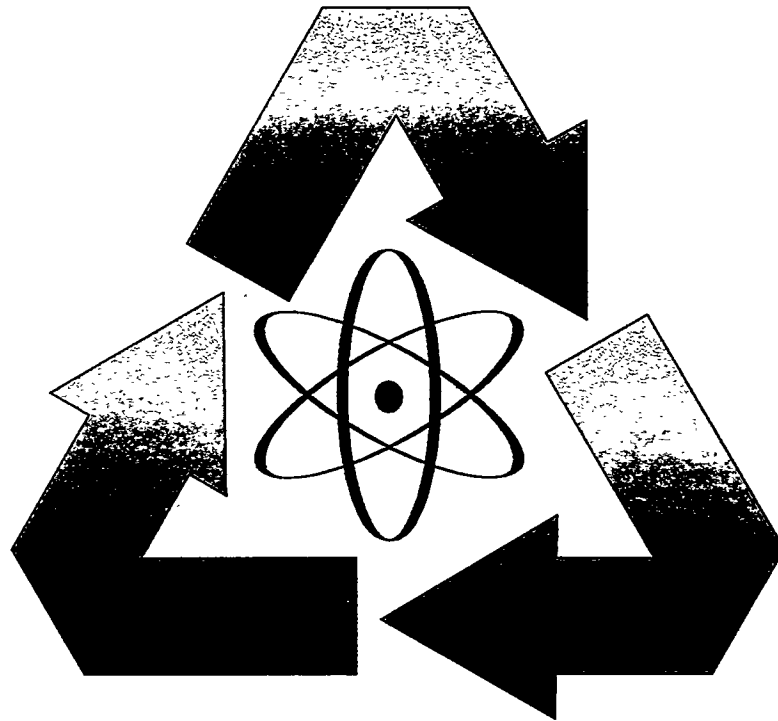


BENEFICIAL REUSE '96

**The Fourth Annual Conference on the Recycle
and Reuse of Radioactive Scrap Metal
October 22-24, 1996**



Sponsored By:
The University of Tennessee's
Energy, Environment, and Resources Center
&
Oak Ridge National Laboratory's
Center for Risk Management

February 1997
Knoxville, Tennessee

MASTER

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FOREWORD

From October 22-24, 1996 the University of Tennessee's Energy, Environment and Resources Center and the Oak Ridge National Laboratory's Center for Risk Management cosponsored Beneficial Reuse '96: The Fourth Annual Conference on the Recycle and Reuse of Radioactive Materials. Along with the traditional focus on radioactive scrap metals, this year's conference included a wide range of topics pertaining to naturally occurring radioactive materials (NORM), and contaminated concrete reuse applications. As with previous Beneficial Reuse conferences, the primary goal of this year's conference was to bring together stakeholder representatives for presentations, panel sessions and workshops on significant waste minimization issues surrounding the recycle and reuse of contaminated metals and other materials. A wide range of industry, government and public stakeholder groups participated in this year's conference. An international presence from Canada, Germany and Korea helped to make Beneficial Reuse '96 a well-rounded affair.

It takes a great deal of effort to plan and implement a conference with the scope and breadth of Beneficial Reuse '96. Thanks go to Bruce Clemens, Louis Allen and Tad McGalliard for their assistance in the overall management of this conference. Gail Farris (registration and conference facilities), Debbie Bower (hotel liaison and registration) and Tina Cordy (badging and registration) helped to keep things running smoothly. Other EERC contributors included Justin Harris, Wayne Harris, Todd Gilbert, Eric Harvey, Tina Manuel, Kim Davis, Kimberly Stetson and Steven Sherriff. At ORNL, Dr. Curtis Travis, Beth Ladd, Lois Thurston and Jeff Mellon assisted in the strategic focus and planning for this year's conference. Val Bouchard was the most hard-working chair (NORM session) it has ever been our good fortune to call upon. Of course, our other chairs, including Dan Burns, Ralph Perhac, Peter Gray, Dennis Floyd, Frank Parker, Ken Ayers and Val Loiselle were crucial members of our management team, and we truly appreciate the time they spent developing interesting sessions. We also want to thank each and every speaker for making the conference an outstanding one.

Special thanks to DOE's Jeff Short, John Lum and Kent Hancock for their financial assistance and for their technical perspectives during the development of the agenda. Special thanks to the Association of Radioactive Metal Recyclers (ARMR). Both ARMR and its industry members are truly the backbone of this conference, and an important strategic partner in its continued success. Kenneth Walker, the University of Tennessee's Associate Vice Chancellor, Office of Research, provided some thoughtful welcoming remarks to the audience and was also kind enough to help fill in during Jack Barkenbus' absence. Thanks also go to Pat Whitfield, the DOE "father of radioactive metal recycling," for educating and entertaining us at lunch and at the ARMR-sponsored dinner. Finally, it was our great fortune to attract Robert Alvarez, DOE Deputy Assistant Secretary for the Office of Materials and Asset Management, as our keynote speaker!

We hope to see you all again at Beneficial Reuse '97, to be held in Knoxville, Tennessee from August 5-7, 1997!

February, 1997

Jack Barkenbus, Ph.D.
Michael Gresalfi, Ph.D.

Energy, Environment and Resources Center
Oak Ridge National Laboratory

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ACKNOWLEDGMENTS

Beneficial Reuse '96 was financially supported by the U.S. Department of Energy, the Oak Ridge National Laboratory's Center for Risk Management and the University of Tennessee's Energy, Environment and Resources Center. This support does not constitute an endorsement of any of the views or conclusions expressed in the papers of these proceedings, or in the presentations during the conference.

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Kenneth C. Duvall, U.S. DOE Office of Environmental Policy and Assistance

Harold T. Peterson, Jr., U.S. DOE Office of Environmental Policy and Assistance

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Ray Paris, Radiation Protection Service, Oregon State Health Division

Chair, Conference of Radiation Control Program Directors

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Charles T. Simmons, Kilpatrick & Cody, L.L.P.

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Philip V. Egidi, Oak Ridge National Laboratory, Health Sciences Research Division

Instrumentation (paper not available)

Joseph D. Eddlemon, Pulcir, Inc.

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Peter Gray, Editor - The NORM Report

NORM in the Oil Industry (paper not available)

Kevin Grice, Texaco Exploration and Production, Inc.

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Raymond G. Azrak, CORPEX Technologies, Inc.

Overview of NORM and Activities by a NORM Licensed Permanent Decontamination and Waste Processing Facility

Guy A. Mirro, Growth Resources, Inc.

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Charles R. Yard, M.P.H., Tennessee Department of Environment and Conservation

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Richard W. Meehan, U.S. Department of Energy

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Toff B. Garcia, Sandia National Laboratory

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John K. Boren, Vanderbilt University, Civil and Environmental Engineering
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Frank L. Parker, Vanderbilt University, Civil and Environmental Engineering

Economic Analysis of Recycling Contaminated Concrete

Amy Stephen, Vanderbilt University, Civil and Environmental Engineering
Kenneth W. Ayers, Vanderbilt University, Civil and Environmental Engineering
John K. Boren, Vanderbilt University, Civil and Environmental Engineering
Frank L. Parker, Vanderbilt University, Civil and Environmental Engineering

An Evaluation of Concrete Recycling and Reuse Practices

Karen S. Nakhjiri, S. Cohen & Associates, Inc.

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Jason Darby, U.S. Department of Energy Oak Ridge Operations

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Robert G. Levesque, CORPEX Technologies, Inc.

Recycling of Mixed Wastes Using Quantum-CEP™

Bob Sameski, M4 Environmental Management, Inc.

Depleted Uranium Hexafluoride: The Source Material for Advanced Shielding Systems

W. J. Quapp, Nuclear Metals, Inc.

Session 6 - Radioactivity in the Scrap and Steel Industry

The Probability of Detecting Radioactive Materials in Recycled Scrap Metals (paper not available)

Graham Walford, Quintek Corporation

Distribution of Radionuclides During Melting of Carbon Steel

W. C. Thurber, S. Cohen & Associates, Inc.

J. MacKinney, U.S. Environmental Protection Agency

Management Options for Recycling Radioactive Scrap Metals

Jean-Claude Dehmél, S. Cohen & Associates, Inc.

John MacKinney, U.S. Environmental Protection Agency

Appendix A - Participants List

AGENDA, BENEFICIAL REUSE '96
University of Tennessee Conference Center, 4th Floor 600 Henley Street
October 22-24, 1996

Tuesday, October 22, 1996

8:00-8:45 a.m. Registration - Atrium Area, UT Conference Center

9:00-10:00 a.m. Opening Plenary Session - Room 413

Welcoming Remarks - Kenneth Walker, Associate Vice Chancellor - Office of Research, The University of Tennessee

Opening Remarks - Michael Gresalfi, Oak Ridge National Laboratory

Keynote Address - Robert Alvarez, DOE Deputy Assistant Secretary for Office of Materials--Asset Management and National Security Policy Analysis

10:00-10:15 a.m. Break

10:15 a.m. - Noon Radioactive Scrap Metal Policy, Regulations and Issues - Room 413

Chair - Michael Gresalfi, Oak Ridge National Laboratory

One Project's Waste Is Another Project's Resource! - Jeff Short, U.S. DOE Office of Pollution Prevention

DOE's Radioactively Contaminated Metal Recycling: The Policy and Its Implementation - Ed Rizkalla, DOE Office of Waste Management

Noneconomic Factors Influencing Scrap Metal Disposition Decisions at DOE and NRC-Licensed Nuclear Facilities - Mark Ewan, Industrial Economics, Inc.

Assessment of DOE Radioactive Scrap Metal Disposition Options - Steven Bossert, U.S. DOE-Morgantown Technology Center

The M-100 Container Program: Value Analysis and Testing - James D. Greaves, Brainard Associates, Inc.

Noon - 1:30 p.m. Lunch (Provided) Conference Center Dining Area, Room 404

Speaker - Pat Whitfield

(Speaker sponsored by the Association of Radioactive Metal Recyclers)

1:30-3:00 p.m. Radioactive Scrap Metal Recycle Programs at DOE Sites - Room 413

Panel Discussion

Leader - Dan Burns, Trinity Environmental Systems, Inc.

Panel:

Bill Boettinger, Westinghouse Savannah River Company

John Clinard, Lockheed Martin Oak Ridge

Tom Fewell, Idaho National Engineering Laboratory

Scott Thoren, Bechtel Hanford

Karin King, U.S. DOE Oakland Operations

Richard Meehan, U.S. DOE Oak Ridge

Keith Rule, Princeton Plasma Physics Laboratory

Pete Yerace, U.S. DOE Fernald

Rebecca Winston, LMITC-Idaho National Engineering Lab

Pauline Hartwig, Atomic Energy of Canada Limited

3:00-3:30 p.m. Break

3:30-5:00 p.m. Risk Issues - Room 413

Chair - Ralph Perhac, Energy, Environment and Resources Center, The University of Tennessee

Rationales for Regulatory Activity - Ralph Perhac, Energy, Environment and Resources Center, The University of Tennessee

Beneficial Reuse of Empty Depleted Uranium Hexafluoride Cylinders - Leslie Nieves, Argonne National Laboratory

Reutilization of Nuclear Byproducts NaF and HF in the Steel and Glass Industries - J. W. Park, Korea Power Engineering Co.

Wednesday, October 23, 1996

7:50 a.m. to 5:00 p.m. Naturally Occurring Radioactive Materials (NORM) - Room 413

- 7:50 **Opening Remarks** - Val Bouchard, Chair
- 8:00 **Keynote Address** - Peter Gray, Editor NORM Report
- 8:30 **An Overview of Pennsylvania's Experience with NORM** - Jim Yusko, Pennsylvania Department of Environmental Protection, Radiation Protection
- 8:55 **Regulation of NORM by the U.S. Department of Energy** - Kenneth Duvall, U.S. DOE Office of Environmental Policy and Assistance
- 9:45 **Break**
- 10:00 **Proposed Changes for Part N of Suggested State Regulations** - Ray Paris, Radiation Protection Services, Oregon State Health Division and Chair, CRCPD
- 10:25 **Managing Liabilities from NORM** - Charles T. Simmons, Kilpatrick & Cody, L.L.P.
- 10:55 **NORM in the Oil Industry** - Kevin Grice, Texaco Exploration and Production, Inc.
- 11:20 **Morning Round Table**
- 11:55 **Lunch (On Your Own)**
- 1:00 **ELIPGRID-PC and INRADS[®]: Tools for Reducing Costs and Optimizing Data Collection on Sites Contaminated with NORM** - Phil Egidi, Oak Ridge National Laboratory, Health Sciences Research Division
- 1:25 **Instrumentation** - Joseph Eddlemon, Pulcir, Inc.
- 1:50 **NORM Regulations** - Peter Gray, Editor - NORM Report
- 2:15 **Break**
- 2:30 **CORPEX[®] NORM Decontamination Process** - Ray Azrak, CORPEX Technologies
- 2:55 **Overview of NORM and Activities by a NORM Licensed Permanent Decontamination and Waste Management Processing Facility** - Guy Mirro, Growth Resources, Inc.
- 3:45 **Afternoon Round Table**
- 4:05 **Open Discussion**
- 5:00 **Closing Comments - Adjourn**

SESSIONS CONCURRENT WITH NORM

10:00 a.m. - Noon Reindustrialization - Room 406

Chair - Dennis Floyd, Manufacturing Sciences Corporation

Pathways to Privatization: Issues and Concerns on the Road to Privatization of Facilities on the Oak Ridge Reservation - Charles Yard, Tennessee Department of Environment and Conservation, DOE Oversight Division

Recycle of Radioactive Scrap Metal from the Oak Ridge Gaseous Diffusion Plant (K-25 Site) - Richard Meehan, DOE Oak Ridge

Sandia Tritium Research Laboratory Transition and Reutilization Project - Toff B. Garcia, Sandia National Laboratory

Noon - 1:30 p.m. Lunch (On Your Own)

1:30-5:00 p.m. Concrete Reuse - Room 406

Chair - Ken Ayers, Vanderbilt University

Fatal and Nonfatal Risk Associated with Recycle of D&D-Generated Concrete - John Boren, Vanderbilt University

Economic Analysis of Recycling Contaminated Concrete - Amy Stephen, Vanderbilt University

An Evaluation of Concrete Recycling and Reuse Practices - Karen Nakhjiri, S. Cohen & Associates

Crushing Leads to Waste Disposal Savings for FUSRAP - Jason Darby, DOE Oak Ridge

Thursday, October 24, 1996

8:30-10:00 a.m. Association of Radioactive Metal Recyclers (ARMR) Session - Room 406

Chair - Val Loiselle, American Technologies, Inc.

ARMR Progress Report - Val Loiselle

SRS Stainless Steel Beneficial Reuse Program - Bill Boettinger, Westinghouse Savannah River Company

Results of Chemical Decontamination of DOE's Uranium-Enrichment Scrap Metal - Bob Levesque, CORPEX Technologies

Recycling of Mixed Wastes Using Quantum-CEP™ - Bob Sameski, M4 Environmental Management, Inc.

Depleted Uranium Hexafluoride: The Source Material for Advanced Shielding Systems - W. J. Quapp, Nuclear Metals, Inc.

10:00-10:30 a.m. Break

10:30 a.m. - Noon Radioactivity in the Scrap and Steel Industry - Room 406

Chair - Bruce Clemens

The Probability of Detecting Radioactive Materials in Recycled Scrap Metals - Graham Walford, Qunitex Corporation

Distribution of Radionuclides during Melting of Carbon Steel - William Thurber, S. Cohen & Associates

Management Options for Recycling Radioactive Scrap Metals - Jean-Claude Dehmel, S. Cohen & Associates

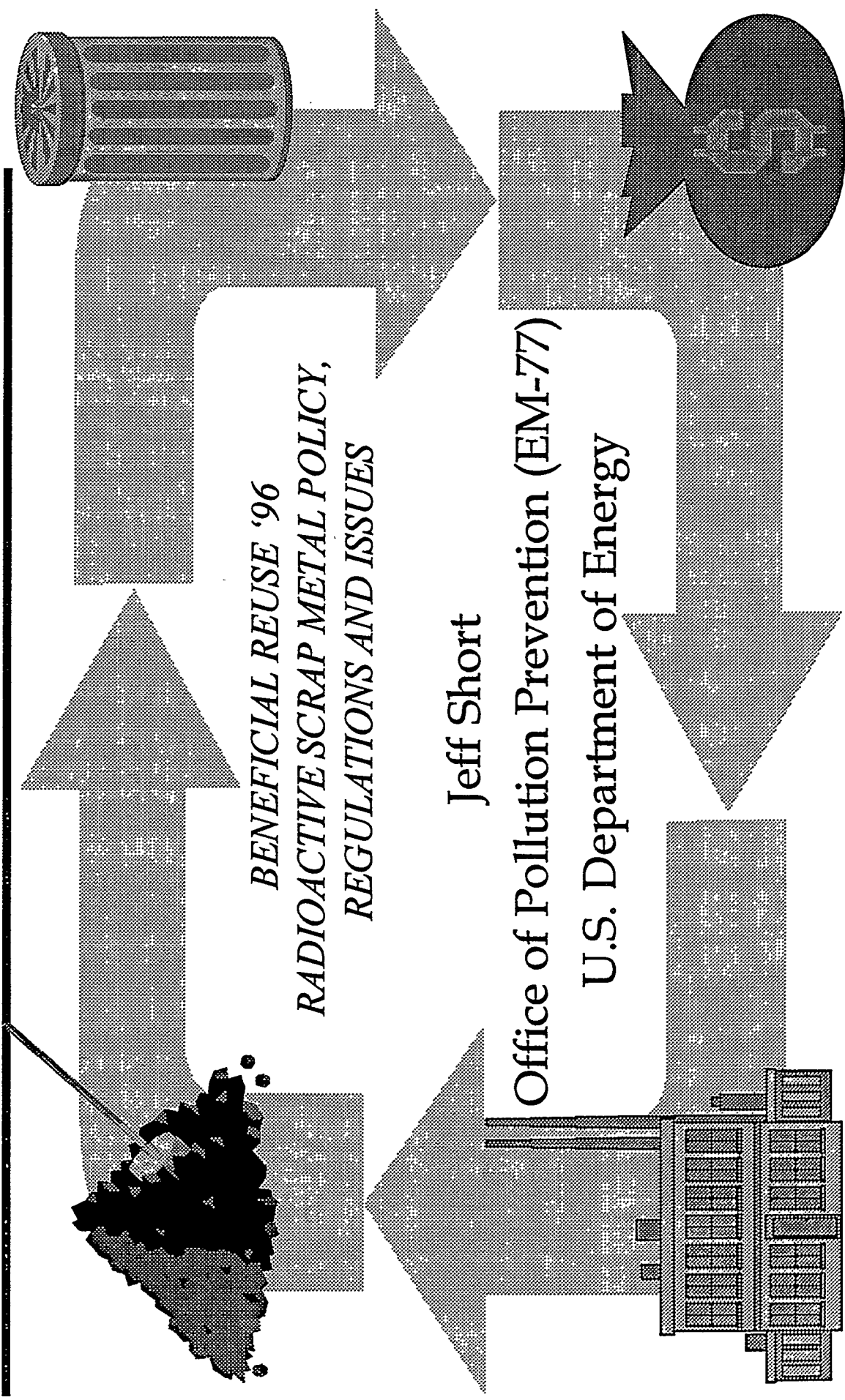
Noon - Adjourn

Session 1 - Radioactive Scrap Metal Policy, Regulations and Issues

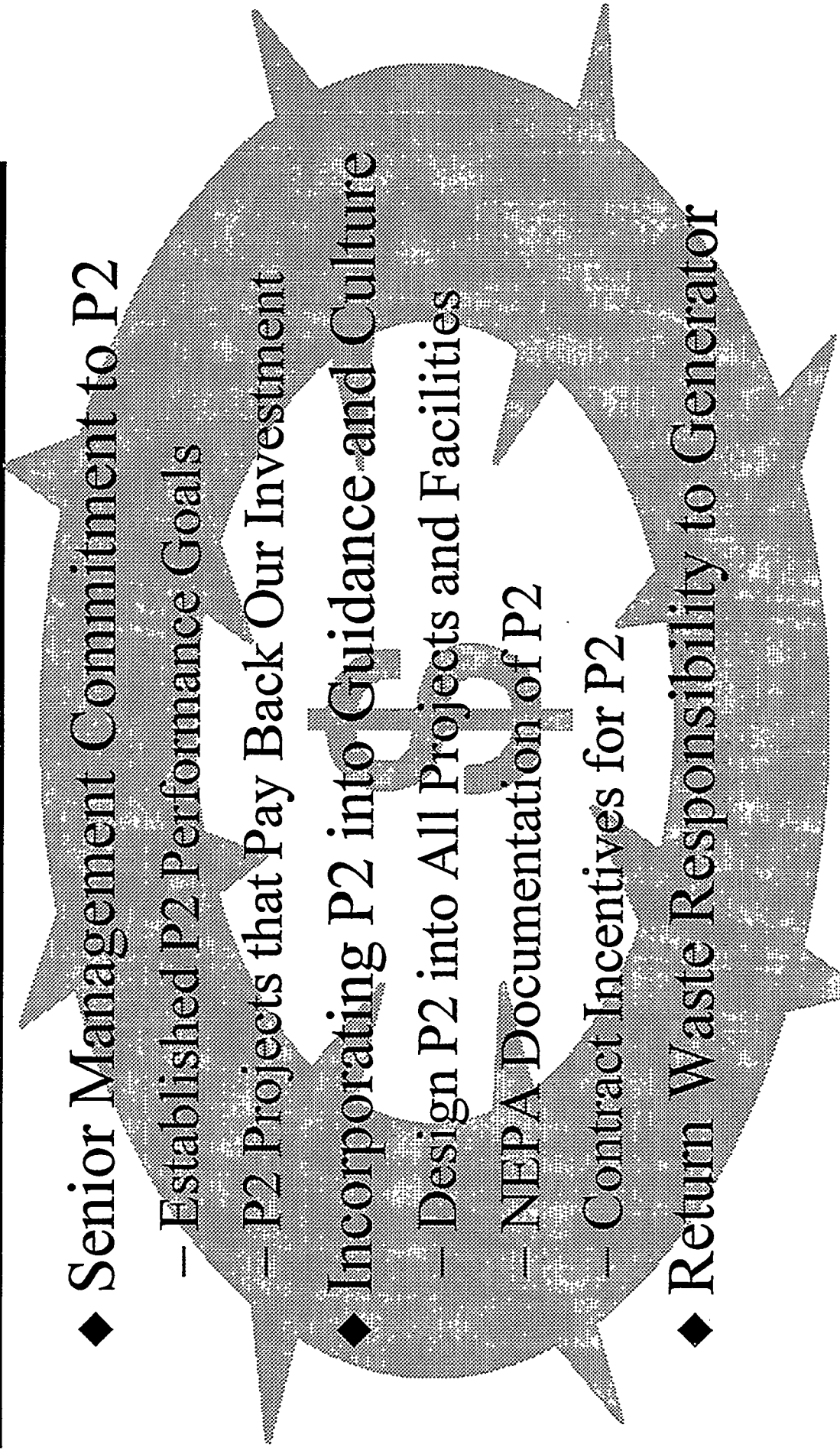
One Project's Waste Is Another Projects's Resource

Jeff Short
Office of Pollution Prevention (EM-77)
U.S. Department of Energy

ONE PROJECT'S WASTE IS ANOTHER PROJECT'S RESOURCE



POLLUTION PREVENTION (P2) IS A GUIDING PRINCIPLE FOR THE FUTURE

- 
- ◆ Senior Management Commitment to P2
 - Established P2 Performance Goals
 - P2 Projects that Pay Back Our Investment
 - ◆ Incorporating P2 into Guidance and Culture
 - Design P2 into All Projects and Facilities
 - NEPA Documentation of P2
 - Contract Incentives for P2
 - ◆ Return Waste Responsibility to Generator

POLLUTION PREVENTION PROJECTS REDUCE COSTS OF OPERATION

- ◆ Return on Investment Projects Accumulate Big Savings for Routine Waste Generation
 - <\$10 million pays back >\$135 million over next decade
- ◆ P2 Case Studies Provide Lessons Learned on Specific Project Implementation
 - \$17 million pays back >\$20 million annually
- ◆ Many Sites Successfully Integrating P2 into Environmental Restoration Activities

KEY TO PREVENTING POLLUTION IS “HEADS UP” PLANNING

- ◆ Reuse of Materials and Equipment Assets
 - Materials Exchange Information for DOE Sites Available through “EPIC” Website
- ◆ Recycling Wastes Can Generate Revenue
 - Offset Costs of Recycling Program
- ◆ Awareness, Accountability and Incentives Stimulate Action

The following Recycling/Reuse examples were extracted from the Draft Report (Revision 1) of "Phase I Complex-wide study on the Successful Integration of Pollution Prevention into the Enviromental Restoration Program, Volume II: Technical Case Studies", dated August 23, 1996.

Negotiations and Planning Phase P2/WM Case Study Matrix

Case Study Number	Symbol	Project Number	FY	Technical Description	Waste Type	Waste Avoided
1		ANL1-B	95	Plutonium gloveboxes used in support of research programs were reused on-site instead of being disposed of as LLW.	LLW	180 cubic feet of LLW (estimate only)
2		ANL2-E	94	Part of a small research reactor complex was reused instead of being demolished. A storage building was converted to a mixed waste storage facility, and a vaporsphere facility was converted to a road salt storage facility.	LLW	Not Quantified
3		ANL3-A	94	The Experimental Boiling Water Reactor (EBWR) was converted to a transuranic (TRU) waste storage facility resulting in significant reductions in the cost of remedial activities and the generation of associated waste streams.	LLW	Not Quantified
66		K-251-D	94/ 95	Oak Ridge K-25 negotiated with the State of Tennessee to reuse construction rubble from decommissioning activities as on-site fill material.	LLW	750,000 cubic feet of LLW
49		LEHR1-A	93	Two radioactive sources at LEHR (Cobalt-60 and Strontium-90) were reused by private industry instead of being disposed of as radioactive waste.	LLW	500 cubic feet of LLW
60		NTS2-A	94	A PPOA was performed at the NTS Junior Hot Cell. It identified reuse opportunities for the hot cell and manipulator arms and also determined that sampling for organics was unnecessary.	LLW	Not Quantified
77		RMI2-B	95/ 96	RMI is currently evaluating the reuse of its main extrusion press and ancillary equipment. Some of the components were shipped to LANL for reuse in a uranium foundry.	LLW	7,840 cubic feet of LLW
77		RMI2-C	95/ 96	At RMI, several hundred gallons of clean industrial oils have been identified as recyclable material.	Sanitary	27 cubic feet of clean oils
86		SNL/CA2-A	94/ 95	Sandia decontaminated and transitioned the Tritium Research Laboratory for reuse as a non-nuclear facility. Excess equipment was also shipped to other DOE facilities for reuse.	LLW	600,000 tons of LLW

Evaluation & Selection Phase

P2/WM Case Study Matrix

Case Study Number	Symbol	Project Number	FY	Technical Description	Waste Type	Waste Avoided
20		ETEC2-A	95	ETEC evaluated decontamination methods for radioactively contaminated lead brick, sheet and shot for the purpose of recycling the lead.	LLMW	8.5 tons of LLMW (estimate only)
23		FEMP3-C	94/ 95	A vacuum blaster was purchased and installed at the FEMP's MRF facility to enhance the decontamination process. Twenty tons of structural steel contaminated with thorium-230 and lead-based paint has been decontaminated for free release.	LLW	20 tons of LLW
25		FUSRAP2-B	94/ 95	A respirator recycling program was developed at the Colonie Site to reduce the number of cartridges used during remedial activities.	LLMW	Respirator cartridge use was reduced by 45% or 3 tons LLMW was avoided
32		HAN2-A	94/ 95	A mobile Asbestos Conversion System was pilot tested to convert non-radiological ACM into asbestos-free material. The final results will determine whether a full-scale radiological system will be built.	TSCA waste	Asbestos waste could be reduced by an estimated 80%
56		MOUND3-A	95	At Mound, contaminated metal from a dismantling project was melted and reused. About 95% of the metal was reused as shielding blocks for other DOE facilities; the remaining 5% was disposed of as slag.	LLW	99 tons of LLW
88		SRS1-A	94/ 95	SRS has installed a Centralized Decontamination Facility for localized, controlled decontamination of dismantled reactor components.	LLW	Not Quantified
92		SRS5-A	94	At SRS, prefabricated containment systems were used in place of hand-built containment huts. The prefabricated huts can be used five times prior to disposal while the hand-built huts require disposal after each job.	LLW	14,124 cubic feet of LLW

Implementation Phase

P2/WM Case Study Matrix

Case Study Number	Symbol	Project Number	FY	Technical Description	Waste Type	Waste Avoided
2		ANL2-A	94	More than 200 tons of scrap metal from a small research reactor was free released for recycling instead of being disposed of via land burial as LLW.	LLW	200 tons of LLW (estimate only)
2		ANL2-C	94	Contaminated soil from a decommissioning project was used as waste package void filler, thereby avoiding the need to ship the soil as a separate waste type and use clean void filler in the waste packages.	LLW	600 cubic feet of LLW (estimate only)
2		ANL2-D	94	More than 35 tons of scrap metal was melted and reused as shielding blocks and radioactive waste containers instead of being disposed of via land burial as LLW.	LLW	35 tons of LLW (estimate only)
3		ANL3-B	94	Approximately 68 tons of lead was melted and reused as shielding blocks for use by the Advanced Photon Source.	LLMW	68 tons of mixed waste (estimate only)
3		ANL3-D	94	More than 2,000 tons of scrap metal from the EBWR was free released for recycling instead of being disposed of as LLW.	LLW	2,000 tons of LLW (estimate only)
4		BCLDP1-B	95	At the BCLDP, 700 pounds of lead from a decommissioning project were surveyed and released for recycling.	LLMW	1,355 cubic feet of LLMW
5		BCLDP2-B	94	Radioactively contaminated metals generated during BCLDP decommissioning activities were melted and reused as shielding blocks or waste containers.	LLW	6,400 cubic feet of LLW
17		BNL12-A	95	A solvent degreasing tank was decontaminated and recycled for reuse as opposed to disposal as sanitary waste.	Sanitary	1 ton of sanitary waste
13		BNL8-C	95	A contaminated containment structure was reused at another facility.	LLW	Not Quantified
21		FEMP1-Q	94/95	During Plant 7 Removal Action, existing wooden cross-ties were used as cushioning materials during implosion of the building instead of clean padding material.	LLW	Included under FEMP1-A

Implementation Phase P2/WM Case Study Matrix

Case Study Number	Symbol	Project Number	FY	Technical Description	Waste Type	Waste Avoided
21		FEMP1-U	94/95	During Plant 7 Removal Action, 450 tons of steel and seven tons of lead were decontaminated and free released for recycling.	LLW	Included under FEMP1-A
23		FEMP3-A	94/95	Through FEMP's Material Release Facility (MRF), 120 tons of radiologically contaminated metal furnace pots were decontaminated and free released.	LLW	120 tons of LLW
23		FEMP3-B	94/95	Through FEMP's MRF, 110 tons of radioactive scrap metal were decontaminated and released for eventual resale.	LLW	110 tons of LLW
24		FUSRAP1-B	94	Concrete from C.H. Schnoor that could not be released to the landfill was crushed and reused as fill material at the site.	LLW	1,107 cubic feet of LLW
24		FUSRAP1-C	94	Lead anchor bolt pourings from C.H. Schnoor were decontaminated and released for recycling.	LLMW	30 pounds of LLMW
25		FUSRAP2-A	94/95	About 1,000 tons of radioactively contaminated scrap metal from the Colonie site was melted and reused as shielding blocks.	LLW	27,000 cubic feet of LLW
25		FUSRAP2-C	94/95	2,100 light ballasts containing PCBs and a small number of lead acid batteries at the Colonie Site were decontaminated and released for recycling.	LLMW	297 cubic feet of LLMW
26		FUSRAP3-A	94	Brick and concrete from dismantlement of a portion of the Aliquippa Forge site was crushed and reused as backfill on the site.	LLW	15,120 cubic feet of LLW
30		FUSRAP7-A	95	Concrete and building rubble from the St. Louis Downtown site was crushed and reused as backfill on the site.	LLW	40,500 cubic feet of Ile(2)
31		HAN1-A	94/95	Used equipment from the former B reactor was surveyed for contamination and sold as scrap metal.	Sanitary	20,798 cubic feet of sanitary waste
31		HAN1-B	94/95	Concrete and masonry block from portions of the former B Reactor were removed and crushed for reuse as fill material.	Sanitary	296,604 cubic feet of sanitary waste
31		HAN1-C	94/95	A steel shear was used to cut steel to manageable length for resale as scrap metal.	Sanitary	Included under HAN1-A

Implementation Phase P2/WM Case Study Matrix

Case Study Number	Symbol	Project Number	FY	Technical Description	Waste Type	Waste Avoided
34		INEL2-D	95	INEL recycled 26,600 cubic feet of uncontaminated scrap metal during the decommissioning of Auxiliary Reactor Area 2.	Sanitary	26,600 cubic feet of metal
34		INEL2-E	95	INEL crushed and reused 3,900 cubic feet of uncontaminated concrete as on-site fill material during the decommissioning of Auxiliary Reactor Area 2.	Sanitary	3,900 cubic feet of concrete
66		K-251-C	94/ 95	Oak Ridge K-25 segregated scrap metal during decommissioning activities, using the rad protocol discussed in Project K-251-B. About 6,500 tons of "clean" scrap metal was sold for recycling.	LLW	6,500 tons of LLW
46		LANL10-A	94	At LANL Technical Area 35, segregated stainless and carbon steel was crushed and shipped to an off-site vendor for recycling.	Sanitary waste	300 tons of sanitary waste (estimate only)
47		LANL11-A	94	At LANL Technical Areas 16, 22, and 46, disposal of PPE and other contamination control equipment was replaced with reusable items.	LLMW	780 cubic feet of LLMW (estimate only)
39		LANL3-B	95	In Field Unit 3, PPE was reused as often as possible. Launderable coveralls were substituted for disposable ones and steel toe chemical resistant boots were used in place of disposable booties.	LLW	1,512 cubic feet of LLW (estimate only)
40		LANL4-C	95	In Field Unit 4, PPE was reused until unserviceable. PPE was removed and was stored within the contamination reduction zone for reuse during the task.	LLW	PPE use was reduced by 50%
41		LANL5-E	95	In Field Unit 5, scrap metal and concrete was surveyed and segregated prior to disposal. Non-contaminated metal was transferred off-site for recycling.	Sanitary	20 tons of sanitary waste (estimate only)
42		LANL6-A	95	In Field Unit 6, structural steel generated during demolition of two buildings was segregated from LLW debris and transferred off-site for recycling.	LLW	6,356 cubic feet of LLW (estimate only)
42		LANL6-B	95	In Field Unit 6, concrete building materials were decontaminated and crushed for reuse as backfill.	LLW	181,714 cubic feet of LLW

Implementation Phase P2/WM Case Study Matrix

Case Study Number	Symbol	Project Number	FY	Technical Description	Waste Type	Waste Avoided
42		LANL6-G	95	In Field Unit 6, decontamination of furnaces resulted in the recovery of 1.5 kilograms of 93% enriched uranium. The uranium was transferred to an on-site laboratory for reuse.	LLW	3 pounds of LLW (estimate only)
42		LANL6-H	95	In Field Unit 6, wooden industrial demolition debris was used as fuel in RCRA-permitted high explosive burn pits.	Sanitary	180 cubic feet of sanitary waste (estimate only)
42		LANL6-I	95	In Field Unit 6, clean soils removed during demolition of structures were reused as fill materials at other on-site locations.	Sanitary	10,800 cubic feet of sanitary waste (estimate only)
42		LANL6-J	95	In Field Unit 6, metal framing and piping was segregated and shipped off-site for recycling to a regional scrap vendor.	Sanitary	27 cubic feet of sanitary waste (estimate only)
42		LANL6-K	95	In Field Unit 6, metal demolition debris was segregated and shipped to a radioactive smelting vendor.	LLW	6,426 cubic feet of LLW (estimate only)
42		LANL6-L	95	In Field Unit 6, ductwork and other materials were decontaminated, surveyed and shipped to a regional salvage/recycling company.	LLW	2,889 cubic feet of LLW (estimate only)
43		LANL7-B	97	At the Omega West Reactor, PPE will be laundered for reuse.	LLW	5,160 feet of LLW (projected)
43		LANL7-C	97	At the Omega West Reactor, wooden debris will be decontaminated and reused on-site as compost or fuel for burn pits.	LLW	718 cubic feet of LLW (projected)
43		LANL7-D	97	At the Omega West Reactor, non-contaminated concrete will be crushed and reused on-site.	Sanitary	100% reduction (projected)
43		LANL7-E	97	At the Omega West Reactor, non-contaminated metal will be recycled.	Sanitary	12,518 cubic feet of sanitary waste (projected)
43		LANL7-F	97	At the Omega West Reactor, fluorescent lights and PCB ballasts will be recycled.	TSCA waste	100% reduction (projected)

Implementation Phase

P2/WM Case Study Matrix

Case Study Number	Symbol	Project Number	FY	Technical Description	Waste Type	Waste Avoided
44		LANL8-A	94	At the former Zia Motor Pool, two 10,000-gallons USTs and one 2,500-gallon UST were removed and recycled.	State-regulated waste	1,350 cubic feet of state-regulated material (estimate only)
44		LANL8-D	94	At the former Zia Motor Pool, bulk containers or rollaway bins used to ship contaminated soil were reused. This avoided increased volume disposal resulting from secondary packaging (i.e. drums).	HW (RCRA-regulated)	1,561 cubic feet of RCRA-regulated waste (estimate only)
45		LANL9-B	94	At LANL Technical Area 49, non-contaminated soils were shipped to other environmental restoration sites for reuse.	LLW	Included under LANL9-A
45		LANL9-C	94	At LANL Technical Area 49, PPE was carefully segregated to enable its reuse.	LLW	Included under LANL9-A
48		LBNL1-A	95	About 35% of the radiation shielding blocks at the Bevalac accelerator facility will be reused at another DOE facility; the remaining blocks are being evaluated for reuse in decommissioning work at Chernobyl.	LLW	165,957 cubic feet of LLW
64		NTS6-A	95/ 96	NTS segregated 120 tons of scrap metal for recycling from other materials at the Tonopah Test Range. (This includes roller coaster lagoons and north disposal trench).	LLW	120 tons of LLW
65		NTS7-A	95/ 96	NTS segregated 120 tons of scrap metal from other materials for recycling from the Roller Coaster Lagoons and North Disposal Trench. (This includes Tonopah test range).	LLW	Included under NTS6-A
67		PGDP1-D	94/ 95	At PGDP, reusable plastic ground covers were used to prevent contamination of ground surfaces instead of disposable plastic covers.	LLW	221 cubic feet of LLW
82		RF5-A	95/ 96	Rocky Flats is segregating and decontaminating usable metal for recycling or reuse by the National Conversion Pilot Project.	LLW	1,000 cubic feet of LLW

**DOE's Radioactively-Contaminated Metal Recycling:
The Policy and Its Implementation**

Stephen Warren
Office of Environmental Restoration
U.S. Department of Energy

Edward Rizkalla
Office of Waste Management
U.S. Department of Energy

DOE's Radioactively-Contaminated Metal Recycling:
The Policy and It's Implementation

by

Stephen Warren, U. S. Department of Energy
Office of Environmental Restoration
and

Edward Rizkalla, U. S. Department of Energy
Office of Waste Management

SUMMARY

In 1994, the Department of Energy's Office of Environmental Restoration initiated development of a recycling policy to minimize the amount of radioactively-contaminated metal being disposed of as waste. During the following two years, stakeholders (including DOE and contractor personnel, regulators, members of the public, and representatives of labor and industry) were invited to identify key issues of concern, and to provide input on the final policy. As a result of this process, a demonstration policy for recycling radioactively-contaminated carbon steel resulting from decommissioning activities within the Environmental Management program was signed on September 20, 1996. It specifically recognizes that the Office of Environmental Management has a tremendous opportunity to minimize the disposal of metals as waste by the use of disposal containers fabricated from contaminated steel. The policy further recognizes the program's demand for disposal containers, and it's role as the major generator of radioactively-contaminated steel. The policy goes on to state:

"Effective immediately, it is the policy of the Office of Environmental Management (EM) that, to the degree that it is economically advantageous and protective of worker and public health, radioactively-contaminated carbon steel (RCCS) either in storage or to be generated should be recycled. This EM policy will be in place for three years from the date of this memorandum, at which time it will be reevaluated. This policy is fully supportive of the various site-specific recycling initiatives underway or planned. More details on implementation of this policy are in the attachments.

Specifically, the policy for radioactively-contaminated materials, including RCCS, generated by the EM Program, shall be: survey, decontaminate as necessary and appropriate (in compliance with DOE Orders), and release for unrestricted use any material that meets the applicable criteria. If decontamination for release for unrestricted use is not economically feasible, then the RCCS that is recycled shall be fabricated into one-time-use containers for disposal of low-level wastes generated by the EM Program, consistent with the attached radiological guidance."

This paper discusses the development of the policy in detail, including the extensive interactions between the Department and it's stakeholders. This paper also describes the development of standardized low-level waste disposal containers (to support recycling), as well as the actions undertaken at DOE-HQ

to support site-specific implementation of recycling, including supporting the development of project-specific cost-benefit analyses and procurements specific to recycled metals.

THE NEED TO RECYCLE

Millions of tons of potentially recoverable materials have accumulated over the years at U.S. Department of Energy (DOE) sites and facilities now undergoing environmental restoration. These materials include thousands of tons of scrap metals that can be recycled into new products to conserve natural resources, avoid costly disposal, and reduce environmental impacts. While some recoverable materials can be free-released and possess a significant market value, other materials are radioactively-contaminated, either on the surface or in mass, which limits their reuse or recycle in the open market. The existing inventory in scrap piles has been variously estimated to include from 150,000 to 400,000 tons of potentially-radioactively-contaminated scrap metal.

The Environmental Management Program has a responsibility to protect the environment, including minimizing the volume of waste requiring disposal. [Waste minimization is also in accordance with Executive Order 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements" (August 3, 1993).] A key way to minimize waste disposal is to recycle materials that have outlived their original use but still may be recycled to have economic value. Much of the radioactively-contaminated scrap metal that has been or will be generated within the EM Program is suitable for reuse, but because of the type or distribution of radioactive contamination, it cannot economically be decontaminated for unrestricted release.

The idea for a policy grew from the recognition that the carbon steel scrap pile would continue to grow as DOE's Environmental Management Program decommissions surplus facilities no longer required to support the Department's mission. DOE already has decommissioned more than 100 structures under the Environmental Restoration Program and more than 800 others have been accepted by the Environmental Restoration Program for eventual decommissioning. Amounts of scrap metals to be generated by decommissioning projects are conservatively estimated at more than one million tons. With another 1,200 buildings likely to be in the pipeline for eventual decommissioning, the scrap metal inventory, including carbon steel, is expected to increase significantly.

THE RECYCLING POLICY CONCEPT

Initially, the objective of the "Recycle 2000" policy under consideration was to set a target: *"By the year 2000, 50% of the low-level waste disposal containers used by the Environmental Management program will be fabricated from RCCS"*. However, as DOE worked with stakeholders, it quickly became clear that there were significant economic uncertainties associated with the potential costs of recycling vs. disposal and purchase of disposal containers fabricated from virgin materials. Therefore, it was determined that a

numerical target was inappropriate. Instead, DOE would provide an environment in which recycling could be pursued to the extent that it can be economically advantageous.

CURRENT PRACTICES

In order to provide an environment supportive of recycling, DOE had to identify current practices, then assess what changes may be necessary.

Current practice is that radioactively-contaminated scrap metal has primarily been managed in one of two ways:

- packaged as low-level waste and disposed of via shallow land burial
- stored pending funding availability for packaging and disposal

The first approach incurs the costs associated with managing this material within the current program budget. The second approach defers these costs, and potentially increases them, as this storage is generally outdoors, and there is potential for migration of contaminants from the stored radioactively-contaminated scrap metal (most of which is carbon steel). Additionally, the second approach causes deterioration of the metal, potentially making it unsuitable for recycling. Although a number of sites have recycled materials or are actively pursuing recycling, to date the majority of radioactively-contaminated carbon steel is still being managed in one of the above two ways.

AN INNOVATIVE POLICY DEVELOPMENT APPROACH

Therefore, the Office of Environmental Restoration explored developing a recycling policy to address the large volumes of radioactively-contaminated scrap metal. Communications were initiated with key stakeholders (Department of Energy Operations Offices, management and operation contractors, public interest groups, regulators, labor and industry) in mid 1994. Based on feedback from this group, a workshop was held in December, 1994, where a broader range of stakeholders were asked to identify issues associated with establishing a recycling policy.

The result of this workshop was that stakeholders were supportive of the recycling concept subject to certain conditions, which included:

- protective of public and worker health and safety;
- developed through an open, credible process;
- economic compared to other viable waste disposal options;
- equitable (takes into account equity among sites and States);

- environmentally responsible, neither compromising cleanup nor adding to existing problems; and
- designed not to preclude further recycle initiatives.

Based on the above workshop conclusions, and a request from workshop participants for more and better information upon which to base policy development, DOE committed to conducting analyses of potential health and safety impacts associated with recycling radioactively-contaminated scrap metal, the transportation of this material for purposes of recycling, and the cost of recycling. In addition, in response to a workshop recommendation, DOE also committed to developing a standardized low-level waste disposal container suitable of being fabricated out of radioactively-contaminated scrap metal. (The standardized container development process and results are addressed later in this paper.)

Although initial discussions did not focus on a particular type of radioactively-contaminated scrap metal, DOE narrowed the scope to focus exclusively on radioactively-contaminated carbon steel (RCCS) because it is abundant across the complex, its low market value limits incentive for decontamination and release, and it is suitable for making the low-level waste disposal containers in demand with the Environmental Management program.

Three options for managing RCCS were explored with stakeholders:

- (1) Continuing RCCS disposal operations as currently practiced;
- (2) Processing RCCS into ingots (a volume reduced form) for disposal, and
- (3) Processing RCCS into disposal containers for one-time use within the Environmental Management Program.

In response to the request for more information on which to base a policy, the following analyses were performed:

"Assessment of Risks and Costs Associated with Transportation of DOE Radioactively-Contaminated Carbon Steel" - S. Y. Chen, L. A. Nieves, J. Arnish, S. Folga, Argonne National Laboratory, November 1995

"Recycling of DOE Radioactively-Contaminated Carbon Steel: Limiting Concentrations and Risk Evaluation" - M. A. Simek, C. W. Smith, J. L. Legg, D. A. Wollert, Center for Risk Management, Oak Ridge National Laboratory, November 1995.

"Cost Model for DOE Radioactively-Contaminated Carbon Steel Recycling" - S. W. Warren, U. S. DOE, R. S. Moore, R. E. Gant, CACI International (Automated Sciences Group), K. Robertson, The Robertson Group, November 1995.

"White Paper - Issues Discussion and Recommended Resolution of Commingling, Production Cost, Mixed Waste, Throughput Assumptions and Background for

Recycle 2000 Option 3 (rev 2)" - D. Burns, Trinity Environmental Systems, Inc., November 1995.

The results of these analyses were presented at a second workshop, held in September, 1995, after having been reviewed twice in draft form by interested stakeholders prior to being finalized.

Based on the results of these analyses, stakeholders indicated a strong preference for recycling RCCS. Specifically, they encouraged DOE to establish a RCCS recycling policy with a two-to-three year demonstration period, then re-evaluate the success and cost of the policy. They further recommended that DOE pursue the processing of RCCS into disposal containers, but felt these disposal containers should be used by waste generating sites as one-time-use-only packages for low-level waste disposal at DOE facilities. Stakeholders also wanted to ensure that any processing of the RCCS would be in a facility licensed by the Nuclear Regulatory Commission or Agreement State (if done by industry) or in compliance with DOE orders. Further, they wanted to ensure that all secondary wastes from the processing would remain the responsibility of the Department.

THE POLICY

Below is the full text of the policy signed by Assistant Secretary Al Alm on September 20, 1996:

I am fully supportive of all efforts to minimize the disposal of metals as waste. We have a tremendous opportunity to accomplish this by the use of disposal containers fabricated from contaminated steel, especially since we not only have a significant demand for disposal containers, but we are the major generator of radioactively-contaminated steel.

Effective immediately, it is the policy of the Office of Environmental Management (EM) that, to the degree that it is economically advantageous and protective of worker and public health, radioactively-contaminated carbon steel (RCCS) either in storage or to be generated should be recycled. This EM policy will be in place for three years from the date of this memorandum, at which time it will be reevaluated. This policy is fully supportive of the various site-specific recycling initiatives underway or planned. More details on implementation of this policy are in the attachments.

Specifically, the policy for radioactively-contaminated materials, including RCCS, generated by the EM Program, shall be: survey, decontaminate as necessary and appropriate (in compliance with DOE Orders), and release for unrestricted use any material that meets the applicable criteria. If decontamination for release for unrestricted use is not economically feasible, then the RCCS that is recycled shall be fabricated into one-time-use containers for disposal of low-level wastes generated by the EM Program, consistent with the attached radiological guidance.

I am looking for a site to aggressively lead the implementation of this policy. The lead site will be responsible for working with all EM sites to manage RCCS from generation to disposition as low-level waste disposal containers, including brokering small-site RCCS and achieving complex-wide economies of scale. I have attached the criteria I will utilize to evaluate your proposals. If your staff have any questions regarding this policy or the attachments, or if you wish to submit an application for the lead site by 14 October 1996, contact Stephen Warren (EM-43, (301) 903-7673).

STAKEHOLDER INPUT INTO THE FINAL POLICY

As an attachment to the RCCS policy, Assistant Secretary Al Alm provided additional guidance to Environmental Management programs at each field site. Specifically, for waste generating sites, containers fabricated from RCCS should be utilized to the extent practicable. Further, disposal sites should accept waste packaged in disposal containers made from RCCS provided the waste and packages meet all site-specific waste acceptance criteria. Finally, sites were told that release or processing of any contaminated or previously contaminated metals must be in compliance with applicable requirements, which may include Nuclear Regulatory Commission or State licensing requirements.

Stakeholders recognized that initiating recycling operations within the EM Program may increase near-term costs in some cases. However, they strongly believed the benefit to the environment of decreasing the volume of material being disposed of, as well as avoiding the use of clean metal for disposal packages, justified this near-term cost increase. They recognized that implementing this policy may require sites to reallocate existing funding. Discussions with the metal recycling industry suggested that there is limited existing capacity for recycling DOE's RCCS into disposal containers. Other analyses indicated that although the industrial infrastructure is not fully in place, recycling into disposal containers can be done cost effectively. However, Assistant Secretary Alm recognized that in the early stages of implementing this policy, the cost of recycling will exceed the cost of disposal. Therefore, sites were directed to develop site-specific cost analyses to assess the cost-effectiveness of recycling. Further, sites were told that these analyses should include the cost savings associated with avoiding the disposal of the RCCS as waste, since disposal is also a cost to the EM Program. Sites were also encouraged to work with their site-specific stakeholders to assess their views on recycling and to determine their level of support for recycling of RCCS into disposal containers in the event it initially costs more than disposal. Such discussions with stakeholders in advance of recycling decisions would enable sites to assess the acceptability to stakeholders of allocating additional site funds to recycling activities.

Stakeholders agreed that, based on these analyses, it was clear that recycling (including transportation of RCCS to an industrial location for decontamination, melting, and fabrication into disposal containers, as well as transportation and use of these containers at a Department of Energy generating site) can be done in a manner that protects DOE's workers, the public, and the environment. These analyses identified specific contamination

levels as suitable for recycling; these levels were provided to the sites with the policy, along with the guidance that they shall be followed in the absence of site-specific guidelines.

Some sites have existing compliance agreements or have made commitments to stakeholders to dispose of radioactively-contaminated carbon steel through onsite bulk disposal. In establishing the recycling policy, the Assistant Secretary recognized that disposal is the appropriate option for these materials, as well as metals that are too deteriorated or too highly contaminated to recycle.

The policy further recognized that there may be some question about the applicability of the National Environmental Policy Act (NEPA) when implementing the RCCS recycling policy. The sites were informed that: if the decommissioning decision document is prepared under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and covers the disposition of the metal, then no further NEPA analysis should be required. If the decommissioning decision document is prepared under CERCLA but does not cover the disposition of the metal, or if the decommissioning decision has been made under some authority other than CERCLA, sites should consult your NEPA Compliance Officer to determine the appropriate NEPA review strategy.

Finally, the policy recognized that innovative approaches may exist to enhance implementation of this policy, including: (1) Operations Offices working together to place orders for disposal containers made from radioactively-contaminated carbon steel, thereby enabling vendors to realize economies of scale; (2) surveying and segregating metals either in storage or being generated at a site to enable immediate accumulation of an inventory suitable for recycling (consistent with applicable regulatory requirements and commitments); and (3) identifying vendors willing to provide recycling services, provided that ownership of the metal (and any resulting wastes) is retained by DOE. Sites were encouraged to pursue these and other approaches to implement the RCCS Recycling Policy cost-effectively.

INNOVATIVE APPROACHES TO IMPLEMENTATION

To ensure innovative approaches are identified and pursued, a "Lead Site" will be selected (as noted in the final paragraph of the policy). Sites were invited to submit applications for the lead site, which will be evaluated by a team of DOE-HQ personnel representing the Offices of Waste Management, Site Operations, Science and Technology, and Environmental Restoration. A recommendation will be made to the Assistant Secretary, who is expected to select the lead site in November.

OTHER RECYCLING INITIATIVES

The Office of Environmental Management is also pursuing several other recycling initiatives. Specifically, the Offices of Waste Management and Environmental Restoration are working with Savannah River Site personnel to

evaluate the potential for using recycled radioactively-contaminated stainless steel canisters for the Defense Waste Processing Facility's vitrified high-level waste. The Savannah River site has the majority of stainless-steel available for recycling. Cost data is being collected so a comprehensive cost analysis can be developed to determine the economic feasibility of using the recycled stainless steel. The results of this cost analysis will be presented to management mid-January.

The Offices of Waste Management, Environmental Restoration, and Facility Transition are also working together with the SRS to assess the availability, suitability, and feasibility of using SRS stainless steel to fabricate plutonium storage package needs.

It is anticipated that additional opportunities for recycling will be identified as the Lead Site is selected and begins working closely with all EM sites.

STANDARDIZED LOW-LEVEL WASTE DISPOSAL CONTAINER DEVELOPMENT

Also as part of the policy development, the Department developed a standard container suitable for disposal of low-level waste.

The Department is the largest generator of low-level radioactive waste (LLW) in the United States (generating nearly 70% of the total national volume). In 1993, DOE disposed of more than 50,000 cubic meters of LLW.

This waste is packaged in a variety of containers and disposed of via shallow land burial at the Hanford Reservation in Washington state, the Idaho National Engineering Laboratory in Idaho; the Los Alamos National Laboratory in New Mexico, the Nevada Test Site in Nevada, the Oak Ridge Reservation in Tennessee, and the Savannah River Site in South Carolina.

In 1995, as a result of stakeholder recommendations from the December, 1994, Recycling Policy Workshop, the Department initiated an effort to develop a standard container for disposal of DOE's LLW. The objective was to enable DOE to order larger numbers of containers at one time, thereby reducing purchasing costs. Further, DOE anticipated that a standardized container had the potential to reduce costs in two additional ways: (1) by enabling new disposal container fabricators to enter the market, competition would be enhanced and prices reduced; and (2) by enabling the generating and disposal sites to concentrate on a single container, future storage, loading and disposal operations would be simplified, different types of equipment required for these operations would be minimized, and operating costs would be reduced.

To ensure such a container would be used by the different DOE sites, a development team was established. This team included representatives from the major generating and disposal sites. Representatives of the Transportation Management program were also included, since another objective was that the container be a DOT-certified 7A Type A transportation package. A key factor in site acceptance and use of this container was the process of achieving consensus among generators and disposal operations personnel at DOE sites.

The objectives for the standard container development initiative were:

- Design a family of standardized low-level waste disposal boxes (M-100 series)
- Enhance economies of scale through larger DOE orders of uniformly designed containers
- Improve transportation efficiencies by minimizing variety of disposal containers used by DOE waste generators
- Minimize void space at disposal sites through use of standard size containers
- Reduce uncertainty for vendors of what is a "B-25-type" container

The M-100 container has the following attributes:

- The M -100 series containers can be easily fabricated, using standard tooling and nonproprietary parts;
- The M -100 series container design can accommodate both RCCS and commercial fabrication paths;
- Each M-100 design can use a single gauge or metal thickness for all components (i.e., all 8-gauge or all 12-gauge components); and
- The M -100 series containers can meet Waste Acceptance Criteria for all DOE low-level waste disposal sites.

The M-100 series of containers are designed so a fully loaded container can be lifted by forklift or overhead hoist and the container is suitable as a six, 55-gallon drum overpack.

Design of the container was completed in late 1995, and a prototype was fabricated for testing purposes. The full suite of Department of Transportation 7A tests will be performed on the container at the Hanford test facility in 1997, completing all design and documentation activities for the containers.

CONCLUSION

The development and issuance of the Office of Environmental Management's policy for recycling radioactively-contaminated carbon steel has been a successful collaborative effort between the Department of Energy and its stakeholders. The standard low-level waste disposal container design provides a specific product which can be made form RCCS, thereby providing a "closed loop" for RCCS recycling. The Environmental Management Program personnel are looking forward to implementing this policy and reducing the environmental impacts of addressing the legacy of the cold war.

United States Government

Department of Energy

memorandum

DATE: APR 17 1996

REPLY TO
ATTN OF: EM-43 (S. Warren, 301-903-7673).

SUBJECT: Use of Standardized Low-Level Waste Disposal Containers

TO: Distribution

The purpose of this memorandum is to establish an Environmental Management (EM) policy on the use of standardized low-level waste disposal containers for EM-generated waste. We are establishing this policy because we believe that complex-wide use of standardized disposal containers offers the potential for larger purchases, thereby reducing the costs of each container.

The Offices of Waste Management and Environmental Restoration jointly sponsored development of a family of standardized low-level waste disposal containers. The M-100 family of containers was specifically designed to be suitable for disposal of 80 percent of the volume of low-level waste requiring disposal containers. The container is suitable for compacted soil disposal or as an overpack for a six-pack of standard 55 gallon drums, as well as for bulk wastes requiring containment prior to disposal.

The M-100 container family can be constructed entirely out of non-proprietary parts and is also designed to be responsive to changes that may occur in disposal site waste acceptance criteria. Additionally, the containers have been tested and are certified to meet the requirements of all currently operating Department of Energy disposal sites.

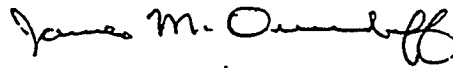
Specifications for the containers are attached to this memorandum. These specifications are flexible; the containers can be fabricated either out of commercially produced or radioactively contaminated carbon steels.

Complex-wide use of these standardized containers supports EM's draft recycling policy "that radioactively contaminated carbon steel from decommissioning activities should be recycled into low-level waste disposal containers and used for disposal of EM-generated waste" because fabricators already accustomed to making M-100 containers will face fewer manufacturing modifications to make them out of radioactively contaminated carbon steel.

Therefore, to ensure rapid implementation of this policy, we request that:

- (1) generators maximize the use of the M-100 family of containers for low-level waste disposal, and
- (2) low-level waste disposal sites specifically include these containers in site waste acceptance criteria.

We look forward to the cost savings that will result from the use of these standardized containers.



James M. Owendoff
Deputy Assistant Secretary
for Environmental Restoration



Stephen P. Cowan
Deputy Assistant Secretary
Office of Waste Management

Attachment

cc: W. Myers, AL
F. Sienko, CH
J. Hoyles, ID
J. Bradbery, NV
P. Dayton, OR
A. Pino, OAK
M. Snyder, OH
A. Valdez, RL
C. Dan, RF
R. Simpson, SR

DISTRIBUTION:

B. Twining, AL
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J. Wagoner, RL
M. Silverman, RF
J. Turner, OAK
M. Fiori, SR

**The Department of Energy's
Radioactively-Contaminated Metal Recycling:
The Policy and Its Implementation**

**Presented to
Beneficial Reuse '96
October 22, 1996**

BACKGROUND

- o Thousands of tons of potentially re-usable Radioactively Contaminated Carbon Steel (RCCS) accumulating at DOE sites
- o Thousands of additional tons will be generated during decommissioning activities
- o Environmental Restoration LLW may require over 4 million “B-25-type boxes” for disposal
- o Recycle and reuse offers opportunities for:
 - responsible materials management
 - environmental stewardship

RECYCLE POLICY DEVELOPMENT APPROACH

- o Engaged stakeholders from the beginning
- o Identified and assessed issues
- o Identified and developed options
- o Researched and analyzed options
 - Option 1: Continue present practices
 - Option 2: Melt to intermediate form and dispose
 - Option 3: Process into “one-time use” LLW disposal containers

ANALYZED HEALTH AND SAFETY IMPACTS TO WORKERS AND GENERAL PUBLIC

- o RCCS can be processed well within regulatory constraints
- o Use of RCCS-fabricated containers will not alter disposal operations
- o Within the sensitivity of the analysis, no difference between health risks associated with the three options

ANALYZED TRANSPORTATION CANCER FATALITIES AND HEALTH EFFECTS

- o Total risk dominated by traffic accident risks
- o External dose is higher for truck transport than rail due to closer proximity to population
- o Continuing present practices is lowest risk due to lowest mileage

ANALYZED AND MODELED COSTS

- o All three options yield very similar costs (within the sensitivity of the analysis)
- o Recognizing significant uncertainties, volume-reduced disposal costs are marginally less recycling which is marginally less than direct disposal costs

POLICY STATUS

- o M-100 Standardized Container Policy signed April 17, 1996
- o Recycling policy signed by ASEM Al Alm, September 20, 1996
- o Site-specific implementation and a three-year demonstration period
- o Lead site nominations requested
 - Lead site selection by ASEM Alm anticipated in November, 1996

POLICY STATUS (continued)

- o Policy recognizes recycling RCCS is likely to cost more (in the near term) than current practices, and recommends obtaining input from stakeholders

M-100 CONTAINER STATUS

- o Container fabricated and tested, 1995
- o Container will be tested to DOT 7A standards at Hanford facility, 1997
- DOT certification likely to increase M-100 disposal container use
- o Several sites have indicated an interest in using M-100's; to date unable to obtain at competitive price with "B-25" containers

NEW INITIATIVES - DWPF CANISTERS

- o Outside of policy (because made from stainless steel) but consistent with ASEM Alm's direction
- o Potential for significant long-term cost savings
- o Cost model (based on RCCS analysis) being developed to inform management of cost feasibility

NEW INITIATIVES - PLUTONIUM STORAGE CONTAINERS

- o Office of Facility Transition (EM-60) needs stainless steel containers to store plutonium
- o Stainless steel gloveboxes also needed
- o Savannah River Site (SRS) has radioactively-contaminated stainless steel in storage
- o Recycling team promoting discussions between EM-60 and SRS

Backup Information

Current Commercial Recycling Facilities

- o **Manufacturing Sciences Corporation, Oak Ridge, TN**
 - **10,000 tons/year, existing**
- o **Carolina Metals, Barnwell, SC**
 - **500 tons/year, existing**
- o **Scientific Ecology Group, Oak Ridge, TN**
 - **24,000 tons/year, existing**

Backup Information

Current Commercial Recycling Facilities (Continued)

- o **Molten Metal Technology, Oak Ridge, TN**
 - **25,000 tons/year, under construction**
- o **Manufacturing Sciences Corporation, Rocky Flats, CO**
 - **10,000 tons/year, planned as pilot project**
- o **Carolina Metals, Barnwell, SC**
 - **20,000 tons/year, proposed**

Backup Information on M-100 Container

- o Developed because “B-25 type” container is not standardized, resulting in
 - Transportation-related inefficiencies
 - Differing disposal site equipment and potential for disposal site void space
- o M-100 series containers can accommodate up to 80% of DOE’s LLW disposal container needs
 - Suitable as 6 x 55-gallon drum overpack

Backup Information on M-100 Container (Continued)

- o A standardized container can
 - Enhance economies of scale through larger DOE orders
 - Improve transportation and disposal site efficiencies
 - Reduce uncertainty for vendors of what is a “B-25 type” box
- o M-100 series containers can be easily fabricated
 - No proprietary parts
 - Standard tooling
 - Use either 8 gauge or 12 gauge metal

**Noneconomic Factors Influencing Scrap Metal Disposition Decisions
At DOE and NRC-Licensed Nuclear Facilities**

Mark D. Ewen
Lisa A. Robinson
Industrial Economics, Incorporated

NON-ECONOMIC FACTORS INFLUENCING SCRAP METAL DISPOSITION DECISIONS AT DOE AND NRC-LICENSED NUCLEAR FACILITIES

Mark D. Ewen
Lisa A. Robinson
Industrial Economics, Incorporated¹

ABSTRACT

The U.S. Environmental Protection Agency (EPA) is currently developing radiation protection standards for scrap metal, which will establish criteria for the unconditional clearance of scrap from nuclear facilities. In support of this effort, Industrial Economics, Incorporated is assessing the costs and benefits attributable to the rulemaking. The first step in this analysis is to develop an in-depth understanding of the factors influencing scrap disposition decisions, so that we can predict current and future practices under existing requirements and compare them to the potential effects of EPA's rulemaking.

These baseline practices are difficult to predict due to a variety of factors. First, because decommissioning activities are just beginning at many sites, current practices do not necessarily provide an accurate indicator of how these practices may evolve as site managers gain experience with related decisions. Second, a number of different regulations and policies apply to these decisions, and the interactive effects of these requirements can be difficult to predict. Third, factors other than regulatory constraints and costs may have a significant effect on related decisions, such as concerns about public perceptions. In general, our research suggests that these factors tend to discourage the unconditional clearance of scrap metal.

¹ Industrial Economics, Incorporated is an economics consulting firm specializing in the cost-benefit analysis of environmental policies and regulations. We are conducting the work reported in this paper for the U.S. Environmental Protection Agency (EPA) under contract number 68-D4-0102. Reid Harvey of EPA's Radiation Protection Division is the Work Assignment Manager. The opinions expressed in this report are our own and do not reflect EPA's positions or policies.

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is currently developing radiation protection standards for the release of scrap metal from nuclear facilities, and has contracted with Industrial Economics, Incorporated to support the Regulatory Impact Analysis (RIA) for this rulemaking. The purpose of the RIA is to compare the effects of current requirements with the effects of alternative EPA standards, and to determine the changes in costs and benefits attributable to the new standards. The RIA is one of many analyses used to inform EPA and stakeholder decision-making, and is required for most major Federal rulemakings under Executive Order 12866. The purpose of this paper is to present our current understanding of certain factors affecting scrap metal management decisions and solicit feedback and additional information relevant to the analysis.

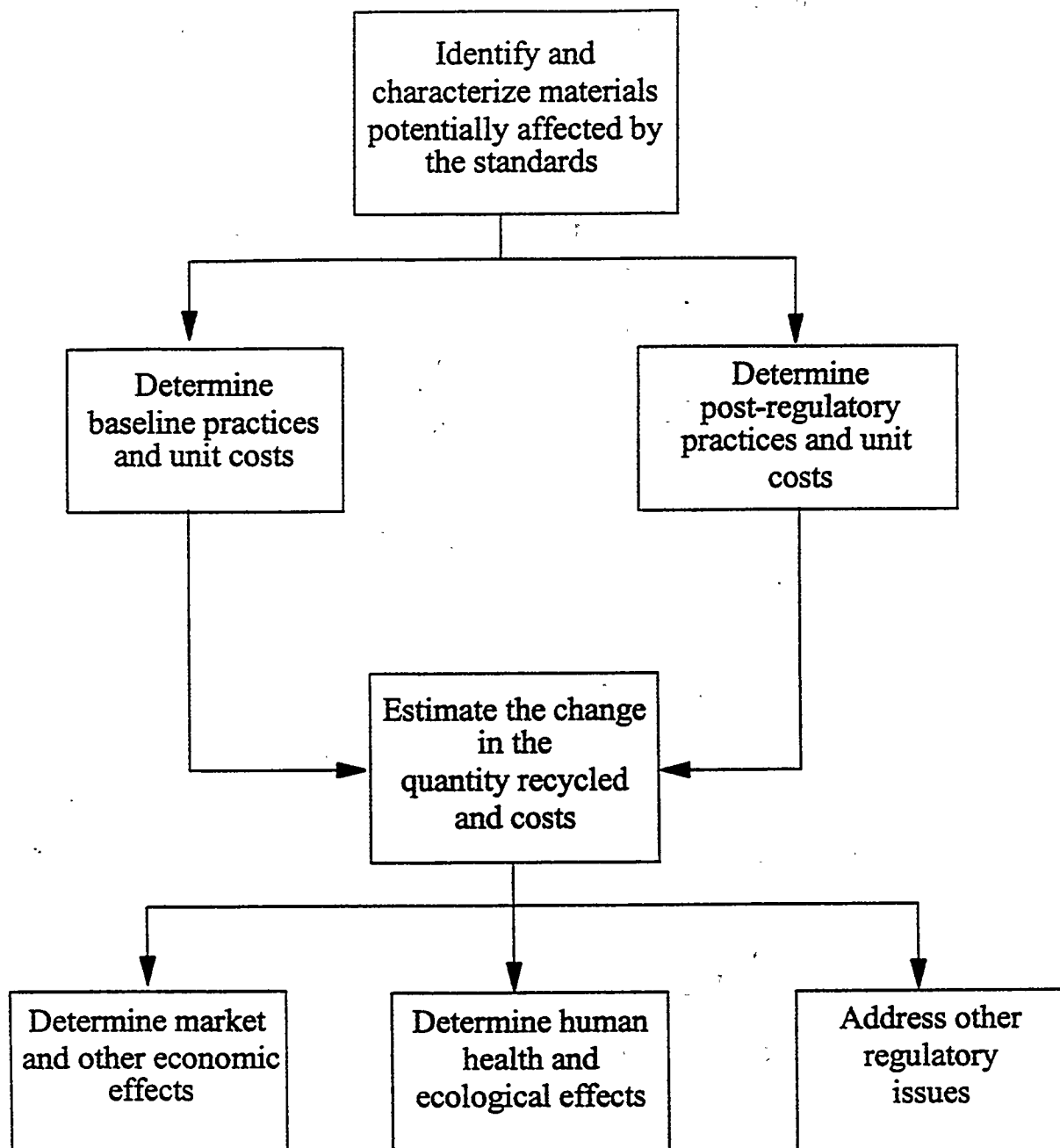
Exhibit 1 provides an overview of the major topics to be addressed in the RIA. As indicated by the exhibit, the analysis focuses on comparing baseline conditions to the incremental effects of the new clearance standards, estimating the change in the amount of materials recycled and considering the effects of this change on scrap market conditions, risks to human health and the environment, and other areas of concern such as effects on small businesses and environmental justice. A key issue in conducting a RIA is developing a thorough understanding of current and potential future practices in the absence of EPA's rulemaking. The analysis then focuses on the changes in these baseline practices likely once the rule is promulgated.

Because many facilities are just beginning to consider scrap disposition options as they enter decommissioning, some of the factors affecting related decisions are not well understood. To better understand these practices, we are investigating the potential effect of a variety of non-economic factors on site managers' decisions to recycle scrap metal. We focus on practices at major U.S. Department of Energy (DOE) sites undergoing decommissioning and at Nuclear Regulatory Commission (NRC)-licensed commercial power plants because we expect these facilities will generate the majority of the scrap metals potentially affected by EPA's rulemaking. Our investigation includes review of the relevant literature and numerous interviews with individuals at DOE and NRC headquarters as well as site managers at DOE and NRC-licensed nuclear facilities. The individuals contacted as part of this analysis are included in Appendix A; a list of major references is also attached.

The results of this analysis will be used in combination with an economic model to predict the quantities of scrap likely to be released for recycling under baseline conditions and alternative regulatory standards. Although the economic analysis also includes significant uncertainties, we focus on non-economic factors in this paper.

Exhibit 1

CONCEPTUAL APPROACH FOR REGULATORY IMPACT ANALYSIS



The remainder of this paper is separated into three sections. In the first section, we discuss current DOE scrap management practices and examine a variety of factors that influence scrap disposition decisions. We discuss these same topics for NRC licensees in the second section. In the third section, we discuss the implications of our analysis and consider the effect these non-economic factors may have on the volume of metals released in the baseline.

DOE BASELINE PRACTICES

To better understand DOE scrap metal management practices, we collected data on current practices at 11 DOE facilities.² These facilities contain a large proportion of DOE's current scrap inventory and will generate the majority of future scrap flows from within the DOE complex.

Site managers may consider four scrap disposition options: unconditional clearance; restricted recycle; intermediate or long-term storage; and on-site or off-site burial.³ We summarize DOE's use of these options in Exhibit 2. As illustrated in this exhibit, most of the sites are engaging in some form of unconditional clearance or restricted recycling activities. Seven of the 11 sites are decontaminating radioactive scrap metal and releasing it for unconditional use. Six of the 11 sites, including four sites engaging in unconditional clearance activities, are involved in restricted recycling initiatives.

The volumes of scrap released under these initiatives are small relative to both the total volume of scrap currently in DOE's inventory and the amount that will be generated during future decontamination and decommissioning (D&D) activities. For example, the quantities of scrap being released range from negligible amounts at Hanford to about 400 tons at Oak Ridge. In contrast, DOE estimates that the total volume of contaminated or unspecified carbon steel alone currently in inventory equals approximately 116,511 tons.⁴

² These sites include: Fernald Environmental Management Project (Fernald); Hanford; Idaho National Engineering Laboratory (INEL); Los Alamos National Laboratory (LANL); Nevada Test Site (NTS); Oak Ridge facilities (Oak Ridge National Laboratory -- ORNL, K-25, and Y-12); Pinellas; Portsmouth; Rocky Flats; Savannah River Site (SRS); and Weldon Springs.

³ Unconditional clearance refers to the release of scrap metal from DOE or NRC-licensed facilities with no restrictions on its use; i.e., sale to scrap dealers for recycling. Restricted recycling refers to materials that are recycled without leaving the control of nuclear regulatory agencies; e.g., metals recycled by DOE into storage or disposal containers for nuclear materials.

⁴ U.S. Department of Energy. Taking Stock: A Look at the Opportunities and Challenges Posed By Inventories from the Cold War. Office of Environmental Management and Office of Strategic Planning and Analysis. Washington, D.C., January 1996, page 32. DOE/EM-0275. Also known as the "MIN" -- materials in inventory -- report.

Future D&D activities may generate approximately 470,000 tons of additional scrap carbon steel.⁵

Exhibit 2					
CURRENT SCRAP METAL DISPOSITION ACTIVITIES (1995-1996)					
DOE Site	Clean Scrap Sales ^b	Unconditional Clearance	Restricted Recycle	Long-term Storage	Burial
Fernald		•	•	•	•
Hanford	•	•			•
INEL	•		•		•
LANL	•	•	•		•
NTS	•	•		•	•
Oak Ridge ^a	•	•	•	•	c
Pinellas	•	•			•
Portsmouth		•	•	•	c
Rocky Flats	•				•
SRS	•		•		•
Weldon Springs					•
Notes: ^a Includes activities at ORNL, K-25, and Y-12. ^b Clean scrap refers to scrap from areas not exposed to radioactivity. ^c Sites have buried scrap metal in the past, but are currently storing available metal for potential use in recycling programs. Sources: IEc interviews with DOE personnel, July - September 1996. U.S. Department of Energy, <u>Taking Stock: A Look at the Opportunities and Challenges Posed by Inventories from the Cold War Era</u> , Office of Environmental Management and Office of Strategic Planning and Analysis, Volume II, Washington DC, January 1996. DOE/EM-0275. (i.e., the "MIN Report".)					

DOE sites are releasing relatively small volumes of previously-contaminated scrap metal due to a variety of factors. While the primary factor may be the perceived low cost of storage or disposal relative to recycling options, other considerations affect site managers'

⁵ S. Cohen and Associates, Incorporated. Analysis of the Potential Recycling of Department of Energy Radioactive Scrap Metal (Volumes I-IV). Prepared for the U.S. Environmental Protection Agency, McLean, VA, August 14, 1995, page 4-58.

decisions. For example, current release requirements lead to case-by-case decision-making, potentially causing variation in the application of the requirements across different sites. In addition, other factors, such as concerns about public perceptions, may affect baseline practices in hard-to-quantify ways. We discuss these issues below, examining the current regulatory framework and other factors that affect DOE disposition decisions.

Current DOE Guidance

Site managers must comply with a variety of DOE regulations and guidelines to release radioactive material for unconditional use. We illustrate the requirements and their relationship to the release process in Exhibit 3. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," provides related requirements, which are based in part on NRC guidelines contained in Regulatory Guide 1.86.⁶ DOE is promulgating new regulations under 10 CFR 834 in an effort to formalize and clarify the standards and release guidance established by the DOE Order. The goal of the requirements is to protect the public and the environment from undue risk of radiation exposure from DOE activities.

To achieve this goal, DOE Order 5400.5 establishes limits on the amount of radiation exposure an individual and the public can receive. The Order sets a primary dose limit for the public from all exposures of 100 mrem per year and requires that any single release of material from DOE must account for only a fraction of this total (e.g., 1/4 or less of the primary dose limit for the public).⁷ DOE guidance issued in November 1995 indicates that release of materials that may lead to doses in excess of 1 mrem (individual) or 10 person-rem (collective) annually must be approved by DOE headquarters. Materials at levels below these limits may be released with approval of the relevant DOE field office.

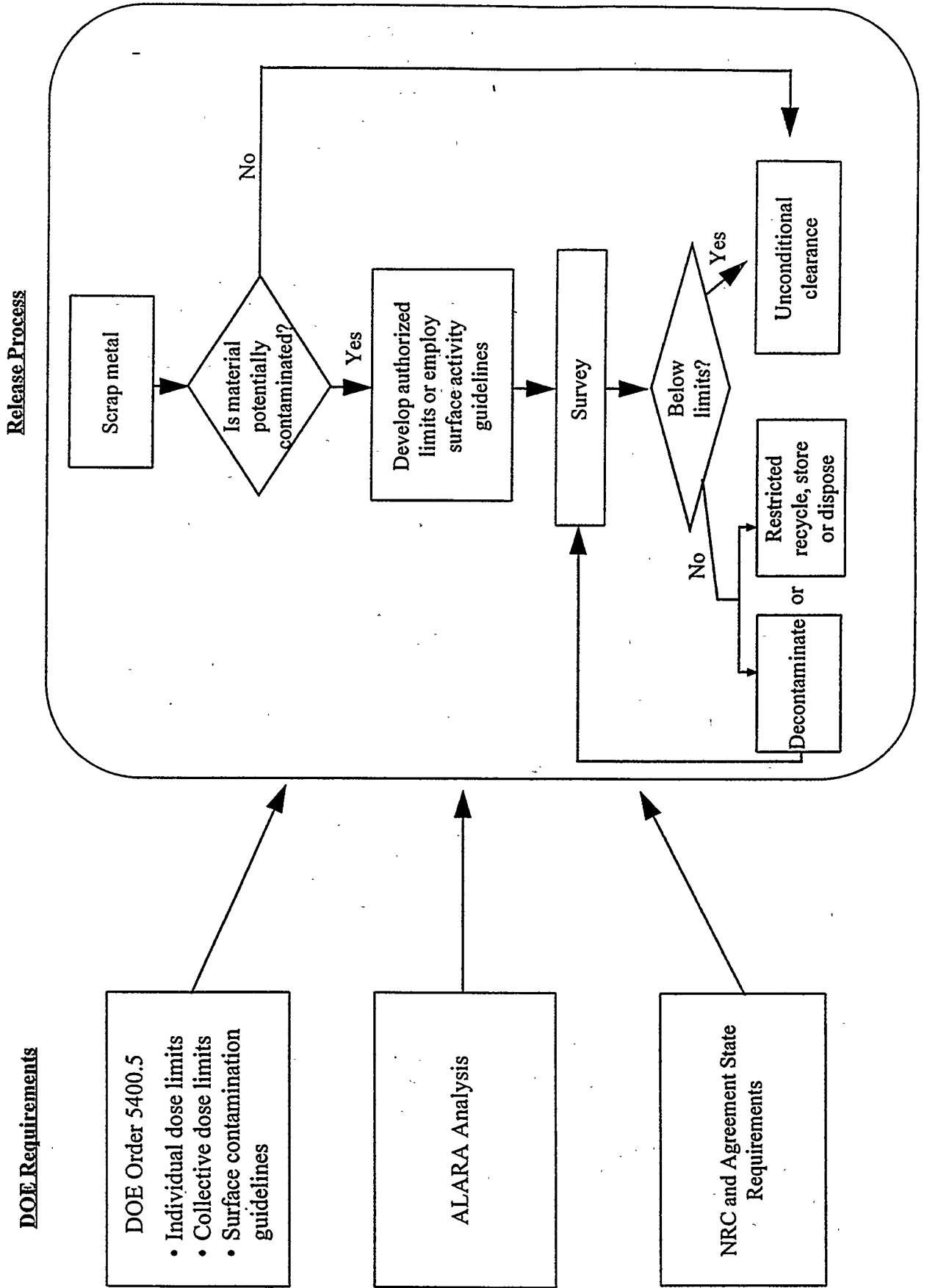
DOE Order 5400.5 prohibits the release of contaminated material unless sufficient analyses have been completed to ensure that the release will not result in harmful exposure. The analyses must document that the level of radioactivity is as low as reasonably achievable (ALARA). ALARA is the process through which site managers ensure compliance with the DOE Order 5400.5 release requirements, as well as other requirements developed to minimize worker and general population exposure to radiation.

⁶ U.S. Atomic Energy Commission. Regulatory Guide 1.86: Termination of Operating Licenses for Nuclear Reactors. Washington, DC, June 1974. U.S. Department of Energy. DOE Order 5400.5: Radiation Protection of the Public and the Environment. Washington, DC, 1990.

⁷ "Response to Questions and Clarifications of Requirements and Processes: DOE 5400.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material)," DOE Assistant Secretary for Environment, Safety and Health, Office of Environment (EH-41), November 17, 1995.

Exhibit 3

OVERVIEW OF DOE REGULATORY FRAMEWORK



ALARA analyses are used to develop authorized limits for concentrations of residual radioactivity. Authorized limits are the maximum amount of radioactivity that may be present for material to be released and are established to ensure that any release will not result in exceedences of the basic dose limits. A full scale ALARA assessment involves developing alternative disposition options and completing a radiological risk and economic assessment of these alternatives.

To facilitate the release process, DOE established a set of surface contamination guidelines which site managers can generally apply in lieu of authorized limits derived on a case-specific basis. The ALARA principles still apply in these instances; however, only a semi-quantitative or qualitative assessment is generally required to meet the ALARA requirements. DOE has not established similar activity guidelines for material that is volumetrically-contaminated. Authorized limits for the release of volumetrically-contaminated material must generally be derived using a full, quantitative ALARA assessment. Site managers must also develop and seek approval of surveying protocols to ensure that radiation levels fall below the authorized levels.

Existing DOE guidance has two key implications for the cost-benefit analysis of EPA's radiation protection standards. First, the levels of allowable residual activity are difficult to predict because they may vary on a case-by-case basis, due to the application of ALARA and other factors. Second, the analytic requirements and approval processes associated with unconditional clearance impose costs that must be taken into account in determining whether recycling is likely to be desirable from an economic perspective. Such costs may be particularly significant in determining whether to release volumetrically contaminated scrap, since no guidelines on allowable levels of activity are available. These factors are likely to limit the quantities of materials released for unconditional use under current and future baseline conditions.

Other Influencing Factors

Within the policy and regulatory constraints discussed above, other factors will influence the extent to which scrap metal is released from DOE sites. During our interviews, site managers identified a number of factors beyond direct costs and absolute policy constraints that they consider when making disposition decisions. These factors include site-specific implementation issues, general DOE policy, and concerns about public perceptions. The magnitude of the impact of these factors on the decision-making process is difficult to quantify and likely to change over time. In addition, these factors have counterbalancing effects -- some may encourage free release of scrap while others may discourage the activity. We summarize these factors and their indicated affect on unconditional clearance in Exhibit 4.

Exhibit 4			
EFFECT OF OTHER FACTORS			
DOE Site	Site-Specific Release Concerns	Public Perceptions	DOE Policy Initiatives*
Fernald	D	E	
INEL	D	D	
LANL	D	U	E
NTS			
Oak Ridge		U	
Pinellas	E		E
Portsmouth			
Rocky Flats		U	
SRS			
Weldon Springs			
Notes: * Includes waste minimization and recycling initiatives. D = Discourages unconditional clearance E = Encourages unconditional clearance U = Unclear effect; may limit or encourage unconditional clearance Blank = Factor not specifically identified as limiting or encouraging unconditional clearance.			
Source: IEc interviews with DOE personnel, July - September 1996			

Site-Specific Release Concerns

DOE managers noted two types of site-specific issues that affect their scrap disposition decisions. The first includes general beliefs about the difficulties inherent in the clearance process. Complying with all of the regulatory details contained in DOE Order 5400.5 and meeting ALARA requirements is a relatively complex process. For example, according to INEL personnel, site managers are concerned about properly applying the release criteria, limiting the volume of material released by such sites. In contrast, managers at Pinellas feel that the current requirements are working well and want little change.

Second, in addition to general concerns about the release requirements, some managers apply site-specific release criteria which may result in activity levels below those set by DOE Order 5400.5. For example, Fernald sets an "undistinguishable from background" activity standard for material cleared for unconditional release. The equipment used at Fernald to survey the material is apparently more sensitive than the

levels assumed for DOE Order 5400.5. As a result, activity levels in material released from Fernald are typically well below those set by DOE Order 5400.5.

Public Perceptions

Site managers provided a mixed review of the effect of public opinion on recycling activities. Several noted that public perception plays an important role in encouraging recycling initiatives (Fernald, Oak Ridge, and SRS), particularly for restricted recycling projects. Others (LANL, INEL) believe that the public is not fully informed about the risks of radiation exposure and may oppose the unconditional clearance of material with a nuclear pedigree. While the ultimate trend is unclear, site managers generally agree that DOE should make a greater effort to educate the public on the true risks of radiation. To the extent these efforts are successful, interest in recycling may increase.

DOE Policy Initiatives

As a Federal agency, DOE bases its decisions in part on general policy goals and in part on economic factors. Some of these policies may encourage unconditional clearance of scrap metal in cases where it is not the least-cost disposition option and vice-versa. For example, DOE has implemented a waste minimization policy that encourages sites to limit the amount of waste they generate. Representatives from Pinellas consider this policy to be an important incentive to recycle material. In addition, DOE recently finalized its policy for its restricted recycling initiative ("Recycle 2000") to fabricate waste containers out of contaminated carbon steel. The effect of this policy on decisions to release scrap metal is unclear. For example, Oak Ridge representatives suggest that the policy will not significantly affect their current recycling activities, while other sites (e.g., Portsmouth) are likely to participate in the Recycle 2000 program.

NRC BASELINE PRACTICES

For NRC-licensed facilities, we focus on scrap management practices at commercial power reactors because these facilities are likely to generate the majority of scrap metal volumes within the NRC complex. While managers of NRC-licensed power plants may consider scrap disposition options similar to those considered by DOE facilities (i.e., unconditional clearance, restricted recycling, storage or disposal), they generally have less experience in addressing related concerns. Only a handful of the approximately 120 commercial reactors have ceased operations and begun to enter the decommissioning phase. Projections of available scrap metal indicate that commercial power plants will not begin to release the bulk of their scrap until several decades from now, as the pace of decommissioning increases.

As a result, current recycling activities are mostly limited to recycling tools and small amounts of materials from active reactors. For example, according to personnel at Southern California Edison, the San Onofre power plant in California is decontaminating and releasing small quantities of scrap generated through ongoing operations. According to our interviews, no NRC power plants have requested approval for plans to directly release large volumes of metal, although some scrap is released after decontamination by waste management firms.

The limited amount of recycling activities that have occurred to date provide little indication of how such practices may evolve in the future. However, NRC facilities currently face higher disposal charges than DOE facilities, which may encourage unconditional clearance of scrap metal. Release is limited, however, by NRC release criteria and by other concerns such as fear of adverse public reaction.

Current NRC Guidance

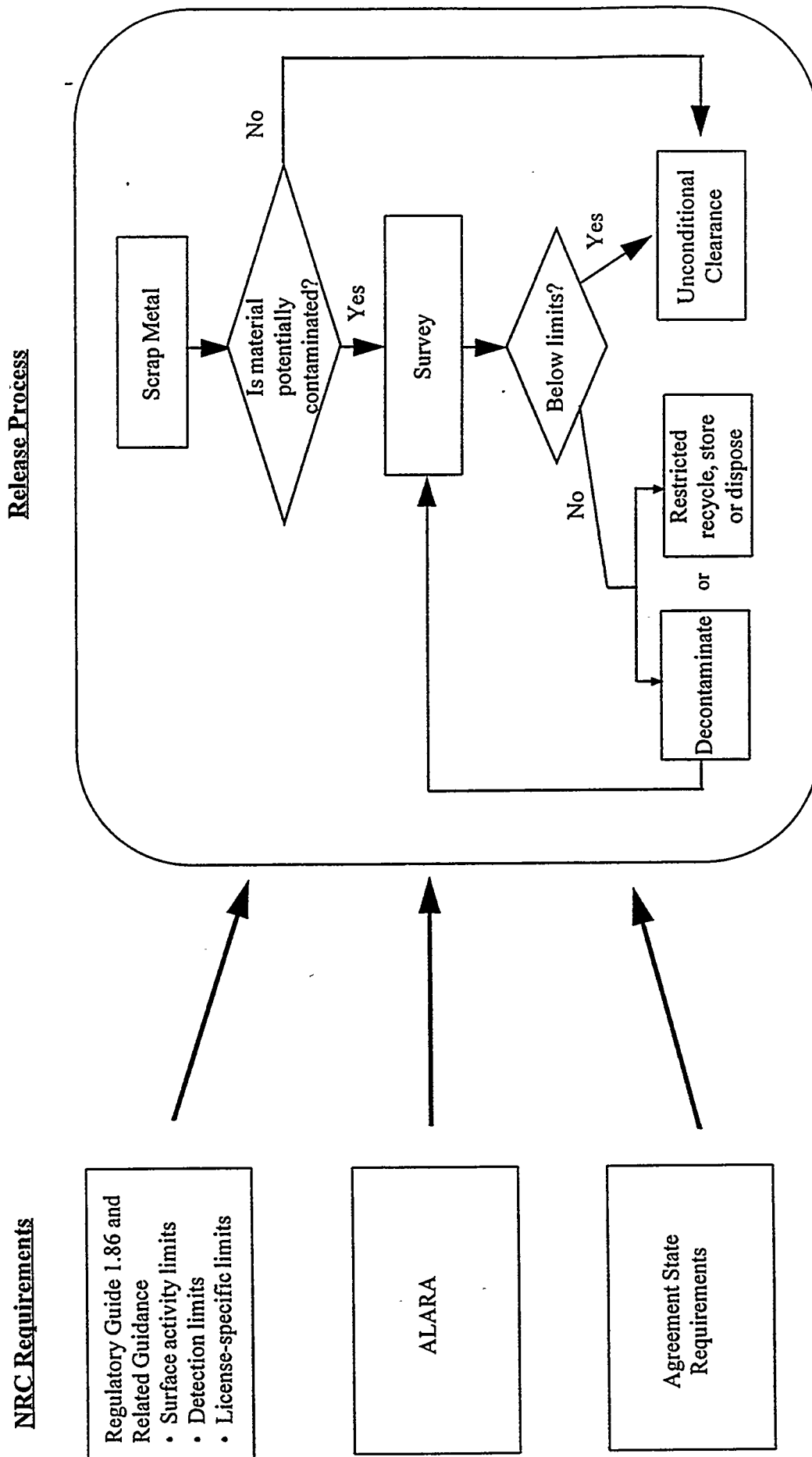
NRC-licensed nuclear facilities must comply with a variety of requirements to release scrap metal for unconditional use. Regulatory Guide 1.86 provides guidelines for nuclear reactors interested in terminating their operating licenses and releasing the site for unrestricted use, and is often applied to decisions to release scrap metal. Like DOE Order 5400.5, the goal of Regulatory Guide 1.86 is to protect public health and safety by limiting exposure to radioactivity. We illustrate the release requirements and their relationship to the release process in Exhibit 5.

Somewhat different NRC release criteria apply to nuclear power plants and to decontamination and waste management firms. State-level requirements also affect the release criteria applied by the latter firms. In addition to specific release criteria, both materials (waste management) and source (power plants) licensees are required to use "procedures and engineering controls based upon sound radiation control principles to achieve occupational doses and doses to members of the public that are as low as reasonably achievable (ALARA)."⁸ This process may lead to activity levels below the levels indicated in the relevant guidance documents.

⁸ 10 CFR 20, "Standards for Protection Against Radiation," page 291.

Exhibit 5

OVERVIEW OF NRC REGULATORY FRAMEWORK



Guidelines for Source Licensees

Source licensees (i.e., nuclear power plants) generally do not release materials with detectable levels of radiation. Regulatory Guide 1.86, published in 1974, includes "acceptable surface contamination limits" based on the detection limits of the technology available at the time and indicates that licensees must demonstrate that "reasonable effort has been made to reduce residual contamination to as low as practicable levels."⁹ According to interviewees, this guidance is generally interpreted to mean that materials cannot be released if they contain detectable levels of radiation. Although Regulatory Guide 1.86 provides information on detection limits (and hence the residual activity levels in released material), actual levels may be lower to the extent licensees are employing more sensitive surveying equipment than the equipment used in the 1970s. The guidance focuses on surficial contamination; activity levels for volumetric contamination are not explicitly addressed.

NRC clarified its guidelines for releasing material in IE Circular 81-07, which it developed to "establish operational detection levels below which the probability of any remaining, undetected contamination is negligible and can be disregarded, when considering the practicality of detecting and controlling such potential contamination and associated negligible radiation doses to the public."¹⁰ These standards generally mirror those established by Regulatory Guide 1.86.¹¹ To release material, NRC facilities must meet the limits in their licenses, comply with ALARA requirements, and document the measurement sensitivity of the equipment used.

Guidelines for Materials Licensees¹²

NRC release requirements for materials licensees (which include waste management and decontamination firms) differ from those of nuclear power plants. While power plants are prohibited from releasing materials with any detectable levels of radioactivity, materials licensees can release any material at the limits specified in their individual licenses, even if

⁹ U.S. Atomic Energy Commission, June 1974, page 3-5.

¹⁰ U.S. Nuclear Regulatory Commission. IE Circular 81-07, "Control of Radioactively Contaminated Material," May 14, 1981.

¹¹ IE Information Notice 85-92, published in 1985, describes in detail the type of detection equipment that should be used to ensure protection from radiation.

¹² Requirements for materials licensees affect DOE disposition decisions as well as decisions made by NRC-licensed power plants, because DOE sites also use these firms to decontaminate scrap metal for unconditional clearance.

that limit is detectable. In general, these limits are influenced by the Regulatory Guide 1.86 guidelines, but are codified as a set level.¹³

In addition, twenty-nine states have formed agreements with NRC to assume regulatory responsibility for materials licensees. Agreement states regulate waste management services and disposal sites directly, conducting site inspections and issuing licenses for these sites. These states do not have the authority to create new regulations for power plants, which are still directly regulated by NRC. The state regulations affecting materials licensees are often identical to those promulgated by NRC, but may be more stringent in some cases. Waste management companies must also measure activity levels and demonstrate that the material is below the limits specified in their individual licenses.

Existing NRC guidance has several implications for the cost-benefit analysis of EPA's clearance standards. Although the levels of residual activity in scrap that is released from NRC licensees will be at or below the surficial contamination limits established in Regulatory Guide 1.86, actual levels will vary for three reasons. First, scrap released directly by nuclear power plants will contain levels of radioactivity that vary depending on the sensitivity of the detection equipment used. To the extent that surveying technology has improved since Regulatory Guide 1.86 was written, actual detection limits may be lower than those specified in the guidance, resulting in lower activity levels in released scrap. Second, the levels of radioactivity in scrap released through a decontamination firm will vary depending on the conditions in the individual firm's licensees. Third, we are uncertain about the extent to which the application of ALARA reduces residual activity levels below detection limits and/or the limits contained in decontamination firm's licenses.

Other Influencing Factors

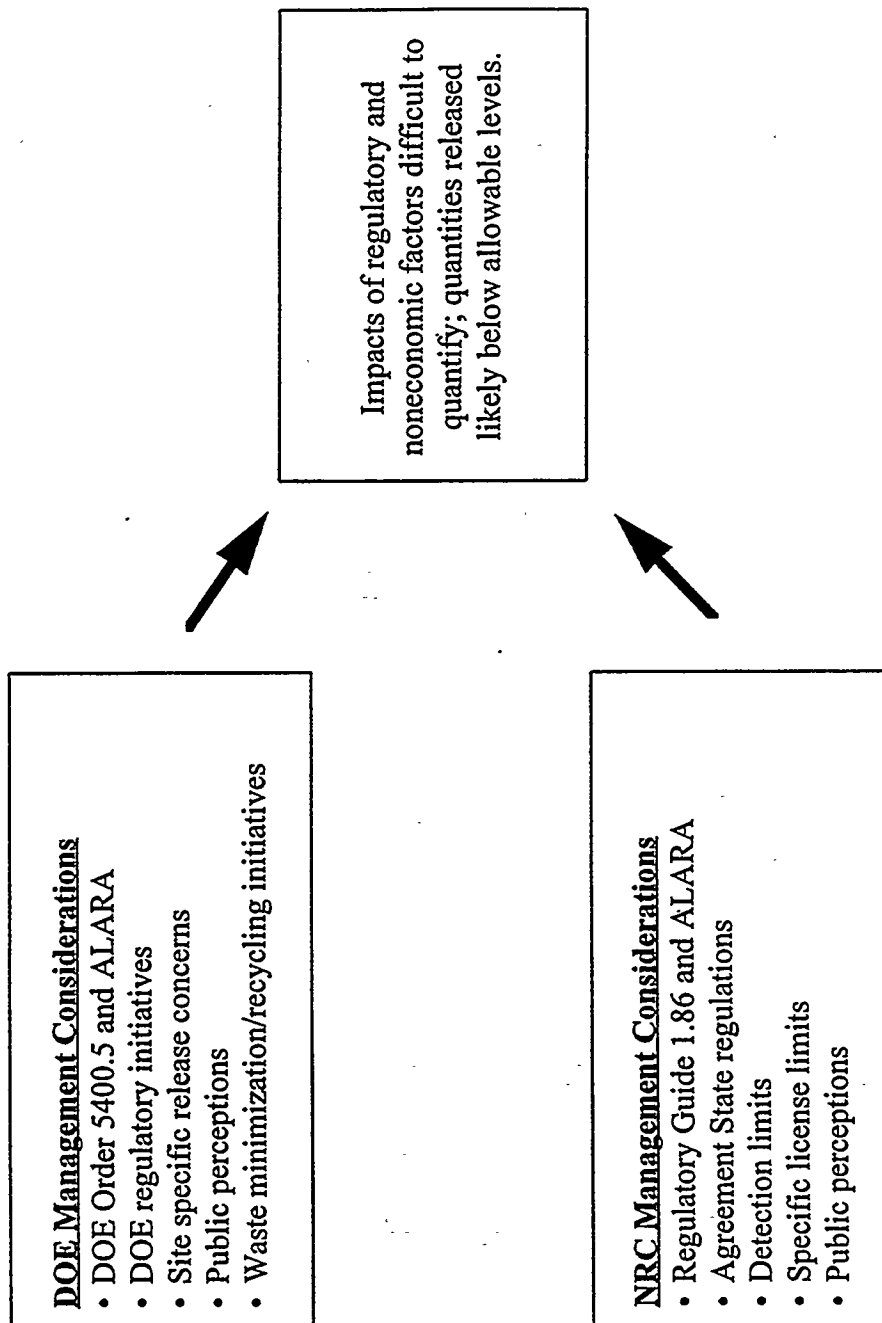
Beyond direct economic considerations and policy and regulatory constraints, concern about adverse public reaction is likely to have an important effect on release decisions. Our interviews suggest that managers at power reactors are very concerned about negative public reactions resulting from the release of radioactive materials. For example, Yankee Rowe does not release any material directly from the plant that originated from within the radiation control area even if it shows no detectable levels of radioactivity. In addition, its contracts with decontamination firms stipulate that all contaminated metal sent from the plant must be used in restricted use products and not free released. Yankee Rowe's managers are concerned that Massachusetts residents would react negatively to anything being released from Yankee Rowe. San Onofre also limits its releases based on public opinion concerns. For example, the plant does not recycle aluminum soda cans. These concerns, more than any other factor, have the potential to limit the free release of scrap under current standards.

¹³ Sanford Cohen and Associates, Incorporated. August 14, 1995, page 2-22.

CONCLUSION

In addition to direct costs, the factors mentioned by DOE and NRC site managers as influencing recycling decisions may both encourage and discourage unconditional clearance of scrap metal. These factors include current release requirements, site-specific release concerns, DOE and NRC policy initiatives, and public perceptions, as illustrated in Exhibit 6. At minimum, the responses of the interviewees indicate that non-economic factors can play a significant role in the decision-making process. In addition, they suggest that, for at least some sites, these non-economic factors may reduce the quantities of scrap released significantly below the levels potentially allowable under current regulations and guidance. These factors therefore increase the uncertainty surrounding future baseline recycling practices.

ESTIMATING DOE AND NRC BASELINE RECYCLING ACTIVITIES



REFERENCES

- "Response to Questions and Clarifications of Requirements and Processes: DOE 5400.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material." DOE Assistant Secretary for Environment, Safety and Health, Office of Environment (EH-41), November 17, 1995.
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U.S. General Accounting Office. Radioactive Waste: Status of Commercial Low-Level Waste Facilities, GAO/RCED-95-67, May 1995.

U.S. Nuclear Regulatory Commission. "Control of Radioactively Contaminated Material," IE Circular 81-07, May 14, 1981.

U.S. Nuclear Regulatory Commission. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle Safety and Safeguards, Washington, DC, April 1993.

Appendix A
DOE AND NRC INTERVIEW LISTS

Industrial Economics, Incorporated

Exhibit A-1

DOE CONTACTS LIST

Organization	Name	Position
DOE Headquarters	Stephen Warren	Team Leader, Office of Program Integration, Office of Environmental Management
	Edward Rizkalla	Program Manager, Office of Environmental Management
	Jann Buller	Senior Associate, Booz-Allen and Hamilton, Inc.
	Julie D'Ambrosia	Program Manager, EnviroTech Associates
	Andrew Wallo	Director, Air, Water, and Radiation Division; Office of Environment, Safety and Health
	Edward Regnier	Chief, Waste Management Unit, Air, Water, and Radiation Division; Office of Environment, Safety and Health
	Harold Peterson	Chief, Radiation Protection Unit, Air, Water and Radiation Division; Office of Environment, Safety and Health
	Kenneth Duvall	Physical Scientist, Air, Water, and Radiation Division
DOE Facilities:		
Fernald Environmental Management Project	Peter Yerace	Waste Minimization/ Recycling Coordinator
Idaho National Engineering Laboratory (INEL)	Richard Mesurvey	Consulting Engineer/Scientist
	Fred Hughes	Facility Manager, Radioactive Waste Management Complex
Los Alamos National Laboratory (LANL)	Dan Stout	Project Leader
Nevada Test Site (NTS)	Carl Gertz	Deputy Director, Environmental Management
Oak Ridge National Laboratory (ORNL)	John Kennerly	Senior Development Staff Member
	Roy Sheely	Scrap Metal Program Director
Pinellas Plant	Gary Schmidtke	Waste Management Program Manager
Portsmouth	Ron Parnell	Project Manager
Rocky Flats Environmental Technical Site	Mark Shepard	Project Manager, Waste Minimization/Recycling Coordinator
Savannah River Station (SRS)	William Boettinger	Manager of Beneficial Reuse Programs
	John Harley	Engineer, Westinghouse Savannah River Co.
Weldon Springs	Glenford Newtown	DOE Project Engineer
	David Hixson	Compliance Department Manager
	Dan Hoffman	ES&H Department Manager

Exhibit A-2**NRC CONTACTS LIST**

Organization	Name	Position
NRC Headquarters	William Lahs	Project Manager, Office of Nuclear Material Safety and Safeguards
	Steve Klementowicz	Health Physics Specialist, Office of Nuclear Reactor Regulation
NRC Licensed Facilities:		
Southern California Edison San Onofre Power Plant	Mark Lewis	ALARA Supervisor
	Brian Metz	Supervisor, Hazardous Materials
Yankee Atomic Electric Company Rowe Power Plant	Adam Mancini	Senior Nuclear Engineer
U.S. Ecology Oak Ridge, Tennessee	Dick Fasnacht	Director of Operations

Assessment of DOE Radioactive Scrap Metal Disposition Options

Carey R. Butler
Kenneth M. Kasper, CHP
Waste Policy Institute

Steven J. Bossart
Morgantown Technology Center
U.S. Department of Energy

ASSESSMENT OF DOE RADIOACTIVE SCRAP METAL DISPOSITION OPTIONS

Carey R. Butler
Kenneth M. Kasper, CHP
Steven J. Bossart*

Waste Policy Institute
1224 Pineview Drive
Morgantown, WV 26505
304-598-9383 (telephone)
304-598-9392 (facsimile)

*U.S. Department of Energy
Morgantown Energy Technology Center
3610 Collins Ferry Road
Morgantown, WV 26507
304-285-4643 (telephone)
304-285-4403 (facsimile)

I. Introduction

The DOE has amassed a large amount of radioactively-contaminated scrap metal (RSM) as a result of past operations and decontamination and decommissioning (D&D) projects. The volume of RSM will continue to increase as a result of the D&D of more than 6,000 surplus facilities and many of the 14,000 operating facilities in the DOE complex. RSM can be either surface contaminated or volumetrically contaminated, or both, with varying amounts of radioactivity. Several options exist for the disposition of this RSM, including disposal as radioactive waste, recycling by decontamination and free-release for unrestricted use, or recycling for restricted reuse inside a DOE controlled area.

The DOE Office of Science and Technology (EM-50) has been actively investing in technology and strategy development in support of restricted-reuse RSM recycling for the past several years. This paper will assess the nature of the RSM recycling issue, review past investment by DOE to develop technologies and strategies to recycle RSM, and then discuss some recommendations concerning future investments in support of RSM management. Available information on the supply of RSM will be presented in Section II. The regulatory and policy framework concerning recycling RSM will be presented in Section III. A review of DOE investment in RSM recycling technology and current programs will be presented in Section IV. The current and projected industrial capacity will be described in Section V. And, finally, a discussion of issues and recommendations regarding DOE technology development interests in RSM recycling will be presented in Section VI and VII, respectively.

II. Supply- The Radioactive Scrap Metal Inventory

As several reports have indicated, there is a massive quantity of RSM that has been accumulating over the years at the various U.S. Department of Energy (DOE) facilities throughout the country. Based on the four most comprehensive reports, estimates of the mass of RSM ranges from 154,000 to 396,000 tons and includes carbon steel, stainless steel, nickel, copper, aluminum, and

lead. Additionally, according to US Environmental Protection Agency's (EPA) calculations, current and future D&D-generated RSM quantities will exceed 1,200,000 tons (S. Cohen & Associates 1995).

S. Cohen & Associates completed a thorough report for the EPA in 1995 on the subject of RSM recycling (S. Cohen & Associates 1995) which estimated a total of 154,062 tons of RSM in existing stockpiles. This estimate was based primarily on existing literature, supplemented by specific inquiries where information was questionable. DOE recently completed a report on the "Materials in Inventory Initiative" (DOE 1995) which used teams to collect data from 25 DOE sites and estimated the amount of scrap metal available for recycling to be 154,949 tons. Parsons Engineering Science, Inc., RMI Environmental Services, and the U.S. Steel Facilities Redeployment Group, contracted through the Hazardous Waste Remedial Actions Program, completed a study in 1995 (Parsons 1995) which estimated a total of 202,869 tons of RSM in existing stockpiles based on a comprehensive survey of 11 DOE facilities. Morgantown Energy Technology Center (METC) published a report in 1993 based on a collation of inventory data collected by both Quadrex Corporation and SRS Technologies (Duda 1993) from literature sources, which estimated a total of 396,306 tons of RSM in existing stockpiles.

Additionally, a large quantity of RSM is expected to be generated from future D&D activities throughout the complex. According to the METC report (Duda 1993), an additional 600,000 tons of RSM, including a large volume of high-value metals, is expected to be generated from the decommissioning of the three gaseous diffusion plants (GDP) alone. The EPA report (S. Cohen & Associates 1995) estimated that a total of 1,060,000 tons could be generated by the D&D of DOE facilities including the GDPs.

III. RSM Recycling Regulatory and Policy Framework - Initiatives and Issues

Based on input from stakeholders involved in the Recycle 2000 program, a policy development and evaluation effort led by EM-43, EM has focused the policy-making effort on recycling radioactively-contaminated carbon steel (RCCS) which is not suitable for free-release. RCCS comprises nearly 80 percent of the RSM inventory. The policy specifies that "to the degree that it is economically advantageous and protective of worker and public health, radioactively contaminated carbon steel either in storage or to be generated should be recycled." The policy goes on to specify that radioactively contaminated materials, including RCCS, generated by the EM Program, shall be decontaminated and released for unrestricted use if the material can meet the applicable criteria and decontamination is economically feasible. Otherwise, the policy specifies that the RCCS shall be fabricated into one-time-use containers for disposal of low-level wastes generated by the EM Program. The policy includes radiological guidance to clarify the safety aspect of recycling RCCS (DOE 1996).

Surface contamination limits specified for use by DOE activities are the same as those specified in the NRC Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors,"

and are well accepted. Materials with volumetric contamination are more difficult to release in an unrestricted manner. Although, DOE Order 5400.5 has allowed the release of volumetrically contaminated materials, EH-1 approval has been required and the process was difficult and time-consuming. DOE recently distributed guidance that delegates authority to site managers to approve the free release of materials that are volumetrically-contaminated with very low levels of radioactivity within certain limitations (DOE 1995-b). Further guidance on the release of volumetrically-contaminated materials is expected to be adopted as DOE develops implementation guidance for the proposed federal regulation (10CFR834) which will supplant DOE Order 5400.5. This guidance is expected to be issued soon. Additionally, the NRC and EPA are currently engaged in joint rulemaking which will address criteria for the unrestricted release of material with volumetric radioactive contamination. DOE is providing technical input to this rulemaking activity. A few DOE activities are actively recycling RSM for unrestricted use and restricted-reuse under existing DOE policy and NRC regulations.

The EPA recently completed a comprehensive study which analyzed several management options for DOE RSM (Cohen & Associates 1995). The EPA study included a thorough review of key literature concerning DOE, NRC, and international RSM recycling activity. The study reviews technical issues associated with RSM recycling and assesses the economic and health risk of five options for the disposition of RSM, including restricted-reuse recycling. The analysis suggests that both restricted and unrestricted recycling of RSM is desirable from a life-cycle cost perspective compared to direct disposal.

During the Recycle 2000 policy development process, EM-43 undertook several analyses to examine the viability of recycling RSM including a transportation risk and cost assessment, a risk analysis which assessed the limiting concentrations of RSM contamination, and a cost model. All three assessments have undergone one or more comment periods. In each of these analyses, three RCCS management options are addressed: (1) continued disposal of RCCS; (2) processing RCCS into ingots for disposal (volume reduction); and (3) processing RCCS into disposal containers for one-time use within the EM program (Warren 1995).

EM-43 developed a cost model for an economic assessment of recycling RCCS. The estimates of reasonable unit costs for recycling RCCS; including the costs for melting, casting, rolling, treating, and fabrication; ranged from \$0.92 to \$2.98 per pound of feed material. The Recycle 2000 White Paper conclusion was to use a cost of \$1.65 per pound as representative for a facility operating at a capacity and efficiency to economically recycle RCCS (50,000 tons per year). This cost includes \$0.34 per pound for melting and casting, \$0.58 per pound for rolling and treating, and \$0.73 per pound for container fabrication. The highest cost evaluated for the model, \$5.71 per pound, was based on actual invoices from Westinghouse Savannah River Company (WSRC) to Nuclear Metals Inc. to recycle 20 tons of stainless steel into 16, B-25 boxes. This higher figure was not used because of the small quantities of feed material involved (Trinity 1995). Transportation costs and the cost to dispose of secondary waste are not included in these figures. The output of the model showed that recycling RCCS into waste containers is competitive with disposal, if the disposal cost is greater than \$32 per cubic foot (Warren 1996-b).

The transportation risk and cost assessments concluded that the total risk of transporting RSM is dominated by traffic accident risks. Radiological consequences are a small part of the total risk (less than 10 percent) and, because more people reside closer to roads than rail, the total risk is higher for road transport. The risk from all scenarios is on the order of 10^{-8} fatalities per transportation mile. The cost of transportation is less than ten percent of the target unit cost of recycling RSM of \$1.65 per pound (Derived from Chen et. al. 1995).

The objective of the EM-43 risk assessment was to identify the limiting concentration of radionuclides in RCCS which could go through the recycling process while maintaining worker and public exposure levels below regulatory guidelines. The guidelines used in the evaluation were 2,000 millirem per year (mrem/yr) for workers and 10 mrem/yr for a member of the public. First, the risk model indicated that the risks posed by each of the three options considered were equivalent. Furthermore, the limiting concentrations for recycling are often more constrained by Department of Transportation (DOT) threshold limits than by exposure to either workers or the public. For example, the RCCS feed material from a uranium enrichment facility has a limiting concentration of $3.4 \text{ E}+07$ picocuries per gram (pCi/g) (which are assumed in the assessment to be uranium isotopes) based on each of two exposure scenarios; on worker handling of slag material and on public exposure to emissions from the melting facility. However, to not exceed the 2 nanocuries per gram (nCi/g) DOT threshold for the finished products, the limiting concentration of uranium in the feed material was calculated to be $3.4 \text{ E}+04$ pCi/g (Simek et.al. 1995).

In response to another workshop recommendation, EM-43 developed a standardized low level waste disposal container fabricated out of RSM. EM-43 contracted Brainard Associates to design, manufacture and test the M-100 series of boxes with the intent of promoting efficiency in the manufacture of containers from RCCS. A prototype of the container successfully completed the appropriate DOT drop test in September 1995 (Warren 1995). EM-40 and EM-30 recently issued a joint policy on the use of standardized low-level waste disposal containers for EM-generated waste, based on the M-100 series of containers.

IV. Investment- EM-50 Technology Development Initiatives

The Office of Science and Technology (EM-50) has been actively investing in technology development for recycling RSM since 1993. In conjunction with the Program Research and Development Announcement (PRDA) issued by METC, the D&D Focus Area has invested an estimated \$21 million during the past 3 years. The EM-50 funded programs are summarized in Table 1. The EM-50 investment has focused on developing the capability to recycle high-value metals. The primary industrial partners in the EM-50 program have been Carolina Metals, Inc., Manufacturing Sciences Corporation (MSC), Scientific Ecology Group, Inc. (SEG), and Molten Metal Technologies, Inc. The capability and activities of each will be discussed in Section V. The technology development programs are discussed below.

TABLE 1
OFFICE OF SCIENCE AND TECHNOLOGY INVESTMENT IN RSM RECYCLING

Principal Industrial Participant⁽¹⁾	Title	Funding in Thousands	Final Year of Funding
Carolina Metals, Inc. MSC	Stainless Steel Beneficial Reuse Demonstration	\$5,064	FY96
None	Metal Recycle Technology Development	\$299	FY95
None	Demonstration of Contaminated Metal Recycle Integration	\$649	FY95
SEG	Recycle & Reuse of RSM	\$682	FY95
MSC	Advanced Technologies for Decontamination and Conversion of RSM	\$1,761	FY96
Molten Metal Technology, Inc.	Catalytic Extraction Process for RSM	\$16,614 ⁽²⁾	FY97
	Total	\$25,069	FY97

Notes:

(1) Manufacturing Sciences Corporation (MSC), Scientific Ecology Group, Inc. (SEG).

(2) Total funding for the Catalytic Extraction Process (CEP) is \$33,228,000 through FY96. The benefit of the CEP includes both RSM recycling and mixed-waste treatment. Therefore, only half of the total EM-50 funding is presented in this table.

Stainless Steel Beneficial Reuse Demonstration

The Stainless Steel Beneficial Reuse Demonstration was funded by EM-50 to assess the practicality of recycling stainless steel RSM. WSRC subcontracted Carolina Metals, Inc. and MSC to receive stainless steel RSM, melt the metal, pour the metal into ingots, roll the ingots into sheet metal, and produce products from the sheet metal. Three types of products were initially selected for fabrication: boxes having a 100 cubic-foot volume (RD-100), 55-gallon drums (RD-55), and 85-gallon overpacks (RD-85). To date, a total of sixteen, RD-100 boxes have been delivered. Several hundred drums (RD-55 and RD-85) are currently in the fabrication process. Two of the RD-100 boxes were delivered to the Savannah River Site's (SRS) High Level Waste Organization to be used for the storage of mixed waste. One additional box was delivered to the site's Tritium Organization to store 4,000 Curies of tritiated mixed-waste.

Managers for the Transportable Vitrification System (TVS) in Oak Ridge identified a need for 40 stainless steel containers for vitrified wastes. These containers could be manufactured from approximately 8 tons of stainless steel RSM available from SRS and Los Alamos National Laboratory. Because these would otherwise have to be commercially manufactured in a limited quantity, the cost to manufacture these containers from RSM is expected to be closer to the cost of a virgin material product. They may be more economical for DOE than virgin material containers, when the avoided cost of disposal is considered. A total of 20 TVS containers have been delivered.

A third opportunity for this demonstration is the manufacture of stainless steel heavy water (D₂O) storage containers for SRS. The design of these drums is different from either the RD-55 or the RD-85 drums. These containers can be manufactured from the more than 20 tons of scrap D₂O drums at SRS. A contract was recently signed with MSC to manufacture 100 D₂O drums.

Metal Recycle Technology Development

The objective of this program was to support activities of the D&D Metals Recycle Technical Support Group at Oak Ridge. The program also provided early support to the SRS Stainless Steel Recycle Program. An industry solicitation was issued to provide Phase I funding to several firms to investigate the potential to decontaminate technetium-contaminated nickel from the K-25 GDP by melt-refining. None of the firms were successful within the scope of this program.

Demonstration of Contaminated Metal Recycle Integration

The Western Environmental Technology Office completed a study which analyzed the feasibility of recycling RSM in a 30,000 ton per year regional mill located in the western United States. The report, "Feasibility Analysis of a Western U.S. Radioactive Scrap Steel Mill," (Nichols 1995) outlined a course of action to recycle RSM safely and cost effectively. The purpose of the study was to establish a conceptual design that integrates commercial steel mill technology with RSM processing to produce carbon and stainless steel sheet and plate at a grade suitable for fabricating into radioactive waste containers. The report examined the economic feasibility of constructing the micro-mill at a western location. The report concluded that it should be possible to profitably recycle RSM into high quality steel sheet and plate by charging a processing fee equal to low-end burial costs. The report also provided recommendations, directed to a consortium of vendors and customers, for implementation of the plan.

Recycle & Reuse of Radioactively Contaminated Scrap Metal

Under this PRDA, SEG undertook a project to decontaminate about 70 tons of surface-contaminated scrap metal from Fernald and convert it to waste containers. A primary objective of this project was to investigate the economics of processing RSM in a larger, more efficient commercial steel mill with inherent large-scale rolling capabilities. The metal was surface-decontaminated by shot blasting, prior to melting, to allow it to be handled outside of a

radiologically controlled area for rolling. The commercially rolled material was fabricated into B-25 and B-12 boxes by SEG. A total of nine, B-25 boxes and four, B-12 boxes were fabricated from the Fernald material. The scrap material resulting from the box manufacturing process was recycled into shielding blocks. Additional work was performed under this PRDA to investigate the economics of alternative container types which could be manufactured using RSM including reinforced concrete containers for vitrified radioactive wastes. EM-50 funding for this project ended in FY95 with some FY96 activity continuing on carry-over funding. A final report from this project is expected soon.

Advanced Technologies for Decontamination and Conversion of RSM

The objective of this project is to develop and successfully demonstrate a technically-effective and cost-efficient process to remove or reduce the radioactive contamination in nickel. The scope also includes the study of options to recycle the nickel as a constituent in alloys to produce new metal products. Under this PRDA, MSC determined that the predicted level of decontamination could not be achieved using a melt-refining technique. They are investigating distillation of nickel to remove technetium contamination based on the observation that condensed vapors from contaminated nickel contained no measurable activity.

A total of 11 ingots of 304 stainless steel have been produced in MSC's vacuum induction melting (VIM) furnace located in Oak Ridge. Machining, rolling, heat treating, welding, forming, corrosion testing, and mechanical property testing confirmed that the stainless steel produced from technetium-contaminated nickel was metallurgically identical to stainless steel produced in a similar manner with uncontaminated nickel. MSC has also investigated potential restricted end-use products including, multipurpose canisters for the containment of spent reactor fuel, high level waste vitrification containers, and boxes and drums for waste disposal. MSC, in partnership with Covofinish, has performed preliminary research activities for descaling stainless steel using nonhazardous chemicals. MSC is currently testing a pilot-scale electro-refining cell, constructed by Covofinish, to decontaminate technetium-contaminated nickel.

Catalytic Extraction Processing of Contaminated Scrap Metal

Under a PRDA with METC, Molten Metal Technology, Inc. applied their patented Catalytic Extraction Process (CEP) to RSM. RSM feed materials were fed into a sealed molten iron bath operating at 2,000° K. Through the addition of selective reactants, the constituent elements recombine into three phases; metal, ceramic, and gaseous. Theoretically, the metal phase is no longer contaminated and, although it has not yet been demonstrated, may be reusable without radiological restriction. The dense, low-volume ceramic phase contains the majority of the radioactive contaminants. The process, originally developed as a metal decontamination process, is also effective as a mixed waste treatment system.

In summary, OST has mainly focused their investment on recycling or decontaminating the high value metals in the scrap inventory, primarily stainless steel and nickel. The investment has

addressed a broad range of issues and demonstrated the technical capability to effectively recycle these high value metals into products for restricted-reuse within the DOE complex. The next section will examine the capability of the RSM recycling industry.

V. Industrial Capacity

Industry has developed a small, but effective, capacity to recycle RSM. Based on information obtained directly from industry, the current capacity to melt and cast RSM is approximately 35,000 tons of feed material per year. This capacity is divided among the industrial partners from the EM-50 technology development program and is presented in Table 2. An additional 27,700 tons per year of RSM recycling capability is expected from M4 Environmental, Inc. and the National Conversion Pilot Project at Rocky Flats Environmental Technology site.

Manufacturing Sciences Corporation

MSC is the only fully integrated recycler in the industry today. At their two plants in Oak Ridge, they have the capability to melt, cast, roll, and fabricate products from RSM. At their first facility, they have two 3/4-ton VIM furnaces which were converted from their original design to melt and cast uranium metal. This facility also includes state-of-the-art rolling and fabricating equipment. MSC recently invested \$28M of private funding in a new facility, also in Oak Ridge, which contains a 6-ton VIM furnace and state-of-the-art remote handling and decontamination equipment. MSC estimates the combined capacity of these two facilities to be 10,000 tons of feed material per year (MSC 1996).

MSC recently won a contract awarded by Lockheed Martin, Oak Ridge, to recycle 700 tons of metal from the K-25 GDP into boxes and drums. MSC will manufacture an estimated 3,500 containers from both stainless steel and carbon steel RSM. MSC also is under contract with Fernald to perform an engineering study to recycle an estimated 1,400 tons of contaminated copper. Under this project, MSC will decontaminate 30 tons of copper. MSC has also submitted an unsolicited proposal, under the National Conversion Pilot Project, to refurbish and convert a former uranium metal processing facility at Rocky Flats Environmental Technology site into a RSM recycling facility. They were awarded a sole source contract to decontaminate and restore the facility, and are expected to bid on the lease to use the facility.

Carolina Metals, Inc.

Carolina Metals, Inc., a subsidiary of Nuclear Metals, Inc. (NMI), has a small facility in Barnwell, SC dedicated to recycling RSM. The facility contains two, 1.75-ton air induction melting (AIM) furnaces in a controlled atmosphere enclosure. Carolina Metals has the capability to melt RSM and cast either slabs or ingots. Their facility does not have a rolling capability but can perform limited fabrication of RSM products. The estimated capacity of this facility is 500 to 1000 tons per year depending on the size of the feed material (NMI 1996).

TABLE 2
INDUSTRIAL CAPACITY TO RECYCLE RSM

Company	Location	Melt Capacity (tons per year)
Manufacturing Sciences Corporation	Oak Ridge, TN	10,000
Carolina Metals	Barnwell, SC	500-1,000
Scientific Ecology Group	Oak Ridge, TN	24,000
Anticipated in FY-97 or 98		
M4 Environmental	Oak Ridge, TN	25,000 ⁽¹⁾
National Conversion Pilot Project	Rocky Flats, CO	2,700

Note:

(1) The M4 Environmental facility is expected to have a melt capacity of 25,000 tons per year when fully operational in FY98. When initially complete in FY96, the capacity will be 2,500 tons per year, expanding to 5,500 tons per year in FY97.

NMI recently submitted an unsolicited proposal to SRS to construct a facility in South Carolina which could melt and roll 20,000 tons per year of RSM at a cost of about \$1 per pound, which is competitive with costs identified in Section III (\$0.92 per pound for melting and rolling), in exchange for a multi-year commitment from SRS.

Scientific Ecology Group, Inc.

SEG has a relatively large RSM recycling facility in Oak Ridge. The facility includes a 20-ton AIM furnace equipped with a high-efficiency particulate air filtration unit. The estimated capacity of this facility is 24,000 tons of feed material per year (SEG 1996). Like Carolina Metals, Inc., SEG has no inherent rolling capability. SEG has been recycling RSM since 1993 when they began melting and casting shield blocks for high-energy physics applications.

SEG has invested a substantial amount of private funding in the development of commercially viable RSM products. Using private funding, SEG has continued development of cost-effective applications for recycling RSM, which began under the METC PRDA, particularly the reinforced-concrete vitrification waste containers. They used private funding to pursue an electro-chemical process to remove technetium contamination from nickel, as opposed to the melt-refining and evaporative processes being funded by other EM-50 projects.

SEG is currently working with Fernald and Oak Ridge personnel on a small-scale demonstration under an agreement with the State of Tennessee to allow the controlled temporary transfer of volumetrically contaminated RSM, which has been melted and cast, to be rolled in non-radioactively controlled facilities. The processed metal will then be returned to SEG for product fabrication. This arrangement could significantly improve the economics of recycling RSM in Tennessee, and provide a competitive edge to SEG which has not invested in a dedicated rolling capability. According to SEG, outsourcing the rolling process would reduce rolling costs from about \$2 per pound to about \$0.05 per pound. SEG plans to recycle about 700 tons of RSM from Fernald and Oak Ridge during this demonstration.

Molten Metal Technology, Inc

Molten Metal Technology, Inc. is the developer of the patented CEP which converts mixed-waste and also recycles RSM. The primary benefit of this technology is the delisting of certain DOE mixed wastes thereby avoiding long-term storage and management costs. Based on the potential profit from this aspect alone, Molten Metal Technologies formed a limited partnership with Lockheed Martin in Oak Ridge named M4 Environmental, Inc. (M4). M4 is licensed to market use of the CEP and has invested approximately \$20M in a new facility in Oak Ridge. The facility is currently under construction. The capacity of this plant is estimated to be 25,000 tons of contaminated feed material per year when fully operational in FY98.

National Conversion Pilot Project at Rocky Flats

MSC identified the potential capability of surplus equipment located at Rocky Flats and submitted an unsolicited proposal to decontaminate the building and equipment and place it back in service as a RSM recycling center. Based on the proposal, DOE established a three year Cooperative Agreement with MSC to decontaminate and reactivate the equipment under the National Conversion Pilot Project. DOE will later solicit competitive bids for the lease to occupy the buildings and use the equipment.

The facility includes approximately 200,000 square feet in four buildings. The facility contains 8, 3/4-ton VIM furnaces similar in design to the two original furnaces in the MSC facility in Oak Ridge with a total estimated capacity of 2,700 tons of feed material per year. The facility also contains adequate casting, rolling and fabrication equipment to manufacture waste containers for reuse within the DOE complex.

VI. Discussion

It has been estimated that 1.2 million tons of RSM will be available for recycling over the course of the next 30 years from dismantlement of the DOE nuclear weapons complex. The regulatory and policy framework currently exists to support recycling this RSM by both decontamination and free-release and by recycling for restricted-reuse. Studies have shown that recycling RSM

can be safe and cost-effective on a large-scale, and there are no technological barriers to RSM recycling. The final barriers to recycling RSM on a large scale are primarily economic.

A principle factor in the economic decision to recycle is the cost of disposal. The low disposal cost of many onsite disposal facilities detracts from the economic motivation to recycle RSM. However, as demonstrated by the Recycle 2000 model, recycling RSM into reusable products on a large scale can be economically competitive with the disposal option when the cost of disposal exceeds \$32 per cubic foot of waste. Issuance of the RCCS recycling policy will be an important step to institutionalize a commitment by DOE to recycle RCCS over the next three years, if it is found to be economically viable and accepted by local stakeholders. A draft methodology was prepared at Fernald Environmental Management Project (FEMP) to assess RSM disposition alternatives in which both economic and non-economic factors are weighed and evaluated (Yuracko 1996). They include; direct cost and benefits; socio-economic analysis; and environment, safety, and health analysis. This process allows the weighted analytical evaluation of the many complex issues surrounding RSM disposition. A model such as this one may make the decision on how to disposition RSM more quantitative in the future.

Decontamination processes are effective and fairly well developed, although not optimized for large-scale operations. Typical costs to decontaminate and survey scrap metal which is surface-contaminated with low-levels of radioactivity are in the range of \$1.50 to \$1.63 per pound of material (MSC 1996 and FERMCO 1996). Comparing this figure to the current and projected cost to recycle RSM for restricted reuse suggests that the maximum amount of RSM should be recycled by decontamination and free-release. There are substantial savings available from releasing metals for unrestricted use for three reasons: 1) avoided disposal costs; 2) avoided RSM recycling/processing costs, and; 3) returned asset value of scrap metal.

That portion of available, slightly-contaminated RSM which cannot be cost-effectively decontaminated should be recycled into products for reuse within the complex. An example of a low-production cost product which is currently being manufactured from RSM are shield blocks for high-energy physics applications. The standardized M-100 container, developed by EM-43, should minimize the production cost for this common size of waste container. Other types of products which should prove cost-effective to manufacture from recycled RSM are specialty containers which would otherwise have to be special ordered or manufactured in limited quantities. The premium cost of these specialty products manufactured from virgin materials may accommodate the higher cost of recycling and still provide a cost-benefit to DOE. Coincidentally, several EM-50 projects are currently pursuing the development of these specialty containers. MSC is manufacturing stainless steel containers for TVS vitrified wastes and will soon be manufacturing D₂O drums under the Stainless Steel Beneficial Reuse Demonstration. SEG is currently investigating the process to manufacture reinforced-concrete containers for wastes from the FEMP vitrification process. A clear advantage of these reinforced-concrete containers is that the metal reinforcement is spun and does not have to go through expensive rolling processes.

Of concern is how much material will be suitable for recycling by melting and fabricating into recycled products and, consequently, how much should be invested in this recycling area compared to decontamination and free-release. Theoretically, every portion of the anticipated 1.2 million tons of RSM will be best suited for one of the three options mentioned at the outset of this paper. Some portion will be unsuitable for recycling, at any cost (e.g., due to excessive contamination or degradation), and should be disposed of as waste. If the remaining material can be cost-effectively decontaminated, then it can be recycled as clean scrap. If the material cannot be cost-effectively decontaminated for free-release, then the material can be recycled for restricted reuse. As DOE develops experience decontaminating and releasing large volumes of material and recycling material for restricted reuse, it will be able to better define the appropriate disposition for a given type of RSM based on actual cost data and rapid material characterization.

Experience from around the complex suggests that the amount of material which can be cost-effectively decontaminated for free-release may be substantial. However, there is currently insufficient data to quantitatively ascertain how much of the anticipated 1.2 million tons of RSM will fall into this category. The following examples provide insight into the effectiveness of current metal decontamination processes:

The Fernald Environmental Management Project successfully decontaminated and free-released 58% of the steel from the decommissioning of Plant 7. The remainder of the structural steel from Plant 7 was mangled during the demolition process resulting in surfaces that could not be decontaminated or surveyed for release. Fernald plans to add clauses in future demolition procurement packages that will result in structural steel that is more amenable to decontamination and survey processes (FERMCO 1996-b).

The Savannah River Site established a decontamination facility that processes metal for free-release. Facility personnel have been selective about the material that is accepted for decontamination but indicated that 100% of the metal that has undergone decontamination processes has been successfully decontaminated. Interviewed personnel indicated that the greatest problem they are encountering is accurately surveying the inside of decontaminated piping (WSRC 1996).

Scientific Ecology Group, Inc. (SEG), determined that a substantial portion of the RSM they were contracted to process (possibly as much as 90%) could qualify for free-release, and be recycled as clean scrap, with little decontamination effort (SEG 1996).

In the NRC Regulatory Guide "Technology, Safety and Costs of Decommissioning a Reference Uranium Fuel Fabrication Plant," it is estimated that 88% of equipment, pipes, ducts, hoods, conduit, and fixtures can be decontaminated and free-released (NRC 1980).

The RSM in the foregoing projects may not be representative of all the RSM currently in inventory. Factors which may limit the success of decontamination and free-release efforts for RSM include the cost of subsequent material handling and characterization, the degree of contamination, and material degradation due to weathering. However, the favorable success rate for decontamination and free-release of this material suggests that a large percentage of the

estimated 1.2 million tons of RSM expected to be available for recycling may be most cost-effectively recycled by decontamination and free-release to commercial markets.

Another factor which will substantially impact DOE's RSM recycling efforts will be the eventual acceptance and large-scale implementation of current and future guidance concerning the release of volumetrically-contaminated materials. Currently, very little volumetrically-contaminated metal is being free-released, regardless of the contamination levels. This may be, in part, due to unfamiliarity and lack of acceptance of the recent DOE Order 5400.5 guidance which establishes a process for releasing volumetrically-contaminated material. Additional guidance facilitating the free release of RSM is anticipated with the distribution of implementation guidance supporting the issuance of 10CFR834.

Many of the recent programs that involved the restricted-reuse of RSM involve metal that could have been free-released. For example, RSM in the Oak Ridge/SEG recycle program is contaminated at one-tenth of the release value provided in the recent DOE Order 5400.5 guidance (WPI 1996). At this low level, SEG is able to release metal to a commercial steel mill for cost-effective milling processes. It is not clear if metal could be released in a similar fashion if only higher-level volumetrically-contaminated RSM was used. Higher contamination levels may hinder or preclude cost-effective RSM recycling by fabrication into reusable products.

For pieces that do not lend themselves well to decontamination, metal melting can be considered if, again, the guidance for the release of volumetrically-contaminated metal is used. As stated previously, the target cost for melting and casting RSM is only \$0.34 per pound; or about 20% of the total target cost of \$1.65. Configuration or accessibility is no longer an issue when metal is melted and contaminants are homogeneously mixed throughout the metal matrix resulting in an accurate determination of specific radioactivity.

VII. Recommendations

The investigation and analysis associated with this study leads to three recommendations to further the interests of DOE technology development in recycling RSM. First, DOE needs additional information on the quality of the RSM inventory. Specific information on the quantity of RSM which has a high potential of being cost-effectively decontaminated and released, and the quantity which is not suitable for either decontamination or melting and fabrication into reusable products, is essential to making informed decisions regarding investment in support of RSM recycling. Feedback from the complex suggests there is a potential that a relatively large portion of the projected inventory could be cost-effectively decontaminated for free-release. With this in mind, there may not be sufficient inventory to warrant capitalizing a facility capable of melting and fabricating products from RSM at high production rates.

Second, DOE should promote policy and technology which enhances implementation of guidance on the free-release of materials with inconsequential levels of volumetric

contamination. If sites are reluctant to implement the guidance, issues driving the reluctance should be identified and addressed from a complex-wide level. The wide use of this guidance should have a significant impact on the inventory of RSM which can be cost-effectively decontaminated for free release.

Lastly, if the quantity of material suitable for restricted-reuse recycling, and the potential savings in waste management costs, is sufficient to warrant continued investment in recycling technology, DOE should continue to influence development of economical recycled products and the market for those products. The future demand for cost-effective recycled RSM products will be important to determining the long-term viability of recycling RSM for restricted-reuse.

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The M-100 Container Program: Value Analysis and Testing

James D. Greaves
Brainard Associates, Inc.

(Paper not available)

Session 2 - Radioactive Scrap Metal Recycle Programs at DOE Sites
Panel Discussion

Panel Discussion
Radioactive Scrap Metal Recycle Programs at DOE Sites

Leader

Dan Burns, Trinity Environmental Systems, Inc.

Panel

Bill Boettinger, Westinghouse Savannah River Company
John Clinard, Lockheed Martin Energy Systems-Oak Ridge
Thomas Fewell, LMITC-Idaho National Engineering Lab
Rebecca Winston, LMITC-Idaho National Engineering Lab
Pauline Hartwig, Atomic Energy of Canada Limited
Richard Meehan, U.S. DOE-Oak Ridge Operations Office
Karin King, U.S. DOE-Oakland Operations Office
Keith Rule, Princeton Plasma Physics Lab
Pete Yerace, U.S. DOE-Fernald Area Office
Scott Thoren, Bechtel Hanford, Inc.

**DOE Site Representative Panel Session
Beneficial Reuse Conference
October 22, 1996**

Panelists

Bill Boettinger	Westinghouse Savannah River Company
John Chnard	LMES
Thomas Fewell/Rebecca Winston	LMITC, INEL
Pauline Hartwig	AECL
Richard Meehan	USDOE, Oak Ridge Operations Office
Karin King	USDOE, Oakland Operations Office
Keith Rule	Princeton Plasma Physics Laboratory
Pete Yerace	USDOE, Fernald Area Office
Scott Thoren (unable to attend)	Bectel Hanford Inc.
Dan Burns (facilitator)	Trinity Environmental Systems, Inc.

The purpose of this panel session is to provide the conference attendees with a deeper understanding of the RSM and Recycle Programs at various DOE sites. Each of the panelists has been invited to share and communicate the scope, objectives, implementation initiatives, operational and budgetary constraints, and other considerations associated with the responsible management of RSM and other waste which may be candidates for alternative disposition.

The session is intended to be an open forum of dialog and question and answers between the panel and attendees. No presentations are scheduled.

In preparation for the session each of the panelists were requested to provide open and terse responses to 18 questions. The questions and responses are intended to be a point of departure for the session and to stimulate discussion. The questions are the result of informal interviews with personnel throughout the country with an interest in the topics of RSM and Recycling.

I would like to thank each panelist for their effort, participation, and insight. The panel should be commended for their openness and willingness to share their insights.

The handout contains the responses from each of the sites for the following questions:

BACKGROUND AND NEEDS

1. What is your site's current inventory of RSM?
2. What is your site's anticipated generation of RSM?
3. What types of RSM are in inventory and anticipated at your site?
4. What are your site's RSM classifications and what are your site's segregation practices.
5. What disposition options for RSM are employed at your site and what is the current distribution of quantities of RSM managed in each option?
6. What is the cost of each of the disposition/management options mentioned above? Please include cost for each significant element and assumption of the cost (e.g., packaging efficiency, inspection, burial, etc.)
7. Does your site employ an unrestricted release program? Does the program include both surface and volumetric standards?
8. What are the release criteria?
9. Does your site have an on-site decontamination facility? If yes, please describe the scope, capacity, capability, utilization, cost and funding source of the facility.
10. Does your site subcontract for decontamination services? If yes, please describe the scope, capacity, capability, utilization, cost and funding source of the vendor.

ORGANIZATIONAL

11. Who is chiefly responsible for RSM management at your site?
12. Who decides on the disposition/management option employed for RSM when it is generated?
13. What criteria is used to decide on the disposition/management option?
14. If the answer to question 11 and 12 are different personnel or entities, please describe the tools used to coordinate and provide consistent management decisions?
15. Does your site have a focused Recycle Program? If yes, please describe the scope and objectives of the program and identify key personnel.

INITIATIVES AND IMPEDIMENTS

16. Please list your site's current or near future initiatives involving RSM and/or recycling.
17. Does your site currently purchase or plan to purchase products fabricated from RSM? If so, please identify the candidate products and anticipated needs.
18. What are the three most significant impediments to initiating or/and sustaining a RSM and Recycle program at your site?

1. What is your site's current inventory of RSM?

Hanford

- Very little left from Clinch River (currently being dismantled)
- Other storage areas cleaned up
- Lead - 9 million pound

Oakland Operations Office

- SLAC - 150 tons
- LBNL - 3200 tons of steel and copper - still intact (mostly contained in shutdown Betatron facility)

Oak Ridge Operations

- < 1 Billion Pounds

Savannah River Site

- Over 10,000 tons of stainless steel readily available
- About the same amount of carbon steel

Princeton

- 5 to 10 tons of volume activated stainless
- 5 tons of carbon steel

AECL Chalk River (Decommissioning Branch)

- Unknown

Fernald

- Structural Steel
 - 1500 tons from Plant 4 Implosion
 - 300 tons from Plant 7 Implosion (returned from ALARON)
- Copper
 - 1250 tons of motor windings
 - 65 tons of ingots

INEL

- Minimal

2. What is your site's anticipated generation of RSM?

Hanford

Oakland Operations Office

Fluctuates and is dependent upon facility closing, upgrades and repairs to the accelerator

Oak Ridge Operations

- < 100 tons per year, *for now*

Savannah River Site

Unknown at this time because of site mission uncertainty. If, for example, an area shuts down because of lack of mission, much equipment would be excessed causing the creation of much RSM.

Princeton

- 250 tons of high purity copper
- 17.5 tons of titanium
- 400 tons of stainless steel
- 10 - 20 tons of Aluminum

AECL Chalk River (Decommissioning Branch)

A quantitative assessment has not been done. However, it is estimated that significant volume of RSM will be generated from planned Decommissioning Branch activities

Fernald

From OU3 Demolition

- 15,000 tons structural steel (63,000 unbulked cu.ft.)
- 1,730,000 unbulked cu.ft. "inaccessible" metals
- 151,000 unbulked cu.ft. "process related" metals
- 7,100 unbulked cu.ft. lead

INEL

- 23.5 Million pounds

3. What types of RSM are in inventory and anticipated at your site?

Hanford

- Carbon
- Stainless
- Titanium

Oakland Operations Office

- Iron
- Stainless Steel
- Copper
- Aluminum
- Carbon Steel

Oak Ridge Operations

- Iron
- Nickel
- Copper
- Aluminum

Savannah River Site

- Most of the RSM consists of excessed equipment:
- Heat exchangers
 - cranes
 - evaporators,

Princeton

Stainless, unknown time frame possibly FY2000

AECL Chalk River (Decommissioning Branch)

- Stainless Steel
- Brass
- Copper
- Aluminum
- Carbon Steel
- undifferentiated scrap

Fernald

- Carbon Steel (structural and light gauge)
- Copper
- Lead
- Stainless
- Nickel Alloys

INEL

Carbon Steel

4. What is your site's RSM classifications and what are your site's segregation practices?

Hanford

Princeton

- High grade copper
 - Stainless Steel
- Segregated each in B-25 containers in preparation for shipping. Beginning detailed characterization

Oakland Operations Office

All Low-Level Waste

- Surface contaminated
- Volumetrically contaminated
- Strong attempt is made to segregate material (metal) types

AECL Chalk River (Decommissioning Branch)

Decommissioning Branch classified RSM according to IAEA Safety Series 6 for transportation off-site. Decommissioning is currently operating a pilot-scale waste segregation facility to develop methodologies for segregation and clearance.

Oak Ridge Operations

- Contaminants are; U & daughters + Tc + Np
- Sorted by metal type & sometimes by contaminant; particularly the EU contaminated pile is separated from the DU pile

Fernald

See OU3 RI/FS for classification category definitions
Segregation practices are evolving

Savannah River Site

- In general we classify RSM as being:
- volumetrically versus surface contaminated
 - radioactive versus mixed contaminated
 - TRU versus FP versus Tritium contaminated (Tritium, because of its ability to diffuse into a metal lattice structure is unique at SRS)

INEL

Varies program to program

5. What disposition options for RSM are employed at your site and what is the current distribution of quantities of RSM managed in each option?

Hanford

- | | |
|------------------------|--------|
| • Decontamination | ~ 1.5% |
| • Re-use (tanks, etc.) | ~ 0.5% |
| • Burial | ~ 98% |

Oakland Operations Office

- | | |
|----------------------------------|-----|
| • Waste Disposal (LLW & Indust.) | 50% |
| • Re-use and Recycle | 50% |

Oak Ridge Operations

- | | |
|-------------------------------------|--|
| • Shield Blocks (SEG) | |
| • Disposal | |
| • Value added product manufacturing | |
| • some free release | |

Savannah River Site

Disposition options are:

- bury
- store
- recycle

For RSM which could be recycled we are trying to eliminate option 1 (burial). The issue is one of trying to determine what can be recycled economically.

Princeton

- | | |
|--------------------------------|-----|
| • Survey and free release | 10% |
| • Store for decay | 60% |
| • Store for recycle | 20% |
| • Dispose as radioactive waste | 10% |

AECL Chalk River (Decommissioning Branch)

- | | |
|------------------------------------|------|
| • Rad Waste Storage | >99% |
| • Off-site Recycling | <1% |
| • Decontamination and Free Release | <1% |

Fernald

Being evaluated by "Decision Methodology for Fernald Scrap Metal Disposition Alternatives."

Options include:

- on-site disposal
- off-site disposal
- on-site decon and free release
- off-site decon and free release
- Recycle 2000 type scenario

INEL

Land Disposal

**6. What is the cost of each of the disposition/management options mentioned above?
Please include cost for each significant element and assumption of the cost (e.g., packaging efficiency, inspection, burial, etc.).**

Hanford

- Burial (LLW) ~ \$18/cu.ft. (burial costs only, doesn't include containers, loading, packaging, inspections, etc.)

Princeton

- Survey & Free Release - 0.5 to 1 ton per hour @ \$60/hr.
- Store for decay - \$6/sq.ft plus packaging (B-25, \$700, holds 4 tons max., w/30 sq.ft. footprint, \$180) \$880 per year for 4 tons.
- Store for recycle - Same as 2
- Dispose as LLW - 4 tons per B-25, 90 cu.ft. burial @ \$30/cu.ft. = \$3400 + 1200 (trans.) = \$ 4600

Oakland Operations Office

- LLW Disposal - \$ 3,000/cu.ft.
- Re-use & Recycle - \$1,000 to \$3000/cu.ft.

AECL Chalk River (Decommissioning Branch)

- Not Available

Oak Ridge Operations

- Shield blocks ~ \$1.30/lb
- Disposal ~ \$1.00/lb
- Products ~ \$2 to 3/lb
- Decon for Free release ~ \$1.00/lb

Fernald

Good question! We're trying to nail that down.

Savannah River Site

Costs are so dependent on specifics that a generalization can not be made. Having recognized this, the site has stopped publishing yearly cost numbers for use by potential dispositioners. A new assessment system is being initiated.

INEL

Varies program to program

**7. Does your site employ an unrestricted release program?
Does the program include both surface and volumetric standards?**

Hanford

- Yes
- Yes

Princeton

Yes, not applicable to volumetric unless you can prove that material is at or below background,
Surface contamination release is applicable to 10CFR835 standards in dpm/100cm2

Oakland Operations Office

OAK does employ an unrestricted release program and yes it does include both surface and volumetric standards

AECL Chalk River (Decommissioning Branch)

Yes, we employ an unrestricted release program, and it includes both surface and volumetric standards.

Oak Ridge Operations

Only surface free release

Fernald

Yes, currently only surface standards are utilized , however, we plan to pursue volumetric release opportunities in the not-too-distant future.

Savannah River Site

We release only surface contaminated items that fall below the release limits. No volumetrically contaminated items are released.

INEL

Yes, In accordance to DOE Order 5400.5, minimal quantities released.

8. What are the release criteria?

Hanford

- Surface from 10CFR835
- Volumetric from Hanford Site Waste Acceptance Criteria

Oakland Operations Office

- Material which can be sampled is verified via spectral analysis. Other material is surveyed (100%) w/a 1x1 sodium Iodide detector
- All release is based on "no rad added" i.e., no detectable non-natural radioactivity is released

Oak Ridge Operations

- DOE Order 5400.5 ~ NUREG 1.86

Savannah River Site

- Standard surface release criteria

Princeton

- <1000 dpm/100cm² - Beta/Gamma
- <1000 dpm/100cm² - tritium
- < or = Background using micro-rem meter

AECL Chalk River (Decommissioning Branch)

- 1 Bq/cm² or 1 Bq/g for Beta/Gamma
 - 0.2 Bq/cm² or 0.2 Bq/g for Alpha
- Note:* 1 Bq = 27 pCi 0.2 Bq = 5.4 pCi

Fernald

- DOE Order 5400.5 ~ NUREG 1.86

INEL

- DOE Order 5400.5

9. Does your site have an on-site decontamination facility? If yes, please describe the scope, capacity, capability, utilization, cost and funding source of the facility.

Hanford

- Yes, T-Plant Canyon for large items, smaller facility for small items
- Funded by project

Oakland Operations Office

No, Decon facilities. Decon is taking place on a limited basis at ETEL using various tools in the RadWaste Management Facility

Oak Ridge Operations

Not used, all metal decon is off-site

Savannah River Site

A decontamination facility is in the planning phase

Princeton

No

AECL Chalk River (Decommissioning Branch)

The Chalk River Laboratories site has a steam decontamination facility operated by Waste Management Operations.

Fernald

Yes, (a.k.a. the FEMP Material Release Facility MRF).

- water wash
- steam/detergent wash
- abrasive blasting

Capacity and production rates are still being defined. Funding comes from EM-30 and EM-40 (and EM-77?). Initial cost estimate is \$0.27/pound

INEL

Yes, these facilities are primarily for Decon of components

10. Does your site subcontract for decontamination services? If yes, please describe the scope, capacity, capability, utilization, cost and funding source of the vendor.

Hanford

Yes, will survey and release material, funded by project

Oakland Operations Office

Not to date, except for HAKE and Associates for some lead at ETEL. EM-30 funded.

Oak Ridge Operations

Yes, some small test cases.

Savannah River Site

A Basic Ordering Agreement (BOA) has been issued in conjunction with the site's Large Equipment Disposition initiative.

Princeton

No

AECL Chalk River (Decommissioning Branch)

No

Fernald

Not routinely, but we have in the past (large scale subcontracts with ALARON, SEG, MSC, etc.).

INEL

11. Who is chiefly responsible for RSM management at your site?

Hanford

Individual Facility owners and generators.

Oakland Operations Office

Waste Management and operational Health Physics groups.

Oak Ridge Operations

ER Program Office (LMES + DOE/ORO)

Savannah River Site

The Solid Waste Management Division is primarily responsible for RSM management. Each generating division must fund its disposition activities. The Facilities Decommissioning Division will play an active role.

Princeton

The ERWM branch, EM-30 personnel, small organization of 6 - all are cross trained

AECL Chalk River (Decommissioning Branch)

AECL Waste Management Operations

Fernald

Jointly shared by Facilities Demolition and Waste Management organizations.

INEL

Environmental Management, J.A. Vanuliet, Deputy General Manager

12. Who decides on the disposition/management option employed for RSM when it is generated?

Hanford

Facility owners and/or generators (whichever is funding the generation and disposition.

Oakland Operations Office

Waste Management and operational health physics groups.

Oak Ridge Operations

LMES working with DOE/ORO (Site Office).

Savannah River Site

The generating division in conjunction with the Solid Waste Division and the Facilities Decommissioning Divisions will decide the option to be employed.

Princeton

Cognizant engineer with review and approval of health physics and ERWM waste engineers.

AECL Chalk River (Decommissioning Branch)

For AECL Decommissioning projects, the project manager, in consultation with myself (Pauline Hartwig) and the Waste Management Operations, performs the disposition options analysis

Fernald

Same as 11; of course DOE-FN has the final authority, with input from EPA, FRESH, etc.

INEL

Project/Program Manager.

13. What criteria is used to decide on the disposition/management option?

Hanford

Cost benefit analysis.

Oakland Operations Office

- type of material
- radiation level
- isotopic breakdown

Oak Ridge Operations

Cost + Politics + law = Uncertainty

Savannah River Site

The least cost option criterion ranks first. Funding availability is always an issue.

Princeton

Potential future use, level of hazard to personnel and environment, potential for free-release, potential for recycle

AECL Chalk River (Decommissioning Branch)

For AECL Decommissioning projects, the criteria are:

- cost
- dose
- contamination control
- schedule impacts, volume reduction
- potential for generation of secondary wastes, ease of packaging and transport

Fernald

Decision Methodology for Fernald Scrap Metal Disposition Alternatives "takes cost, schedule, local economic, institutional, social, environmental, public health, and worker safety impacts into consideration.

INEL

Cost and DOE Order Criteria

14. If the answer to questions 11 and 12 are different personnel or entities, please describe the tools used to coordinate and provide consistent management decisions.

Hanford

Oakland Operations Office

Oak Ridge Operations

We have not yet developed a consistent decision methodology. We are studying the options/issues/fallout.

Savannah River Site

The site is currently undergoing a transition to a new Integrating Contract with additional partners. Details are yet to be communicated/determined.

Princeton

Excellent question, a form is used to justify the storage or other disposition with review signatures.

AECL Chalk River (Decommissioning Branch)

Management decisions within the Decommissioning Branch use a central RSM Recycling co-ordinator (myself).

Fernald

INEL

15. Does your site have a focused Recycle Program? If yes, please describe the scope and objectives of the program and identify key personnel.

Hanford

Yes, paper, chemicals, and batteries, clean metal (note - does not deal with rad contaminated material).
Rick Dahlin (509) 376-6093

Oakland Operations Office

No, recycle program in a formal sense. When enough material is accumulated a specific exemption is filed with the state.

Oak Ridge Operations

Yes, based on waste min. Description of recycled products remains in question because of free release uncertainties.

Savannah River Site

Yes, the Stainless Steel Beneficial Reuse Program. To date the focus has been on stainless steel because of its high value relative to carbon steel. About half of the site's RSM is stainless. Personnel devoted to the program are Bill Boettinger, Dale Kemp, and Rod Stewart of WSRC and Sherron Johnson and Karen Hooker of DOE.

Princeton

Program is just beginning. Have dedicated B-25 containers and storage locations for stainless steel. Developing characterization and description methods.
Objective - prevent disposal of high value metals in anticipation of recycling opportunities/policy
Keith Rule, Scott Larson, S. Elwood

AECL Chalk River (Decommissioning Branch)

The recycle program at the CRL site is for inactive materials from the administrative portions of the site. It is operated by Waste Management Operations.

Fernald

Yes, Its basically organized to address the recycling of two areas broadly identified as "operational" and "remedial". Operational focuses on paper, aluminum cans, laserjet cartridges, rubber tires, etc. *Alisa Bollinger and Michelle Ledbetter.*
Remedial focuses on scrap metal, and other materials generated by demolition of building (such and transite). *Bob Lehrter and Chuck Menche.*

INEL

no

16. Please list your site's current or near future initiatives involving RSM and/or recycling.

Hanford

No RSM initiatives. Recycling ongoing when feasible (cost benefit)

Oakland Operations Office

SLAC Putting together a proposal to recycle ~300,000 pounds of metals (copper, iron, Alum. and Stainless steel) as scrap.
ETEC Decontaminating numerous steel doors from D&D project
LBNL D&D metal and concrete reuse

Oak Ridge Operations

- Large Scale Metals Recycle Project
- Current: Small Scale Metal Recycle Project
- Consortium approach to D&D K-25 GDP building may start as early as mid-1997.

Savannah River Site

We are trying to match product needs with recycle of RSM. Our product needs are heavy water storage drums, overpacks, and DWPF canisters. Other containers for TRU and mixed waste are potentials.

Princeton

Future initiatives will involve recycling of materials during decommissioning as identified in question 2. Continued involvement with EM planning/policy and with ARMR.

AECL Chalk River (Decommissioning Branch)

Decommissioning Branch is currently recycling 8000 kg (17,600 lbs.) of surface contaminated stainless steel, including decontamination and fee release, radioactive scrap melting and rolling, and manufacture of type A 55 US gallon stainless steel drums.

Fernald

- Copper Wire recycling study (30 tons).
- Plt. 4 steel recycling study
- Plt. 7 steel recycling (300 tons rejected by ALARON)
- Material Release Facility (MRF) operation and enhancements.

INEL

Recycled shielded storage containers (RCCS) for the storage of RH-TRU.

17. Does your site currently purchase or plan to purchase products fabricated from RSM?
If so, please identify the candidate products and anticipated needs.

Hanford

LLW Barrels

Oakland Operations Office

No

Oak Ridge Operations

Yes, LLW containers to start with.

Savannah River Site

Yes, however the needs are dependent upon budget uncertainties.

Princeton

No, not currently. Can foresee purchasing carbon steel containers for packaging of radioactive waste. M-100 and 55 gallon drums

AECL Chalk River (Decommissioning Branch)

The purchase of RSM products would have to be supported by the appropriate AECL purchase procedures.

Fernald

Shipping containers (M-100?) a la Recycle 2000 scenario.

INEL

Yes, RCCS

- Drums - 83, 55, & 41
- Boxes - 2.5x4x4 & 4x4x8

18. What are the three most significant impediments to initiating or/and sustaining a RSM and Recycle program at your site.

- Risk of re-use/release liability
- Lack of solid national policy and standard for "true" free release
- Market uncertainties for restricted-re-use product.
- Low initial Cost of burial
- Exposure risk during decon
- little infrastructure
- Lack of global policy and global or local participation to create a turn-key operation
- Subsidized DOE disposal site costs which dramatically effect cost-benefit analysis
- Low quantity (current) of material available for recycle
- Funding
- Time
- Resources
- Not available. The review of waste management practices at CRL includes the options for recycle of both RSM and inactive material.
- Lack of funding and personnel resources
- Frequent upper-level management personnel turnover (i.e., ever time we reorganize, a different VP-level person has authority over WM/PP/Recycling. A few favor it, most don't).
- DOE bureaucracy results in dilution of WM/PP directives from HQ (i.e., - HQ is always issuing grandiose memos and policies, but by the time they reach the local offices, they're watered down or outdated; WM/PP initiatives from HQ are seldom translated into requirements for site contractors.
- Cost of program
- Availability of product
- Commitment to concept of Recycling at the local and project level
- Availability of funding, a priority issue
- Credit for avoided disposal cost savings
- Life cycle costing

Session 3 - Risk Issues

Rationales for Regulatory Activity

Ralph M. Perhac
The University of Tennessee
Energy, Environment and Resources Center

Rationales for Regulatory Activity:

- 1) Paternalism (private risks)
- 2) Promotion of Social Welfare (public risks)
- 3) Protection of Individual Rights (public risks)

Defining an Acceptable Level of Individual Risk:

- 1) arbitrarily (as has been done, e.g., 10^{-6})
- 2) on the basis of public preferences/values
 - The public reveals levels of risk acceptability in their behavior
 - Comparisons problematic because of different levels of associated benefits
 - Public considers many qualitative factors in arriving at risk acceptability

Promotion of Social Welfare:

- Maximize benefits to society
 - summed across individuals (Utilitarianism)
 - society as an organic whole
- Utilitarianism as Cost-Benefit Analysis
- Risk perceptions are relevant
- Focus on population risks
- No such thing as an acceptable level of risk per se

Problems with Promoting Social Welfare:

- Disregard for distributive justice
- Disregard for individual rights

Specific Problems with CBA

- Equates human lives with dollars
- That which isn't quantifiable gets left out

Protection of Individual Rights (duty not to harm)

- Natural rights theories
- Treat persons as ends not means (to a greater social good)
- focus on individual risk (not population risk)

Issues:

- Does psychological harm count?
- Sensitive subpopulations
- Future generations

Problems with Individualistic Approach:

- An absolute right to protection would halt virtually all industrial activity
- What is an acceptable level of risk to the individual?

Appeal to the Notion of Hypothetical Consent

- A rational person would accept such and such a risk
- Avoids problems with lack of unanimity

Under what conditions-

- Strictly self-interested individuals
- Risk-neutral individuals
- When expected benefits exceed expected costs

Comes full circle to CBA

Reconciling Individual Rights with Imposition of Some Risk

- By way of individual consent
 - Explicit consent (e.g., children's vaccinations)
 - Implied Consent (e.g., smoking)

Consent only if:

1)uncoerced

2)Informed

- For many risks it is difficult to argue that explicit or even implied consent exists
- Lack of unanimity (even where some consent)

**Reuse of Nuclear Byproducts, NaF and HF
in Metal and Glass Industries**

J. W. Park

H. W. Lee

Korea Power Engineering Co., Inc.

S. H. Yoo

H. S. Moon

N. C. Cho

Korea Nuclear Fuel Co., Ltd.

Reuse of Nuclear Byproducts, NaF and HF in Metal and Glass Industries

J. W. Park,¹ H. W. Lee,¹ S. H. Yoo,² H. S. Moon,² N. C. Cho²

¹ Nuclear Engineering Department
Korea Power Engineering Co., Inc.
360-9, Mabuk-ri, Kusong-myon,
Yongin-si, Kyunggi-do, Korea

² New Project Department
Korea Nuclear Fuel Co., Ltd.
P.O. Box 14 Yusung-gu,
Daejeon, Korea

Abstract

A study has been performed to evaluate the radiological safety and feasibility associated with reuse of NaF(Sodium Fluoride) and HF(Hydrofluoric Acid) which are generated as byproducts from the nuclear fuel fabrication process. The investigation of overseas experience reveals that the byproduct materials are most often used in the metal and glass industries. For the radiological safety evaluation, the uranium radioactivities in the byproduct materials were examined and shown to be less than radioactivities in natural materials. The radiation doses to plant personnel and the general public were assessed to be very small and could be ignored. The Korea nuclear regulatory body permits the reuse of NaF in the metal industry on the basis of associated radioactivity being 'below regulatory concern'. HF is now under review for reuse acceptability in the steel and glass industries.

1. Introduction

The Korea Nuclear Fuel Company (KNFC) has been producing the nuclear byproduct, NaF from the wet uranium reconversion($UF_6 \rightarrow UO_2$) process in the fuel fabrication plant for nuclear power plants since 1988. It is also scheduled to produce HF from the new dry reconversion process to be used at KNFC's new fuel fabrication plant which is presently under construction. The amounts of NaF and HF produced per year are approximately 300 tons[1] and 200 tons[2], respectively.

A study was performed to evaluate the radiological safety and feasibility associated with the reuse of NaF and HF in the Korean metal and glass industries. NaF and HF are licensed chemicals and have been utilized in various industries. The NaF and HF generated by KNFC, however, contain trace amounts of uranium isotopes, which require an analysis of the radiological effects associated with reuse. Although the radioactivity levels in NaF and HF are low enough to be ignored, the permanent disposal of NaF as radwaste via deep repository or shallow land burial, and the discharge of HF into streams, are not allowed because of their high chemical toxicity.

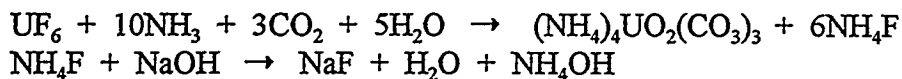
After deciding to reuse the byproduct material in industrial processes, we investigated reuse experiences in several countries which have nuclear fuel fabrication plants. The results[3,4] of the investigation showed that most of the nuclear byproducts containing the element fluorine(F), generated from nuclear fuel cycles, are reused in various industries, and support the sale and reuse

of comparable byproduct materials in the metal and glass industries of Korea. Examples for the reuse of nuclear byproducts are shown in Table 1.

2. Radioactivity Analysis

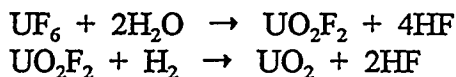
The nuclear byproducts, NaF and HF are produced in the process of uranium reconversion from concentrated UF_6 to UO_2 for nuclear power plant fuel. The NaF is generated from the conventional wet uranium reconversion process in which liquid water is provided. The concentrated UF_6 is combined with NH_3 , CO_2 and water to make $(\text{NH}_4)_4\text{UO}_2(\text{CO}_3)_3$ and NH_4F . The $(\text{NH}_4)_4\text{UO}_2(\text{CO}_3)_3$ (named AUC) is converted into UO_2 through the continuous main process, and is used in the fabrication of nuclear fuels, while NH_4F is converted into NaF using the waste treatment process. The reaction processes are as follows.

NaF Production



HF is generated from the new simplified dry process in which dry steam is used instead of liquid water. The final product of HF contains about 50% water. The reaction processes are as follows.

HF Production



NaF is solid material and is stored in 200 gallon drums, while HF is a toxic liquid and will be stored in large polyethylene storage tanks. Most uranium elements are removed from the NaF and HF through subsequent uranium collection processes, however, trace quantities of uranium (limited to naturally found U^{234} , U^{235} and U^{238}) still remain in the NaF and HF. The maximum detected uranium concentration in a NaF drum is 50 ppm[1], while the value in HF is conservatively assumed to be 5 ppm[2] at which an alarm actuates and the HF production process is stopped. These uranium concentrations correspond to radioactivities of 6 Bq/g-NaF and 0.6 Bq/g-HF for NaF and HF, respectively. The specific radioactivities of each uranium isotope are presented in Table 2. However, the average radioactivities are about 3.2 Bq/g for NaF and less than 0.1 Bq/g for HF. These values are compared to the natural radioactivities in fluospar, phosphate rock or bituminous shale in Table 3, and shown to be about the same or less than them.

3. Methods of Reuse

It was observed that NaF and HF are widely used in the chemical industry and the metal industry because of the strong reaction characteristics of the fluoride(F) element. Major applications include use as fluxing agents for steel and aluminium production, and use in magnesium, metallurgy, welding, ceramic, glassware, electronics, antiseptic and insecticide industries. Among these, the metal and glass industries consume the most amounts of NaF and HF in Korea.

It is proposed to transport NaF to intermediary factories where it would be blended with other chemicals to form tablets or powder for eventual use as fluxing agents in the aluminium- and steel-producing industries. The fluxing agents would contain a maximum of 20% NaF. About 3 kg of the fluxing agents are put into metal furnaces per 100 kg of molten metal. Some of the fluxing agents are melted into the end products, while most of the uranium remains in the sludge because of its relatively high molecular weight. The NaF is known to soften metals with the help of the sodium(Na) element and to degas from the molten metal due to the fluorine(F) element.

The proposed action for the HF is to release it to stainless steel-producing factories or glass factories. In stainless steel-producing factories, HF is stored in an elevated polyethylene storage tank. Then it flows into a mixing tank by gravity where it is mixed with nitric acid and water. The HF concentration is less than 5% in the mixing tank. The annealed stainless steel products are dipped into the mixing tank for about half an hour. The HF in the mixing tank plays an important role in descaling, pickling and degreasing of annealed cast-iron products. In this process, HF reacts with magnesium(Mg), iron(Fe), manganese(Mn), zinc(Zn) and chromium(Cr), which makes the surface of the cast-iron smooth and white. After it is used, the weak acid in the mixing tank is neutralized by NaOH and changed into a compound salt. This compound salt is finally turned to waste in the form of soil colored cakes after dewatered by a centrifuge, followed by permanent disposal at a special industrial waste disposal site. In the glass factories, HF is diluted to a concentration of less than 1.0 % and used to erode glass products for etching. The methodology to prepare used HF for disposal is similar to that described for the stainless steel-producing process.

4. Radiation Dose Assessment

The radiation doses to persons who work with the reused NaF and HF were assessed for all potential exposure pathways. It included truck drivers who transport NaF, HF and the fluxing agents made of NaF; the workers in fluxing agent-making factories, aluminium and steel-producing factories and glass factories; and the general public who live close to the factories and waste disposal areas. Individual effective dose equivalents to a worker ranged from $2.5\text{E-}5$ to $4.7\text{E-}4$ mSv/yr, and the doses to members of the general public are much less. The results of dose assessment show that the contribution by inhalation of potentially contaminated air is the largest and dominant. The assessed inhalation doses to a worker are based on the maximum allowable Fluorine(F) concentration of 2.4 mg/m^3 in air per Korean Environmental Law. The annual 50 year-committed lung dose and the committed effective dose equivalent to the maximum exposed individual are summarized in Table 4. From the radiation protection view point, these doses are negligible, compared to the annual dose limit of 1 mSv total effective dose equivalent (TEDE) to a member of the general public around

nuclear power plants, given in 10 CFR, Part 20. Additionally the radiation doses due to accidents, such as the overturning of a transportation vehicle or breakage of a HF storage tank[5], were also assessed. The accidental dose to an emergency response worker was shown to be less than the maximum individual dose during normal conditions.

4. Conclusions

The byproducts NaF and HF, generated from KNFC's fuel fabrication plants, are proposed to be reused in the metal and glass industries. In order to support the safety and the feasibility for the reuse of NaF and HF, dose assessments and the investigation of overseas experience with reuse have been carried out. Fortunately, the radiological impacts associated with reuse of the NaF and the HF were shown to be negligible. Overseas data shows that most of the nuclear byproducts, generated from nuclear fuel fabrication plants, are reused in industry. The evaluation also suggests that the reuse of NaF and HF in industries is an acceptable and only method for its permanent disposal, considering the cost reduction in nuclear fuel fabrication and the environmental impact.

For these reasons, the Korean nuclear regulatory body, KINS accepted the proposal to reuse NaF in the metal industry, and is reviewing positively the proposal to reuse HF in the metal and glass industries. The environmental requirements, due to the chemical toxicity of NaF and HF, shall be regulated separately according to the appropriate environmental laws.

[REFERENCES]

- [1] Safety Analysis Report for KNFC's Uranium Reconversion Plant, KNFC, March 1988.
- [2] Safety Analysis Report for New Fuel Fabrication Plant, KNFC, November 1994.
- [3] Safety Evaluation Report for Re-release of CaF_2 to Briquette Manufacturers for Use in the Steel Making Industry, US NRC, January 1992
- [4] Reutilization of Contaminated By-Products from Uranium Enrichment Industry in Europe, AEA Technology, October 1993
- [5] Accident Analysis Report of Korea Fuel Fabrication Plant, KNFC, August 1986.

Table 1. Reuse Experiences of Nuclear Byproducts

Producer		Byproducts	Application
USA	Allied-Signal	CaF_2	Steel Industry
	Westinghouse	CaF_2	Steel Industry
	GE	CaF_2	Steel Industry

United Kingdom	BNFL	MgF ₂	Magnesium Industry
		HF	Chemical Industry
France	FBFC	HF	Steel Industry
Germany	SIEMENS	NH ₄ F	Raw Material for Na ₂ AlF ₆
Canada	NFR	NH ₄ NO ₃	Agricultural Fertilizer

Table 2. Maximum Specific Radioactivities of Uranium Isotopes in NaF and HF

Isotopes		U-234	U-235	U-238	Total
Mass Fraction (%)		0.0454	5.0	94.95	100
Specific Radioactivity (Bq/g)	NaF	5.2	0.2	0.6	6.0
	HF	0.52	0.02	0.06	0.6

Table 3. Comparison of NaF and HF Radioactivities with Natural Radioactivities

Material	Average Radioactivity	Comments
Korea Fluospar	0.67 Bq/g	Raw material for Fluoride
Florida Phosphate Rock	4.44 Bq/g	Raw material for Fertilizer
Tennessee Bituminous Shale	1.8-3 Bq/g	Raw material for Coal
Cattle Feed Supplement	4.51 Bq/g	Regulation Limit
NaF (KNFC)	3.2 Bq/g	-
HF (KNFC)	0.1 Bq/g	-

Table 4. Calculated Maximum Individual Doses for Reuse of NaF and HF

Byproduct	Lung Dose	CEDE
NaF Reuse	3.9E-3 mSv/yr	4.7E-4 mSv/yr
HF Reuse	1.0E-3 mSv/yr	1.2E-4 mSv/yr

Beneficial Reuse of Empty DUF₆ Cylinders

L. A. Nieves

J. Arnish

B. Nabelssi

Argonne National Laboratory

Background

- Disposition options are needed for depleted uranium hexafluoride (UF_6) storage cylinders when emptied
- Over 46,000 cylinders are presently stored
- Primarily located at the Paducah, Portsmouth and Oak Ridge (K-25) gaseous diffusion plant sites

Disposition Issues

- 60,000 tons of steel, available over 20 yr disposition period
- Health risks
- Environmental impacts
- Costs and the hassle factor
- DOE metal recycle policy

Cylinder Characteristics

- 2,600 lb of carbon steel
- 4 ft diameter by 13 ft.
- 5/16 in wall thickness
- 0.0022 pCi/g total U, 3.6 pCi/g Th-234 and 3.6 pCi/g Pa-234m, 1yr after cylinder washing

Options Evaluated

- Recycle into LLW disposal containers
- Reuse as LLW disposal containers
- Free release for remelting
- Crush, package and bury

Option Feasibility Analysis

- Scrap can meet DOE Order 5400.5 free release criteria if most-contaminated sections are segmented out
- Most scrap can meet DOE recycle policy criteria
 - A few additional months storage will allow hot spots to meet criteria

Risk Analysis

- Included processing and transportation
- Covered normal operations and accidents
- Risk categories
 - Radiological
 - Chemical
 - Physical trauma

Annual Health Risks

	<u>Chem</u>	<u>Rad</u>	<u>Trauma</u>	<u>Total</u>
Recycle	1×10^{-3}	1×10^{-6}	6×10^{-3}	7×10^{-3}
Reuse	8×10^{-3}	1×10^{-6}	3×10^{-2}	4×10^{-2}
Release	1×10^{-3}	9×10^{-6}	7×10^{-3}	7×10^{-3}
Bury	3×10^{-3}	2×10^{-7}	2×10^{-2}	2×10^{-2}

Environmental Impacts

	<u>Steel Use</u>	<u>Burial</u>
Recycle	reduced container use	only residuals
Reuse	reduced container use	reduced impact
Release	no resource loss	no impact
Bury	containers?	normal impact

Cost Comparison

	<u>Cost Estimate</u>
Recycle	\$3,200
Reuse	700
Release	500
Bury	3,300

Conclusions

- Chemical and trauma risks dominate
- Risk levels are about equal across options
- Environmental impacts are
 - highest for burial
 - lowest for free release
- Costs are
 - higher for burial and recycling
 - lower for reuse and free release

Session 4A - Naturally Occurring Radioactive Materials (NORM)

Keynote Address - NORM Session

Peter Gray
Editor, The NORM Report

Naturally Occurring Radioactive Material (NORM) -- An Emerging Environmental Problem

What is NORM?

**NORM = Naturally Occurring
Radioactive Materials**

Definition of NORM

Technologically Enhanced Naturally Occurring Radioactive Material (NORM) includes any radionuclides whose physical, chemical, radiological properties or radionuclide concentration have been altered from their natural state.

Radioactive Contamination

**Radioactive contamination
is radioactive material in
an undesired location**

Industrial NORM Contamination

- **Petroleum**
- **Uranium mining**
- **Phosphorus & phosphates**
- **Fertilizers**
- **Fossil fuels**
- **Forestry products**
- **Water treatment**
- **Metal mining & processing**
- **Geothermal energy**

NORM in the Petroleum Industry

Important NORM in the Oil Industry

Radium - 226

Radium - 228

Radon - 222

Important NORM in the Gas Industry

Radon - 222

Lead - 210

Bismuth - 210

Polonium - 210

NORM

Contamination in the Petroleum Industry

- **Radium contamination**
- **Radon (lead-210)
contamination**

NORM Survey

**The key to a good NORM
control program is good
survey work**

NORM Hazards

The hazards of NORM are primarily due to:

- **Radon emanation**
- **Gamma radiation**
- **Inhalation / Ingestion of radioactive dust**

NORM Contamination

NORM contamination may trigger a range of assigned liabilities:

- **Worker exposure**
- **Radiation exposure to the public**
- **Environmental impact**

NORM Disposal Options

**Options for NORM-contaminated
wastes include:**

- **Landspreading**
- **Landspreading with dilution**
- **Non-retrieved production pipe**
- **Burial with unrestricted site use**
- **Surface mine**

(continued)

NORM Disposal Options

Factors considered for viable options:

- **Enviromental acceptability**
- **Public acceptability**
- **Economic acceptability**
- **Universal availability**
- **Time to make the option viable**

NORM Disposal Options

(Continued)

- **NORM disposal facility**
- **Commercial LLW disposal site**
- **Municipal landfill**
- **Surface mine**
- **Plugged and abandoned well**
- **Well injection**
- **Hydraulic fracturing**
- **Salt dome disposal**

Disposal Options

Envirocare

US Ecology

Newpark

Campbell Wells

“China”

“Russia”

Vitrification

Contaminated Equipment

- **No harm to the public has been reported as a result of incidents that have occurred when contaminated equipment has been released for unrestricted use**

Management and NORM Regulations

The best tools to protect the environment while reducing exposure to long-term liability are :

- Management of NORM**
- NORM education**
- NORM training**

Management and NORM Regulations

Three key programs will reduce legal exposure and surprises:

- **Waste minimization**
- **NORM assessment (surveys)**
- **NORM compliance (training)**

Concerns

- **NORM contamination probably exists at every oil and gas facility**
- **Contamination with radium-226 and lead-210 will be a concern for a long time.**

An Overview of Pennsylvania's Experience with NORM

James G. Yusko, CHP
Pennsylvania Department of Environmental Protection
Radiation Protection

An Overview of Pennsylvania's Experience with NORM

James G. Yusko, CHP
PA Dept. Environmental Protection
Radiation Protection -- Pittsburgh

presented at the 4th Annual
Beneficial Reuse Conference
Knoxville, TN October 22-24, 1996

Notices

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A STATE'S PERSPECTIVE ON NORM

JAMES G. YUSKO, CHP
PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
RADIATION PROTECTION
PITTSBURGH, PA

for presentation at the University of Tennessee
Beneficial Reuse '96 Conference
Knoxville, Tennessee
October 22-24, 1996

Although Pennsylvania may be thought of as the state who brought you indoor radon, courtesy of a discovery of a residence with radon concentrations in excess of a few thousand picocuries per liter, this is not our only claim to NORM fame. In the early years of the twentieth century, Pennsylvania was the largest producer of radium, utilizing its industrial base to produce large quantities of this "miracle cure" from ores mined in the West, and transported to a separation and purification facility in Western Pennsylvania. The company successfully held off foreign and political pressure, and generated large quantities of uranium tailings as well, until a fire one New Year's Eve destroyed the separation plant, and the company faded from view. The tailings were remediated as part of the Uranium Mill Tailings Remedial Action Project, on the only site east of the Mississippi River.

We are all aware that radon is (virtually) everywhere; prior to the discovery of this residence, we in the bureau had not suspected that radon and other naturally-occurring radioactive materials would cause that much of a health problem. The "Reading Prong," a large geological formation relatively rich in uranium in Eastern Pennsylvania, was at one time viewed as a potential resource to be developed for energy production in atomic power plants. The uranium concentrations in this area, however, are not as rich as those in the Western United States or Canada, and were not felt to be commercially viable or economically feasible, unless the price of uranium increased drastically.

As examples, the figure illustrates some of the common sources of NORM. We have been involved with all of these, in some way or another.

In Pennsylvania, the majority of the population gets its drinking water from surface streams ("city water"). Wells serving small populations, such as trailer parks and similar entities, are tested by the Department's Bureau of Water Supply and Community Health. These wells are typically shallow, a few hundred feet or

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less. The larger suppliers are regulated by our Bureau of Water (Quality) Management. As part of the chemical testing done on these facilities, radionuclide concentrations (e. g., radium) are also determined, and no suppliers furnish water in excess of the Environmental Protection Agency's drinking water limits. One area where NORM could arise from water suppliers is from filters to reduce or eliminate calcium compounds, since radium will be carried with calcium (being of the same chemical family). Problems conceivably could occur from the filter banks trapping radium/NORM, both from a potential worker exposure standpoint as well as from filter disposal.

Our involvement with NORM doesn't end with radon or uranium, either. The Bureau of Radiation Protection was dragged, almost kicking and screaming, into the issue of NORM from energy production when roll-off boxes, containing solidified brine sludges, kept triggering radiation alarms at a local landfill where the sludges were sent after chemical treatment of the brines from oil and gas production. Radiation levels from these solidified brine sludges were around 50 microroentgens (500 nanosieverts) per hour, and concentrations of ^{226}Ra and ^{228}Ra ran around 25 pCi ($\sim 1 \text{ Bq}$) g^{-1} each. When we heard of these levels and concentrations, we began wondering what to do.

Right. We formed a committee. Actually, we formed several, some involving Radiation Protection personnel only, but others with staff from other bureaus within our Department of Environmental Resources, as we were known formerly, such as the Bureau of Waste Management, and the Bureau of Oil and Gas Management.

Our first task was to try to define how big a problem we might be facing from NORM in energy production.

With the assistance of personnel from the Bureau of Oil and Gas Management, and utilizing low range scintillation type survey meters, we started surveying radiation levels around some of the oil and gas wells within Pennsylvania. The existing estimate was that there were around 40,000 oil wells and 40,000 gas wells in Pennsylvania. The survey meters were calibrated against a radium-226 standard at a local, contracted instrument calibration facility. Much to our relief, only a small percentage of the wells and their ancillary local equipment surveyed showed radiation levels beyond "normal" background of 5 uR (50 nSv) h^{-1} or so. A very few showed levels of 50 uR (500 nSv) h^{-1} .

Brine from energy production in Pennsylvania is disposed by one of three options: it may be put back into the earth through an injection well; it may be treated and disposed; or it may be used

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as a dust suppressant on unimproved (dirt) roads. These options have both positive and negative features, as will be explained.

Putting the fluids back into the earth seems like the easiest solution, so that one does not end up with an environmental NORM "problem," but this has drawbacks, at least in Pennsylvania. In some areas of the country, such as the Gulf states, reinjection works well; not so in Pennsylvania. Although these fluids are pumped back into the ground at pressures to 2,000 psig, the flow is relatively low. When we performed our surveys of these facilities, we were informed that the sands into which reinjection is performed are much tighter and have much lower porosity. None of the injection wells are located in a flood field for enhanced recovery of oil or gas, which would make injection suitable and economically feasible. This helps explain why this method is not used much in Pennsylvania.

Our radiation surveys of these facilities did not show any increase over the background radiation levels, probably ascribable to the low usage and flow. The largest capacity injection well in Pennsylvania can inject up to 2.2 million gallons of fluid per year, but a large treatment facility can process that same volume of fluid in a month or two. Radiation levels we measured around the two largest wells were in the range of 15-20 uR (150-200 nSv) h^{-1} , although a few places showed slightly elevated levels (to 40 uR (400 nSv) h^{-1}). Other wells we surveyed showed no radiation levels above the normal background range. Thus, in Pennsylvania, injection wells pose no environmental NORM problem.

Brines are also used as a dust suppressant on non-improved secondary (i.e., "dirt") roads. Treated or untreated brine may either be sold or donated to municipalities for spreading. Private companies may also spread brine on their access roads or parking lots. An application must be filed with our Bureau of Oil and Gas Management, and a permit is issued. Permit conditions limit the rate of application, the proximity to streams and water wells, the grade of the road, the proximity to certain residential or agricultural areas, etc. The permit application must also map, describe, or otherwise identify which roads will be spread. Generators are also required to report monthly the quantity of brines spread and upon which roads. A chemical analysis of the brine is also required, typically when the application is completed. At present, there is no regulatory requirement for follow-up chemical sampling and analysis.

As this practice has been going on for years, and since we were unsure of either the total applied brine and the consequent NORM concentrations in those brines, we thought that some of the

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roads spread with brine would show radiation levels distinctly elevated from nearby, non-treated roads.

We used two methods for conducting radiation surveys of the roads. Our first attempt was to use two 2" x 2" (5 cm x 5 cm) NaI(Tl) scintillation probes (Ludlum Corp. model 44-10) coupled to rate meters (Ludlum Corp. model 2350 "data logger"). The probes were attached to a metal frame which was fastened to the front bumper of a vehicle. The probes were approximately 1.5' (~50 cm) above the road surface and 4.5' (~1.5 m) apart. With the equipment configured this way, we could cover the road surface on two passes, one for each lane travelled. This required two personnel, one to operate the vehicle, while other watched the meter readout(s). Although meter readings were viewed in progress, a "hard" measurement was taken every 0.1 mile distance travelled and the results recorded. The vehicle was driven at low speeds (~5 mph) during these surveys. Problems encountered with this system included metal fatigue in the bolts and hardware used to attach the detectors to the angle iron. These problems were fixed almost immediately, to prevent the larger problem of a dropped and dragged detector, which costs about \$1,000 to replace. Ambient temperature and humidity/moisture also showed effects, as well as increased noise from the longer cable lengths needed to connect the detectors to the readouts in the cab of the vehicle. This issue of cable length and noise was addressed during the (re-)calibration of the systems.

A newer system was also put into service later. This utilized a 3" x 3" (7.6 cm x 7.6 cm) NaI(Tl) detector coupled to a meter and strip chart recorder (Mount Sopris Instrument Co., model SC-132). The larger detector was placed on a wooden mount which was located in the rear area of a passenger van. With the strip chart recorder, we could survey the road at a constant vehicle speed of approximately 5-10 mph (8-16 km h⁻¹). Although two individuals were still needed, annotations could be made directly onto the strip chart, and this facilitated data collection. The detector was in the vehicle's ambient temperature and humidity, so there was no problem with thermal or mechanical shock to the detector.

A total of about 350 miles (~550 km) of roads were surveyed, again primarily in Western Pennsylvania. No radiation levels significantly above background were noted. In the conduct of one road survey, we did encounter higher radiation levels, but this was explainable to the shale outcroppings through which we were driving.

We also tried to take air samples from brine spreading operations. This was good in theory, but not so in practice. The

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equipment we would use for taking air samples for emergency or accident conditions at nuclear power electric generating stations includes (12 volt) air samplers. The theory was to follow a tanker truck while brine was being spread on a road scheduled for treatment. Mutually agreed-upon scheduling turned out to be more difficult than expected, due to weather, etc., and we were able to complete only one survey of airborne radioactivity. Analysis of the air sample showed no elevated concentrations of radionuclides, however.

Brine spreading as a dust suppressant works - very well. As one travels along the roads, those sections treated show virtually no dust resuspended from vehicle traffic, while vehicles traversing non-treated road sections generate considerable dust.

Concurrent with the road surveys, we also conducted surveys of the facilities which handle or treat the drilling fluids (frac waters) or production fluids (brines) resultant from energy production. The techniques used by the nominal ten or so permitted facilities ranged from simple to modern, state-of-the-art, high tech ones.

The so-called "medium" and "high" technology approaches treat the brines similarly, solidifying the solids (for disposal at landfills) and discharging the cleaned water to nearby streams or rivers. The figures show a wide range of throughputs.

We visited these treatment facilities, and conducted radiation surveys while we were there. We didn't find ambient radiation levels which would require regulatory involvement, as projected exposures were below the non-occupational limit. The survey results are shown.

While we were conducting a survey at a treatment facility, which processes brine as well as other similar fluids, a truck pulled up to the facility to dump a load of brine for treatment. Our radiation survey of the vehicle showed nothing worth noting, with radiation levels at or near instrument background. However, while this truck was present, another tanker pulled up, and we also surveyed it, and found much higher radiation levels around the tanker due to its load -- fluids from a paint processing plant in an adjacent state.

There are a few companies who perform cleaning or refurbishing activities on energy production piping and equipment. We also surveyed these with our low level survey meters, but we did not find tubulars or equipment with elevated radiation levels.

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As another part of our investigations, we also looked at the bottom and fly ash samples from some of the (bituminous) coal-fired electric power generating stations in our territory. We obtained samples of both bottom and fly ash from several of the power plants and sent these to our Bureau of Laboratories for isotopic analysis of concentrations of various radionuclides. The results from these were in typically around 1 pCi (0.037 Bq) g^{-1} , although a few range upwards to ~5 pCi (~0.2 Bq) per gram. Again, nothing unexpected was found in these samples.

One process known for its technological increase in natural radioactivity is the phosphate fertilizer industry. There are, however, no production facilities of this type in Pennsylvania, so no samples could be obtained from this industry.

One location where NORM does show up routinely, however, is in the metal recycling industries. Metals such as steel, iron, aluminum, copper, titanium, etc.; are all recycled, and as these metals were typically used in industrial applications, the metal manufacturing mills have begun screening their scrap feedstock for radiation content, as the facilities do not wish to smelt a radiation source. As the mills have begun screening, their supplier yards are similarly screening the materials coming to them for processing for abnormal radiation levels. NORM is the radioactive material found most commonly by these monitors, as the equipment may have been used in resource processing, such as oil and gas, paper, or other chemical or mineral production, etc. The processing involves chemicals, and NORM which might be borne with the minerals or materials may plate out on the piping, tanks, or other surfaces. When these industrial processes are modernized or demolished, the piping, etc., is cut up and sent for recycling. Demolition contractors do not routinely check for radioactivity, and they are usually surprised to be informed that some of the loads they shipped for recycling show radioactive materials present. Of course, on occasion, discrete radiation sources may also be present, but this is a separate matter.

As part of our efforts, we looked at other media for sampling, too. One example of this was furnace dust from the steel-manufacturing mills in the area. On some occasions, we found ^{137}Cs and ^7Be in the samples. The beryllium is a cosmogenic radionuclide, and is (or should be) found in samples of air-type media such as furnace dusts. Barring smeltings of radiation sources, low concentrations of cesium (around 1-2 pCi (0.037-0.074 Bq) g^{-1}) are expected in the furnace dusts, principally as the consequence of atmospheric testing of nuclear weapons. Although this testing has stopped, cesium is still present as fallout, and will show up in samples.

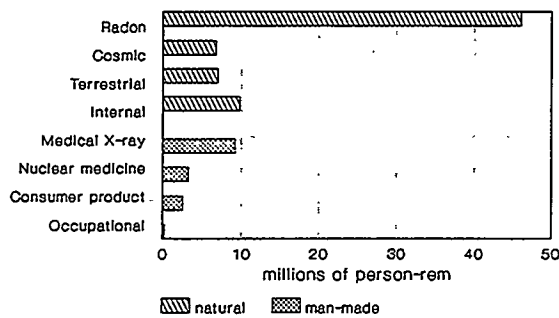
A State's Perspective on NORM

Most of the discoveries of NORM in the metals recycling industry have been from surplused equipment arriving either at metal manufacturing or recycling facilities. This includes old equipment from the paper industry. When a tank from one paper mill was scrapped, the radiation monitors at the recycling facility alarmed, and the contaminant was found to be NORM. Certain processes, such as the addition of kaolin to paper (to enable the full color glossy photographs to be printed), we expected, but our investigation disclosed that the paper mill did not process that kind of paper, and that the NORM contamination was from the digester. Another paper mill in the area uses a similar process, was also visited (to see if the finding was generic), but no elevated concentrations were found. About the only difference was that the one paper mill relied on lake water, while the other used surface water from a stream in its processes. No elevated concentrations of radionuclides were found in the feedstock for the paper mill.

As a consequence, we in the Radiation Protection staff of the Pennsylvania Department of Environmental Protection do not feel that, with the exception of (indoor) radon, NORM is that big a problem in the Commonwealth. The radionuclide concentrations in the ash from our coal fired electric generating stations is not too great. The radiation levels at the brine treatment facilities does not constitute a concern about worker exposure, the sludges are characterized by the treatment facilities, and those which are disposed are placed in double-lined, leachate monitored landfills. We haven't seen wide-spread elevated radiation levels around our producing oil and gas wells. The roads spread with brines haven't shown increases in the ambient radiation levels. We don't have major producers of phosphates for fertilizers or gypsum. The occasions on which we generally find higher than expected NORM concentrations or contamination is in metal recycling. The metal manufacturing mills and their feeder yards monitor for radioactivity to prevent exposure problems.

In conclusion, as far as Pennsylvania goes, we do not see any need to regulate a problem which isn't there. And unless some industries or processes change our viewpoint, it is likely to remain this way, in this era of not having any regulations stricter than those of the federal government (and the EPA has not shown any interest in addressing this either).

Annual Collective Effective Dose Equivalent to U.S. population



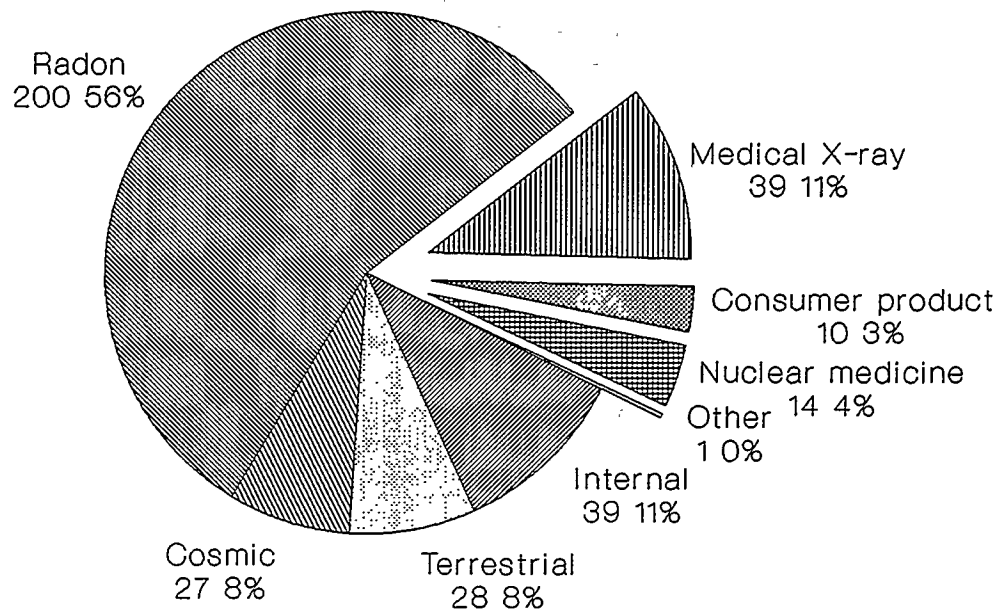
source: NCRP Report #93 (1987)

Annual Effective Dose Equivalent to U.S. population

Source	population exposed	Avg. DE (mrem)
Natural sources		
Radon	250,000,000	200
Other natural	250,000,000	100
Misc. Environ.	25,000,000	0.06
Man-made sources		
Occupational	930,000	.9
Nuclear Fuel Cycle		.05
Consumer Products	120,000,000	10
Medical		
Diagnostic Xray	100,000,000	39
Nuclear Medicine	5,000,000	14
rounded total		360

from: NCRP Report #93 (1987)

Average annual effective dose equivalent to U.S. population from radiation



source: NCRP Report #93 (1987)

total is ~ 360 mrem / year

Example sources of NORM

- Energy production -
oil, coal, natural gas
- Construction materials
- Mineral extraction -
uranium, thorium (products);
- Ground Water
- Phosphate industry -
feedstock, fertilizer, gypsum
- Other industries -
paper products, metal, metal recycling

Brine Disposal Options (in Pennsylvania)

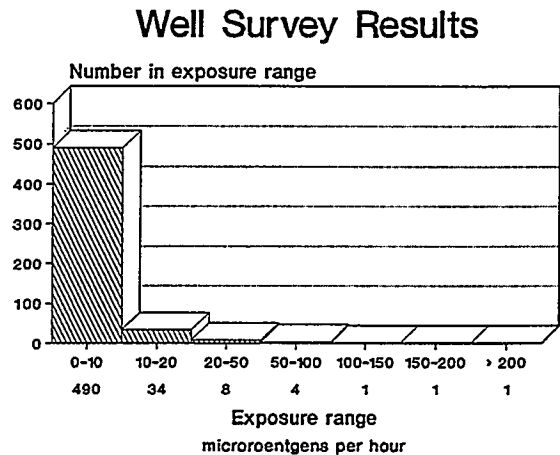
Return through injection wells

Treat and dispose

Road spreading

Well Survey Results

- Of > 500 wells surveyed, most were at background radiation levels (≤ 10 uR/h)
- 34 in range of 10 - 20 uR/h
- 8 in range of 20 - 50 uR/h
- 4 in range of 50 - 100 uR/h
- 3 greater than 100 uR/h
(1 @ 125, 1 @ 200, 1 @ 250 uR/h)



Well Surveys BRP, BOGM personnel

- Checked gas, oil, combination wells
- Used very low range (uR/h) meters
(Ludlum model 19, Bicorn microR, microrem,
Ludlum 2221 meters & 2"x2" NaI(Tl) probes)
- Meters calibrated against Radium-226
- 545 wells in 18 counties checked
- Elevated readings generally from deep
formations (e.g., Oriskany)

Road Spreading Surveys by BRP personnel

- Equipment used: Ludlum 2350 data loggers with 2" x 2" dia. NaI(Tl) probes
- Data loggers operating as Single Channel Analyzer, for gamma energy range of 400 to 850 keV (typical Ra)
- Equipment calibrated against Radium-226
- Equipment checked for proper function:
 - ✓ Battery checked (meter readout);
 - ✓ Background checks before, during, after;
 - ✓ Source checks before, during, after;

Road Spreading Surveys (revised) by BRP personnel

- Equipment used: Mount Sopris SC-132 portable scintillometer with 3" x 3" NaI(Tl) probe, chart recorder
- Equipment calibrated against Radium-226
- Equipment checked for proper function:
 - ✓ Battery checked (meter readout)
 - ✓ Background checks before, during, after;
 - ✓ Source checks before, during, after;
- Enables data collection in moving vehicle, with data recorded on chart (reduces meter fluctuation, operator bias)

Road Spreading Surveys BRP results

- Thus far, 246 roads surveyed in 9 counties
- > 350 miles surveyed
- Measurements taken at least every 0.1 mile, more if needed; taken at center of road
- Soil samples taken if readings > 1000 cpm
- More surveys to be conducted

PA Brine Treatment Facilities

- "Low Tech" - *virtually no treatment*
- "Medium Tech" - *flocculation, others treat and dispose solids*
- "High Tech" - *flocculation, dewater solids and dispose*

PA Brine Treatment Facilities

- "Low Tech" facility:
typically treats 8,000 gallons/day;
fluids discharged to river

PA Brine Treatment Facilities

- "Medium Tech" facilities (2):
facility "B" treats 15,000 gallons/day
solids sent to landfill;
fluids disposed to river
facility "C" treats 8,000 gallons/day
(treatment is sporadic)
solids sent to landfill;
fluids disposed to creek and through
road spreading

PA Brine Treatment Facilities

- "High Tech" facilities (4):
facilities treat between 12k and 200k
gallons per day (12, 75, 100, 200);
solids from all facilities sent to landfills
fluids disposed to rivers and through
road spreading

PA Brine Treatment Facilities

Radiation levels measured (uR/h)

<u>Facility</u>	<u>Brine Rx</u>	<u>Flocculation</u>
A - low tech	N/A	N/A
B - medium tech	N/A	10-15
C - medium tech	N/A	- 150
D - high tech	10-30	10-30
E - high tech	35-40	
F - high tech	- 300	- 190
G - high tech	Bkg	15-20

(background: 5-10 uR/h)

PA Brine Treatment Facilities

Radiation levels measured (uR/h)

<u>Facility</u>	<u>Filter Press</u>	<u>Filter Cake Stg</u>
A - low tech	N/A	N/A
B - medium tech	N/A	N/A
C - medium tech	N/A	N/A
D - high tech	10-30	10-30
E - high tech	25-30	- 40
F - high tech	- 50	- 60
G - high tech	Bkg	10-15

(background: 5-10 uR/h)

PA Brine Treatment Facilities

Radiation levels measured (uR/h)

<u>Facility</u>	<u>Lamella Sep.</u>	<u>Solids tanks</u>
A - low tech	N/A	N/A
B - medium tech	N/A	20-25
C - medium tech	N/A	N/A
D - high tech	10-30	10-30
E - high tech	10-55	10-15
F - high tech	- 200	- 70
G - high tech	N/A	Bkg

(background: 5-10 uR/h)

PA Brine Treatment Facilities

Radiation levels measured (uR/h)

<u>Facility</u>	<u>Oil Storage</u>	<u>Other Equip.</u>
A - low tech	N/A	Bkg - pipes
B - medium tech	Bkg	
C - medium tech	Bkg	~40 - polisher
D - high tech	10-30	10-30
E - high tech	10-15	
F - high tech	- 220	- 450 - monitor
G - high tech	- 75	- 120 - trough

(background: 5-10 uR/h)

Regulation of NORM by the U.S. Department of Energy

Kenneth C. Duvall
Harold T. Peterson, Jr.
U.S. Department of Energy
Air, Water and Radiation Division
Office of Environmental Policy and Assistance (EH-41)

RADIATION STANDARDS FOR PROTECTION OF THE GENERAL PUBLIC

**The DOE's major requirements are in
Order DOE 5400.5 and 10 CFR Part 834.**

These requirements include:

- **basic dose limits for protection
of the general public,**
- **radionuclide concentration
guidelines for air and water, and**
- **surface contamination criteria for
controlling the release of soil
and equipment for restricted or
unrestricted use.**

Draft Final 10 CFR Part 834

- **Embodies most of Order DOE 5400.5**
- **Published for public comment
Federal Register of March 25, 1993
[58 FR 16268].**
- **Notice of availability of draft rule for
additional comment published
August 31, 1995 [60 FR 45381].**
- **Final rule expected in December
1996; effective in January 1997.
Implementation required 2 years
after publication.**

**10 CFR PART 834
PRIMARY PUBLIC DOSE LIMIT**

Radiation exposures to individuals in the general public from *all radiation sources* and exposure pathways combined from routine DOE activities shall not exceed:

1 mSv (100 mrem) TEDE in a year.

10 CFR Part 834

Public Dose Limit follows the recommendations of the:

- **International Commission on Radiological Protection (ICRP 26,1977; ICRP 60, 1990)**
- **National Council on Radiation Protection and Measurements (NCRP Reports No. 91, 1987 and 116, 1993)**

and are numerically consistent with the public exposure limit found in NRC's revised 10 CFR Part 20.

10 CFR Part 834

Keeping Radiation Exposures As Low as is Reasonably Achievable (ALARA)

Compliance with dose limit is a necessary condition, but in itself is not sufficient to satisfy DOE's radiation protection requirements.

Order DOE 5400.5 and proposed 10 CFR Part 834 also require that radiation exposures to the public be as far below the dose limit as is reasonably achievable.

DOE sites must develop procedures for evaluating doses and analyzing alternatives that would reduce them.

10 CFR Part 834

CRITERIA FOR DECONTAMINATION AND DECOMMISSIONING

Individual Dose

- **Goal should be to reduce the levels of radioactive materials as near to background levels as practicable based on ALARA analyses.**
- **The 1 mSv dose limit applies to the total dose to a member of the general public from all sources. Decommissioning activities cannot use the entire 1 mSv.**
- **Guidance suggests that alternatives should be considered that will control doses to below 0.3 mSv in a year (30 mrem/year).**

Elements of DOE Material Release Process

- **Derive Authorized Limits**
- **Develop Survey and Review Protocol.**
- **Coordinate with Appropriate Agreement State (or NRC in non-Agreement State).**
- **Obtain DOE Operations Office or Area Office Approval (for Surface Contamination)**
or
- **Obtain Approval from Assistant Secretary for Environment, Safety and Health (for Volume Contamination).**

10 CFR Part 834

Guidelines for ALARA Analysis

Graded-Approach: Level-of-effort based on risk estimated from actual and likely use scenarios

- **QUANTITATIVE ALARA ASSESSMENTS:** collective doses exceed or approach 100 person-rem (1 person-sievert) and dose to maximum exposed individual is near 30 mrem (0.3 mSv)/year.
- **SEMI-QUANTITATIVE ALARA ASSESSMENTS:** collective doses are less than 100 person-rem (1 person-sievert) and dose to maximum exposed individual is less than 30 mrem (0.3 mSv)/year but greater than 10 mrem (0.1 mSv)/year.
- **QUALITATIVE ALARA ASSESSMENTS:** collective doses are less than 10 person-rem (0.1 person-sievert) and dose to maximum exposed individual is only a few (1-5) mrem/yr.

Information on Survey and Review Protocols for Releasing Decommissioned Sites

- **DOE Environmental Implementation Guide for Radiological Survey Procedures (expected 1/97)**
- **Multiagency Radiation Survey and Site Investigation Manual (MARSSIM) (draft for public review expected 12/96).**

PROPOSED 10 CFR Part 834

CRITERIA FOR DECONTAMINATION AND DECOMMISSIONING

***Naturally-occurring radionuclides
and "by-product" materials***

**Limits are specified for radium-226
and radium-228 of:**

200 Bq/kg (5 pCi/g)

**in the first 0.15 m of the surface soil
layer**

560 Bq/kg (15 pCi/g)

**in any subsequent 0.15 m
subsurface layer.**

SURFACE ACTIVITY GUIDELINES

Allowable Total Residual Surface Activity
(dpm/ 100 cm²)

Radionuclide	Average	Maximum	Removable
Group 1 Transuranics, I-125, I-129, Ac-227, Ra-226, Ra-228, Th-228, Th-230, Pa-231	100	300	20
Group 2 Th-natural, Sr-90, I-126, I-131, I-133, Ra-223, Ra-224, U-232, Th-232	1000	3000	200
Group 3 U-natural, U-235, U-238, and associated decay products, alpha emitters	5000	15000	1000
Group 4 Beta-gamma emitters (+ radio-nuclides with decay modes other than alpha emission or spontaneous fission, except Sr-90 and others noted above.)	5000	15000	1000
Tritium (applicable to surface and subsurface)	Not Applicable	Not Applicable	10000

Derived from NRC Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," (June 1976) except for tritium values which are from: "Response to Questions and Clarification of Requirements and Processes: DOE 5400.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material," (October 27, 1995), Table 1 page 9.

Proposed Changes for Part N of Suggested State Regulations

Ray Paris
Radiation Protection Services
Oregon State Health Division

Chairperson
Conference of Radiation Control Program Directors

Conference of Radiation Control Program Directors (CRCPD)

COMMISSION on NORM

MEMBERS:

FEDERAL RESOURCES:

Ray Paris (Oregon) CHAIRPERSON

Sam Finklea (South Carolina)

Bill Russo (EPA)

Tommy Cardwell (Texas)

Walter Cofer (Florida)

CONSULTANT:

James Hickey (Former Director)

Rhode Island Radiation Program

NORM COMMISSION

CHARGES

- 1) Develop suggested state regulations for the regulation of NORM.**
- 2) Perform (or have performed) a risk-based assessment and supporting rationale and justification for NORM standards, and a cost-benefit analysis on the degree of regulation needed.**

CRCPD NORM COMMISSION

MAJOR ISSUES

A. CONTAMINATION CRITERIA

- For unrestricted use**
- Potential for restricted use
(e.g., industrial, oilfield release, land
farming, disposal in sanitary landfills)**

B. RECYCLING

C. DISPOSAL OPTIONS

CRCPD NORM ADVISORY COMMITTEE

PURPOSE:

- 1) Provide the CRCPD NORM COMMISSION with the best available information on all possible issues regarding the regulation of NORM**
- 2) solicit support and "buy-in" to recommendations of the CRCPD from non-regulatory sectors**

NORM Advisory Committee

No more than 15 members selected from the following areas:

- | | |
|----------------------------------|----------------------------------|
| 1) ZIRCON INDUSTRY | 6) MISCH METAL INDUSTRY |
| 2) OIL & GAS INDUSTRY | 7) HEALTH PHYSICS SOCIETY |
| 3) RARE EARTH INDUSTRY | 8) ACADEMIA |
| 4) PHOSPHATE INDUSTRY | 9) NCRP |
| 5) WATER TREATMENT | 10) NORM WASTE MGMT IND. |
| INDUSTRY | |

11) TWO MEMBERS REPRESENTING ENVIRONMENTAL GROUPS

Commission on NORM

Advisory Committee Membership

<u>Name</u>	<u>Representing</u>
▶ David Bernhardt, CHP	Environmental interests
▶ Gregory Crinion	Legal aspects
▶ Jean-Claude Dehmel	Rare Earth/HPS
▶ William Geiger	Phosphate industry
▶ David Gooden, PhD, JD, CHP	Legal aspects
▶ Kevin Grice	Oil and gas industries
▶ Bill Guerard	Oil and gas industries
▶ Michael Kletter, PhD	Rare Earth/Zircon industry
▶ Michael Mattia	Waste management industry
▶ Al Rafati	Waste management industry
▶ John Richardson	Rare Earth industry
▶ Charles Roessler, PhD, CHP	Academia
▶ Michael Ryan, PhD, CHP	NCRP
▶ Max Scott, PhD	Academia
▶ Anthony Thompson	Uranium mining industry

Commission on NORM

Key Issues to Resolve

- ▶ Is there a better “Definition” of NORM?
- ▶ What is threshold for starting regulatory action?
- ▶ Where does Cost vs. Benefit factor in?
- ▶ What is background -- how is it determined?
- ▶ Can release criteria be based on direct external measurements only?

- ▶ Will regs be based upon dose or concentration limits?
- ▶ Will flexibility be permitted in site remediation?
 - Cost -- remoteness -- projected land use?
 - Past practices vs. current use?
- ▶ What is appropriate clean-up standard?
 - (10, 15, 25, 100, 500, or? mRem)
 - (5, 10, 15, 30, or? pCi/gm Ra-226)
- ▶ Should Radon be included/exclude from calculations?

- ▶ Should ALL exposure pathways be used in calculations? (Can food pathways be excluded)
- ▶ Should NORM disposal criteria be kept separate from LLW criteria?
- ▶ Is a person/organization culpable if they were unaware they had material that needed to be regulated?
- ▶ Is there a universal exposure limit or concentration limit to capture all industries?

Definition of Regulated Material in Part N

The material being regulated is “Technologically Enhanced Naturally Occurring Radioactive Material” [TENORM]. TENORM means “naturally occurring radioactive material not regulated under the Atomic Energy Act [AEA] whose radionuclide concentrations have been increased by or as a result of human practices.” TENORM does not include the natural radioactivity of rocks or soils, or background radiation, but instead refers to materials whose radioactivity is technologically enhanced by controllable practices [or by past human practices]. For the purposes of Part C of the SSRCRs, TENORM is “radioactive Material.”

SUBSTANTIVE CHANGES TO PART N

- ▶ More clearly defines what is regulated & calls it “TENORM”
- ▶ Uses a “dose based” instead of a “concentration based” standard
- ▶ Refines the exemptions from regulation
- ▶ Excludes radon from Total Effective Dose Equivalent (TEDE) calculations

- ▶ Gives considerable flexibility to the states for implementation
- ▶ Includes prospective, remedial & operations aspects for TENORM
- ▶ Provides for institutional controls to be part of the equation for problem solving

OTHER ISSUES

- ◆ The need for “Implementation Guidance” was recognized & plans to develop this guidance are being initiated.
- ◆ There is a need to look further at recycling options for TENORM.
- ◆ ALARA is excluded from the regulations to prevent it from being interpreted as a standard of care.
- ◆ A time schedule for finalization of Part N has been established.

Draft Schedule for Part N Approval

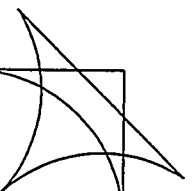
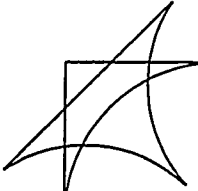
Oct 15, '96 Rationale to be completed.

Oct 31 NORM Advisory Committee start
review.

Nov 6 Working group for "implementation
guidance" established.

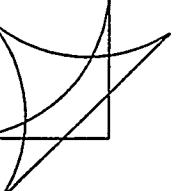
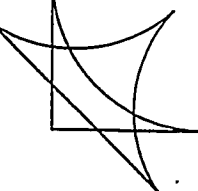
Dec 6 Advisory Committee comments
due to Commission.

Jan 15, '97	Commission complete review of comments.
Jan 22	Draft Part N & rationale sent out for public comment.
Mar 31	Public comment period ends.
July 1	Finalized Part N send to CRCPCD Board of Directors for action.
	Guidance anticipated to be completed by July 1, 1997.



JOURNEY TO SUCCESS

*One ship drives east, and another west
With the self-same winds that blow;
'Tis the set of the sails
And not the gales,
That decides the way we go.
Like the winds of the sea are the ways of fate,
As they voyage along through life;
'Tis the will of the soul
That decides its goal
And not the calm or the strife.*



Ella Wheeler Wilcox, American poet

Managing Liabilities for NORM

Charles T. Simmons
Thomas K. Bick
Kilpatrick & Cody, L.L.P.

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journal
article
removed

DO NOT SCAN

The NORM Factor: Managing Liabilities from Naturally Occurring Radioactive Material

THOMAS K. BICK AND CHARLES T. SIMMONS

Beginning in the mid-1950s, the primary focus of government regulation of radioactive materials has been on the control of exposures to nuclear fuel cycle materials (i.e., those radioactive materials that are generated during the course of the mining, processing, and use of uranium to produce weapons and energy). The Nuclear Regulatory Commission (NRC) and its predecessor agency have had exclusive jurisdiction over such nuclear fuel cycle materials. The past five years, however, have seen a substantial increase in government interest in preventing the potentially harmful effects of human exposures to other forms of radioactive materials not regulated by the NRC (collectively referred to as naturally occurring radioactive materials, or NORM). As government warnings about the potential hazards of NORM have increased and regulations designed to control NORM have proliferated, the number of lawsuits alleging property damage or bodily injury from exposures to NORM-containing substances has also increased. This litigation, in turn, has generated disputes between insurers and policyholders over whether standard-form liability policies were meant to provide coverage for such claims.

Until very recently, those in the business of producing, using, transporting, or disposing of radioactive materials had little reason to be concerned about government regulation of those materials, or about claims for bodily injury or property damage arising out of alleged exposures to those materials. Historically, the federal government has regulated a relatively narrow category of radioactive substances: materials generated during the mining, processing, and use of uranium to produce

Thomas K. Bick is a partner in the Environmental and Natural Resources Practice Group in the Washington, DC, office of Kilpatrick & Cody. He has over 17 years of experience in environmental counseling and litigation, and representing policyholders in environmental insurance coverage cases. Charles T. Simmons is an associate in Kilpatrick & Cody's Environmental and Natural Resources Practice Group. One of his specialty areas is the regulation and management of radioactive materials. The authors thank summer associate Lee Ann Bambach for her legal research and analysis.

DO NOT SCAN

4. See 42 USC §§201(z), (e), and (a).
5. Actually, there is a third category of radionuclides, sometimes referred to as "accelerator-produced radioactive material." The small quantities of such material are not subject to NRC regulation and are not addressed in this article.
6. 42 USC §9601 et seq.
7. As discussed later in this article, there is judicial precedent for remediation of radionuclide contaminated sites under CERCLA. See, e.g., *Amoco Oil* (cited on p. 00).
8. See NCRP Report No. 116, *Limitation of Exposure to Ionizing Radiation* (March 1993) at p. 50.
9. 59 Fed. Reg. 66414.
10. See 29 CFR §1910.1200.
11. California Proposition 65 requires a warning label for products that contain "substances known to the State of California to cause cancer or reproductive harm."
12. *Canadian Radium & Uranium Corp. v. Indemnity Ins. Co. of North Am.*, 104 N.E.2d 250 (Ill. 1952) (insured settled with technician who alleged affliction with radium poisoning as a result of her work with radon ointment, then sued insurer who refused to defend the action).
13. *Kerr-McGee* (cited on p. 52); *McCormick v. United Nuclear Corp.*, 557 P.2d 589 (N.M. Ct. App. 1976).
14. Although no such cases have so far been reported, the very real possibility of such exposure is attested to by the fact that at least 25 confirmed smeltings of radioactive devices have taken place in the United States (as reported by R. Turner, *Federal and State Requirements for Handling Radioactive Scrap Problems*, IBSM, May 1995).
15. *Amoco Oil* (cited on p. 53) at 667, *T&E Industries* (cited on p. 54) at 708.
16. See, e.g., *T&E Industries* (cited on p. 54) at 696, 708.
17. The background levels of radiation are based on the levels of radiation found naturally in the soil in that area.
18. *T&E Industries, Inc. v. Safety Light Corp.*, 587 A.2d 1249, 1252 (N.J. 1990).
19. USC §9607; see also *Polcha v. AT&T Nassau Metals Corp.*, 837 F. Supp. 94 (M.D. Pa. 1993) (no private cause of action to recover damages for personal injuries is expressly or impliedly created by CERCLA).
20. *T&E Industries, Inc. v. Safety Light Corp.*, 680 F. Supp. at 699; *T&E Indus., Inc. v. Safety Light Corp.*, 587 A.2d 1249, 1254 (D.N.J. 1990).
21. *Borden* (cited on p. 59); see also discussion of underlying suit, *Amoco* (cited on p. 53).
22. *EAD Metallurgical, Inc. v. Aetna Casualty & Surety Co.*, 905 F.2d 8 (2d Cir. 1990).
23. Although this case dealt with an "absolute" pollution exclusion clause, the question of whether the NORM source is a pollutant is generally the same with respect to the "qualified" exclusion.
24. P. MacDowell, "Insurance Industry's Proactive Response for Total Radioactive Liability Avoidance," *Mealey's Litigation Reports—Insurance*, Vol. 10, No. 14 (Feb. 14, 1996) at 23.

Statutory/Regulatory Sources of NORM Liability

I. Federal

- **Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA" or "Superfund")**
- **Atomic Energy Act of 1954 ("AEA")**
- **Department of Transportation ("DOT") Hazardous Materials Regulations**
- **Occupational Safety and Health Administration ("OSHA")**
- **Radiation Site Cleanup/Decommissioning Rule (Not Final)**

Statutory/Regulatory Sources of NORM Liability

II. State

- **General Radiation Control Regulations**
- **NORM-Specific Regulations**
 - **Licensing**
 - **Possession**
 - **Use and Reuse**
 - **Commercial Distribution**
 - **Disposal**
 - **Equipment Decontamination**

Trends

I. Federal

- **Superfund Reauthorization**
- **Radiation Site Cleanup Rule**
- **Definition of "Source Material"**

II. States

- **New Jersey - Site Cleanup**
- **Ohio - NORM**
- **Florida - NORM**

**Conference of Radiation Control Program
Directors ("CRCPD")**

NORM LIABILITY AND INSURANCE ISSUES

- I. LIABILITY FROM NORM EXPOSURE
 - A. SOME INDUSTRIES AT RISK
 - B. MOST LIKELY NORM LIABILITY SCENARIOS
 - 1. WORKER EXPOSURE
 - 2. CERCLA-TYPE LIABILITY FOR PROPERTY CONTAMINATION
 - 3. PRODUCT LIABILITY
- II. INSURANCE COVERAGE FOR BODILY INJURY OR PROPERTY DAMAGE FROM NORM EXPOSURE
 - A. POLLUTION EXCLUSIONS
 - 1. "QUALIFIED" POLLUTION EXCLUSION
 - 2. ABSOLUTE POLLUTION EXCLUSION
 - B. NUCLEAR EXCLUSIONS
 - 1. NUCLEAR ENERGY LIABILITY EXCLUSION
 - 2. ABSOLUTE NUCLEAR EXCLUSION
 - 3. RADIOACTIVE MATTER EXCLUSION
- III. PRECAUTIONS AGAINST NORM LIABILITY
 - A. STATUTORY/REGULATORY
 - B. MANAGEMENT SAFEGUARDS
 - C. INSURANCE COVERAGE

I. LIABILITY FROM NORM EXPOSURE

A. SOME INDUSTRIES AT RISK

1. OIL AND GAS PRODUCERS
2. PHOSPHATE MINERS
3. METAL MINERS AND MINERAL PROCESSORS
4. FERTILIZER MANUFACTURES
5. URANIUM MINERS AND PROCESSORS
6. SCRAP METAL DEALERS
7. FOUNDRIES
8. REFRACTORIES INDUSTRIES USING ZIRCON OR ALUMINA BAUXITE
9. MEDICAL WASTE GENERATORS AND MANAGERS
10. ZIRCON/ZIRCONIUM PRODUCERS AND USERS

B. MOST LIKELY NORM LIABILITY SCENARIOS

1. WORKER EXPOSURE

- SUCH CLAIMS FIRST SURFACED 50 YEARS AGO (*LA PORTE v U.S. RADIUM* (D.N.J. 1935)--RADIUM PAINTED WATCH DIALS)
- MANY SUCH CLAIMS IN NUCLEAR ENERGY INDUSTRY (E.G., SILKWOOD CLAIM AGAINST KERR-McGEE) SUPREME COURT: GOVERNMENT STANDARDS ARE NOT A SHIELD
- OTHER CASES: OIL AND GAS PRODUCTION WORKERS, URANIUM MINERS, RADON OINTMENT PRODUCERS, PHOSPHATE MINERS
- INITIALLY, PLAINTIFF'S COULD NOT OVERCOME "CAUSATION" HURDLES (*JOHNSON v. U.S. (D. KAN. 1984)* (WORKERS REPAIRED RADIUM-COATED AIRCRAFT INSTRUMENTS))
- MAJOR ISSUE BESIDES CAUSATION: DOES WORKERS COMPENSATION LAW PROVIDE EXCLUSIVE REMEDY?
- NOT EXCLUSIVE REMEDY IN SOME STATES IF DELIBERATE OR RECKLESS CONDUCT
- NOT EXCLUSIVE REMEDY IN SOME STATES IF ULTRAHAZARDOUS ACTIVITY
- NOT APPLICABLE IF EXPOSURE WAS AWAY FROM THE WORK PLACE
- INJURED WORKER WILL OFTEN LOOK TO THE SUPPLIER

2. CERCLA-TYPE LIABILITY FOR PROPERTY CONTAMINATION

EXAMPLE: *AMOCO OIL CO. v. BORDEN, INC.* (5TH CIR. 1990)

FACTS:

- **AMOCO PURCHASED PROPERTY FROM BORDEN**
- **SITE CONTAMINATED WITH PHOSPHOGYPSUM, BY-PRODUCT OF BORDEN'S FERTILIZER MANUFACTURING**
- **PHOSPHOGYPSUM PILE CONTAINED LOW-LEVEL RADIOACTIVITY FROM RADIUM AND RADON**

HELD:

- **RADON AND DAUGHTER PRODUCTS ARE CERCLA HAZARDOUS SUBSTANCES (COURT REJECTED BORDEN'S ARGUMENT THAT NO CERCLA LIABILITY BECAUSE RADIATION WAS NATURALLY OCCURRING)**
- **NO QUANTITATIVE REQUIREMENT ON AMOUNT OF HAZARDOUS SUBSTANCE RELEASED**
- **HOWEVER, COURT DID ESTABLISH THRESHOLD: NO LIABILITY UNLESS RADIATION LEVELS WERE GREATER THAN THE MOST STRINGENT A GOVERNMENT STANDARD (HERE: RADIUM LEVELS VIOLATED STANDARD FOR INACTIVE URANIUM MILL TAILINGS STANDARDS)**

**EXAMPLE: *GRAY v. MURPHY OIL USA, INC.*,
(D.S.D. MISS. 1994)**

FACTS:

- **PROPERTY OWNER ALLEGED THAT DEFENDANTS' OIL AND GAS PRODUCTION OPERATIONS CONTAMINATED HIS PROPERTY WITH RADIUM AND RADON**
- **PROPERTY OWNER ALLEGED TRESPASS, NEGLIGENCE, NUISANCE, STRICT LIABILITY FOR ULTRAHAZARDOUS ACTIVITY, ASSAULT AND BATTERY (NO CERCLA CLAIM)**

LESSON: CERCLA AMENDMENTS WILL NOT BE A CURE-ALL

EXAMPLE: *T&E INDUSTRIES, INC. v. SAFETY LIGHT CORP.* (D. N.J. 1988)

FACTS:

- T&E PURCHASED PROPERTY AND THEN DISCOVERED IT WAS CONTAMINATED WITH RADON BY PRIOR OWNER'S RADIUM EXTRACTION OPERATIONS
- T&E SUED PRIOR PROPERTY OWNER UNDER CERCLA AND COMMON LAW COUNTS

HELD:

- RADIOACTIVE ORE TAILINGS WERE NOT EXCLUDED FROM CERCLA DEFINITION OF "HAZARDOUS SUBSTANCES" UNDER MINING WASTE EXCLUSION ("BEVILL AMENDMENT")
- MOST OF T&E RESPONSE COSTS WERE RECOVERABLE UNDER CERCLA
- T&E COULD COMPEL FURTHER SITE REMEDIATION BY PRIOR SITE OWNER UNDER COMMON LAW CLAIMS
- T&E ALSO FILED SUIT IN STATE COURT FOR AND RECOVERED BUSINESS RELOCATION COSTS AND LOST PROPERTY VALUE
- N.J. SUPREME COURT (1990): DEFENDANT STRICTLY LIABLE (NO FAULT) BECAUSE PROCESSING AND DISPOSAL OF RADIUM = "ABNORMALLY DANGEROUS ACTIVITY"

EXAMPLE: *AMAX, INC. v. SOHIO INDEPENDENT PRODUCTS CO.* (S.Ct. N.Y. 1983)

FACTS:

- **DEFENDANT OPERATED ORE PROCESSING PLANT TO PRODUCE ZIRCONIUM METALS, AND BURIED NORM-CONTAINING WASTE ON-SITE**
- **PLAINTIFF BOUGHT PROPERTY AND SUED DEFENDANT FOR CLEANUP COSTS**

HELD:

- **NO STATUTE OF LIMITATIONS BAR BECAUSE INJURY TO PROPERTY WAS "CONTINUOUS TRESPASS" UNDER N.Y. LAW**

3. PRODUCT LIABILITY

FALCON PRODUCTS v. INS. CO. OF STATE OF PA
(D.C. MO. 1985)

FACTS:

- **SCRAP DEALER BOUGHT OBSOLETE MEDICAL TELETHERAPY EQUIPMENT WHICH CONTAINED RADIOACTIVE MATERIAL (COBALT-60)**
- **EQUIPMENT HOUSING RUPTURED AT SCRAP DEALER'S FACILITY, CAUSING RAD. CONTAM. OF OTHER SCRAP METAL, WHICH WAS THEN SOLD TO FOUNDRY**
- **FOUNDRY MADE TABLE BASE CASTINGS, AND SOLD THEM TO HIS CUSTOMERS**
- **WHEN CUSTOMERS DISCOVERED CONTAMINATION, FOUNDRY INCURRED HUGE LOSS**

RESULTS:

- **SCRAP DEALER INSOLVENT AND FOUNDRY'S INSURANCE COMPANY REFUSED TO PAY**

**EXAMPLE: *WAYNE v. TENNESSEE VALLEY AUTHORITY*
(5TH CIR. 1984)**

FACTS:

- **CONCRETE BLOCKS MADE WITH PHOSPHATE SLAG USED IN HOMEOWNER'S BASEMENT CONSTRUCTION HAD HIGH RADON LEVELS**
- **HOMEOWNER SUED TVA (WHICH PRODUCED THE PHOSPHATE SLAG AS A BY-PRODUCT IN ITS FERTILIZER PLANT), THE BLOCK MANUFACTURER, AND THE BLOCK SELLER**
- **HOMEOWNER ALLEGED BREACH OF IMPLIED WARRANTY, NEGLIGENCE, PRODUCT LIABILITY, AND FRAUDULENT CONCEALMENT (BY TVA), CLAIMING LOSS OF PROPERTY VALUE AND BODILY INJURY FROM RADON EXPOSURE**

HELD: ALL CLAIMS BARRED BY 10-YEAR STATUTE OF LIMITATIONS

II. INSURANCE COVERAGE FOR BODILY INJURY OR PROPERTY DAMAGE FROM NORM EXPOSURE

A. POLLUTION EXCLUSIONS

1. "QUALIFIED" POLLUTION EXCLUSION

- **EXCLUSION READS: "[THIS INSURANCE DOES NOT APPLY] TO BODILY INJURY OR PROPERTY DAMAGE ARISING OUT OF THE DISCHARGE, DISPERSAL, RELEASE OR ESCAPE OF SMOKE, VAPORS, SOOT, FUMES, ACIDS, ALKALIS, TOXIC CHEMICALS, LIQUIDS OR GASES, WASTE MATERIALS OR OTHER IRRITANTS, CONTAMINANTS OR POLLUTANTS INTO OR UPON LAND, THE ATMOSPHERE OR ANY WATER COURSE OR BODY OF WATER; BUT THIS EXCLUSION DOES NOT APPLY IF SUCH DISCHARGE, DISPERSAL, RELEASE OR ESCAPE IS SUDDEN AND ACCIDENTAL."**
- **ADDED TO MOST CGL POLICIES IN 1972 OR 1973**
- **AMBIGUITY OF PHRASE "SUDDEN AND ACCIDENTAL" HAS CREATED ENORMOUS AMOUNT OF LITIGATION FROM CONTAMINATION EXPOSURE CLAIMS**
- **UNSETTLED QUESTION: DOES THIS EXCLUSION APPLY TO PROPERTY DAMAGE OR BODILY INJURY DUE TO NORM EXPOSURE?**

(CONT...)

- **GENERALLY, THIS IS A TWO-PART QUESTION:**
 - (1) **IS NORM AN "IRRITANT," "CONTAMINANT" OR "POLLUTANT"?**
 - (2) **IF SO, WAS ITS RELEASE INTO THE ENVIRONMENT SUDDEN AND ACCIDENTAL?**

EXAMPLES

- **EAD METALLURGICAL v. AETNA CASUALTY & SURETY (2D CIR. 1990) (EXCLUSION PRECLUDES INSURANCE COVERAGE FOR CERCLA LIABILITY RESULTING FROM DISPOSAL OF NORM INTO SEWER LINES BY MANUFACTURER OF FOIL ELEMENTS IN SMOKE DETECTOR--SUCH CONTINUOUS DISPOSAL WAS NOT "SUDDEN AND ACCIDENTAL.")**
- **BORDEN, INC. V. AFFILIATED FM INSURANCE (S.D. OHIO 1987) (LONG-TERM DEPOSITING OF RADIOACTIVE PHOSPHATE WASTE ON PROPERTY OF FERTILIZER PRODUCER NOT "SUDDEN AND ACCIDENTAL.")**
- **CANADIAN RADON v. URANIUM CORP. SEVEN-MONTH EXPOSURE OF WORKER TO "RADON OINTMENT" NOT "SUDDEN AND ACCIDENTAL"**
- **HOWEVER, COURTS IN GA, WV, WI, NJ, IL, WA, OR, IN, AND SC MIGHT HAVE RULED OTHERWISE (IN THOSE STATES, EVEN GRADUAL RELEASES OF NORM ARE "SUDDEN AND ACCIDENTAL" IF THEY'RE EXPECTED OR INTENDED)**

2. ABSOLUTE POLLUTION EXCLUSION

- **ADDED TO MOST CGL POLICIES IN 1985 OR 1986 BECAUSE OF ADVERSE "SUDDEN AND ACCIDENTAL" CASES**
- **TYPICAL LANGUAGE: "[THIS EXCLUSION DOES NOT APPLY] TO BODILY INJURY OR PROPERTY DAMAGE ARISING OUT OF THE ACTUAL, ALLEGED, OR THREATENED DISCHARGE, DISPERSAL, RELEASE OR ESCAPE OF POLLUTANTS."**
- **"POLLUTANTS" ARE DEFINED AS "ANY SOLID, LIQUID, GASEOUS OR THERMAL IRRITANT OR CONTAMINANT, INCLUDING SMOKE, VAPOR, SOOT, FUMES, ACIDS, ALKALIS, CHEMICALS AND WASTE."**
- **SOME POLICIES DEFINE WASTE TO INCLUDE "MATERIALS TO BE RECYCLED, RECONDITIONED OR RECLAIMED."**
- **SOME COURTS: "POLLUTANTS" DO NOT INCLUDE NON-ENVIRONMENTAL CONTAMINANTS (E.G., LEAD PAINT) OR NON-WASTE-TYPE CONTAMINANTS (GASOLINE FUMES; SEWAGE; WATER IN OIL TANK).**
- **MANY COURTS: THIS EXCLUSION DOES NOT APPLY TO PRODUCT LIABILITY CLAIMS (BECAUSE A PRODUCT IS NOT A "WASTE").**

**ISSUE: DOES ABSOLUTE POLLUTION EXCLUSION
APPLY TO NORM?**

**YES: *CONSTITUTION STATE INS. CO. v. ISO-TEX INC.*
(5TH CIR. 1995):**

FACTS:

- **WASTE HANDLING COMPANY ALLEGEDLY
WAS LIABLE FOR DEATH AND BODILY INJURY
OF PERSONS EXPOSED TO RADIOACTIVE
MEDICAL WASTE STORED ON COMPANY'S
PROPERTY.**

HELD:

- **COURT CONCLUDED THAT THE MEDICAL
WASTE WAS CLEARLY A "POLLUTANT"
BECAUSE IT WAS IN A WASTE PRODUCT.**

**SEE ALSO: *USF&G v. B&B OIL WELL SERVICE* (S.D.
MISS. 1995)**

HELD:

- **NORM-CONTAINING PIPE SCALE, RUST AND
SALTWATER DEPOSITED ON PROPERTY FROM
OIL AND GAS PRODUCTION WAS A
"POLLUTANT"**

BUT COMPARE:

- **SITUATIONS WHERE NORM-CONTAINING MATERIAL CAN BE CHARACTERIZED AS A "PRODUCT" RATHER THAN AS "WASTE"**

EXAMPLE: *MINNESOTA MINING AND MANUFACTURING CO. v. WALBROOK INS. CO.* (MINN. CT. OF APPEALS, JAN. 9, 1996)

FACTS:

- **3M'S MANUFACTURED AND SOLD STATIC ELIMINATORS CONTAINING TINY BEADS OF A RADIOACTIVE ISOTOPE WHICH EMITS ALPHA PARTICLES THAT ELIMINATE STATIC BY IONIZING SURROUNDING AIR. 3M WAS SUED BY SEVERAL CUSTOMERS AFTER BEADS CAME LOOSE AND SPILLED OUT OF ELIMINATORS, CAUSING CUSTOMERS TO INCUR SUBSTANTIAL CLEANUP COSTS.**

HELD:

- **THE RADIOACTIVE BEADS WERE NOT "POLLUTANTS" AND THEREFORE EXCLUSION DID NOT APPLY. COURT: "WE DO NOT AGREE . . . THAT THE BEADS WERE POLLUTANTS SIMPLY BECAUSE THEY WERE RADIOACTIVE." "WE CONCLUDE THAT THE BEADS WERE NOT POLLUTANTS BECAUSE THEIR RELEASE DID NOT AFFECT SURROUNDING AIR, SOIL OR WATER."**

B. NUCLEAR EXCLUSIONS

1. NUCLEAR ENERGY LIABILITY EXCLUSION (NELE)

- TYPICAL LANGUAGE EXCLUDES COVERAGE FOR INJURY, SICKNESS, DEATH OR DESTRUCTION BY (1) AN INSURED WHO IS ALSO INSURED UNDER A NUCLEAR ENERGY LIABILITY POLICY ISSUED BY NUCLEAR ENERGY LIABILITY INSURANCE ASSOCIATION (2) AN INSURED ENTITLED TO FINANCIAL PROTECTION UNDER THE ATOMIC ENERGY ACT OF 1954; OR (3) EXPOSURE TO "NUCLEAR MATERIAL" THAT IS AT OR DISPERSED FROM AN INSURED'S "NUCLEAR FACILITY" OR IS "CONTAINED IN SPENT FUEL OR WASTE."
- "NUCLEAR MATERIAL" IS DEFINED AS SOURCE, SPECIAL OR BY-PRODUCT MATERIAL.
- THIS EXCLUSION HAS BEEN A COMMON ENDORSEMENT IN CGL POLICIES SINCE THE MID 1950's.
- COURTS HAVE GENERALLY INTERPRETED THIS EXCLUSION NARROWLY TO APPLY TO NUCLEAR FUEL CYCLE MATERIALS ONLY.
- EXAMPLE: *CHEMETRON INVESTMENTS v. FIDELITY & CASUALTY CO.*, (W.D. PA. 1994): EVEN THOUGH PROPERTY CONTAMINATION BY INSURED WAS BY "SOURCE MATERIAL," EXCLUSION DID NOT APPLY BECAUSE THE PROPERTY WAS NOT A "NUCLEAR FACILITY" AND SOURCE MATERIAL WAS NOT CONTAINED IN "SPENT FUEL" OR "WASTE."

2. ABSOLUTE NUCLEAR EXCLUSION

- IN SOME POLICIES SINCE MID 1980s
- TYPICAL LANGUAGE: "[THIS EXCLUSION DOES NOT APPLY] TO ANY "INJURY OR DAMAGE TO OR ARISING OUT OF ANY NUCLEAR DEVICE, RADIOACTIVE MATERIAL, ISOTOPE . . . OR ANY OTHER CHEMICAL ELEMENT HAVING AN ATOMIC NUMBER ABOVE 83 OR ANY OTHER MATERIAL HAVING SIMILAR PROPERTIES OF RADIOACTIVITY."
- NOTE: NO "POLLUTANT" OR "WASTE" REQUIREMENT

3. RADIOACTIVE MATTER EXCLUSION

- BEGAN APPEARING IN COMMERCIAL LIABILITY INSURANCE POLICIES IN 1994.
- TYPICAL LANGUAGE: "THIS POLICY DOES NOT APPLY TO BODILY INJURY OR PROPERTY DAMAGE ARISING OUT OF THE ACTUAL, ALLEGED OR THREATENED EXPOSURE OF PERSONS OR PROPERTY TO ANY RADIOACTIVE MATTER."

III. PRECAUTIONS AGAINST NORM LIABILITY

- A. STATUTORY/REGULATORY
(E.G., CERCLA AMENDMENTS)**
- B. MANAGEMENT SAFEGUARDS
(E.G., PRODUCT STEWARDSHIP)**
- C. INSURANCE COVERAGE**

1. RETROACTIVE MEASURES:

- **IF YOU BELIEVE YOU MAY BE SUBJECT TO A THIRD-PARTY CLAIM, NOTIFY YOUR INSURERS IMMEDIATELY**
- **NOTIFY ALL CARRIERS ON THE RISK FROM DATE OF EARLIEST POSSIBLE EXPOSURE**
- **IF A PRODUCT LIABILITY CLAIM AND NO ABSOLUTE NUCLEAR EXCLUSIONS, THERE IS USUALLY COVERAGE**
- **IF A CERCLA-TYPE CLAIM AND NO ABSOLUTE NUCLEAR EXCLUSIONS, MAY BE COVERAGE, ESPECIALLY IF PRE-1985 EXPOSURE**

2. PROACTIVE MEASURES:

- **AVOID ABSOLUTE NUCLEAR EXCLUSIONS IN YOUR POLICIES**
- **CONSIDER BUYING SPECIAL NUCLEAR LIABILITY INSURANCE (OFFERED BY COMMERCE & INDUSTRY AND OTHERS)**

**ELIPGRID-PC and INRADS[®]: Tools for Reducing Costs
and Optimizing Data Collection on Sites Contaminated with NORM**

Philip V. Egidi
Oak Ridge National Laboratory-Health Sciences Research Division

WORKS IN PROGRESS

ELIPGRID-PC and INRADS®: Tools for Reducing Costs and Optimizing Data Collection on Sites Contaminated with NORM

Philip V. Egidi

Oak Ridge National Laboratory/Health Sciences Research Division
Environmental Technology Section
Grand Junction, Colorado

ABSTRACT

Oak Ridge National Laboratory (ORNL), Environmental Technology Section (ETS), located in Grand Junction, Colorado has more than ten years experience in radiological surveying and more than twenty years as part of the ongoing Formerly Utilized Sites Remedial Action Project surveys conducted by ORNL Health Sciences Research Division. As part of our mission, ETS researches, develops, and applies innovative technologies to share with private industry. The ELIPGRID-PC software and INRADS® multi-detector radiologic survey instrument are works in progress discussed. ELIPGRID-PC is a tool that aids in survey design, and the INRADS system automates and increases the amount of data collected.

INTRODUCTION

The purpose of this paper is to discuss two tools being developed by Oak Ridge National Laboratory (ORNL) Environmental Technology Section (ETS) located in Grand Junction, Colorado. ORNL/ETS has been conducting radiological surveys for more than ten years in conjunction with numerous U.S. Department of Energy (DOE) Projects, including the Uranium Mill Tailings Remedial Action Program (UMTRAP), the Monticello Remedial Action Project, the Formerly Utilized Sites Remedial Action Program, and the Decontamination and Decommissioning (D&D) Program. Much of its work in these programs involves investigating uranium and radium contamination from the uranium mining and milling part of the fuel cycle. In the course of investigating these mill-related tailings and debris, we often encounter naturally occurring radioactive material (NORM) in many forms and places. We encounter elevated levels of NORM in many forms: dinosaur bone, decorative rock, building materials, old radium dial watches, contaminated piping and steel that have been released from the old mill sites (Wilson 1993). Our experience has led us to develop methodologies that are applicable to some NORM projects. Two tools we are developing are the ELIPGRID-PC software and the INRADS system. ELIPGRID-PC is a tool that aids in survey design, and the INRADS system automates and increases the amount of data collected.

ELIPGRID-PC

One important factor to determine when designing a radiological survey is the amount of samples to collect in order to satisfy data quality objectives (DQOs) for the project. Some items to consider in this process are:

- The sensitivity of the instrumentation,
- the average contaminant concentration compared to background,
- the smallest size and shape of pockets of residual contamination to be detected,
- the level of confidence that an area of residual contamination will be detected, and
- the cost involved in detecting these pockets (called hot-spots).

If the MDA of the instrumentation is not low enough to detect residual contamination at guideline levels with confidence, scanning alone may not be sufficient to release the items or area of interest from radiological control to the public. Formulas for determining MDA can be found in the literature (U.S. NRC 1992). In addition, some projects require static measurements or samples regardless of MDA. The ELIPGRID-PC software is used to aid in the design of these surveys.

The standard approach for calculating the probability of detecting elliptical hot spots is based on ELIPGRID, a FORTRAN IV program developed by Singer (1972) and based on a mathematical procedure for determining the probability of success in locating elliptical geologic deposits (Singer and Wickman 1969). Designed to calculate the probability of success in locating elliptical targets with square, rectangular, and hexagonal (triangular) grids, ELIPGRID employs data input and code designed for the then-standard punch-card computer.

In 1984, J. Zirschky and R.O. Gilbert developed a nomographic procedure based on ELIPGRID to aid detection of highly contaminated areas at chemical- or nuclear-waste disposal sites (Zirschky and Gilbert 1984). Gilbert used these nomographs as the basis for the chapter "Locating Hot Spots" in his widely referenced book on environmental statistical methods (Gilbert 1987). Subsequently, these nomographs were used in 1989 by the U.S. Environmental Protection Agency (EPA) to develop tables for calculating the probability of missing various hot spots when using triangular and square sampling grids (U.S. EPA 1989). Both Gilbert's nomographs and EPA's tables have some inherent limitations not found in the original ELIPGRID program. They include the following:

- Gilbert's nomographs give probabilities for only one rectangular sampling grid size; no data for rectangular grids are given in the EPA tables.
- Neither approach allows specific orientation angles for suspected hot spots. For example, the tables and nomographs cannot provide the probability of detecting a given target with a given grid for a specific orientation angle.
- Data extracted from a graph are less likely to be accurate than computer program output resulting from the same input data.

ELIPGRID-PC removes these limitations by allowing a large number of rectangular grids, allowing specification of orientation angles for suspected hot spots, and calculating the results with a computer algorithm. ELIPGRID-PC was designed as a DOS utility by James R. Davidson of ORNL/ETS (Davidson 1995). It is user friendly and simple to operate. A Windows 3.x version of the program is now in development.

Some capabilities of ELIPGRID-PC are:

- Calculates grid size, given the desired probability of detecting a specified hot spot,
- calculates approximate grid size, given desired cost and hot spot specifications,
- calculates the smallest hot spot detectable with a given probability and size, and
- provides capability for graphing the probability of detection versus cost for various scenarios of interest to stakeholders.

The program assumes:

- The target is elliptical or circular,
- measurements or samples are taken on a square, rectangular, or triangular grid,
- the distance between points is much larger than the size of the sample being measured,
- the definition of a hot spot is clear and unambiguous, and
- there are no measurement misclassification errors; that is, no errors are made in deciding when a hot spot has been detected.

The recently published *ELIPGRID-PC: Upgraded Version* (Davidson 1995) provides step-by-step examples, with color illustrations, of ELIPGRID-PC being used to solve the sample problems in Gilbert's chapter on hot spots (Gilbert 1987).

ELIPGRID-PC can be downloaded from the World Wide Web at the following URL:

<http://terrassa.pnl.gov:2080/DQO/software/eligrid.html>

INRADS

The INRADS system is being developed as an indoor version of the Ultrasonic Ranging and Data System (USRADS[®]) system. As part of the UMTRA Program, ORNL was requested to survey thousands of public, residential, and commercial properties where the presence of uranium mill tailings was suspected. USRADS was developed at ORNL to automate much of the gamma radiation survey process and provide tabular and graphical data display in the field or in the office for report generation. Tests and use of USRADS by ORNL/ETS showed that the system is effective in locating radiation hot spots. The USRADS system and its use is described in detail elsewhere (Berven, et al 1991).

USRADS uses an ultrasonic signal to locate the position of the surveyor and FM radio to transmit data to a receiver module. The surveyor position and instrument measurements are recorded and stored once each second in a computer. As the surveyor progresses, the past and present positions are displayed on the screen to denote the completeness of coverage by the surveyor. During the survey, the software checks incoming information and provides a prompt if errors are detected in either the survey data or the position data. Over 3,500 data points can be collected in an hour. The data can be then interpreted and displayed with the software. Data can be exported by the USRADS software to a variety of formats, including AutoCAD. USRADS has been adapted to numerous uses including geophysical instruments, X-ray fluorescence detectors, alpha-beta gas proportional detectors, tissue-equivalent dose rate meters, and organic vapor detectors. CHEMRAD Tennessee, Inc., of Oak Ridge, Tennessee is the licensee of the USRADS and INRADS technologies.

INRADS takes the USRADS concept and technology and adapts it for indoor use. Instead of locating the surveyor's position over a large outdoor area with many stationary receivers (SRs), the position of the multiple detectors are tracked as they are moved along a wall surface using between one and three SRs. Depending on the array of the detectors, a 2-m high scan can be performed in two to four passes. The first prototype of the INRADS system used sodium iodide detectors for gamma radiation detection and gas flow proportional detectors for alpha and beta detection. Individual instruments were used for each detector and they were mounted on a cart. The current prototype detector array consists of five dual-phosphor scintillation detectors mounted on a pole. The ultrasonic crystal is also located on the detector array. The detectors are coupled to high-voltage and dual-pulse discriminator circuits housed in a central unit located on a backpack. The backpack unit can be controlled by the surveyor with a hand-held terminal. The location of the detector array and the data from the detectors are then transmitted to the host computer.

The software normalizes the data from each detector. Color-coded track maps are generated showing data points for each detector. The graphical display of the results of this initial qualitative scan identifies areas of high activity using color-coded dots correlated to the range of the detector's output. Areas of high activity are sequentially resurveyed, and a stationary 1-minute count is obtained at each elevated area for quantitative interpretation.

CHEMRAD Tennessee has successfully used the first prototype for indoor radiation scans. The INRADS system eliminates uncertainties in data recording, and provides excellent permanent documentation. In most cases, it reduces the cost of the survey, especially when data processing and the risk of contingent liabilities are included. A detailed characterization of interior surfaces can be formulated by directly sending survey data from multiple detectors to a PC that performs statistical treatment of the data. INRADS ensures complete survey coverage and increased data reliability through the elimination of transcription errors and conversion of direct instrument readout to appropriate radiological units.

PROPOSED PROJECTS

ORNL/ETS is currently planning to use the INRADS system on independent verification surveys at two sites this fiscal year. The Grand Junction Projects Office Remedial Action Project is a D&D project that has in its current scope the release of metal buildings. INRADS is being considered for a survey of metal building panels. The survey results will be used to independently verify the status of the panels. The National Conversion Pilot Program at the Rocky Flats Environmental Technology Center is currently in the process of remediating former uranium stamping and forming facilities and transferring them to the private sector for use in radioactive scrap metal recycling. As part of this effort, ORNL/ETS is proposing to perform an independent verification of the baseline survey being conducted to document the condition of the facilities prior to transfer. ELIPGRID-PC and INRADS are planned for use in designing and conducting these surveys.

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Instrumentation

Joseph Eddlemon
Pulcir, Inc.

(Paper not available)

NORM Regulations

Peter Gray
Editor, The NORM Report

**Naturally Occurring
Radioactive Material
(NORM) -- An
Emerging
Environmental Problem**

Regulations of NORM

**Past practices implicated in the
growing regulations of NORM**

- **Lack of survey data**
- **Use of broker systems**
- **Non-employees (contractor)
involvement**
- **Contaminated equipment sent
to smelters, scrap yards, etc**

NORM REGULATIONS

- **Worker Protection**
- **Exempt low risk materials**
- **Scrap recycling**
- **Remediations**
- **Disposal options**

Federal Regulations

NORM

- **No NRC rules**
- **No EPA rules**
- **OSHA has radiation rules**
- **DOT has regulations for the transportation of radioactive material**

OSHA Regulations

- **OSHA has safety regulations to limit worker radiation exposures**
- **The regulations are in 29CFR1910.96**

State Regulations

- **States with NORM regulations in effect as of October 1, 1996:**

Arkansas

New Mexico

Georgia

Oregon

Louisiana

South Carolina

Mississippi

Texas

State Regulations

- Additional states that are in various stages of developing NORM regulations are:

Alabama

New Jersey

Connecticut

Ohio

Illinois

Oklahoma

Kentucky

Washington

Michigan

State Regulations

**Even though most states
do not have specific
NORM regulations, these
states do have regulations
for the control of radiation**

Release of Facilities

- **Regulations require equipment be “Clean” before being released**
- **There are potential liabilities if NORM - contaminated facilities are released**

NORM in the Oil Industry

Kevin Grice
Texaco Exploration and Production, Inc.

(Paper not available)

CORPEX[®] NORM Decontamination Process

Raymond G. Azrak
CORPEX Technologies, Inc.

CORPEX[®] NORM Decon Process

- The CORPEX[®] NORM Decon process has been broadly employed to free release a variety of metallic and non-metallic items heavily contaminated with NORM.
- CORPEX Technologies Inc. works with applicators or directly with the equipment owners to assure proper, effective use of this decontamination process.
- The chemicals are non hazardous, non destructive and non RCRA regulated. The process is applicable where hydroblasting or mechanical decontamination are not effective because they cannot access the contaminated regions and/or because of the size and shape of the parts to be decontaminated.
- The CORPEX[®] products/processes are equally effective in removing fixed ^{226,228}Radium, ²¹⁰Lead and ²¹⁰Polonium as well as removing these radionuclides embedded in a variety of scales, oxides and hydrocarbons.
- CORPEX Technologies Inc. is a Responsible Care[®] Partner.

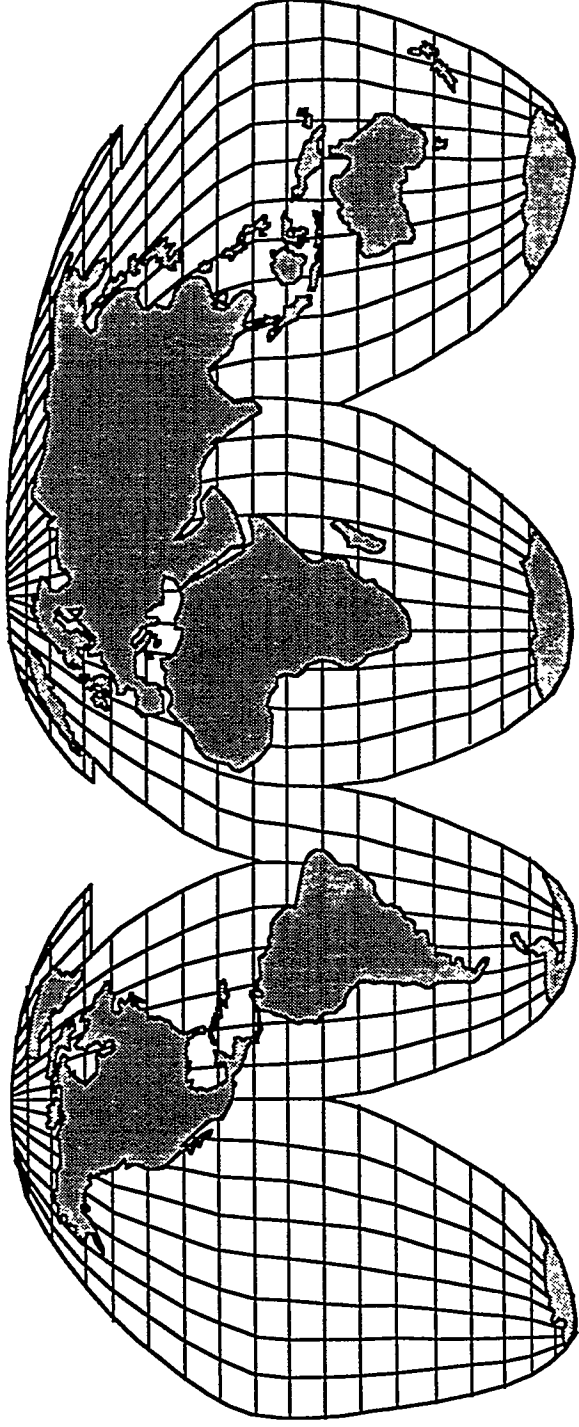
Call on us to help assess and solve your NORM problems

CORPEX® NORM Decontamination

Process

Beneficial Reuse

October 1996



Who is CORPEX Technologies Inc.

- **Innovative Chemical technology company**
 - Products & Processes for surface decontamination
 - Not applicators
- **Removing organic and inorganic contaminants**
- **Nuclear and Industrial markets**
- **Responsible Care® partner**

**Focusing on niche markets &
complex surface treatment problems**

CORPEX Technologies' approaches to NORM Decontamination

- **Assemble a team to handle customer problems**
CORPEX - Applicator - Health Physics
- **Provide chemistry and consultation for customer to decon**
- **Decon Sites**
Set-up sites with partners to accept and decon equipment

Today's discussion

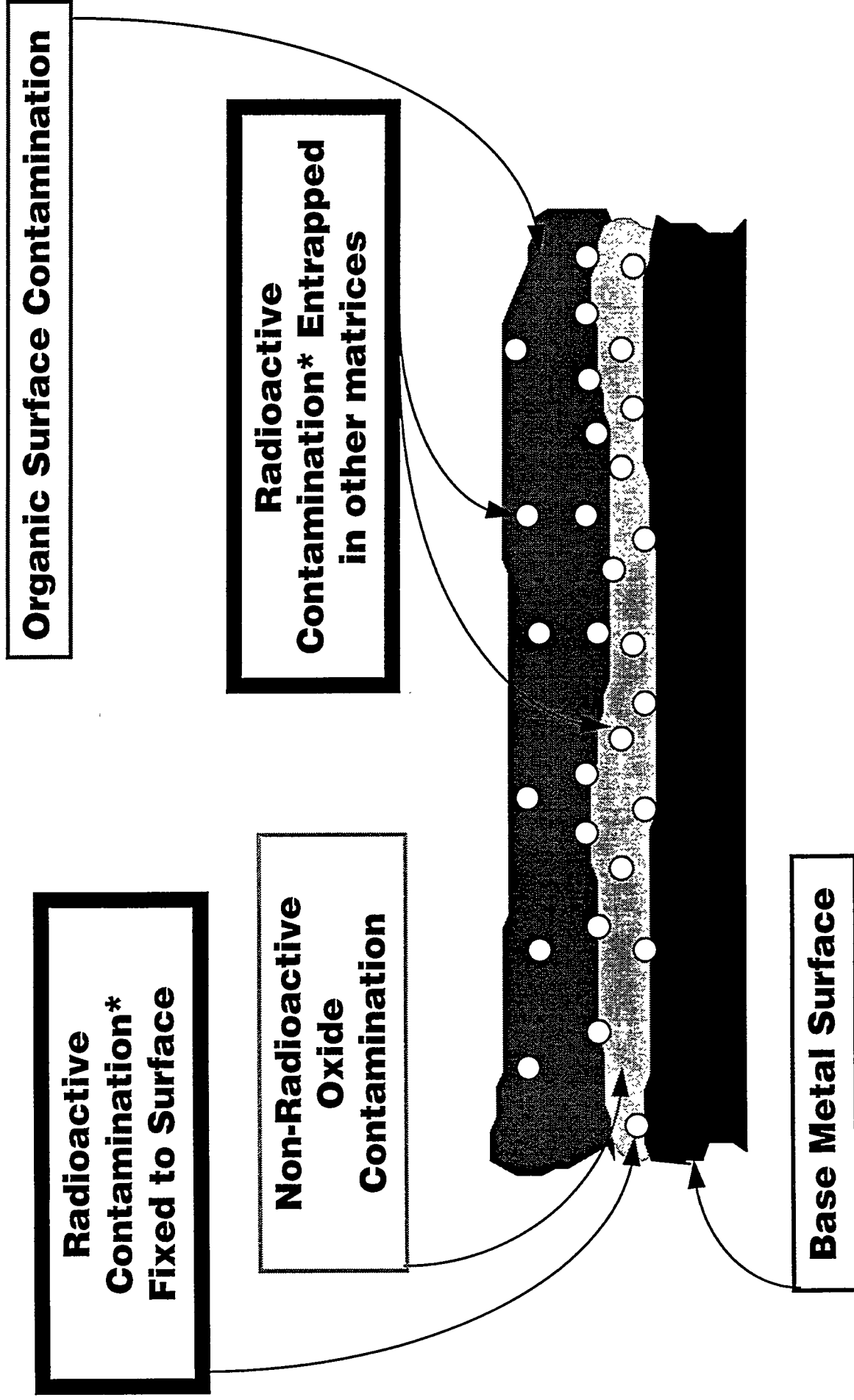
•Chemical Approach

- Patented chemistry and process

•Benefits

•Field Experiences

Typical Contamination Plate-out Pattern



* Typically $^{226,228}\text{Ra}$, ^{210}Pb and ^{210}Po

NORM Decon Processes

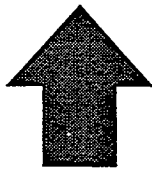
must have chemistries to deal with:



Greases & other hydrocarbons



Various scales & oxides



^{226,228}Radium

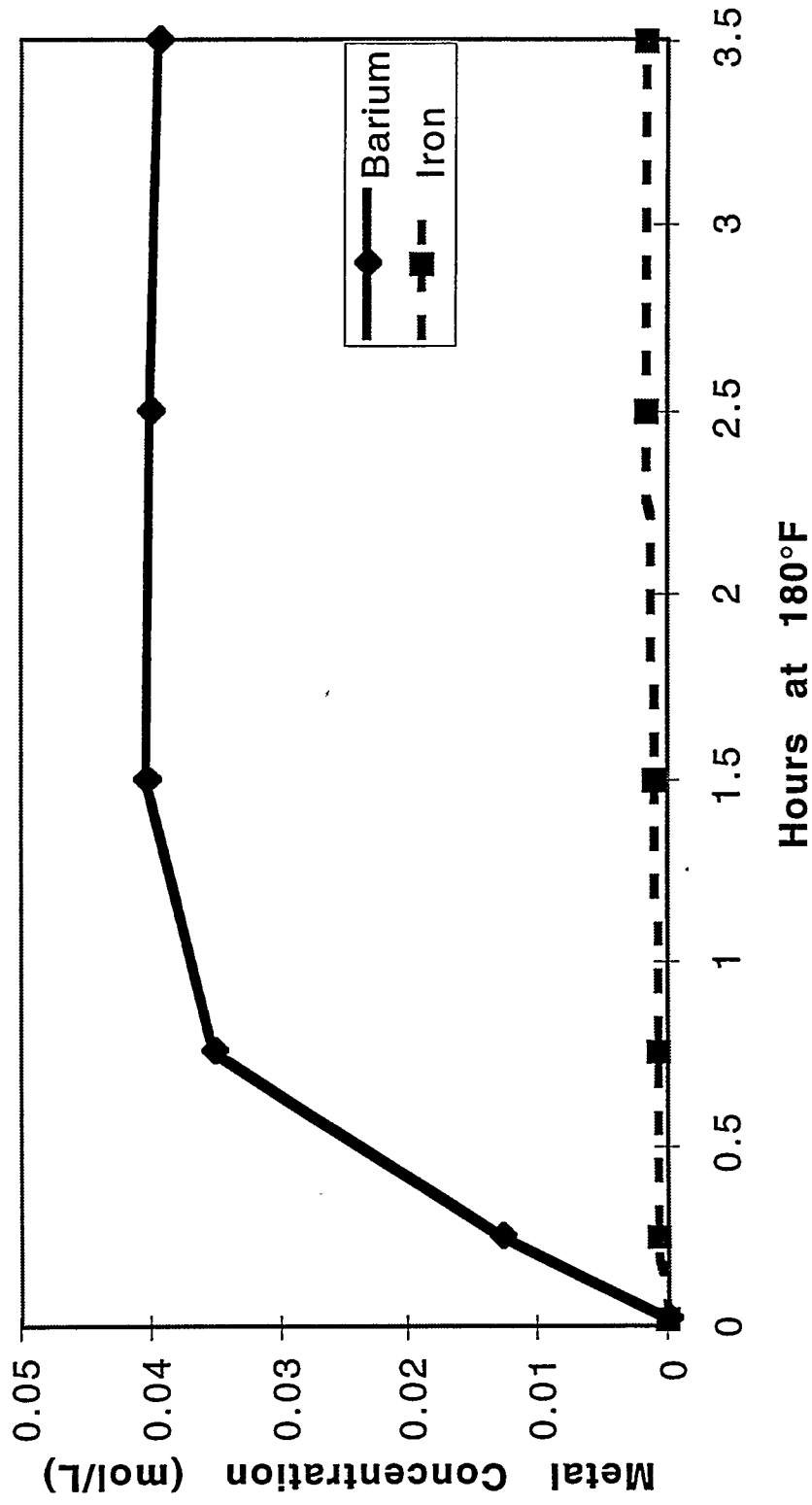


²¹⁰Polonium/ ²¹⁰Lead

CORPEX chemistries are not RCRA regulated

Selectivity of NOXOL®-771

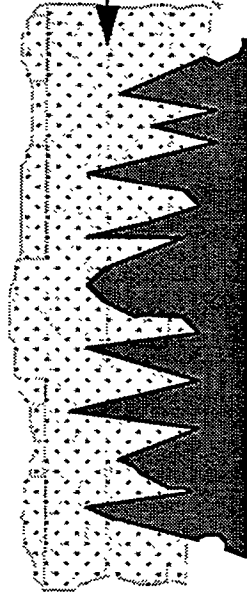
Barium Sulfate Scale in the Presence of Rust*



* Other Chemistries designed to deal with radionuclides, scales, and rust.

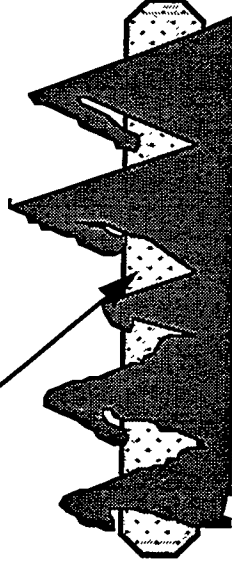
Comparison of Chemical and Mechanical Decon Processes

**Microscopic views showing the effect on metal and
contamination of chemical decontamination
versus mechanical removal**

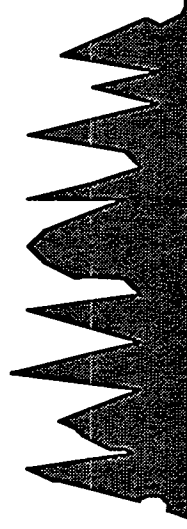


Before Decontamination

Contamination



After Mechanical Removal



**After Chemical
Decontamination**

CORPEX® NORM Decon Process

Advantages



Decontamination below regulatory limits to free release



Waste is minimized through concentration



CORPEX® chemistry is non-toxic, non RCRA regulated and non-destructive



Process does not embed and entrap contaminants



Clean equipment inaccessible to Hydroblasting



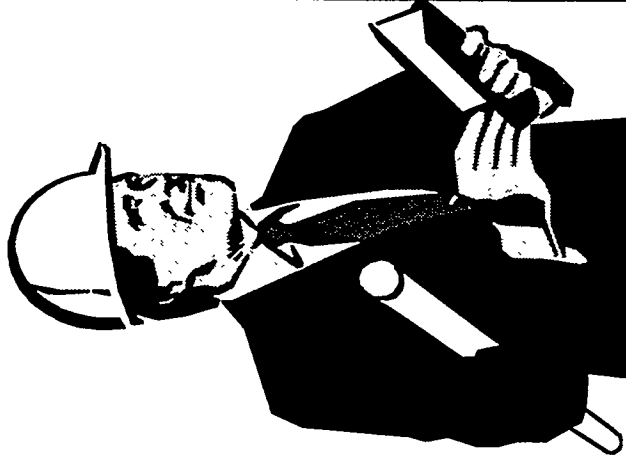
Use process in a turnaround or during normal operation



Savings: reuse of equipment & reduced disposal costs

Pre-Decontamination Activity

- Locate Deposits
- Characterize Deposits

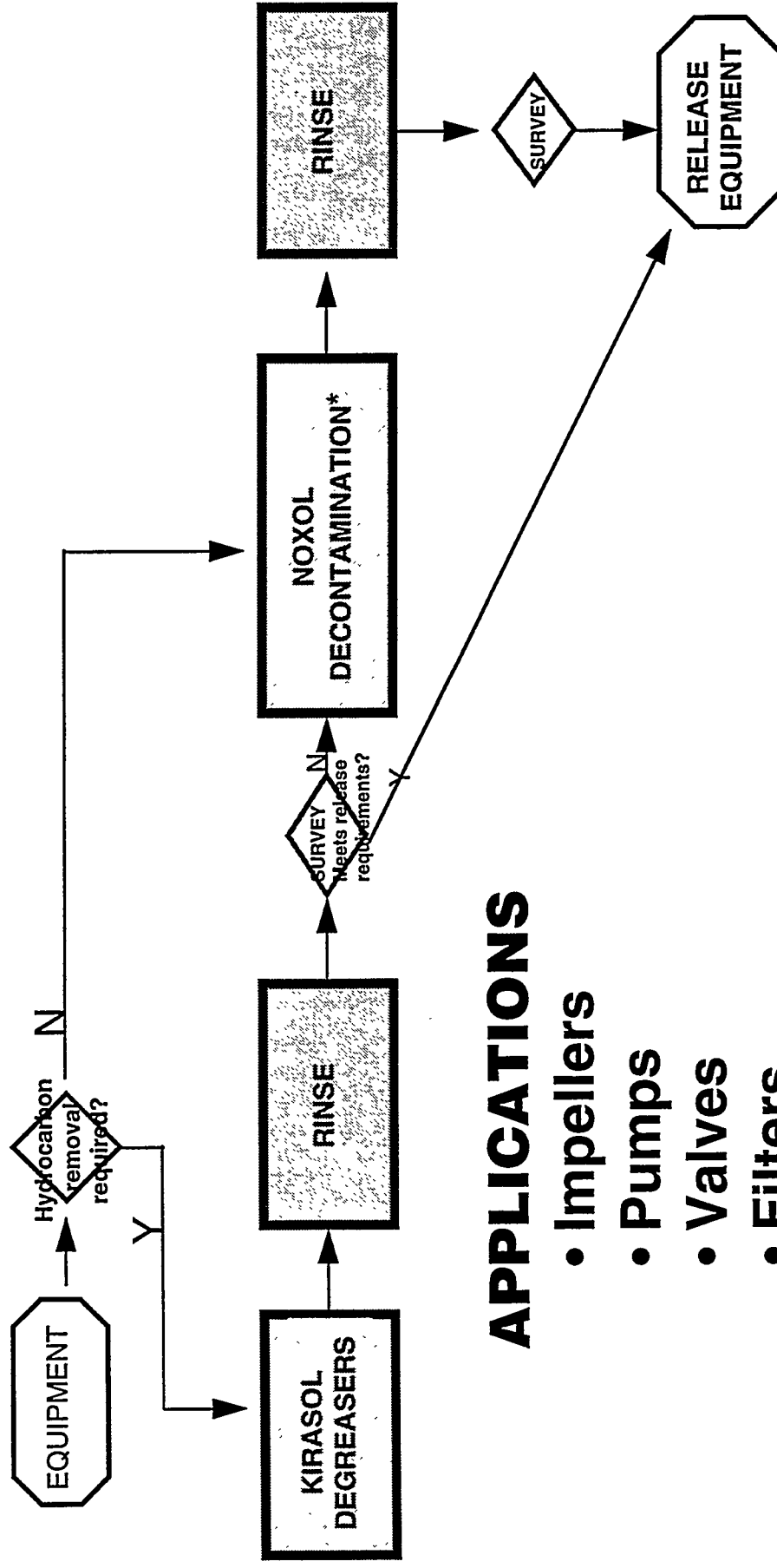


• Evaluate Decontamination Work

by:

- component metallurgy
- component size
- component operating conditions

Vat Treatment Example



APPLICATIONS

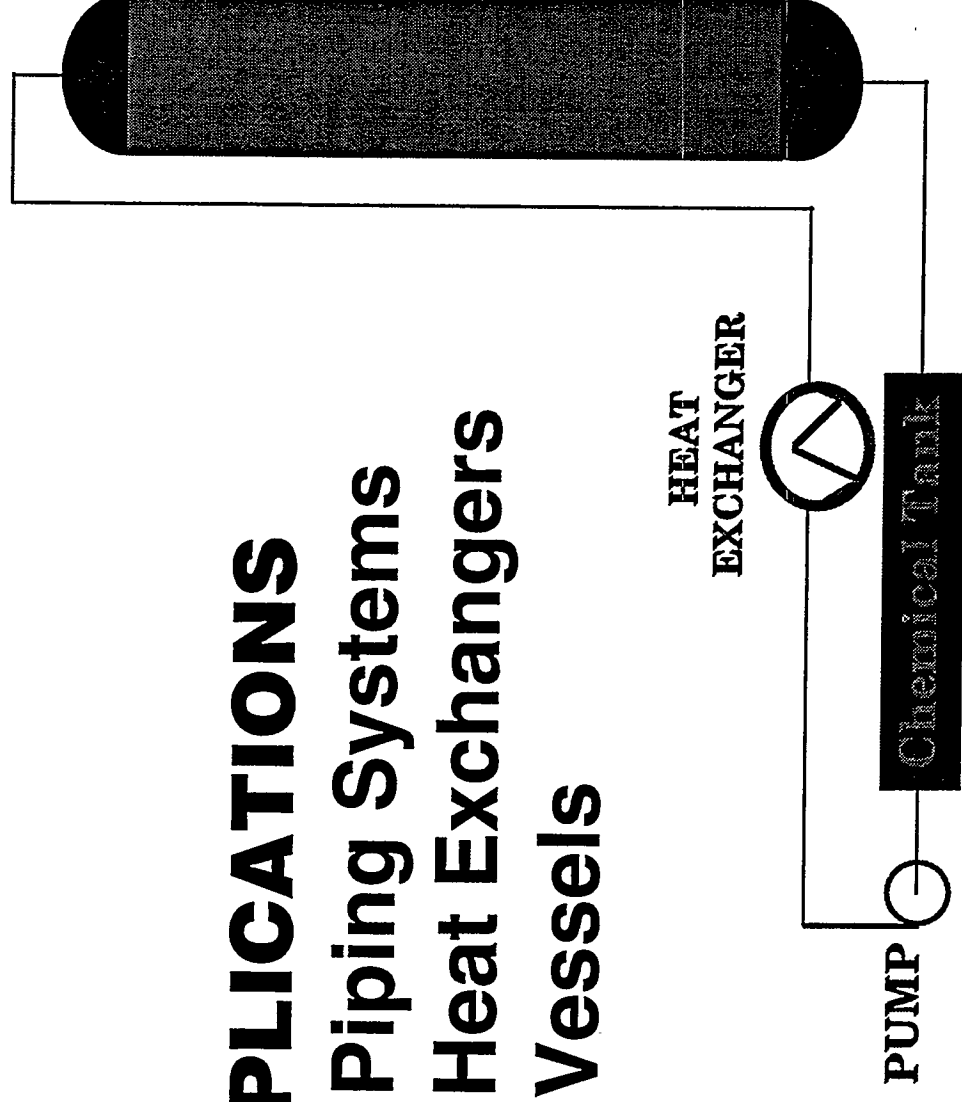
- Impellers
- Pumps
- Valves
- Filters
- Smaller parts

* e.g. NOXOL®-771 for 226,228Ra
NOXOL®-680 for 210Po, 210pb

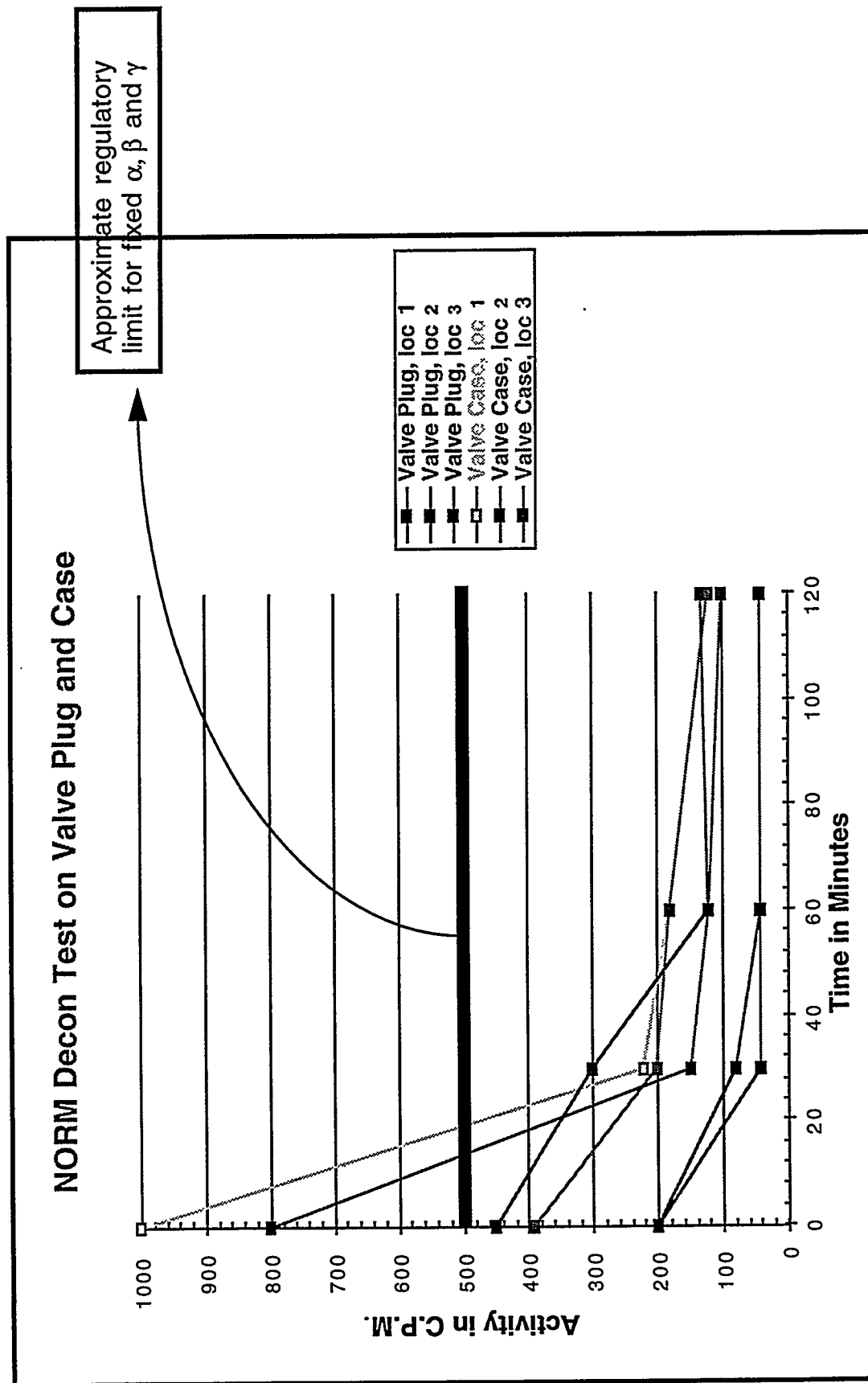
Closed Loop Circulation Example

APPLICATIONS

- Piping Systems
- Heat Exchangers
- Vessels



CORPEX® NORM Decon Process ²¹⁰Po and ²¹⁰Pb Decontamination Case



CORPEX® NORM Decon Process

Waste Management and Disposal Options

• **Direct Disposal at Plant**

(typically)

• **Chemical Treatment**

- Chemical Destruction with NOXOL®-260
- Precipitation of Radioactive Components

• **Solids Separation**

- Filtration
- Centrifugal
- Evaporation

• **Disposal**

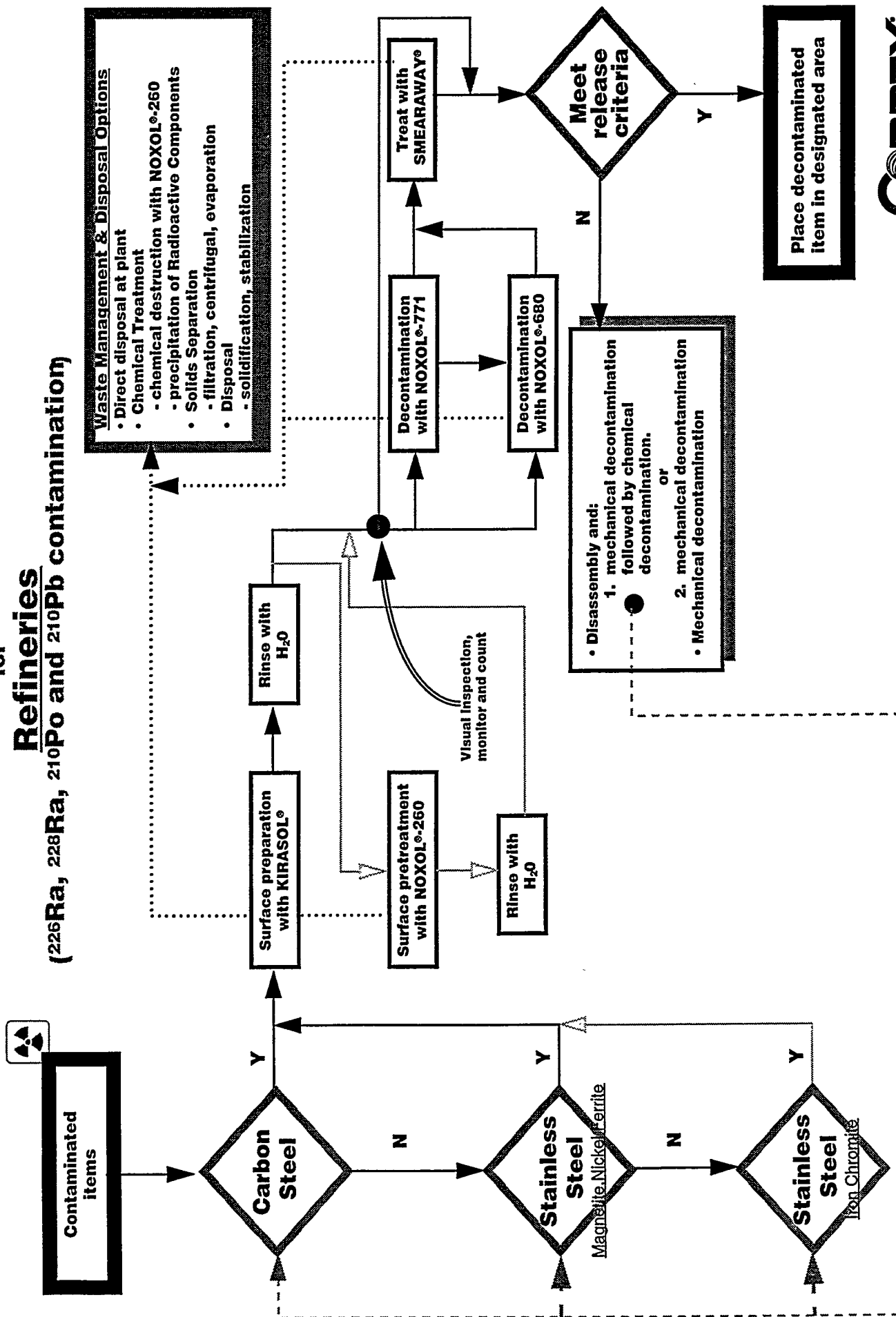
- Solidification
- Stabilization

CORPEX® NORM Decon Process

for

Refineries

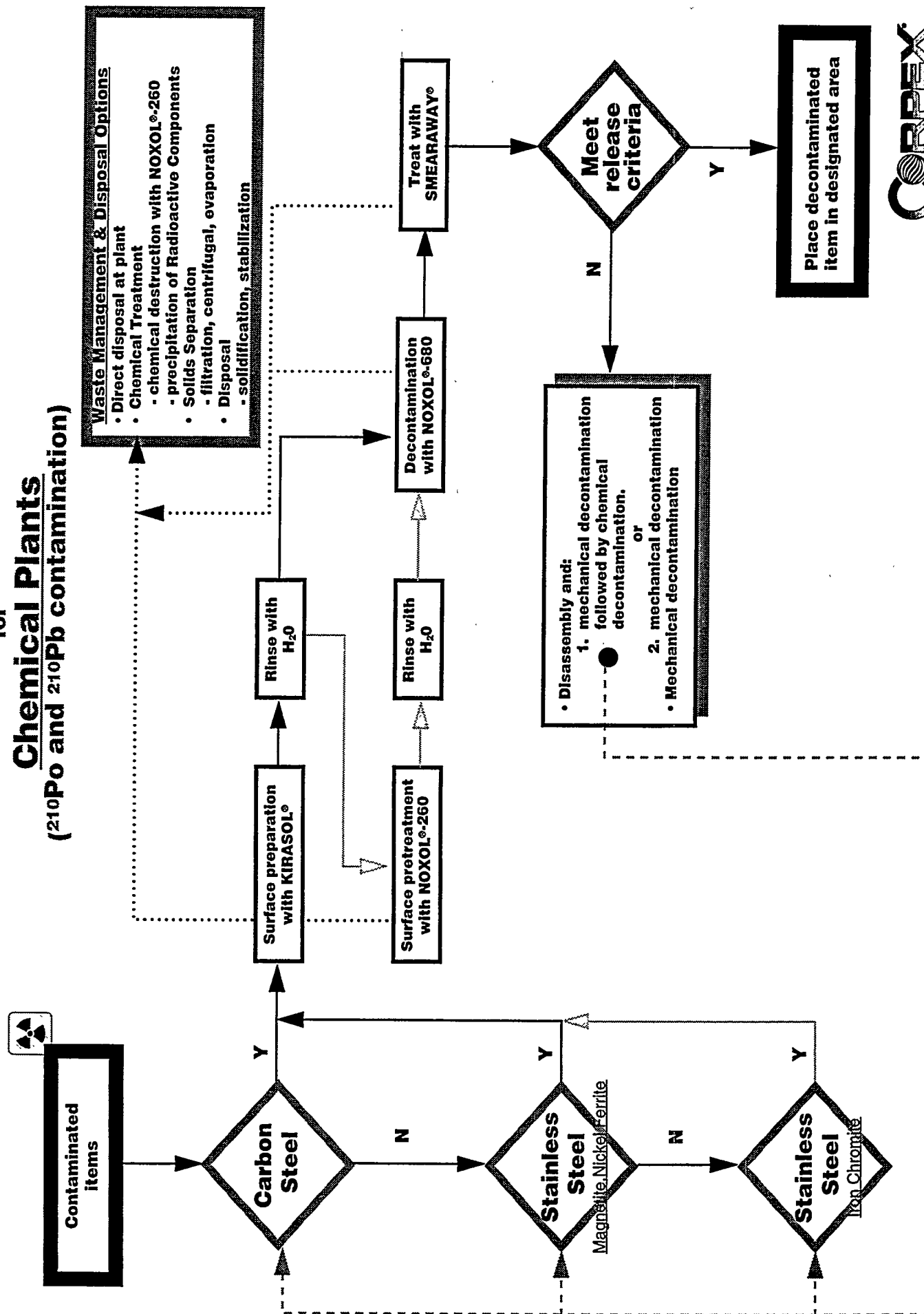
(²²⁶Ra, ²²⁸Ra, ²¹⁰Po and ²¹⁰Pb contamination)



CORPEX® NORM Decon Process

for

Chemical Plants (²¹⁰Po and ²¹⁰Pb contamination)

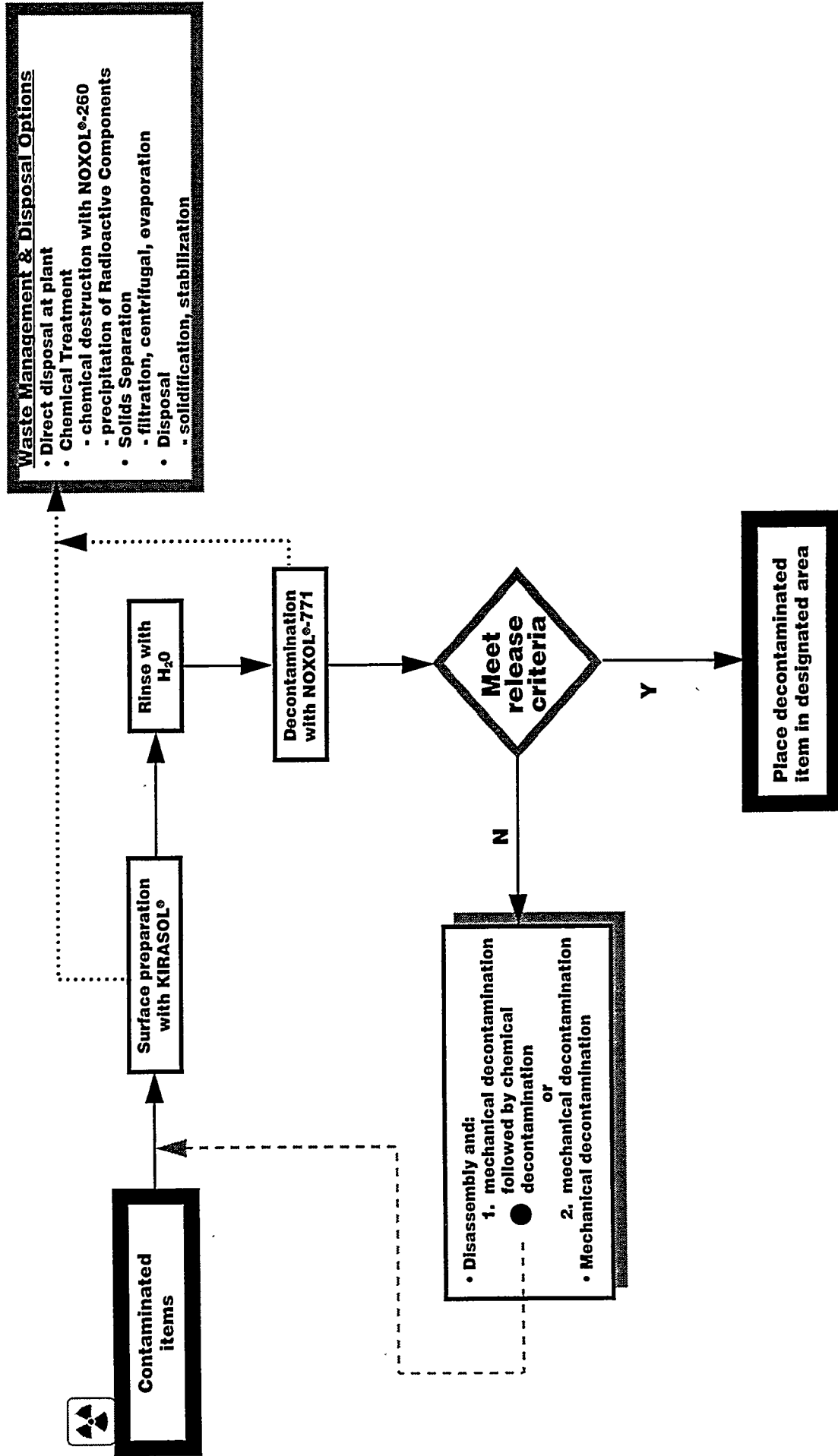


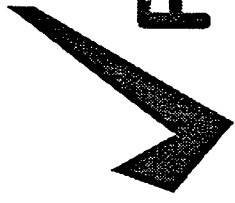
CORPEX® NORM Decon Process

for

Exploration & Production

(²²⁶Ra, ²²⁶Ra, ²¹⁰Po and ²¹⁰Pb contamination)





Petrochemical Turnaround

Problem:

Various type of valves contaminated with ²¹⁰Pb were on the critical path for equipment decontamination

Previous action:

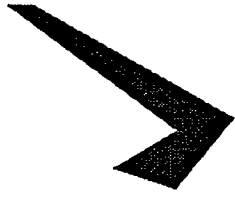
None

CORPEX Solution:

Use KIRASOL®-340 to degrease the valves and then vat treatment in a 12oz/gal solution of NOXOL®-680 @ 190°F for 2 to six hours.

Results:

Successfully decontaminated the valves to background levels during the turnaround.



Oil & Gas Producer

Problem:

Expensive High Pressure Separator contaminated with NORM deposits, typically Radium and Barium sulfate scales. Customer wanted to clean without cutting open and destroying the Separator

Previous action:

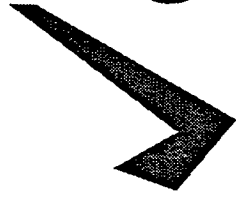
Could not access the separators for direct access with the scale.

CORPEX Solution:

Recirculation of a NOXOL®-771 solution @ 180°F.

Results:

The decontamination reduced the activity from 200uR to background level in 36 hours.



Oil & Gas Producer

Problem:

Twenty drums of metal and other material contaminated with Barium/Radium scale

Previous action:

None; accumulating with no way to decontaminate

CORPEX Solution:

Vat treatment in a 30% solution of NOXOL®-771 @ 210°F for 12 hours.

Results:

Allowed for solids to be combined and disposed of at a non-hazardous oilfield waste facility. Remaining fluids were pumped downhole.



Oil & Gas Service Applicator

Problem:

Oily-water separator and surge vessel contaminated with Radium Sulfate scales. Company wanted to sell equipment, but wanted to decon first to avoid future liability.

Previous action:

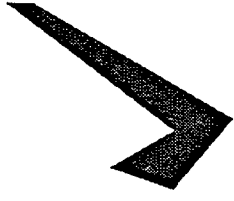
Hydroblasting unsuccessfully

CORPEX Solution:

Recirculation of a NOXOL®-771 solution @ 180°F.

Results:

The decontamination treatment reduced the activity from 200uR to background level in 36 hours.



E & P Facility

Problem:

Pump with 15,000-17,000 dpm of alpha/beta activity on its surface needed repair but company chose not to send off-site because of NORM.

Previous action:

None

CORPEX Solution:

Vat treatment in a 75% solution of NOXOL®-680 @ 180°F, overnight.

Results:

Highest reading for the pump was 1700 dpm well below the release limits; readily repaired.

CORPEX[®] NORM Decon Process

Advantages



- Equipment can be decontaminated below regulatory limits to or close to background levels offering substantial savings in equipment utilization and/or burial costs



- Waste is minimized through concentration by large orders of magnitude to reduce PRP responsibility



- Chemicals are Non-Toxic, Non-Destructive to components and Essentially Non-Hazardous



- All these activities can occur during a turnaround and during normal operations with minor impact on other activities



- Process does not further embed or entrap contaminants through peening as occurs in some blasting applications



- OVERALL COST EFFECTIVE PROCESS

**Overview of NORM and Activities by a NORM Licensed
Permanent Decontamination and Waste Processing Facility**

Guy A. Mirro
Growth Resources, Inc.

OVERVIEW - NORM ISSUES

NORM Sources, Problems, Regulations and Disposal Options

Potential NORM Hazards, Safety Equipment and PPE

Personnel Protection Requirements

OVERVIEW - NORM PERMANENT FACILITY

Description of Permanent Facility

Permanent Facility NORM Operations

Specific Radioactive Material License

Operating and Safety Procedures

Equipment Decontamination Capabilities

NORM Waste Processing Capabilities

Offsite NORM Services

URANIUM SERIES

Element	Half-Life / Disintegration	New Element
Uranium - 238	4.5 billion years/ α	Thorium - 234
Thorium - 234	24.1 days/ β	Protactinium - 234
Protactinium - 234	147 days/ β	Uranium - 234
Uranium - 234	2.5×10^5 years/ α	Thorium - 230
Thorium - 230	7.5×10^4 years/ α	Radium - 226
Radium - 226	1,620 years/ α	Radon - 222
Radon - 222	3.83 days/ α	Polonium - 218
Polonium - 218	3.05 minutes/ α	Lead - 214
Lead - 214	26.8 minutes/ β	Bismuth - 214
Bismuth - 214	19.7 minutes/ β	Polonium - 214
Polonium - 214	1.5×10^{-4} seconds/ α	Thallium - 210
Thallium - 210	1.32 minutes/ β	Lead - 210
Lead - 210	19.4 years/ β	Bismuth - 210
Bismuth - 210	5.01 days/ β	Polonium - 210
Polonium - 210	138.4 days/ α	Lead - 206 (stable)

THORIUM SERIES

Element	Half-Life / Disintegration	New Element
Thorium - 232	1.39 X 10 ¹⁰ /α	Radium - 228
Radium - 228	5.7 years/β	Actinium - 228
Actinium - 228	6.13 hours/β	Thorium - 228
Thorium - 228	1.91 years/α	Radium - 224
Radium - 224	3.64 days/α	Radon - 220
Radon - 220	56 sec/α	Polonium - 216
Polonium - 216	0.15 sec/α	Lead - 212
Lead - 212	10.64 hours/β	Bismuth - 212
Bismuth - 212	60.6 minutes/α	Thallium - 208
Bismuth - 212	60.6 minutes/β	Polonium - 212
Thallium - 208	3.1 minutes/β	Lead - 208 (stable)
Polonium - 212	0.30 μseconds/α	Lead - 208 (stable)

NORM in the Petroleum Industry

Important NORM in the Oil Industry

Radium-226

Radium-228

Important NORM in the Gas Industry

Radon-222

Lead-210

Radium-226

Bismuth-210

Polonium-210

WHEN DO NORM REGS APPLY

EQUIPMENT

Exempt if it does not exceed **50 μ R/hr** including background.

Acceptable Surface (Removable) Contamination

1000 dpm/100cm²

SOILS

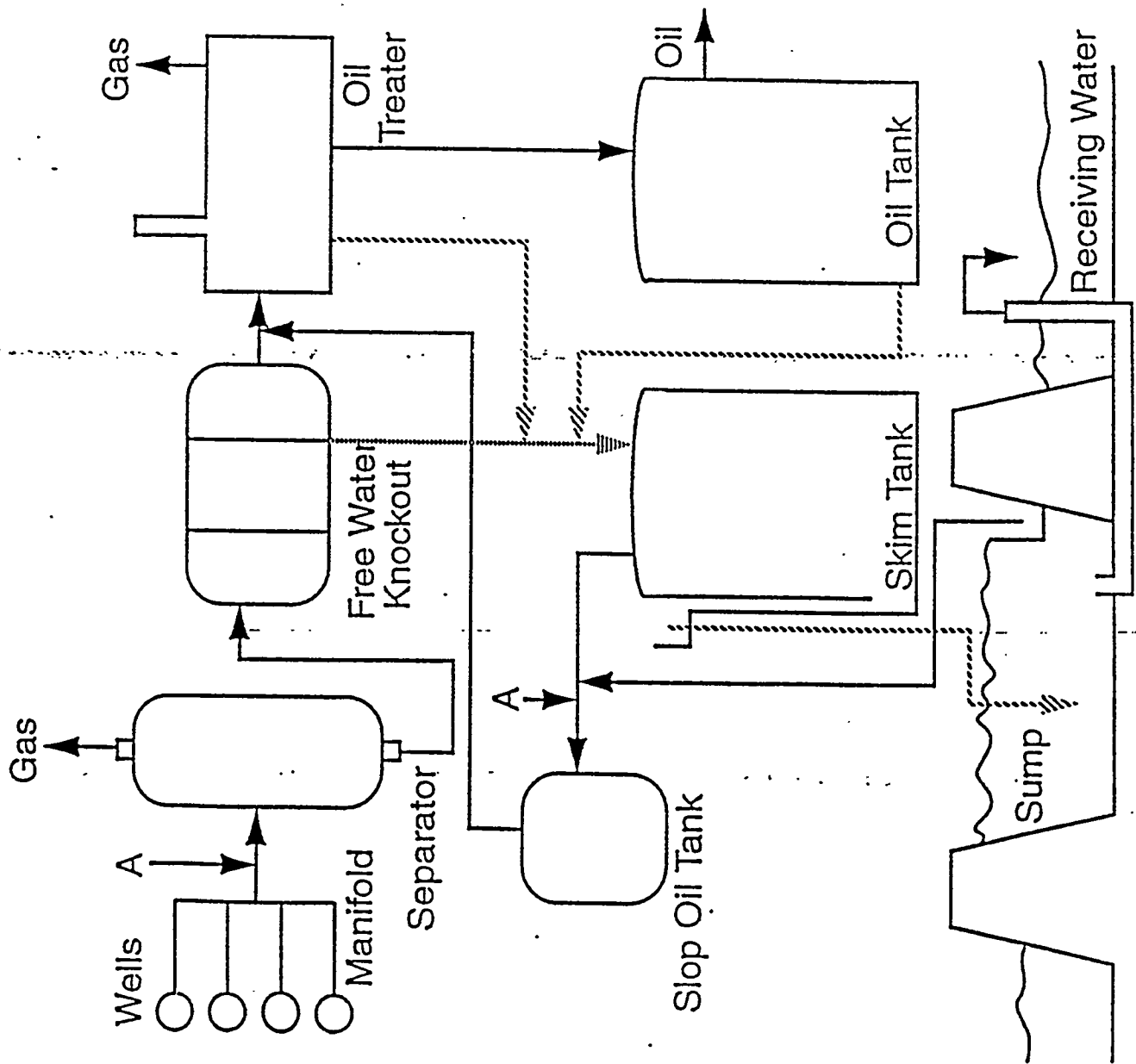
Exempt if the specific activity does not exceed **30 pCi/g** averaged over any 100 square meter area and the effective dose equivalent to individual members of the public (continually present) does not exceed **100 mrem** in a year. Otherwise, must not exceed **5 pCi/g**.

OR

150 pCi/g of any other NORM radionuclide

NORM PROBLEMS

- **Pit Contamination**
- **Soil Contamination**
- **Pipe Scale**
- **Drums**
- **Tubulars**
- **Vessels**
- **Tanks**
- **Produced Water**



Problems of the Scrap / Recycle Industry

Will not accept NORM contaminated equipment with elevated external background levels - approx. 5-20 uR/hr.

No steel mill or smelter have routinely accepted NORM contaminated equipment exceeding these background levels.

All equipment will be required to be decontaminated below these background levels or they will be rejected by the respective scrap facility.

All scrap and steel mill facilities need to perform their own external and removable NORM screening surveys before accepting shipment.

SOURCE OF NORM

Radium - 226

Dissolved in produced waters

Saltier the water, the greater the NORM concentration

Found in scale - Scaling problems prime candidates for NORM

Not commonly associated with drilling activity

Associated with production and processing activities

Has a long half-life*

Associated with Nonhazardous Oilfield Wastes (NOW)

*A half-life is the time it takes for a given amount of a radionuclide to decay to one-half of its original amount (1,620 years for Radium - 226)

NORM Regulation - State

<u>Specific Regulations</u>		<u>General Regulations</u>
<u>In Place</u>	<u>In Process</u>	
Arkansas	Alabama	Nevada
Georgia	Connecticut	New York
Louisiana	Illinois	Tennessee
Mississippi	Michigan	Utah
Texas	*New Mexico	Virginia
* *	Oklahoma	West Virginia
	*South Carolina	11 Other States

Ongoing studies in California & Florida



LA Dept. of Environmental Quality (DEQ) LA LAW AND NORM

Documents

LAC Title 33 (ENVIRONMENTAL QUALITY)
Part XV (Radiation Protection)
Chapter 14. (Regulation and Licensing of NORM)
June, 1992
Revised Regulations Effective January 20, 1995

Implementation Manual for Management of NORM in LA

DISPOSAL

NOW FACILITIES

Can receive NOW wastes up to 30 pCi/g
Only a Department of Natural Resources NOW Manifest Required

SPECIFICALLY LICENSED NORM FACILITIES

Can receive NOW containing NORM at concentrations above 30 pCi/g

TEXAS DEPARTMENT OF HEALTH

Bureau of Radiation Control

Texas Regulations for Control of Radiation

Part 46

Licensing of Naturally Occurring Radioactive Material (NORM)

Part 46 covers the storage, transportation, processing, treatment, transfer, use, decontamination, and recycling of NORM contaminated materials

RAILROAD COMMISSION OF TEXAS

OIL & GAS DIVISION

RULE 94

Disposal of Oil & Gas NORM Waste

Effective Date - February 1, 1995

All wastes in TX below 30 pCi/g are exempt from the regulations.

Equipment must not exceed 50 μ R/h

STATE NORM DISPOSAL

**Four States Have NORM Disposal Facilities for Oil &
Gas Wastes**

U.S. Ecology, Richland Washington, Landfill

Envirocare, Clive, Utah, Landfill

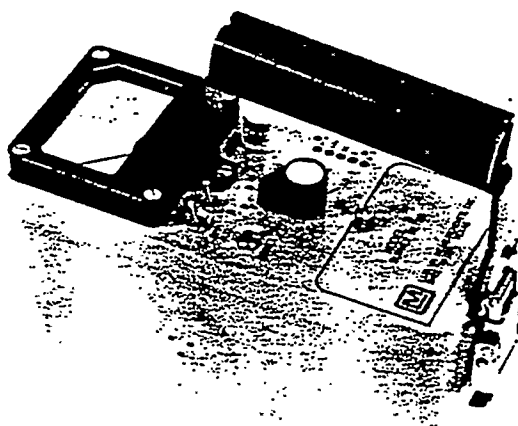
Campbell Wells, Lacassine, Louisiana, Landfarm

**Newpark/SOLOCO, Port Arthur, Texas
Treatment / Class II Injection**

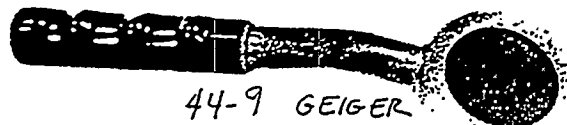
Practical Worker Protection Concepts

- Have survey instruments available.
- Make training available.
- Have protective equipment available.
Gloves - Protective Clothing etc.
- Use common sense:
 - Understand and comply with the regulations.
 - Do not expose workers or the general public.
 - Don't generate dust.
 - Don't spill waste on the soil.
 - Do not release contaminated materials for unrestricted use.
 - Do not do anything to increase legal liability or regulatory scrutiny by the state.

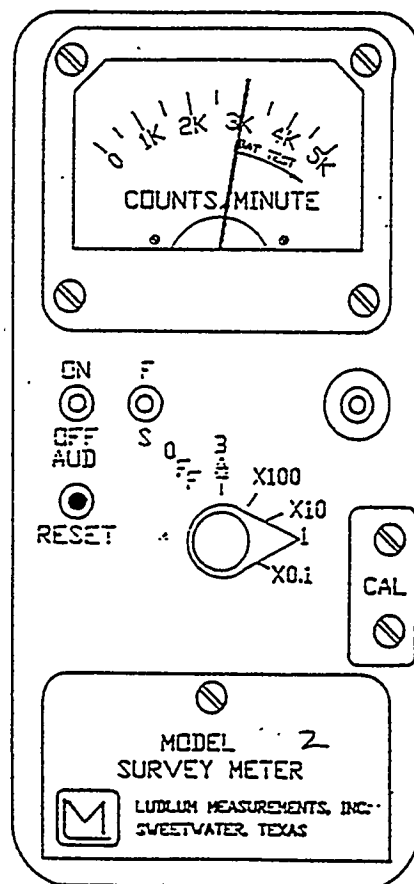
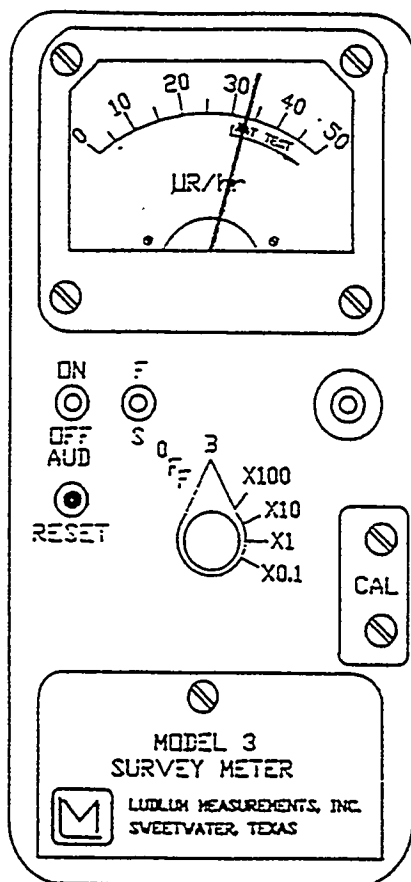
Radiation Survey Instruments



44-2 SCINTILATOR



44-9 GEIGER



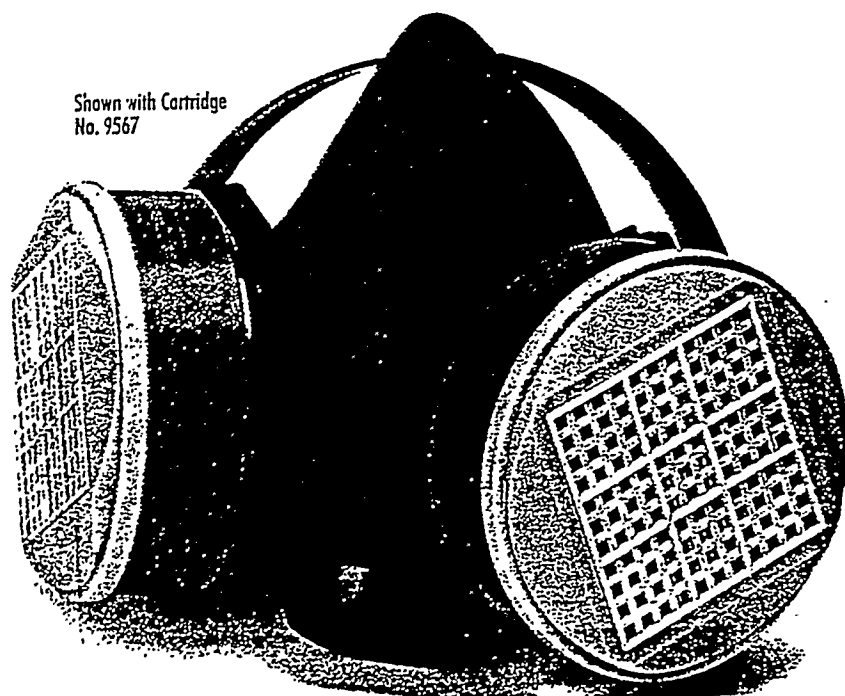


GLOVES



Attached hood and
gloves give you
comprehensive
protection.

PROTECTIVE
CLOTHING



Shown with Cartridge
No. 9567

RESPIRATOR

RADIOACTIVE



MATERIAL LICENSE

RADIATION PROTECTION DIVISION
P.O. BOX 82135
BATON ROUGE, LOUISIANA 70884-2135

LICENSEE Growth Resources, Inc. 200A Burgess Drive Broussard Louisiana 70518 Attention: Mike Carty, Corporate RSO	LICENSE NUMBER	EXPIRATION DATE
	LA-6672-S01	November 30, 1996
	AMENDMENT NUMBER	PREVIOUS AMENDMENTS ARE VOID
	8	
THIS LICENSE ISSUED PURSUANT TO AND IN ACCORDANCE WITH		
Letter SIGNED BY: Charles Greer DATE: March 18, 1996		

RADIOISOTOPE	MAXIMUM NUMBER OF SOURCES	MAXIMUM ACTIVITY OR QUANTITY FOR SOURCE	SEALED SOURCE IDENTIFICATION	STORAGE CONTAINER OR EXPOSURE DEVICE
ELEMENT	MASS NO.		CHEMICAL FORM--PHYSICAL STATE	AUTHORIZED USE

Ra 226/228 and daughters	Total	As Needed	Any Chemical Form Radioactive Material From Oil/Gas Drilling, Production, and Related Activities.	See Condition #1
--------------------------	-------	-----------	---	------------------

1. Growth Resources, Inc. is authorized to perform decontamination/cleaning/remediation and maintenance of equipment, land, tanks, vessels, pipe, tubulars, pits, soil and facilities; NORM waste processing - treatment, slurring, grinding, pumping, volume minimization, particle size segregation, separation, encapsulation, and the placement of NORM downhole for disposal.
2.
 - A. Radioactive material shall be handled, stored and used at 200A Burgess Drive, Broussard, Louisiana 70518 and at the Bayou Black facility (N1361DC), 242 Geraldine Road, Gibson, Louisiana 70356 and at temporary jobsites of the licensee in and offshore Louisiana.
 - B. Prior to operation at temporary jobsites, the licensee shall comply with applicable provisions of other regulations of the Department of Environmental Quality, and obtain all applicable state and local permits.
 - C. This condition does not prohibit use in other Agreement States and states under the jurisdiction of the U.S. Nuclear Regulatory Commission under reciprocity procedures which may be established by an Agreement State or the U.S. Nuclear Regulatory Commission.
3. Radioactive material listed in the schedule shall be used by, or under the supervision of, Charles Greer, G. Wayne Grooms, Kim Merrill, Robert Bidwell, Zhimin Wang, Lydia Litinsky, Michael Carty, Paul Whatley, Mark Landress, Guy Mirro, Glen Rachal, Mark Briley, Dionne Fontenot, Larry Guilbeaux, John Harding, Charles James, Jovian Jones, Mark Landress, Pedro Merida, and Michael Zirlott.
4. Upon beginning a new temporary jobsite involving commercial NORM services, the licensee must notify the Division, using the Form RPD-35.
5. The participation in the disposal of NORM into the wellbore of a well to be plugged and abandoned shall have prior written approval from the Assistant Secretary of the Office of Air Quality and Radiation Protection.
6. No individual shall handle radioactive material until having satisfactorily completed Division-accepted training in the safe handling of radioactive materials and who has been so designated by Mike Carty.
7. Pursuant to LAC 33:XV.104 and Chapter 4, records of receipt, transfer, and disposal of radioactive material shall be maintained for five years for inspection by the Division.
8. A quarterly report of job activities shall be submitted to the Division which includes customer name, jobsite location and dates, amount of waste generated, and date the waste was transferred. Such report shall be submitted to the Division no later than 30 days after the end of each calendar quarter.
9.
 - A. Contamination surveys, appropriate to the job, shall be performed at each temporary jobsite at the beginning and conclusion of every job, including in the vicinity of waterways.
 - B. Contamination surveys shall be performed in the laboratory at intervals not to exceed one (1) week. Records shall be kept in units of microcuries and maintained for inspection by the Division.
 - C. Quarterly contamination surveys shall be performed at the Bayou Black facility in the barge slip area which is potentially impacted by the loading, unloading, and NORM remediation activities.
 - D. Survey records shall be maintained for five years for inspection by the Division.
10. The licensee is authorized to calibrate and repair radiation detection instruments as a customer service in accordance with the procedures submitted September 20, 1993.

DEPARTMENT OF ENVIRONMENTAL QUALITY
OFFICE OF AIR QUALITY AND RADIATION PROTECTION
RADIATION PROTECTION DIVISION
BATON ROUGE, LOUISIANA 70884-2135

LICENSEE Growth Resources, Inc.			LICENSE NUMBER LA-6672-S01		AMENDMENT NO. 8	EXPIRATION DATE November 30, 1996
RADIOISOTOPE ELEMENT MASS NO.		MAXIMUM NUMBER OF SOURCES	MAXIMUM ACTIVITY* OR QUANTITY PER SOURCE	SEALED SOURCE IDENTIFICATION CHEMICAL FORM--PHYSICAL STATE	STORAGE CONTAINER OR EXPOSURE DEVICE AUTHORIZED USE	

11. Sealed sources containing radioactive material shall not be opened by the licensee.
12. Each container holding NORM-contaminated waste must be permanently marked with an identification number traceable to records documenting the original source of the contents.
13. Transfer of NORM, NORM waste, and NORM contaminated equipment shall only be to persons specifically licensed to receive such material, or to persons generally licensed under LAC 33:XV.1408.
14. Containerized NORM waste shall not be stored for more than ninety (90) days at a temporary jobsite.
15. Containerized NORM waste shall not be stored for more than one year at the Bayou Black facility (N1361DC).
16. Documentation supporting all NORM activities shall be maintained for five years for inspection by the Division. This includes, but is not limited to, training, fit tests, and safety meetings.
17. Except as specifically provided otherwise by this license or LAC 33:XV, the licensee shall possess, handle, and use radioactive material in the schedule of this license in accordance with statements, representations, and procedures contained in the licensee's application dated October 10, 1994 and in all subsequent correspondence.

GVB:jpt

* μ Ci-microcurie; mCi-millicurie; Ci-Curie

PAGE 1 SIGNED BY: Gustave Von Bodungen, P.E., Assistant Secretary	DATE MAY 23 1996	PAGE OF 4	PAGES 4
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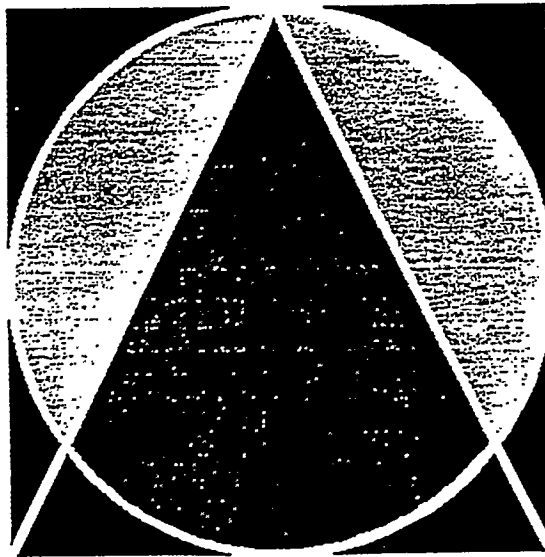
**NORM PERMANENT FACILITY
HEALTH PHYSICS PROGRAM and WORKER PROTECTION
PROCEDURES**

1. Introduction
2. Personal Protective Equipment
3. Personnel Monitoring
4. Training
5. Standard Work Practices
6. Environmental Monitoring
7. Survey Programs and Hazardous
Identification
8. Transportation
9. Emergency Procedures
10. Instrumentation
11. Contractors
12. Documentation & Record Keeping
13. NORM Storage
14. Transfer and Disposal of NORM
15. Waste Processing and Handling
16. Decontamination
17. References

GROWTH RESOURCES, INC.

BAYOU BLACK FACILITY

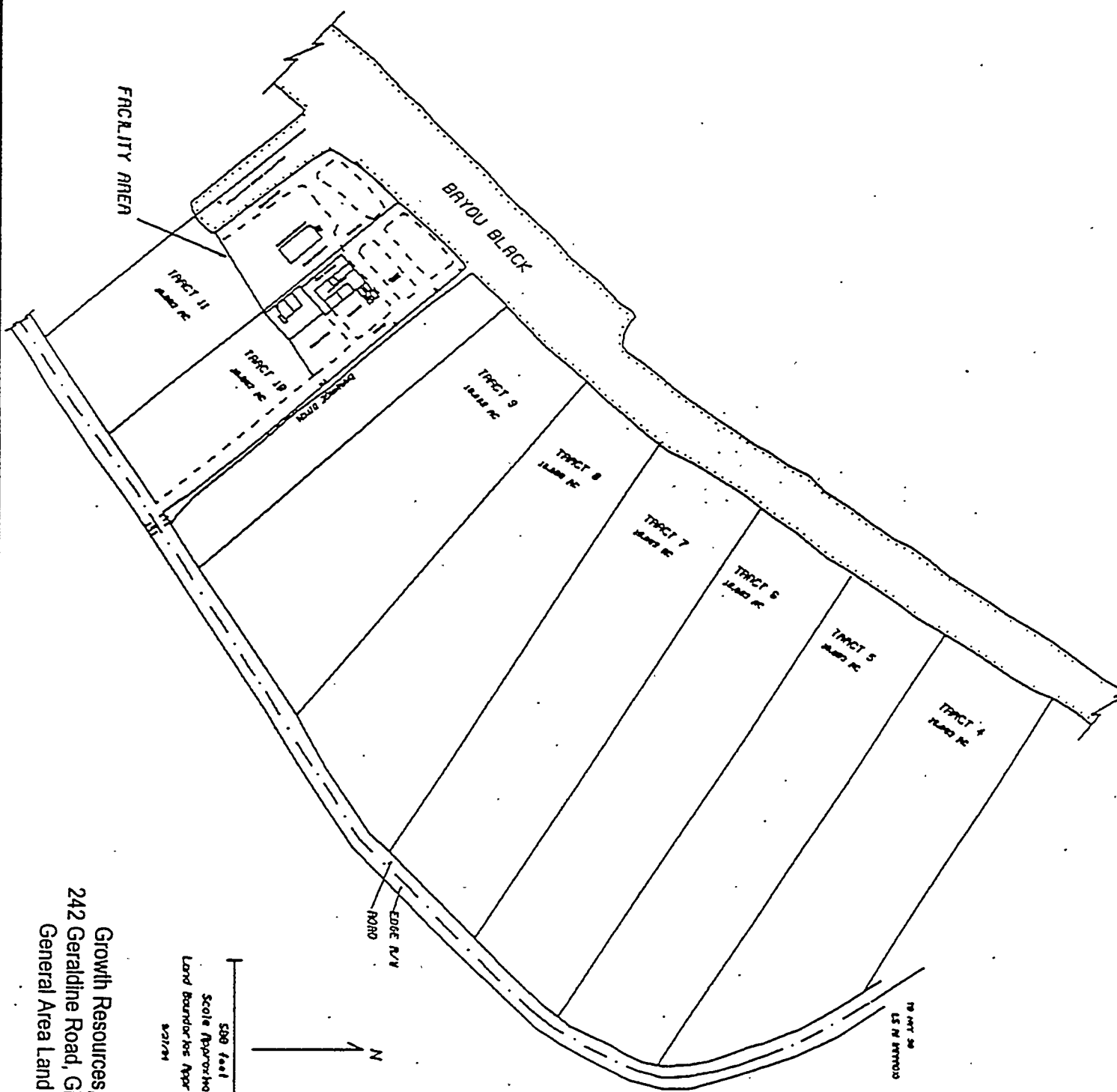
**NORM DECONTAMINATION
& WASTE MANAGEMENT SERVICES**



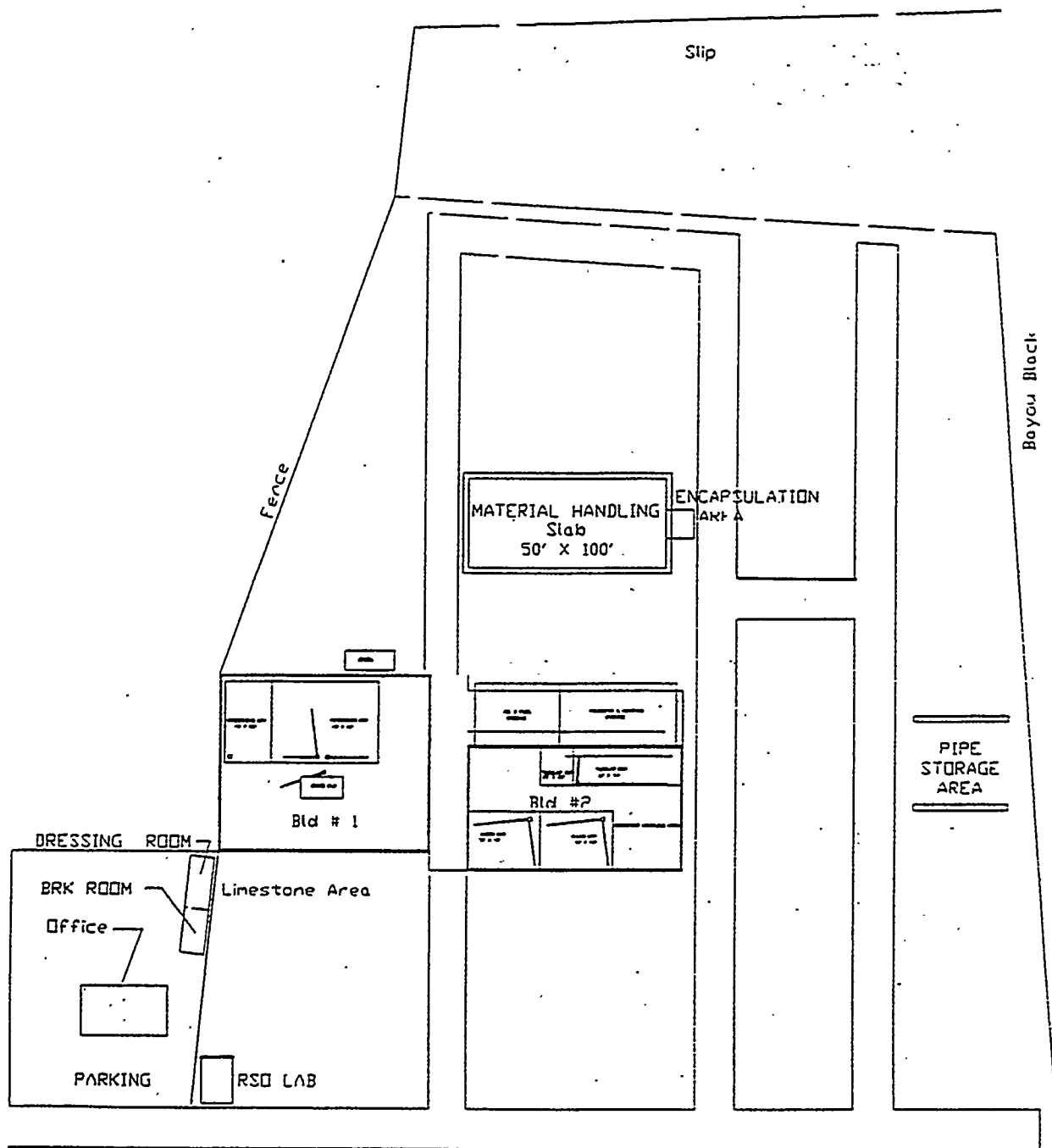
GROWTH RESOURCES, INC.

P.O. Box 52844
Lafayette, LA 70505
(318) 837-8600

P.O. Box 1409
Amelia, LA 70340
(504) 575-8085



Growth Resources, Inc.
 242 Geraldine Road, Gibson, La
 General Area Land Map



GROWTH RESOURCES, INC.
BAYOU BLACK FACILITY

DRAWN BY: KJM

DATE: 3-22-96

SHEET NO.

BAYOU BLACK FACILITY

Description

PROCESSING BUILDING

- 12,000 sq ft covered building with 6" concrete berm (secondary containment)
- 57' by 60' processing bay with 12" berm and sumps
- 26' by 34' processing support bay with 12" berm and sump
- Growth's proprietary waste processing system for dewatering, washing, particle size segregation, minimization and solidification

DECONTAMINATION BUILDING

- 62' by 18' tubular decontamination bay with 12" concrete berm
 - 20,000 PSI range 2 lance
 - can rotate lance nozzle and/or pipe separately
 - water recycling system
- Two 40' by 31' decontamination bays with 12" concrete berms
 - Independent water recycling systems and sumps
- Personnel decontamination facility

MATERIAL HANDLING AREA

- 50' by 100' slab with 18" high berm
- 12" berm near the middle providing for 2 bays with independent sumps
- Used for large tank and vessel decontamination, slurry jobs, waste handling and repackaging, tubular inspection, etc.

ENCAPSULATION AREA

- 16' by 16' bay with concrete berm and sumps
- Two 35' vertical cased holes with movable hopper

BAYOU BLACK FACILITY

Description (continued)

CLIENT-DESIGNATED STORAGE AREAS

- 12" packed limestone over 6" filter cloth
- Up to 1 year storage of containerized NORM waste
- Storage areas designated by storage container and/or separate fenced area

SUPPORT FACILITIES AND OTHER FEATURES

- Administration Office
- Radiation Safety Office / Lab
- 12' by 60' change / break room with personnel decon area
- Over 60,000 sq. ft of packed limestone yard space
- 480 volt, 3 phase, 600 AMP electrical supply
- Fresh water and compressed air
- Exclusive use of 380' barge slip with moorings
- 500' water front access with moorings on Bayou Black

ADDITIONAL SUPPORT EQUIPMENT

- 15-ton cherry picker
- 15-ton all-terrain forklift
- 15,000 lb forklift
- 5,000 lb forklift
- 10,000 PSI hydroblaster
- 3,500 PSI portable pressure washers
- 250 CFM air compressor

BAYOU BLACK FACILITY

Integrated Services

NORM SURVEY SERVICES

- On location while pulling pipe, or on the rack
- Informational Surveys
- Confirmatory and Release Surveys

DECONTAMINATION SERVICES

- Tubular / Flowline
- Equipment (i.e. Production, Gas Processing, etc.)
- Vessel / Tank / Confined Space
- Barge / Rig

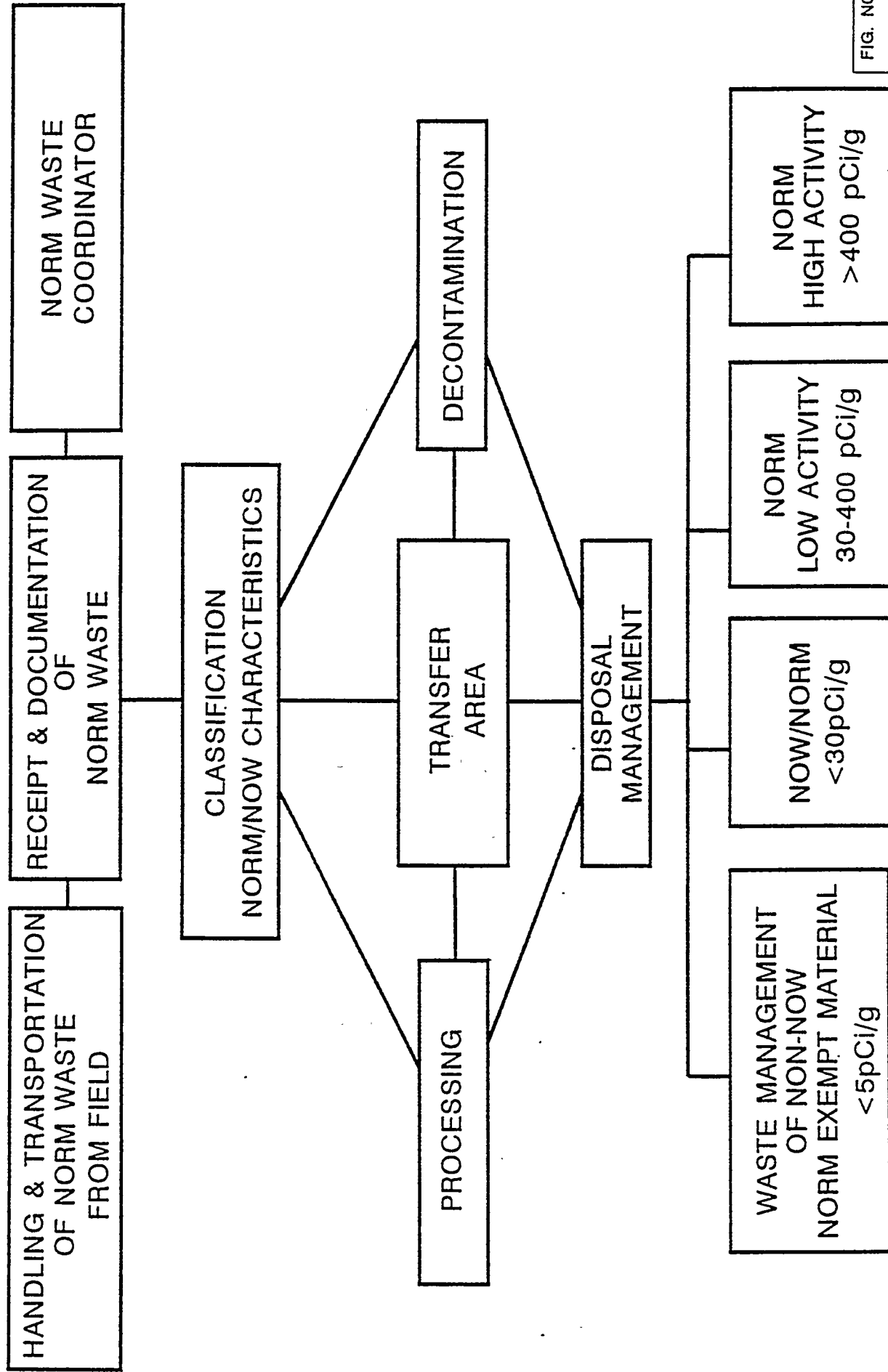
WASTE MANAGEMENT SERVICES

- Waste Handling / Classification / Segregation
- Waste Minimization to reduce disposal costs
- Waste Stabilization for disposal at near-surface burial sites
- Slurry Preparation for downhole disposal or injection
- Encapsulation for storage or downhole disposal
- Equipment / Waste Packaging for Transport
- 1-Year Storage of Containerized Waste in Client-Designated Storage Areas
- Disposal Management for logical, time-effective, cost-effective solutions
- Downhole Disposal thru encapsulation or injection, in client wells



Growth
Resources
Inc.

NORM MANAGEMENT SERVICES





GROWTH RESOURCES, INC.

"NORM Specialists"

Serving the oil and gas industry with NOW/NORM services

INTEGRATED NORM SERVICES

- | | |
|--------------------------------------|---|
| <i>Surveying and Site Assessment</i> | <ul style="list-style-type: none">• Site and equipment surveys to determine and evaluate the presence of NOW/NORM contamination |
| <i>Laboratory</i> | <ul style="list-style-type: none">• NORM and related radioisotope analysis for air, solid and liquid samples• Sample pickup and delivery for quick results |
| <i>Instruments</i> | <ul style="list-style-type: none">• Survey meter and air sampler calibration and repair services |
| <i>Training</i> | <ul style="list-style-type: none">• In-house or group seminars for NORM RSO, Supervisor, Worker, and Surveyor |
| <i>Cleaning/Decontamination</i> | <ul style="list-style-type: none">• Complete cleaning and decontamination services for all types of oil and gas equipment for both onshore and offshore projects |
| <i>Waste Minimization</i> | <ul style="list-style-type: none">• Equipment capabilities to process and minimize NOW/NORM waste |
| <i>Remediation/Pit Closure</i> | <ul style="list-style-type: none">• Site remediation of NOW/NORM; Experienced in soil, shell, sludge, pit, and underwater NOW/NORM remediation |
| <i>Specific License</i> | <ul style="list-style-type: none">• Louisiana - reciprocity with Mississippi, Texas, Arkansas, New Mexico• Washington State Broker Site Use Permit |
| <i>Disposal</i> | <ul style="list-style-type: none">• Processing and stabilization for near-surface burial• Slurry preparation for downhole disposal or deepwell injection |
| <i>Personnel</i> | <ul style="list-style-type: none">• Radiation Safety Officers, Project Managers and Field NORM Supervisors on staff; Certified NORM workers are the backbone of Field Operations |
| <i>Licensed Permanent Facility</i> | <ul style="list-style-type: none">• Transfer stations with NORM waste storage up to one year• Secure pipeyard; shipping by truck or barge; slip and canal-side moorings• Custom-designed tubular cleaning bay with unique lance system• Separate equipment and component cleaning bays• Processing system for minimization, stabilization, slurry preparation• Vertical NORM waste encapsulation unit designed for use with casing |
| <i>Documentation</i> | <ul style="list-style-type: none">• Complete documentation system to trace and manifest ownership and source of NOW/NORM waste• Comprehensive NOW/NORM waste management system |

For more information contact

Corporate, Sales and Operations:
P.O. Box 52844
Lafayette, Louisiana 70505-2844
(318) 837-8600 • (800) 293-8787
(318) 837-5700 Fax

New Orleans Sales:
1907 Oak Creek Rd Suite 114
New Orleans, LA 70123
(504) 733-5983
(504) 733-6258 Fax

GROWTH RESOURCES, INC.

Session 4B - Reindustrialization

**Pathways to Privatization: Issues and Concerns
on the Road to Privatization of Facilities
on the Oak Ridge Reservation**

Charles R. Yard, M.P.H.
Tennessee Department of Environment and Conservation
DOE Oversight Division

Pathways to Privatization: Issues and Concerns on the Road to Privatization of Facilities on the Oak Ridge Reservation

Charles R. Yard
M.P.H.
Environmental Specialist 5
Tennessee Department of
Environment and Conservation
DOE Oversight Division

Abstract

Through the cooperative efforts of the State of Tennessee and the Department of Energy, privatization of the first federal facility on the Oak Ridge Reservation has become a reality. One section of the facility has been transferred to private industry while the other portion of the facility remains in control of the government's prime contractor. Due to this unusual arrangement, there are significant issues to be dealt with. This paper will describe the issues and concerns expressed by the participants in the process.

The State of Tennessee's efforts are primarily conducted by two Divisions of the Department of Environment and Conservation. These two Divisions (Radiological Health and DOE-Oversight) share the responsibility of assuring that the privatization effort is properly implemented. This shared responsibility is divided along distinct lines by the Divisions' respective regulatory and nonregulatory functions. DOE responsibilities during transfer are delineated in the Federal Facilities Agreement (FFA) section XLIII. Property Transfer. The FFA states (in part) that "the DOE shall include notice of this agreement in any document transferring ownership or operation of the site to any subsequent owner and/or operator of any portion of the site and shall notify EPA and TDEC of any such sale or Transfer." The FFA continues by stating that "No change in ownership of the site or any portion thereof or notice pursuant to Section 120 (h) (3) (B) of CERCLA, 42 U.S.C. § 9620 (h) (3) (B) , shall relieve the DOE of its obligation to perform pursuant to this agreement. No change of ownership of the site or any portion thereof shall be consummated by the DOE without provision for continued maintenance of any containment system, treatment system, or other response action(s) installed or implemented pursuant to this Agreement. This provision does not relieve the DOE of its obligation under 40 C.F.R. Part 270."

Two possible routes exist in the privatization effort. The difference between these routes lies in the initial selection of the facility to be leased. The selection of the facility will have a direct impact on the degree of difficulty involved in the process.

This paper includes a case study of one facility on the Oak Ridge K-25 site. The K-1401 facility at this site has presented a number of challenges to participants in the privatization effort.

Recommendations for simplifying the privatization process are presented in the concluding comments.

Introduction

The privatization of numerous facilities on the Oak Ridge Reservation is imminent. At the time of this writing, one portion of facility K-1401 at the K-25 Gaseous Diffusion Plant has been leased to private industry. Leases on several other sections of that facility are pending. This paper will explore the role of the State of Tennessee in the effort to privatize portions of that federal facility. This paper will illustrate some of the processes that take place between the Department of Energy, its prime contractor, and the State of Tennessee.

In the Tennessee State Government structure, two Divisions of the Tennessee Department of Environment and Conservation (TDEC) share primary responsibility for activities on the Oak Ridge Reservation. One of these divisions is the TDEC Division of Radiological Health (DRH). This division has regulatory powers over private industries which require permitting due to radiological activities conducted at their facilities. The second TDEC State Division is the Department of Energy Oversight Division (DOE-O). This Division is nonregulatory in nature and works closely with the Department of Energy on all Oak Ridge Reservation activities. When a private industry leases space on the grounds of a federal facility such as the K-25 site for radiological operations, jurisdiction transfers from DOE-O to DRH. The industry then becomes subject to full regulation by DRH. The State of Tennessee is a Nuclear Regulatory Commission (NRC) Agreement State. All industries in the State which manufacture or use nonexempt radiological materials are subject to State and/or NRC regulations.

TDEC DOE-Oversight Division

The State of Tennessee has a contract with the Department of Energy. This contract is commonly known as the Tennessee Oversight Agreement (TOA). Through this contract, the DOE-Oversight Division of State government was created. All employees of the Division are directly employed by the State of Tennessee. This Division of State Government was designed to be representative of all branches of the Tennessee Department of Environment and Conservation. The Division has four program areas, they are Radiological Monitoring and Oversight (RMO), Environmental Restoration (EM), Waste Management (WM), and Environmental Monitoring/Compliance (EMC). Each program has distinct areas of responsibility, but all four programs are housed in the same office. By having such an organizational structure in a single State environmental office, all areas of environmental expertise are available in house.

The responsibility for surveying and inspecting facilities on the Oak Ridge Reservation lies with the Site Evaluation and Emergency Response (SEER) section of the RMO program.

The functional responsibilities between DOE-O and DRH are clearly defined by the designation of a facility as being regulated or nonregulated. When a federal facility is turned over to private industry three things occur;

- a) The State of Tennessee is notified of the potential lease agreement by the Department of Energy or its Prime Contractor. This information is provided to DOE-O and the DRH.
- b) The DOE Oversight Office conducts a survey of the facility. This survey includes a historical background search on past processes conducted in the facility, a physical walk-through inspection of the facility, and the generation of a comprehensive report. The report attempts to capture all information on the facility which may affect its suitability for future use.
- c) The responsibility for the regulating radiological processes in the facility is transferred to DRH.

The Oak Ridge Reservation is included in the National Priorities Listing as a Superfund site. As a result of this designation, all leased facilities must satisfy the requirements of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and the Federal Facilities Agreement (FFA). This portion of the privatization process lies in the jurisdiction of the DOE-O Environmental Restoration Program.

State Organizational Responsibilities

According to the Memorandum of Understanding (MOU) between the DRH and DOE-O, the latter will “assure that all non-operating radiological storage areas and abandoned facilities on the Oak Ridge Reservation are properly closed in accordance with all existing rules.” The MOU also addresses routine operations in facilities on the Oak Ridge Reservation in that the DOE Oversight Division “inspects all operations on the Oak Ridge Reservation to assure compliance with good health physics practices”. Sections of

facility K-1401 were operational when the private lease of other portions of the facility was signed. This situation presented and continues to present a unique challenge to the State of Tennessee. Two different State Divisions share responsibility for operations in a single facility. The problems posed by this situation are numerous and will be discussed in the case study portion of the paper.

Facility Survey Program

Before a facility is released to private industry, DOE-O staff members conduct a survey of the area or facility to be leased. This survey process begins with an information request on facility history. Information typically requested at this stage includes plumbing diagrams, structural engineering drawings, and information on past processes. This request is made to the Tennessee Oversight Agreement (TOA) office. The TOA office is operated by DOE and the Oak Ridge Reservation prime contractor representatives. It is the responsibility of this office to secure the information requested by the State and to assure that all information is cleared for public release by the security classification office. After the initial information request, the survey team will visit the facility and interview the facility manager. This first visit allows the team to observe the structural layout of the facility and gather additional background information. The background check focuses on past processes which may have contributed to chemical or radiological contamination in the facility. In some cases, legacy contamination is the primary obstacle to privatization of a facility. After this initial interview and visit, the team leader will request any additional information available on the facility from the TOA office.

The next step of the process consists of the physical inspection of the facility. After reviewing all of the available background information, the team will conduct this portion of the facility survey. This survey will include a walk through of all accessible areas of the facility. The facility manager normally accompanies the team on this visit to provide additional information and answer questions that may arise. If warranted, a Health Physicist will accompany the team. The survey team typically uses a 2X2 NaI (Sodium Iodide) probe on the inspection surveys. If an area of the facility is suspected to have unidentified radionuclide contamination, DOE-O has a Gamma Spectroscopy unit which may be used. Alpha and Beta contamination is normally identified through records of past processes and previously identified contamination area postings.

The final report prepared by the team leader contains; pictures of the facility, a written facility description, a completed fifty three item questionnaire (developed by DOE-Oversight for the facility survey program), and attachments. This report is distributed to the Department of Energy, the prime contractor and key members of each organization. All facilities surveyed are ranked in a hazard ranking system developed by the Division for facility risk comparison purposes.

One primary goal of the facility survey program is to create a database on all Oak Ridge Reservation facilities which is available to the general public. These records are provided to the citizens of the State on request. The files consist of previously conducted surveys

of facilities at K-25, Y-12 and the Oak Ridge National Laboratory and other facility specific information gathered by the teams.

The Privatization Process

In an ideal scenario, a federal facility being considered for privatization will proceed through the following stages. First, a free standing facility will be selected for privatization based on the needs of the Department of Energy. The selected facility will enter the Decontamination and Decommissioning (D&D) process. The facility will be fully characterized for contamination either before or during the entry into D&D program. If the facility is found to be contaminated, decontamination efforts will be undertaken and the contamination levels will be lowered to an acceptable level. The decommissioning process will follow decontamination. If the facility is found to be clean enough and structurally sound enough to lease, the Department of Energy will conduct negotiations with private industry to determine the specifics of the lease. The Department of Energy is bound to follow the guidelines set forth in the Federal Facilities Agreement and CERCLA while conducting these negotiations.

The State of Tennessee's DOE-Oversight Division will survey the facility if a survey has not been previously conducted. The State Division of Radiological Health will assume control of the facility and begin the permit application process exactly as it would with any other licensed industry. The facility will then be regulated and regularly inspected by the Division of Radiological Health.

Concerns

One of the most important aspects of a facility survey is the availability of background information on the facility. If the information is very limited and/or incomplete, the product produced (the survey report) will be incomplete and of very limited use. For this reason, adequate background information on the facility is crucial.

Background information may be unavailable to the researcher for a variety of reasons. On the Oak Ridge Reservation, the process of conducting research is complicated by the fact that many facilities are over fifty years old. A host of other complications may contribute to problems in acquiring background information. The complicating factors include; lack of proper record keeping; loss of files; disorganized files; lack of manpower for research; and classification issues. It is recommended that persons conducting research in sensitive facilities hold proper security clearances.

The very nature of past activities conducted in a facility may have a serious impact on the suitability of that facility for lease. Facilities which were used in the early years of nuclear research and (1940's and 1950's) warrant special scrutiny in the background research process. The potential for rare radionuclides and unusual types of chemical contamination exist in these facilities due to the experimental nature of past research projects. When searching for documents on facilities used for early experimental research, records of processes may be inadequate or classified, thus complicating the effort to assess the facility for future use.

Case Study K-1401

The facility at K-1401 has presented a series of logistical complications for the participants in this effort. This facility encompasses 416,000 square feet, is constructed of brick and corrugated steel siding and has a 60,000 square foot basement which is contaminated both chemically and radiologically.

The primary lease area covers 44,600 square feet. The area selected for this initial lease is an irregular section of the facility. The area consists of a highly irregular shape bordering radiological and chemical contamination zones. Employees from the prime contractor and private industry may be conducting operations in the same air space. Due to this arrangement, any airborne contamination from processes is a potential concern to employees in both leased and non leased sectors of the facility. A more manageable scenario would exist if the lease had been signed on a self contained facility that was not divided into federal and private sectors. This arrangement presents a significant problem for State. Part of the facility is regulated by the State and part of the facility is under the jurisdiction of the State's non-regulatory DOE-Oversight Division. The complex lease boundaries, high ceilings, and the lack of a substantial barrier separating the processes complicates the situation for the State and makes potential liability for future clean up efforts at the facility difficult to assess.

The high ceilings in K-1401 are of concern due to the following problems. Areas above eight feet have not been fully characterized for radiological contamination. These areas

are posted as "potential contamination" areas. This potential legacy contamination problem will reflect on future processes. Processes carried out in the facility that could potentially create additional radiological contamination problems will result in a situation where the party responsible for the contamination will be difficult to determine. Assessing liability for future decontamination costs will be complicated and costly.

There are liability issues to be considered in addition to those created by the contamination status of the facility. The lack of substantial barriers between federal areas and private lease areas of the facility will combine with the existing high ceiling problem to create a potential health and safety concern. If airborne contamination levels become elevated and personnel suffer exposures, there will be a question of liability for the exposures. Employees from private industry will be working in close proximity and breathing the same air as DOE contract employees. The problems created for Industrial Hygiene and Health Physics personnel will be substantial.

Other contamination areas exist in the facility. The basement of K-1401 is designated as a "Contamination Area" requiring a Radiation Work Permit (RWP) for entry. As an illustration of the concerns posed by legacy contamination areas adjacent to current operations, additional postings at the entry to the basement of K-1401 include the following warnings. "Due To The Airflow In This Area, Work Activities Could Affect Non Radiological Areas On The First Floor." A second posting on the basement entrance warns "Contact the Building Operator and the RCO Prior to Performing Any Activities In This Area."

Due to the sharing of air between legacy contamination areas in the basement and potential lease areas upstairs, a potential health and safety concern exists in the facility.

Conclusion

Since the end of the cold war, Federal and State officials have struggled with the privatization issue. The most logical approach to follow in dealing with reuse and privatization issues is to simplify the process. This process may be simplified by locating structurally sound facilities, decontaminating those facilities and reusing them. The only other options involve either destroying the existing facilities or continuing to pay surveillance and maintenance costs indefinitely. A cost benefit approach to privatization suggests that the facilities which are structurally sound should be reused as assets, rather than destroyed. The issues remaining involve the logistics of the process used to privatize facilities.

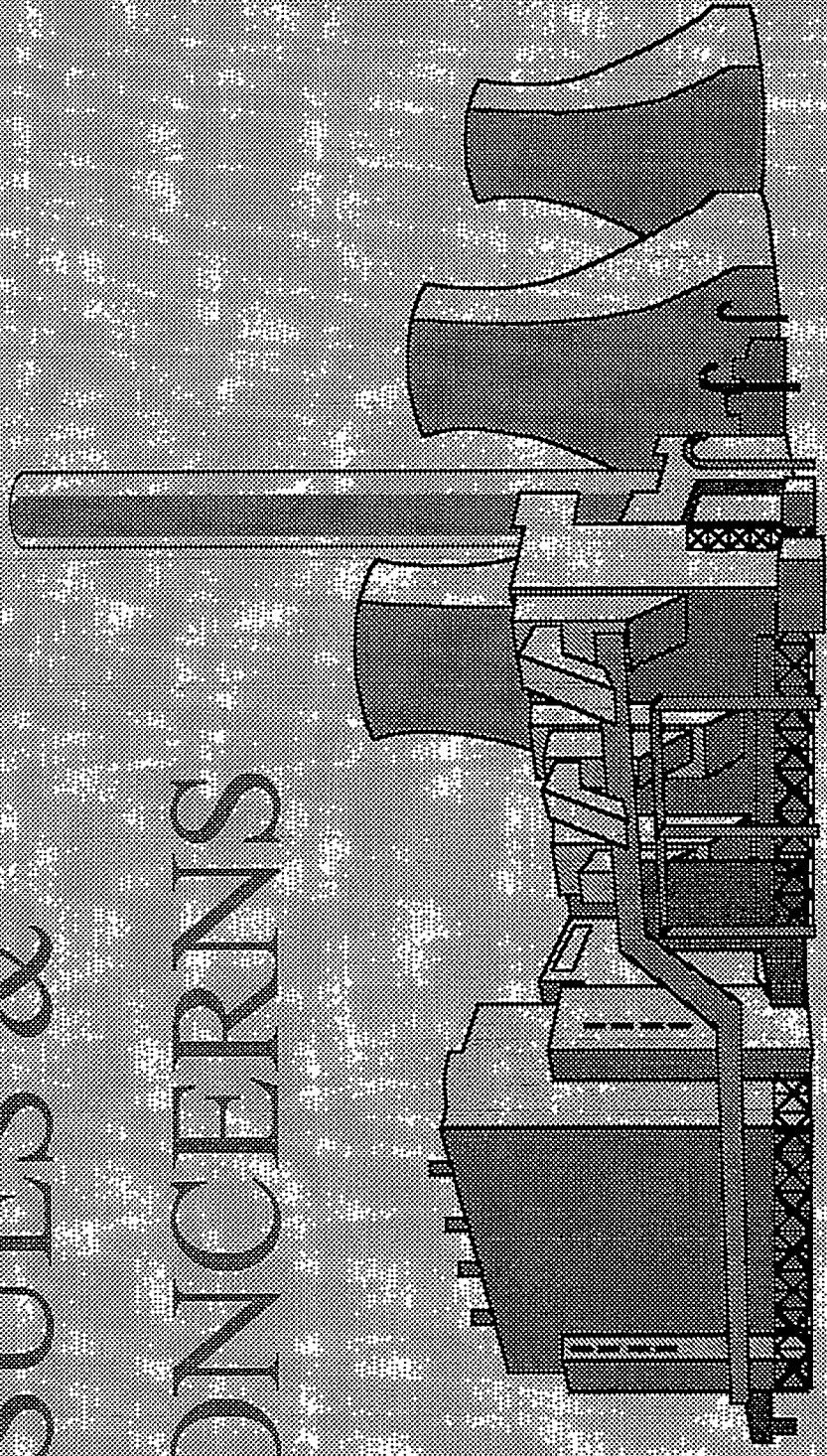
In Tennessee, the State is taking a very active role in the privatization process. By taking a pre-emptive role in this process, money can be saved and public assets can be put to their fullest potential. The cooperative effort being undertaken by the State and the Department of Energy allows problems to be solved through active negotiation rather than by more time consuming and less effective processes.

Problematic issues do arise in the privatization process, but these issues may be minimized by selecting facilities for lease that are free standing and structurally sound.

To further minimize obstacles in the privatization process, facilities selected for privatization should be good candidates for decommissioning.

PATHWAYS TO PRIVATIZATION

ISSUES & CONCERNS



Tennessee Department of Environment and Conservation

- Two Divisions of TDEC
 - ASSURE THAT THE PRIVATIZATION INITIATIVE IS CARRIED OUT ACCORDING TO APPLICABLE LAWS AND REGULATIONS
 - DOE-OVERSIGHT
 - RADIOLOGICAL HEALTH

DOE OVERSIGHT DIVISION

DIRECTOR

ASSISTANT DIRECTOR

RADIOLOGICAL MONITORING
AND OVERSIGHT

WASTE MANAGEMENT

ENVIRONMENTAL
RESTORATION

ENVIRONMENTAL MONITORING
AND COMPLIANCE

DOE-O FACILITY SURVEY PROGRAM

ITEMS FOR SURVEY

- RAD. CONTAMINATION STATUS
- CHEM. CONTAMINATION STATUS
- HEALTH AND SAFETY RESTRICT.
- ENVIRONMENTAL CONTROLS
- ENVIRONMENTAL RELEASE POT.
- STRUCTURE CONDITIONS

Applicable Regulations affecting Leasing of ORR Facilities

- **Federal Facilities Agreement (FFA)
Section XLIII. Property Transfer**
- **Comprehensive Environmental
Response, Compensation and Liability
Act of 1980 (CERCLA) Section 120 (h)
U.S.C. 9620 (h) (3) (B)**

TWO PATHWAYS TO PRIVATIZATION

- **SIMPLE DECONTAMINATION &
DECOMMISSIONING FOLLOWED BY
SINGLE LEASE ON ENTIRE FACILITY**
- **COMPLEX MULTIPLE PARTY LEASES OF
SINGLE FACILITY**

A. Simple Lease of Entire Facility to One Company

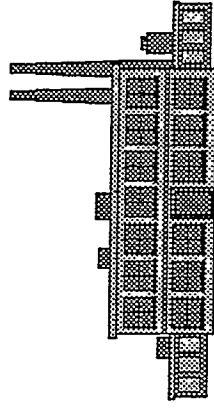
Company

(Clean Facility)

A

D and D Complete

Simple Lease



Flow Chart For Process

Facility is selected for privatization
(based on government needs and industry demands)

Facility suitability evaluation conducted

Facility enters the D&D process if found to be suitable for lease

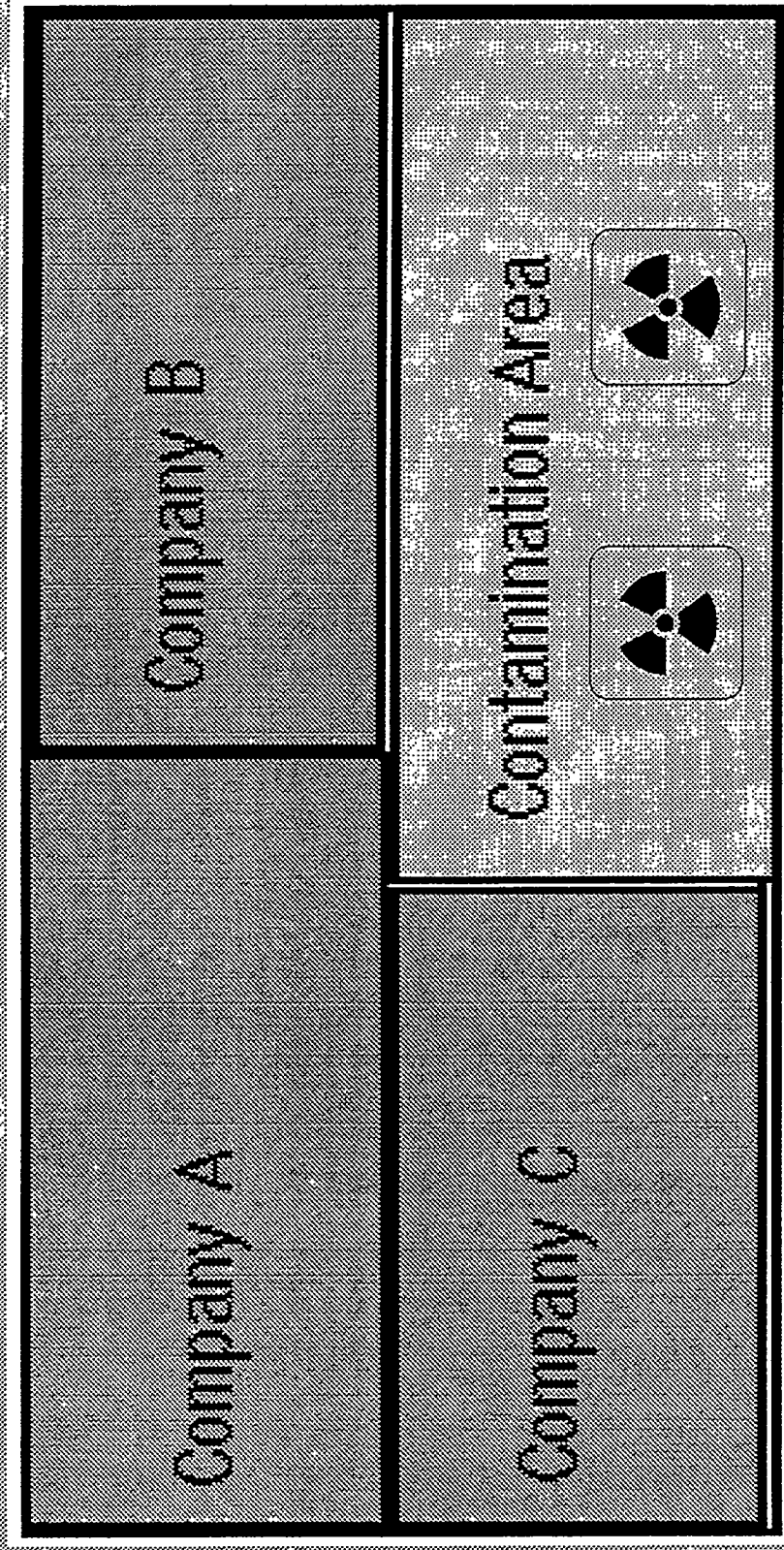
Facility is characterized for contamination

Facility is decontaminated

Tennessee Department of
Environment and Conservation
is notified

Lease negotiations begin

B. Complex, Multiple Company Single Facility Lease



Multiple Party, Single Facility Lease

Tract A	Tract B
Tract C	Contamination Area

Flow Chart For Process

Facility is selected for privatization
(based on government needs and industry demands)

Suitability evaluation

Portion of facility is selected for lease

Lease portion of the facility is decontaminated

The Tennessee Department
of Environment and Conservation
is notified

Negotiations begin on the Portion of the
facility to be leased

Evaluation of remaining portions of facility continues,
study of how one lease area may affect another complicates process

Lease negotiations must include decontamination issues

Applicable Regulations After Leasing of Oak Ridge Reservation Facilities

- All applicable private sector laws and regulations . . . for operations requiring permits for radiological operations, all applicable regulations enforced by the State Division of Radiological Health and the Nuclear Regulatory Commission

CONCLUSIONS

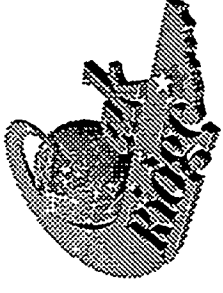
- PRIVATIZATION OF MANY ORR FACILITIES IS NEARING REALITY
- PRIVATIZATION ISSUES ARE BEING CURRENTLY NEGOTIATED
- LEASE OF AN ENTIRE FREE STANDING FACILITY SIMPLIFIES THE LEASE PROCESS
- COOPERATION WITH STATE AUTHORITIES IS ADVISABLE

**Recycle of Radioactive Scrap Metal
from the Oak Ridge Gaseous Diffusion Plant (K-25 Site)**

Richard W. Meehan
U.S. DOE-Oak Ridge Operations Office



U. S. Department of Energy Oak Ridge Operations Office



Recycle of Radioactive Scrap Metal from the Oak Ridge Gaseous Diffusion Plant (K-25 Site)

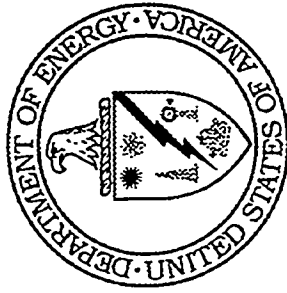
**Richard W. Meehan
U.S. Department of Energy**



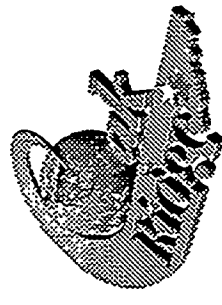
U.S. Gaseous Diffusion Plants Contain:



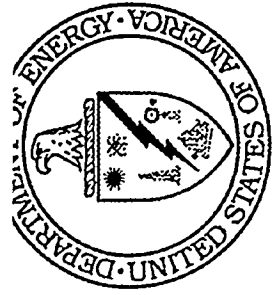
- Metals
 - Nickel - 22 million pounds
 - Aluminum - 17 million pounds
 - Copper - 47 million pounds
 - Steel - 835 million pounds
- Wide Variety of Surplus Industrial Equipment
- Other Items of Value



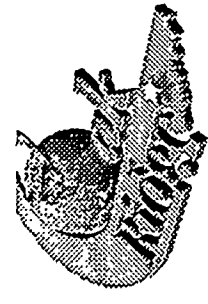
Several Pilot Recycling Efforts Have Been Completed:



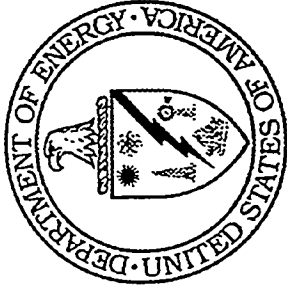
- Bench/Batch Scale
- Diffusion converter recycled into ASTM 304 stainless steel plate.
- Plate fabricated into prototype restricted use products (e.g., drums, vitrification canister, box)
- Low residual activity of recycled material permits non-licensed possession and transportation of products.



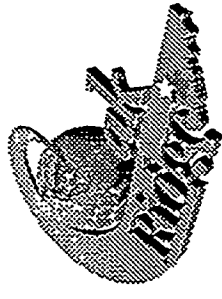
Several Pilot Recycling Efforts Have Been Completed (con't):



- Pilot Scale
- Small scale project initiated to simulate production decontamination and decommissioning effort.
- Scope included:
 - process cell dismantlement
 - pretreatment (e.g., grit blasting)
 - carbon steel recycling
 - melt - cast - roll
 - direct roll
 - stainless steel manufacturing
 - GDP nickel used
 - ASTM 304 plate produced



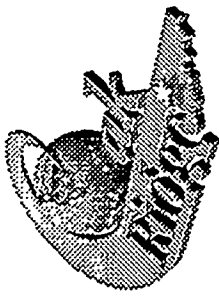
Performance/Results:



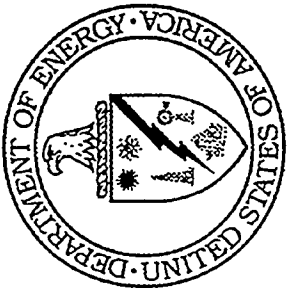
- Radionuclide Concentrations:
 - Average for all shipments to small scale project
 - Uranium - 51 pCi/g
 - Technetium - 125 pCi/g
- Post-Recycle Activity
 - Variable with rigor of pretreatment
 - 85% Free release achievable
 - Minimal pretreatment resulted in residual contamination of:
 - >20 pCi/g U
 - >25 pCi/g ⁹⁹Tc



Candidate End Use Markets for RSM Manufactured Products:

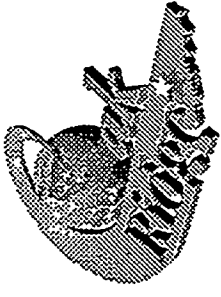


- Free Release
 - Small scale project demonstrated that over 80% of the ferrous material could be free released per NUREG 1.86 after pretreatment.
 - Aluminum economical to chemically decontaminate
 - Nickel can be electrorefined for export under international standards
- Restricted Use
 - Adequate markets exist within DOE programs to absorb the current and projected inventory of RSM
 - Organizational "stovepipes" make effective "marketing" of RSM products difficult.
- Prices for RSM products can be competitive

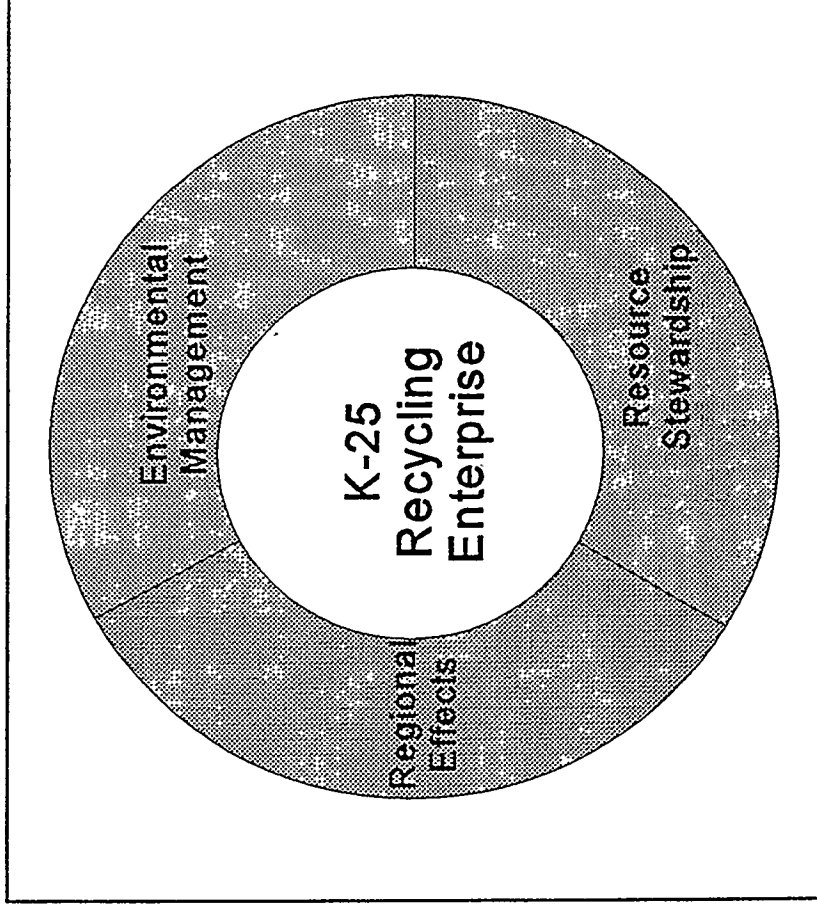


Conclusion:

Recycling Provides Linkages for Cost Effective GDP Disposition



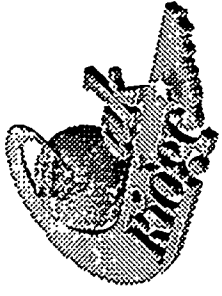
EM and Department of
Energy mission
performance is
enhanced through
synergism made
possible with
establishment of a
commercial recycling
enterprise





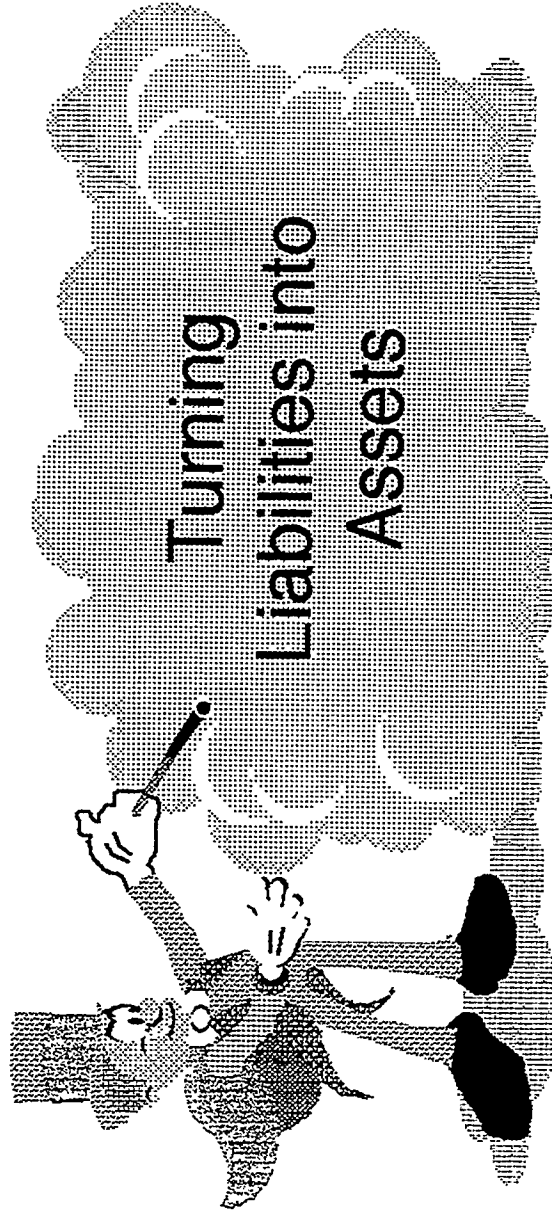
Summary:

- Recycling provides a realistic, workable, cost-effective strategy to reduce the K-25 Mortgage
- Privatization is essential to achieve the economies of scale necessary for the recycling option
- Once established, the K-25 Recycling Enterprise can play a major role in reducing waste dispositioning costs across the DOE complex
- Processing capabilities can be transitioned to applicable to commercial customer base
- Recycling and associated industries can play a major role in reindustrialization of K-25.



**Sandia, California Tritium Research Laboratory
Transition and Reutilization Project**

Toff B. Garcia
Sandia National Laboratory



“Sandia, California Tritium Research Laboratory Transition & Reutilization Project” October 22-24, 1996

“Converting a Liability Into an Asset”

Overview

- ✦ TRL History, 1977 - 1993
- ✦ The Clean-up & Transition Project, 1993 - 1996
 - » miscellaneous aspects & stakeholder matrix
 - » clean-up & transition reclassification process & flow diagram
 - » cost & schedule comparison, cost saving summary
 - » environmental releases & exposure data
- ✦ Reutilization Phase, 1996 - 1997
 - » transition to a Chemical & Radiation Detection Laboratory
 - » status building occupancy
- ✦ Summary

"The TRL, 1977-1993"

✦ The Tritium Research Laboratory was authorized in the AEC contingency budget of FY72. Construction was completed in September of 1975. Equipment installation was completed in June 1976. The TRL became operational in September of 1977.

- » B968: 15,000 sq. ft. gross, 13 lab rooms w/single pass ventilation
- » B967: 4,000 sq. ft., Maintenance Building: 2,500 sq. ft.
- » cost for construction and equipment: total \$12 M

✦ The TRL was the first major tritium facility to embody a system for protecting personnel and the environment from tritium releases.

- » the containment was achieved using hermetically sealed glove boxes connected by manifolds to two central decontamination systems, the Gas Purification System and the Vacuum Effluent Recovery System.

“The TRL, 1977-1993”

✦ **The mission of the TRL was to provide an applied research capability for developing a sound, fundamental understanding of the interaction between tritium and materials.**

✦ **Specifically, the TRL conducted a diverse range of experimentation using gram amounts of tritium for:**

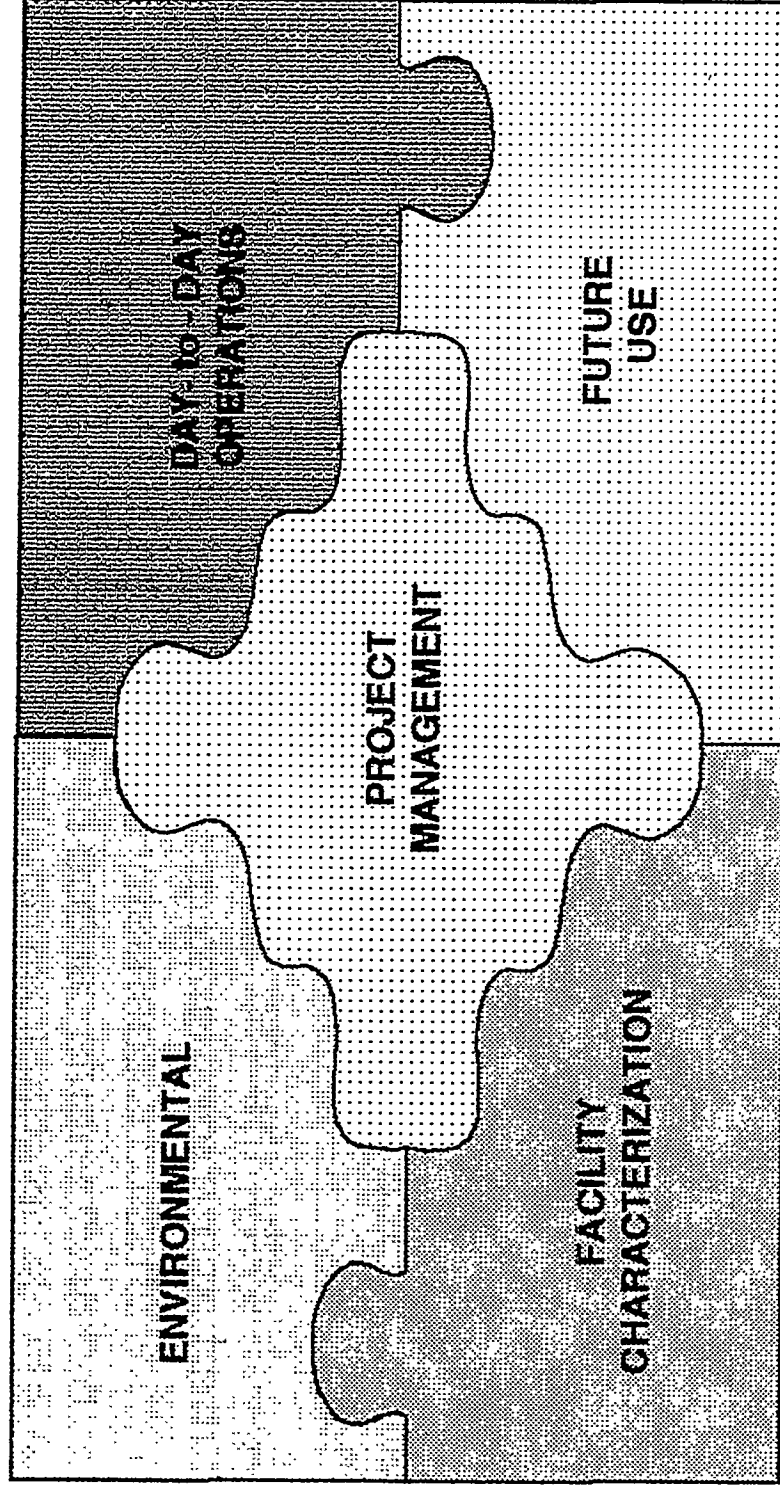
- » the physics & chemistry of tritium and its compounds;
- » radiation effects caused by tritium;
- » effects on structural properties of materials;
- » transportation properties of tritium; and
- » safe handling techniques for tritium.

✦ **Examples of significant contributions:**

- » Measured super-conducting temperature of palladium-tritide.
- » Studied helium embrittlement of metals from T2 decay.

“Converting a Liability into an Asset”

Miscellaneous Aspects of Converting a Facility



"The Clean-up & Transition, 1993-1996"

- ✦ Changing world and local conditions and the high cost of nuclear facility operation (\$4M per year) prompted a consolidation of tritium research and development activities. DOE & SNL Management decided to terminate tritium operations at the TRL facility in 1991.
- ✦ SNL Management in cooperation with DOE, opted to develop a "facility reuse" alternate to the traditional Decontamination and Decommissioning process.
- ✦ This project ties our goal of compliance with ES&H requirements to our strategic thrusts by developing a methodology for converting an unneeded facility (liability) to new uses (asset).
- ✦ While the facility continued to operate as a Class II, non-reactor nuclear facility, a six phase plan to relocate experiments and inventory was made.

"The Clean-up & Transition, 1993-1996"

♦ **The original plan consisted of six distinct phases, estimated completion shown in ():**

- » Inventory reduction and experiment transfer to other DOE sites (9/93)
- » Preliminary Facility Characterization (11/93)
- » Environmental Review (1/94)
- » Technical Engineering to assure alternative actions and associated environmental issues are identified and assessed (4/94)
- » Decommissioning Operations (6/97)
- » Post Decommissioning Operations, Final Characterization, & Independent Verification (6/97)
- » Continued Environmental Monitoring (2000+)

"The Clean-up & Transition, 1993-1996"

- ✦ **The actual clean-up and transition was performed by the personnel responsible for operating the TRL and assisted by SNL Environmental, Facilities, and Maintenance staff.**
- ✦ **The clean-up & transition was performed in half the time required to perform D&D.**
 - » In November 1994 the tritium inventory was reduced to zero.
 - » The final facility characterization was completed in January 1996.
 - » The facility was reclassified a low-hazard laboratory after independent verification.
 - » A model agreement with DOE & EPA provides for discontinuation of stack release monitoring October 1996.
- ✦ **Savings of \$106 million dollars in direct and indirect costs can be attributed to the reuse process.**

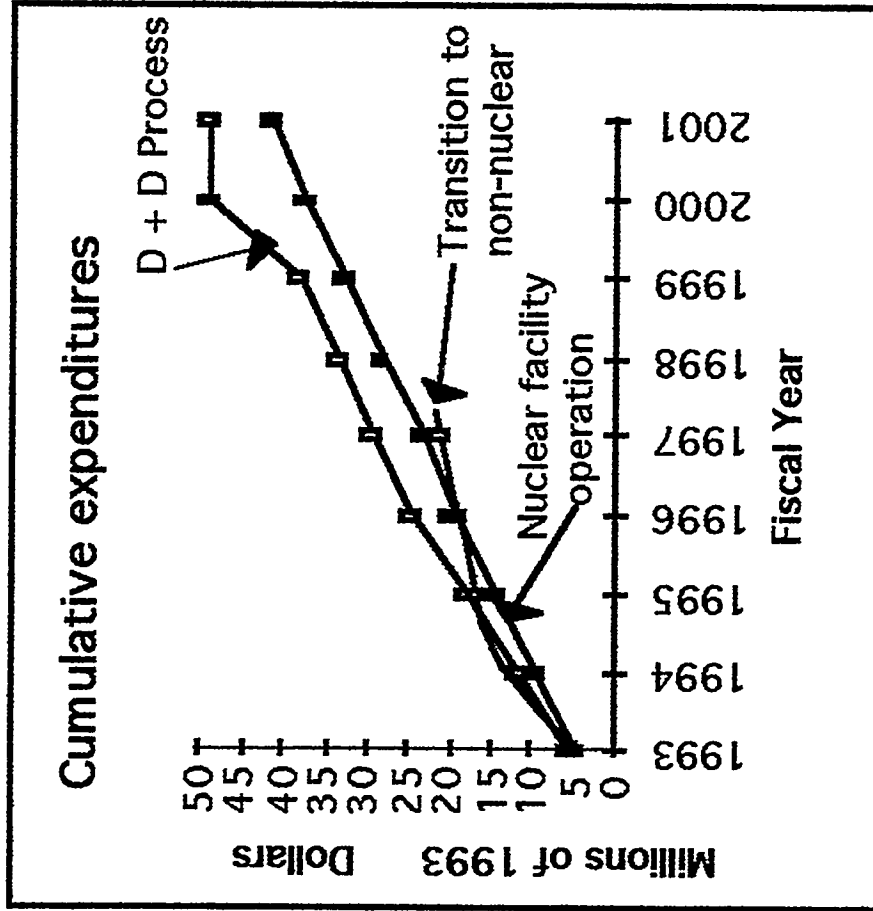
"The Clean-up & Transition, 1993-1996"

Cost Savings Summary

\$ 43.5 mil Replacement value of reallocated equipment
 \$ 24.9 mil Avoided waste disposal costs
 \$ 33.0 mil Cost difference to execute full D&D
 \$ 5.0 mil Direct project administration expense savings
\$106.4 mil Total Savings

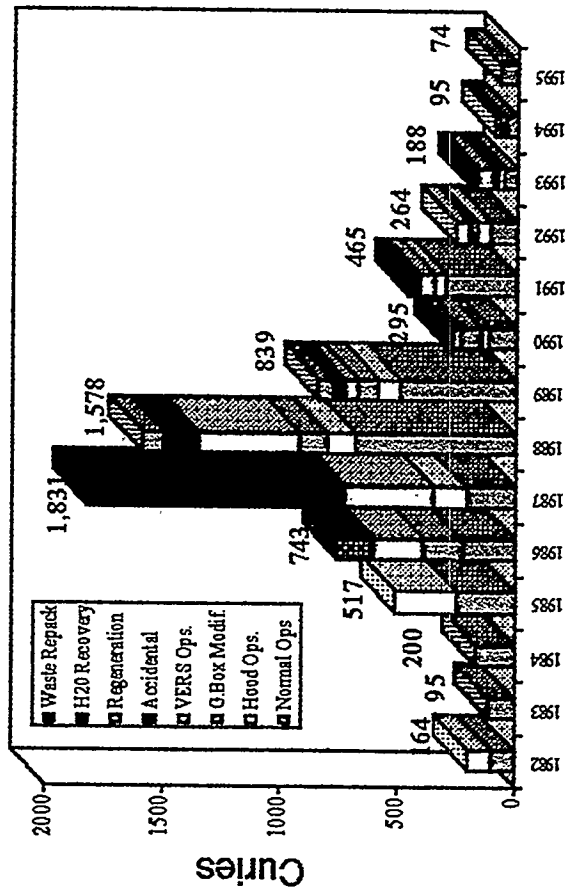


Process	Time line	Cost
Original D&R project	7 years	\$25,730,000
Actual D&R project	4 years	\$20,880,000
D&D project Bldg. Replacement	9 years 5-10 years	\$48,550,000 \$5,200,000

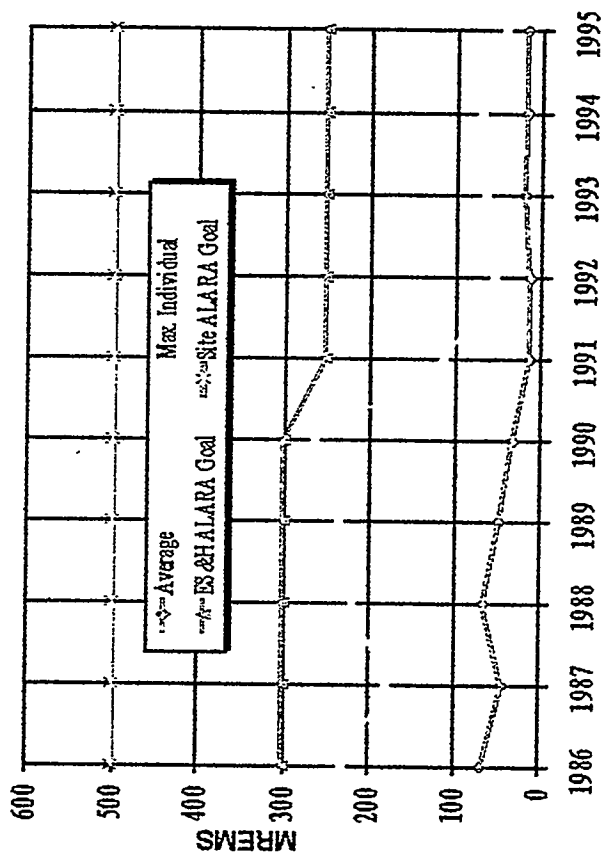


The Clean-up & Transition, 1993-1996

Stack Releases Breakdown by Years



Internal Dosimetry Exposures (1986–1995)



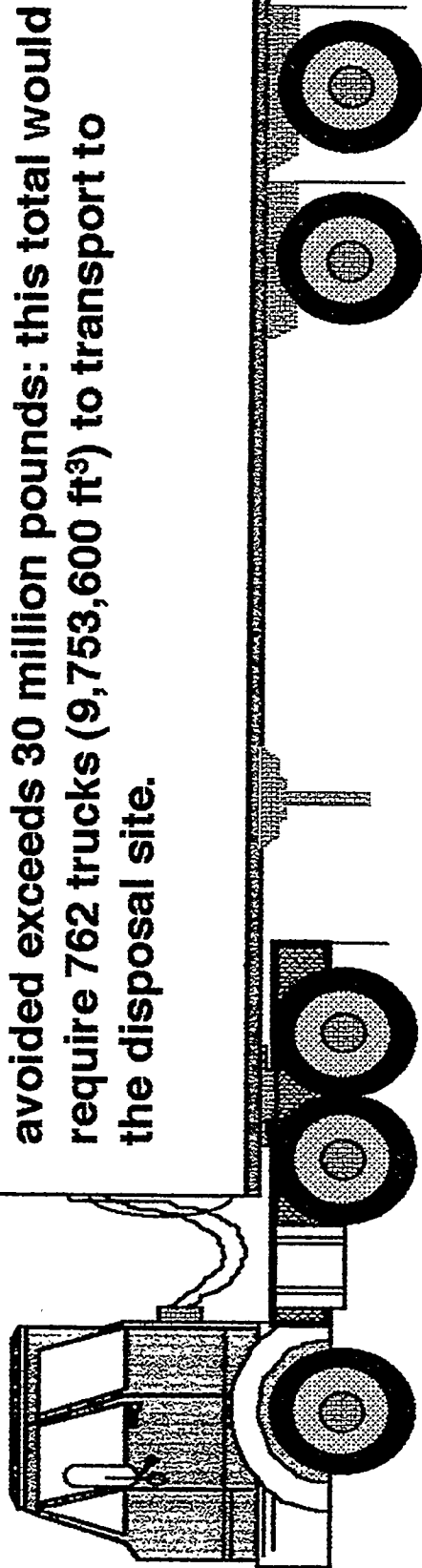
Federal Limit = 5000 millirems
DOE Control Limit = 2000 millirems

"The Clean-up & Transition, 1993-1996"

Waste actually shipped = 12,800 ft³



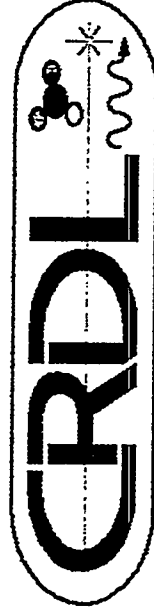
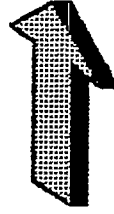
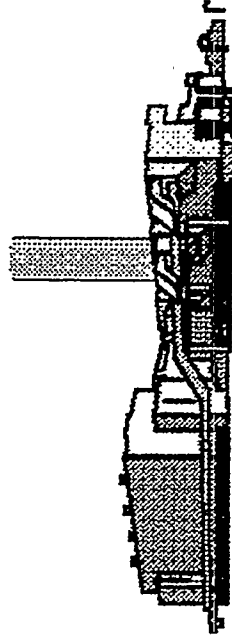
Calculations of the low-level radioactive waste avoided exceeds 30 million pounds: this total would require 762 trucks (9,753,600 ft³) to transport to the disposal site.



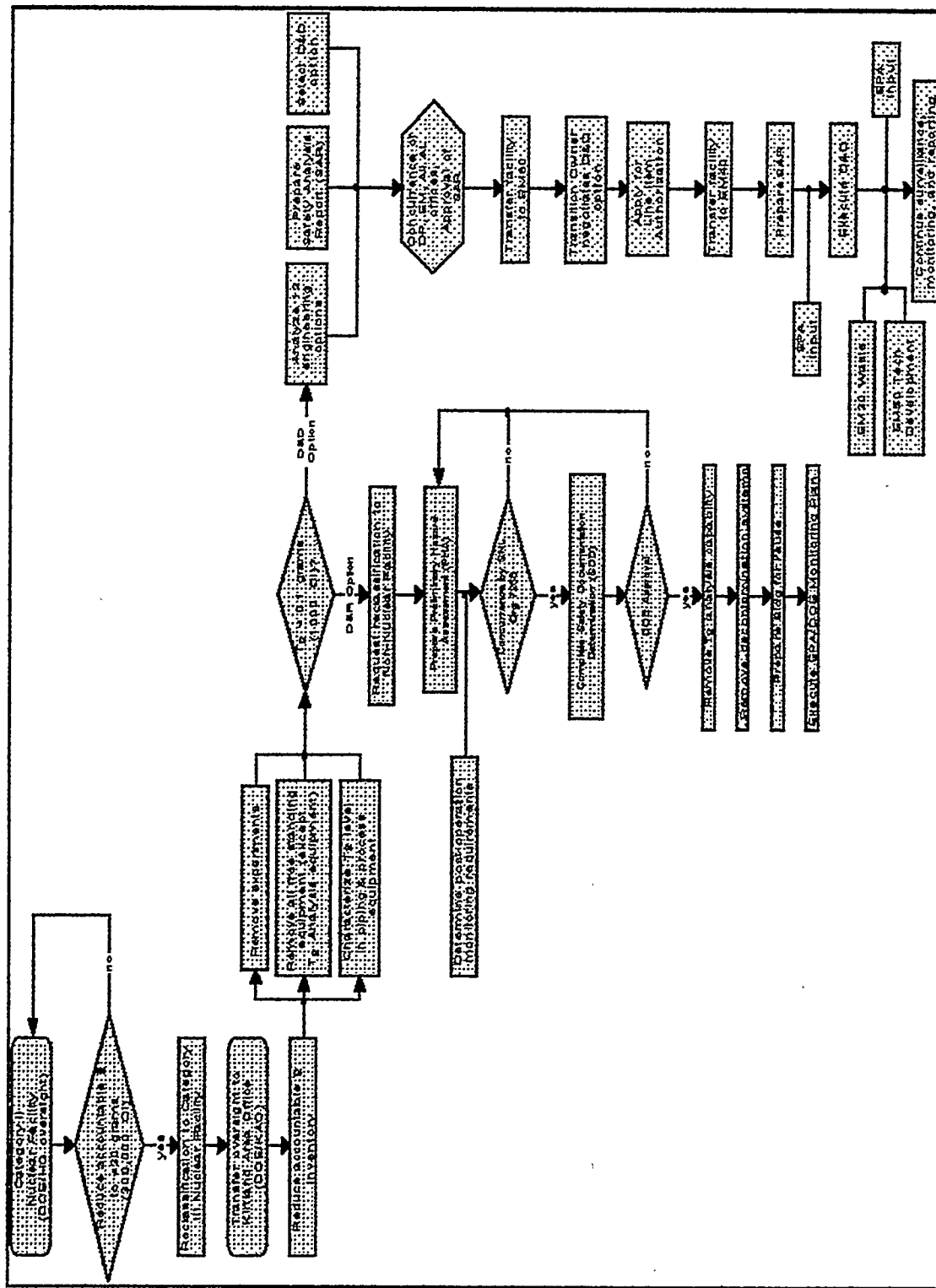
“Converting a Liability into an Asset”

Reutilization Phase

Objective: Aligning the TRL transition tasks with relocation of growing SNL Program requirements optimizes the use of resources and serves as a *model of converting a liability to an asset.*



RECLASSIFICATION PROCESS FLOW DIAGRAM



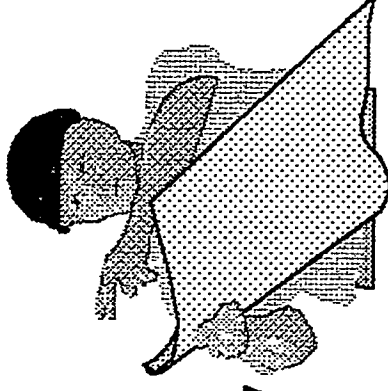
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5/19/96

"Chemical & Radiation Detection Laboratory"

FY96 Building 968 Occupancy

- ◆ Nine completed (goal: 5 labs)
 - » Room 114 Microscopy Laboratory
 - » Room 115D Meeting Room
 - » Room 116 Microprocessor Design Analysis Laboratory
 - » Room 119 Radiation Detector Testing Laboratory
 - » Room 120 Radiation Detector Fabrication Laboratory
 - » Room 122 Microelectronic Biosensors Laboratory
 - » Room 125 Biological Chemistry Laboratory
 - » Room 126 Laser-Based Chemical Detection Laboratory
 - » Room 127/129 Biological Chemistry Laboratory
- ◆ Two newly committed
 - » Room 115A & 112 Environmental Fluorescence
- ◆ Five unassigned
 - » Room 102, 115B-C, 110, 117, 121 (rm. 121 is presently HP lab)



“Converting a Liability Into an Asset”

Summary

- ✦ This transition project ties Sandia's goal of compliance with ES&H requirements to its strategic thrusts by developing a methodology for converting an unneeded facility (liability) to new uses (asset).
- ✦ Compared to the D&D options, the process saved at least five years and in excess of \$100 million in direct and indirect costs.
- ✦ Reutilization scheduled for completion 1997.

Session 4C - Concrete Reuse

**Fatal and Nonfatal Risk Associated with Recycle
of D&D-Generated Concrete**

John K. Boren
Kenneth W. Ayers
Frank L. Parker
Vanderbilt University
Civil and Environmental Engineering

FATAL AND NON-FATAL RISK ASSOCIATED WITH RECYCLE OF D&D-GENERATED CONCRETE¹

By John K. Borén², Kenneth W. Ayers³, and Dr. Frank L. Parker⁴

ABSTRACT

As decontamination and decommissioning activities proceed within the U.S. Department of Energy Complex, vast volumes of uncontaminated and contaminated concrete will be generated. The current practice of decontaminating and landfilling the concrete is an expensive and potentially wasteful practice. Research is being conducted at Vanderbilt University to assess the economic, social, legal, and political ramifications of alternate methods of dealing with waste concrete. An important aspect of this research work is the assessment of risk associated with the various alternatives. A deterministic risk assessment model has been developed which quantifies radiological as well as non-radiological risks associated with concrete disposal and recycle activities. The risk model accounts for fatal as well as non-fatal risks to both workers and the public. Preliminary results indicate that recycling of concrete presents potentially lower risks than the current practice. Radiological considerations are shown to be of minor importance in comparison to other sources of risk, with conventional transportation fatalities and injuries dominating. Onsite activities can also be a major contributor to non-fatal risk.

INTRODUCTION

The United States Department of Energy (DOE) owns a large number of aging facilities. Many of these facilities have served their purpose or are approaching the end of their operational lives. Decontamination and decommissioning (D&D) operations are an important concern for the DOE because of the large number of facilities and the high cost associated with D&D. Therefore, the development of alternatives for utilizing the decommissioned facilities or their components is a high priority within DOE.

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²Master of Science candidate, Vanderbilt University, P.O. Box 6304, Station B, Nashville, TN 37235

³Doctor of Philosophy candidate, Vanderbilt University, P.O. Box 6304, Station B, Nashville, TN 37235

⁴Professor and Principal Investigator, Vanderbilt University, P.O. Box 6304, Station B, Nashville, TN 37235

The "Recycle 2000" program is an example of a recycling and reuse alternative. It is proposed that the estimated existing inventory of 157,000 tons of radioactively contaminated carbon steel (RCCS), along with the additional 470,000 tons of RCCS throughout the complex awaiting decommissioning, be used to manufacture waste disposal casks to support D&D activities (Parsons ESI *et al.*, 1995). This large inventory of RCCS is eclipsed by the enormous volume of concrete that will be generated by D&D activities. The total volume of concrete comprising these facilities is not accurately known, but is estimated to approach 390,000,000 ft³ (approximately 30 million tons).

The current concrete D&D practice consists of decontamination of concrete surfaces, disposal of removed surfaces in a licensed low level radioactive waste (LLW) disposal facility, demolition of the structure, separation of reinforcing bars (rebar) and concrete, and disposition of the concrete rubble at a Construction/Demolition (C&D) landfill.

A research project at Vanderbilt University is examining alternatives to the landfill disposal of this rubble. Five recycle/reuse alternatives have been identified and compared to the current practice. The overall viability of the alternatives depend on economic, technical, social, political, and legal considerations⁵. Each of the aforementioned components incorporates the notion of risk. This paper explains the methodology being used to quantify and compare risks to both workers and the public from the current practice and for each of the five alternatives. Preliminary results are also presented.

⁵An economic assessment has been completed as part of this project, and a companion paper to this paper is presented in the Conference Proceedings.

METHODOLOGY

The goal of this project is to quantify the fatal and non-fatal risk to workers and the public resulting from recycling or disposal of concrete from decommissioned DOE facilities. The scenarios listed in Table 1 were developed. Deaths and injuries resulting from construction/demolition activities, material transportation, and radiation exposures were evaluated.

Table 1. Candidate Scenarios

Scenario No.	Title	Description
1	Removal	Remove contaminated surfaces; dispose of LLW; demolish structure; crush concrete to aggregate; recycle aggregate
2	Treatment	Treat contaminated surfaces; dispose of LLW; demolish structure; crush concrete to aggregate; recycle aggregate
3	Cap	Rubblize facility/building w/o decontamination; consolidate rubble; cap site; monitor
4	Treat/Cap	Decontaminate surfaces; dispose of LLW; rubblize facility; consolidate rubble; cap site
5	Onsite Facility	Demolish facility w/o decontamination; crush concrete to aggregate; use aggregate to construct onsite LLW disposal facility
6	C&D	Current practice: decontaminate surfaces; dispose of rubble in C&D landfill; dispose of surfaces in LLW landfill

The risk model was developed for use on standard spreadsheet software. The model currently allows site specific input for: (concrete) floor area, slab thickness, depth of contamination, and geographic location. Contamination was assumed to be present at levels representative of a generic research and development facility, as designated in the Generic Environmental Impact Statement (GEIS) in Support of Rulemaking on Radiological Criteria for Decommissioning of NRC-Licensed Nuclear Facilities (U.S. NRC, 1994): 102,000 dpm/100 cm² (⁶⁰Co) and 33,300 dpm/100 cm² (¹³⁷Cs).

The fraction of total floor area assumed to be contaminated at these levels was estimated to be 15 percent, and the maximum depth of contamination was set at 1-inch. Exposure to radioactive materials was calculated by RESRAD and RESRAD-BUILD, two models developed at Argonne National Laboratory (Yu *et al.*, 1993; Yu *et al.*, 1994). The dose conversion factor for radiation exposure was 5×10^{-4} deaths/rem.

Occupational injury rates from the Bureau of Labor Statistics (BLS) for the construction industry (SIC codes 15, 16 and 17) (US DOL, 1995) were assumed to be representative of the frequency of fatal and non-fatal injuries that would be experienced during the onsite work for each scenario. Haulage of any low-level radioactive waste (LLW) was assumed to be via rail, and the disposal facility used for this study is in Clive, Utah. Haztrans[®] was used to compute rail route distances between the DOE facility and the disposal site, and to estimate population densities along the corridor and within proximity of each facility.

To help quantify the risks associated with each scenario, each operation was broken down into specific tasks to a resolution sufficient to permit distinction between the scenarios. Table 2 illustrates the tasks for Scenario 1. Next, the production rate for each task was determined. The daily output for construction activities was derived from the Means Construction Cost Index, supplemented with data from Dickerson (1995), technology vendors, the Department of Transportation (for transportation-related data), as well as the U.S. Air-force Remedial Action Cost Engineering and Requirements System (RACER) model. The United States Army Corps of Engineers (COE) provided data concerning typical capping projects.

Using BLS construction industry data, the expected number of fatalities per man-hour worked was computed. The total expected fatalities per scenario was estimated by multiplying the expected

number of fatalities by the estimated duration of each task. The BLS data on non-fatal injuries were used to estimate the number of workdays lost for a “typical” accident. This expected value was used to estimate the days lost (non-fatal) per task. Similar statistics and methods were used to estimate days lost per non-fatal transportation accident. Transportation accidents for rail travel were obtained from the Federal Railroad Administration.

Due to the fact that a portion of the facility floor-area is assumed to be contaminated with ^{60}Co and ^{137}Cs , remediation/demolition workers will be subjected to radiation exposure. Since assumed contamination levels are too low to induce acute, non-fatal injuries (such as radiation burns), the impact from radiation exposure was assumed to be fatalities from cancer. The RESRAD (Yu *et al.*, 1993) and RESRAD-BUILD (Yu *et al.*, 1994) models, developed at Argonne National Laboratory, were used to assess the exposure rate from various onsite activities. RESRAD-BUILD allows the user to modify source-receptor geometries so that different tasks, such as demolition, bulldozing, and loading, can be modeled. For instance, heavy equipment operator exposure can be modeled by elevating the receptor and shielding him with a sheet of iron. Other workers were modeled by a receptor at 1-meter elevation, spatially situated either on the source or to the side of the source.

Model runs with varying sizes of floor area were executed for each task to develop relationships between dose rate and floor area. Those relationships were incorporated into the model, enabling it to assign a dose rate based on the size of facility being examined. An example of the dose rate vs. floor area developed from RESRAD-BUILD model outputs for an onsite worker outside of

Table 2. Scenario 1 Task Breakdown (Facility Size: 150,000 ft²)

No.	Task Description	Comment	Processing		
			Rate	Units	Total man-days
1	Site Prep	travel of workers to site - 50 miles	1	50 miles	NA
2		set up job trailer	22,857	mh/each + 50 mi	2.9
3		construct access road - 100 yd ³ of gravel	0.067	mh/yd ²	5.0
4		install chain link fence around perimeter	0.16	mh/ft	19.7
5		grade	8	mh/acre	1.7
6	Characterization	characterize building for action	2.2E-03	mh/ft ²	40.7
7		transport of samples to lab (?)	1	50 miles	NA
8	Surface Removal	Abrasive Jetting Plastic Pellet	240	ft ² /hr	46,875
9		collect waste (from removal technology) - fill drums, load on train	0.16	mh/3 ft ³	1.13
10		collect debris and load into dump trucks	0.012	mh/yd ³	0.15
11	LLW disposal	haul LLW to EnviroCare	941.97	miles	NA
12		unload LLW at EnviroCare	0.5/0.17	bulk/drum	0.1
13	Demolition	demolish concrete slab only	0.035	mh/yd ²	72.9
14		crush concrete - load on crusher, screen	200	tph	6.94
15		transport to sale point (FOB)	0.1	miles	NA
16	Rebar	separate rebar	100	tpd	7.8
17		test rebar	6,86E-06	mh/lb	1.3
18		load and haul rebar	25	miles	NA
19	Clean-up	site cleanup	0.008	mh/yd ²	25.0
20		remove job trailer, fence	22,857	h/each + 50 mile	2.9
21		demobilization travel of workers	1	50 miles	NA
22	Fines	load	0.012	mh/yd ³	2.47
23		haul	50	miles	NA

the contaminated area is shown in Figure 1. Relationships based on RESRAD outputs were developed in a similar fashion for estimating the dose rate to workers from capping the site (Scenarios 3). Following estimation of the dose rate, radiologically induced fatalities for each onsite task were computed as follows:

$$R_{onsiterad} = (dose\ rate, \frac{mrem}{yr}) (task\ duration, days) \left(\frac{1\ yr}{365\ days} \right) \left(\frac{1\ rem}{1,000\ mrem} \right) (5 \times 10^{-4} \frac{deaths}{rem})$$

Transportation of LLW results in two types of exposure: 1) exposure from incident-free transportation; and 2) exposure from releases during accidents. The incident-free transportation risk methodology is based on work by Raj, Abkowitz, and Allen (1996) which estimates the risks to persons living along the railroad tracks (off-link population), persons in on-coming and other trains (on-link population), train crew, and populations at stops. The risk to off-link population is expressed as:

$$R_{off-link} = a_1 \bar{\rho} t_L$$

where a_1 is the constant coefficient for the off-link population group, $\bar{\rho}$ is the mean population density over the route within the exposure range of significant radiation, and t_L is the overall shipment duration from origin to destination (excluding stop times). Similarly, the component risk to on-link population is expressed as:

$$R_{on-link} = a_2 T t_L^2 / L$$

where α_2 is a coefficient for the on-link exposure group, T is the on-link traffic density, and L is the route length. The crew exposure is given by:

$$R_{crew} = \alpha_3 \bar{N}_{crew} t_L$$

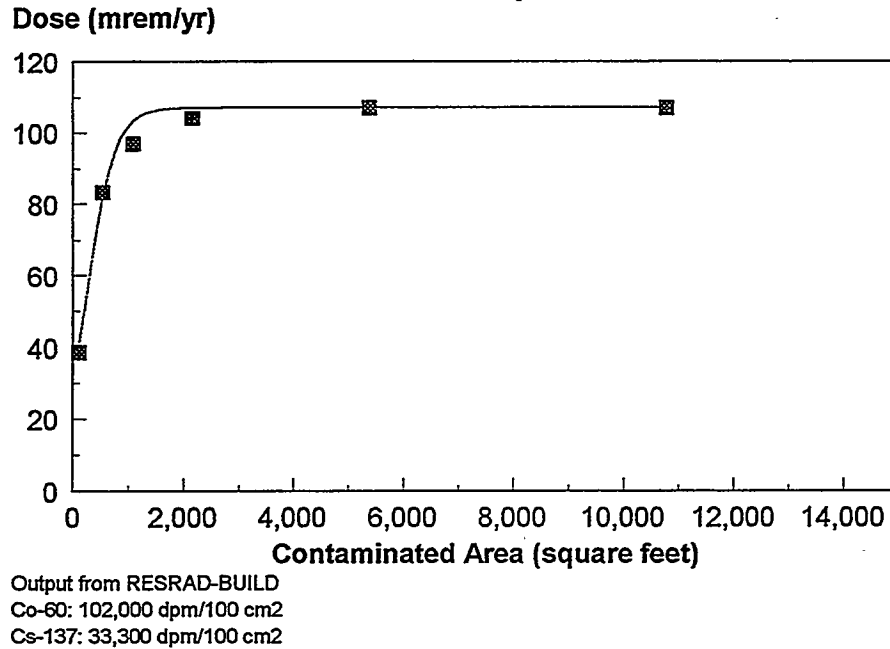
where $\bar{N}_{crew}$ is the average number of persons on board the train, and α_3 is the coefficient for the crew exposure group. The exposure to population at stops is expressed by:

$$R_{stoppop.} = \alpha_4 L$$

The overall incident-free risk is computed as the summation of the four component risks. The coefficients α_1 through α_4 were computed using a package dose rate of 13 mrem/hr at a distance of 2 meters; to compensate for the reduced source strength of the LLW being transported, the overall risk was scaled-down according to the following methodology. The population exposure computed by Raj, Abkowitz, and Allen (1996) (computed for higher activity source) was compared to the exposure estimate computed from the Gaussian-puff model described below. The risk is assumed to be proportional to the source activity, the ratio of these exposure rates was used as a scaling-down factor for the incident-free risk value. Total fatalities expected are then computed by applying the factor 5×10^{-4} deaths/rem to the population exposure.

The population exposure from radiation releases due to rail accidents was computed using an atmospheric Gaussian-puff model (Turner, 1967; Lamarsh, 1983). Following an accident, the LLW material being transported was assumed to constitute a point source release of particulate matter. Three sizes of particulates were modeled, each with different diameters and deposition

Figure 1. Example of RESRAD-BUILD Model Use
External Exposure



velocities: sand, dust, and cement-dust. The equation describing the concentration of suspended particulates along the centerline of the plume at any distance x from the source is:

$$C = \frac{M}{(2\pi)^{1.5} \sigma_x \sigma_y \sigma_z} \exp\left[-(\Lambda x + h^2/2\sigma_z^2)\right]$$

In the above equation, the Slade (1968) dispersion coefficients, σ_x , σ_y , and σ_z , reported by Schnelle (1992) were used, M is the total mass of material released in the puff, Λ accounts for deposition velocity of the particulate, and h is the height of release. Radioactive decay has been omitted due to the comparatively long half-lives of the ⁶⁰Co and ¹³⁷Cs. A reverse deposition of 1% of the total mass of rubble was assumed. The radiation and dose was computed using an estimated concrete-concentration of 75.2 pCi/g ⁶⁰Co and 24.6 pCi/g ¹³⁷Cs following removal of a 1-inch surface layer

(from 102,000 and 33,300 dpm/100 cm² ⁶⁰Co and ¹³⁷Cs, respectively). Average longitudinal and lateral concentrations (~42% of peak value for 3σ, or 99.75% of plume mass) were used to calculate concentrations that would be experienced by receptors along the plume swath (neutral atmospheric stability with windspeeds of 2 m/s were used in initial model runs). Population exposure was integrated from 0 to 4,000 meters downwind, taking into account doses from inhalation, cloud immersion (β-rays and γ-rays), and ground-shine (γ-rays). The dose contribution by both ⁶⁰Co and ¹³⁷Cs were summed together to estimate total population absorbed dose ($H_{air\ model}$).

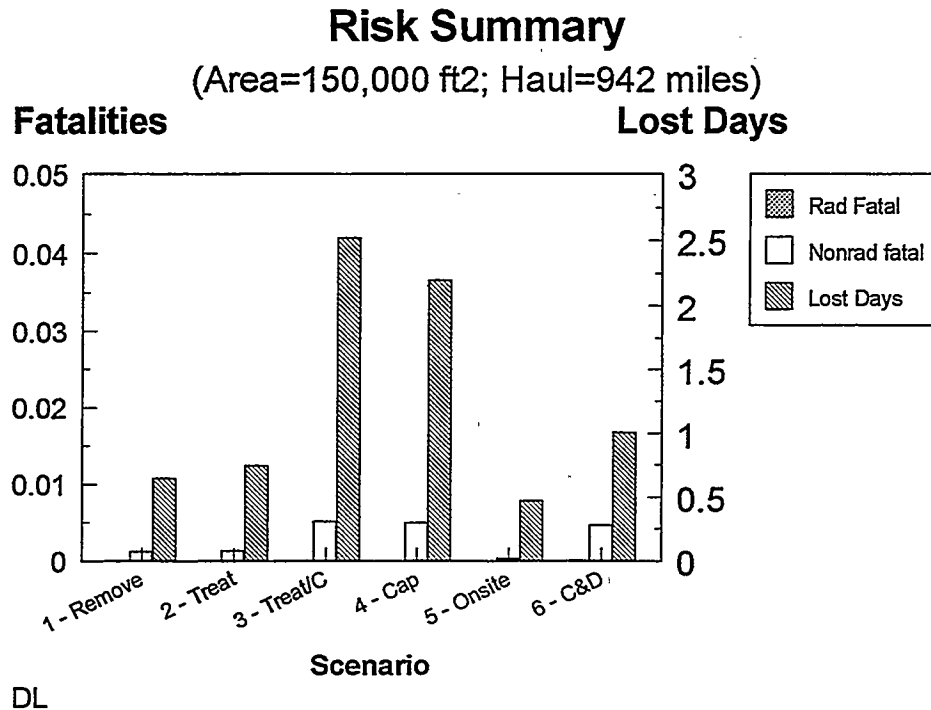
The Gaussian-puff model yields the consequence of a release caused by an accident. Therefore, to estimate the risk, the consequence is multiplied by the probability of an accident occurring during transport. The equation for exposure from accident-related releases is:

$$R_{t,acc,rad} = (H_{airmodel})(route\ length)(accidents/miles)(5 \times 10^{-4} deaths/rem)$$

RESULTS

An example of the ranking and relative risks for a relatively large building of 150,000 ft² and a LLW haul distance of approximately 940 miles (distance from Los Alamos National Laboratory to disposal facility - a "medium range" distance) is shown in Figure 2. The two left-hand bars in each grouping are read from the left axis (fatalities), while the cross-hatched bars are lost days and are read from the right hand axis. The total risk for the scenarios for this example range from 0.001 to 0.005 fatalities, and from 0.5 to 2.5 lost days. The radiological contribution to overall risk, less than 5%

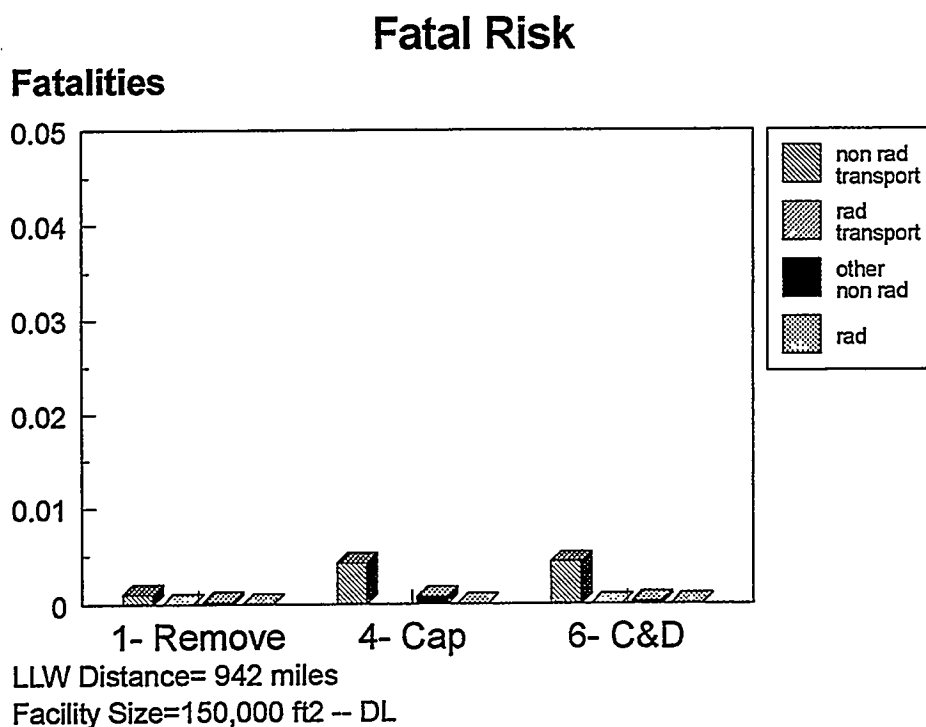
Figure 2. Summary of Risk



in all cases and usually less than 1%, is barely visible on the chart. The results for Scenario 5 (construction of an onsite disposal facility) are considered most sensitive to underlying assumptions and are currently being reassessed. Estimated Lost days are also less than or equal to the present practice for several alternatives.

It is also interesting to examine which functions contribute most to total fatalities. Figure 3 shows the relative contributions of non-radiological transportation, radiological transportation, other radiological, and other non-radiological components to total fatal risk for scenarios 1, 4 and 6. These results parallel the previous observation that risk from radiological origins is minor in comparison to total risk, and that non-radiological transportation risks are the greatest contributor to total fatal risk. In both scenarios 4 and 6, the largest contributor to fatal risk is non-radiological transportation: risk from hauling cap material to the site in scenario 4 and the risk of hauling concrete rubble to the C&D

Figure 3. Fractionation of Total Fatal Risk



landfill in scenario 6. The construction of an onsite cap adds risk to scenario 4, making it a less desirable alternative from a risk perspective, though in all cases risks remain small.

CONCLUSIONS

A number of preliminary conclusions can be drawn from the results presented. First, each of the scenarios represent very small risks, generally on the order of less than 0.01 fatalities. It is also clear that several alternatives to C&D disposal of waste are alternatives with similar, or lower, risks. Specifically, decontaminating and then recycling the concrete (scenarios 1 and 2) appear to be as low a risk as the other alternatives. Secondly, the risks resulting from the radiological exposure represent negligible incremental risk. In fact, the single highest contributor to fatalities appears to be transportation activities associated with common haulage. On the other hand, onsite non-radiological

work appears to be the leading contributor to non-fatal injuries, and subsequent lost days from work.

The model results indicate that recycling of the contaminated concrete will essentially result in as few fatalities and as few days lost because of injuries as either the current practice of C&D landfilling, or capping the rubblized concrete in place.

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Economic Analysis of Recycling Contaminated Concrete

Amy Stephen
Kenneth W. Ayers
John K. Boren
Frank L. Parker
Vanderbilt University
Civil and Environmental Engineering

ECONOMIC ANALYSIS OF RECYCLING CONTAMINATED CONCRETE

Amy Stephen, Kenneth W. Ayers, John K. Boren and Frank L. Parker

ABSTRACT

Decontamination and Decommissioning activities in the DOE complex generate large volumes of radioactively contaminated and uncontaminated concrete. Currently, this concrete is usually decontaminated, the contaminated waste is disposed of in a LLW facility and the decontaminated concrete is placed in C&D landfills. A number of alternatives to this practice are available including recycling of the concrete. Cost estimates for six alternatives were developed using a spreadsheet model. The results of this analysis show that recycling alternatives are at least as economical as current practice.

INTRODUCTION

One of the primary challenges facing the Department of Energy's (DOE) decontamination and decommissioning (D&D) program is to find an ecologically and economically sound method to deal with the tremendous volume of concrete that will be generated by the decommissioning and environmental restoration process. Current D&D practices within the DOE entail decontaminating the concrete surfaces, disposing of the decontamination waste streams in a licensed low level waste disposal facility, demolishing the structure, and disposing of the concrete rubble and rebar at a construction and demolition (C&D) landfill. This practice is not only expensive but places a severe burden on ever diminishing land disposal capacity. Additionally, failure to utilize the decontaminated aggregate requires the opening of new quarries for the production of virgin materials and the accompanying environmental degradation.

Concrete may be recycled in a number of forms. Uncontaminated and decontaminated concrete can be crushed and used as aggregate in new concrete; used as base and sub-base material for roads and foundations; used as fill material; and, left in large pieces and used as riprap to stabilize slopes and stream channels. State highway

departments have been successfully recycling concrete for over two decades to avoid disposal costs and to provide aggregate in urban areas and areas lacking suitable natural material.

An examination of the economic feasibility of recycling options is presented in this paper including the costs of continuing the current practice, burying the concrete as low level waste, and recycling scenarios. This economic analysis of recycling alternatives is part of a larger project, funded by a DOE grant from the Office of Science and Technology (EM-50), investigating the economic, risk, legal, and social implications of recycling contaminated concrete.

METHODOLOGY

Because the costs of D&D alternatives are dependent on the quantities of concrete and levels of contamination, estimates for these values are required. A recent DOE report, *Contaminated Concrete: Occurrence and Emerging Technologies for DOE Decontamination* (Dickerson et al. 1995), provides two estimates of the amount of contaminated concrete in the DOE complex. The first estimate is based on the 1995 Baseline Environmental Management Report (BEMR) and the second is based on site queries. Neither of these estimates is complete. Each is lacking data on some of the major facilities. Additionally, estimates of the total volume of concrete, both contaminated and uncontaminated, are not specifically addressed. Since the uncontaminated concrete constitutes a major portion of the material that could be recycled, its inclusion in the volume estimate is vital.

In order to overcome these problems, the Surplus Facilities Inventory and Assessment (SFIA) database was used as a starting point for estimating the total volume

of concrete potentially available for recycling. Total floor areas for surplus facilities throughout the DOE complex were taken from the database. To approximate both the volumes of contaminated and uncontaminated concrete for all facilities in the complex from the SFIA data, we developed a “scale-up” factor. The scale-up factor was based on the weighted average of the ratio of total floor area of representative facilities to the floor area listed in the SFIA database as shown in Table 1. The SFIA data for each facility was multiplied by the scale-up factor to determine the estimated total floor area for each facility¹

Table 1. Calculation of Scale-Up Factor

Facility	SFIA Floor Area	Total Floor Area	Scale-up Factor
ORNL	747,000	3,850,000	5.15
LLNL	198,000	6,000,000	30.31
RFP	525,000	3,080,000	5.87
SRS	5,464,000	10,950,000	2.00
Average			10.83
Weighted average			10.11

Fifteen percent of the total estimated floor area was assumed to be contaminated for this estimate. This was based on the National Research Council’s (1996) estimate that 15% of the floor area in process support buildings at DOE’s gaseous diffusion plants is contaminated. Contamination of process support buildings was assumed to be 102,000 dpm/100 cm² ⁶⁰Co and 33,300 dpm/100 cm² ¹³⁷Cs. These levels were taken from the US NRC’s 1994 *Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for Decommissioning of NRC-Licensed Nuclear Facilities* as being

¹ The total floor areas for the K-25 site at Oak Ridge, Tennessee, the Paducah, Kentucky GDP, and the Portsmouth, Ohio GDP were taken from the NRC’s report (National Research Council 1996). The floor areas for the GDP facilities were entered without applying the scale-up factor. The floor areas for the Hanford site and INEL were estimated directly from SFIA and BEMR data.

representative of the type of contamination to be encountered during the D&D of most facilities.

Volumes of contaminated and uncontaminated concrete were estimated from the areas based on a thickness of one foot and a one inch depth of contamination. The one foot thickness was assumed to approximate all concrete floor areas. The one inch depth of contamination is based on actual site experiences (Dickerson et al. 1995, US Nuclear Regulatory Commission 1994, Bechtel 1995) and an agreement between the Fernald Environmental Management Project (FEMP) and the Ohio Environmental Protection Agency (Longenbach 1996). Estimated volumes of contaminated and uncontaminated concrete are shown in Table 2.

There are a number of possible ways to handle concrete in the D&D process. A decision tree outlining the options available, shown in Figure 1, was developed to assist in creating the scenarios evaluated during this study.

Six scenarios, representing different paths through the decision tree, were chosen for further analysis. These scenarios are:

1. Decontamination by Surface Removal, Demolition, Recycle Clean Aggregate
2. Decontamination by Surface Treatment, Demolition, Recycle Clean Aggregate
3. Decontamination, Demolish in Place, Cap
4. Demolish in Place without Decontamination, Cap
5. Demolition without Decontamination, Recycle as On-Site Disposal Facility
6. Decontamination, Demolition, Disposal as Construction Debris

Table 2. Estimated Concrete Volumes

Facility	Contaminated Volume (cf)	Clean Volume (cf)	Total Volume (cf)
ANLE	5,000	434,000	440,000
ANLW	35,000	2,804,000	2,839,000
BNL	2,000	128,000	130,000
ETEC	36,000	2,825,000	2,861,000
HANFS	1,381,000	109,071,000	110,452,000
INEL	1,050,000	82,974,000	84,024,000
LANL	61,000	4,793,000	4,853,000
LBL	18,000	1,445,000	1,463,000
LLNL	25,000	1,975,000	2,000,000
METC	1,000	48,000	49,000
NTS	107,000	8,470,000	8,577,000
NV	115,000	9,057,000	9,171,000
OR	2,000	165,000	167,000
ORISE	4,000	278,000	282,000
ORNL	94,000	7,462,000	7,556,000
PANTE	47,000	3,701,000	3,748,000
RFP	66,000	5,246,000	5,313,000
RSL	19,000	1,483,000	1,501,000
SNL	759,000	59,951,000	60,710,000
SRS	691,000	54,555,000	55,246,000
Y12	5,000	362,000	366,000
ZZOTH	5,000	399,000	404,000
K25	136,000	10,764,000	10,900,000
PADUC	80,000	6,320,000	6,400,000
PORTS	103,000	8,098,000	8,200,000
Total	4,847,000	382,808,000	387,652,000

The use of surface treatment and removal technologies is assumed for decontamination. Surface treatment technologies are those which target the contaminant constituents in the matrix, that is, decontamination is achieved without the actual removal of concrete. Surface removal technologies are those which remove the surface layer of the concrete matrix and therefore the contaminants contained in the surface layer. Twenty-three surface removal and nine surface treatment technologies were evaluated in this analysis and are shown in Table 3.

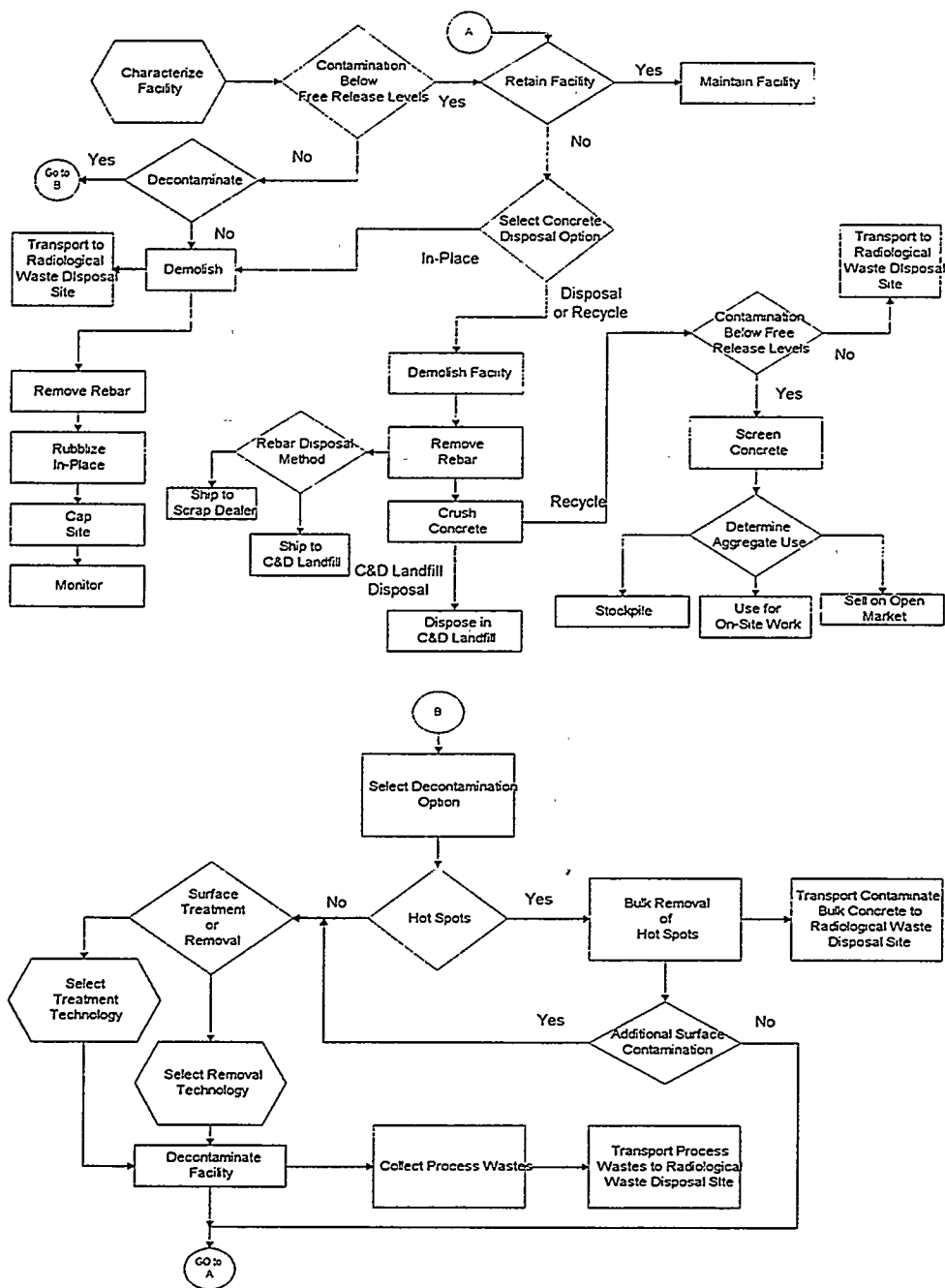


Figure 1. Decision Tree

COST MODEL

A spreadsheet cost model which evaluated each scenario was developed. Each scenario was divided into unit operations: mobilization/demobilization, characterization, site preparation, decontamination, demolition, and secondary waste handling. Unit (per square foot of floor space) costs were established for each unit process.

Table 3. Decontamination Technologies Reviewed

Surface Removal		Surface Treatment
Ice blasting	Hand grinding	Chelation
Plastic pellet blasting	High pressure H ₂ O	Chemical extraction
Sand blasting	High pressure H ₂ O (ultra)	Chemical foams
Soft media blasting	Laser heating	Chemical gels
Centrifugal cryogenic CO ₂	Microwave scabbling	Electrokinetic
Compressed-air CO ₂	Milling	Flashlamp cleaning
CO ₂ blasting	Scarification	Laser ablation
CO ₂ blasting (supercritical)	Multi-unit scarification	Microbial degradation
Drill and spall	Shot blasting	Sponge blasting
Electro-hydraulic scabbling	Soda (NaHCO ₃) blasting	
Explosive	Strippable coating	
Flame scarifying		

The Remedial Action Cost Engineering and Requirements System v3.1 1994 (RACER) model was used as the basis for developing the unit costs. RACER costs were supplemented with cost data from Dickerson et al. (1995), DOE (1994), and R. S. Means (1992) to fully develop the cost model.

The unit operation estimates were then combined to develop scenario cost estimates based on the volume of concrete, level of contamination, duration of the project, haul distances and disposal fees. The value of aggregate and/or rebar generated by the scenario was credited to the total cost.

RESULTS

The model was run for single structures and entire facilities. Results for a medium building (60,000 ft²) are shown in Figure 2. The least expensive scenario is Scenario 5 - Demolition, Recycle as On-Site Disposal Facility at \$670,000. From least costly to most costly, Scenarios 2, 6, 1, 4 and 3 follow at costs of \$670,000, \$870,000, \$890,000, \$1,100,000, and \$1,300,000 respectively.

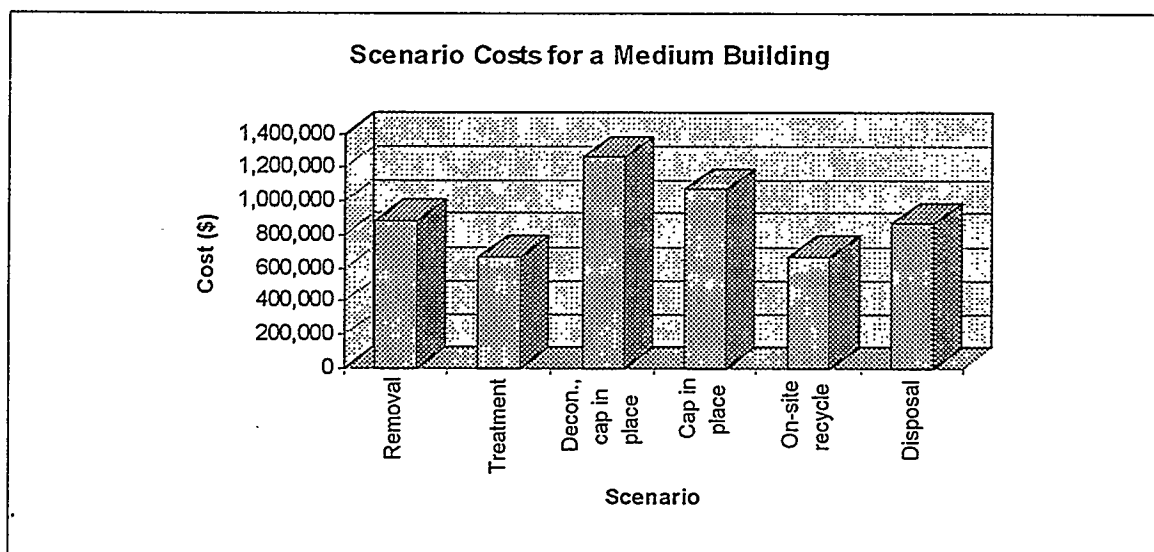


Figure 2. Scenario Costs for a Medium Building

Average costs for treating an entire facility² are shown in Figure 3. Once again, the least expensive scenario is Scenario 5 at a cost of \$170,000,000. The ranking from least expensive to most expensive is the same as the ranking for medium buildings except for Scenario 4 which becomes less expensive than Scenarios 6 and 1. After Scenario 5, the scenarios from least expensive to most expensive are Scenarios 2, 4, 6, 1, and 3. The

² The average costs were determined by running the model using the floor area of each facility and averaging the total costs for each facility.

costs of these scenarios are \$170,000,000, \$190,000,000, \$220,000,000, \$230,000,000, and \$310,000,000 respectively.

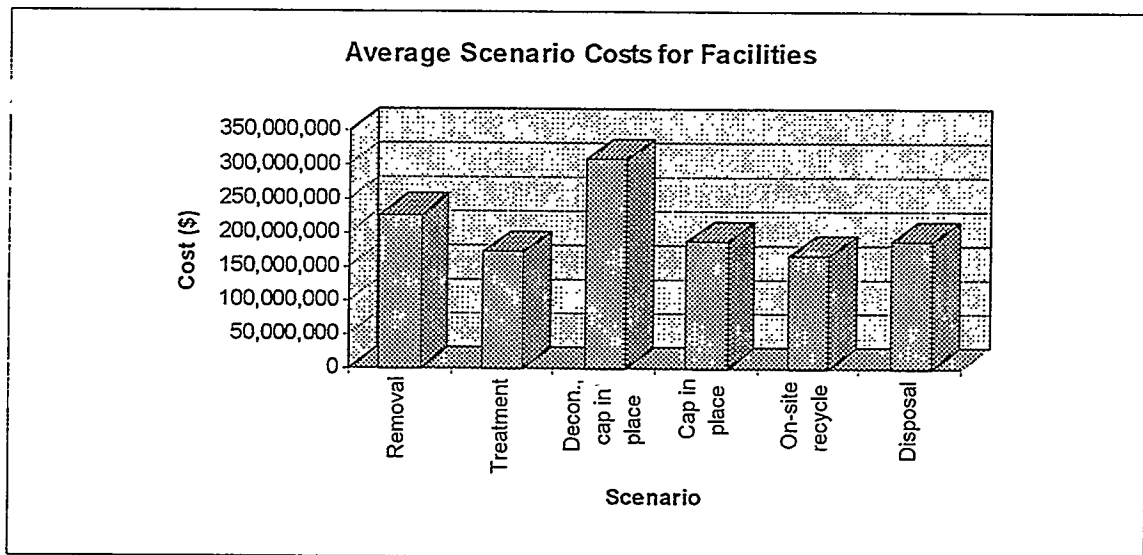


Figure 3. Average Scenario Costs for Facilities

The cost model's ranking of scenarios only changes as the volume of concrete increases with the emergence of Scenario 4 as a more viable alternative. This is a result of minimum capping and monitoring costs which are independent of volume for small volumes. When larger volumes are considered, the capping and monitoring costs do not increase as rapidly as costs for other scenarios which are more dependent on area. Scenario 4 becomes more competitive when dealing with sites larger than approximately 150,000 - 200,000 ft².

CONCLUSIONS

Our analysis indicates that decontaminating and recycling concrete is at least as economically feasible as the current practice of decontamination and sending the rubble to C&D landfills.

Using recycled concrete, without first decontaminating the structure, to construct an on-site disposal facility appears to be the most economically feasible alternative examined. The recycling of contaminated concrete in this manner is further supported by preliminary calculations suggesting the resulting volumetric contamination will be below proposed free release levels of 15 pCi/gm. Additionally, by retaining all of the material within the site boundaries, potential liabilities from third-party legal actions are lessened. However, Scenario 5 is the most sensitive to the model's assumptions. Further refinement of these costs is in progress.

Rubblizing structures in place without first decontaminating them appears to be an economically viable alternative once a threshold volume of between 150,000 and 200,000 cubic feet is reached. As with recycling concrete without decontamination, this alternative should result in rubble with volumetric contamination less than the proposed free release levels of 15 pCi/gm.

Decontaminating the concrete and then rubblizing the structure in place was shown to be the least economical alternative for all volumes of concrete.

There are several considerations which have not yet been incorporated into this model. The first is the favorable perception from being "green" by avoiding the environmental impacts of developing and utilizing a new source of natural aggregate and the resultant public reaction. Second, by recycling, the time at which a new source of virgin aggregate is needed can be delayed; thereby, delaying the considerable expenditures for environmental reviews and permits for a new facility. Avoidance of additional liability concerns is also not included.

FUTURE WORK

The next steps in this analysis are: continue to refine scenarios, build on the work already done by applying a probabilistic approach to the problem, and develop additional site specific costs. Future work will also include investigating the risk, legal, and social/political considerations involved in the scenarios. These parts of this study will be integrated into the final report. There is also potential for future work to be done on an analysis of the impact of non-radiological contamination.

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An Evaluation of Concrete Recycling and Reuse Practices

Karen S. Nakhjiri
S. Cohen & Associates, Inc.

J. MacKinney
U.S. Environmental Protection Agency

AN EVALUATION OF CONCRETE RECYCLING AND REUSE PRACTICES

Karen S. Nakhjiri, S.Cohen & Associates, Inc.
J. MacKinney, U.S. Environmental Protection Agency

INTRODUCTION

Nuclear facilities operated by the Department of Energy (DOE), Department of Defense (DOD), and NRC licensees contain many concrete structures that are contaminated with radioactivity. Dismantling these structures will result in significant quantities of waste materials, both contaminated and uncontaminated. Bartlett 94 estimates the total volume of waste from demolition of concrete structures to be on the order of 4 million cubic meters, but that only 20,000 cubic meters would be contaminated with radioactivity. Other studies suggest that as much as 5% of the concrete in these facilities would be contaminated with radioactivity (Abel 86). While the actual quantity of contaminated material should be fixed with greater precision, the fact that so much uncontaminated concrete exists (over 95% of the total 4 million cubic meters) suggests that a program that recycles concrete could produce substantial savings for both government agencies (DOE, DOD) and private companies (NRC licensees).

This paper presents a fundamental discussion of 1) various methods of processing concrete, 2) demolition methods, especially those compatible with recycling efforts, and 3) state-of-the-art concrete dismantlement techniques.

OVERVIEW OF CONCRETE RECYCLING AND REUSE

A recent study (Whiting 93) conducted for the Strategic Highway Research Program (SHRP) indicates that future trends for improving the nation's infrastructure will increase the demand for building materials in the next 5 - 10 years. This will result in an increased demand for aggregates, which comprise a major portion of construction materials.¹ At the same time, land-based sources of aggregate continue to diminish. In some areas there are no locally available supplies of virgin aggregates. In other areas, available sources of new rock are inaccessible, either because of high land values or zoning constraints. As a result, the search for new aggregate sources is increasing, especially in aggregate-poor states, and more emphasis is being placed on using recycled concrete aggregate, waste materials, and synthetic aggregates made of waste materials. This situation is

¹ As expected, aggregate use is greater in or near major metropolitan areas. In addition, transportation costs for concrete rubble and aggregate tend to make concrete recycling a regional industry. The regional nature of this industry can have pronounced impacts on the cost and benefits of any potential concrete recycling program.

leading to improvements in recycling technology and establishment of standard specifications for recycled concrete. The SHRP study concludes that in the near future a thriving market will exist for the recycling and reuse of concrete, even to the degree that the demand may be greater than the supply.

In some areas, landfills will not accept waste concrete for disposal, while in others, the cost of concrete disposal is greater than for other waste materials. Figure 1 depicts the relationship of tipping fees at a landfill and a recycling yard in the central coast area of California (Pearson 88). Figure 1 shows that both the recycling yard and the companies using it benefit from producing a quality reusable product from construction debris.

When a concrete pavement is removed prior to replacement with a new pavement, the project is a prime candidate for recycling—with the old pavement serving as a source of aggregate in the new concrete. Examples of where this has been done successfully are the I-94 project in Chicago and Detroit's Lodge Freeway (Pearson 88).

Not only is the expense of disposing of the material eliminated, but, if the project is large enough, additional savings can be realized by setting up a concrete processing plant onsite, thereby eliminating transportation costs which have grown considerably over the last few years, especially if there are long haul distances involved.

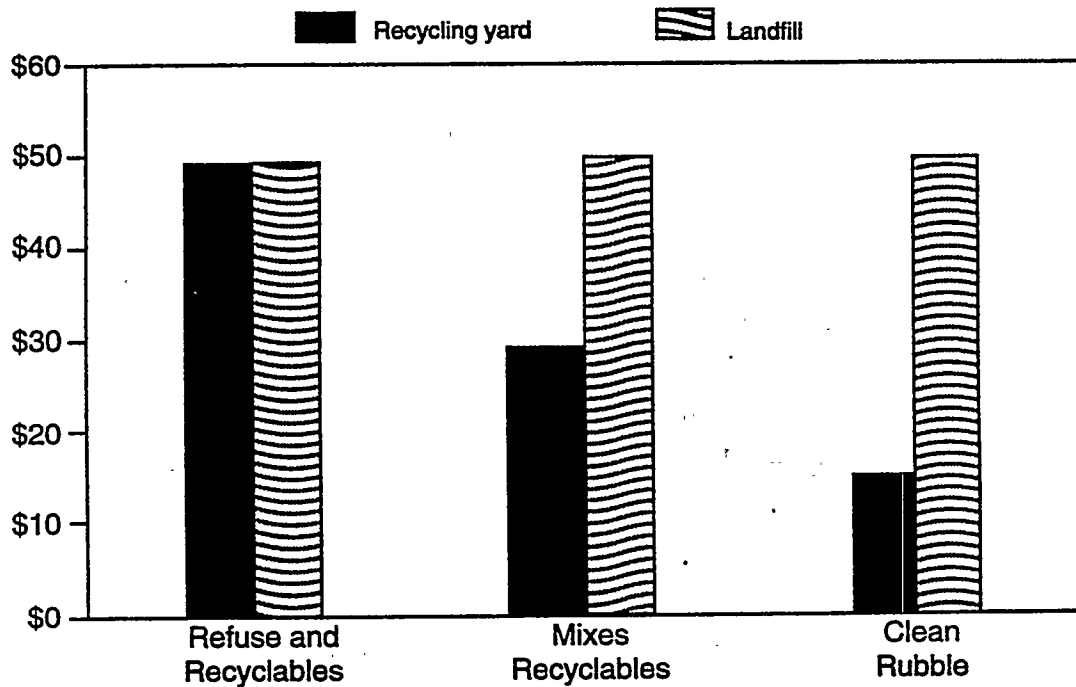


Figure 1. Tipping Fees at a Recycling Yard Versus a Landfill

The results of a 1971 survey conducted by the Texas State Highway Department and the Texas Transportation Institute indicate that, at the time, little consideration was given by most states to recycling existing pavement material other than as unstabilized base courses. Concrete removed from a roadway was normally disposed of in landfills or, at best, used as erosion control in drainage ditches. This attitude changed as the continued use of natural resources and energy required for their processing has had an increasing economic impact (HRB 73).

Initial proposals to use recycled concrete as aggregate material generated a number of questions. For instance, what would the quality of the new concrete containing the recycled material be as compared to the old concrete, and how would it compare to new concrete made with natural aggregate? Would the crushed concrete make quality aggregate? Could the reinforcing be easily

removed?² Would recycling for this purpose be an economically viable alternative to natural material? These questions and many others concerning the recycling of concrete have been substantially answered in the last 20 years, many within the last 10 years.

Data do not exist to answer the question of approximately how much concrete is recycled on an annual basis, nationwide (Donovan 91). Based on various reports and numerous discussions with many individuals associated with national associations related to concrete and construction, as well as individuals affiliated with national solid waste organizations, a conclusion has been reached that there are no dependable statistics or accurate information for how much concrete is generated from demolition activities nationally each year nor how much concrete is recycled, stockpiled, or landfilled on an annual basis. However, concrete is recycled with greater frequency in some areas of the United States more than in other areas. Most states in the South or the Great Plains region are aggregate-poor. More concrete is recycled in these states than in aggregate-rich states associated with the Cascades, the Rockies, and the Appalachian Mountain Range. For instance, in California most demolished concrete is recycled, whereas in Pennsylvania, the largest aggregate-producing state in the United States, concrete recycling is almost nonexistent.

While there are no dependable figures or accurate information regarding generation or disposal rates of demolished concrete on a national level, the amount of demolished concrete generated and needing disposal depends on the following factors (Donovan 91):

- the extent of growth and overall economic development, and the resulting level of construction, renovation, and demolition
- periodic special projects, such as urban renewal, road construction, and bridge repair programs
- unplanned events, such as Hurricane Hugo (1989), the San Francisco earthquake (1990), and the Los Angeles earthquake (1994)
- availability and cost of hauling and disposal options

² Most concrete recycling technology has been developed for lightly reinforced non-contaminated concrete and concrete pavement that, in general, contains much less steel reinforcement than will be encountered in DOE facilities or NRC licensee sites. Thus, there is some need to modify the existing recycling technology for the high levels of reinforcing steel in DOE facilities and NRC licensee sites.

- local, state, and federal regulations concerning separation, reuse, and recycling of concrete
- availability of recycling facilities and the extent of end-use markets

This report addresses the recycling of demolished concrete, assuming that only non-contaminated concrete will be a candidate for recycling. Interest in recycling concrete is growing along with the equipment and technology to do the actual recycling. Recycled concrete is primarily used for aggregate base coarse under new pavements. It is also used as an aggregate in granular subbases, lean concrete subbases, soil-cement, pipe bedding for utility trenches, structural backfill, and, in some limited cases, actually used as coarse aggregate in new Portland cement concrete as the only source of aggregate or as a partial replacement. In addition, recycled concrete blocks are also used as harbor rock (i.e., for breakwaters and controlling erosion). For example, in the Puget Sound area, nearly all the major governmental agencies—such as the Port of Seattle, Metro, King County, and the Washington State Department of Transportation—use recycled concrete for many of the applications mentioned above.

A discussion is included that addresses dismantlement techniques used on contaminated and non-contaminated concrete. The majority of concrete demolition work conducted to date involves non-contaminated structures. However, when considering the dismantlement of DOE nuclear facilities and NRC licensee sites where an estimated 2 to 5 percent of the concrete is contaminated, steps must be taken to protect workers from coming into contact with the activated concrete. These steps include minimizing time of exposure, maintaining sufficient distance, and providing appropriate shielding. An overview is provided of various approaches taken by contractors who have or are currently dismantling nuclear facilities, and some of the innovative methods they have demonstrated during the concrete dismantlement process.

CONCRETE PROCESSING TECHNIQUES

The key steps in recycling reinforced concrete are breakaway, separation of concrete and steel, and crushing to a specified size. Existing concrete, if processed properly, should produce more than the required coarse aggregate to recast a similar structure. An existing pavement, if processed properly will produce more than 80 percent of the total coarse aggregate volume needed to replace the removed section. This value decreases as steel reinforcing percentages increase. Concrete processing from nuclear-related facilities would likely yield lower aggregate quantities since steel reinforcing percentages are higher in nuclear structures than in most

pavements or typical concrete structures. However, the grade and type of concrete does not have a major affect on the concrete recycling process.

There are two primary approaches to processing concrete: onsite with mobile crushing units or at a stationary processing facility. Typical concrete crushing facilities use three principal size-reduction unit processes: jaw crushers, impactors, and cone crushers (SWANA 93). Most concrete recycling plants use jaw crushers as their primary crushers. The reasons for this are: high reliability, low maintenance costs, and greater particle-size control. A secondary crusher (e.g., a cone crusher) may be used for more precise and final product sizing. Standard cone crushers with a reduction ratio of 6 - 8 to 1 can reduce material to a minimum size of less than 3/4 inch.

Figure 2 shows material flow through a representative concrete processing plant. Concrete delivered to a mobile or stationary concrete processing facility is initially inspected and then placed by a front end loader into in a primary crusher. Once crushed, the material is referred to as aggregate. The aggregate is conveyed from the crusher to a large magnetic separator, where ferrous metal, such as rebar, is separated. The ferrous metal is typically sold to scrap metal dealers or discarded.

The aggregate then passes through a series of screens that separate the material by size into three grades. Aggregate sized at 3 inches in diameter is classified as Grade A material and is primarily used in foundations. Aggregate sized at 3/4 inch to 1 1/2 inches in diameter is classified as Grade B material and is primarily used for sidewalks and other applications exposed to weather. Aggregate sized at less than 3/4 inch in diameter is classified as Grade C material and is used as a subbase material; e.g., for footings in foundations.

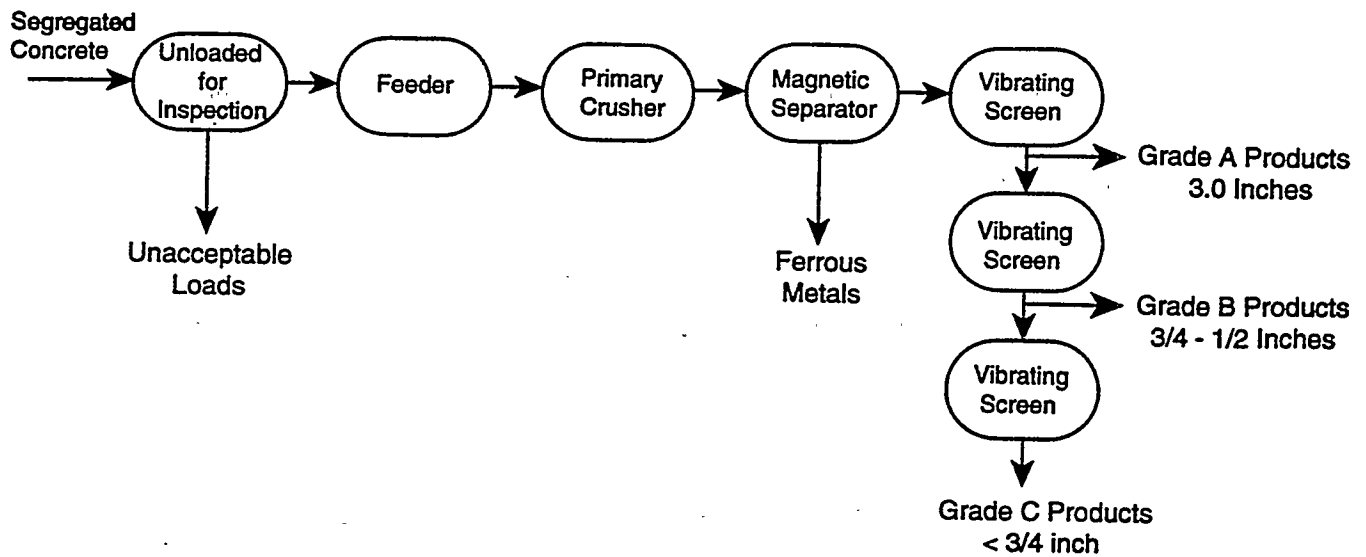


Figure 2. Concrete Processing Facility Flow Diagram

Typical equipment found at a concrete processing facility include:

- **Tracked Front End Loader** — Separates non-processible material and moves surge piles
- **Front End Loader** — Loads feeder/screen from nearby surge piles, and loads products into trucks for removal and reuse
- **Feeder/Screen** — Vibrating grizzly screen designed to pass sand, dirt, and small rock
- **Crusher** — Set to crush material to nominal 8 inches and smaller
- **Feed Conveyor** — Moves oversized material from the feeder and the crusher to the screen
- **Magnetic Separator** — Removes reinforcing rod and other ferrous metal
- **Double Deck Screen** — Vibrating screen with two decks to produce three products: oversized (for recycling back to crusher), middling - an aggregate material, and fines - dirt-like material

- **Recycle Conveyor** — Moves oversized material from the screen to the crusher
- **Middling Conveyor** — A two-part belt conveyor (short fixed discharge conveyor and a stacking conveyor) for discharge of the aggregate fraction
- **Fines Conveyor** — A two-part belt conveyor (short fixed discharge conveyor and a stacking conveyor) for discharge of the undersize (fines) fraction

CHARACTERISTICS OF RECYCLED CONCRETE AGGREGATES

Recycled concrete aggregate is primarily used as: 1) gravel for roadbase material, 2) aggregate in asphalt paving, 3) aggregate in granular subbases (in fact, due to its properties, recycled aggregate is considered to be more desirable for use as a subbase material than conventional aggregate), 4) lean concrete subbases, 5) soil-cement, 6) pipe bedding for utility trenches, 7) structural backfill, and 8) in some limited cases, as coarse aggregate in new portland cement concrete as the only source of aggregate or as a partial replacement. Table 1 delineates those states with policies for utilizing recycled concrete aggregate in road construction (SWANA 93).

Properties of Recycled Concrete Aggregate

The characteristics of recycled aggregates have been well documented. A number of laboratory studies have compared the properties of aggregate material made from crushed concrete with the properties of natural aggregates. Early work in this area was done by the U.S. Army Engineers Waterways Experiment Station (WES). WES examined the properties of aggregate made from crushed concrete containing chert gravel (coarse) and natural sand (fine), and a second aggregate made from crushed concrete containing limestone (coarse) and natural sand (fine). These manufactured aggregates were tested and compared with natural aggregate and then incorporated into concrete mixes for further comparisons. Results of absorption and specific gravity tests are shown in Table 2.

Results of studies conducted by WES, the Iowa Department of Transportation, Massachusetts Institute of Technology, the Minnesota Department of Transportation, the Michigan Department of Transportation, and the Federal Highway Administration (FHWA) are summarized in Yrjanson 81.

Table 1. States with Policies for Utilizing Recycled Concrete Aggregate in Road Construction

State	Reclaimed Asphalt Concrete	Concrete as Aggregate	Concrete in Concrete
Arizona	✓		
Arkansas	✓		
California	✓	✓	
Colorado	✓	✓	
Connecticut	✓	✓	
Delaware	✓		
Florida	✓		✓
Hawaii	✓		
Illinois	✓	✓	
Iowa	✓	✓	
Kansas	✓		
Kentucky	✓		
Louisiana	✓	✓	✓
Massachusetts	✓		
Michigan	✓	✓	✓
Minnesota	✓	✓	
Nebraska	✓	✓	
New Jersey	✓	✓	
North Dakota	✓	✓	
Ohio	✓	✓	
Oregon		✓	
South Carolina		✓	
Texas	✓	✓	
Virginia	✓	✓	
Washington	✓	✓	

Table 2. Absorption and Specific Gravity of Crushed Concrete and Natural Aggregates

	Recycled Material		Natural Material	
Coarse fraction	Chert Concrete	Limestone Concrete	Chert Gravel	Crushed Limestone
Absorption	4.0 - 4.3	3.9	2.6	0.8
SSD SP. Gr.	2.43 - 2.44	2.52	2.52	2.67
Fine Fraction			Sand	
Absorption	7.6 - 9.0	----	0.4	
SSD Sp. Gr.	2.36	----	2.63	

These agencies all found that the aggregate particles produced by crushing concrete have good shape, high absorption, and low specific gravity compared to natural mineral aggregates.

The Michigan Department of Transportation (MDOT) conducted a laboratory investigation of a series of crushed concrete materials for comparison with natural aggregate. Table 3 shows the test results (Fergus 81). The tests conducted by MDOT indicate that recycled portland cement concrete as aggregate can provide concrete with good durability when compared to concrete produced with natural aggregates. This, of course, is related to the overall quality of the original material being recycled.

Table 3. Properties of Crushed Concrete and Natural Aggregates (Fergus 81)

	Recycled Material		Natural Material
	Once Recycled	Twice Recycled	Gravel
Coarse Fraction			
Absorption	3.43 - 5.00	8.36	1.02
Bulk Sp. Gr.	2.31 - 2.40	2.11	2.67
Fine Fraction			
Absorption	7.17 - 8.31	----	1.38
Bulk Sp. Gr.	2.15 - 2.23	----	2.60

Michigan also tested a concrete material that had been recycled twice. Its specific gravity was still lower (2.11) and the absorption even higher (8.35 percent) than once-recycled material. These results are predictable since, with each successive recycling event, the amount of natural aggregate decreases when expressed as a percent of the aggregate material, and the amount of lighter, more absorptive cement paste increases.

Recycled Concrete Aggregate Specifications

Several states (e.g., California and Iowa) have developed specifications for removing, crushing, storing, and incorporating recycled materials in new concrete (Huisman 81). These specifications cover all phases of the construction and are usually based on national standards. The specifications primarily address the use of aggregate in concrete, which determines the strength of the material. One of the tests concrete must pass is the "California Wear" density test. This test determines the strength per cubic foot (or per cubic yard) of the material. The aggregate must also be tested before it is mixed with cement to form concrete. This is referred to as the "FM" test, or the Fines Modulus test, which measures the size of material in the aggregate (Donovan 91).

Specifications related directly to recycled aggregate material Stephen Forster addresses the following areas: 1) removal and contamination, 2) crushing and stockpiling, 3) mix proportions, 4) durability, and 5) air entrainment (Forster 86).

Forster 86 states that, in general, mix proportions should be determined based on trial mixes made in the laboratory. An effort should be made to proportion use of the coarse and fine recycled material in the same ratio as it is produced by the crusher. The cement factor is determined according to the strength desired, as with a conventional mix, and water is used in a ratio which will provide acceptable workability and finishability without being so high that excessive cement is required to maintain strength.

To this end, addition of natural fine aggregate, as previously noted, may be specified to improve these characteristics while holding the water content at a reasonable level. Water-reducing admixtures may also be considered for the specification to maintain the water-cement ratio at an acceptable level. Air entrainment and fly ash will also increase workability.

Forster goes on to say that the durability of the concrete produced should be checked in the laboratory according to ASTM C666 or some equivalent method. If alkali-aggregate reactive material is being recycled, the expansive characteristics of the new concrete may also be checked by ASTM C227 or equivalent to determine if it will perform acceptably.

In summary, specifications for recycled concrete aggregate material should have the same performance requirements that are generally applied to natural aggregates. Attention must be paid to the recycled material's effect on the workability of the new mix and the various ways to improve it.

Characteristics of New Concrete Made from Recycled Concrete Aggregate

New concrete made from recycled concrete aggregate generally has good workability, durability, and resistance to saturated freeze-thaw action. The compressive strength will vary with the compressive strength of the original concrete and the water-cement ratio of the new concrete. The compressive strength may be increased by using a higher cement content and replacing some of the recycled concrete aggregate with conventional aggregate. The new concrete will also have a lower density. As with any new aggregate source, recycled concrete aggregate should be tested for durability, gradation, and other properties as stated above.

Concrete trial mixtures should be made to check the new concrete's quality and to determine the proper mixture proportions. One major problem with using recycled concrete is the variability in the properties of the old concrete that will in turn affect the properties of the new concrete. This can partially be avoided by frequent monitoring of the properties of the old concrete that is being recycled. Adjustments in the mixture proportions may then need to be made (Neville 86).

DEMOLITION TECHNIQUES AND CONCRETE RECOVERY CASE STUDIES

As a result of the deterioration of the nation's infrastructure, and recent earthquakes in many parts of this and other countries, the need for the dismantling of concrete structures has increased. In open rural areas methods that employ equipment such as wrecking balls and jackhammers are adequate and still widely accepted. Other methods, such as dramatic engineered implosions, have brought large structures down in a relatively short time. But along with the impressive collapse of these structures comes high volumes of dust and noise and the probability of damage to adjacent structures. These adverse impacts may no longer be tolerated in many congested metropolitan areas and the building demolition industry has been obligated to develop more efficient demolition techniques which are quieter and less intrusive. Demolition is also being examined more closely with an emphasis on public safety, safety of demolition personnel, speed and efficiency of the demolition process, and the reuse of materials.

Demolition Techniques

There are numerous demolition techniques available. Some of those utilized for the removal of concrete include:

Diamond Wire Cutting Method — This method is highly accepted in the demolition industry. However, the cutting of large diameter rebar and recovery of the resultant fluid waste (slurry) are still listed as technology elements in need of improvement.

Hydraulic Jaw System — This system is commonly used for low-rise structures due to the height limitation of the hydraulic jaw.

Hydraulic Concrete Breaker — This machine functions similar to a jackhammer and applies loads as great as 10 kips per square foot. This method is highly effective; however, the most common problem with this method is the vibration and noise, especially if nearby buildings are

occupied. A health and safety plan associated with the operation of this method is critical. The hydraulic concrete breaker is used for footings and other below grade application; or, in some cases, in spiraled columns with large amounts of reinforcement.

Conventional Jackhammer, Wrecking Ball, etc. — These methods have high industry acceptance. However, systems must be developed to contain dust and control the noise generated from their use. These methods may require follow-up processes to reduce the size of the rubble for transport or recycling.

Implosion — With this method, the first task is to remove all non-structural elements such as stairs, etc.; all floors and columns are then sawcut. After the structure is demolished, it will be inspected for the size of concrete pieces, and evaluated concerning the need for primary crushing prior to the concrete being transferred to recycling facilities. This method is generally used for low-rise and mid-rise structures.

The DOE has conducted significant industry surveys of available demolition techniques with respect to dismantlement of nuclear facilities and published this information in documents which include the Decommissioning Manual (DOE 94) and the Technology Logic Diagram (DOE 93). This series of documents presents findings assembled by the DOE concerning dismantlement of mass concrete for the decontamination and decommissioning of three DOE facilities: Oak Ridge National Laboratory (ORNL) facilities Y-12, K-25 and X-10 (DOE 93). Each of these three facilities have separate documents addressing the applicability of various concrete removal, cutting or scarification methods with respect to site-specific conditions. The Technology Logic Diagram assumes dismantlement methods will not be dependent upon the type of contamination encountered provided containment and worker protection are provided. The Technology Logic Diagram assessed a number of dismantlement technologies as "highly useful" with respect to DOE needs. They include: 1) high-pressure abrasive water jet, 2) diamond wire cutting method, 3) conventional jackhammer, wrecking ball, etc., and 4) grapppler.

With regard to concrete recycling and reuse, The Technology Logic Diagram, states the following:

"Six technologies were identified that show promise for the removal of massive concrete from gaseous diffusion facilities. These technologies will permit the on-site burial of uncontaminated waste, or the technologies will use on-site burial as fill material for future road construction or foundation fill."

Concrete Recovery Case Studies

A Stationary Concrete Recycling Facility. A leading producer of recycled aggregate in the Northwestern U.S. is Renton Concrete Recyclers (RCR) based in Renton, Washington, just outside of Seattle. This concrete and asphalt recycling facility began operation in 1990 and now processes approximately 700 to 800 tons per day of waste concrete, asphalt, masonry block and brick. Of the incoming loads, 60 to 70 percent are concrete, with and without rebar (Vigus 95).

A tipping fee of up to \$10.92 per ton is charged for waste accepted at the plant (this is the tipping fee for concrete containing rebar; for concrete loads without rebar, the fee is \$1.50 per ton less). Although the plant is capable of processing mixed loads of rubble, the company prefers to process concrete separate from asphalt, and then to mix the materials together in differing proportions, depending on the end use.

The recycling facility is located on approximately 10 acres of land at the site of a former quarry. Company equipment includes a crusher, belts and conveyors, a screening plant, a magnet, a feed hopper, and a portable power unit. The capital cost of developing the plant was approximately \$1 million. Ten employees operate the facility; they staff the scale house, and operate the processing equipment as well as the heavy equipment.

RCR produces three grades of material, all of which are approved by the Washington State Department of Transportation. The material can be used directly as aggregate or it can be mixed with cement to make concrete. All of the material meets the same specifications as virgin aggregate: 2 - 4 inch minus recycled aggregate is sold as impervious backfill material and processed aggregate; 1 1/4 inch minus aggregate is sold as processed subbase material; and 3/4 inch minus ground asphalt is sold for base material under driveways and sidewalks.

RCR charges up to \$6.50 per ton for recycled aggregate, depending on the grade of material at the time of sale. Prices do not include trucking. New aggregate, which generally sells for \$5 to \$7 per ton in the Pacific Northwest, sells for up to \$20 per ton in the Northeastern U.S. (these

prices do not include trucking). Currently, RCR's prices are approximately the same as prices for virgin aggregate in the Pacific Northwest; however, as virgin aggregate sources dry up and prices consequently increase, RCR's prices will become more competitive. An advantage RCR offers is that the same truck that delivers waste material to them can leave the site loaded with recycled aggregate. This decreases hauling costs.

A Mobile Concrete Recycling Facility. The Rhine Construction Company of Seattle, WA owns a mobile concrete recycling plant which has been used successfully to complete many concrete demolition projects in the Puget Sound area. For a typical structure, Rhine will first sawcut the perimeters of the floor and provide temporary shoring. Then the concrete will be removed by a hydraulic jaw pulverizer by LaBounty Crusher. The sizes of the concrete pieces removed by this process range anywhere from gravel size to 2 ft². Some rebar is also removed at this stage due primarily to the "bite action" of the crusher. The concrete pieces are then placed on the ground and sorted. Clean rebar will be transferred to steel recyclers, and the remaining concrete, with and without rebar, will be transferred by a front end loader to the feeder. The concrete passes through the primary crusher and magnet (a 3-foot by 8-foot plate) where it is crushed into smaller pieces and the rebar removed; this is called Stage A. The crushed concrete pieces are then transferred by conveyor belts to the next stage. Stage B is similar to Stage A, and the pieces go through a secondary magnet to remove smaller rebar and welded wire fabrics (WWF is used in light concrete slabs and slab-on-grade). The residual material then passes onto vibrating screens and the product achieved is a 1 1/4 inch minus aggregate. If needed, the process noted above can be repeated with the material going through another crusher to achieve even finer material. The product is then dropped onto a long conveyor belt and transferred into trucks. Rhine's charges for concrete demolition projects, including processing the concrete, range from \$25 per cubic yard to \$100 per cubic yard depending on the level of effort required.

Typical concrete demolition projects where there is also concrete processing result in a 90 to 95 percent level of concrete recycled; the remaining amount usually goes to a landfill. However, the Rhine Company typically experiences a 98 percent rate of recycling with their concrete demolition projects.

Some concrete contractors who have stationary concrete processing facilities have decided to take their operation "on the road" due to economics. By using mobile crushers like the one described above used by Rhine, the entire operation can be taken to the job site if there is enough

concrete and the specific demands can be met by the operation. Means 95 provides cost data for these mobile operations, and the break-even point can be clearly defined.

A medium-sized crusher costs approximately \$600,000. Mobilization costs include transporting the crusher (approximately seven tractor-trailer trucks, or \$10,000 to \$15,000), permits, maintenance (\$0.50 to \$0.90 per ton), and the cost of obtaining property (no cost to \$0.10 per ton) on which to set up the operations. These figures and others are used in Figure 3, showing a break-even point analysis for this type of operation (Means 95).

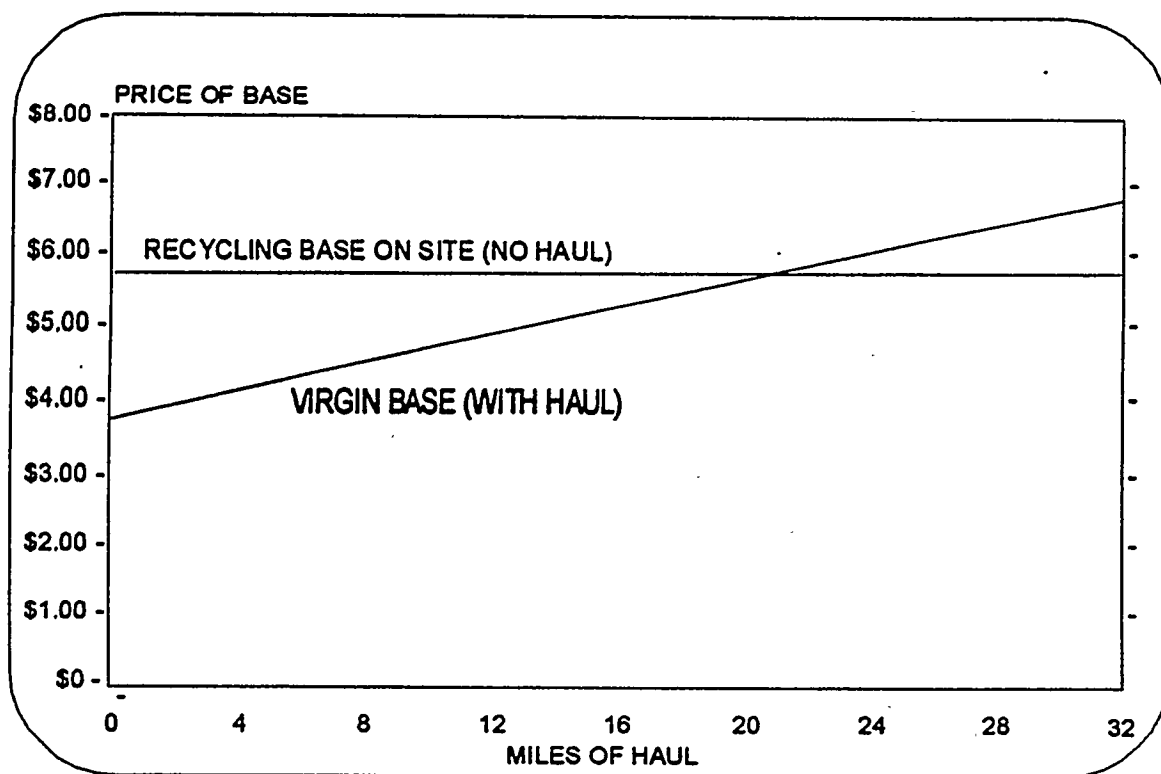


Figure 3. Cost of Recycling Base Onsite Versus Hauling Virgin Material from a Remote Location

CONCRETE DEMOLITION COSTS

There is a wide range of costs for the demolition of concrete structures, which includes removal and subsequent recycling (and landfill disposal, if needed) of the concrete. Typical costs range from approximately \$25 per cubic yard to \$100 per cubic yard (e.g., a 6-inch slab-on-grade removal cost is approximately \$25 per cubic yard, whereas a second floor removal in a controlled environment is approximately \$100 per cubic yard). The costs can vary due to several factors: 1) the selected demolition method and equipment used, 2) the type of structure (including the amount of reinforcing steel) being demolished, and 3) the size and location of the structure being demolished, i.e., is the concrete from the facility undergoing demolition being taken to a stationary concrete recycling plant or landfill (including the cost of hauling concrete to these locations), or is the concrete being processed at a mobile concrete recycling facility located onsite.

Costs associated with non-contaminated and contaminated concrete dismantlement of nuclear facilities can average considerably higher. An overview of the costs and specialized methods of concrete dismantlement associated with nuclear facilities are discussed in later sections of this report.

GUIDELINES FOR DEMOLITION WITH RESPECT TO CONCRETE RECYCLING

Demolition guidelines can be a strong tool to improve the quality of the waste and raise the quantity of the recycled concrete fraction. To realize this goal, demolition guidelines and recycling objectives should act in synergy.

A study of the recycling process conducted in Belgium discusses the elements involved in recycling (Simons 94). The waste is generated during construction, renovation or demolition of structures. It is transported to recycling installations, onsite or centralized (sometimes by a separate installation) or to a landfill. The use of recycled aggregate in construction work closes such a loop. A key to keeping the recycling process as economically attractive as possible is to prevent or minimize "bottlenecks" in the flow of materials. One such bottleneck is caused by heavily reinforced concrete and the subsequent need for separation of rebar and concrete which may impact the demolition method selected. As mentioned earlier, grapples and shears are one demolition method that effectively separates reinforcing steel from concrete during the cutting process. This method is a good candidate for the demolition of non-contaminated concrete associated with nuclear facilities, or the demolition of buildings in active earthquake regions

constructed with ductile moment resisting frames (i.e., containing a high percentage of steel reinforcement spaced closely together) intended for recycling.

Bigger processing units might be the answer to these bottlenecks (Busse 94). The R.I. Busse Company utilizes crushers having 62-inch jaw openings allowing large pieces of concrete with reinforcing steel to be processed. After crushing, the steel is removed by magnetic separators. Costs to recycle concrete can vary from \$1.50 to \$4.00 per ton to process material, plus the cost to mobilize onsite and stockpile the processed material. The resulting material selling price varies depending on the local needs, the intended use and/or the specification requirements. On average \$4.75 to \$5.50 per ton for finished material crushed to a top size of 1 1/4-inch is reported as common.

Atlantic Aggregate Recyclers of Norfolk, Virginia product prices generally range from \$5.00 to \$8.00 per ton. This recycler utilizes a LaBounty Crusher and has modified their equipment to accept heavily reinforced sections 22 inches wide by 12 feet long. Larger sections require preliminary crushing to reduce its size but no additional costs are charged. Road base is the predominant use of recycled concrete aggregate sold by this firm

PROCESSED CONCRETE MARKETS

New aggregate sells for \$12 to \$20 per ton in the Northeastern U.S.; for \$5 to \$7 per ton in the Pacific Northwest; and for \$5 to \$9 per ton in the Southeastern U.S. On average recycled aggregate sells for approximately \$5 to \$9 per ton throughout the U.S., depending on the grade of the material and whether additional crushing is needed before mixing the aggregate with cement to produce concrete. End-use markets for recycled aggregate include state transportation agencies, municipalities and concrete contractors.

DISMANTLEMENT OF NON-CONTAMINATED CONCRETE

Current Methods—an Overview of Demolition Techniques

Dismantlement technologies began with demolition methods used for conventional structures which is understandable since contractors began tearing down ordinary structures long before nuclear facilities required dismantlement. However, today the approach taken by demolition contractors concerning nuclear facilities is one of "engineered deconstruction" where the sequence of dismantlement very nearly reverses the original construction sequence. New or modified

techniques are being reported more frequently and contractors want the freedom to use the method which is most effective. Some methods of interest include the following:

Blasting — especially miniblasting (e.g., plasma blasting or controlled blasting) which uses small quantities of explosives. Computer simulation is used to predict the collapse of a structure and assess methods to reduce the nuisance factors of dust and noise.

Diamond Wire Concrete Cutting — especially useful for cutting massive sections of concrete. This method has been utilized for cutting large hydropower and other massive non-contaminated structures and is also used for contaminated concrete dismantlement. Diamond wire sawing, also listed in the DOE's technology logic diagram as highly useful, has been used successfully to dismantle various elements of nuclear facilities such as the Shorham facility in Long Island, NY, the Trojan Nuclear Power Plant in Rainier, OR and Fort St. Vrain in Platteville, CO. This cutting method offers many advantages such as limited generation of waste or rubble, no vibration, no dust, and depending on the amount of reinforcing steel encountered, it is a relatively expedient process. Disadvantages include treatment or disposal of the cutting slurry and the requirement of a properly sized crane to remove the cut section.

Heating Methods — including thermic lance, electric heating of reinforcing steel by direct current and induced current. Heating methods have shown success and are basically broken into three categories or types: 1) thermal boring using high temperature flame, plasma or laser, 2) cracking and peeling concrete cover by electrical heating of reinforcing steel, and 3) breaking and peeling by direct application of electrical energy (Nakagawa 93). These methods have been successful in breaking the concrete to reinforcing steel bond but must frequently be combined with another demolition process to yield properly sized broken pieces of steel and concrete to be transported or recycled.

Microwave Techniques — effective in peeling off surface concrete in flakes with reportedly low levels of dust. Microwave techniques could be applicable in the removal of contaminated surficial concrete as found behind the biological shield wall of a nuclear reactor. Disadvantages include local interferences with electric waves, telephone, and television signals and other methods of communication. Microwaves also require shielding to prevent harmful effects to workers.

Most demolition work is carried out using a combination of two or more methods noted above. Contractor selection of demolition approach is based on speed and efficiency, contractor experience and expertise, and the general nature of the dismantlement project.

EMERGING TECHNOLOGIES

A literature survey and discussions with industry personnel indicate that there are various concrete demolition technologies that are considered innovative. Some of those technologies are:

BROKK BM 250 — remote controllable, moveable demolition equipment.

Sunburst Excavation — a company located in Denver, CO has developed and patented a rock breaking technology based on using a small charge of propellant to fracture and excavate a controlled volume of rock. This method does not appear to be applicable for use in dismantlement of nuclear facilities without additional steps taken to break the concrete and reinforcing steel bond and separate material.

Dilute Explosives — the Stanford Research Institute (SRI) developed and patented a castable, dilute explosive that offers unique advantages over high power explosives in that this dilute explosive can be cast in almost any shape with arbitrary dimensions and it provides not only substantial flexibility in tailoring the resulting pressure pulse, but also a means of applying a blast directly to complex and contoured structures.

Plasma Blasting — a new technology which employs the transformation of electrolyte energy into a high-pressure, high temperature plasma. The plasma produced by the transferred energy expands faster than the normal seismic wave propagation velocity and forms a shock wave. The shock wave reportedly produces a stress field that shatters rock without causing excessive dust and debris.

Controlled Blasting — a method that is relatively inexpensive, has a low noise level, and can be installed expeditiously.

As mentioned earlier, one demolition technology that appears to have the capacity to simultaneously remove and separate reinforced concrete materials is hydraulic demolition. The development of hydraulic demolition equipment has started to revolutionize the demolition of non-contaminated concrete. Hydraulic demolition attachments have been in use for 20 years. However, with the addition of jaw-like pulverizers and shears to conventional machinery such as cranes and booms, faster and more controlled removal of concrete is now possible. During the process, shears cut the steel and pulverizers effectively separate reinforcing steel from the concrete, allowing recycling of both materials at the same time.

CASE STUDIES

The Bluegrass Bit Company has utilized diamond wire saw cutting, robotic hammering, BROKK machinery, and Bristar expansive grouts to dismantle nuclear facilities. The BROKK machinery is used with various hydraulic attachments and/or used in combination with Bristar expansive grout. One of the nuclear facilities where the Bluegrass Bit Company performed concrete dismantlement activities was the Trojan nuclear facility (Beckman 95).

The Trojan nuclear facility owned by Portland General Electric and located in Rainier, OR underwent some dismantlement activity performed by the Bluegrass Bit Company and completed in April 1995. The concrete removal project involved making an opening in the containment structure for the eventual removal of four steam generators (each generator was 15 feet in diameter by 70 feet high). The concrete dismantlement method of choice was diamond wire saw cutting. The project took approximately nine weeks to complete with a 10-person crew. The outside containment wall was cut into 12 blocks; inside walls totaled 22 blocks, and each block weighed approximately 25,000 pounds. The vertical cuts were 24 feet in length and the horizontal cuts were 22 feet in length. An estimated 20 hours per cut was projected, however some cuts took half that amount of time while others did take that long due to the difficulty of cutting through the tendon sheaths present in the walls. The tendon sheaths consisted of approximately 180 wires inside a 5-inch diameter corrugated steel pipe. There were 18 horizontal tendons and 8 vertical tendons. Other items in the walls included a substantial amount of rebar ranging in size from No. 6 to No. 18 and a 1/4-inch steel plate.

To prevent this situation from developing, the Bluegrass Bit Company discovered that if they started cutting with the largest diamond wire (13 mm), and then gradually decreased to smaller wires (11 mm and 9 mm) as needed, much of the uneven cutting was substantially reduced. Core borings were also used for the outside containment wall and additional core borings were also used for wire access holes.

Water was used for dust control. A tent was placed around the saw to control the spray from the drive wheel. Catch basins were lined with polyethylene. As stated earlier, with the diamond wire saw cutting method there is very little airborne particulate matter because of the water spray that is used; however, a major problem that stems from the use of the water is containment of the slurry that results from the cutting process. In Trojan's case, the slurry was placed in 55-gallon drums and later dewatered.

For this project, the Bluegrass Bit Company used four saws, although a majority of the time only two saws were used, to cut approximately 1,800-2,000 ft² of surface area.

The 22 blocks from the inside walls are currently being stored in the rad waste building at Trojan. These blocks exhibited some slight radioactivity (tritium at <500 pCi/100 cm²) and were painted with an encapsulate (PBS) to lower the release of radioactivity. Surface contamination penetrated to 0.4 inch and activation was found at up to 2 inches. The 12 blocks from the outside containment wall exhibited levels of europium-152 <500 pCi/100 cm². The 12 blocks are being temporarily used as an outside security barrier near one of Trojan's warehouses. As noted, the concrete blocks are stockpiled onsite, and there are no plans to recycle any of the concrete from this dismantlement project. Reasons given by Trojan staff include: 1) haul cost to recycle offsite—there is no concrete recycling facility nearby nor is there enough concrete to warrant a mobile concrete processing facility to come onsite; 2) high landfill disposal costs; 3) possible future on-site use; and 4) processing of this concrete in the future along with the concrete that will result from the dismantling of the cooling tower in 1997.

The Long Island Power Authority recently completed a dismantlement project at its Shorham nuclear facility (Giacomazzo 95). The project involved the removal of 60 feet of the bioshield wall. The bioshield wall was a 24-inch thick circular wall of which the upper eight feet consisted of two 1-inch steel plates separated by a void in the middle; the lower 52 feet of the bioshield wall consisted of two 1-inch thick cylindrical plates separated by concrete in the middle. Every few feet was a horizontal steel plate and some vertical plates. Trentec, of Loveland, OH, was the concrete removal contractor. The method of choice for concrete removal was diamond wire saw cutting. The project took approximately five months to complete. None of the non-contaminated concrete was recycled, but is being retained onsite in 5 ft by 6 ft by 2 ft blocks inside a storage facility. Shorham personnel elected to store the blocks onsite because they did not want to incur the "unnecessary expense of haul costs at this time" since the future of the site is uncertain.

DISMANTLEMENT OF CONTAMINATED CONCRETE

As mentioned previously, the majority of concrete demolition projects involve ordinary structures. When considering the dismantlement of DOE nuclear facilities or NRC licensee sites, it is estimated that the majority of the concrete in such facilities is uncontaminated and only 2 or 5 percent is contaminated (Bartlett 94). Although smaller in removal volume, this contaminated concrete dismantlement will cost significantly more per unit volume to cut, remove, transport, and dispose of than conventional concrete.

For structures with contaminated concrete, steps must be taken in order to protect workers from coming into contact with activated concrete. These measures include minimizing time of exposure, maintaining sufficient distance, and providing appropriate shielding. In examining approaches by others who have or are currently dismantling nuclear facilities, several innovative methods have been demonstrated.

Dismantlement of the Japan Power Demonstration Reactor

The dismantlement of the Japan Power Demonstration Reactor (JPDR) by the Japan Atomic Energy Research Institute (JAERI) was started in 1981 with actual dismantlement activities starting in 1986 and completed in 1994. Highly activated components such as the reactor internals, the reactor pressure vessels (RPV) and the activated inward surface of the biological shield concrete were removed by using remote operated tools (Yokota 93). A summary of the JPDR dismantlement methods is shown in Table 5.

Reactor internals were removed by using two types of underwater plasma arc cutting systems and robotic manipulators. These systems were controlled by a microcomputer to maintain a constant torch angle, elevation, and distance from the cutting surface. The work was remotely monitored with four TV cameras installed in the RPV away from the highly activated cutting objects but within the focal range of the cameras' zoom functions.

To contain airborne contamination generated during the cutting process, a green house was erected over the water in the work area. In order to contain escaping gases, an air curtain was placed above the water. Almost no increase in radioactivity was detected in the air in the upper portion of the air curtain.

Table 4. Cutting Techniques, Ability and Components Dismantled by Developed Cutting Tools (Yokota 93)

Technique	Components Dismantled	Cutting Ability
Underwater arc saw	Reactor pressure vessel (RPV)	250 mm (10 in) thick carbon steel in water
Underwater plasma arc	Reactor internals	130 mm (5.2 in) thick stainless steel in water
Rotary disc knife	Piping connected to RPV	12 in., Sch 160 (stainless steel)
Shaped explosive	Piping connected to RPV	26 in., Sch 80 (carbon steel)
Mechanical cutting	Biological shield	Cutting efficiency: 1.3 m ² (2.0 yd ³) per hour
Abrasive water jet	Biological shield	450-600 mm (18-24 in) thick reinforced concrete
Controlled blasting	Biological shield	Blasting efficiency: 0.1 m ³ per hour

The water was filtered through an ion exchanger to reduce the concentration of radioactivity below limits of detection.

The cutting conditions of the plasma torch were reported as shown in Table 6.

Table 5. Removal of the Reactor Internals Cutting Conditions and Results of the Plasma Torch (Yokota 93)

Cutting Current	500 A
Voltage	170 V
Gas Flow	Ar + H ² 50 (30 + 20) l/min
Cutting Length (max.)	2500 mm (100 in)
Thickness of cut (max.)	110 mm (4.4 in)
Cutting Time (max.)	1410 sec.

The dismantlement of the RPV was accomplished using the underwater arc saw cutting system. The saw was remotely operated from a control room located outside the reactor enclosure.

The RPV was cut vertically and horizontally into 65 pieces measuring approximately 23 to 35 inches by 29 to 33 inches. A total of 24 blades was needed to accomplish the cutting of the RPV. Cutting waste was collected in a filtering system utilizing a 0.9 μm cartridge filter, followed by a separator before being fed into a shielded container.

The JPDR biological shield was removed using a combination of dismantlement methods: mechanical cutting (diamond sawing and coring, or stitch drilling), abrasive (steel grit) water jet, and controlled blasting. The inner part of the reactor that was activated by neutron irradiation during its operation required remote removal methods. Diamond sawing and coring was used for the highly activated upper portion of the biological shield. Stitch drilling, by cutting approximately 100 vertical overlapping adjacent cores, was used to cut around the perimeter of the biological shield. Two types of blades were used for diamond sawing and coring—cubic boron nitride (CBN) and diamond blades. The CBN blades are durable at high temperatures and were used to enhance cutting of the steel liner. Diamond blades were used to cut reinforced concrete. A dust collection and slurry processing system was used to process cutting waste. The processed waste was placed in containers for disposal.

The lower portion of the highly activated biological shield was dismantled using the abrasive water jet system containing steel grit. The system included the cutting robot, water jet generating unit, abrasive supply unit, lift assembly, the block bucket, slurry treatment unit, dust collector, and control system. The maximum water pressure was 28,440 psi and a flow rate of 13.2 gallons per minute. A total of 102 blocks of concrete and steel were removed. The radioactive waste or slurry was separated and the abrasives and sludge were mixed with cement and placed in drums for disposal. The amount of secondary waste was significant as abrasives, sludge, and waste water totaled 642 tons.

The next dismantlement step was to remove the remainder of the biological shield. At this stage in the dismantlement process the highly activated concrete had been removed and the dose rate in the cavity of the biological shield concrete decreased to 3 mrem/s per hour or less. This allowed the remaining concrete to be dismantled manually by controlled blasting. This method utilized a platform for the dismantling work such as drilling and setting charges, a contamination control envelope, a ventilation unit and a waste transporter. The explosive used was Urbanite, an improved form of dynamite which has a relatively slower detonation velocity. Vertical blasting holes were drilled 16 inches behind the inner steel liner of the biological shield. To help

successfully control blast influence, slits were cut to a depth of 10 inches at the boundary of each block.

After blasting, the remaining partially fractured concrete was separated from reinforcing steel using jackhammers. Exposed reinforcing steel was cut with an oxyacetylene torch. This level of manual or direct contact with the concrete would not have been conducted if the concrete had been highly activated.

Dismantlement of the Fort St. Vrain Nuclear Facility

The Fort St. Vrain Nuclear Facility in Platteville, CO is the first major nuclear power reactor in the United States to be dismantled after operating commercially (McGraw-Hill 94). Fort St. Vrain commenced operation in 1976; now it is being converted to a 471 Mw combined cycle facility with the addition of gas turbines.

The 330 Mw gas cooled power plant contains a reactor vessel which is shaped like a massive concrete hexagonal silo with an inside diameter of 30 feet buried 105 feet in the ground. The interior is lined with steel, backed by insulation. The 8- to 15-foot thick walls are post-tensioned vertically and circumferentially. The top head and 5-foot thick bottom slab are prestressed.

The \$157 million dismantlement project was contracted to Westinghouse-MK Ferguson Group (WMKFG), Cleveland, OH, who was selected over six other bidders, many of whom had proposed expensive robotics. The unique aspect of work is that WMKFG elected to flood the reactor with water. Water shields workers from radiation, permitting use of low-tech, line-of-sight tools. The 300,000 gallons of constantly filtered water was utilized to minimize worker exposure. Over the course of the project to date, WMKFG has utilized 22 divers.

The reactor was largely dismantled using diamond wire. For circumferential cutting of the reactor walls access had to be provided for the diamond wire rope initial pathway. Trentec accurately cut laser guided 4-inch diameter intersecting horizontal cores. The core holes intersected well within the diameter of the core barrel despite traveling as much as 30 feet. The hollow core barrel provided stability against drift or wander. The diamond wire rope was then fed through the core holes to initiate cutting. Cutting slurry was collected in containers stationed at four diamond wire exit points around the reactor walls.

Trentec installed a rotating steel working floor on top of the reactor with two open bays. This allowed workers additional shielding while reaching down into the reactor to extract cut elements. The existing 170-ton capacity overhead fuel handling crane was used to remove the dismantled sections.

The 30-foot diameter, 5-foot thick core support floor was also cut by diamond wire rope and lifted out in sections weighing as much as 110 tons. Additional diamond wire cutting was used in adjacent cutting tents to yield smaller size pieces of concrete which was transported for disposal at Hanford, WA. The smaller sections (36 total) weighed approximately 40 tons each and were disposed at Hanford at a cost of approximately \$80,000 each. Some concrete was recycled and used as rip rap on a nearby river embankment.

Comparison of Dismantlement Techniques

In comparing the dismantlement techniques used in the two case studies above there is a distinct contrast between the JPDR dismantlement and the approach used at Fort St. Vrain. Since Fort St. Vrain is being decommissioned and converted to an alternate fuel source, the remainder of the structure must remain undamaged. The diamond wire rope method provides excellent control, avoiding vibration or shock transmission to adjacent concrete. Trentec was able to take advantage of existing ducts for cutting purposes whereas the JPDR project required drilling of blast holes 16 inches behind the bioshield wall. Trentec was also able to take advantage of the existing fuel handling crane directly over the work area which was invaluable in the removal of dismantled sections and equipment.

In removing concrete around the perimeter of the biological shield at the JPDR, 102 stitch cores or overlapping adjacent core holes were cut to accomplish the task. The JPDR project experimented with a number of cutting technologies generally using more aggressive methods as the level of radioactivity in the work areas decreased.

CONCLUSION

Most concrete recycling technology has been developed for lightly reinforced concrete structures and concrete pavement that, in general, contain much less steel reinforcement than is encountered in DOE facilities or NRC licensee sites. Therefore, a need exists to modify the present concrete recycling technology for the high levels of reinforcing steel found in DOE facilities and NRC

recycling technology for the high levels of reinforcing steel found in DOE facilities and NRC licensee sites.

Technology development is not, however, the primary barrier to recycling. Economic barriers must be addressed. First, it should be recognized that the maximum value obtainable for recycled concrete materials will never approach the cost of dismantlement. Therefore, unless there are other factors dictating dismantlement, such as the need or ability to put the land occupied by the current structure to a better use, dismantlement solely for the salvage value of the concrete cannot be economically justified. When a structure is dismantled, the potential for recycling the concrete is driven by the local demand for aggregates and the pricing of virgin aggregates. A major portion of aggregate cost, regardless if the aggregate source is virgin or recycled, is transportation cost. Thus, it is more difficult to find markets for aggregate derived from recycled concrete if not located near the area of demand for aggregates. In spite of these barriers, it is anticipated the market and demand for recycled concrete is growing as sources of virgin aggregate become more scarce and the cost of obtaining virgin aggregates increases.

The demolition technology for the dismantlement of contaminated concrete has evolved from the demolition techniques of conventional structures. These conventional technologies are adapted or modified to address safety issues encountered when working with contaminated concrete. These modifications can change from job to job depending upon working conditions, level of contamination, and time allowed to complete the work. The demolition techniques used for the dismantlement of non-contaminated concrete are typically the same as, or very similar to, those techniques used for contaminated concrete dismantlement. Also, many of the same worker health and safety practices apply in both situations. One difference, though, is the level of concrete recycling and reuse that can be engaged in. For non-contaminated concrete, a much greater emphasis must be placed on recycling and reusing the concrete removed during the course of the dismantlement process. Guidelines concerning safety, project duration, and required recycling practices, etc., should be included as operating parameters for each project. Specifications must stipulate a certain level of worker health and safety protection, and require recycling and reuse of the demolished concrete, or penalties and/or fines will be levied if the specifications are not met.

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Crushing Leads to Waste Disposal Savings for FUSRAP

Jason Darby
U.S. Department of Energy
Former Sites Restoration Division

JASON DARBY

**Program Manager
Former Sites Restoration Division
U.S. DOE
Oak Ridge, TN**

Jason is currently serving as a Program Manager in DOE's Former Sites Restoration Division and is responsible for waste management and transportation, pollution prevention, site characterizations and RCRA/TSCA compliance. He received an MS in Geology from Louisiana State University in 1987 and began his career with the U.S. Geological Survey, Water Resources Division in Richmond, VA. Later he went to work for EPA Region 4 in the RCRA program. With EPA he worked primarily on RCRA land disposal permits, site characterization and remediation. He also worked in the Region 4 laboratory performing field investigations at RCRA and CERCLA sites throughout the southeast. He came to DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP) in early 1995. Today he is here to give a presentation on the use of a commercially available rock crusher during FUSRAP cleanup actions and the resulting cost savings.

Crushing Leads to Waste Disposal Savings for FUSRAP

Crushing Leads to
Waste Disposal
Savings for FUSRAP

FUSRAP

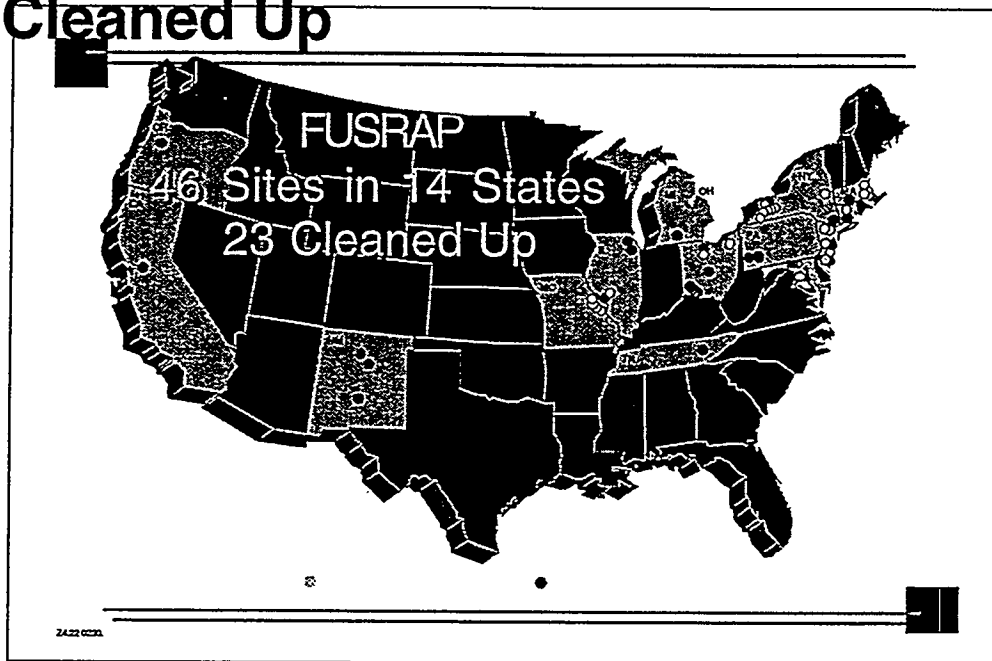


2422 (2/82)

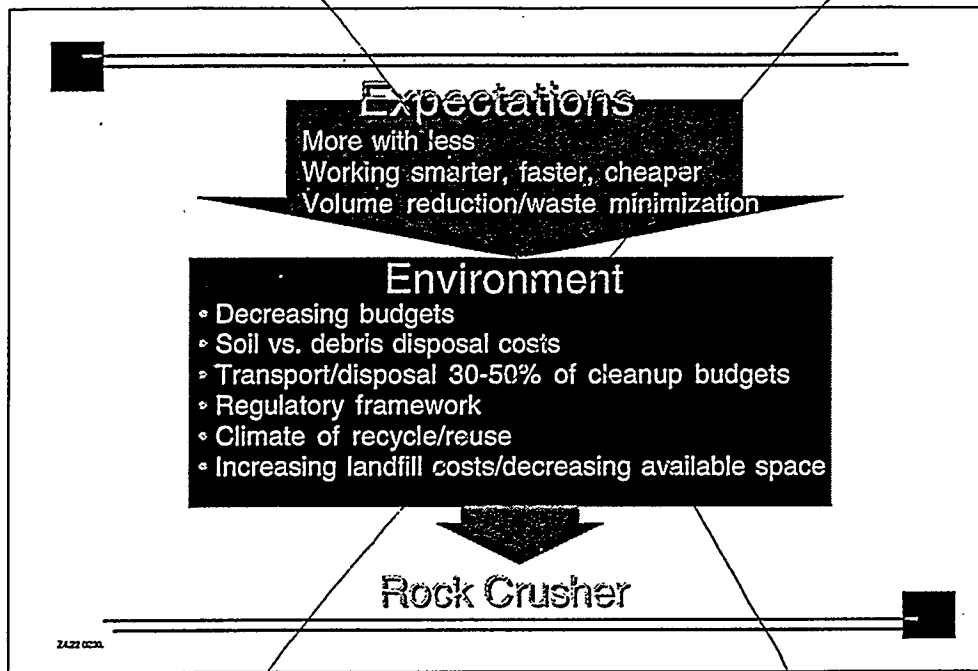
FUSRAP

46 Sites in 14 States

23 Cleaned Up



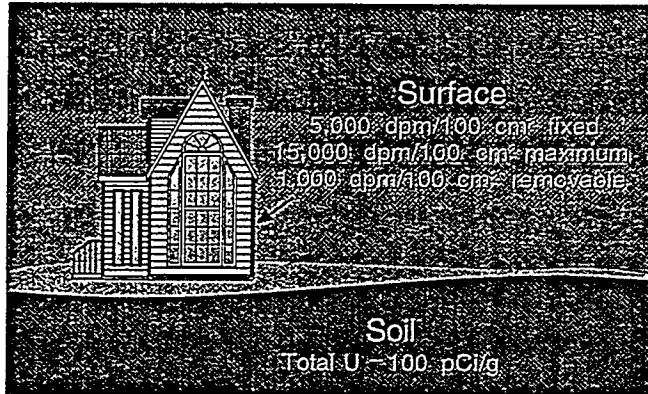
Expectations



Regulatory Issues

Regulatory Issues

- DOE Order 5400.5

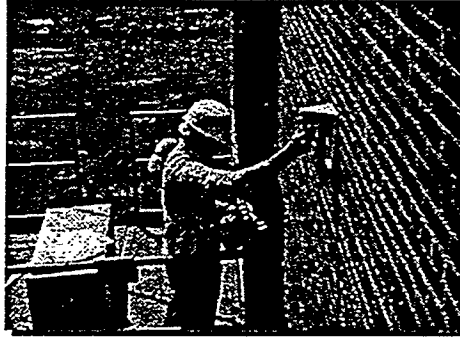


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Regulatory Issues

Regulatory Issues

- DOE Order 5400.5
- Surface criteria

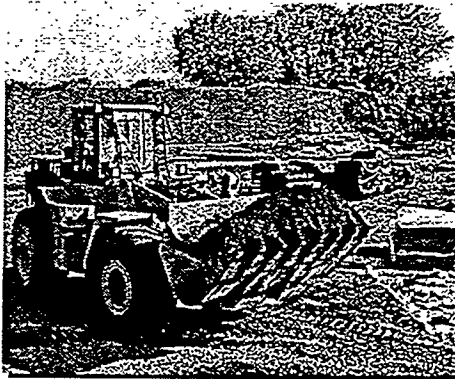


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Regulatory Issues

Regulatory Issues

- DOE Order 5400.5
- Surface criteria
- Volumetric criteria

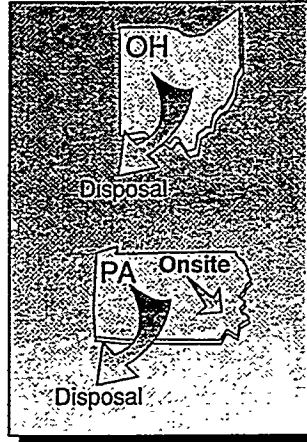


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Regulatory Issues

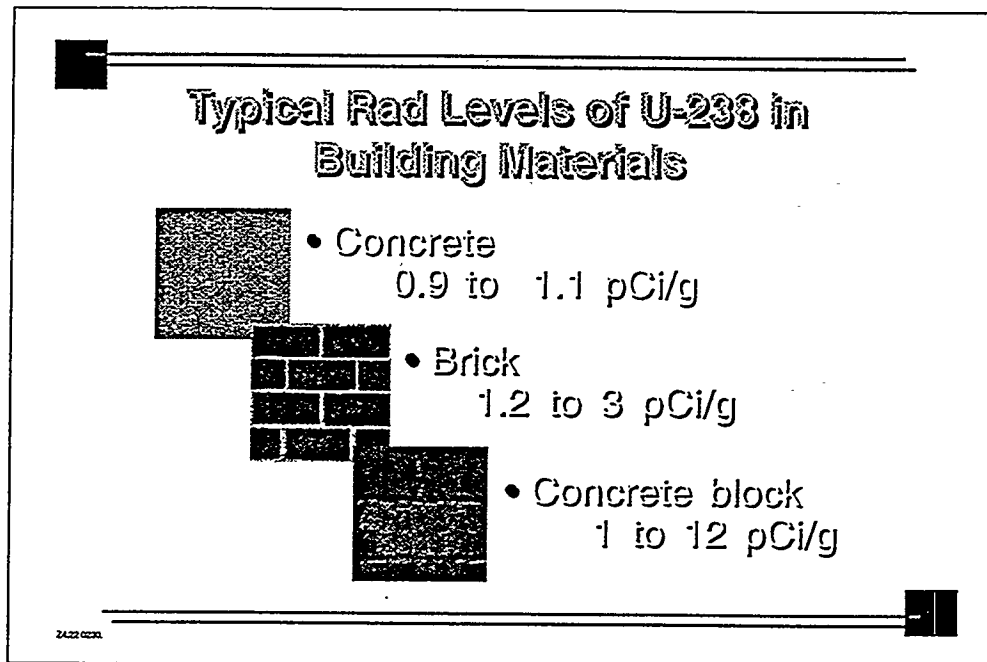
Regulatory Issues

- DOE Order 5400.5
- Surface criteria
- Volumetric criteria
- State requirements

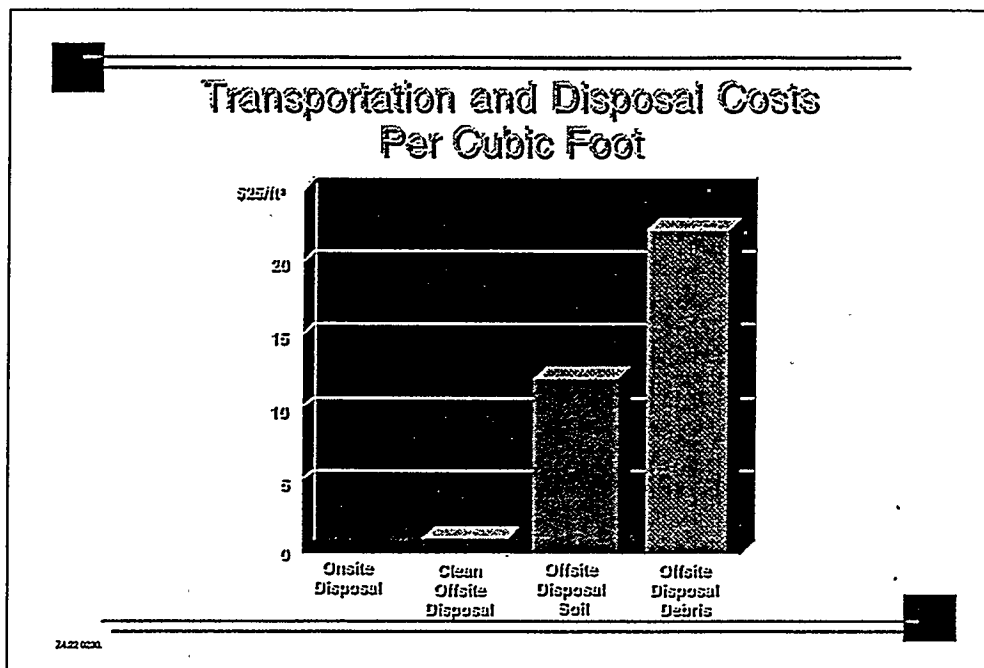


2422 0220

Typical Rad Levels of U-238 in Building Materials



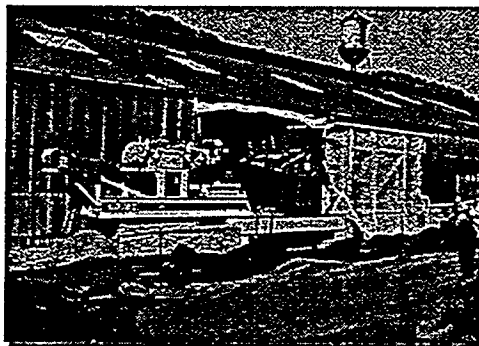
Transportation and Disposal Costs Per Cubic Foot



Aliquippa

Aliquippa

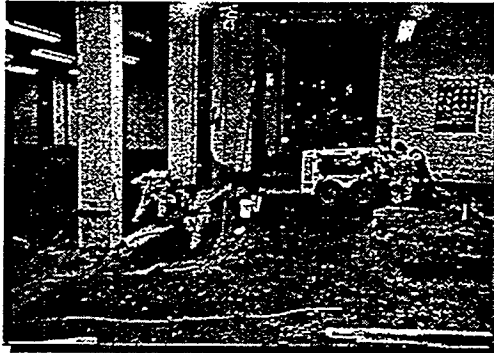
- 500 yd³
- Cleanup criteria:
50 pCi/g U-238
- Crushed material:
~10 pCi/g U-238
- Savings \$304,000



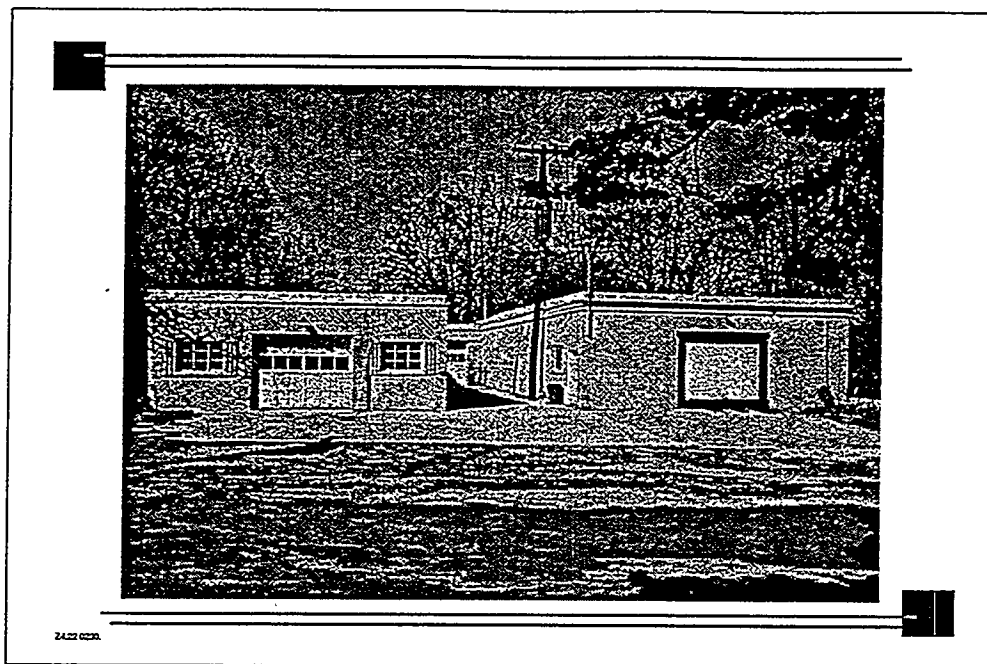
2422 0020

C.H. Schnoor

- 41 yd³
- Cleanup criteria:
50 pCi/g U-238
- Crushed material:
~8 pCi/g U-238
- Savings \$24,100



2422 (03)



Alba Craft

Alba Craft

- 500 yd³
- Cleanup criteria:
35 pCi/g total U
- Crushed material:
~3 pCi/g total U
- Savings \$111,000

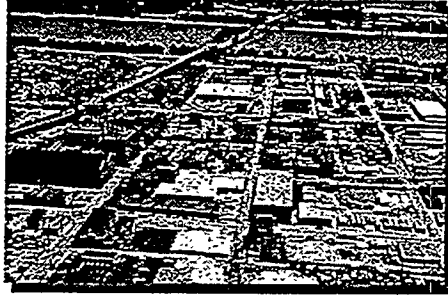


2422 0020

St. Louis Downtown Site (Plant 10)

St. Louis Downtown Site (Plant 10)

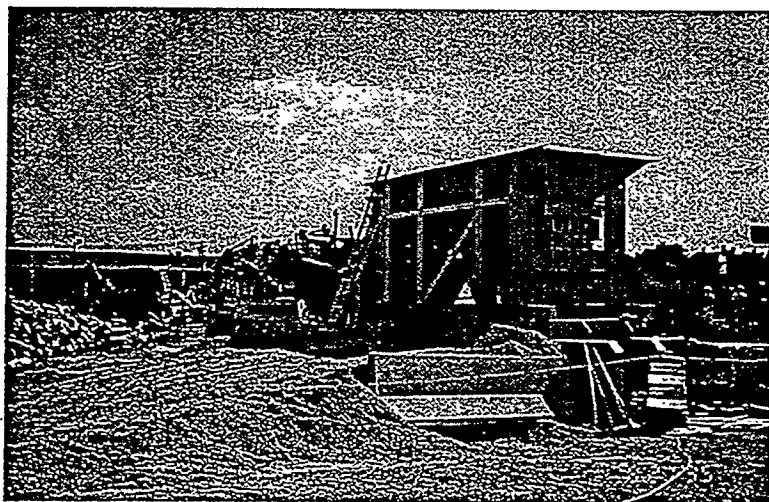
- 1500 yd³
- Cleanup criteria:
50 pCi/g U-238
- Crushed material:
3.1 pCi/g total U-238
- Savings \$784,000



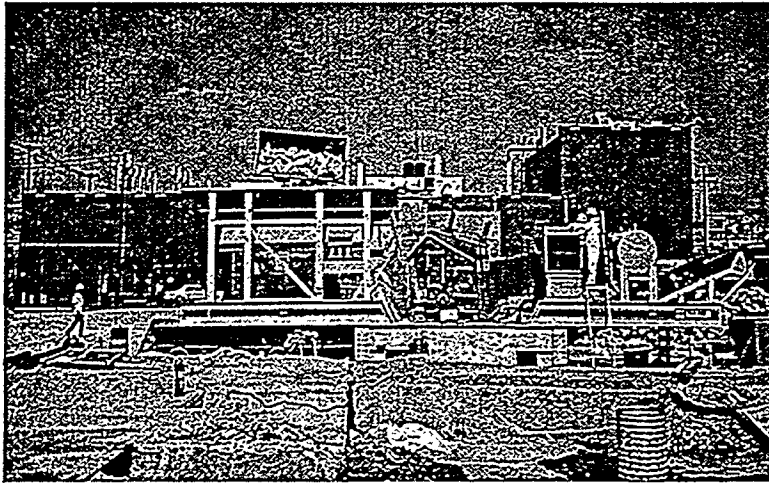
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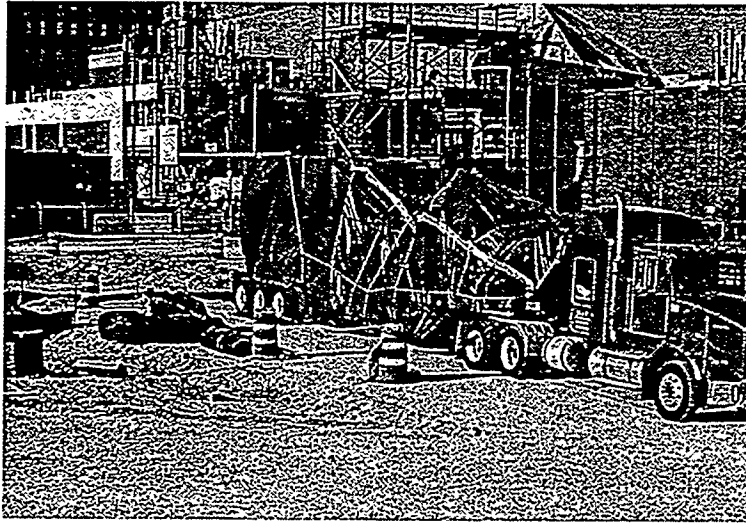
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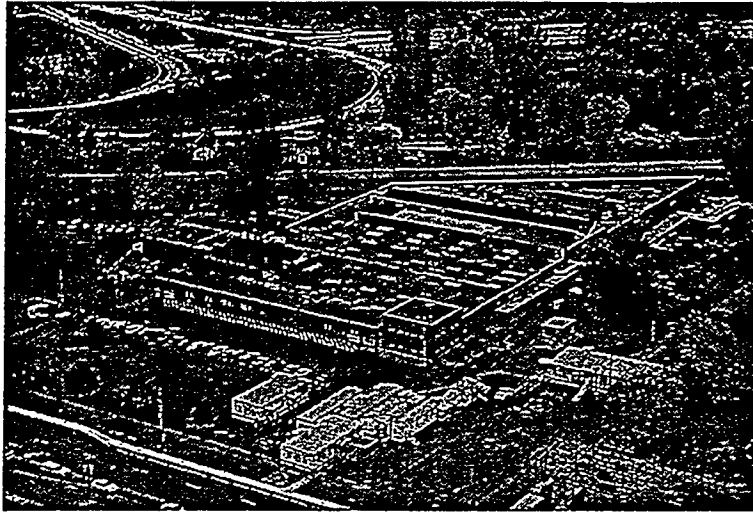
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2A22 CCR



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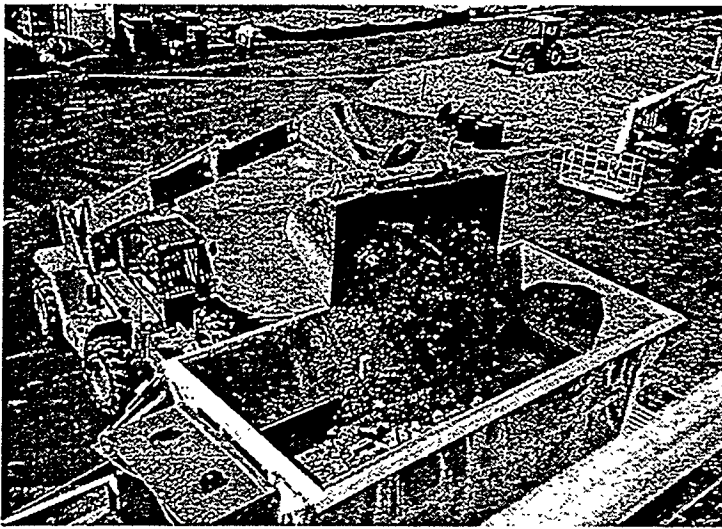
Colonie

Colonie

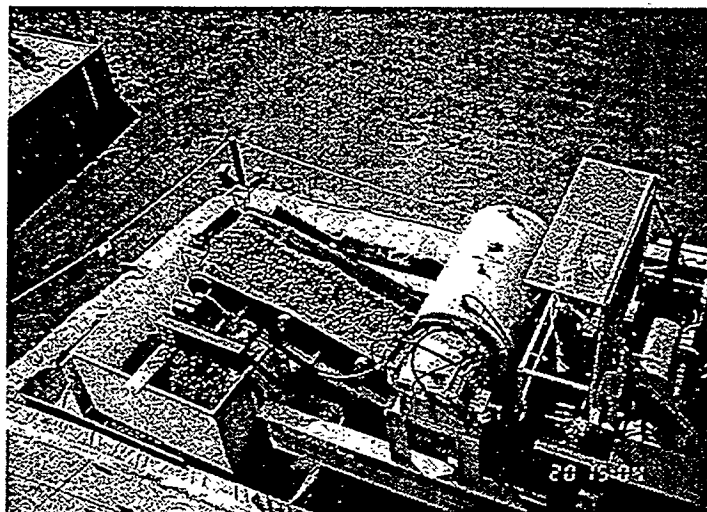
- 3000 yd³
- Cleanup criteria:
35 pCi/g U-238
5 pCi/g RA-226 &
TH-232
- Crushed material:
~29.0 pCi/g total U-238
- Savings \$2,250,000



24.02.0000



2422 0020



20 15-08

Summary

Summary

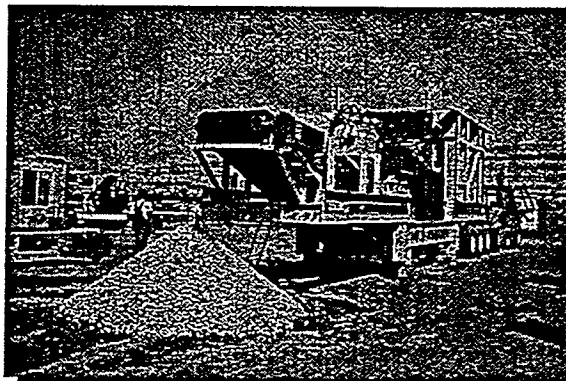
- 6 sites
- Transportation and disposal costs avoided:
 - Aliquippa \$304,000
 - Schnoor \$24,100
 - Alba Craft \$111,000
 - St. Louis Downtown \$734,000
 - Colonie \$2,250,000
- Total saved at these sites — \$3,473,100

2422 0220

Crusher Specifications

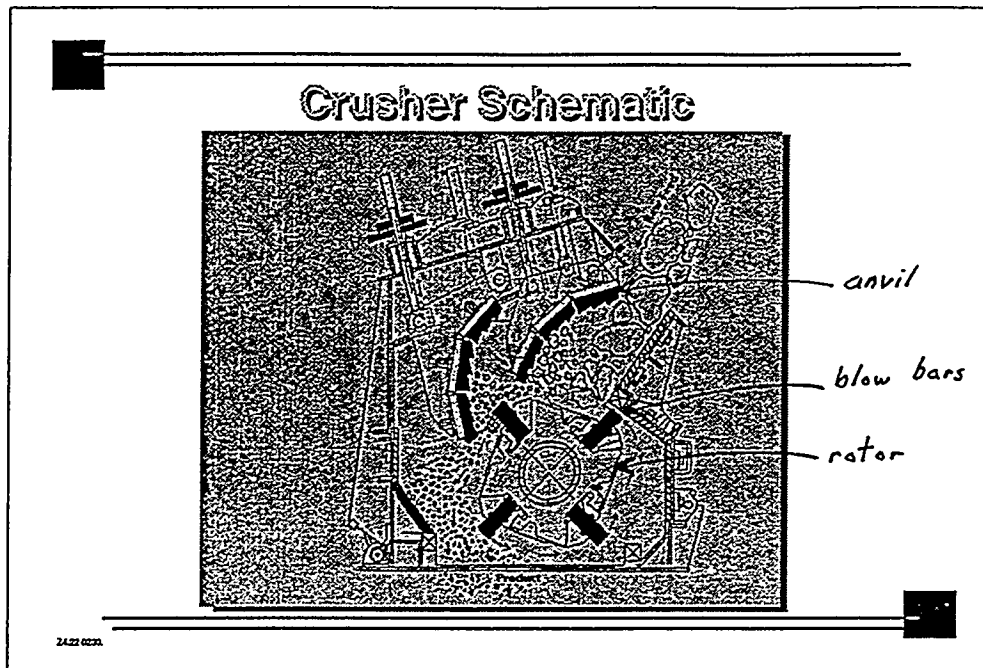
Crusher Specifications

- 150 ton/hr capacity
- 50 ft x 8.5 ft x 14 ft
- \$230,000 cost



2422 CCR

Crusher Schematic



- Anvils adjust to vary size of crushed material
- Anvils & blow bars wear and must be replaced
- Blow bars wear quicker and can be rotated

Crusher Benefits



Crusher Benefits

- Apply volumetric release criteria
- Disposal cost savings — soil vs. debris
- Onsite disposal allows transportation and disposal savings
- Discourages inappropriate material reuse

24.02 0030



Session 5 - Association of Radioactive Metal Recyclers (ARMR)

SRS Stainless Steel Beneficial Reuse Program

W. L. Boettinger
Westinghouse Savannah River Company

SRS Stainless Steel Beneficial Reuse Program
W. L. Boettinger
WSRC, Savannah River Site

Background

The US Department of Energy's (DOE) Savannah River Site (SRS) has thousands of tons of stainless steel radioactive scrap metal (RSM). Much of the metal is volumetrically contaminated. There is no "de minimis" free release level for volumetric material, and therefore no way to recycle the metal into the normal commercial market. If declared waste, the metal would qualify as low level radioactive waste (LLW) and ultimately be dispositioned through shallow land buried at a cost of millions of dollars. The metal however could be recycled in a "controlled release" manner, in the form of containers to hold other types of radioactive waste. This form of recycle is generally referred to as "Beneficial Reuse". Beneficial reuse reduces the amount of disposal space needed and reduces the need for virgin containers which would themselves become contaminated.

Stainless steel is particularly suited for long term storage because of its resistance to corrosion. The following table depicts the durability in a normal environment of three types of steel drums (carbon steel, galvanized steel, and stainless steel).

Durability of 55 gallon drums			
drum type	carbon steel	galvanized steel	stainless steel
expected life	1 to 2 decades	2 to 4 decades	over a century

To assess the practicality of stainless steel RSM recycle the SRS Beneficial Reuse Program began a demonstration in 1994, funded by the DOE Office of Science and Technology. Two private industrial companies were contracted to receive stainless steel RSM, melt the metal, cast it into ingots, roll the ingots into sheet metal, and fabricate products from the sheet metal. The companies are: Carolina Metals Inc. of Barnwell, SC, and Manufacturing Sciences Corporation of Oak Ridge, TN. Two types of products were initially selected for fabrication: boxes having a 100 cubic foot volume (designated RD-100) and 55 gallon drums (designated RD-55). After surveying a number of DOE sites it was determined that 85 gallon drums (designated RD-85), often referred to as "overpacks", would also be fabricated as part of the demonstration.

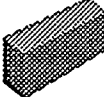
In early 1996 as the fabrication of the prototype boxes and drums proceeded an opportunity emerged to make an additional product. The Transportable Vitrification System (TVS), a separate project, needed stainless steel containers for its vitrified waste stream. Recycled stainless steel from SRS and Los Alamos National Laboratory was

used to make the TVS containers. Analyses show that when the avoided RSM disposal costs are taken into account, the TVS containers made from the recycled metal are more economical than commercially procured containers.

Another opportunity emerged in 1996. SRS is in need of 1000 to 3000 heavy water (D₂O) storage drums. The D₂O drums are stainless steel and could be made from recycled stainless steel RSM. To demonstrate the capability to fabricate D₂O drums from recycled RSM an order for 100 units was placed. Delivery of these drums will be in mid 1997. Cost estimates show an advantage to using recycled RSM for the fabrication of D₂O drums.

Strategy for Success

The following figure displays product progression through late 1996. Programmatic funding provided 100 per cent of the cost for the first three items produced (RD-100, RD-55, RD-85). However starting with the TVS containers, programmatic funding was leveraged with funding from other sources to pay total production costs.

Product Progression			
<u>Item</u>		<u>Status</u>	<u>Funding Source</u>
RD-100		Fabrication complete	Programmatic
RD-55 (UN1A2 Certified)		Fabrication complete	Programmatic
RD-85 (UN1A2 Certified)		Fabrication underway	Programmatic
RD-TVS		Initial Shipment made	Multiple
RD-D ₂ O		Activity commenced	Multiple

A cornerstone of the strategy for future activities will be to continue the practice of leveraging by obtaining multiple sourced funding within the DOE funding structure. The funding should come from those organizations which benefit from the program. In general there will be three benefactors:

(1) the RSM generator who does not have to pay to dispose of the scrap (which would otherwise be declared waste),

(2) the disposal facility "owner" who does not have to dispose of the RSM, thereby extending the life of the present facility, and

(3) the user of the product.

Other elements of the strategy for success will be to move forward moderately, taking modest incremental steps, and making products which promise a potential for being competitive with commercially produced equivalents. Credit for the avoided RSM disposal cost will be included in cost comparisons. Containers for high level waste from the SRS Defense Waste Processing Facility and containers for spent fuel are contemplated in the future.

Distribution and utilization of products

A requirement of the program is to provide products to other DOE sites. The following table shows a listing of the participating site and the approximate number of products each site will receive. A completion of the initial product fabrication and delivery to other sites will occur in 1996 and 1997.

Site	RD-100	RD-55	RD-85	RD-TVS	RD-D ₂ O
Savannah River	11	157	121		100
Idaho National Eng. Lab			126		
Los Alamos National Lab		81	45		
Hanford Site		81	45		
Oak Ridge National Lab	5	81	63	40	
Total	16	400	400	40	100

SRS has already used a number of products fabricated in the program.

- The first product to be received was an RD-100. The box was filled with over 4000 curies of tritiated mixed waste, welded shut, and is currently stored at the site's mixed waste storage building.
- A shipment of RD-85's was used to overpack deteriorating carbon steel drums containing HEU low level waste.
- The first RD-55 utilization will be for the containment of transuranic waste from one of the site's processing facilities.

An additional activity initiated in 1996 is the recycling of a contaminated 10 ton reactor pump. The pump will be disassembled, and the stainless steel portion melted and cast into ingots for future use in the program.

Container costs compared to commercially available products

Even at low production rates the recycle of stainless steel RSM can be competitive with similar virgin metal products when the savings from the avoided RSM disposal is taken into account. For example, the following table provides a summary avoided cost calculation for the fabricated TVS containers. Notice that the actual container fabrication costs are higher when recycled RSM is utilized. However the Department saves as a whole since the RSM disposal cost is avoided. This results in a cost savings of over \$1000 per TVS container.

TVS Container Avoided Cost Comparison (assuming free RSM*)

<u>Item</u>	<u>Fabrication from Recycled RSM</u>	<u>Commercially available Fabrication</u>
Fabrication cost	\$2,485 per container**	\$2,200 per container
Disposal of radioactive scrap metal		\$1,428 per container ***
Transportation	\$ 63 per container	
Waste disposal (LLW)	\$ 14 per container	
Subtotal	\$2,562 per container	\$3,628 per container
Savings	\$1,066 per container	

* Accumulation & preparation of RSM is the same for both alternatives

** Actual Firm Fixed Contract Price

*** @ \$50 per cu. ft. crushed drums disposal in E-Area Vaults

Barriers to full implementation

There are a number of barriers which must be overcome before recycle can be fully implemented. Two of these are briefly described in the following paragraph.

First, under the current method of activity funding by the Department, the user of recycled products can not always take credit for the avoided disposal savings and is therefore financially motivated to procure non-recycled products (even though the Department as a whole would benefit from the procurement of the recycled product). Due to the manner in which funding is appropriated this is not a simple issue to resolve. However, progress is being made in addressing this issue through the initiation of "Charge-Back" and "Set-Aside" programs.

Second, there is a difficulty in transitioning from “developed technology” to “business reality”. Once technical feasibility is proven the developing organization tends to take the position that “the technology is fully developed”, while the potential product user organizations take the position that the products can not be afforded because they are not yet “cost competitive” with the commercial market place. The net result is that technical feasibility is proven but commercialization is unattainable. This is a traditional economies of scale dilemma.

To be truly commercialized will require the assurance of a certain level of initial sustaining through-put.

Availability of stainless steel RSM

Sufficient quantities of RSM can be found through out the DOE sites. A substantial portion of the readily available RSM at SRS is contained Process Water heat exchangers. Each heat exchanger weighs about 100 tons, 95% of which is Type 304 stainless steel. There a total of 94 such heat exchangers. The following table depicts the number of 55-gallon drums which could be fabricated yearly from the metal in the heat exchangers and the time it would take before the supply is exhausted.

	Five scrap heat exchangers recycled per year	Ten scrap heat exchangers recycled per year
Tons of stainless steel recycled	500 tons per year	1000 tons per year
Number of drums fabricated from the recycled metal	12,000 drums per year	24,000 drums per year
Time before the heat exchanger supply is exhausted	18 years	9 years

Conclusion

The DOE is well on its way in beneficially reusing its contaminated stainless steel scrap. This initiative will provide a fiscal as well as environmentally attuned reward for the nation.

**Results of Chemical Decontamination
of DOE's Uranium-Enrichment Scrap Metal**

Robert G. Levesque
CORPEX Technologies, Inc.

BENEFICIAL REUSE' 96

Results of Chemical Decontamination of DOE's Uranium-Enrichment Scrap Metal

The CORPEX® Nuclear Decontamination Processes were used to decontaminate representative specimens obtained from the existing DOE scrap-metal piles located at the gaseous diffusion plants. The specimens selected by DOE to undergo decontamination were obtained from K-25 Facility in Oak Ridge, TN and PORTS Facility in Piketon, OH and were:

- Nickel-plated carbon steel pipe
- Aluminum baffle material
- Aluminum compressor blades
- Aluminum nut/bolt assembly
- Monel pipe flange
- Monel bellows
- Monel thermal-well
- Copper pipe
- Bronze elbow
- Stainless-steel threaded fitting.

The contaminated surfaces were radiologically and metallurgical characterized by DOE before decontamination was initiated.

In September 1995, under contract to Lockheed Martin Energy Systems, MELE Associates, Inc. performed the chemical decontamination of the specimens at PORT, using CORPEX Technologies Inc. provided chemical decontamination reagents and process logic. These chemical reagents are user and environmentally friendly. The specimens were decontaminated in a fume hood, for contamination control, using MELE Associates, Inc. generated plans and procedures. Lockheed Martin Energy Systems provided project radiological and industrial-safety oversight.

This paper presents the decontamination results for the scrap-metal demonstration which proved that significant amounts of the DOE scrap-metal could be economically released for beneficial reuse.

BENEFICIAL REUSE '96

Results of Chemical Decontamination of Rockwell International's Waste Lead

The CORPEX® Nuclear Decontamination Process was selected to be used to chemically decontaminate radiologically contaminated lead which had been used as shielding over an extensive period by Rockwell International. This lead had been used on various projects and was contaminated with various beta, gamma, and alpha emitting isotopes. Since Rockwell International's decommissioning group had no further need of it, an economic means for disposing of the contaminated lead was sought. In the spring of 1995, Rockwell International contracted with the Frank W. Hake Associates of Memphis, TN to decontaminate 226,000 pounds of lead in the form of lead shield block, plate, and brick and 8,000 pounds of lead shot. Frank W. Hake Associates subcontracted the actual decontamination to ARC. ARC, a licensed applicator of CORPEX Technologies Inc., decided to decontaminate the larger components that did not have complex surface geometry using CO₂ blasting technology and for lead brick, lead shot, and components having complex surface geometry to utilize CORPEX®-982.

CORPEX®-982 is an aqueous based chelant that performs well at room temperature. Since the reagent does not remove base metal, the used reagent contains only the lead removed as oxides and the radioactive metallic contaminants. The used CORPEX®-982 is reacted with KMnO₄ at an elevated pH, using CORPEX®-960. The chelant is almost totally oxidized and can be disposed of as a non-chelated waste. During the destruction of the chelant, the heavy metal ions precipitate as metal hydroxides and oxides along with the insoluble MnO₂ produced. The insoluble fraction can be reacted with approved solidification agents (e.g., Portland cement /lime). The resulting solidified waste did not have any hazardous RCRA characteristics and did not contain any RCRA listed constituents, therefore, was disposed of commercially as a non-chelated low-specific radioactive waste (i.e., LSA).

This paper details decontamination results and other parameters which could help owners of radiologically contaminated lead decide if decontamination and beneficial reuse of the lead is a viable option.

Results of Chemical Decontamination of Scrap Metal at the Portsmouth Uranium Enrichment Facility

Abstract

The CORPEX® Nuclear Decontamination Processes were used to decontaminate representative scrap metal specimens obtained from the existing scrap metal piles located at the Department of Energy (DOE) Portsmouth Gaseous Diffusion Plant (PORTS), Piketon, Ohio. In September 1995, under contract to Lockheed Martin Energy Systems, MELE Associates, Inc. performed the on-site decontamination demonstration.

The decontamination demonstration proved that significant amounts of the existing DOE scrap metal can be decontaminated to levels where the scrap metal could be economically released by DOE for beneficial reuse. This simple and environmentally friendly process can be used as an alternative, or in addition to, smelting radiologically contaminated scrap metal.

Introduction

DOE has generated significant quantities of radiologically contaminated scrap metal at several of its uranium enrichment facilities. In the past, attempts to chemically decontaminate this scrap metal was not undertaken for the following reasons:

- The chemical reagents were not user and environmentally friendly.
- The resulting waste stream often had to be classified as a RCRA hazardous waste.
- There was conflicting guidance on what levels of residual contamination were safe.

Since the existing scrap metal represented a significant waste management problem, DOE began looking for ways to manage the waste in a cost effective manner. They determined that a considerable savings could be obtained using smelting technologies to convert the contaminated scrap metal into forms which would allow beneficial reuse as a radioactive metal. Based on an extensive radiological study, DOE has accepted the Nuclear Regulatory Commission guidance on contamination levels for unrestricted use. The scrap metal that exceeds the unconditional release level will be smelted and converted into products for restrictive reuse. During the period DOE was exploring ways to use the scrap metal in a more beneficial manner, CORPEX Technologies Inc. was developing processes that could decontaminate those portions of the scrap metal that were not bulk contaminated (i.e., surface contaminated only). DOE authorized MELE Associates, Inc. to demonstrate the CORPEX® decontamination processes on representative samples of the scrap metal in bench scale tests to be conducted at PORTS. Metal specimens selected by the client to be tested were:

- Nickel-plated carbon steel pipe
- Aluminum baffle material
- Aluminum compressor blades
- Aluminum nut/bolt
- Monel pipe flange
- Monel bellows
- Monel thermal well
- Copper pipe
- Bronze elbow
- Stainless-steel threaded fitting.

Physical and radiological characterization data indicated that the specimens were contaminated with various amounts of uranium fluoride and oxide compounds as well as ⁹⁹Tc.

CORPEX® Nuclear Decontamination Processes

The CORPEX® Nuclear Decontamination Processes are aqueous based chemical agents that have been proven to be effective in removing films (e.g., oil, grease, paint, grime), insoluble salts (e.g., carbonates, sulfates), and corrosion products (e.g., oxides). These processes have been used separately or in combination to achieve excellent decontamination factors on a wide range of substrates:

- Metal alloys
- Concrete
- Soil.

These processes have resulted in the unconditional release of materials similar to those selected for the decontamination demonstration at PORTS, but these processes are not effective on bulk contaminated materials (e.g., neutron activated, smelted-metal alloys, and porous items).

The CORPEX® chelant decontamination reagent, proven so effective in removing heavy metal oxides, is a new molecular structured chelant that CORPEX Technologies Inc. holds a United States patent on. This reagent is effective over broad pH and temperature ranges and is unlike other chelants that do not function well at near neutral pH or low temperatures. This chelant is described as a tetrahydrazide of an amino polycarboxylic acid and functions by forming coordination compounds with polyvalent metal ions, thereby dissolving them. After rinsing the used decontamination reagent from the cleaned specimen, the reagent is mineralized (converted to CO₂) using an oxidizing agent (e.g., NaOCl, KMnO₄). The CORPEX® chelant decontamination reagent is governed by an EPA Consent Order (August, 1994), and CORPEX Technologies Inc. allows only its licensed applicators use of the reagent as a means of assuring compliance with the consent order. MELE Associates, Inc. is a licensed applicator of the CORPEX® Nuclear Decontamination Processes.

Decontamination Protocol

CORPEX Technologies Inc. authorized MELE Associates, Inc. to use certain CORPEX® reagents identified for the on-site decontamination demonstration at PORTS:

- CORPEX®-918, an organic degreasing agent
- CORPEX®-921, the patented polydentate chelant
- CORPEX®-945, a reactive metal (e.g., Al, Mg, etc.) decontamination agent
- CORPEX®-960, a powerful oxidizing agent
- CORPEX®-995, a paint stripping agent
- SMEARAWAY®, a loose-surface decontamination agent.

Decontamination Protocol, continued . . .

CORPEX Technologies Inc. provided process logic diagrams to be used by MELE Associates, Inc. at PORTS for the various scrap metal specimens to be tested. These logic diagrams identify the decontamination steps to be employed based upon simple visual inspection to be made by the decontamination operator for the following metal categories:

- Aluminum
- Copper, Monel
- Mixed Steel, Zinc, Magnesium & Tin
- Ferrous alloys.

The process logic diagrams are:

- Figure 1: Aluminum Treatment Procedure
- Figure 2: Copper and Monel Treatment Procedure
- Figure 3: Mixed Steel Treatment Procedure
- Figure 4: Ferrous Alloy Treatment Procedure.

In addition, CORPEX Technologies Inc. specified decontamination operation parameters to be used for the listed process logic diagrams. The specified parameters included:

- Application temperature
- Application time
- Solution agitation requirements
- Volume of rinse water
- Quality of rinse water.

CORPEX Technologies Inc. provided all project support to the applicator, including but not limited to:

- Familiarity with CORPEX® decontamination reagents
- Material Safety Data Sheets
- Chelant destruction procedures
- Verification of chelant destruction procedures
- Hydrazine/Hydrazide field test kit
- Portland cement/lime sludge solidification procedure
- Technical field support
- All project reagents.

ALUMINUM

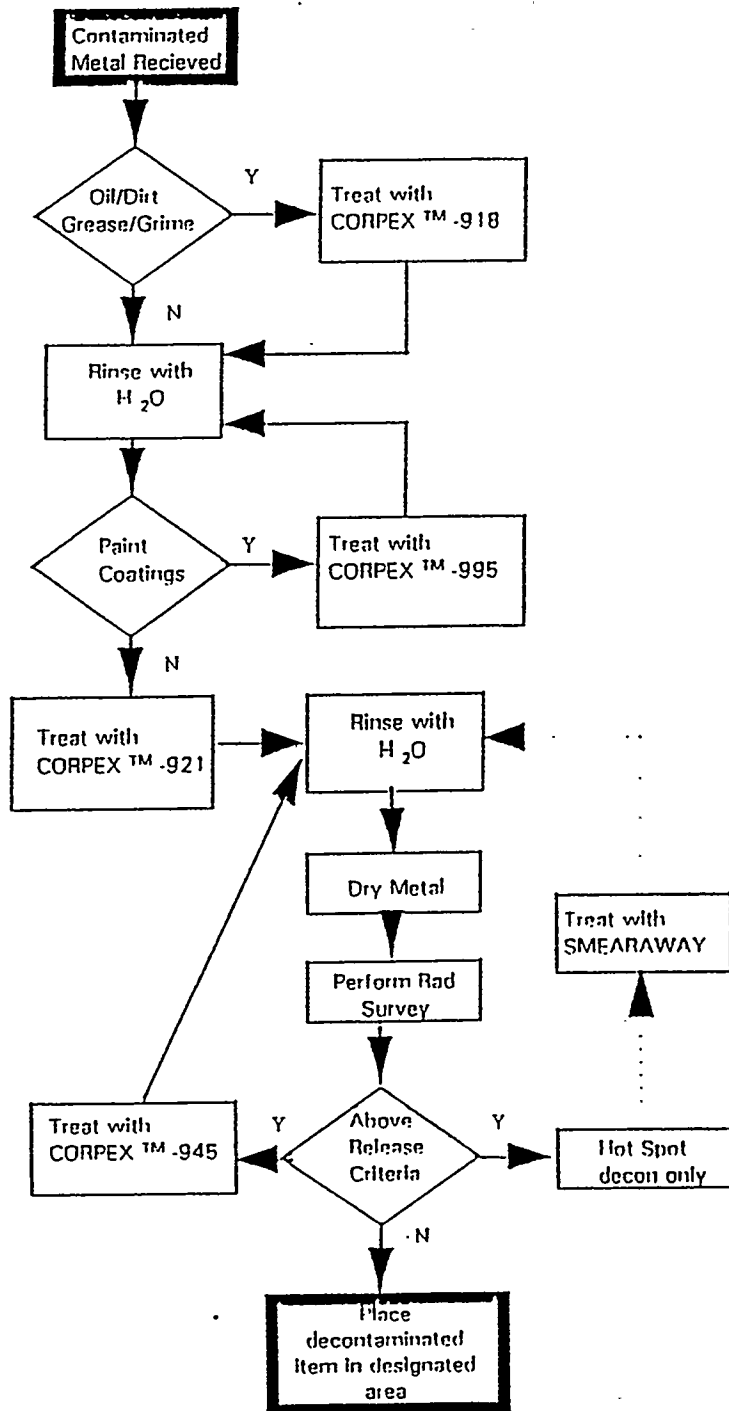


Figure 1: Aluminum Treatment Procedure

COPPER, MONEL

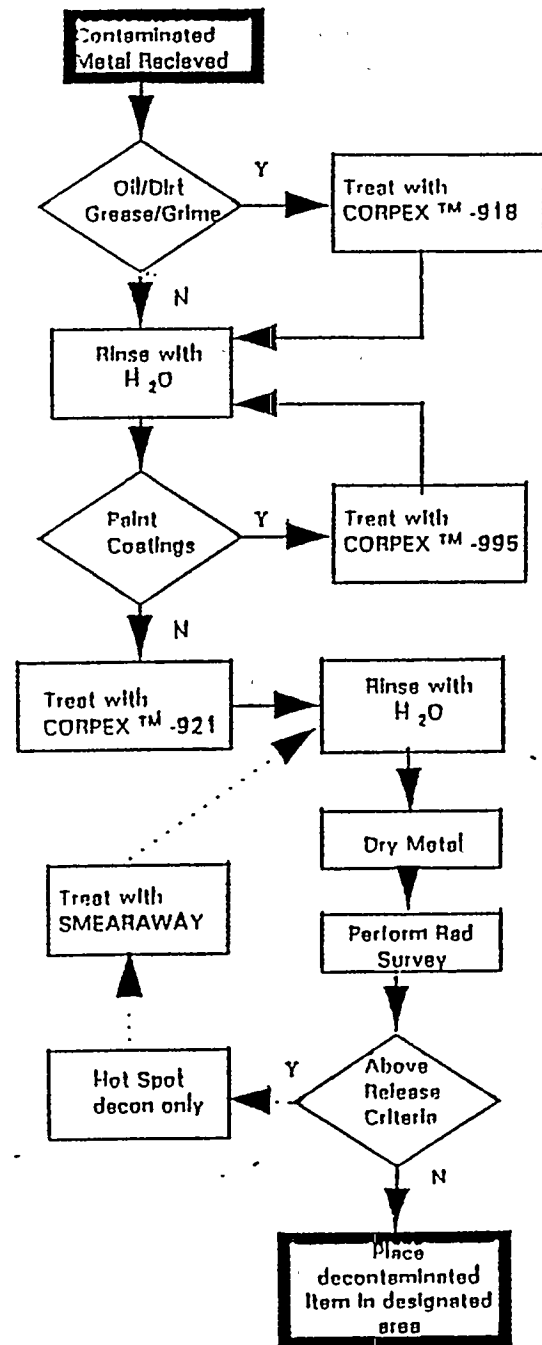


Figure 2: Copper and Monel Treatment Procedure

MIXED STEEL, ZINC, MAGNESIUM & TIN

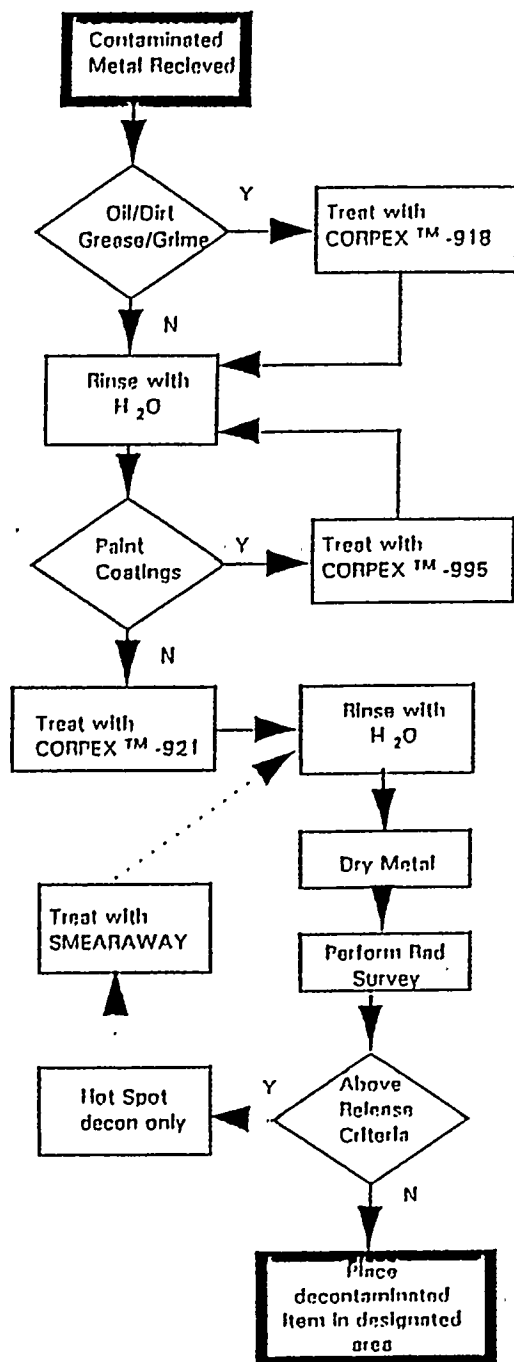


Figure 3 : Mixed Steel Treatment Procedure

FERROUS ALLOYS

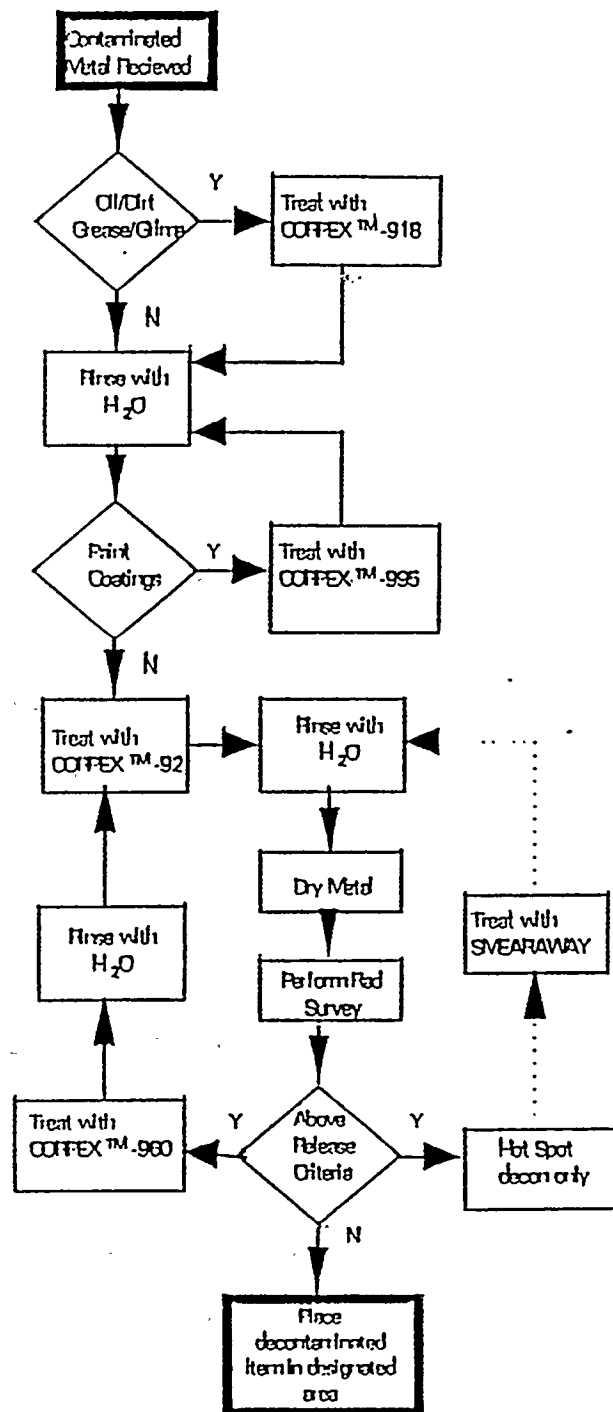


Figure 4 : Ferrous Alloy Treatment Procedure

Decontamination Demonstration

MELE Associates, Inc., as the contractor and applicator, prepared the client required plans and procedures, provided qualified decontamination workers, and provided all project related decontamination equipment. The decontamination equipment included:

- Portable heaters
- Stainless -steel pails
- Electric mixers
- Weighing scales
- Tongs
- Peristaltic pump
- Thermometer
- Decontamination reagents
- Solidification materials.

In addition, the contractor brought reverse electroplating equipment to PORTS to demonstrate CORPEX Technologies Inc. patented technology for removing local fixed decontamination using chelants as electrolytes. But due to time constraints, this technology could not be used in the demonstration.

Lockheed Martin Energy Systems, as the DOE Prime Contractor at PORTS, provided:

- An operating chemical laboratory fume hood and a radiological controlled area
- Project radiological and safety support
- Analytical analysis for the project
- X-ray characterization of the specimens mineral and oxide deposits
- Personal protective clothing for project personnel
- Radiation exposure monitoring services
- Utilities
- Miscellaneous expendable supplies (e.g., tape wipes)
- Packaging for the solidified destroyed chelant waste.

In September, 1995, MELE Associates, Inc. personnel using project procedures demonstrated the CORPEX® Nuclear Decontamination Processes. This included:

- A single decontamination application on 12 specimens
- A partial decontamination application on another specimen
- Destruction of all CORPEX®-921 and subsequent verification of destruction
- Volume reduction of resulting aqueous decontamination wastes
- Solidification of the resulting sludge from the volume reduction operation.

Decontamination Results

Sample Specimen Origin

The sample specimens came from both PORTS and DOE's Oak Ridge K-25 Facility. The samples that came from the Oak Ridge K-25 Facility were comprised of aluminum compressor baffle plates and blades. Similar specimens had previously undergone chemical decontamination, and the acid decontamination procedure was considered unsuccessful.

Sample Description and CORPEX® Decontamination Performance

Sample 01 (PORTS Tag No. 003)

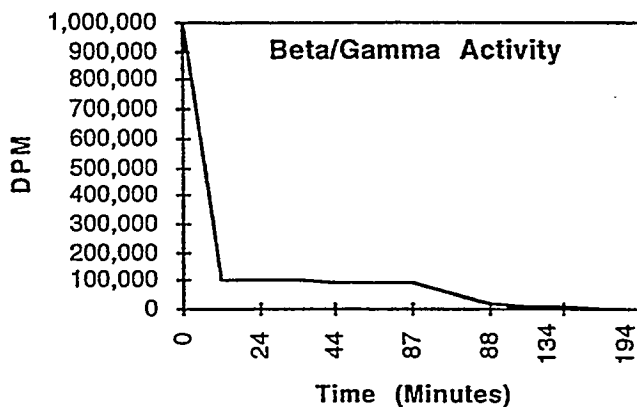
Source: PORTS contaminated scrap metal yard

Description: Nickel Plated Carbon Steel Pipe This sample was cut with a bandsaw on one end and with a torch on the other. It is heavily corroded by what appears to be iron oxide (rust) containing slag on its end. The sample also has a sharp jagged edge with a V-notch cut in its end by the bandsaw.

Dimension: 3.5 in diameter x 5.5 in length x 0.375 in thickness

Process: This specimen was decontaminated exclusively with CORPEX®-921 for about 134 minutes at about 90 °C.

Graphic Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	< 400 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	None	None
Total Beta/Gamma:	1,000,000 DPM/100 cm ²	< 5,000 DPM/100 cm ² *
Removable Beta/Gamma:	None	None

* Except for a local hot spot within the slag.

Sample Description and CORPEX® Decontamination Performance

Sample 02 (ORNL Tag No. 001)

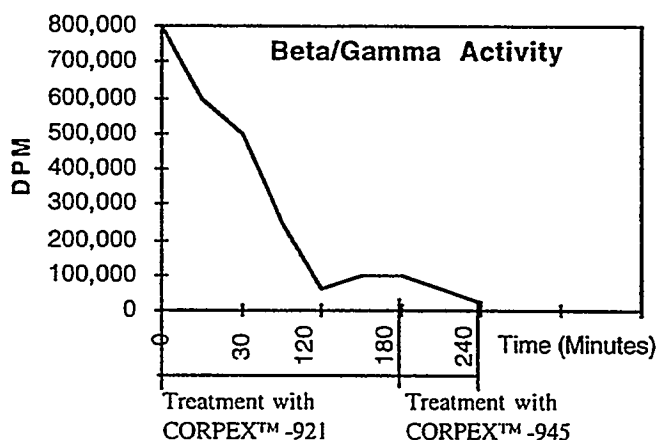
Source: Oak Ridge K-25 Facility

Description: Aluminum Compressor Baffle Plate This specimen had a yellow coloring that was probably yellow-zinc chromate painted over spray used in marking the specimen. One corner of the specimen appears to have been torn away.

Dimension: 3.5 in width x 5.5 in length x 0.375 in thickness

Process: In the first 4 hours, CORPEX®-921 was used at about 90°C. After a steady rate of contamination removal noted during the first 3 hours, a contamination rise was noted in the fourth hour which lead to changing to CORPEX®-945. In the last hour, a gradual contamination reduction was noted. The test on this specimen was terminated in order to reserve time for other specimens.

Graph Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	Initial	Final
Total Alpha:	24,000 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	600 DPM/100 cm ²	None
Total Beta/Gamma:	800,000 DPM/100 cm ²	50,000 DPM/100 cm ²
Removable Beta/Gamma:	7,000 DPM/100 cm ²	None

Sample Description and CORPEX® Decontamination Performance

Sample 03 (ORNL Tag No. 002)

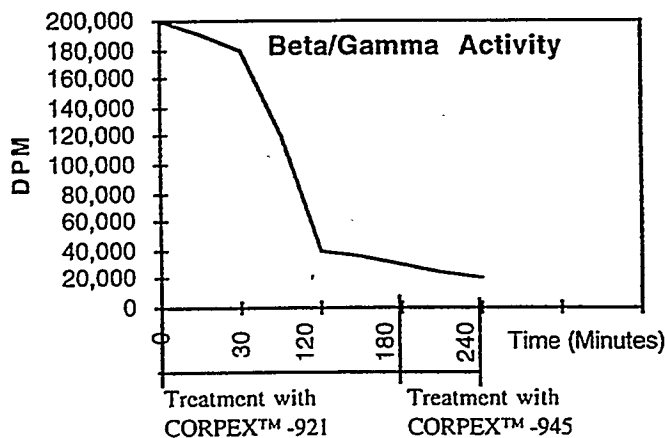
Source: Oak Ridge K-25 Facility

Description: Aluminum Compressor Blade This specimen had a yellow coloring that was probably yellow zinc chromate spray paint used in marking the specimen. One end of the specimen had threads and had the highest contamination levels.

Dimension: 3.5 in width x 5.5 in length x 0.375 in thickness

Process: In the first 4 hours, CORPEX®-921 was used at about 90°C. After a steady rate of contamination removal noted during the first 3 hours, a plateau was reached in the fourth hour that lead to changing to CORPEX®-945. In the last hour, a gradual contamination reduction was noted. The test on this specimen was terminated in order to reserve time for other specimens.

Graph Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	2,000 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	None	None
Total Beta/Gamma:	200,000 DPM/100 cm ²	25,000 DPM/100 cm ²
Removable Beta/Gamma:	840 DPM/100 cm ²	None

Sample Description and CORPEX® Decontamination Performance

Sample 05 (PORTS Tag No. 13/14)

Source: PORTS contaminated scrap metal yard

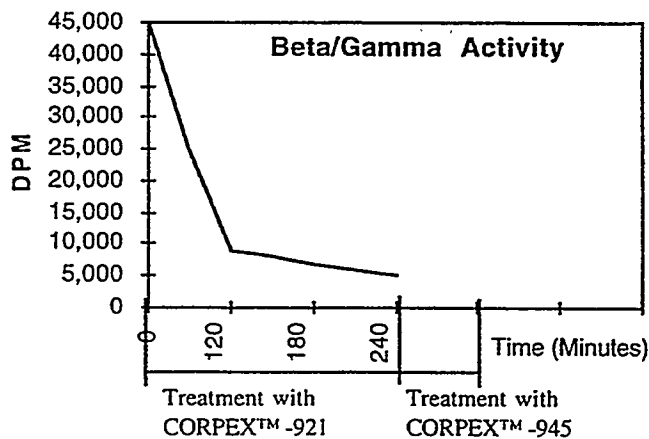
Description: Aluminum Nut and Bolt No other feature was considered remarkable.

Dimension: Nut: 0.75 in thickness x 2 in diameter

Washer: 0.0625 in thickness x 2 in diameter

Process: CORPEX®-945 was used at about 90°C for about 0.5 hours. At this point, the decontamination was terminated because the project criteria had been achieved.

Graphic Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	< 400 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	None	None
Total Beta/Gamma:	5,000 DPM/100 cm ²	< 5,000 DPM/100 cm ²
Removable Beta/Gamma:	None	None

Sample Description and CORPEX® Decontamination Performance

Sample 04 (ORNL Tag No. 003)

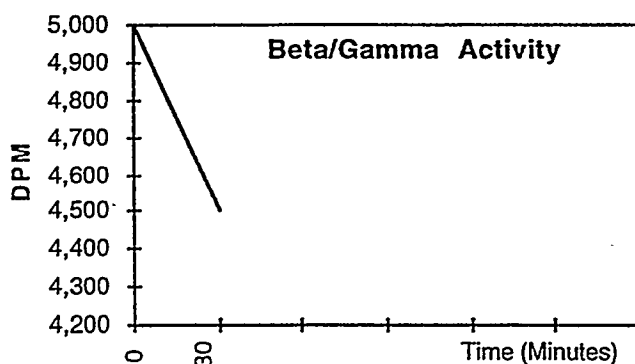
Source: Oak Ridge K-25 Facility

Description: Aluminum Compressor Blade This specimen had a yellow coloring that was probably yellow zinc chromate spray paint used to mark the specimen. One end of the blade contains a bolted portion with no threads.

Dimension: 4 in width x 5.75 in length x 0.25 in to 0.375 in thickness

Process: This specimen was decontaminated with CORPEX®-921 and CORPEX®-945. During the third hour of cleaning using CORPEX®-921 at about 90°C, a significant decrease in the rate of contamination removal was noted. The decontamination reagent was changed over to CORPEX®-945 at 95°C in the last hour in an attempt to improve the contamination removal rate.

Graphic Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	< 400 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	None	None
Total Beta/Gamma:	45,000 DPM/100 cm ²	< 5,000 DPM/100 cm ²
Removable Beta/Gamma:	None	None

Sample Description and CORPEX® Decontamination Performance

Sample 06 (PORTS Tag No. 007)

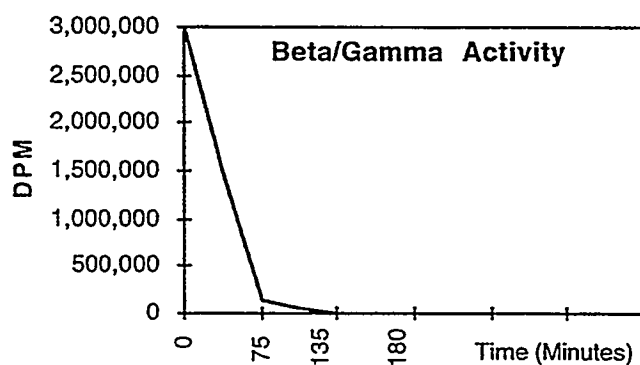
Source: PORTS contaminated scrap metal yard

Description: Monel Flange with a Welded Brass/Copper Pipe Section This specimen had significant verdigris on the inner surface in the weld area. Gray paint and marker writings were present on the outer surfaces.

Dimension: 6 in diameter x 2.75 in height

Process: The specimen was treated with CORPEX®-921 at about 90°C for about 3 hours. At this point, the decontamination was terminated because the project criteria had been achieved.

Graphic Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	8,000 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	1,200 DPM/100 cm ²	None
Total Beta/Gamma:	3,000,000 DPM/100 cm ²	< 5,000 DPM/100 cm ²
Removable Beta/Gamma:	4,200 DPM/100 cm ²	None

Sample Description and CORPEX® Decontamination Performance

Sample 07 (PORTS Tag No. 002)

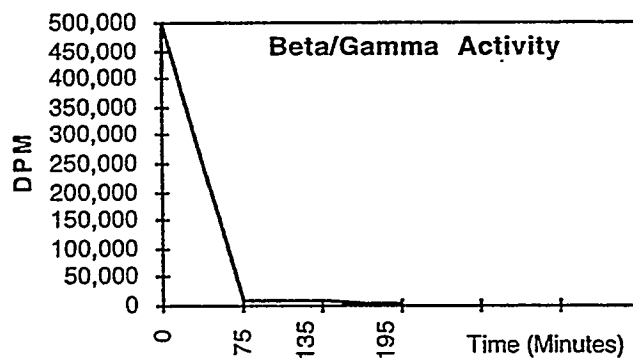
Source: PORTS contaminated scrap metal yard

Description: Monel Bellows Section This specimen had mild corrosion on the outer and inner surfaces, as well as tape residue on the outer surface. A V-notch had been cut from the bellow's section that resulted in rough and rolled edges.

Dimension: 4 in diameter x 2.25 in height x 0.5 in thickness

Process: The specimen was treated with CORPEX®-921 at about 90°C for about 2.15 hours. At this point, the decontamination was terminated because the project criteria had been achieved.

Graphic Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	< 400 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	None	None
Total Beta/Gamma:	500,000 DPM/100 cm ²	< 5,000 DPM/100 cm ² *
Removable Beta/Gamma:	None	None

* Specimen was not released since there was inaccessible areas which could not be monitored.

Sample Description and CORPEX® Decontamination Performance

Sample 08 (PORTS Tag No. 015)

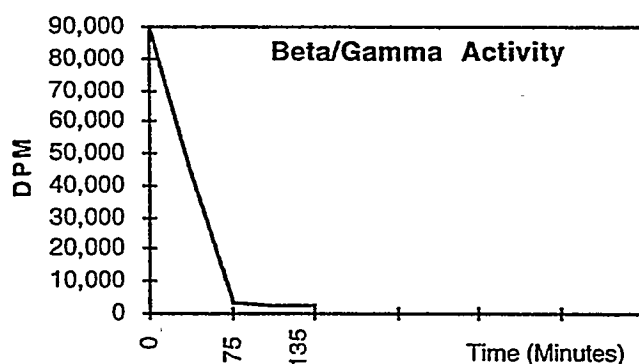
Source: PORTS contaminated scrap metal yard

Description: Monel Thermal-well Section This specimen had mild corrosion on the outer and inner surfaces.

Dimension: 5 in length x 0.625 in diameter

Process: The specimen was treated with CORPEX®-921 at about 90°C for about 2.15 hours. At this point, the decontamination was terminated because the project criteria had been achieved.

Graphic Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	< 400 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	None	None
Total Beta/Gamma:	90,000 DPM/100 cm ²	< 5,000 DPM/100 cm ²
Removable Beta/Gamma:	None	None

Sample Description and CORPEX® Decontamination Performance

Sample 09/10 (PORTS Tag No. 006)

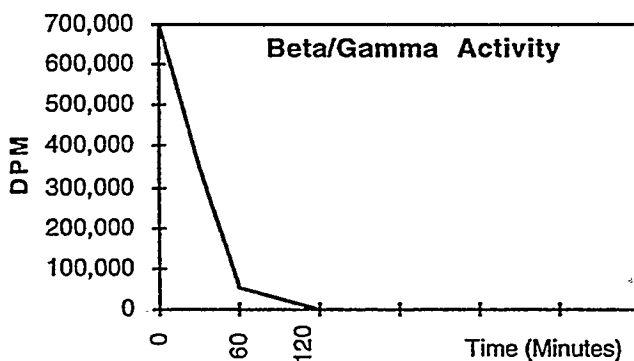
Source: PORTS contaminated scrap metal yard

Description: Two Copper Pipe Sections These specimens had mild corrosion on the outer and inner surfaces. An oily residue was present on the inner and outer surfaces. The ends of the specimens are rough.

Dimension: 0.75 in diameter x 5 in lengths

Process: The specimens were treated with CORPEX®-921 at about 90°C for about 2 hours. At this point, the decontamination was terminated because the project criteria had been achieved.

Graphic Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	160,000 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	7,000 DPM/100 cm ²	None
Total Beta/Gamma:	700,000 DPM/100 cm ²	< 5,000 DPM/100 cm ²
Removable Beta/Gamma:	4,000 DPM/100 cm ²	None

Sample Description and CORPEX® Decontamination Performance

Sample 11/12 (PORTS Tag No. 005)

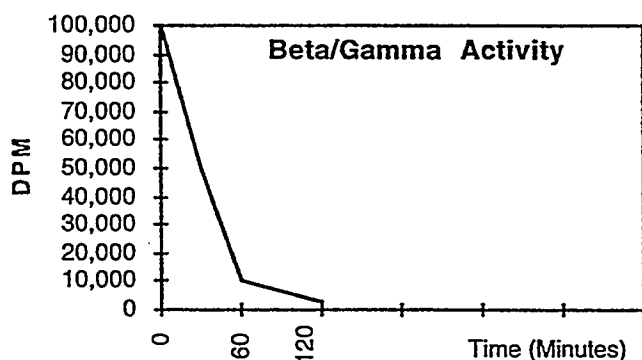
Source: PORTS contaminated scrap metal yard

Description: Two Bronze Elbow Sections These specimens had mild corrosion on the outer and inner surfaces. Red paint was present on the outer surfaces of both pieces. Engraving was present on both pieces as identification markings.

Dimension: 1.25 in diameter x 2.5 in overall length

Process: The specimen was treated with CORPEX®-921 at about 90°C for about 2 hours. At this point, the decontamination was terminated because the project criteria had been achieved.

Graphic Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	160,000 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	2,000 DPM/100 cm ²	None
Total Beta/Gamma:	100,000 DPM/100 cm ²	< 5,000 DPM/100 cm ²
Removable Beta/Gamma:	1,400 DPM/100 cm ²	None

Sample Description and CORPEX® Decontamination Performance

Sample 13 (PORTS Tag No. 014)

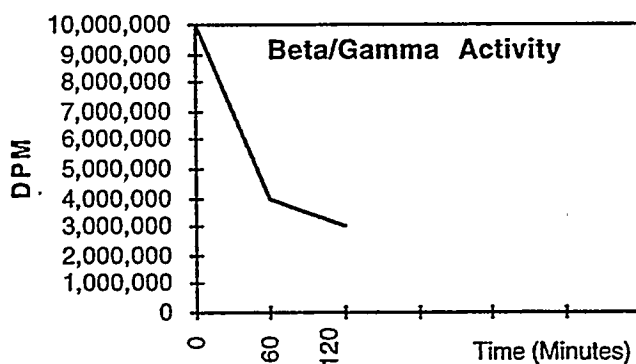
Source: PORTS contaminated scrap metal yard

Description: Brass Sealing Ring Section This specimen had mild corrosion on the outer and inner surfaces. The outer surface of the specimen had an oily residue and ink markings, as well as engravings used as identification markings. Hardened joint sealing compound was embedded in the threads of the inner surface.

Dimension: 5.25 in length x 2 in width x 0.375 in thickness

Process: The specimen was treated with CORPEX®-921 at about 90°C for about 2 hours. At this point, the planned use of CORPEX®-960 to remove the sealing compound in the threads and a final CORPEX®-921 to decontaminate the now exposed threaded surface was abandoned because of project time constraints.

Graphic Plot of Activity vs. Decontamination Time:



PORTS Radiological Characterization Data:

	<u>Initial</u>	<u>Final</u>
Total Alpha:	800 DPM/100 cm ²	< 400 DPM/100 cm ²
Removable Alpha:	None	None
Total Beta/Gamma:	10,000,000 DPM/100 cm ²	3,000,000 DPM/100 cm ² *
Removable Beta/Gamma:	7,000 DPM/100 cm ²	10,000 DPM/100 cm ²

* The Beta/Gamma reading was in the threaded area and would most likely been removed with the sealing compound.

Summary of Results

The following summary table gives the fixed beta/gamma measurements of the specimens that were decontaminated in the demonstration project. For details, see the individual specimen data sheets.

Ports Decontamination Results

Beta/Gamma Contamination
(DPM/100 square cm.)

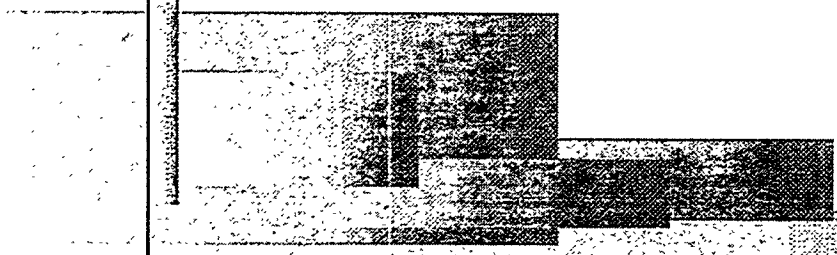
Specimen No.	Material	CORPEX Reagent No.	Treatment Time (hours)	Initial	Final
1	Ni plated Fe	921	3.25	1,000,000	≤ MDA
2	Al	921/945	3.0/1.0	800,000	50,000
3	Al	921/945	3.0/1.0	200,000	25,000
4	Al	921/945	3.0/1.0	45,000	≤ MDA
5	Al	921	0.25	5,000	≤ MDA
6	Monel	921	3.0	3,000,000	≤ MDA
7	Monel	921	3.25	500,000	≤ MDA
8	Monel	921	2.25	90,000	≤ MDA
9	Cu	921	2.0	700,000	≤ MDA
10	Cu	921	2.0	700,000	≤ MDA
11	Bronze	921	2.0	100,000	≤ MDA
12	Bronze	921	2.0	100,000	≤ MDA
13	Bronze	921	2.0	10,000,000	10,000

Conclusion

The MELE Associates, Inc. decontamination demonstration conducted at PORTS using CORPEX® Nuclear Decontamination Processes on representative scrap metal specimens from Oak Ridge K-25 and PORTS was highly successful.

This demonstration was significant because DOE proved that chemical decontamination technology exists for use on the contaminated scrap metal that is:

- Effective
- User and environmentally friendly
- Economical.



PORTS Scrap Metal Decontamination

CORPEX Technologies Inc.

Decontamination Process Utilized, Decontamination Results,
Management of the Chelated Waste

Goal and Objective

- *Provide DOE with an Alternative to Recycling Contaminated Scrap Metal by Smelting*
- *Demonstrate the Usage of CORPEX Chelants to Decontaminate Doe's Uranium Contaminated Scrap Metal to Achieve Unconditional Release Guidelines*

Radioactive Scrap Metal

Doe's Beneficial Reuse of Radiologically Contaminated Scrap Metal:

- *Package*
- *Transport*
- *Smelt*
- *Produce products for controlled use*
- *Dispose of radioactive slag*

Description of Demonstration

- *Selection of CORPEX Applicator*
- *Characterization of the Contaminate*
- *Development of Project Procedures*
- *Procure Demonstration Equipment*
- *Decontaminate Metallic Coupons*
- *Destroy Chelant by Wet Oxidation*
- *V/R Operations & Waste Solidification*

Decontamination Results

Specimen No.	Material	CORPEX Reagent No.	Treatment Time (hours)	Initial	Final
1	Ni plated Fe	921	3.25	1,000,000	≤ MDA
2	Al	921/945	3.0/1.0	800,000	50,000
3	Al	921/945	3.0/1.0	200,000	25,000
4	Al	921/945	3.0/1.0	45,000	≤ MDA
5	Al	921	0.25	5,000	≤ MDA
6	Monel	921	3.0	3,000,000	≤ MDA
7	Monel	921	3.25	500,000	≤ MDA
8	Monel	921	2.25	90,000	≤ MDA
9	Cu	921	2.0	700,000	≤ MDA
10	Cu	921	2.0	700,000	≤ MDA
11	Bronze	921	2.0	100,000	≤ MDA
12	Bronze	921	2.0	100,000	≤ MDA
13	Bronze	921	2.0	10,000,000	10,000
Units are in DPM / 100 cm ²					

CONCLUSIONS

*Decontamination of PORTS
Scrap Metal is:*

- *Effective*
- *User and environmentally friendly*
- *Economical*

Recycling of Mixed Wastes Using Quantum-CEP™

Bob Sameski
M4 Environmental Management, Inc.

Recycling of Mixed Wastes Using Quantum-CEP™

Bob Sameski

Presented at Beneficial Reuse '96

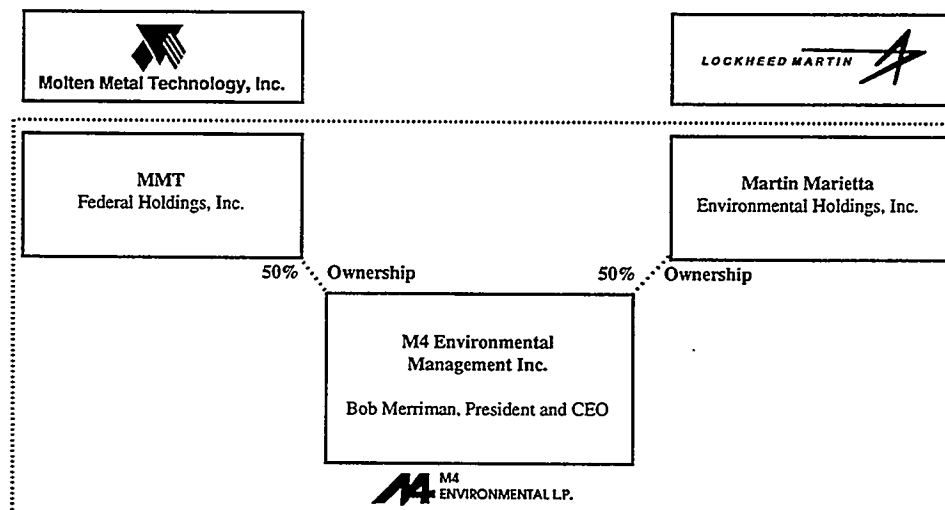
October 24, 1996



M4 ENVIRONMENTAL L.P.

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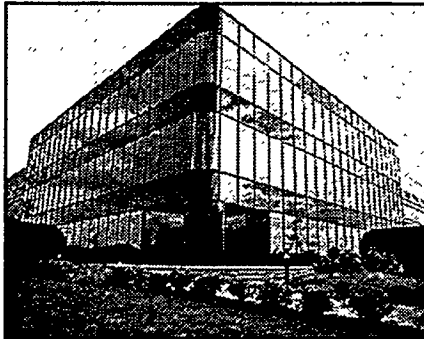
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M4 Oak Ridge Site

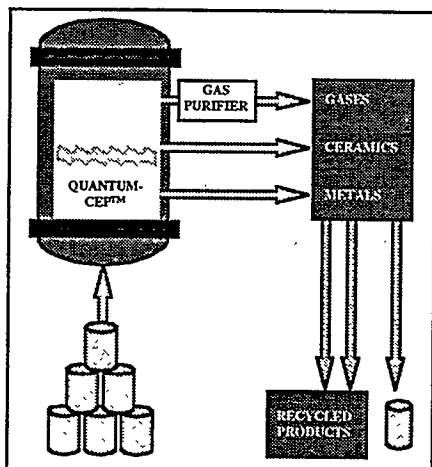


- **Location:** Commerce Park Technology Center (100,000 ff building) and Corporate Center (31,000 ff)
- **Employees:** 183
- **Capital:** \$40 million
- **Capabilities:** R&D validation
commercial processing

Market Sector Definitions

DUF ₆	• Depleted Uranium Hexafluoride generated in the uranium enrichment process • Stored outside in steel cylinders
Mixed Waste	• Both radioactive and hazardous • May contain alpha as well as beta/gamma radiation • Stored in drums, etc.
Chem De-Mil	• Both nerve and blister agents (organic compounds with chlorine, fluorine, sulfur, and/or phosphorus) • May be in storage tanks ("bulk agent") or weaponized • May include metal parts, energetics and other associated scrap materials • May be at an official stockpile site or buried elsewhere ("non-stockpile")
DoD Hazardous	• Includes the full spectrum of industrial hazardous wastes plus military wastes (energetics, etc.)
Tanked Waste	• Both radioactive and hazardous • May be highly radioactive (1 million times Mixed Waste) • Solutions, sludges, salts, etc., in underground tanks

Quantum-CEP™ For Radioactive Waste



- **Quantum-CEP™ Features**
 - Uses molten metal as a catalyst and solvent
 - Converts compounds to elements, dissolving bonds
 - Partitions radionuclides from non-radioactive elements
 - Destroys hazardous and toxic materials in mixed waste
 - Captures radionuclides in a stable, nonleachable matrix
 - Decontaminates gases and metals for potential reuse/recycle
- **Quantum-CEP™ Benefits**
 - Reduces volume of radioactive material -- 30:1 to 1000:1
 - Stabilizes radioactivity, reducing risk of leaching or exposure
 - Creates new source of raw materials through recycling
 - Provides broadly applicable, cost-effective solution for radioactive and mixed waste



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12/96

Mixed Waste

- **Year ago**
 - CEP viewed as developmental R&D
 - M4 viewed as unproven, unpermitted, unlicensed, no-operational and overly optimistic on deployment/processing/ recycle claims
 - no contracts pending
- **Today**
 - M4 licensed, permitted, processing waste
 - unprecedented regulatory success
 - recycle determination granted
 - Combo facility operations expected within "promised" time frame
 - CEP units in-place and operating
 - significant contract role for M4 in; Commercial, DOE & DoD mixed waste
 - M4 emerging as processing contractor for multiple technologies/ opportunities
 - additional contracts/ opportunities through Retech acquisition



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timeline



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M41037
12/94

Mixed and Hazardous Waste Processing Experience at M4

- **Treatability Study Testing Completed**
 - West End Treatment Facility Sludges (inorganic sludge)
 - Duke Power organic liquids and sludges (halogenated and non-halogenated)
 - DOE Mixed Waste Demonstration Project Phase I - organic liquids (oil/solvent mixture)
 - Transuranic tanked waste surrogates
- **Treatability Studies Under Contract**
 - Duke Power organic and inorganic solids, and debris with volatile heavy metals
 - DOE Mixed Waste Demonstration Project Phase II - soils contaminated with RCRA metals and organics, including PCBs
 - Iowa Electric organic liquids and sludges, including paints, and organic and inorganic solids
 - Air Force Center for Environmental Excellence organic liquids and sludges, including chlorinated wastes, and mixed aqueous wastes (hazardous only)



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M41028
12/94

M4 Treatability Studies Summary

- **RPU-2 Bench-Scale Units**
 - 60 runs with an average of ~ 6 hours molten time/run
- **RPU-3 Pilot-Scale Unit**
 - 10 runs with greater than 600 hours of molten time
 - >3,600 lbs of waste fed (>3,300 lbs of mixed waste)
 - average feed rate of 9.2 lb/hr for organic liquids and sludges with an average injection rate of 72 percent
 - operational experience continues to scale up with longer runs and greater percentage of on-stream time



M4 ENVIRONMENTAL L.P.

M412533
12/96

Significant Regulatory Achievements

- **Lease signed for M4 Technology Center on July 28, 1995**
M4 permitted and licensed to:
 - process DUF₆ in October 1995
 - process West End Treatment Facility Sludge in December 1995
 - process Duke Power Mixed Waste in June 1996
- **Technology Center fully licensed and permitted in 10 months**
- **Received nation's first mixed waste recycling approval**
- **Received TSCA R&D permit to process PCB's**
- **Successfully reviewed by regulators, M&O contractors, and numerous commercial nuclear firms**



M4 ENVIRONMENTAL L.P.

M412533
12/96

CEP Produces Commercially Valuable Products that Meet Established Specifications

- Synthesis gas (carbon monoxide and hydrogen) and specialty gases (e.g., anhydrous hydrogen fluoride, anhydrous hydrogen chloride, etc.)
- Specialty inorganic chemicals (e.g., hydrochloric acid, sodium hydroxide, etc.)
- Ceramic materials (e.g., cementitious materials, abrasives, aggregate, neutralizing media, mineral wool/man-made vitreous fibers, etc.)
- Metal and metal alloys



M4 ENVIRONMENTAL L.P.

M4102311
12/96

Synthesis Gas

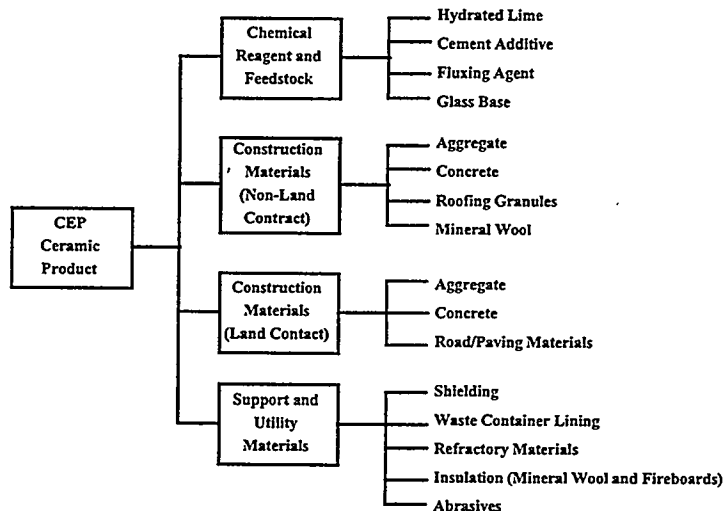
- Commercial product with demonstrated value, markets and specifications
- Indistinguishable from synthesis gas produced by alternative methods
- Will meet any required boiler specifications, as well as federal, state and local requirements for fuel combustion in the same manner as other commercially available syngas
- Will be used to power a steam boiler at the M4 Technology Center for:
 - decontaminating drums and process equipment
 - providing heat to a waste water evaporator
 - supplementing building heat



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M4102312
12/96

CEP Ceramic Product Market is Diverse



M4 ENVIRONMENTAL L.P.

M4102313
12/94

Ceramic Product Applications Will Be Consistent With Levels of Radioactivity Present

- Cementitious material (substitute for Portland cement and/or ground-granulated blast furnace slag) for low-level and mixed waste stabilization activities
- Abrasive blasting media for use in radioactively-contaminated environments
- Neutralizing media for radioactive wastewater treatment operations
- Concrete shielding
- Fabrication of fiberglass containers for low-level and mixed waste storage and disposal
- Other applications will also be pursued as identified



M4 ENVIRONMENTAL L.P.

M4102314
12/94

Metal/Metal Alloy Product Applications Will Be Consistent With Levels of Radioactivity Present

- Reuse within metal baths in M4 Technology Center and/or other M4 facilities
- Shielding blocks
- Low-alloy iron containers for low-level and mixed waste transportation, storage, and disposal
- Spent nuclear fuel canisters
- Other applications will also be pursued as identified



M4 ENVIRONMENTAL L.P.

AM110315
12/5/96

**Depleted Uranium Hexafluoride:
The Source Material for Advanced Shielding Systems**

W. J. Quapp
Nuclear Metals, Inc.

Summary
DEPLETED URANIUM HEXAFLUORIDE:
THE SOURCE MATERIAL FOR ADVANCED SHIELDING SYSTEMS

W. J. Quapp
Nuclear Metals, Inc.

Prepared for the
Beneficial Reuse '96 Conference

DUCRETE shielding is a new material that has been developed at the Idaho National Engineering Laboratory for spent fuel and other high radiation shielding applications. The work has been sponsored by the USDOE Office of Science and Technology. The origin of DUCRETE shielding is presented in the attached full paper which was prepared for and presented at the Third International Uranium Hexafluoride Conference, November 28 to December 1, 1995 in Paducah, Kentucky. This brief summary discusses the composition of DUCRETE shielding and provides an update on developments which have occurred since the attached paper was prepared.

DUCRETE shielding was developed as an economical method for using the extensive supplies of depleted uranium for shielding applications. More traditional uranium shielding applications have always employed uranium as a metal. Though uranium is extremely effective as a gamma shield, its high costs prevents deployment for spent fuel or high level waste dry storage applications. DUCRETE shielding is composed of a patented depleted uranium aggregate made from uranium oxide. This aggregate is used in concrete mixtures in place of traditional aggregate. Since the depleted uranium aggregate has a specific gravity near 9, this results in a concrete with density near 450 lb/ft³.

When used in spent fuel applications where attenuation of both a neutron source as well as the gamma ray energy is required, DUCRETE shielding is shown to be very effective in reducing the external field with minimal wall thickness compared to other metallic shields and concrete systems. The presence of the high density uranium aggregate effectively stops gamma rays far better than traditional concrete. But the presence of the chemically bound water in concrete is shown to be very effective in stopping the neutron penetration. No other material has this combined matrix composition. These characteristics allow large weight and size reductions in concrete spent fuel storage systems.

Nuclear Metals, Inc., is in the process of designing and installing a pilot scale aggregate production facility at its Carolina Metals facility near Barnwell, SC. This facility will be capable of producing approximately 1 ton per day of depleted uranium aggregate. The aggregate will be used in continued spent fuel storage cask development programs. The process will be capable of producing the aggregate with either UO₂ or UO₃ as the source material. The system is expected to be operational in the first quarter of 1997.

Other applications for DUCRETE shielding include high activity storage and disposal boxes and

radiation shielding applications.

DEPLETED URANIUM HEXAFLUORIDE: THE SOURCE MATERIAL FOR ADVANCED SHIELDING SYSTEMS

W. J. Quapp and P. A. Lessing
Idaho National Engineering Laboratory
Idaho Falls, Idaho USA

C. R. Cooley
U.S. Department of Energy
Office of Technology Development
Germantown, Maryland USA

ABSTRACT

The U.S. Department of Energy (DOE) has a management challenge and financial liability problem in the form of 50,000 cylinders containing 555,000 metric tons of depleted uranium hexafluoride (UF_6) that are stored at the gaseous diffusion plants. DOE is evaluating several options for the disposition of this UF_6 , including continued storage, disposal, and recycle into a product. Based on studies conducted to date, the most feasible recycle option for the depleted uranium is shielding in low-level waste, spent nuclear fuel, or vitrified high-level waste containers. Estimates for the cost of disposal, using existing technologies, range between \$3.8 and \$11.3 billion depending on factors such as the disposal site and the applicability of the Resource Conservation and Recovery Act (RCRA). Advanced technologies can reduce these costs, but UF_6 disposal still represents large future costs.

This paper describes an application for depleted uranium in which depleted uranium hexafluoride is converted into an oxide and then into a heavy aggregate. The heavy uranium aggregate is combined with conventional concrete materials to form an ultra high density concrete, DUCRETE, weighing more than 400 lb/ft³. DUCRETE can be used as shielding in spent nuclear fuel/high-level waste casks at a cost comparable to the lower of the disposal cost estimates. Consequently, the case can be

made that DUCRETE shielded casks are an alternative to disposal. In this case, a beneficial long term solution is attained for much less than the combined cost of independently providing shielded casks and disposing of the depleted uranium. Furthermore, if disposal is avoided, the political problems associated with selection of a disposal location are also avoided.

Conceptual design studies have shown that a ventilated storage container for dry fuel storage similar to the Sierra Nuclear Corporation VSC-24 can be made from such ultra high density concrete. DUCRETE shielding results in a large reduction in both weight (35 tons) and diameter (40 inches smaller diameter) compared to conventional concrete casks.

Thus, a beneficial use has been found for the depleted uranium and the non-productive costs associated with disposal of the depleted uranium as a waste can be redirected to supporting nuclear utilities' needs for spent fuel storage casks.

Other studies have also shown cost benefits for low level waste shielded disposal containers.

INTRODUCTION

As part of the Department of Energy's Environmental Management (EM) Program, Office of Technology Development, in FY 1993 evaluation began on options for managing the

as metal (Reference 1). Most of this material is stored as uranium hexafluoride (UF_6) at the gaseous diffusion enrichment plants. Additional uranium supplies exist in metallic and oxide forms elsewhere in the DOE complex.

The objective of the EM project was to evaluate management options by determining if there were any potential uses for the uranium and, if so, the associated costs. As a starting point, a disposal study was performed to establish a cost estimate for disposal of the uranium as radioactive waste (Reference 2). A summary of all EM-sponsored evaluations is provided in Reference 3.

DISPOSAL OPTIONS

The disposal study concluded that uranium hexafluoride would have to be converted to an oxide before disposal since it is chemically reactive with water. This conclusion is consistent with management practices in the French and British nuclear programs. Thus, the cost estimates were developed to include UF_6 conversion to U_3O_8 , neutralization of the anhydrous hydrogen fluoride to calcium fluoride, packaging, transportation and disposal of U_3O_8 and CaF_2 .

The DOE Nevada Test Site (NTS) and Hanford were considered in the disposal study since these sites are in an arid climate and probably most suitable for such large-scale disposal actions. (There was no effort to assess the technical viability of disposal at eastern DOE sites.) Disposal at private sites was considered, but deemed too costly. The study also considered the waste acceptance criteria at NTS and Hanford and modified the uranium oxide accordingly. At NTS, bulk oxide in metal containers was acceptable but at Hanford the oxide material required stabilization.

Stabilization of uranium oxide was assumed for the study. It was estimated that stabilization in polyethylene would double the volume of waste disposed (This is a very optimistic loading and the volume of the mixture could easily go higher). The disposal unit cost was also different at each site and, over the duration of the study, changed at the NTS. The range of

cost estimates for the baseline case with disposal at NTS and Hanford is presented in Table 1 (from Reference 3). This information has been adjusted from that presented in Reference 2.

Table 1. Comparison of Disposal Costs for Baseline and Advanced Technology Disposal Options (375,000 MTU Basis)

<i>Baseline Conversion Technology</i>	Billions
Oxide LLW Disposal (NTS & Hanford)	\$3.8 to \$5.6
Oxide RCRA Disposal (Hanford)	\$11.3
Metal LLW Disposal (NTS)	\$3.9
<i>New Plasma UF_6 Reduction</i>	
Metal LLW Disposal (NTS)	\$1.8
<i>Advanced UF_6 Conversion & Elimination of CaF_2</i>	
Oxide LLW Disposal (NTS & Hanford)	\$1.9 to \$2.5
Oxide RCRA Disposal (Hanford)	\$4.7 to \$6.6
<i>Advanced UF_6 Conversion to Oxide and U-Aggregate</i>	
LLW Disposal (NTS & Hanford)	\$1.6 to \$1.9
RCRA Disposal (Hanford)	\$2.4 to \$3.4

IMPACT OF ADVANCED TECHNOLOGY ON DISPOSAL COSTS

The technology improvements leading to the greatest cost reductions are:

- processes for conversion of uranium hexafluoride to oxide with recovery of the hydrogen fluoride for recycle, and
- densification of the oxide into depleted

uranium aggregate.

Recovery and recycle of the hydrogen fluoride eliminates neutralization with calcium oxide and additional radioactive waste packaging, transportation and disposal costs. Although no contracts for such advanced conversion have actually been awarded, private sector companies have suggested that costs of less than half of that used in Reference 2 could be expected in a competitive proposal (Reference 4).

Disposal as a compressed, sintered aggregate rather than bulk oxide produces an estimated incremental savings of \$300 to \$600 million because of reduced disposal volume, which reduces the number of disposal containers and the disposal fees. Densification of the oxide powder into an aggregate reduces the cost of disposal by producing a waste form having a bulk density near 8 g/cm³. This compares to a bulk density of the powder of less than 3 g/cm³. Thus, disposal containers and disposal facility volume are reduced by about 60%. Furthermore, the aggregate should be an acceptable waste form without further stabilization, resulting in even more savings at disposal sites requiring stabilization. Costs for large-scale production of the aggregate are unknown, but are anticipated to be small based on similar processes in the minerals industry.

DEPLETED URANIUM SHIELDING

After establishing the cost of disposal, a search for potential applications for the depleted uranium was made (Reference 3). The most viable use was determined to be for shielding of nuclear waste, especially spent fuel and high-level waste. Traditionally, uranium used in shipping cask shielding has always been metallic uranium. Costs to convert from uranium hexafluoride to uranium metal and then to fabricate to a final shape have been estimated to be near \$20/kg (Reference 5). Only in special applications where cask weight or volume limitations demand the high gamma shielding efficiency of metallic uranium can such costs be justified. A metallic uranium spent fuel storage cask was estimated to be several times the cost of those of more conventional materials such as

concrete (Reference 5).

Thus, either major cost reductions for UF₆ conversion to metal and metal fabrication or some other method would be required to use uranium in shielded containers. This situation gave rise to the concept of DUCRETE, which is compared to traditional concrete in Table 2.

Table 2. Comparison of Conventional Concrete and DUCRETE

Concrete	DUCRETE
Type II Cement	Type II Cement
Sand (SiO ₂ based)	Sand (SiO ₂ based) ^a
Gravel (SiO ₂ based)	Gravel (UO ₂ based)
Density—150 lb/ft ³	Density—400 to 450 lb/ft ³
Compressive Strength—3500 to 4000 lb/in ²	Compressive Strength—similar ^b

The key to making DUCRETE is the ability to fabricate a low-cost uranium oxide aggregate. (Note that this aggregate is the same as described above under the disposal cost reduction section. Thus, development of the aggregate has merits for both the disposal option and for use in DUCRETE.) Other chemical compounds of uranium such as uranium silicides were considered by the authors but rejected due to higher expected cost. Uranium oxide dissolved in a vitreous material, e.g. an aluminosilicate such as iron-enriched basalt, was also considered but limitations on concentration and aggregate density as well as high production costs were anticipated.

^aConsideration has been given to using other sands such as colemanite and bauxite because of the presence of hydrogen in these minerals.

^bLimited tests on DUCRETE showed lower strength (~20%), but this difference was attributed to the smooth surface of the "gravel" pellets (Ref. 9).

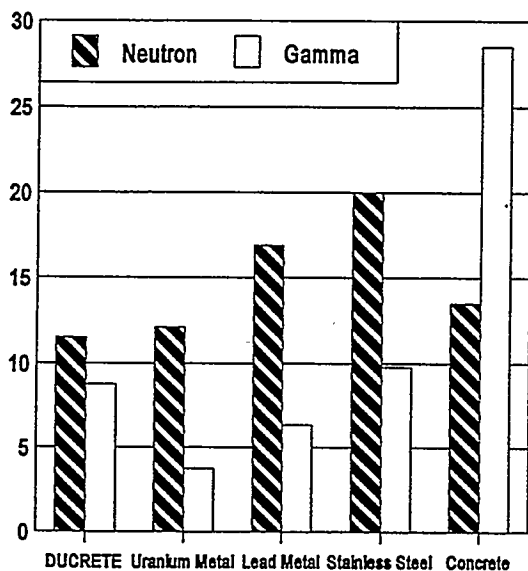


Figure 1. Comparison of Minimum shielding Wall Thickness for a Source Term from 24 PWR Spent Fuel Assemblies.

Theoretical estimates of the shielding effectiveness of DUCRETE compared to other materials in a spent fuel storage cask application have been made for a cask containing 24 PWR fuel assemblies. The results of this calculation are shown in Figure 1. The minimum wall thickness for attenuating the gamma dose and the neutron dose is shown for several common cask materials as well as DUCRETE. It is clear that metals are good for gamma shielding but are not as effective for neutrons. On the other hand, ordinary concrete is relatively good for neutrons (on a unit mass basis) because of the water of hydration but not as effective for gamma attenuation. DUCRETE, however, combines the benefits of a high Z material (in an oxide form) while preserving the presence of hydrogen in the water of hydration. This feature also allows the optimization of high and low Z material by adjusting the relative depleted uranium aggregate concentration in the DUCRETE mixture.

DUCRETE CHEMICAL AND STRUCTURAL FEASIBILITY TESTS

Uranium dioxide is a relatively stable material and is considered essentially insoluble in water (Reference 6). Natural uraninite (UO_{2+x}) mineral deposits in contact with groundwater

yield uranium concentrations from 50 to 200 ppb in the water (Reference 7). Thus, it was expected that uranium oxide aggregate would be chemically stable in the more basic environment of a Portland cement mixture (Reference 8). However, to verify this premise, depleted uranium oxide fuel pellets were obtained and a series of experiments were performed (Reference 9). These depleted uranium oxide fuel pellets were not the same aggregate that had been conceived for making DUCRETE, but were the only uranium oxide pellet material readily available within the DOE system. (Manufacturing a small quantity of depleted uranium aggregate for these proof-of-concept tests involved too much cost and lead time to be acceptable during the early phase of the project.)

To establish the initial feasibility of DUCRETE, Lessing (Reference 9) devised a series of experiments to test the physical characteristics of DUCRETE. Cement mixtures with varying concentrations of conventional crushed river aggregate (primarily quartz) and ceramic uranium oxide pellets were prepared. Samples from each mixture were fabricated for mechanical testing. The samples were prepared with careful attention to the exact composition, including water additions. A shear mixer was used to blend the ingredients.

Samples were cured per ASTM C 192, *The Method of Making and Curing Concrete Test Specimens in the Laboratory*. Compression strength for all samples were determined using ASTM C 39-72, *Compressive Strength of Cylindrical Concrete Specimens*. Brazilian tests were also performed to estimate the tensile strength of the specimens.

Samples of DUCRETE were formed with density as high as 400 lb/ft³; conventional concrete density with the same volume percent gravel was 132 lb/ft³. The samples were allowed to cure for times of 7, 28, and 90 days before testing.

These tests established that the mechanical properties of DUCRETE were similar to those of conventional concrete at the same volumetric

loading of gravel. All samples of DUCRETE were above 3000 psi in the compression tests. In these tests, the DUCRETE samples displayed a slightly lower (~20%) strength than the gravel concrete samples. This result was attributed to the smooth surface of the fuel pellets used as aggregate. Having been made for other purposes, the pellets were centerless ground to a very smooth surface as required for nuclear fuel. This smooth surface causes very poor bonding of the cement fraction compared to the surface of crushed gravel. It is expected that DUCRETE fabricated with uranium aggregate that has rougher surfaces will behave similarly to crushed rock and will not display the lower strength observed in these tests. However, even these strengths are sufficient to be used in spent nuclear fuel casks (Reference 10).

DUCRETE CASK DESIGN

Since current spent nuclear fuel dry storage applications almost exclusively use concrete, it seems logical to substitute DUCRETE. Using low-cost aggregate fabrication methods from the minerals industry, it seemed feasible to produce the depleted uranium aggregate. Initial estimates were that DUCRETE with a density near 450 lb/ft³ could be produced (a density of 400 lb/ft³ was later confirmed by tests).

In parallel to the concrete tests described previously, several analytical studies were initiated to test the concept from a shielding performance perspective. INEL staff performed a variety of shielding calculations to determine if the postulated benefits of the high density concrete were suitable for source terms emanating from spent nuclear fuel. Additional studies were conducted by commercial firms in the shielded container and cask business.

Haelsig (Reference 11) considered several cask and shielded container applications and identified the potential benefits of a DUCRETE mixture based on the theoretical compositions predicted by the INEL staff. Haelsig conceived a modular, segmented cask design with applications for spent fuel, high-level waste, and as an overpack for polyethylene high-integrity

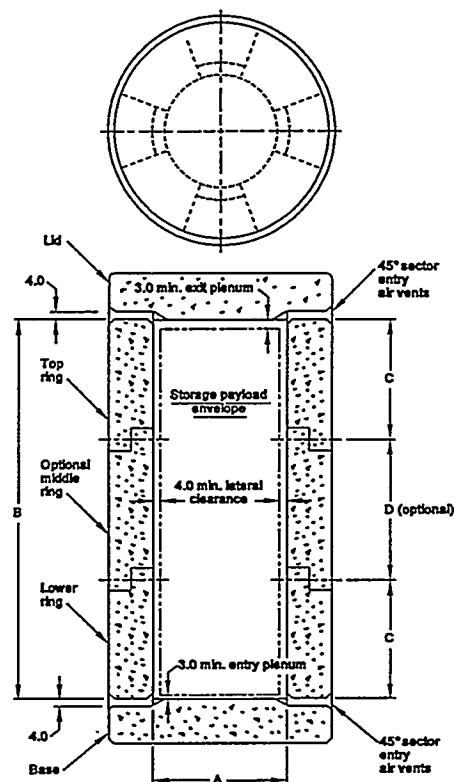


Figure 2 DUCRETE Modular Segmented Cask Concept. containers. This concept is presented in Figure 2.

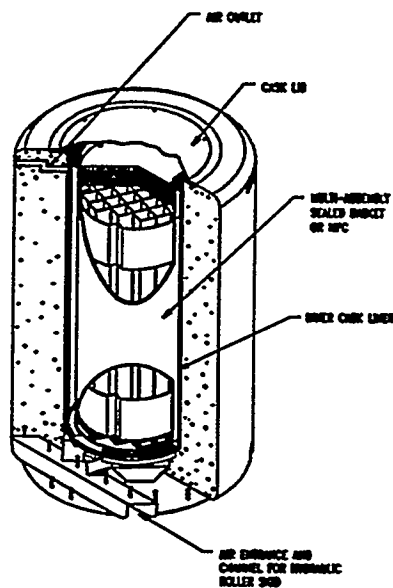


Figure 3 Sierra Nuclear Ventilated Storage Cask

In a later study, after some DUCRETE had been made, Hopf (Reference 12) determined that a ventilated storage container holding 24 PWR fuel assemblies could be designed with DUCRETE as the shielding material. This cask design was based on the Sierra Nuclear Company cask known as the VSC-24—a dry storage cask that uses natural circulation cooling to maintain fuel temperatures at suitable levels. An illustration of the VSC-24 is provided in Figure 3. Inside the VSC-24, a metal basket contains the spent fuel. This basket is dimensionally similar to the DOE Multi-Purpose Container.

The conceptual design of the DUCRETE VSC-24 is similar to the standard VSC-24 but is considerably smaller. Although the fuel load—24 PWR fuel assemblies—is the same, the external diameter is reduced by about 40 inches—from about 130 to 90 in.. The diameter varies somewhat depending on the assumed density of the aggregate and the volume fraction in the cement mixture. Hopf established a wall thickness range of about 8 to

12 in. for an aggregate density of 8 g/cm^3 and various loading fractions. The total weight is also reduced, to about 100 tons from 135 tons. The design uses external and internal 0.5 in. thick steel shells with DUCRETE sandwiched between the shells. Nearly all other cask features are expected to be similar to the VSC-24.

This smaller diameter storage cask then stimulated the question of transportability since the diameter was well below the 128 inch limit for rail shipments.. Could the DUCRETE VSC-24 with the loaded spent fuel storage basket be placed inside of a steel overpack and transported to a disposal facility? Hopf conducted a further study (Reference 13) that assessed this feasibility. The study used estimated thermal properties of DUCRETE, since no thermal performance data were yet available. This preliminary study indicated that transport inside of an overpack was possible, but would be limited by the heat generation rate of the fuel (age of the fuel since discharge from the reactor), the thermal performance of the DUCRETE cask, and heat rejection through the steel overpack. The concept also required a more sophisticated design for the DUCRETE storage container that used fins to conduct heat through the DUCRETE wall during transport. This design was estimated to be considerably more expensive than the basic DUCRETE storage cask design.

A further system benefits analysis by Powell (Reference 14) compared the economic performance of the VSC-24, the DUCRETE VSC-24, and the Transportable DUCRETE VSC-24. This study concluded that the transportable cask had no significant cost or performance advantages over the DUCRETE storage-only cask even if the thermal issues could be overcome. The DUCRETE cask compared well with the VSC-24 traditional concrete storage cask, showing a slightly lower life-cycle cost. Because of the lighter weight, the DUCRETE VSC-24 could be loaded directly in the fuel pools. This direct loading would reduce fuel handling costs and worker exposure.

ECONOMICS OF DUCRETE

The above referenced studies have established the technical feasibility of a spent fuel storage cask designed similar to the Sierra Nuclear Ventilated Storage Cask System. The economic viability is dependent primarily upon the cost of making uranium aggregate. In the cost studies, it has been assumed that the cost of conversion of uranium hexafluoride to uranium oxide could be ignored as that step would be necessary for any option available to DOE other than "store indefinitely".

Given depleted uranium oxide powder, the aggregate can be fabricated using bulk material processing operations such as briquetting or extrusion followed by sintering. The fabrication process must involve low-cost methods at every step or the uranium aggregate will be impractical for this application or for disposal. Processes are under development that show promise for producing the low-cost aggregate. Results from projects planned for FY 1996 should establish the fabrication cost range for the aggregate.

BREAK-EVEN COST The lowest cost of the disposal options considered (as presented in Table 2), \$1.6 billion, equates to about \$170,000 per 40 tons of uranium, which is the approximate mass of uranium needed for a DUCRETE VSC-24 cask. This disposal option assumes a low-cost process for conversion of the oxide into uranium oxide aggregate. Thus, if a cask can be made for this price, it is clearly a reasonable economic alternative to disposal of UF_6 . As the cost of disposal increases, the allowable costs for fabricating DUCRETE casks increase accordingly.

Based on the estimate (Reference 3) for the future cost of large-scale conversion of UF_6 to oxide of \$4.20 per kg U (\$1.90 per lb-U), the 40 tons of uranium oxide will cost about \$150,000 to convert to oxide. Thus, for the low-cost disposal option, only about \$20,000 of avoided cost remains for construction of the cask at a break-even cost. This avoided cost represents the cost of containers, transportation, and disposal fees. However, as disposal costs increase (consistent with recent history), the break-even point increases. At the disposal cost estimate of \$1.9 billion (the Hanford disposal

option), there is about \$50,000 avoided cost for fabrication of the cask.

The above discussion optimistically assumes that a disposal site is available with no protracted delay or other large costs beyond the disposal costs of \$30 per cubic foot used at the NTS and \$59 per cubic foot used at Hanford. History has shown this optimism to be unwarranted when disposal of large quantities of radioactive material are involved. Thus, the actual avoided cost clearly will be higher than estimated in these studies and the cost of the break-even option will exceed the stated values of \$20,000 to \$50,000.

TARGET FABRICATION COST Detailed design of a DUCRETE storage cask has not been performed and, thus, there is not a good cost estimate for the fabrication. However, it is expected that the cost will be near \$100,000 based on similarities to existing concrete systems. If this estimate is correct, the casks would cost only about \$50,000 to \$80,000 more than the break-even cost.

SYNERGISTIC SOLUTION In the absence of a geologic disposal system to accept spent fuel, utilities have been faced with the prospect of providing their own spent fuel storage. Although DOE was to have accepted fuel by the year 1998, that outcome is doubtful. Consequently, utilities are acquiring dry fuel storage capability from firms specializing in such systems. These storage casks or vaults cost near \$200,000 for the storage of 24 PWR assemblies or 65 BWR assemblies.

So, if the utilities are forced to store spent fuel in dry storage casks, nearly 9500 casks will be required—assuming the plants run to the end of their design life. Thus, at about \$200,000 for each storage cask, the utilities face a \$1.9 billion future cost for dry storage systems. (As of today, only a very small fraction of the 9500 casks have been fabricated.)

Consequently, it appears that if the UF_6 were converted to DUCRETE casks, a significant cost savings could be achieved over the cost of solving the UF_6 disposal problem and the spent

fuel dry storage problem independently. As the taxpayers and nuclear utility rate payers are usually the same people, the potential for substantial savings is a real benefit. To exercise this option, DOE would need to contract for a service that converted UF₆ and produced casks. The casks could then be sold or leased to utilities at a reduced cost compared to their current options using conventional materials.

LOW-LEVEL WASTE DISPOSAL CONTAINERS

Another application for DUCRETE shielding is low-level waste (LLW) that cannot be contact handled due to high levels of radioactivity. (In the United States, low-level waste does not necessarily have low activity.) At the DOE site at Fernald, Ohio, there are plans to vitrify wastes containing radium that, after vitrification, is estimated to have a surface dose near 1 rad.

Present disposal plans are considering a recycled concrete disposal box to provide the necessary shielding and strength for transportation. The box is projected to have a 6-in. wall thickness. For the same shielding effectiveness, the wall thickness using DUCRETE would be only about 2 in. This thin DUCRETE wall would not be suitable by itself for such a container due to structural limitations. However, DUCRETE could be used as a liner inside a steel box that satisfied the DOE and DOT structural requirements for a Type A container.

The advantage of this concept is that, for a fixed external volume, the DUCRETE-lined steel box would have a larger payload volume. Since most disposal costs for such waste are based on external volume, considerable cost savings are projected for a box with a larger usable internal volume. A cost model has been developed for determining the life-cycle costs of various shipping and container options (Reference 15). This model has been adapted to assess the DUCRETE box option. A comparison of a concrete box with 6-in. wall thickness and a steel box with a 2-in. DUCRETE lining is shown in Table 3. It is clear that a DUCRETE

wall container has a cost advantage for low-level waste disposal applications when all elements of the life-cycle cost are considered.

RECYCLED METAL USE

For each spent fuel storage cask, approximately 20 tons of steel are used. If DOE establishes a recycle capability for the contaminated steel throughout the DOE complex, a considerable portion of such steel could be used in spent fuel casks provided the metallurgical quality of the steel meets the needed standards. Similar applications exist for LLW and HLW containers. Small quantities of fixed surface or internal contamination of the steel will make little difference to the external dose to radiation workers since the total external dose is dominated by radiation from the waste inside. Thus, additional savings may accrue if recycled steel is available for use in casks or LLW containers.

ULTIMATE DISPOSITION OF DUCRETE CASKS

The DUCRETE cask, constructed from depleted uranium, is slightly radioactive and, as such, must be disposed as radioactive waste at the conclusion of its life. Since the DUCRETE cask has a small diameter, it can be shipped by rail and could be

Table 3. Comparison of Concrete and DUCRETE Shielded Boxes for Disposal of Fernald Vitrified Waste

Description	Portland Cement Concrete Construction	Steel Box with DUCRETE Shielding
Purchase Cost ^c	\$3500	\$3500
Outside Dimensions	72"x54"x58"	72"x54"x58"
Wall Thickness	6"	Steel-0.15" Ducrete-2.2"
Internal Volume	61.3ft ³	94.6 ft ³
Empty Weight	10371 lb	10899 lb
Loaded Weight	19353 lb	24772 lb
Number of Boxes Required	3177	2057
Life-Cycle Cost (\$/ft ³ of waste disposed)	\$172	\$110

used by utilities as a Type A LLW container. This heavily shielded cask could be used to dispose of the activated core components from reactor decommissioning (piping, reactor vessel segments, mechanical components), resins, filters, sludges, etc. and any other Class B and greater wastes.^d The polyethylene high-integrity containers currently used require a concrete box overpack for burial in any low-

^c The cost for the concrete box has been used by FERMCO staff for life-cycle planning. It is assumed that the DUCRETE box can be fabricated for a similar cost.

^dPer 10CFR61, B and C wastes must remain stable for 300 years. Class C and greater must be protected with intrusion barriers for 500 years.

level waste site to prevent subsidence. DUCRETE casks would satisfy this requirement (Reference 11). Conventional concrete casks cannot fill this function as their diameter is above that allowable for unrestricted rail transport.

Alternatively, the DUCRETE cask can be shipped to the geologic repository and disposed within the ample space available in the drifts not occupied by fuel. If there is no future repository, the uranium oxide aggregate, contained in a concrete matrix within a steel-walled container, is a very suitable disposal waste form and waste package.

URANIUM AGGREGATE LEACH BEHAVIOR

Recent tests on samples of the depleted uranium aggregate have shown very low uranium leach rates. The results are comparable to those obtained from iron-enriched basalt and are superior to those of borosilicate glass. Thus, the leaching of uranium after disposal in the DUCRETE container matrix would be minimal and much lower than for U₃O₈ disposed as bulk powder.

CONCLUSIONS

This paper has summarized the DUCRETE materials development and applications studies conducted for the Department of Energy, Office of Technology Development.

As a disposal waste form, depleted uranium aggregate was shown to reduce the cost of disposal of uranium oxide by \$300 to \$600 million, depending on the disposal location. If the depleted uranium aggregate is used in DUCRETE for spent fuel/high-level waste casks or for shielding in low-level waste containers, further large cost avoidance is achieved.

These studies have shown that depleted uranium can be used for nuclear shielding applications and that significant performance and cost benefits are obtained compared to the disposal option.

Further work on the production-scale fabrication of depleted uranium aggregate is needed to improve cost estimates. Final design and demonstration of a DUCRETE spent fuel cask is needed to verify the technical feasibility discussed in this paper.

ACKNOWLEDGMENTS

This work was supported by the U.S. Department of Energy, Assistant Secretary for Environmental Management, under DOE Idaho Operations Office Contract No. DE-AC07-94ID13223.

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Depleted Uranium Hexafluoride: The Source Material for Advanced Shielding Systems

W. J. Quapp, PE
Nuclear Metals, Inc.

Presented at the
Beneficial Reuse 96 Conference
October 21 to 24, 1996

Like Depleted Uranium,

This Paper Is Being Recycled

The original version was presented at the
Third International UF₆ Conference

Paducah, KY, Nov 29 to Dec 1, 1995

Acknowledgments

- This work has been sponsored by DOE Office of Technology Development
- Carl Cooley, DOE Program Manager, initiated the work on evaluating UF₆ management options in 1993

The other title could be:

"What Do We Do With All This Stuff?"

DOE "Owns" 550,000 tons of UF_6
and
significant amounts of depleted
uranium in other forms.

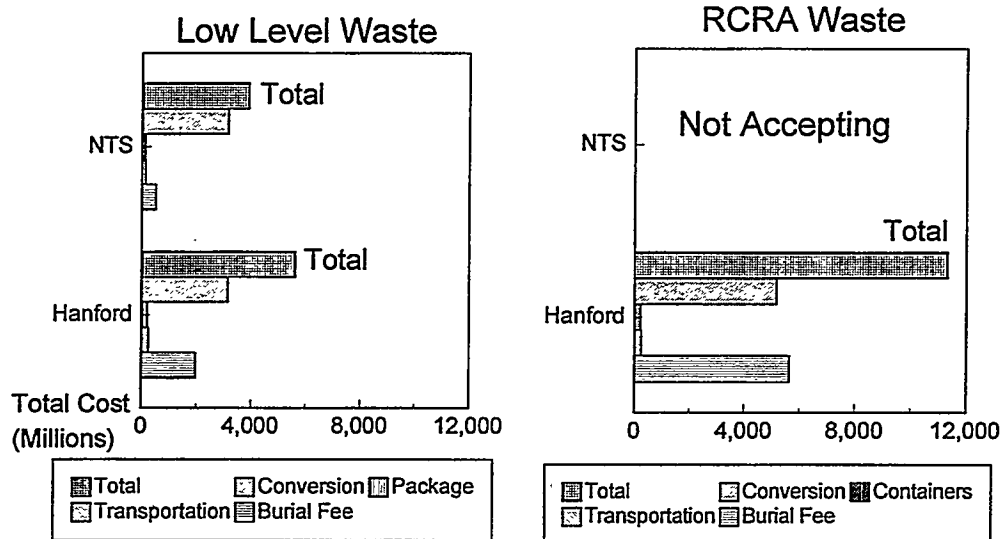
DOE EM 50 Began to Address the Depleted Uranium Issue In FY 1993

• Information Needs

- Cost of disposal
- Possible uses in DOE, DOD, etc.
- Commercial applications

-
- Establish req'ts for disposal
 - Estimate the costs for conversion to oxide
 - Evaluate cost reduction options
 - Search for new technologies
 - Search for new ideas

Disposal Costs Estimated for NTS and Hanford



DOE EM 50 Studies Completed By INEL, SNL, ORNL and Industry

- Shielding applications were the only large quantity use found
- Cost of uranium metal storage casks for spent fuel were estimated to cost at least \$1.5 million
- Driven by high cost of uranium metal ~ \$20/kg
- Studies identified some technology development opportunities to make major cost reductions
 - Plasma conversion of UF_6 to metal estimate to reduce conversion cost by 60%
 - DUCRETE shielding

High Costs of Traditional DU Metal Storage Casks Led to New Concept

DUCRETE Shielding

- Convert UF_6 to an aggregate
- Use DU aggregate in concrete as replacement for gravel
- Estimated that densities near 450 lb/ft³ were possible (normal concrete 150 lb/ft³)

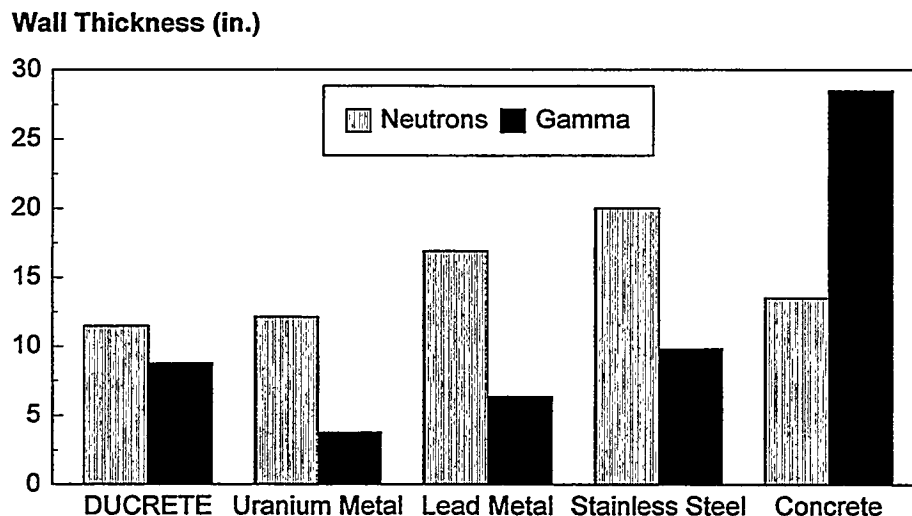
DUCRETE Is Conceptually Simple and Requires no Breakthroughs

- | | |
|--|--|
| ✓ Portland Cement Based Concrete | ✓ Portland Cement Based DUCRETE |
| ▸ Type II cement | ▸ Type II cement |
| ▸ Sand (SiO_2) | ▸ Sand (SiO_2) |
| ▸ Gravel (SiO_2) | ▸ Gravel (UO_2) |
| ▸ Density -- 150 lb/ft ³ | ▸ Density -- 400 to 450 lb/ft ³ |
| ▸ 3500 -- 4000 lb/ft ² compressive strength | ▸ Comparable compressive strength |

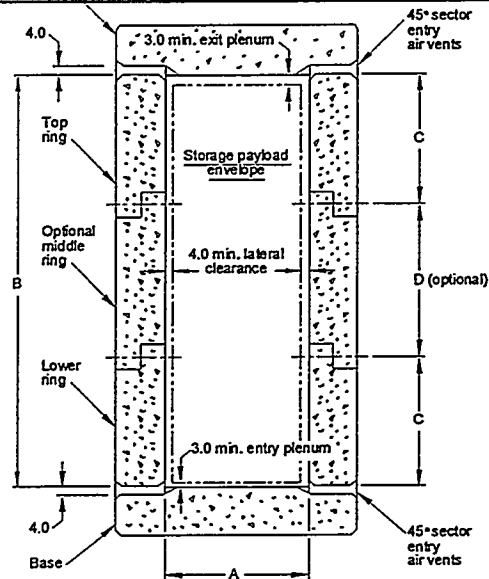
DUCRETE Shielding Can be Adapted to Conventional Concrete Dry Storage Systems

- DUCRETE provides a tailorable combination of materials (H and U) for attenuation of neutrons and gammas in a single matrix
- DUCRETE has potential advantages over other shielding materials
 - Highly effective for both neutron and gamma attenuation (Wall thickness of 10 vs 30 inches)
 - Neutron poisons can be incorporated in the aggregate for additional control over reactivity
- DUCRETE is slightly radioactive and must be controlled but that is the nature of SNF storage

Comparison of Wall Thickness to Attenuate Neutron and Gamma Doses to 10 mR/h From 24 PWR Spent Fuel Assemblies



Modular Dry Storage Cask For Spent Nuclear Fuel and High Level Waste

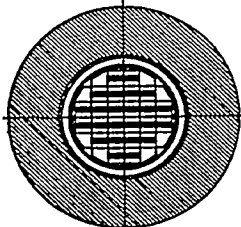


FRS 1106

Comparison of Conventional and DUCRETE Spent Fuel Dry Storage Casks

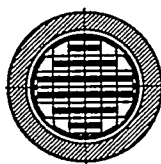
The DUCRETE cask is 35 tons lighter and 40 in. smaller in diameter than casks made from ordinary concrete

Concrete

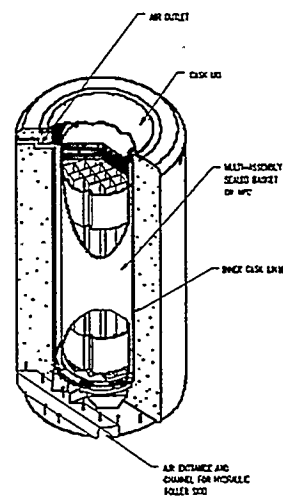


92 ft²

DUCRETE



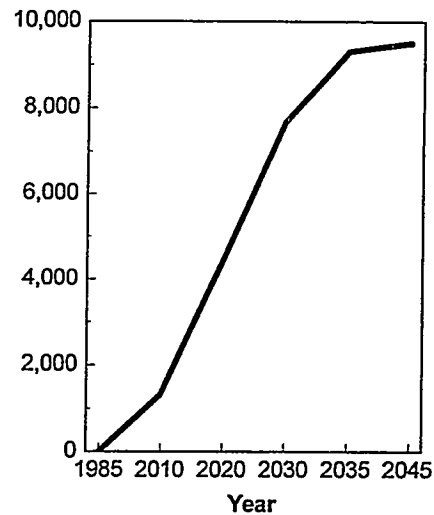
44 ft²



All of the DOE Depleted Uranium Could Be Used in Commercial Spent Fuel Storage Containers

- ✓ If Yucca Mtn opens in 2010, 1300 storage containers req'd
- ✓ If Yucca Mtn doesn't open, 9500 containers ultimately req'd
- ✓ DOE Inventory of DU sufficient for 8700 containers
- ✓ Plus - USEC is generating DU at 15,000 MT/y (375 containers/y)

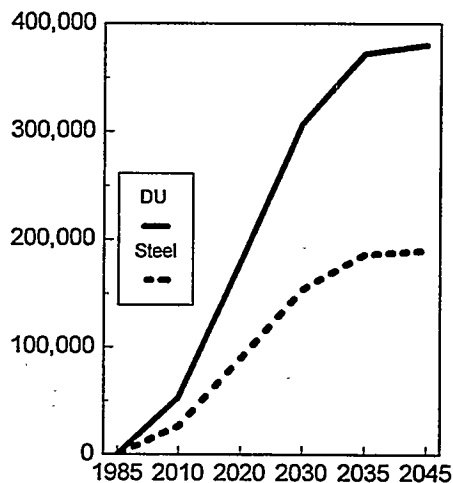
Cumulative Containers



Both Depleted Uranium and Steel Can Be Recycled in DUCRETE Casks

- Depleted uranium oxide is available at SRL for over 500 casks
- Conversion of UF_6 to oxide not needed until about 2005
- Recycled carbon and stainless steel can be used to supply metal components

Metric Tons Metal



High Activity Low Level Waste Containers Can Use DUCRETE and Reduce Total Life Cycle Costs

- Low Level Waste Disposal Involves:
 - Disposal package cost -- per container
 - Transportation cost -- weight basis
 - Labor cost -- per container
 - Burial cost -- external volume basis
- DUCRETE provides thinner walls for the same shielding
- Thus, more internal volume and lower cost per cubic foot of waste disposed

Example of Cost Savings for Fernald Vitrified Waste Application (194,000 ft³, 1 R source term)

Parameter	Recycled Concrete	Steel & DUCRETE
Purchase cost	\$3500	\$3500
External volume (ft ³)	131	131
Wall Thickness (in)	6	0.15; 2.2
Internal volume (ft ³)	61	102
Empty weight (lb)	10371	11371
Loaded weight (lb)	19353	26370
No of boxes req'd	3177	1903
Life cycle cost (\$/ft ³)	172	103

Technology Demonstration Steps For DUCRETE Container Options

- Completed
 - Demonstration of aggregate feasibility
 - Demonstrated leach resistance of aggregate
 - Completed conceptual design of SNF cask
 - Demonstrated economics of LLW boxes
- Needed
 - Low cost UF₆ to oxide conversion process
 - Demonstration of large scale production of aggregate -- in progress at NMI
 - Detailed design, manufacturing demonstration, and licensing of cask

Conclusions

Concept Provides Major Cost Savings by Recycling of DU Into Shielded Containers

- Stable, high density, leach resistant DU aggregate can be produced
- Recycle of the DU aggregate into containers eliminates need for DU disposal facility
- DUCRETE LLW disposal boxes reduce disposal life cycle costs for other materials
- DUCRETE SNF casks could reduce SNF and HLW storage costs for DOE and utilities
 - Easier handling, factory fabrication, shipable to MRS or geologic repository

Session 6 - Radioactivity in the Scrap and Steel Industry

**The Probability of Detecting Radioactive Materials
in Recycled Scrap Metals**

Graham Walford
Quintek Corporation

(Paper not available)

Distribution of Radionuclides During Melting of Carbon Steel

W. C. Thurber
S. Cohen & Associates, Inc.

J. MacKinney
U.S. Environmental Protection Agency

DISTRIBUTION OF RADIONUCLIDES DURING MELTING OF CARBON STEEL

W.C. Thurber, S. Cohen & Associates, Inc.

J. MacKinney, U.S. Environmental Protection Agency

INTRODUCTION

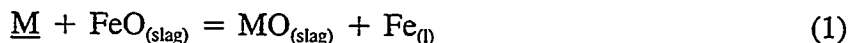
During the melting of steel with radioactive contamination, radionuclides may be distributed among the metal product, the home scrap, the slag, the furnace lining and the off-gas collection system. In addition, some radionuclides will pass through the furnace system and vent to the atmosphere. To estimate radiological impacts of recycling radioactive scrap steel, it is essential to understand how radionuclides are distributed within the furnace system.

For example, an isotope of a gaseous element (*e.g.*, radon) will exhaust directly from the furnace system into the atmosphere while a relatively non-volatile element (*e.g.*, manganese) can be distributed among all the other possible media. This distribution of radioactive contaminants is a complex process that can be influenced by numerous chemical and physical factors, including composition of the steel bath, chemistry of the slag, vapor pressure of the particular element of interest,¹ solubility of the element in molten iron, density of the oxide(s), steel melting temperature and melting practice (*e.g.*, furnace type and size, melting time, method of carbon adjustment and method of alloy additions).

This paper discusses the distribution of various elements with particular reference to electric arc furnace (EAF) steelmaking. The first two sections consider the calculation of partition ratios for elements between metal and slag based on thermodynamic considerations.² The third section presents laboratory and production measurements of the distribution of various elements among slag, metal, and the off-gas collection system; and the final section provides recommendations for the assumed distribution of each element of interest.

THERMODYNAMIC CALCULATION OF PARTITION RATIOS

Partitioning of a solute element between a melt and its slag under equilibrium conditions can be calculated from thermodynamic principles if appropriate data are available. Consider a divalent solute element $\underline{M}$, such as cobalt, dissolved in molten iron which reacts with iron oxide in the slag according to the following equation:



where $\underline{M}$ is the symbol for solute dissolved in liquid iron.

¹ Since the chemical and physical (non-nuclear) properties of different isotopes of the same element are virtually identical, radionuclides are referred to by their element.

² Reference to a given element does not necessarily imply that it is in the elemental form. For instance, a metallic element might be found in the elemental state in the melt while its oxide is found in the slag.

Equation (1) can be written as the difference between the following equations:



and



The Gibb's free energy for Equation 1, ΔF°_1 can be expressed as the difference in the free energies of equations 2 and 3, viz.:

$$\Delta F^\circ_1 = \Delta F^\circ_2 - \Delta F^\circ_3$$

Thermodynamic data for Equation 2 are normally tabulated assuming that the standard state for M is the pure liquid or solid, but it is often desirable to convert from the pure elemental standard state to a hypothetical standard state where M is in a dilute solution. In steelmaking, 1 wt% M in solution in iron is commonly used for this new standard state³ as defined by the transformation:



The free energy change for M from the pure state to $\underline{M}$ in the dilute state is where T is the absolute temperature in kelvin (K), R is the universal gas constant (1.987 cal/K·mole), γ°_M is the Henry's Law activity⁴ coefficient (based on atom fraction) of M at infinite dilution in iron, M_{Fe} is the atomic weight of iron and M_M is the atomic weight of M (DAR53).

Equation 2 can also be written as the difference of Equation 5 (below) and Equation 4.



Therefore, $\Delta F^\circ_2 = \Delta F^\circ_5 - \Delta F^\circ_4$ and the Gibb's free energy change for Equation 1 can be written as

$$\begin{aligned} \Delta F^\circ_1 &= \Delta F^\circ_5 - \Delta F^\circ_3 - \Delta F^\circ_4 \\ &= \Delta F^\circ_{f,MO} - \Delta F^\circ_{f,FeO} - RT \ln \left(\frac{\gamma^\circ M_{Fe}}{100 M_M} \right) \end{aligned} \quad (6)$$

where ΔF°_f is the free energy of formation of the particular oxide.

³ Concentrations are expressed here as wt% instead of mass % since wt% is commonly used in the steelmaking literature. The terms are synonymous.

⁴ Generally, throughout this paper, activity refers to thermodynamic activity, not radioactivity.

At equilibrium

$$\begin{aligned}\Delta F_1^\circ &= -RT \ln K_1 \\ &= -RT \ln \left(\frac{a_{\text{Fe}} a_{\text{MO}}}{a_{\text{FeO}} a_{\text{M}}} \right)\end{aligned}\quad (7)$$

where a is the activity of each species in Equation 1 and K_1 is the equilibrium constant. In the steel bath, a_{Fe} can be assumed to be 1, while $a_{\text{FeO}} = \gamma_{\text{FeO}} N_{\text{FeO}}$. To estimate N_{FeO} , the mole fraction of FeO in the slag, the nominal composition of the slag was assumed to be 50 wt% CaO, 30 wt% SiO₂ and 20 wt% FeO. Thus, N_{FeO} is 0.167. Various investigators have described the activity of FeO in ternary mixtures of CaO, FeO, and SiO₂ (PHI51, ANS84). For the slag composition assumed here, based on the ternary diagram in ANS84, when N_{FeO} is 0.2, a_{FeO} is about 0.4, *i.e.*, γ_{FeO} is about 2. Consequently, $a_{\text{FeO}} = 0.333$.

For the dilute standard state, a_{M} is equal to wt% $\underline{\text{M}}$ and, for dilute solutions of MO in the slag, one can assume that $a_{\text{MO}} = N_{\text{MO}}$. It follows that

$$\frac{N_{\text{MO}}}{\text{wt}\% \underline{\text{M}}} = a_{\text{FeO}} \exp \left(\frac{-\Delta F_1^\circ}{RT} \right) \quad (8)$$

where $N_{\text{MO}}/\text{wt}\% \underline{\text{M}}$ is one form of the partition ratio for M between the melt and the slag.

For metal oxides other than those formed from divalent cations, the differing stoichiometry must be accommodated in equations 6, 7, and 8.

Using values of γ° for various solute elements in iron at 1,873 K tabulated by Sigworth and Elliott (SIG74)⁵ and free energy of formation data for oxides tabulated by Glassner (GLA57), partition ratios between melt and slag were calculated for this study and are presented in Table 1.

When the partition ratio is large, the solute element is strongly concentrated in the slag under equilibrium conditions. This is true for Al, Ca, Ce, Nb, Ti, U, and Zr, all of which have partition ratios (as defined here) of 80,000 or greater. Similarly, when the partition ratio is small, the solute element is concentrated in the molten iron. Examples of this are Ag, Co, Cr, Cu, Ni, Pb, Sn, Mo, and W, all of which have partition ratios of 0.008 or less. Mn, Si, and V, with partition ratios ranging from about 3 to 40, are expected to be more evenly

⁵ The value of γ° for Ce is from ANS84. A compendium of values for γ° similar to that in SIG74 has been prepared by Japan Society for the Promotion of Science (JAP88). Some differences exist between values in SIG74 and JAP88, particularly for W, Co, Pb, and Ti. JAP88 proposes a value of γ° for Ce_(l) of 0.332. This difference in γ° values does not affect the conclusions about Ce partitioning.

distributed between melt and slag. Ag will not react with FeO in the slag, so on the basis of slag/metal equilibria, this element should remain in the melt. However, Ag has a relatively high vapor pressure at steelmaking temperatures (*i.e.*, 10^{-2} atm at 1,816 K), so some would tend to be removed at a rate dependent on the rate of transfer of Ag vapor through the slag.

Table 1. Partition Ratios at 1,873 K for Various Elements Dissolved in Iron and Slag

M	Oxide	γ°_M	$\Delta F^{\circ}_{f,MO}$ (Kcal/mole) ^a	Partition Ratio	
				($N_{MO}/wt\%M$)	(mass in slag/ mass in metal)
Ag _(l)	Ag ₂ O	200	+20.6	3.89E-04 ^{b,c}	
Al _(l)	Al ₂ O ₃	0.029 ^d	-257	1.32E+05 ^b	
Ca _(g)	CaO	2240	-104	1.53E+09	1.1E+10
Ce _(l)	CeO ₂	0.026	-176	4.33E+07	1.1E+09
Co _(l)	CoO	1.07	-18.2	4.79E-05	5.0E-04
Cr _(s)	Cr ₂ O ₃	1.14	-80.0	1.21E-04 ^b	
Cu _(l)	Cu ₂ O	8.6	-11.0	1.99E-03 ^b	
Mn _(l)	MnO	1.3 ^e	-58.0	2.74E+00	2.7E+01
Mo _(s)	MoO ₃	1.86	-89.1	1.23E-05	2.1E-4
Nb _(s)	Nb ₂ O ₅	1.4	-275	8.12E+04 ^b	
Ni _(l)	NiO	0.66	-19.0	3.72E-05	3.9E-04
Pb _(l)	PbO	1400	-15.5	8.55E-03	3.2E-01
Si _(l)	SiO ₂	0.0013	-129	3.76E+01	1.9E+02
Sn	SnO ₂	2.8	-47.6	6.07E-06	1.3E-04
Ti _(s)	TiO ₂	0.038	-147	7.72E+04	6.6E+05
U _(l)	UO ₂	0.027	-180	8.87E+07	3.8E+09
V _(s)	V ₂ O ₅	0.1	-206	7.68E+00 ^b	
W _(s)	WO ₃	1.2	-96.2	2.77E-05	9.1E-04
Zr _(s)	ZrO ₂	0.037	-178	1.59E+08	2.6E+09

^a $\Delta F^{\circ}_{f,FeO} = -34.0$ Kcal/mole

^b $PR = N^{1/2}/wt\% M$

^c Ag will not react with FeO; Ag₂O is unstable at 1,873K

^d According to ANS84, $\gamma^{\circ}_{Al} = 0.005$

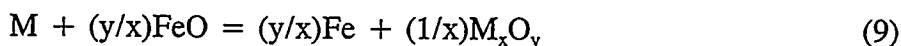
^e According to ANS84, $\gamma^{\circ}_{Mn} = 1.48$

It is instructive to examine the impact of assuming a dilute solution in iron rather than the pure element as the standard state for the solute. For those elements that tend to partition strongly to the melt (Co, Cr, Cu, Mo, Ni, Sn, and W), change of standard state from the pure metal to the dilute solution increases partitioning to the melt by factors of about 10 to

300. Lead is an exception, presumably due to its strong deviation from ideal solution behavior. Similarly, use of a dilute solution as the standard state decreases partitioning to the slag for the strong oxide formers such as Al, Ce, Nb, Ti, U, and Zr by factors of about 100 to 16,000. The exception is calcium with strong positive deviation from ideality. These observations emphasize the importance of using a dilute solution as the standard state when adequate data are available.

ESTIMATES OF THE PARTITIONING OF OTHER CONTAMINANTS

Values of the Henry's Law activity coefficient (γ°_M) are not available for many solute elements of interest in RSM recycling. However, an indication of partitioning between the melt and the slag can be obtained by calculating the Gibb's free energy for the reaction



where M is the pure component rather than the solute dissolved in the melt and FeO and M_xO_y are slag components. Values of the standard free energy change for Equation 9 are summarized in Table 2 for all instances where the reaction occurs as written.

Table 2 shows that Ac, Am, Ba, Np, Pa, Pu, Ra, Sm, Sr, Th, and Y all will react with FeO to form their respective oxides as indicated by the calculated free energies. Thus, these elements should be preferentially distributed to the slag. By chemical analogy to similar species in Table 1, one can estimate that the partition ratios ($N_{\text{MO}}/\text{wt\% M}$) should be on the order of 10^4 or greater⁶. The solute elements Bi, Cd, Cs, Ir, K, Na, Po, Re, Ru, Sb, Se, Tc, and Zn do not react with FeO either because the oxides are unstable or Equation 9 is thermodynamically unfavorable. Of these elements, Ir, Re, Ru, and Tc are expected to remain in the melt. As indicated in Table 3, the solute elements Bi, Cd, Cs, Po, Sb, Se, and Zn have low boiling points and would be expected to vaporize from the melt to some degree at typical steelmaking temperatures of 1,823 to 1,923 K. For example, Cs would tend to be removed at a rate dependent on the rate of transfer of vapor through the slag unless some stable compound such as Cs_2SiO_3 forms in the slag. Should Cs_2O form during the melting process before a continuous slag had formed, it would be volatilized since the boiling point of the oxide is about 915 K. The boiling point of metallic cesium is in the same temperature range. Even though an element may have a low boiling point, it cannot be assumed, a

⁶ The free energies in Table 2 were recalculated assuming that γ° in Equation 6 was unity and partition ratios were then calculated using Equation 8. All partition ratios calculated in this manner for elements expected to partition to the slag were greater than 10^4 except Ba ($6.3\text{E}+03$) and Ra ($3.2\text{E}+02$). If all these calculated partition ratios were reduced by a factor of 10^3 to adjust for the fact that values of γ° are expected to be less than unity, estimated partition ratios are greater than 10^3 for all slag formers except Ba ($6.3\text{E}+00$), Ra ($3.2\text{E}-01$), and Sr ($1.5\text{E}+01$). These three elements are in Group II of the periodic table and have electronic structures and chemical properties similar to Ca. As discussed previously, Ca has a value of γ° of 2,240. By analogy, one would expect that the partition ratios of Ba, Ra, and Sr would actually be higher than calculated with a unity value for γ° . For example, if γ° for Ra was 2,000, the partition ratio as defined by equation 8 would be $6\text{E}+05$.

priori, that the element will completely vaporize from the melt. Some may remain in the melt and some may be contained in the slag. For example, elements such as Ca, Mg, K, and Na are found as oxides and silicates in steel slags (HAR90).

Pehlke has shown that, for a solute M dissolved in a solvent (liquid Fe), the following equation applies (PEH73):

$$P_M = P_M^\circ \gamma_M N_M \quad (10)$$

where - P_M is vapor pressure of M over melt
 P_M° is vapor pressure of pure M [$P_M^\circ = f(T)$]
 γ_M is activity coefficient of M in melt
 N_M is mole fraction of M in melt

Thus as the temperature of the melt increases, the quantity of the volatile element M in the melt decreases by an amount determined by the temperature dependency of P_M° . Based on vapor pressure data for Pb, Sb, and Bi from BRA92 and Zn from PER92, one can estimate that increasing the temperature of the iron bath from 1,873 to 1,923 K will reduce the content of Pb, Sb, or Bi by about 25% while Zn will be reduced by about 18% (assuming that γ_M is independent of temperature over the same range and P_M is constant). Actually, γ_M is an increasing function of temperature for Sb (NAS93) and a decreasing function for Zn (PER92).

Table 2. Standard Free Energy of Reaction of Various Contaminants with FeO at 1,873 K

Contaminant	Oxide	ΔF° (Kcal)	Comments
Ac _(l)	Ac ₂ O ₃	-120	Ac should partition to slag
Am _(l)	Am ₂ O ₃	-103	Am should partition to slag
Ba _(l)	BaO	-57.1	Ba should partition to slag
Bi _(g)	Bi ₂ O ₃		Bi will not react with FeO, some may vaporize from melt
Cd _(g)	CdO		CdO unstable at 1,873 K, Cd should vaporize from the melt
Cs _(l)	Cs ₂ O		Cs ₂ O unstable at 1,873 K, Cs should vaporize from melt, some Cs may react with slag components
Ir _(s)	IrO ₂		IrO ₂ unstable above $\approx 1,100$ K, Ir should remain in melt
K _(g)	K ₂ O		K ₂ O less stable than FeO, other K compounds stable in slag
Na _(g)	Na ₂ O		Na ₂ O less stable than FeO, other Na compounds stable in slag
Np _(l)	NpO ₂	-100	Np should partition to slag
Pa _(l)	PaO ₂	-94.7	Pa should partition to slag

Po _(g)	PoO ₂		PoO ₂ unstable above about 1,300 K, some may vaporize from melt
Pu _(l)	Pu ₂ O ₃	-87.6	Pu should partition to slag
Ra _(g)	RaO	-47.7	Ra should partition to slag
Re _(s)	ReO ₂		Re will not react with FeO, Re should remain in melt
Ru _(s)	RuO ₄		RuO ₄ unstable above about 1,700 K, Ru should remain in melt
Sb _(g)	Sb ₂ O ₃		Sb will not react with FeO, some may vaporize from melt
Se _(g)	SeO ₂		Se will not react with FeO, some may vaporize from melt
Sm _(l)	Sm ₂ O ₃	-102	Sm should partition to slag
Sr _(g)	SrO	-58.6	Sr should partition to slag, but low boiling point could cause some vaporization
Tc _(s)	TcO ₂		Tc will not react with FeO, should remain in melt
Th _(s)	ThO ₂	-142	Th should partition to slag
Y _(l)	Y ₂ O ₃	-101	Y should partition to slag
Zn _(g)	ZnO		Zn will not react with FeO, Zn should vaporize from melt

Table 3. Normal Boiling Point of Selected RSM Contaminants (DAR53)

Contaminant	Normal Boiling Point (K)
Bi	1,900
Cd	1,038
Cs	963
Pb	2,010
Po ₂	1,300
Ra	1,410
S ₂	1,890
Se ₂	1,000
Sb ₂	1,890
Zn	1,180

OBSERVED PARTITIONING

Dose modeling studies conducted by SC&A indicate that most retroactive scrap metal exposure scenarios are dominated by various isotopes of five elements - Cs, Co, Ra, Pu, and U. This section discusses available experimental and production information on the distribution of these possible radioactive contaminant elements among the melt, slag, and off-gas collection system in steelmaking.

Cesium

Based on free energy and vapor pressure considerations, Cs would be expected to be volatilized from the melt. Furthermore, Cs has no solubility in liquid iron. According to ASM93:

From the scant data reported here and by analogy with other iron-alkali metal binary phase diagrams, it is evident that Cs-Fe is virtually completely immiscible in the solid and liquid phases.

A number of investigators have reported measurements on the experimental distribution of Cs during steel melting. Sappok *et al.* observed during air induction melting of about 2,000 tons of steel that no Cs-134/137 remained in the melt (SAP90). Cs was found both in the slag and in the dust collection system but the distribution was not quantified.

Nakamura and Fujuki of the Japanese Atomic Energy Research Institute (JAERI) obtained similar results from air induction melting of both ASTM-A335⁷ and SUS 304 steels (NAK93). The Cs-137 was about equally distributed between the slag and the dust collection system, but only about 77% of the amount charged was recovered.

At the Idaho National Engineering Laboratory (INEL), Larsen *et al.* found Cs both in the slag and in the baghouse dust when melting contaminated scrap from the Special Power Excursion Reactor Test (SPERT) III (LAR85a). In tracer tests, Larsen *et al.* found that 5 to 10% of the Cs remained in type 304L stainless steel ingots (LAR85b).

Gomer described results of three 5-ton electric arc furnace and one 500-kg induction furnace melts in which the chemical form of Cs addition and the slag chemistry were varied (PFL85, GOM85). Based on the fraction of Cs-134 recovered, the distribution of this nuclide is summarized in Table 4, below.

⁷ This ASTM specification covers various seamless ferritic alloy steel pipes for high temperature.

Table 4. Distribution of Cs-134 Following Steel Melting

Furnace Type	Cs Addition	Cs Concentration (%)			Cs Recovery (%)
		Steel	Slag	Off Gas	
EAF	CsCl	0	0	100	100
Induction	CsOH	0	100	0	91
EAF	CsOH	0	7	93	50
EAF	Cs ₂ SO ₄	0	66	34	64

In the melt where the Cs addition was CsCl, the chloride—which is volatile below the steel melting temperature—was not collected in the slag because the slag had not formed before the CsCl had completely evaporated. In the induction furnace test, CsOH was added to the liquid steel under a quiescent acid slag. In the related arc furnace test with CsOH, the slag was not sufficiently acid to promote extensive formation of cesium silicate which would be retained in the slag. In the arc furnace melt with the Cs₂SO₄ addition, this compound was apparently incorporated into the slag to a significant extent.

Harvey concluded that the hot, basic slags typical of EAF melting were not conducive to Cs retention in the slag (HAR90). A comparison of three arc furnace melts with varying slag compositions showed the following amounts of Cs retention in the slag 16 minutes after Cs was added to the melt:

- SiO₂/CaO = 3.1/1, 48% recovery
- SiO₂/CaO = 1.3/1, <4% recovery
- SiO₂/CaO = 0.41/1, 0% recovery

In these tests, no Cs remained in the melt.

Menon *et al.* recounted that no Cs was found in the ingots or the slag after melting 332 tons of carbon steel in an induction furnace (MEN90), but substantial Cs-137 (21,000 Bq/kg) was collected in the ventilation filters. During production of two heats of stainless steel, no Cs was found in the ingots; 32% was in the slag; and 68% in the baghouse dust (MEN90).

Cobalt

Free energy calculations indicate that Co should remain primarily in the melt. Nakamura and Fujuki found this to be the case in 500-kg air induction melts of carbon steel and stainless steel where Co-60 was detected only in the ingots (NAK93). During the melting of six heats of contaminated carbon steel scrap at INEL some (unquantifiable) Co-60 activity was detected in the dust collection system and some in the slag (LAR85a). In subsequent tracer tests with three heats of type 304L stainless steel, between 96 and 97% of the Co-60 was recovered in the ingots (LAR85b). Sappok *et al.* noted that, during the induction

melting of steel, Co-60 was mostly found in the melt although unquantifiable amounts were detected in the slag and in the dust collection system (SAP90). In an earlier paper, Sappok cited the Co-60 distribution from nine melts totaling 24 metric tons as 97% in the steel, 1.5% in the slag and 1.5% in the cyclone and baghouse (PFL85). Schuster and Haas measured the Co-60 distribution in laboratory melts of St37-2 steel and reported 108% in the ingot, 0.2% in the slag and 0.2% in the aerosol filter (SCH90).

According to Harvey (HAR90), "cobalt 60 will almost certainly be retained entirely in the steel in uniform dilution in both electric arc and induction furnaces." In support of this conclusion, Harvey described two steel melts in a 5-ton electric arc furnace. In one test, highly reducing conditions were employed (high carbon and ferrosilicon) while, in the other, the conditions were oxidizing (oxygen blow). In neither case was any measurable Co activity found in the slag. The amount of Co-60 found in the melt was in good agreement with the amount predicted from the furnace charge. No Co-60 was found in the furnace dust although some was expected based on transfer of slag and oxidized steel particles to the gas cleaning system. Harvey concluded that the low level of radioactivity in the furnace charge (ca. 0.23 Bq/g) coupled with dilution from dust already trapped in the filters resulted in quantities of Co-60 in the off-gas below the limits of detection.

Menon commented on the air induction melting of 33.6 tons of carbon steel. No Co-60 was detected in the slag, but a small quantity was detected in the baghouse dust (1,300 Bq/kg). The amount remaining in the ingots was not quoted. In two heats of stainless steel weighing a total of 5,000 kg, 26×10^6 Bq of Co-58/Co-60 were measured in the ingots, 4×10^4 Bq in the slag and 7.8×10^4 Bq in the baghouse dust (MEN90).

Plutonium

Thermodynamic predictions suggest that plutonium will partition strongly to the slag. Harvey assumed, based on the chemical similarity of plutonium with thorium and uranium, that the plutonium will form a stable oxide and be absorbed in the slag (HAR90). However, he notes that because of its high density (11.5 g/cc), transfer of PuO_2 to the slag could be slow and some could possibly fall to the base of the furnace and not reach the slag.

Gerding *et al.* conducted small-scale (*i.e.*, 10 and 200 g) tests with plutonium oxide and mild steel in an electric resistance furnace (GER77). The melts were held in contact with various slags for 1 to 2 hours at 1,773 K under He at about 0.5 atm. Slag/steel weight ratios ranged from 0.05 to 0.20. The studies showed that the Pu partitioned to the slag and the partition coefficients (concentration in slag $\div$ concentration in metal) were 2×10^6 to 8×10^6 . Decontamination efficiency was about the same at 400 and 14,000 ppm Pu and composition variables among the various silicate slags were not significant to the partitioning.

Radium

Radium forms a stable oxide in the presence of FeO and thus would be expected to be found mainly in the slag. Starkey described results from the arc furnace melting of eight heats of steel contaminated with Ra (STA61). The average concentration of the Ra in the steel was 9×10^{-11} g Ra/g steel and in the slag was 1.47×10^{-9} g Ra/g slag. Slag/metal mass ratios were not reported, but assuming the mass slag/mass metal is 0.1, then the partitioning ratio (mass Ra in slag/mass of Ra in metal) is > 16 .

Uranium

Free energy calculations suggest that uranium should partition to the slag. Heshmatpour and Copeland conducted a number of small-scale partitioning experiments where 500 to 1,000 ppm of UO_2 was added to 50 to 500 grams of mild steel and melted in either an induction furnace or a resistance furnace. Slag and crucible composition were varied as well (HES81). With the use of highly-fluid basic slags and induction melting, partition ratios (mass in slag/mass in metal) from 1.2 to > 371 were obtained.

Larsen reported that, although U was not detected in the feed stock, it was sometimes found in the slag and in the baghouse dust (LAR85a). Schuster and Haas determined in small laboratory melts that when slag formers were added, the U content was reduced from 330 μg U/g Fe to 5 μg U/g Fe (SCH90). Harvey commented that British Steel had occasionally used uranium as a trace element in steelmaking (HAR90). Based on their experience, the uranium was absorbed in the slag in spite of the fact that UO_2 , which has a density (10.9 g/cc) significantly higher than iron, could conceptually settle in the melt.

Abe *et al.* studied uranium decontamination of mild steel using small (100 g) melts in laboratory furnace (ABE85). Melting was done under reduced pressure Ar (200 mm Hg) in alumina crucibles with 10 wt% flux added to the charge. The uranium decontamination factor was found to be a function of the initial contamination level varying from about 200 to about 5,000 as the uranium concentration increased from 10 to 1,000 ppm. Optimum decontamination occurred when the slag basicity was 1.5 with a $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2$ slag. Decontamination was further enhanced by additions of CaF_2 or NiO to the slag.

SUMMARY

In summarizing the distribution of the various radioactive contaminants that might be introduced into the steel melting process, one must define certain process parameters including:

- ratio of mass of scrap charged to mass of steel produced (R_1)
- ratio of mass of slag to mass of steel (R_2)
- ratio of mass of baghouse dust to mass of steel produced (R_3)
- fraction of baghouse dust from slag (%SI)

- fraction of baghouse dust from steel (%St)
- dust collector efficiency (%eff)

The following values are proposed for each of these process parameters:

- R_1 - 0.9⁸
- R_2 - 0.13⁹
- R_3 - 30 lbs/ton of steel (33 to 36 pounds per EAF ton of carbon steel produced) (ADL93)¹⁰
- %Sl - 33.3¹¹
- %St - 66.7
- %eff - 99.5 (SCA95)

Based on these process parameters and the information presented previously, the assumed distribution of the various elements is summarized in Table 5. If a radionuclide tends to concentrate in the melt, the amount of baghouse dust contributed by the melt would be 20 lbs/ton or 1% of the radioactivity in the melt. Similarly, if a nuclide tends to concentrate in the slag, the amount of baghouse dust contributed by the slag is 10 lbs/ton and, since the mass of the slag is 1/10 the mass of the melt, 5% of the slag activity would be transported to the baghouse. For simplicity, the baghouse efficiency is assumed to be 100% in evaluating atmospheric releases. Where varying results are presented by different investigators, emphasis was placed on results which represented EAF melting of carbon steel with basic slags.

Considerable care must be used in interpreting the experimental results reported in the literature and applying them to the predicted contaminant distribution during the EAF melting of carbon steel. Some concerns are summarized below:

⁸ Bayou Steel states that they typically produce 0.882 tons of steel billets per ton of scrap charged (private communication with Al Pulliam, June 25, 1996). When averaged over the total U.S. production, the process efficiency is much higher. According to the U.S. Geological Survey for the year 1994, the amount of recirculating home scrap was 132,300 tons, while 39.5 million tons of EAF steel were produced. Thus, the annual average ratio of home scrap to steel produced was 0.3% (private communication with M. Fenton, June 25, 1995). The assumed value of 0.9 is based on 1.5% loss to the baghouse, 2% to the slag, 5% to home scrap which is recycled in subsequent heats, and 1.5% unaccounted.

⁹ According to R. West of International Mill Services, a major slag marketer, between 0.12 and 0.14 tons of slag are generated per ton of steel produced (private communication - June 25, 1996). This range of values appears to be a more realistic than the 10% cited in STU84a and the average was used in subsequent modeling.

¹⁰ Based on the baghouse dust composition reported by SAIC (McK95) adjusted for the ZnO content and assuming that all the Fe_2O_3 and half the MnO and SiO_2 are from the melt, the % Sl is 33%.

¹¹ Based on the baghouse dust composition reported by SAIC (McK95) adjusted for the ZnO content and assuming that all the Fe_2O_3 and half the MnO and SiO_2 are from the melt, and % Sl is 33%.

- In many cases, the results are based on induction melting which is a more quiescent process than arc melting. Agitation of the slag and melt should tend to drive reactions toward equilibrium.
- Often, the slag chemistry was either not cited or no attempt was made to optimize the slag/metal reactions as required in commercial melting practice.
- In some cases, results are quoted for stainless steels rather than carbon steels. The activity of solutes in the highly alloyed steel melt should be different from that in plain carbon steels and the slag chemistry will be significantly altered.
- Perspective on kinetically driven processes may be altered by the scale of the melting operation.
- Melt temperatures and holding time in the molten state may be quite different in cited experiments as compared to commercial practice. This can significantly impact conclusions especially with regard to volatile elements.

Table 5. Proposed Distribution of Radionuclides during Carbon Steelmaking (%)

Element	Melt	Slag	Baghouse	Atmosphere	Comments
Ac		95	5		
Ag	99/75		1/25		
Am		95	5		
Ba		95	5		
Bi			100		Assumed same as Pb
C	100/27			0/73	Depends on melting practice
Ca		95	5		
Cd			100		
Ce		95	5		
Cl		50	50		Some Cl in baghouse dust (McK95)
Cm		95	5		
Co	99		1		
Cr	99/40	0/57	1/3		Longest-lived isotope: $t_{1/2} = 27.7$ d
Cs		0/5	100/95		
Cu	99		1		Longest-lived isotope: $t_{1/2} = 2.58$ d
Eu		95	5		
Fe	97	2	1		
H	10			90	Needs further analysis
I				100	

Table 5. Proposed Distribution of Radionuclides during Carbon Steelmaking (%)

Element	Melt	Slag	Baghouse	Atmosphere	Comments
Ir	99		1		
K		50	50		Needs further analysis
Mn	24/65	72/32	4/3		
Mo	99		1		
Na		50	50		Needs further analysis
Nb		95	5		
Ni	99		1		
Np		95	5		
P	9	87	4		Longest-lived isotope: $t_{1/2} = 25.3$ d
Pa		95	5		
Pb			100		
Pm		95	5		
Po			100		
Pu		95	5		
Ra		95	5		
Re	99		1		
Rn				100	
Ru	99		1		
S	19	77	4		Slag % is max. expected. Melt % may be higher. (Maximum $t_{1/2} = 87.2$ d.)
Sb	99/80		1/20		Conflicting reports on Sb distribution
Se	19	77	4		Assumed to behave like S
Sm		95	5		
Sr		95	5		
Tc	99		1		
Th		95	5		
U		95	5		
Y		95	5		
Zn	20/0		80/100		Zn difficult to remove from melt at low concentrations
Zr		95	5		

From a metal concentration perspective, the contamination levels in RSM will be quite low. Consequently, some of the partition predictions made here may be overridden by other factors. For example, if evaporation kinetics of volatile elements control the release, small quantities of zinc may remain in the steel. For strong oxide formers which should partition

to the slag, transfer may be impeded due to the high density of many of the actinide and rare-earth oxides at low concentration levels. The experimental evidence of this possibility is mixed. For example, Eu_xO_y seems to be removed from the melt during normal electric arc furnace melting, but CeO_2 may not be completely removed. One investigator reported that the uranium decontamination factor in mild steel increased with increasing contaminant levels (ABE85).

In addition, the expected partitioning may be altered significantly if melting practice is changed. Examples presented from the steelmaking literature include the removal of Nb from the slag to the melt and movement of W in the opposite direction (WEN90, OST94).

The information in Table 5 does not explicitly consider home scrap or contaminated furnace refractories. Home scrap (*i.e.*, the scrap from the melting process that is recirculated into future furnace charges) should have the same radionuclide distribution as the melt from which it was produced. The contamination of furnace refractories was not studied in this report. However, it should be noted that residuals remaining in the furnace from a melt are frequently recovered in the next one to two melts. For example, when melting a low alloy steel containing, say, 1% Cr, the following heat or two will contain more Cr than expected from the furnace charge for the ensuing heats.¹²

¹² Private communication with J. R. Stubbles, Charter Steel Company - July 1, 1996.

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Management Options for Recycling Radioactive Scrap Metals

Jean-Claude Dehmel
John Bartlett
S. Cohen & Associates, Inc.

John MacKinney
U.S. Environmental Protection Agency

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John MacKinney, U.S. Environmental Protection Agency
John Bartlett, S. Cohen & Associates, Inc.

The feasibility and advantages of recycling radioactive scrap metals (RSM) have yet to be assessed, given the unique technical, regulatory, safety, and cost-benefit issues that have already been raised by a concerned recycling industry. As is known, this industry has been repeatedly involved with the accidental recycling of radioactive sources and, in some cases, with costly consequences. If recycling were deemed to be a viable option, it might have to be implemented with regulatory monitoring and controls. Its implementation may have to consider various and complex issues and address the requirements and concerns of distinctly different industries.

There are three basic options for the recycling of such scraps. They are: 1) recycling through the existing network of metal-scrap dealers and brokers, 2) recycling directly and only with specific steelmills, or 3) recycling through regional processing centers. Under the first option, scrap dealers and brokers would receive material from RSM generators and determine at which steelmills such scraps would be recycled. For the second option, RSM generators would deal directly with selected steelmills under specific agreements. For the third option, generators would ship scraps only to regional centers for processing and shipment to participating steelmills. This paper addresses the potential advantages of each option, identifies the types of arrangements that would need to be secured among all parties, and attempts to assess the receptivity of the recycling industry to each option.

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1. Introduction

The firm of S. Cohen & Associates, Inc. (SC&A) is assisting the U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, in collecting technical information to evaluate the future development of residual radioactivity standards for releasing formerly contaminated equipment and scrap metals. Equipment and scrap metals are being considered for release for unrestricted use, following decontamination and decommissioning from the private sector and Federal facilities. The U.S. Department of Energy has initiated an environmental restoration program involving the clean-up of currently operating facilities and those that were once used in weapons programs and development of civilian nuclear power plants. From the private sector, it is expected that over the next decades, several nuclear power plants will be taken out of service and slated for decontamination and decommissioning.

Such activities will result in the generation of large amounts of surface and volume-contaminated radioactive scrap metals (RSM), including obsolete equipment, process components, structural steel, shielding materials, piping, tanks, wiring, etc. Metals which might be present in scraps include primarily carbon and stainless steel, aluminum, copper, lead, and nickel, and other alloys, e.g., brass and bronze. Ultimately, such materials might be recycled at steelmills, smelters, and foundries and appear as finished products or used as feed-stocks by other industries. Accordingly, the use of such scraps could have adverse impacts on the recycling industry, unless properly regulated.

It should be noted that this paper addresses only residual amounts of radioactivity, which would be governed by limits assigned to first protect public health and the environment. Materials with contamination levels above the criteria would not be recycled, but would be disposed of at designated facilities, e.g., licensed radioactive waste disposal sites. In this paper, the use of "RSM," as a designator, is retained for the purpose of differentiating the origin of such scraps, while recognizing that scrap metals which meet clearance or unrestricted release criteria could and should be managed like any other types of scrap metals.

2. Management Options

There are three basic options for the recycling of such scrap metals. They are: 1) recycling through the existing network of metal-scrap dealers and brokers, 2) recycling directly and only with specific steelmills, or 3) recycling through regional processing centers.

2.1 Recycling Through Existing Network of Metal Scrap Dealers and Brokers

Under the first option, scrap dealers and brokers would receive such scraps and determine at which steelmills it would be recycled, using existing clients or new ones. This option offers the competitive advantage of a large pool of scrap dealers and brokers bidding for scrap metals. For some types of scraps, e.g., stainless steel, local market forces may result in more favorable bidding rates. On the other hand, some steelmills may refuse to recycle such scraps for various reasons. For example, product specifications imposed by customers may exclude the presence of radioactivity in steel, e.g., film products, film manufacturing equipment, computer chips, and medical implants. Similarly, the steel industry may decide that the management of slag and baghouse dust is the critical factor, rather than residual levels of radioactivity in steel. For example, firms that routinely process such materials may no longer accept them because of the presence radioactivity. In other instances, the decision not to use such scraps may be a matter of corporate policy, taking into account a changing regulatory climate, competitive market forces, corporate liability, employee relations, public perception, etc.

Finally, metal scrap dealers or brokers may not accept such scraps for similar reasons. For example, under existing practices, scrap dealers supply materials to steelmills under buy-back agreements if the scrap metals and resulting melt fail to meet contract specifications. Since steelmills typically rely on several dealers or brokers to supply scrap metals, there would be some questions as to the origin the offending materials and, consequently, who should bear the

responsibility and costs of the resulting melt and disposition of slag and baghouse dust. Scrap dealers could also be held liable for other costs, including site and plant clean up and disposition of slag and baghouse dust.

In either cases, it is expected that RSM generators may have to provide ongoing technical support addressing various radiological and regulatory issues. Without a commitment to provide such support, it is expected that the recycling industry might be technically overwhelmed and refuse to process such scraps at the first sign of difficulties.

2.2 Recycling Directly With Specific Steelmills

For this option, RSM generators would deal directly with selected steelmills under specific agreements. In this option, it is assumed that steelmills would have conducted a benefit analyses, assessed the potential business risks and liabilities, and, in the end, accept such risks. This option also offers the competitive advantage of a large pool steelmills and possibly more secure business agreements among steelmills and RSM generators. Essentially, all the issues addressed in the first option for steelmills would apply here as well. It is assumed that the decision to recycle such scraps would take into account that there may be alternate outlets for the resulting steel. If not, the steelmill may be left with steel products it cannot sell, should a customer renege a contract. It should be noted that some steelmills may see the use of recycling such scraps as a business opportunity if it were determined that such scrap metals could be obtained at costs that are below current market rates. For example, steelmills that are marginally profitable may see this as an opportunity to reduce losses.

As before, RSM generators will have to provide ongoing technical support. Without such a commitment, it is expected that the recycling industry will simply refuse to process such scraps, especially if problems are encountered.

2.3 Recycling Through Regional Processing Centers

For the third option, RSM generators would ship scrap metals directly to regional centers for processing and shipment to participating steelmills. The location of the processing centers would be based on the future availability and amounts of such scraps, receptivity of the steel recycling industry, and business considerations. The processing center would conduct radiological surveys for confirmatory purposes, metallurgical analyses, sort and blend scraps, and prepare shipments according to scrap grades meeting ISRI specifications or those of specific steelmills (ISRI 1994). It is envisioned that the processing centers would combine the types of services found at scrap yards and decontamination facilities. The resulting decontamination waste, if any, and RSM failing to meet recycling criteria would be processed for disposal or returned to the generator. The processing center would be responsible for demonstrating that scrap metals shipped to steelmills meet all radiological clearance or free release criteria.

This option offers several advantages. First, the centers combine the roles of scrap brokers and dealers, thereby eliminating a segment of the recycling industry that is not technically competent

to address certain technical issues. The centers would offer a safeguard in ensuring that only RSM that meet regulatory criteria are recycled at steelmills. It is expected that this quality control role would be viewed favorably by regulators and the public. The centers would offer simpler and more reliable logistics for processing RSM and provide technical support to participating steelmills. Finally, materials processed through the regional centers could be made available to scrap dealers, in addition to participating steelmills.

3. Receptivity of the Recycling Industry

If the recycling and steelmaking industries were to process metal scraps of such origin, it is anticipated that such a recycling program would have to be implemented using regulatory controls and industry guidelines. Its implementation would have to consider a broad range of issues addressing the requirements and concerns of distinctly different industries. It is also recognized, that the steel scrap recycling industry, over the past decade, has been involved with the inadvertent recycling of radioactive materials. Accordingly, whatever those requirements might be, it would be imperative to present a comprehensive recycling program. Industry practices might have to change to reflect specific considerations. Such changes in practices would insure the protection of the workers, general public, and the environment.

Since 1983, there have been 24 incidents in the U.S. alone involving the inadvertent melting of radioactive materials (Lubenau and Yusko 1996, 1995). However, such accidents have primarily involved the introduction of high specific activity radioactive sealed sources that are several orders of magnitude higher in radioactivity than what is being considered in this paper. On the other hand, naturally occurring radioactivity found in piping and process equipment is several orders of magnitude lower in radioactivity levels than that found industrial or medical sealed sources. The Nuclear Regulatory Commission and States have also warned the industry and conducted several workshops addressing radiation safety and hazard recognition. The Steel Manufacturers Association has also issued a position statement on the problem (SMA 1995). As a result, the industry has responded by installing radiation monitors to detect the presence of radioactivity in scrap shipments and has proposed recommended practices (ISRI 1993, Kiser 1996). Typically, radiation monitoring systems have been installed at truck and rail car weighing stations. If the monitor detects elevated radiation levels, the load is set aside and the owner or broker and State are contacted. The practice is to return the shipment to its originator.

In a study sponsored by the Petroleum Environmental Research Forum (PERF), a survey of the U. S. steel industry was conducted to assess current steel production processes, recycling practices, in-house radiological capabilities, and receptivity of the industry in accepting NORM-contaminated equipment (Dehmel et al. 1992). A total of 121 questionnaires were sent to steel companies. A total of twenty-seven companies completed and returned the survey questionnaire, for a 22% response rate. The following, as adapted from the 1992 PERF Study, summarizes some of the major findings. The results reflect industry practices of 1992.

Twenty-six of the 27 total respondents completed the question which asks if they would consider recycling NORM-contaminated scrap, if they were provided with adequate information on issues of health, safety, etc. The responses were:

YES	=	1 respondent	(3.9%)
NO	=	11 respondents	(42.3%)
MAYBE	=	9 respondents	(34.6%)
DON'T KNOW	=	5 respondents	(19.2%)

A second question within this category specifically asked if they would consider dedicating production runs for NORM-contaminated equipment if there were a commitment by the oil and gas industry to re-use that steel. All 27 returned questionnaires responded to this question. The responses were:

YES	=	2 respondents	(7.7%)
NO	=	12 respondents	(46.1%)
MAYBE	=	6 respondents	(23.1%)
DON'T KNOW	=	6 respondents	(23.1%)

Based recent informal discussions with representatives from two steelmills located in Pennsylvania, it has been noted that neither steelmill would consider recycling RSM. The major concerns that were identified included corporate liabilities, increased occupational risks to employees, inability to sell or dispose of slag and baghouse dust, and an uncertain regulatory climate, which may result in future environmental liabilities.

Finally, it is not clear if the recycling of such scraps will provide any significant savings to RSM generators and recycling and steelmaking industries. Savings would have to be weighed against other costs, e.g., transportation, personnel, facilities, equipment, liabilities, etc. The recycling of such scraps may also offers other gains to the steel industry. For example, a mean to conserve natural resources, including energy and help fulfill temporary shortages of high quality scrap at the regional level, since scrap metals are seldom shipped over great distances. Finally, in view of the potential costs of managing such a recycling program, scrap dealers and steelmills might only take such scraps at prices that are lower than market rates to help defray such expenses.

4. Recycling Industry Issues

The recycling of such scraps may also require that additional protective measures be implemented at scrap yards and steelmills to address various types of impacts. Many of the issues and protective measures described below apply equally to both, since they are essentially generic. In a regulatory context, however, it is not clear whether there would be a need to extend any requirements to protect workers at scrap yards or steelmills and the environment around such facilities. Currently, there are no regulatory mechanisms to impose specific requirements to these industries, unless operators specifically apply for licenses to possess radioactive materials under existing NRC or State regulations.

4.1 Slag Management

The disposal of furnace slag might be questioned since it might be radioactive. Spent slag is collected for re-use, processing, and disposal. Steelmill operators might have to demonstrate that this would not be a problem, either to a State or Federal agency or slag disposal sites. Currently, about 50% of the facilities keep slag on company property (either on or off-site) for disposal or as stockpiles. The balance of the facilities ship slag to third parties for use in specific applications or metal recovery. The issue of introducing radioactivity may also raise the question as to whether slag is a mixed waste. Such concerns might close access to commercial outlets that process or manage slag for steelmills.

The amounts of potentially contaminated slag could be minimized by controlling the quantities of such scraps introduced in each furnace charge. Similarly, residual slag adhering to discarded refractory bricks would generally be of the same composition of the slag that was in contact with the refractory liner when the furnace was shutdown. Accordingly, the radioactivity of the slag adhering to refractory bricks could be minimized by eliminating such scraps from several charges and melts prior to shutdown.

4.2 Steelmill Stack Emissions

A question might be raised regarding the need to monitor airborne stack emissions from the steelmills. Such a requirement would be driven by the need to assess potential radiological exposures to members of the general public in downwind locations. Risk assessment analyses and engineering studies could be used to determine whether there might be a need to retrofit existing emission control systems or install radiation monitoring systems.

4.3 Personnel Protection

In terms of occupational safety, it is envisioned that such scraps destined for recycling would cause relatively low exposures and risks for two reasons. First, such equipment would have been surveyed and screened out. Any equipment with external radiation exposure rates and contamination levels above specified criteria would be excluded from the recycling process. Second, scrap yards and steelmills rely extensively on remote handling methods, such as cranes, conveyors, etc. Together, such methods minimize exposures and close contact with scraps, thereby further reducing occupational radiation exposures.

The major difference between scrap yards and steelmills is the handling of slag and baghouse filters and dust at steelmills. Depending upon how change-out procedures are set-up, personnel may come in close contact with slag, spent filters, and dust. Since the amount of scraps introduced in each furnace charge might be diluted with other scraps, the resulting concentrations of radioactivity in slag, spent filters, and dust are expected to be very low. Similarly, residual slag adhering to refractory bricks can be minimized by eliminating such scraps from several melt cycles prior to shutdown.

Potential internal radiation exposures due to inhalation and inadvertent ingestion are primarily encountered when equipment are being disassembled or repaired. At steelmills, such equipment include furnaces, ladles, tundishes, shop ventilation systems, and baghouses. At scrap yards, such equipment include shredders, bailers, shears, conveyors, and cranes. Internal exposures are dependent upon how much material is resuspended as an aerosol and inhaled. Inadvertent ingestion is possible when smoking, eating, and chewing in the work place or when following poor personal hygiene. Current industry procedures do not allow such practices in response to OSHA requirements.

4.4 Environmental Protection

Certain operations might result in the generation of radioactive contamination, which may be released in the environment. Such operations might involve the disassembly and cutting of large components and use of processing equipment, such as balers, shredders, and shears. In all cases, contamination control measures might be applied using fairly simple measures. Prior to transporting any equipment, surveys might be conducted to determine the presence and extent of any loose surface contamination. Equipment openings should be flanged or capped-off to prevent the release of contamination during shipments. Similarly, equipment should be free of any standing liquids, sludge, or loose residues.

Whenever equipment is being disassembled, cut open, or processed by mechanized equipment, potential releases can be controlled by localizing the work to the smallest area possible, using confinement methods, and applying dust suppression techniques to minimize or eliminate fugitive emissions. Dust suppression methods include the use of temporary or permanent enclosures. Personnel and vehicular traffic in and out of such areas should be controlled to prevent contamination from being spread out to otherwise clean areas. Work areas should be clearly delineated and posted with signs or instructions describing entry and exit procedures. Radiation and contamination surveys should be conducted periodically to verify that radioactivity is not being dispersed from designated work areas. For outdoor operations, the work area should be prepared to minimize the entrainment of the contamination by surface water run-off or ground infiltration from rain water.

4.5 Equipment Transportation

A shipment manifest and tracking system could be implemented to ensure the safe transportation and accountability of such scraps while in transient. Such a system could be based on Department of Transportation (DOT) regulations, which address the shipment of radioactive materials (including RSM). The regulations are contained in 49 CFR Parts 170 to 189. The DOT regulations address exemptions, packaging, marking and labeling, placarding, monitoring, accident reporting, and shipment manifesting. Most States have adopted, by reference DOT, shipping regulations. In some instances, States have also imposed additional requirements for the transportation of radioactive materials on specific highways (e.g., turnpikes, bridges, tunnels, etc.).

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APPENDIX A
Participants List

Richard Aiken
U.S. DOE-Hq-Policy
1000 Independence Avenue
Washington D.C. 20585

Phone: **202 586-0415**
Fax: **202 586-1737**
E-mail: **richard.aiken@hq.doe.gov**

Robert Alvarez
U.S. DOE, PO-5
1000 Independence Avenue, SW
Washington DC 20585

Phone: **202 586-4640**
Fax: **202 586-3047**
E-mail:

Ken Ayers
Vanderbilt University
P.O. Box 1831, Station B
Nashville TN 37235

Phone: **615 322-2720**
Fax: **615 322-3365**
E-mail:

Young-Jik Bai
Korea Power Engineering Company
360-9 Mabuk-ri, Kusong-myun
Youngin-si Kyunggi-do 449-910
Korea

Phone: **82 331 269-3479**
Fax: **82 331 284-7640**
E-mail:

Louis C. Allen
UT Energy, Environment and Resources
Center
Conference Center Bldg., Suite 311
Knoxville TN 37996 4134

Phone: **423 974-4251**
Fax: **423 974-1838**
E-mail: **lallen1@utk.edu**

Ray R. Arp, Jr.
Lockheed Martin Energy Research
P.O. Box 2008
Oak Ridge TN 37831 6326

Phone: **423 241-4752**
Fax: **423 574-4142**
E-mail: **ArprJr@ornl.gov**

Raymond G. Azrak
CORPEX Technologies
P.O. Box 13486
Research Triangle Park NC 27703

Phone: **919 941-0847**
Fax: **919 941-0652**
E-mail:

Cheryl L. Baker
M4 Environmental Management
1000 Clearview Court
Oak Ridge TN 37831

Phone: **423 220-5066**
Fax: **423 220-5048**
E-mail: **bakerc@m4lp.com**

Kevin Barber
Jacobs Engineering
175 Freedom Blvd
Kevil KY 42053

Phone: **502 462-2550**
Fax: **502 462-2551**
E-mail: **kevin.barber@jacobs.com**

James B. Barrett
B & W, NESI
P.O. Box 10548
2220 Langhorne Road
Lynchburg VA 24506

Phone: **804 948-4814**
Fax: **804 948-4635**
E-mail: **jim.r.barrett@mcdermott.com**

William J. Biloski
Lockheed Martin Energy Systems
P.O. Box 2003
Oak Ridge TN 37831 7169

Phone: **423 574-4182**
Fax: **423 576-7536**
E-mail:

John K. Boren
Vanderbilt University
P.O. Box 1831, Station B
Nashville TN 37235

Phone: **615 322-2720**
Fax: **615 322-3365**
E-mail:

Donald A. Barbour
Carolina Metals, Inc.
681 Emory Valley Road, Suite B
Oak Ridge TN 37830

Phone: **423 220-8300**
Fax: **423 220-8301**
E-mail:

Thomas K. Bick
Kilpatrick & Cody, L.L.P.
700 13th Street NW, Suite 800
Washington D.C. 20005

Phone: **202 508-5844**
Fax: **202 508-5858**
E-mail:

William L. Boettinger
Westinghouse Savannah River Company
MS 719-3A
P.O. Box 616
Aiken SC 29808

Phone: **803 725-4833**
Fax: **803 725-1528**
E-mail: **william.boettinger@srs.gov**

Steven J. Bossart
U.S. DOE, Morgantown
P.O. Box 880
3610 Collins Ferry Road
Morgantown WV 26505

Phone: **304 285-4643**
Fax: **304 285-4403**
E-mail: **sbossa@metc.doe.gov**

Val Bouchard
215 Lakeview Lane
Oak Ridge TN 37830

Phone: 423 482-5802

Fax: 423 220-2112

E-mail:

Sherman D. Brady
Carolina Metals, Inc.
P.O. Box 1366
Barnwell SC 29812

Phone: 803 259-5985

Fax: 803 259-3622

E-mail:

Louise M. Buker
Jacobs Engineering Group
125 Broadway
Oak Ridge TN 37923

Phone: 423 220-4826

Fax: 423 220-4848

E-mail: louise.buker@jacobs.com

Dan Burns
Trinity Environmental Systems
2260 Park Ave, Suite 407
Cincinnati OH 45206

Phone: 513 221-0100

Fax: 513 221-4377

E-mail: trinity@eds.net

Frederick Carden, Jr.
Lockheed Martin Energy Systems, Inc.
P.O. Box 2003
Oak Ridge TN 37831 7357

Phone: 423 574-8025

Fax: 423 576-6222

E-mail: wfc@ornl.gov

J. R. Chastain
Ameristeel
1919 Tennessee Avenue
Knoxville TN 37921

Phone: 423 546-0102

Fax: 423 637-8293

E-mail:

Bruce Clemens
117 Brentwood Drive
Oak Ridge TN 37830

Phone: 423 481-0187

Fax: 423

E-mail: bclemens@utk.edu

Libby Clemens
CDM Federal
800 Oak Ridge Turnpike, Suite 500
Oak Ridge TN 37830

Phone: 423 482-1065

Fax: 423 481-3835

E-mail:

John A. Clinard
Lockheed Martin/Oak Ridge National
Laboratory
P.O. Box 2009
Oak Ridge TN 37830

Phone: **423 574-0727**
Fax: **423 241-3314**
E-mail: **clinardja@ornl.gov**

Kelly W. Crooks
U.S. Army Industrial Operations Command
ATTN: AMSIO-DMW
Rock Island IL 61299 6000

Phone: **309 782-0338**
Fax: **309 782-2988**
E-mail: **kcrooks@ria-emh2.army.mil**

Kristof W. Czartoryski
Tennessee Dept. of Environment &
Conservation
DOE Oversight Division
761 Emory Valley Road
Oak Ridge TN 37830

Phone: **423 481-0163**
Fax: **423 482-1835**
E-mail:

Kim Davis
UT Energy, Environment and Resources
Center
Conference Center Bldg., Suite 311
Knoxville TN 37996 4134

Phone: **423 974-4251**
Fax: **423 974-1838**
E-mail:

Timothy W. Coffield
Westinghouse Savannah River Company
Bldg. 705-3C, Room 17
P.O. Box 616
Aiken SC 29802

Phone: **803 557-6316**
Fax: **803 557-6306**
E-mail:

Jerry R. Cunningham
Lockheed Martin Energy Systems
P.O. Box 2008
Oak Ridge TN 37831 6023

Phone: **423 241-2806**
Fax: **423 576-3515**
E-mail: **GSC**

Jason Darby
U.S. DOE
P.O. Box 2001
Oak Ridge TN 37831

Phone: **423 241-6343**
Fax: **423 576-0956**
E-mail: **darbyjo@oro.doe.gov**

Jean-Claude Dehmel
S. Cohen & Associates
1355 Beverly Road, Suite 250
McLean VA 22101

Phone: **703 264-1117**
Fax: **703 264-1118**
E-mail: **jcdehmel@scainc.com**

Neil Dubry
Commonwealth Edison Company
1411 Opus Place, Suite 115
Downers Grove IL 60515

Phone: 630 663-5894

Fax: 630 663-5905

E-mail:

J. D. Eddlemon
Pulcir, Inc.
9209 Oak Ridge Highway
Oak Ridge TN 37830 3500

Phone: 423 927-6358

Fax: 423 927-6866

E-mail: 76516-3151@compuserve.com

Mark Ewen
Industrial Economics, Inc.
2067 Massachusetts Avenue
Cambridge MA 02140

Phone: 617 354-0074

Fax: 617 354-0463

E-mail: mde@indecon.com

Thomas E. Fewell
Lockheed Martin Idaho
MS-3765
P.O. Box 1625
Idaho Falls ID 83415

Phone: 208 526-7789

Fax: 208 526-0425

E-mail:

Ken Duvall
U.S. DOE (EH-41)
Env. Policy and Assistance
Forrestal Building
Washington DC 20585

Phone: 202 586-0242

Fax: 202 586-3915

E-mail:

Phil Egidi
ORNL/ETS
P.O. Box 2567
Grand Junction CO 81419

Phone: 970 248-6189

Fax: 970 248-6220

E-mail: 7pe@ornl.gov

Steve Ferguson
ALARON Corporation
440 Knox Abbott Drive, Suite 500
Cayce SC 29033

Phone: 803 791-9900

Fax: 803 791-9911

E-mail: alaronjt.aol.com

Dennis Floyd
Manufacturing Sciences Corporation
3000 Youngfield Street
Wheatridge CO 80033

Phone: 303 237-8576

Fax: 303 233-2993

E-mail:

Billy Freeman
Tennessee Dept. of Environment &
Conservation
Division of Radiological Health
2700 Middlebrook Pike
Knoxville TN 37921

Phone: 423 594-6035

Fax: 423 594-6105

E-mail:

Lloyd Generette
U.S. EPA
100 Alabama Street, SW
Atlanta GA 30303

Phone: 404 562-9138

Fax: 404 562-9095

E-mail:

Sandra Gogol
(n.p.) Energy
6501 America's Parkway, NE, Suite 1050
Albuquerque NM 87111

Phone: 505 667-3216

Fax: 505 665-7913

E-mail: sandrag@empo.lanl.gov

Peter Gray
Peter Gray and Associates
7219 SE92nd St., #5
Tulsa OK 74133

Phone: 918 492-5250

Fax: 918 492-4959

E-mail:

Toff B. Garcia
Sandia National Laboratory
P.O. Box 969
Livermore CA 94551 0969

Phone: 510 294-2149

Fax: 510 294-1489

E-mail: tbgarci@sandia.gov

Tom Gilman
U.S. Ecology
109 Flint Road
Oak Ridge TN 37830

Phone: 423 482-5532

Fax: 423 482-5605

E-mail:

Tom Gorman
Sandia National Labs
P.O. Box 969
Livermore CA 94566

Phone: 510 294-3574

Fax: 510

E-mail:

David B. Grayewski
U.S. Ecology
109 Flint Road
Oak Ridge TN 37830

Phone: 423 482-5532

Fax: 423 482-5605

E-mail:

James D. Greaves
Brainard Associates, Inc.
5381 Brainard Road
Solon OH 44139

Phone: 216 498-9199
Fax: 216 498-9141
E-mail:

Michael Gresalfi
ORNL/LMES
12800 Middlebrook Road, Suite 102
Germantown MD 20841

Phone: 301 916-1136
Fax: 301 916-8699
E-mail: i32@ornl.gov

Wayde Gutzman
Atomic Energy of Canada Limited
Chalk River Ontario KOJ1JO
Canada

Phone: 613 584-3311
Fax: 613 584-4249
E-mail: gutzmanw@aecl.ca

Mark Hamon
Tennessee Dept. of Environment & Conservation
Division of Radiological Health
401 Church Street
Nashville TN 37243 1532

Phone: 615 532-0364
Fax: 615 532-7938
E-mail:

Robert M. Grenier
General Atomics
Mail Stop 15-219
P.O. Box 85608
San Diego CA 92186

Phone: 619 455-2583
Fax: 619 455-2596
E-mail: rob.grenier@gat.com

Kevin J. Grice
Texaco Exploration and Production, Inc.
#3169
P.O. Box 1404
Houston TX 77008

Phone: 713 752-6294
Fax: 713 752-4743
E-mail: gricekj@texaco.com

George T. Hamilton
Frank W. Hake Associates
1790 Dock Street
Memphis TN 38113

Phone: 901 942-2206
Fax: 901 942-2207
E-mail: 102650.530@compuserve.com

Susan Hannah
CORPEX Technologies
2000 Executive Park Drive, Bldg. D, Suite 250
Knoxville TN 37923

Phone: 423 691-4877
Fax: 423 691-4990
E-mail: corpex2@aol.com

Jerry L. Harness
U.S. DOE-ORO
P.O. Box 2001
Oak Ridge TN 37831 8620

Phone: 423 576-6008
Fax: 423 576-5333
E-mail: x96@ornl.gov

Reid P. Harvey
U.S. EPA Office of Radiation and Indoor Air
6603J
401 M Street, SW
Washington DC 20460

Phone: 202 233-9429
Fax: 202 233-9650
E-mail: harvey.reid@epamail.epa.gov

Jerry M. Hyde
U.S. DOE
19901 Germantown Road
Germantown MD 20874 1290

Phone: 301 903-7914
Fax: 301 903-7234
E-mail: jerry.hyde@em.doe.gov

Charlotte L. Johnson
SAIC
3rd Floor
20201 Century Blvd.
Germantown MD 20874

Phone: 301 353-1868
Fax: 301 428-0145
E-mail: charlotte.johnson@ccmail.gmt.saic.com

Pauline Hartwig
AECL Decommissioning Branch
Chalk River Laboratories
Chalk River Ontario KOJ1JO
Canada

Phone: 613 584-3311
Fax: 613 584-4249
E-mail: hartwigp@aecl.ca

Lance P. Hull
M4 Environmental Management
1009 Commerce Park Drive, Suite 100
Oak Ridge TN 37830

Phone: 423 220-7602
Fax: 423 220-5047
E-mail: hulllp@m4lp.com

Peter Johnson
CORPEX Technologies
P.O. Box 13486
Research Triangle Park NC 27703

Phone: 919 941-0847
Fax: 919 941-0652
E-mail:

Edith Jones
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge TN 37831 6395

Phone: 423 241-3710
Fax: 423 626-6196
E-mail: e2j@ornl.gov

Michael J. Jump
EET, Inc.
5785 Commons Lane
Alpharetta GA 30202

Phone: **770 569-5545**
Fax: **770 569-5545**
E-mail:

Blake Knight
Champion International Corporation
1 Champion Plaza
Stamford CT 06921

Phone: **203 358-6493**
Fax: **203 358-7407**
E-mail:

Steven Larrick
Structural Metals, Inc.-Texas
P.O. Box 911
Seguin TX 78156 0911

Phone: **210 372-8331**
Fax: **210 372-8331**
E-mail:

Judson Lilly
U.S. DOE, EM-42
Cloverleaf 19901 Germantown Road
Germantown MD 20874

Phone: **301 903-7218**
Fax: **301 903-2747**
E-mail: **judson.lilly@em.doe.gov**

Joelle Key
**Tennessee Dept. of Environment &
Conservation**
Division of Radiological Health
401 Church Street
Nashville TN 37243 1532

Phone: **615 532-0364**
Fax: **615 532-7938**
E-mail:

Dewey Large
10807 Fox Park Lane
Knoxville TN 37931

Phone: **423 927-4026**
Fax: **423 482-8935**
E-mail:

Bob Levesque
CORPEX Technologies
2000 Executive Park Drive, Bldg. D, Suite 250
Knoxville TN 37923

Phone: **423 691-4877**
Fax: **423 691-4990**
E-mail:

Val Loiselle
American Technologies, Inc.
142 Fairbanks Road
Oak Ridge TN 37830

Phone: **423 481-4844**
Fax: **423 4814850**
E-mail:

Steve Lorenz
Commonwealth Edison Company
1400 Opus Place, Suite 800
Downers Grove IL 60515 5701

Phone: **708 663-3821**

Fax: **708 663-3805**

E-mail:

Michael Mallen
Southern Foundry Supply, Inc.
P. O. Box 6216
Chattanooga TN 37401

Phone: **423 756-6070**

Fax: **423 266-0527**

E-mail:

Maureen M. McDonald
Jacobs Engineering Group, Inc.
125 Broadway Avenue
Oak Ridge TN 37830

Phone: **423 220-4836**

Fax: **423 220-4848**

E-mail: **maureen.mcdonald@jacobs.com**

Tad McGalliard
Cornell University Center for the Environment
Work and Environment Initiative
105 Rice Hall
Ithaca NY 14853

Phone: **607 254-5089**

Fax: **607 255-0238**

E-mail: **tnm2@cornell.edu**

Richard Meehan M-7
U.S. DOE Oak Ridge
P.O. Box 2001
Oak Ridge TN 37831

Phone: **423 576-2598**

Fax: **423 241-3314**

E-mail: **meehanrw@oro.doe.gov**

Kyle Millage
Stanford Linear Accelerator Center
2575 Sand Hill Road
Menlo Park CA 94025

Phone: **415 926-3839**

Fax: **415 926-3030**

E-mail: **kkm@slac.stanford.edu**

Michael W. Mobley
Tennessee Dept. of Environment & Conservation
Division of Radiological Health
401 Church Street
Nashville TN 37243 1532

Phone: **615 532-0360**

Fax: **615 532-7938**

E-mail:

Doug Moore
SEG
11029 A SR 128
Harrison OH 45030

Phone: **513 738-5480**

Fax: **513 738-5480**

E-mail: **segfn@mail.fuse.net**

Gerry Motl
SAIC
635 West 7th Street, Suite 403
Cincinnati OH 45203

Phone: 513 721-2668
Fax: 513 723-2605
E-mail: 102126.2646@compuserve.com

Tim Myers
Allied Technology Group, Inc.
99A Midway Lane
Oak Ridge TN 37830

Phone: 423 482-3275
Fax: 423 482-3138
E-mail: atgoakridge@worldnet.att.net

Karen S. Nakhjiri
S. Cohen & Associates
10420 NE 55th Street
Kirkland WA 98033

Phone: 206 822-3953
Fax: 206 827-0868
E-mail: nakhjiri@u.washington.edu

Leslie A. Nieves
Argonne National Laboratory
9700 South Cass Avenue
Argonne IL 60439

Phone: 630 252-3625
Fax: 630 252-5327
E-mail:

Dan Moyers
US Ecology
109 Flint Road
Oak Ridge TN 37830

Phone: 423 220-5257
Fax: 423 482-5605
E-mail:

William T. Nachtrab
Nuclear Metals, Inc.
2229 Main Street
Concord MA 01742

Phone: 508 369-5410
Fax: 508 369-0918
E-mail:

Glenford A. Newtown, Jr.
U.S. DOE, Weldon Springs
7295 Highway 94 South
St. Charles MO 63304

Phone: 314 441-8978
Fax: 314 447-0739
E-mail:

Ray Paris
Radiation Protection Services
Oregon Health Division
800 NE Oregon Street
Portland OR 97232

Phone: 505 731-4014
Fax: 505 731-4081
E-mail:

Jae-won Park
Korea Power Engineering Company
360-9, Mabuk-ri, Kusong-myun
Youngin-si Kyunggi-do 449-840
Korea

Phone: **82-331-260-6157**

Fax: **82-331-263-4147**

E-mail:

Ron Parnell
Lockheed Martin Energy Systems
P.O. Box 628
Piketon OH 45661

Phone: **614 897-2331**

Fax: **614 897-6274**

E-mail:

Ralph Perhac
UT Energy, Environment and Resources
Center
Conference Center Bldg., Suite 311
Knoxville TN 37996 4134

Phone: **423 974-4251**

Fax: **423 974-1838**

E-mail:

William J. Quapp
Nuclear Metals, Inc.
2300 N. Yellow Stone Highway, Suite 106
Idaho Falls ID 83401

Phone: **208 535-9001**

Fax: **208 535-9070**

E-mail: **wjq@srv.net**

Keith Rademacher
Wastren-Grand Junction
2597 B 3/4 Road
Grand Junction CO 81503

Phone: **970 248-6435**

Fax: **970 248-6040**

E-mail:

Al Rafati
Envirocare of Utah, Inc.
46 West Broadway, Suite 240
Salt Lake City UT 84101

Phone: **801 532-1330**

Fax: **801 537-7345**

E-mail:

Sandra Reid
Oak Ridge Site Specific Advisory Board
12 Asbury Lane
Oak Ridge TN 37830

Phone: **423 481-0004**

Fax: **423 482-4967**

E-mail:

Chris Reno
SEG
P.O. Box 2530
1560 Bear Creek Road
Oak Ridge TN 37830

Phone: **423 376-8123**

Fax: **423 376-8484**

E-mail: **74163.3310@compuserve.com**

Edward I. Rizkalla
U.S. DOE
Office of Waste Management
12800 Middlebrook Road, Trev II
Germantown MD 20874

Phone: 301 903-7475
Fax: 301 903-1643
E-mail: edward.rizkalla@em.doe.gov

Keith Rule
Princeton Plasma Physics Laboratory
P.O. Box 451
Princeton NJ 08543

Phone: 609 243-2329
Fax: 609 243-3366
E-mail: krule@pppl.gov

Manfred Sappok
Siempelkamp Giesseri GMBH & Co.
Siempelkampstr. 45
D-47803 Krefeld
Germany
Phone: 49-894-205
Fax: 49-894 455
E-mail:

Charles T. Simmons
Kilpatrick & Cody, L.L.P.
700 13th Stree NW, Suite 800
Washington D.C. 20005

Phone: 202 508-5806
Fax: 202 508-5858
E-mail: csimmons@kilcody.com

Mike Rollor
ALARON Corporation
17 West Jefferson Street, # 104
Rockville MD 20850

Phone: 301 340-9622
Fax: 301
E-mail:

Mike Ryan
Bechtel National, Inc.
P.O. Box 350
Oak Ridge TN 37830

Phone: 423 220-2801
Fax: 423 220-2107
E-mail:

Jeffrey J. Short
U.S. DOE, EM-77 (HQ)
19901 Germantwon Road , TRVII Room 460
Germantown MD 20874

Phone: 301 903-1387
Fax: 301 903-1398
E-mail: jeffrey.short@em.doe.gov

Andrew Smith
SEG
P.O. Box 2530
Oak Ridge TN 37830

Phone: 423 481-0222
Fax: 423 376-8484
E-mail:

Wayne P. Starke
BNFL, Inc.
804 Kerr Hollow Road
Oak Ridge TN 37830

Phone: **423 481-0422**
Fax: **423 483-9276**
E-mail:

Amy Stephen
Vanderbilt University
P.O. Box 1831, Station B
Nashville TN 37235

Phone: **615 322-2720**
Fax: **615 322-3365**
E-mail:

R. Jon Stouky
Mega Tech Services, Inc.
2804 Woudley Ct.
Jamestown NC 27282

Phone: **910 316-0707**
Fax: **910 316-0550**
E-mail:

Greta Stoutt
Manufacturing Sciences Corporation
804 Kerr Hollow Road
Oak Ridge TN 37830

Phone: **423 481-0455 ex 283**
Fax: **423 481-3142**
E-mail: **gstoutt@mnsoci.com**

James N. Taylor
ALARON CORPORATION
440 Knox Abbott Drive, Suite 500
Cayce SC 29033

Phone: **803 791-9900**
Fax: **803 791-9911**
E-mail: **alaronjt.aol.com**

William C. Thurber
S. Cohen & Associates
13 Poplar Point Road
Edgewater MD 21037

Phone: **410 224-3255**
Fax: **410 224-3255**
E-mail:

Daryl K. Tuttle
Wheland Foundry
2800 South Broad Street
Chattanooga TN 37402

Phone: **423 755-9424**
Fax: **423 266-5669**
E-mail:

Karen Utley
SEG
P.O. Box 2530
Oak Ridge TN 37831 2530

Phone: **423 481-0222**
Fax: **423 376-8484**
E-mail:

Gene Valett
Morrison-Knudson Corporation
7295 Highway 94 South
St. Charles MO 63304

Phone: **314 926-7067**
Fax: **314 447-0803**
E-mail:

Graham Walford
Quintek Corporation
1345 Oak Ridge Turnpike, Suite 299
Oak Ridge TN 37830

Phone: **423 927-1811**
Fax: **423 927-6906**
E-mail:

Jim Wells
Fluor Daniel Fernald
P.O. Box 538704
Cincinnati OH 45253 8704

Phone: **513 648-4317**
Fax: **513 648-5754**
E-mail:

Pat Whitfield
Environmental and Management Consulting
2505 Trotters Trail
Cocoa FL 32926

Phone:
Fax:
E-mail:

Parker Wright
Manufacturing Sciences Corporation
804 Kerr Hollow Road
Oak Ridge TN 37830

Phone: **423 481-0455**
Fax: **423 481-3142**
E-mail:

Charles R. Yard
Tennessee Dept. of Environment & Conservation
DOE Oversight Division
761 Emory Valley Road
Oak Ridge TN 37830

Phone: **423 481-0097**
Fax: **423 482-1835**
E-mail:

Lee Young
ATG, Inc.
99A Midway Lane
Oak Ridge TN 37830

Phone: **423 482-3275**
Fax: **423 482-3138**
E-mail: **leeyoungtn@aol.com**

Katherine Yuralko
ORNL
1060 Commerce Park
Oak Ridge TN 37830

Phone: **423 241-2290**
Fax: **423 241-2593**
E-mail: **yyp@ornl.gov**

James G. Yusko
Pennsylvania Department of Environmental
Protection
Sourthwest Regional Office
400 Waterfront Drive
Pittsburgh PA 15222 4745

Phone: **412 442-4000**

Fax: **412 442-4303**

E-mail: **Yusko.James@a1.dep.state.pa.us**