]

While these elements are present in *all* ores and slags at the Cambridge plant, the feed material for the former licensed operations contained slightly elevated concentrations of uranium and thorium. Therefore, the slag from these operations also contains elevated concentrations. Those concentrations were sufficiently elevated that a USNRC license is required for their possession.

Although no USNRC-licensed material has been processed at the Cambridge plant since the mid-1970's, SMC possesses a license (SMB-1507) for possession only of the uranium and thorium in the slag that resulted from the former licensed operations. That slag, and slag produced from other (non-licensed) operations, are currently stored in two piles on the facility property.

Slags have always been a part of steel and iron making, since at least 10 percent of what is produced in the process is slag. However, slags are also important contributors to the production of quality steel. They remove unwanted materials, reduce energy usage, and improve product yields. As such, slag from the Cambridge plant has product value.

SMC's Newfield, New Jersey facility has generated and continues to generate a variety of similar by-products with commercial application. These are ferrovandium slag, known by the trade name of V-40©, and ferrocolumbium slag, known by the trade name of CANAL©. Because of their

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[1] For this report, the term "non-essential" refers to the fact that the elements have no effect on the performance of the product.

aluminum and calcium content, V-40© and CANAL© are valuable additives to the steel making process for reducing impurities in the final product.

The various slag types stored at the Cambridge plant contain constituents similar to those found in V-40© and CANAL©.[2] A combination of these slags, known commercially as EPS (East Pile Slag), serves the same functions in steel production as V-40© and CANAL©. However, like V-40©, the uranium and thorium concentrations in EPS are well-below the concentrations that would require the user to be licensed by the USNRC. Therefore, SMC intends to sell EPS to steel manufacturers and service organizations (i.e., slag blenders) as part of its routine operations.

This report addresses the regulatory and radiological aspects of EPS use as an additive in the steel production process. Included herein is a description of the radiological constituents in EPS, a work plan for staging EPS for sale such that the final product meets the criteria for release for unrestricted use (i.e., contains uranium and thorium concentrations that are well-below those that require a license), a health and safety plan for the staging operation, a regulatory analysis of the final product, and an analysis of potential radiation doses to steel workers and members of the general public from EPS use.

The procedures in this report will ensure that EPS, once staged for sale, will contain only "unimportant quantities" of source material (i.e., less than 0.05% by weight), thus obviating the need for licensing by any recipients.[3] The report also demonstrates that the use of EPS in steel manufacturing poses negligible radiological health and safety risks for workers and the public.

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[2] These slag types are ferroboron, ferrotitanium, ferrovan, ferrovanadium, Grainal (a zircon sand-type), and ferrocolumbium.

[3] Title 10, Code of Federal Regulations, Section 40.13

RADIOLOGICAL CONSTITUENTS IN EPS

Origin of EPS

In the early 1950's, operations at the Cambridge site were begun by Vanadium Corporation of America.[4] One process at the facility involved the use of columbium ores that were considered to be "source material" because they contained licensable quantities of radioactive materials (e.g., uranium and/or thorium in concentrations in excess of 0.05%, by weight). The production of ferrocolumbium continued from 1953 to 1973 under an Atomic Energy Commission license. Ferrocolumbium production resulted in generation of a slag containing uranium and thorium. The ferrocolumbium slag was stockpiled in a surface storage area known as the "East Slag Pile".

In addition to ferrocolumbium production, the site also produced slag from a variety of other metallurgical operations. Some of these slag types were also stockpiled in the East Slag Pile. A recent assessment reveals that the East Slag Pile contains 60,858 tons of slag. Of that amount, approximately 4,006 tons are from ferrocolumbium production and the remainder is from operations which did not use licensed materials as feed.[5,6] EPS will be produced from the contents of the East Slag Pile.

Radionuclides in the East Slag Pile and in EPS

During a remedial investigation/feasibility study of the Cambridge site, the radiological constituents (source term) in the East Slag Pile were determined from three sources of data:

- Analysis of samples collected during a March, 1995 sampling campaign;[7]

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[4] Vanadium Corporation of American later merged with the Foote Mineral Company.

[5] Includes the following processes: Chrome-nickel-alloy, alumino electric, stainless-steel grindings, CEX-11, CEX-17 high speed steel grindings, silica electric, ferrotitanium, Grainal®, Ferrovan®, Solvan®, ferroboron, and miscellaneous production runs.

[6] PTI Report, "Onsite Slag Characterization and Distribution at the Shieldalloy Metallurgical Corporation Site in Cambridge, Ohio", May, 1995.

[7] PTI Environmental Services, Inc., "Work Plan, Remedial Investigation and Feasibility Study at Shieldalloy Metallurgical Corporation Site, Cambridge, Ohio", May, 1995.

- Data compiled from numerous facility records on the volume and disposition of slag at the Cambridge site;[8] and

- Other sampling and analysis used to verify the estimated volumes.[9,10,11]

Table 1 shows the mean source material content of the East Slag Pile. This value is approximately 0.03%, by weight. Table 2 shows the mean concentration of all radionuclides that are currently in the East Slag Pile.[12]

EPS production will include a sorting step wherein the ferrocolumbium in the East slag Pile will be removed prior to final staging and sale of the product. Consequently, as shown in Table 3, the true source material content of EPS will be closer to 0.01% rather than 0.03%, by weight.

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[8] PTI Environmental Services, Inc., "Onsite Slag Characterization and Distribution at the Shieldalloy Metallurgical Corporation Site in Cambridge, Ohio", May, 1995.

[9] Berger, J. D., and R. J. Hysong, "Radiological Survey of the Shieldalloy Metallurgical Corporation Site, Cambridge, Ohio", Oak Ridge Associated Universities, May, 1988.

[10] Cotten, P. R., J. D. Berger, T. D. Herrera, C. F. Weaver, M. J. Laudeman, C. H. Searcy, "Confirmatory Survey of the Shieldalloy Metallurgical Corporation Site, Cambridge, Ohio", Oak Ridge Associated Universities, May, 1991.

[11] ERT, "Decontamination and Decommissioning Plan", ERT Report No. G277-200, November, 1987.

[12] Kelly, B. A., "Source Term Development", Integrated Environmental Management Report No. 94014/G-101, June 10, 1995.

USE OF EPS

Slag is an important contributor to steel quality. It is typically used as a slag fluidizer or conditioner in steel production to remove unwanted oxides, sulfides, nitrides and phosphides from the metal, and to provide a cover to protect refined steel from reoxidation and nitrogen/hydrogen pickup. It can also be an effective calcium treatment for improving castability and continuous caster yields.[13]

SMC has sold V-40©, Revan, and other slag types since 1990. The demand for these materials has been dramatic, as evidenced by the annual sales figures for 1990 (less than 2,000 tons), 1991 (4,000 tons), 1992 (6,000 tons), 1993 (10,000 tons), and from 1994 to the present date (16,000 to 20,000 tons). SMC is confident that there will be equal, if not greater demand for EPS because of its greater percentage of aluminum oxide.

SMC will sell EPS to a commercial slag blender. There it may be sold directly to a steel mill, or it may be custom-blended with other materials prior to sale. However, to maintain an element of conservatism in the findings of this report, it is assumed that only unblended EPS will be purchased by steel manufacturers.

At a steel mill, EPS will be combined with other materials prior to smelting. This will serve to reduce the source material concentration even further.

When the smelting operation is complete, steel and "end slag" will be produced. Because of the mixing steps, the radionuclide concentrations in the end slag will be reduced to a fraction of the concentrations that were present in EPS (e.g., from 9.63 to 4.82 pCi/g of ^{232}Th and from 11.3 to 5.65 pCi/g of ^{238}U).[14] Table 2 shows the individual radionuclide concentrations in end slag from production runs using EPS.

Because of its great volume and additional commercial value, the slag produced at the back end of the steel manufacturing process is not likely to be stored on-site at the steel plant. Instead, it is likely to be crushed and sold. The majority of the end slag at a typical mill is used as aggregate for construction purposes (rail track beds, road beds, jetties). The remaining slag is mixed with

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[13] Williams, M., "Synthetic Slags for Steelmaking", Shieldalloy Metallurgical Corporation Report, 1995.

[14] None of the radioactive constituents will remain in the steel.

other raw materials, such as sand, gypsum, water, and used as an additive for cement manufacturing.

Only a small amount (less than four percent) of the total slag produced at a steel mill is likely to be from production runs using EPS (i.e., from blast furnaces, arc furnaces, BOF, and Q-BOP). However, none of the slag types are likely to be segregated from each other. Therefore, the aggregate sold by the steel plant will contain a *mixture* of newly-produced slags, and will have an average radioactivity concentration of less than 0.19 pCi/g of ^{232}Th and 0.23 pCi/g of ^{238}U.[15] Table 2 shows typical individual radionuclide concentrations in the total volume of end slag from a steel plant.

[15] This calculation conservatively assumes that slag produced from EPS comprises four (4) percent of the total slag produced at the plant.

WORK PLAN FOR EPS PRODUCTION

Because the ferrocolumbium slag is stored in the same location as other slags at the Cambridge plant (i.e., in the East Slag Pile), and because SMC wishes to sell EPS that contains only unimportant quantities of uranium and thorium, a radiological sorting step will be included in the production process in order to remove the high specific activity pieces. The slag that remains after sorting will then be crushed, screened for size, sampled for chemical/radiological product certification, packaged, and staged for eventual shipment as EPS. The following subsections describe the requirements, criteria and procedural steps associated with EPS production.

Work Area Description

All slag sorting that is performed as part of EPS production will occur in an area that is sufficiently remote from the East Slag Pile, and deemed suitable by the Plant Manager. The work area will be designated a "Temporary Restricted Area" while it is in use. As such, equipment and materials that enter the area will be subject to applicable and appropriate radiological controls (e.g., access controls, monitoring requirements, contamination controls, posting, radiation work permits, etc.), and the area will be surveyed prior to its release for unrestricted use after work is complete. The procedure for controlling radiological work in the area will be equivalent to SMC (Newfield) Radiation Safety Procedure RSP-012, "Control of Work", a copy of which will be maintained in the work area throughout the operation.

Personnel Qualifications

To ensure all health and safety considerations are addressed, and to confirm that all lots of EPS meet the criterion for "unimportant quantities" of source materials as defined in 10 CFR 40.13, radiological sorting will be performed by one (1) or more individuals that meets the qualifications of "radiation surveyor" as defined in SMC Radiation Safety Procedure No. RSP-006, "Training and Qualifications of Radiation Protection Personnel", a copy of which will be maintained in the work area throughout the operation.

The field manager for the sorting operation, who will also be qualified as a "radiation surveyor", will also directly supervise all radioactive materials shipments, coordinate sample collection, make all on-site decisions in the event that unexpected radiological conditions or circumstances are encountered, and provide health/safety support for other workers involved in EPS production.

The equipment used to transport, crush, screen, and stage EPS will be operated by SMC or personnel under contract to SMC. These individuals will work under the general direction of SMC and the field manager.

Representatives of SMC, regulatory agencies, or others may observe some or all of the EPS production operations. With few exceptions, these individuals will be asked to remain at a distance of at least three (3) meters from all work areas, in addition to avoiding areas where project-related safety hazards (e.g., equipment operation) exist. Only those who have been authorized by the field manager, and who have been instructed in the physical and radiological controls for the operation, will be permitted to enter the immediate work area.

Instrumentation

A sodium iodide detector connected to a scaler/ratemeter (or functionally-equivalent device) will be used to perform radiological sorting (e.g., to estimate the radionuclide content of the various slag types). The contamination status of equipment and personnel involved in EPS production will be determined using a hand-held rate meter connected to an alpha/beta phoswich detector (or a functionally-equivalent device).

Instruments used for radiological sorting or contamination surveys will have been calibrated within 12 months of use, and will be re-calibrated following any repairs to the ratemeter and/or detector. Each ratemeter will be calibrated with a specific detector, designated by the detector serial number. Instruments will be calibrated using radiation sources which are traceable to the National Institute of Standards and Technology (NIST) by methods that are consistent with ANSI-N323-1978, "Radiation Instrumentation Test and Calibration".

Prior to daily use, each instrument will be checked for battery status, check source response, audible response, physical damage, and calibration status as described in Radiation Safety Procedure No. RSP-008, "Instrumentation and Surveillance", a copy of which will be maintained in the work area throughout the operation. The results of the daily check will be documented.

The background exposure rate for each instrument will be obtained at a location that is in the vicinity of but not near known radiation sources. Background data for exposure rate instruments will be acquired at a minimum of two locations, and consist of the exposure rate (microR per hour) at a height of one meter above the ground surface. Background data for contamination and contact survey instruments will be acquired at a minimum of two locations, with the measurement made on a flat surface such as the side of the ratemeter or any other flat surface that is known to be free of surface contamination. Instruments failing any pre-operational check will be taken out of service, segregated from other instruments, tagged as "out of service", and repaired prior to re-use.

Radiological Sorting

Due to the significant difference in the source material content between ferrocolumbium and the other slag types in the East Slag Pile, contact exposure rate measurements will be a sufficiently-sensitive methodology for segregating ferrocolumbium slag from the remainder. The following is a summary of those procedural steps:

- The survey instruments will be confirmed to be operational and the background will be determined as described above prior to the start of work.

- The East Slag Pile will be excavated with a front-end loader, and the excavated materials will be transferred to a laydown location in the Temporary Restricted Area.

- A radiation surveyor will scan the material in the laydown location by moving the sensitive portion of the radiation detector at a rate of less than two (2) inches or 5.1 centimeters per second over the top of the slag pieces, maintaining a detector height of no greater than one (1) inch (2.5 centimeters) from the slag pieces.

- Slag pieces with an external dimension in excess of four (4) inches that exhibit an exposure rate (or instrument-equivalent response) in excess of 100 μR per hour above background will be assumed to contain ferrocolumbium. These pieces will be spray-painted with a durable and visible mark for later segregation. Appendix A contains the technical basis for this release criterion.

- The spray-painted pieces will be transferred, using a front-end loader, to a separate staging area within the Temporary Restricted Area for eventual disposition.[16]

- The remainder of the slag in the laydown location (e.g., that which meets the release criterion of 100 μR per hour) will be crushed and screened to achieve a uniform size, blended to ensure homogeneous consistency of the product, and staged for shipment in 1,000 ton lots, depending upon buyer demand.[17]

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[16] Disposition options for the spray-painted pieces are beyond the scope of this work plan.

[17] The finished product will not require packaging. Instead EPS will be shipped in bulk by either rail or truck.

- Samples of EPS will be collected and analyzed to provide product certification. Analyses to determine Al_2O_3, CaO, SiO_2, MgO, isotopic thorium, isotopic uranium, gamma spectroscopy, and other constituents that may be of interest to the steel industry (e.g., buyers) and interested regulatory agencies will be performed. The thorium/uranium results will be used to confirm that the source material content of each lot is well-below 0.05% by weight.

At the completion of sorting, crushing and screening operations, all equipment in the area will be surveyed for radiological contamination, and decontaminated, as necessary, until the release criteria shown in Appendix B are met. Appendix A contains the technical basis for site-specific compliance with the Appendix B values.

Confirmatory Sampling

To confirm that the lots of EPS met the criteria for unimportant quantities of source material and the purchaser's specifications, sampling will be performed as each crushing campaign takes place (i.e., after sorting and crushing and stockpiling into the 1,000-ton lots). A series of 27 samples will be collected from the output hopper in each campaign. The sampling frequency will be determined in the following manner:

- The total tonnage to be processed in the campaign is divided by 27 to determine the sampling interval.

- Once the campaign begins, the throughput of the crusher will be monitored on a regular basis.

- Once the crusher has completed enough tonnage to constitute a sample interval, a sample will be collected.

The size of each sample will be established in conjunction with the analytical laboratory. It will be based on the number of analyses to be performed and the sensitivity requirements established for each analysis by the field manager.

The 27 samples collected will be packaged and shipped to a radioanalytical laboratory that has a USNRC or Agreement State radioactive mateials license for sample preparation (i.e., grinding and homogenization) and for performing isotopic thorium/uranium analyses and gamma spectroscopy.[18] The laboratory will have written procedures that document the laboratory's

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[18] Aliquots of the composites may also be analyzed for other constituents that are of interest to the purchasers of the (continued...)

analytical capabilities for these analyses, and a QA/QC program which assures the validity of the analytical results.

A chain-of-custody record for each sample will be initiated by the field manager. A copy of this form will accompany the sample throughout transportation and analysis. Any break in custody or evidence of tampering will be documented. Sample custody will be assigned to one individual at a time in order to prevent confusion of responsibility.[19] The samples will be packaged and shipped to the laboratory by overnight carrier in order to ensure demonstrable chain of custody during transport.

Data Interpretation

Once the analytical results for total uranium and for ^{232}Th become available, the data will be analyzed using either the Wilcoxon Signed Ranks (WSR) test or the Sign test, depending on whether the data distribution is symmetric or skewed. The protocol listed in Section 6 of NUREG-1505 will be utilized to prove with a Type II error level of 0.01 that the uranium and thorium concentrations do not exceed the 0.05% by weight limit in 10 CFR 40.4.[20] Appendix C contains the technical basis for the number of samples collected, the choice of analytical methods, and the means of data interpretation.

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[18] (...continued)
product and/or interested regulatory agencies.

[19] Custody is maintained when (1) the sample is under direct surveillance by the assigned individual, (2) the sample is maintained in a tamper-free or tamper-evident container, or (3) the sample is within a controlled-access facility.

[20] NUREG-1505, "A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys, Draft Report for Comment," dated August, 1995.

HEALTH AND SAFETY PLAN

To address the specific radiological and other safety issues associated with production of EPS, on-site health and safety will be monitored by the field manager operating under the direction of the SMC Radiation Safety Officer (RSO) and the SMC Safety Training and Personnel Manager (Safety Manager).[21] The field manager will provide tailgate safety training, implement personnel monitoring requirements, perform release surveys for personnel and equipment, and maintain the records generated as part of this health and safety plan.

This Plan will remain in effect throughout each production campaign.[22] Changes to the Plan to accommodate static or dynamic conditions may be made by the RSO. The following are the health and safety responsibilities for each member of the operations team:

- The Field manager will be responsible for the implementation of this Plan and recommending changes in the Plan to the RSO.
- The RSO will be responsible for providing oversight for implementation of this Plan and making changes to the Plan to reflect field situations that were not anticipated during the Plan's initial development. Changes in the Plan can only be made by the RSO.
- The team leader of contractor personnel will be responsible for ensuring field implementation of the Plan. This includes communicating site requirements to all personnel on the job, field supervision, and consultation with the Field manager regarding appropriate changes to the Plan.
- The team members will be responsible for understanding and complying with all site health and safety requirements presented to them in a pre-campaign briefing on radiological issues (see below).

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[21] As stated above, the field manager will be qualified as a "Radiation Surveyor" pursuant to RSP-006, "Training and Qualifications of Radiation Protection Personnel".

[22] In the event of a discrepancy between this Plan and existing SMC health and safety policy, the SMC policy will prevail.

Site Entry

The field manager will enter the work area before any work begins in order to verify that work zones have been established. The daily site entry procedure will include the following:

- Determine the wind direction and stay cognizant of it throughout the day, identifying the direction during the tailgate safety meeting;
- Confirm the proper placement of emergency information and operational status of equipment;
- Visually scan for signs of actual or potential life or health threatening hazards;
- Note the physical conditions of the site and determine potential exposure pathways;
- Identify new boundaries of the work zones; and
- Document site activities in a "Field Activity Daily Log", including observations related to field conditions and the site, and samples collected.

Employee Training

General employee training in radiation protection (GET) will be provided to each contractor employee prior to the start of each production campaign. GET will consist of an oral presentation by the SMC Safety Manager or the field manager, hand-out of the materials contained in Appendix D, and completion of the"General Employee Training Acknowledgment Form" (Appendix E). The oral presentation includes the following:

- Potential contaminants (radiological and chemical) which may be encountered;
- The hazards associated with the potential contaminants;
- Protective measures described in this Plan and the provisions of the SMC site-wide Health and Safety Plan;
- Work zone setup and decontamination procedures; and
- Emergency procedures.

Tailgate safety meetings will be conducted by the field manager at the beginning of each shift and whenever new personnel arrive at the job site. The purpose of the meeting will be to discuss health and safety procedures to be followed during the day's work activity. The information discussed in each meeting will be recorded on a "Tailgate Safety Meeting" form, which serves as confirmation that the information was discussed with those persons whose signature is on the form.

Medical Program

Any team member who develops a lost-time illness or sustains a lost-time injury during a production campaign will be examined by a physician. The physician must certify that the employee is fit to return to work before further participation in the production effort can commence.

Emergency Procedures

This plan is established to allow EPS production to be conducted without adverse impacts on worker health and safety. In the event of an accident or other emergency situation, appropriate measures will be taken in order to reduce the impact on worker health and safety.

Minor accidents will be handled on site by the field manager and the team leader. The work area will have a first aid kit to handle minor accidents. Should there be an incident that cannot be handled by the team leader (e.g., a major accident, fire, or chemical release), the SMC Safety Manager will be informed of the location and type of incident, and the need for assistance. The field manager notifies the RSO of all first aid cases so that the potential for radionuclide uptake through wounds can be assessed.

In the event that outside medical attention is needed, the hospital nearest to the SMC site will be used. Injured persons who have not been frisked and released will be accompanied to the hospital by the RSO (or designee) who will perform contamination monitoring and decontamination activities, as necessary, prior to treatment.

A list of emergency response telephone numbers will be compiled and distributed during tailgate safety training. Prior to the start of each day's work activities, the nearest SMC telephone will be identified for use during an emergency, and a radio will be worn by the field manager. The list of emergency phone numbers will be readily available on site, along with directions to the nearest hospital.

ALARA

SMC has the responsibility for providing a work-place environment in which employees, visitors and contractors will be adequately protected from hazards, including the hazards associated with exposure to radiation and radioactive material. While the exposures associated with the EPS production will be low, all exposures are assumed to entail some risk to the employee. Therefore, SMC has adopted the following three principles to govern all work activities with the potential for exposure to radiation or radioactive materials:[23]

- No activity or operation will be conducted unless its performance will produce a net positive benefit.
- All radiation exposures will be kept as low as is reasonably achievable (ALARA) considering economic and societal costs.
- No individual will receive radiation doses in excess of federal or administrative limits.

In addition to administrative controls implicit in this Plan, certain production operations may be performed with a water spray, as necessary, to reduce or eliminate airborne dusts. Finally, administrative requirements for exit surveys and personnel dosimetry, as necessary, will provide confirmation of the adequacy of the ALARA program.

Contamination Controls

To assure radioactive materials remain under the control of SMC, each worker involved in a production campaign will be frisked prior to leaving the controlled area if protective clothing (e.g., shoe covers) are not worn, and if the potential exists for the spread of contamination above the release criteria shown in Appendix B. Equipment and materials will be frisked and decontaminated, as necessary, by the field manager prior to exiting the controlled area. Appendix B contains the release criteria for the Temporary Restricted Area. Records of all release surveys will be maintained on a "Radiological Survey Form" and a "Radiological Survey Map".

Personal Breathing Zone Sampling

To confirm that radiation exposures of personnel are consistent with the design basis of this Plan, personal breathing zone sampling may be performed at the discretion of the field manager. Samplers will be charged, calibrated, deployed and retrieved by the field manager. Filters will be collected on a daily basis and held for decay for 24 hours. They will then be counted in-house or forwarded by overnight mail carrier to an analytical laboratory for determination of gross alpha activity. Any filters with gross alpha activity that is significantly in excess of background (e.g., four times background) will be analyzed for the presence of thorium and uranium isotopes. Records of the breathing zone sampling program will be maintained on an "Air Sampling Data

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[23] Shieldalloy Metallurgical Corporation, Radiation Safety Procedure No. RSP-005, "ALARA Program".

Sheet". A "Chain of Custody Form" will be completed for filters transferred to the analytical laboratory.

Protective Clothing

The initial level of protection for production operations will be hard hats, tyvek or cloth coveralls (or company-issued uniforms), safety glasses with side shields, steel-toed boots, and gloves. Upgrading or downgrading of the level of protection will be based on ambient conditions as work proceeds. The RSO will be notified if it is deemed necessary to upgrade to a higher level of protection.

Personnel Monitoring

Pursuant to 10 CFR 20, individual monitoring for internal and external exposures will not be required for contractor personnel during production campaigns. However, at the discretion of the field manager, exposure monitoring pursuant to RSP-010 may be implemented.[24]

Noise Abatement

As necessary, noise abatement methods and/or hearing protection will be required of the service (e.g., crushing, screening) contractor.

Control of Fugitive Dust

The team leader ensures that dust is controlled through the prudent use of water spray or containment.

Handling of Slag

Slag that cannot be lifted/moved with nominal effort by one person will be transferred/handled by front-end loader or other similar equipment. Personnel will not be permitted to climb slag piles in order to access materials.

Forms

All completed health and safety forms will be maintained on site by the field manager until completion of a production campaign. At that time, they will be relinquished to the RSO.

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[24] Shieldalloy Metallurgical Corporation, Radiation Safety Procedure No. RSP-010, "Exposure Control".

REGULATORY IMPLICATIONS

Title 10, Code of Federal Regulations, Part 40.4, "Domestic Licensing of Source Material", defines source material as:

> "(1) Uranium or thorium, or any combination thereof, in any physical or chemical form or (2) ores which contain by weight one-twentieth of one percent (0.05%) or more of (i) uranium, (ii) thorium or (iii) any combination thereof. Source Material does not include special nuclear material."

As such, a license to receive, possess, use, transfer, or deliver material would be required under the provisions of 10 CFR 40 unless the conditions of exemption as described in §§40.11 through 40.13 are met.

The criteria contained in §§40.11 and 40.12 apply only to facilities who perform work under a USNRC or U. S. Department of Energy (USDOE) contract, or are carriers (transporters) of source material. On the other hand, §40.13, "Unimportant Quantities of Source Material", states that:

> "Any person is exempt from the regulations in this part . . . to the extent that such person receives, possesses, uses, transfers or delivers source material in any chemical mixture, compound, solution, or alloy in which the source material is by weight less than one-twentieth of 1 percent (0.05 percent) of the mixture, compound, solution or alloy. The exemption contained in this paragraph does not include byproduct material as defined in this part."

In 10 CFR 40.4, byproduct material is defined as the "tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes". None of the slag types that comprise the East Slag Pile at the Cambridge plant meet this definition since they were generated during ferroalloy production processes and they are neither tailings nor wastes from a uranium extraction or concentration process. Therefore, based upon its classification as an "unimportant quantity", EPS is exempt from the licensing requirements in 10 CFR 40 because it contains less that 0.05% source material, by weight (see Table 3) and is not a "byproduct material as defined in this part".

While SMC is obliged to account for the source material in the East Slag Pile (by virtue of the conditions of License No. SMB-1507) while it is present at the Cambridge site, the source material in EPS is considered to be an "unimportant quantity". Therefore, purchasers of EPS do not require a license to purchase and use EPS.

RADIOLOGICAL IMPLICATIONS

Dose Objective

A precondition to the use of EPS as a steel-making additive is to demonstrate the acceptability of radiological conditions (e.g., ambient exposure rate, airborne radioactivity) associated with its use. An acceptable dose, in this case, refers to the maximum dose above background that may be incurred by members of the general public from the possession and use of EPS (and its end-use products). This dose ensures that there is negligible risk of radiation-induced health effects from the use of EPS.

There are a number of dose criteria promulgated by standards groups and regulatory agencies that represent negligible risk. Any one of these would constitute an acceptable objective for unrestricted use of EPS. The following are just a few examples:

- The National Council on Radiation Protection and Measurements (NCRP) recommends a dose limit of 100 millirem per year from manmade sources for individual members of the public.[25] This limit is based on scientific recommendations developed through an impartial consensus process.
- The USNRC, in a 1991 Final Rule, adopted the recommendations of the NCRP as its basic dose limit applicable to any licensed facility.[26]
- In 1990, the USNRC issued a Policy Statement which established the framework within which the USNRC would make licensing decisions to exempt some or all regulatory controls over certain practices involving radioactive materials.[27] This Statement set a "below regulatory concern" dose criterion of 10 millirem per year, which was based upon what the USNRC considered to be an acceptable hypothetical lifetime risk of cancer of 3.5×10^{-4} per rem of ionizing radiation dose.[28]

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[25] National Council on Radiation Protection and Measurements, NCRP Report No. 93, "Ionizing Radiation Exposure of the Population of the United States", December, 1987.

[26] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation".

[27] U. S. Nuclear Regulatory Commission, "Below Regulatory Concern Policy Statement", 55 FR 27522 (July 3, 1990).

[28] This policy statement was subsequently withdrawn for reasons unrelated to its technical basis.

- The USEPA sets a dose limit of four (4) millirem total body or organ dose equivalent as the basis for controlling the concentrations of radioactivity in drinking water.[29]

- In the USNRC's final radiological criteria for decommissioning, ALARA requirements are assumed to be met, without further analysis, if a dose objective of 25 millirem (above background) from residual radioactivity can be demonstrated.[30]

For the purposes of this report, a dose objective of four (4) millirem above background is deemed applicable and is used as the basis for demonstrating that EPS may be sold/used without concern for its radiological characteristics. The reasons for selecting this objective are threefold: It is the lowest of the values listed above and demonstrates a desire to implement conservative radiological protection practices; it provides a regulatory basis for development of release criteria for EPS; and the intent is consistent with federal requirements that licensed radioactive materials be handled and released in a manner that ensures that exposures are as low as is reasonably achievable (ALARA) taking into account economic and societal factors.[31]

Characteristics Related to Radiation Dose

The potential radiation dose that workers or the general public may incur from exposure to radioactive material is influenced by a number of factors. These include the amount of radioactivity involved, the types of radiation emitted by the material, the chemical and physical form of the material, the solubility of the material, the particle size distribution, the duration of the exposure, the inhalation pathways (including both airborne material and resuspended material), the ingestion pathways involving contaminated water, food stuffs and animal feeds, and the demographic and physiological characteristics of the population exposed.

With respect to EPS, workers at the steel plant may be exposed to low-levels of ambient gamma radiation during handling of the material upon delivery and with usage. In addition, a worker may be exposed to airborne radioactivity in the event that a container of EPS breaks open or a load of EPS is dropped.

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[29] Title 40, Code of Federal Regulations, Part 141, "National Primary Drinking Water Regulations", 1991.

[30] Federal Register, Vol. 62, No. 139, "10 CFR Part 20, et al. Radiological Criteria for License Termination; Final Rule", July 21, 1997.

[31] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation".

Exposure of the general public may occur from their proximity to the steel mill's end slag that is sold as aggregate.[32] Possible exposure pathways under these circumstances are ingestion of slag by children, external exposure of individuals in the immediate vicinity of the aggregate when it is used as a gravel road or as bedding for a paved road, and the exposure pathways typically associated with the "agricultural farm family" scenario from homes constructed over soils in which slag may have been used as fill, or with cement foundations that contain the slag as an aggregate.

The hypothetical radiation doses to both workers and members of the general public from these exposure scenarios were determined. The intent of this effort was to establish a conservative (i.e., worst case) exposure scenario that is still within the range of possibility. Whenever possible, the assumptions needed to complete the dose assessment were selected conservatively such that the maximum reasonable dose would result. The following is a description of the approach and the assumptions used for each of the exposure scenarios.

Exposure of Mill Workers That Handle Loads of EPS During Steel Production

Evaluation of the ambient radiation exposure of workers who may be in the vicinity of EPS (forklift operators) requires knowledge of the exposure rate in the location of interest, along with the likely duration of the exposure. The following is the calculation methodology used:

$$DE = E_R \times t$$

where DE = the dose equivalent (rem) incurred by workers, E_R = the exposure rate (rem per hour), and t = the exposure duration (hours). The following are the assumptions used for this analysis:

- The EPS is contained in a load with dimensions of 2.5 ft x 2.5 ft x 2.5 ft.
- The load contains only EPS (e.g., it has not been blended with other inert materials).
- The loads are transported with an operator located three (3) feet from the load.
- No shielding exists between the operator and the load.

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[32] Because of its great commercial value, the probability that a slag blender or steel mill might "abandon" a stockpile of EPS in a fashion that might cause a member of the general population to incur a radiation dose above background, is considered to be negligible. The population will only come in contact with end slag from the steel mill which, as shown in Table 2, contains radionuclide concentrations that are only marginally distinguishable from background.

- One load is added to each heat, and the operator participates in four heats per shift, for a total of 1,000 heats per operator per year. In addition, this worker spends 10 minutes staging a load for each production run.

- The same worker spends eight hours per day, one day per month unloading delivered EPS loads. Consequently, the exposure duration (t) for this worker is 263 hours per year.

- The radionuclide concentrations in EPS are as shown in Table 2.

- The exposure rate is 1.82 microR per hour at a distance of one (1) meter (i.e, three feet) from the surface of a load.[33]

From this exposure scenario, the maximum possible dose to a single hypothetical steel worker who performs all tasks is 0.48 millirem per year.[34] If the functions are spread out among a number of workers, individual doses will be much lower.

Exposure of Mill Workers from Re-suspended Airborne Radioactivity from a Dropped Load

To estimate the exposure that may be incurred by workers from radioactivity in EPS that becomes re-suspended as a result of a dropped load requires knowledge of the amount of material that may be re-suspended, the radionuclide concentration of the re-suspended material, the breathing rate of the worker while in the vicinity of the slag pile, and the duration of the worker's exposure. These doses are determined by first estimating the magnitude of intake of material by:

$$I_S = E \times V_m \times C_S \times t$$

where I_S = the number of grams of re-suspended material inhaled, E = the Exposure Duration, V_m = the minute volume of air breathed, C_S = the airborne concentration of slag, and t = the exposure duration. For this analysis, the following parameters are assumed:

- A continuous airborne concentration (C_s) of 200 micrograms of dust per cubic meter of air is representative of the conditions in the vicinity of the dropped load

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[33] The exposure rate one meter from the surface of a single load is estimated using the Microshield 4.21 code (Grove Engineering, Inc. Microshield 4.21, 1995).

[34] For the purposes of this report, R = rad = rem.

for any action being performed. This value is the maximum dust loading noted for dusty occupations.[35]

- The workers' respiratory rate (V_m) is equal to that of an adult male performing heavy work for a minute volume of 40 liters, or 2.4 m^3 per hour.[36]

- No respiratory protection is used by the worker.

- The worker moving EPS is exposed to airborne dust from a dropped load for five (5) minutes. The same worker is also exposed to the same level of airborne dust for 55 minutes during clean-up operations. Therefore, the exposure duration, (E), is a total of one (1) hour.

- The radionuclide concentrations in EPS are as shown in Table 2.

From the estimated intake of re-suspended material, the reasonable maximum intake of radioactive materials is estimated by the following:

$$I_R = I_S \times C_R$$

where I_R = the intake of the individual radionuclides (and daughters), I_s = the number of grams of material inhaled, and C_R = the concentration of radioactivity in the re-suspended EPS. For this analysis, C_R is assumed to be equal to radionuclide concentrations in EPS shown in Table 2.

The U. S. Environmental Protection Agency (USEPA)[37] provides a series of factors to convert annual intake of radioactive materials into committed effective radiation dose equivalent (CEDE).[38] These factors are based upon contemporary metabolic modeling and dosimetric methods. Using the USEPA methodology, the maximum committed radiation dose equivalent which may be incurred by workers as a result of inhalation of suspended EPS is estimated by:

$$CEDE = I_R \times DCF$$

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[35] National Council on Radiation Protection and Measurements, Report No. 91, "Recommendations on Limits for Exposure to Ionizing Radiation", June, 1987.

[36] International Commission on Radiological Protection, Report No. 23, "Reference Man", 1974.

[37] U. S. Environmental Protection Agency, "Federal Guidance Report Number 11", 1988.

[38] The CEDE is the dose equivalent weighted over all body organs for an irradiation period of 50 years.

where CEDE = the committed effective dose equivalent incurred by the workers, and DCF = the dose conversion factor for inhalation of the various radionuclides. The maximum possible dose to steel workers by this pathway is 0.16 millirem per event.

Exposure of Members of the General Public from Homes Built on End Slag as Fill

The dose rate for members of the public that could be exposed to radioactivity from slag used as fill under the foundation of their homes is estimated in the following manner:

- The slag produced from steel-making operations makes up 25% of the soil mass at the base of the home.
- The home has a 0.15 m thick, slab-on-grade foundation, with a density of 3 g/cm^3.
- The average radionuclide concentrations in end slag are as shown in Table 2.
- The soil/slag layer is 15 m x 15 m x 0.3 meters thick, with a density of 2.4 g/cm^3.
- The exposure pathway is direct (ambient) exposure.
- An individual spends 50% of their 70-year lifetime in the home directly above the slab.

The dose rate to this hypothetical individual was calculated using the RESRAD computer code (Version 5.6).[39] The maximum possible dose from this exposure scenario is 0.75 millirem per year.[40]

Exposure of a Child that Ingests End Slag in Soil

The dose rate from ingestion of slag mixed in soil is determined by multiplying the estimated rate of intake of the material by an appropriate Dose Conversion Factor (DCF). For this assessment, the following assumptions were used:

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[39] Argonne National Laboratory Technical Report, Gilbert, T. L., et al, "A Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0", ANL/EAD/LD-2, September, 1993.

[40] Approximately 1000 years into the future, the ^{226}Ra concentration in the fill material will increase by a factor of 20 as it grows into equilibrium with its ^{230}Th parent. If this concentration increase is input to the RESRAD code, the maximum hypothetical dose increases as a result of predicted radon exposures. However, the radon emanation coefficient used for the analysis in this report (0.01) was limited by the values permissible for the RESRAD software. Since emanation coefficients of less than 0.007 are more typical of slag (UNSCEAR, "Sources, Effects and Risks of Ionizing Radiation, United Nations Report, 1988), the calculated dose increase 1,000 years from now is not considered to be realistic.

- The radionuclide concentrations in end slag from the steel mill are as shown in Table 2.
- End slag makes up 25% of the soil's mass, since it is assumed to be used as a soil conditioner.
- The soil ingestion rate is assumed to be 200 milligrams per day for a child under six and 100 milligrams per day for older children and adults.[41]
- For the DCFs, the Environmental Protection Agency, in Federal Guidance Report No. 11,[42] provides a series of factors to convert intake of radioactive materials into radiation dose.[43]

The maximum possible dose from this exposure scenario is 0.51 millirem per year.

Exposure of a Member of the General Public Standing on a Paved Road

In this scenario, a police department official or a parking lot attendant stands on a road or surface constructed with end slag as the road bed. For the purposes of this report, the following is assumed:

- The individual spends eight hours per day (a total of 2,000 hours per year) standing on a road where slag is used as a two-foot thick sub-base.
- The sub-base is covered with 15 centimeters of concrete paving.
- The radionuclide concentrations in the sub-base are as shown in Table 2 for the end slag.
- The exposure rate on the road at a height of one meter above the paved road is 0.02 microR per hour.[44]

The maximum possible dose from this scenario is 0.03 millirem per year.

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[41] Defined in EPA's "Exposure Factors Handbook", EPA/600/8-89/043, July, 1989.

[42] U. S. Environmental Protection Agency, "Federal Guidance Report Number 11", 1988.

[43] These factors are based upon contemporary metabolic modeling and dosimetric methods.

[44] The exposure rate was calculated using the Microshield 4.21 code.

Exposure of a Member of the General Public Standing on a Gravel Road

If the end slag is used to make gravel roads (without pavement), there are two possible exposure scenarios. The first is to road crews laying out a road. The second is to members of the general public who walk on the road.[45] The following are the assumptions for these dose assessments:

- The road crew spends a total of 40 hours per week, one week per month, 12 months per year standing on the road.
- A member of the general public (pedestrian) walks on the road two hours per day, seven days per week, 52 weeks per year.
- The road bed is made up of six inches of gravel.
- The radionuclide concentrations in the road are as shown in Table 2 for the end slag.
- The exposure rate on the road at a height of one meter above the road is 0.11 microR per hour.[46]

The maximum possible dose to the pedestrian and the road crew is 0.08 millirem and 0.05 millirem per year, respectively.

Exposure of a Member of the General Public From the Use of End Slag in Building Foundations

In this scenario, the end slag is used as an aggregate in cement used to construct building foundations. In evaluating this scenario, it is helpful to review the process whereby the end slag might be incorporated into cement.

The end slag that would be produced at a steel mill would contain calcium oxide, aluminum oxide, silicon oxide, magnesium oxide and ferric oxide, making it a useful additive for cement/concrete production. In the form of crushed rocks, it would be transferred by trucks from the steel mill to a cement manufacturing firm. There it is fed into a cement production kiln and mixed with other raw materials (e.g., gypsum) such that it is further diluted. The cement would then be dried in the kiln, packaged, and sold for use in construction, stabilization, and other typical industrial/municipal activities. These might include construction of solid surfaces (e.g., sidewalks

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[45] Exposures for drivers or bikers would be less than for walkers because of the reduced "stay time" on the road.

[46] The exposure rate was calculated using the Microshield 4.21 code.

and road beds), construction of building foundations, and production of cement blocks for use as foundations, walls and fences.

The mean concentration of uranium and thorium in end slag from all production runs at the steel mill (e.g., with and without the use of EPS) is shown in Table 2. In this form, it could be transferred to the cement manufacturer where the end slag may comprise as much as 20 percent of the final dry product. The final concentration of uranium and thorium in dry concrete would be as shown in Table 2. Even without the addition of sand, water and other additives, these concentrations cannot be distinguished from the normal background concentrations of those radionuclides in soil.[47]

The dose rate for members of the public that might use this cement as a foundation for their homes is conservatively estimated using the following assumptions:

- The concentration of dry cement containing end slag is reduced through the addition of sand, water and gravel, by a factor of three in order to produce concrete for the foundation of the home.[48]
- The floor slab is assumed to be 1,000 square meters and 0.3 meters thick, with a density of three (3) g/cm^3.[49]
- The flooring in the home is assumed to be slab-on-grade, rather than wooden flooring mounted some distance above the foundation.
- The exposure pathways for a hypothetical resident are direct (ambient) exposure and radon inhalation.
- The hypothetical resident spends 50% of their lifetime in the home directly above the slab.

The dose rate for this hypothetical individual was calculated using the RESRAD computer code. The maximum possible dose from the relevant pathways is 1.07 millirem per year, occurring at year eight (8) after material placement.

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[47] National Council on Radiation Protection and Measurements, "Ionizing Radiation Exposure of the Population of the United States", NCRP Report No. 93, 1987.

[48] Considine, D. M. and G. D. Considine, Editors, Van Nostrand's Scientific Encyclopedia, Seventh Edition, Van Nostrand Reinhold, New York, 1989.

[49] Chemical Rubber Company, Handbook of Chemistry and Physics, 48th Edition, 1967.

Comparison with Background

Table 4 shows a summary of the previous dose assessment results. These demonstrate that the maximally-exposed hypothetical individual has the potential to incur up to 1.07 millirem per year as a result of living in a home where the foundation contains EPS, a value which is only 27 percent of the dose objective for this work. All other exposure scenarios resulted in lower potential exposures and lower percentages.

To put these values into perspective, it is important to note that everyone in the world is exposed to radiation at all times from natural radiation sources. This is called "natural background radiation". The sources of background radiation include "cosmic" radiation, which is radiation from the solar system and outer space; "terrestrial" radiation, which is radiation from the radioactive elements found in soil; "airborne" radiation primarily from household radon; "internal" radiation from natural sources of radiation found in foodstuffs and the human body itself; and radiation from consumer products, such as emissions from coal-fired plants, smoke detectors, television sets, tobacco products, and a wide variety of other items. In addition to natural background radiation, humans are also exposed to radiation from medical and dental x-rays and nuclear medicine studies.

Natural background radiation is unavoidable and its magnitude varies from one location on earth to another, depending on elevation, soil conditions, and other factors. For instance, the average person living in Dallas, Texas receives a dose of 80 millirem per year due to "cosmic" and "terrestrial" radiation only. The average person living in Denver, Colorado receives 180 millirem per year from the same two sources. The difference of 100 millirem between the two locations is primarily due to Denver's higher elevation.

In certain areas of India and Brazil, the residents receive over 1,000 millirem per year from "terrestrial" radiation alone. However, these residents show no abnormal increase in cancer rates, birth defects, or genetic problems.

The National Council on Radiation Protection and Measurements gives some examples of common radiation exposures.[50,51,52] Members of the general population receive, on average, the following radiation exposures: 1300 millirem per year for the average cigarette smoker; 650 millirem per nuclear medicine examination of the brain; 110 millirem per computerized tomography of the head and body; 7.5 millirem per year to spouses of recipients of certain cardiac pacemakers; 18 millirem per year from the potassium in our bodies; 6 millirem per dental x-ray; 6 millirem per year from the use of phosphogypsum in houses; 5 millirem per year from foods grown on lands in which phosphate fertilizers are used; 4 millirem per year from highway and road construction materials; 1.5 millirem from each 3,000 miles flown in an airplane; 1 to 6 millirem per year from domestic water supplies; 1 millirem per year from television receivers; 0.8 millirem per year from the use of coal for home heating; and 0.5 millirem from eating one-half pound of Brazil nuts.

When all of the general sources of background radiation are considered, the average human being typically receives between 150 and 600 millirem per year, exclusive of medical exposures.[53] The highest maximum reasonable dose calculated for any of the hypothetical individuals listed in Table 4 (1.07 millirem per year for a member of the general public living in a home where the foundation contains EPS) is about 335 times less than the dose associated with typical background radiation exposures received by average members of the general population.

It is important to note that the doses estimated herein reflect the maximum exposure *potential* for the population groups of interest. There is no evidence that any radiation dose in excess of background will occur as a result of their proximity to EPS or its end use products. Furthermore, even after application of generous assumptions, the radiological conditions that may result from the use of EPS in steel manufacturing will not result in demonstrable adverse health effects.

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[50] National Council on Radiation Protection and Measurements, Report No. 93, "Ionizing Radiation Exposure of the Population of the Untied States", 1987.

[51] National Council on Radiation Protection and Measurements, Report No. 95, "Radiation Exposure of the U. S. Population from Consumer Products and Miscellaneous Sources", 1987.

[52] National Council on Radiation Protection and Measurements, Report No. 100, "Exposure of the U. S. Population from Occupational Radiation", 1989.

[53] United Nations Scientific Committee on the Effects of Atomic Radiation, "Sources, Effects and Risks of Ionizing Radiation", 1988 Report to the General Assembly, 1988.

TABLES

1 Table 1 - Mean Source Material Content of the East Slag Pile[54]

	Radionuclide	Mean Concentration (pCi per gram of slag)	Specific Activity (pCi per gram of radionuclide)	Weight Percent (%)
2				
3	U-238	40.4	3.30e+05	1.22e-02
4	Th-234	26.2	2.30e+06	1.14e-13
5	U-234	41.3	6.20e+09	6.66e-07
6	Th-230	980	1.90e+10	5.16e-06
7	U-235	4.68	2.10e+06	2.23e-04
8	Th-231	4.68	5.30e+17	8.83e-16
9	Th-227	26.1	3.20e+16	8.16e-14
10	Th-232	21.3	1.10e+05	1.94e-02
11	Th-228	15.6	8.30e+14	1.88e-12
			Total	**0.03**

[54] Concentrations derived from mean values provided by Kelly, B. A., "Source Term Development", Integrated Environmental Management Report No. 94014/G-101, June 10, 1995, with the contribution from ferrocolumbium slag removed.

Table 2 - Radionuclide Content of EPS and End-use Products

Radionuclide	Mean Concentration in East Slag Pile (pCi/g)*	Mean Concentration in EPS (pCi/g)**	Mean Concentration in End Slag from Run with EPS (pCi/g)	Mean Concentration in End Slag from All Runs (pCi/g)	Mean Concentration in Cement (pCi/g)	Mean Concentration in Concrete (pCi/g)
U-238	40.4	11.30	5.65	0.23	0.05	0.02
Th-234	26.2	10.10	5.05	0.20	0.04	0.01
Pa-234m	41.1	11.40	5.70	0.23	0.05	0.02
U-234	41.3	11.70	5.85	0.23	0.05	0.02
Th-230	980	1030.00	515.00	20.60	4.12	1.37
Ra-226	38.5	21.00	10.50	0.42	0.08	0.03
Rn-222	38.5	21.00	10.50	0.42	0.08	0.03
Po-218	38.5	21.00	10.50	0.42	0.08	0.03
Pb-214	38.5	21.30	10.65	0.42	0.08	0.03
Bi-214	38.5	20.90	10.45	0.42	0.08	0.03
Po-214	38.5	20.90	10.45	0.42	0.08	0.03
Pb-210	32.4	34.40	17.20	0.69	0.14	0.05
Bi-210	12.4	9.30	4.65	0.19	0.04	0.01
Po-210	9.87	6.60	3.30	0.13	0.03	0.01
U-235	4.68	2.31	1.16	0.05	0.01	0.00
Th-231	4.68	2.31	1.16	0.05	0.01	0.00
Pa-231	39.0	29.20	14.60	0.58	0.12	0.04
Ac-227	26.1	16.90	8.45	0.34	0.07	0.02
Th-227	26.1	16.90	8.45	0.34	0.07	0.02
Ra-223	32.5	31.60	15.80	0.63	0.13	0.04
Rn-219	32.5	31.60	15.80	0.63	0.13	0.04
Po-215	32.5	31.60	15.80	0.63	0.13	0.04
Pb-211	32.5	31.60	15.80	0.63	0.13	0.04
Bi-211	32.5	31.60	15.80	0.63	0.13	0.04
Tl-207	32.5	31.60	15.80	0.63	0.13	0.04

Radionuclide	Mean Concentration in East Slag Pile (pCi/g)*	Mean Concentration in EPS (pCi/g)**	Mean Concentration in End Slag from Run with EPS (pCi/g)	Mean Concentration in End Slag from All Runs (pCi/g)	Mean Concentration in Cement (pCi/g)	Mean Concentration in Concrete (pCi/g)
Th-232	21.3	9.63	4.82	0.19	0.04	0.01
Ra-228	21.6	4.20	2.10	0.08	0.02	0.01
Ac-228	21.6	4.20	2.10	0.08	0.02	0.01
Th-228	15.6	3.44	1.72	0.07	0.01	0.00
Ra-224	99.8	45.40	22.70	0.91	0.18	0.06
Rn-220	99.8	45.40	22.70	0.91	0.18	0.06
Po-216	99.8	45.40	22.70	0.91	0.18	0.06
Pb-212	23.7	5.18	2.59	0.10	0.02	0.01
Bi-212	15.9	4.05	2.03	0.08	0.02	0.01
Po-212	10.2	2.60	1.30	0.05	0.01	0.00
Tl-208	7.55	1.46	0.73	0.03	0.01	0.00

* Mean concentration of radionuclides taken from Kelly, B. A., "Source Term Development", Integrated Environmental Management Report No. 94014/G-101, June 10, 1995.

** Mean concentration of radionuclides *excluding* contribution from ferrocolumbium slag derived from Kelly, B. A., "Source Term Development", Integrated Environmental Management Report No. 94014/G-101, June 10, 1995.

Table 3 - Source Material Content of EPS[55]

Radionuclide	Mean Concentration (pCi per gram of slag)	Specific Activity (pCi per gram of radionuclide)	Weight Percent (%)
U-238	11.3	3.30e+05	3.42e-03
Th-234	10.1	2.30e+06	4.39e-04
U-234	11.7	6.20e+09	1.89e-07
Th-230	1030	1.90e+10	5.42e-06
U-235	2.31	2.10e+06	1.10e-04
Th-231	2.31	5.30e+17	4.36e-16
Th-227	16.9	3.20e+16	5.28e-14
Th-232	9.63	1.10e+05	8.75e-03
Th-228	3.44	8.30e+14	4.14e-13
		Total	**0.01**

[55] Concentrations adjusted from Kelly, B. A., "Source Term Development", Integrated Environmental Management Report No. 94014/G-101, June 10, 1995 (ferrocolumbium contribution removed).

Table 4 - Summary of Dose Assessment Results

Exposure Scenario	Maximum Individual Dose (millirem per year)	Percent of Four (4) Millirem per Year Dose Objective
Direct Exposure of a Steel Worker Handling Loads of EPS	0.48	12
Inhalation Exposure of a Steel Worker per Dropped Load of EPS	0.16	4
Exposure of a Member of the General Public from Homes Built on End Slag	0.75	19
Exposure of a Child that Ingests Soil Containing End Slag	0.51	13
Exposure of a Member of the General Public Standing on Paved Roads over End Slag	0.03	1
Exposure of a Road Crew Member Constructing Roads with End Slag	0.05	1
Exposure of a Member of the General Public Walking on Roads Constructed of End Slag	0.08	2
Exposure of a Member of the General Public in Homes with Foundations Constructed of End Slag.	1.07	27
Recommended Dose Limit (above background) to Individual Members of the General Public by the International Commission on Radiological Protection	100	2500
Exposure of a Member of the General Public from Normal Background Radiation (including medical exposures)	360	9000

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APPENDICES

Appendix A - Technical Basis for Screening and Release Criteria

Screening Criteria

During slag sorting, ferrocolumbium slag will be segregated from other slag types based upon its contact exposure rate. If the exposure rate exceeds 100 μR per hour, the slag will be assumed to be ferrocolumbium slag and thus contain greater than 0.05% of uranium or thorium, by weight.

This contact exposure rate limit was determined from computer modeling of the exposure rate from a rectangular slab source containing equal concentrations of uranium (plus daughters in equilibrium) and thorium (plus daughters in equilibrium) using the Microshield computer code.[56] As input to the code, it was conservatively assumed that the ferrocolumbium slag consists of an equal mixture of natural uranium and natural thorium, that the density of the material is three (3) grams per cubic centimeter, and that the sensitive area of the sodium iodide detector is positioned at a height of one (1) inch (2.5 centimeters) from the surface of a rectangular slab source.[57,58] The result of this analysis is an exposure rate of 230 μR per hour, above background.

A similar analysis was repeated for the other slag types in the East Slag Pile. The same assumptions were used as input to the code. These results range from 0.45 to 25.4 μR per hour, with a mean value of 5.47 $\pm$ 8.97 μR per hour. Therefore, a screening criterion of 100 μR per hour is sufficiently sensitive to segregate the ferrocolumbium slag pieces from the remaining slag types.

Site-specific Release Criteria

Materials and equipment used to produce EPS may be released for unrestricted use if they meet the release criteria contained in USNRC Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors" (1974) in regard to surface contamination. The criteria applicable to SMC are shown in Appendix B. Assuming that the surface contamination consists of a 2.5-to-one (1) mixture of removable natural uranium and natural thorium, the criteria for alpha activity, as determined by direct frisk using the zinc sulfide portion of a phoswich detector, is 770 disintegrations per minute per 100 cm^2 area.[59] The measured levels may be averaged over one (1)

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[56] Microshield Code, Version 4.21, Grove Engineering, Inc., 1995.

[57] Kelly, B. A., "Source Term Development", Integrated Environmental Management Report No. 94014/G-101, June 10, 1995, Table 3-11 shows that the mixture is actually 2.5-to-one uranium to thorium. Therefore, the assumption of equal concentrations being present is conservative.

[58] The "equal mixture" assumption for uranium and thorium is conservative even in light of the elevated ^{230}Th concentrations in certain of the slag types that comprise EPS. This is due to the relative dosimetric and licensing importance of ^{232}Th (plus progeny) and ^{230}Th. In both cases, the limiting radionuclide is ^{232}Th (plus progeny).

[59] As used in this Plan, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by the appropriate detector for background, efficiency, and

(continued...)

square meter, provided the maximum surface activity in any area of 100 cm^2 is less than 2,300 disintegrations per minute per 100 cm^2.[60]

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[59] (...continued)
geometric factors associated with the instrumentation.

[60] For purposes of averaging, any square meter of surface is considered to be above the release criteria if: (1) from measurements of a representative number (n) of sections it is determined that $1/n \sum_n S_i \geq 770$, where S_i is the dpm/100 cm^2 determined from measurement of section i; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm^2 area exceeds 2,300 dpm/100 cm^2.

Appendix B - Release Criteria for the Cambridge Facility

RADIONUCLIDE [1]	REMOVABLE[2,4]	TOTAL[2,3] (FIXED PLUS REMOVABLE)
U-nat, U-235, U-238 and associated decay products	1,000 dpm α/100 cm^2	5,000 dpm α/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	200 dpm/100 cm^2	1,000 dpm α/100 cm^2
Mixture of U-nat and Th-nat		600 dpm α/100 cm^2 by direct frisk[5]

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1 Where surface contamination by both α and β-gamma-emitting radionuclides exists, the limits established for α and β-gamma-emitting radionuclides should apply independently.

2 As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

3 The levels may be averaged over 1 m^2, provided the maximum surface activity in any area of 100 cm^2 is less than three times the guide values. For purposes of averaging, any square meter of surface shall be considered to be above the activity guide <u>G</u> if: (1) from measurements of a representative number (n) of sections it is determined that $1/n \sum_n S_i \geq G$, where S_i is the dis/min-100 cm^2 determined from measurement of section I; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm^2 area exceeds 3G.

4 The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. (Note - The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. Except for transuranics and Ra-226, Ra-228, Ac-227, Th-228, Th-230, and Pa-231 α emitters, it is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

5 Assumes removable activity is limiting

Appendix C - Technical Basis for the Confirmatory Sampling Program

Limit for Unimportant Quantity

Title 10 CFR 40.4 ("Definitions") defines source material as: "(1) Uranium or thorium, or any combination thereof, in any physical form or (2) ores which contain by weight one-twentieth of one percent (0.05%) or more of: (i) Uranium, (ii) thorium or (iii) any combination thereof. Source material does not include special nuclear material." To show that the East Pile slag contains unimportant quantities of source material, the sampling program has been designed to show that, with a Type II error level of 0.01, the sum of the uranium and thorium concentrations in the slag are less than 500 parts per million (ppm).

Decision Rules

One of the decision rules is to ensure that the EPS meets the criterion for an unimportant quantity of source material - a total of 500 ppm for uranium and thorium. For the purposes of designing the sampling program, a Type II error level of 0.01 has been selected for this criterion.

Determination of an appropriate Type I error level will be based on product consistency considerations. If virtually all of the ferrocolumbium slag is removed from the EPS (a 99% efficiency is assumed for the screening surveys), the average concentration of uranium and thorium in the EPS should be 35 ppm for uranium and 10 pCi/g for Thorium-232. To ensure a consistent product, each slag crushing campaign should produce a product with approximately these concentrations. The variability of the data around the goal need not be as restrictive as for the unimportant concentration evaluation. Accordingly, a Type I error level of 0.1 has been selected.

Derived Radiological Criteria

The radiological characteristics for the East Pile are contained in the Source Term Development Document[61]. Table 3-11 of the Document shows that the ratio of Uranium-238 to Thorium-232 varies between 0.62 (for Grainal) to 2.91 (for Solvan). The most conservative ratio to use in setting the criteria for the EPS, however, is 1.0. If this ratio is assumed, the limits for the EPS will be 250 ppm each for uranium and thorium. Actual ratios that are greater than or less than 1.0 will overestimate the concentration of one of these elements in the EPS, and thus provide a conservative measure of compliance.

The analytical technique of choice for uranium is for total uranium utilizing kinetic phosphorescence analysis (KPA). This analysis provides results directly in ppm and can thus be used directly in the assessment of the samples. The decision level, as discussed in the previous paragraph, is one-half of the 500 ppm limit, or 250 ppm.

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[61] Integrated Environmental Management, Inc. Report 94014/G-101, "Source Term Development, Shieldalloy Metallurgical Corporation, Cambridge, Ohio," Dated June 10, 1995.

For thorium, there is no comparable analytical technique to KPA (i.e., one that provides results on a mass basis directly). Total thorium analyses involve gross alpha counting of a chemically-separated sample, providing activity data on four different thorium isotopes (Th-232, Th-228, Th-230, and Th-227). Converting these activity concentrations to mass concentrations would normally require isotope-specific analysis, conversion of each activity to mass, and summation. This technique would involve not only the cost of the analysis but also a more complicated statistical analysis, due to propagation of errors.

A simpler approach is to compute the thorium mass concentration based solely on the Thorium-232 concentration. Given Thorium-232's extremely low specific activity with respect to all other thorium isotopes in the samples, the Thorium-232 activity concentration will be the predominant contributor to the mass of thorium present. Therefore, the mass concentration limit for thorium was converted to a Thorium-232 activity concentration, resulting in a limit of 27.5 pCi/g.

Estimating the Number of Samples

Since the principal criterion for EPS is to ensure that it contains unimportant quantities of uranium and thorium, there is no need to compare the EPS sample data to a reference distribution. Accordingly, a "one-sample test" (described in Section 6 of NUREG-1505) was selected. There is no information available on whether the EPS data distribution will be symmetrical or skewed, so it is not possible to determine whether the Wilcoxon Signed Rank (WSR) or the Sign test will be conducted. The greater number of samples required by each of the two tests was therefore selected.

Most of the values required to determine the number of samples have been defined. To determine the probability that a random measurement is less than the decision criterion, an estimate of the distribution standard deviation is required. To obtain an estimate of it, it was assumed that the standard deviation should be no greater than the square root of the Type I decision rule. Using this value, the decision criteria for total uranium and for Thorium-232, and the error levels selected, the number of samples was calculated to be 22. In accordance with the guidance in Section 6, this number was increased by 20%, resulting in an estimated number of samples of 27.

Data Evaluation

Once the data are available, they will be plotted to determine if the distribution is symmetrical or skewed. This determination will dictate whether the WSR or the Sign test will be used. The appropriate test will be conducted to demonstrate that the EPS crushed during the campaign met the decision criteria. The methodology in NUREG-1505, Section 6, will be used to conduct this test.

In addition, a one-sample quantile test will be conducted, again using the methodology of NUREG-1505, Section 6. The test will assume lot sizes characteristic of the amount that will be sold as a product. The quantile test will be used to show, at the same Type I and II error levels discussed above, that the EPS in each lot also will meet the design criteria that the EPS represents an unimportant quantity of source material.

Appendix D - General Employee Training Handout

Introduction

Employees of and visitors to Shieldalloy Metallurgical Corporation (SMC) face a number of potential hazards. While these hazards cannot be eliminated entirely, they can be minimized through development and implementation of prudent safety practices. Exposure to ionizing radiation is one such hazard.

The management of SMC is committed to assuring a safe work environment for all employees, and to protection of facilities, the environment, and members of the general public from the potentially-harmful effects of radiation. The basic policy of SMC, in regard to radiation exposure and to control of radioactive materials, is summarized in the following four statements:

- Personnel will not be exposed to ionizing radiation without there being a demonstrable need for the activity that causes the exposure.
- Radiation exposures are maintained as low as is reasonably achievable (ALARA) in light of economic impacts.
- Radiation exposure limits for personnel and members of the general public, as promulgated by the U. S. Nuclear Regulatory Commission (USNRC) in Title 10, Code of Federal Regulations, Part 20, *Standards for Protection Against Radiation*, will not be exceeded.
- Control measures instituted to maintain radiation exposures ALARA will not increase an individual's risk of harm from other non-radiological hazards.

The SMC Radiation Safety Officer has prepared this training handout for staff and unescorted visitors. The manual complies with Federal regulations (10 CFR 19 and 29 CFR 1910) and outlines general safety practices for protecting personnel and property. It is essential that during your visit to or employment at SMC you pay close attention to our radiation safety rules, which are outlined in this manual. A good radiation safety program does not happen by accident - it is planned. It is the responsibility of every person on site to assist us in maintaining our high standard of safety.

The Risk of Low-level Occupational Radiation Exposure

It is generally accepted by the scientific community that exposure to ionizing radiation can cause biological effects that are harmful to the exposed organism. These effects, however, are only observed in cases of radiation exposure that is much higher (hundreds of rems) than those permitted occupationally today. Although studies have not shown a cause-effect relationship between health effects and current levels of occupational radiation exposure, it is prudent to assume that some health effects do occur at the low exposure levels.

Instructions and Reference Reports for Workers

The USNRC, in accordance with 10 CFR 19, requires that the following information be available to workers:

- NRC Form 3, "Notice to Employees"
- The Shieldalloy Metallurgical Corporation Radiation Protection Program Plan
- Information and warning signs
- Title 10, Code of Federal Regulations, Parts 19 and 20
- Title 29, Code of Federal Regulations, Part 19
- USNRC License No. SMB-1507
- Additional information concerning what is currently known about the health risks from exposure to ionizing radiation

This information is available for your review in the office of the SMC Radiation Safety Officer. You are encouraged to contact the Radiation Safety Officer to review any or all of these materials, and to obtain information on any radiation protection issue that may arise.

Controlled Areas and Posting

Controlled access areas at SMC exist within the plant boundaries. All personnel permitted unescorted access to these areas must be able to recognize the fact that they are entering a controlled access area. Each building or location that has been designated a controlled access area for radiation protection purposes is marked with a sign that is magenta (purple) and yellow in color, bearing the words "RADIOACTIVE MATERIAL" along with the three-blade radiation symbol. You must not enter controlled access areas without specific authorization by a SMC supervisor or the Radiation Safety Officer.

Radiation Safety Rules for Employees, Visitors and Contractors

1. All employees, visitors and contractors are restricted to the areas where they are performing work. All other buildings and operating areas are out-of-bounds.

2. Safety hats, safety glasses, long-sleeved shirts and good quality shoes are required. Specifically excluded from use in the plant area are tennis shoes or any type of athletic shoe.

3. No eating, drinking, or smoking is permitted within controlled access areas, except where specific places to do so are designated by SMC.

4. No work with or around radioactive materials may be started until the individual has obtained approval from the appropriate SMC supervisor and the Radiation Safety Officer.

5. All personal injuries that occur within a controlled access area must be reported as defined in the Radiation Protection Program Plan.

6. Personnel that have been in the temporary restricted area must wash their hands before exiting.

7. Personnel with unprotected cuts or breaks in the skin, particularly on the hands and forearms, shall not enter a controlled access area.

8. Observe all posted signs.

9. Report to your supervisor or the Radiation Safety Officer any condition that may lead to an unsafe situation or unnecessary exposure to radioactive materials.

10. Avoid unnecessary exposure to radioactive materials.

11. Comply with all SMC safety practices.

Appendix E - General Employee Training Acknowledgment Form

Name (Print):
Signature:
Social Security Number:
Employee/Social Security Number:
Today's Date:

I have received a copy of the handout entitled "General Employee Training in Radiation Protection".

I agree to comply with the safety requirements contained in the manual.

I understand that I may contact the SMC Radiation Safety Officer at any time to discuss any radiation safety issue that may arise.

I will not enter any controlled access area unless escorted, or unless I have been permitted to do so by an appropriate SMC Supervisor or the Radiation Safety Officer.

Individual administering briefing:

Signature:______________________________ Date:________

SMC Radiation Safety Officer:

Signature:______________________________ Date:________

This report was prepared under the direction of
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by

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