NUREG-0518

Draft Environmental Statement

concerning proposed rulemaking exemption from licensing requirements for smelted alloys containing residual technetium-99 and low-enriched uranium

U.S. Nuclear Regulatory Commission

Office of Standards Development

October 1980

8010290310

COVER SHEET

1. This Environmental Statement was prepared by the U.S. Nuclear Regulatory Commission, Office of Standards Development (the staff) in response to a request for rule making from the Energy Research and Development Administration (predecessor of the Department of Energy).

2. Title of the Proposed Action

   EXEMPTION FROM LICENSING REQUIREMENTS
   FOR SMELTED ALLOYS CONTAINING RESIDUAL
   TECHNETIUM-99 AND LOW-ENRICHED URANIUM

3. Mr. James J. Henry is the SD Task Leader for this task. Mr. Henry may be contacted at the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, DC 20555 or at 301-443-5946.

4. This environmental statement is concerned with the costs and benefits to be incurred in the exemption from federal (NRC) licensing requirements for smelted alloys containing residual Technetium-99 and low enriched uranium at concentrations of 5 ppm and 17.5 ppm, respectively. The contaminated metals considered explicitly in the statement for smelting are the scrap copper, nickel, and iron resulting from the improvement and upgrading of the Department of Energy's gaseous diffusion plants. The environmental impacts considered are primarily the radiological doses derived from the smelted metal by the general public including foundary and fabrication workers. Economic impacts associated with building and operating the facilities to smelt the scrap are also considered. In addition, the energy savings through recycling of these materials back into the commercial marketplace instead of burying them is estimated. The principal alternatives to this proposed action are the sale of surface decontaminated scrap, recycle of decontaminated equipment, burial of contaminated scrap, surface storage of contaminated scrap; and issuance of either a general or specific license for scrap disposal.

5. Comments on this Draft Environmental Statement must be received by December 22, 1980.

ABSTRACT

This environmental statement is concerned with the costs and benefits to be incurred in the exemption from federal (NRC) licensing requirements for smelted alloys containing residual Technetium-99 and low enriched uranium at concentrations of 5 ppm and 17.5 ppm, respectively. The contaminated metals considered explicitly in the statement for smelting are the scrap copper, nickel, and iron resulting from the improvement and upgrading of the Department of Energy's gaseous diffusion plants. The environmental impacts considered are primarily the radiological doses derived from the smelted metal by the general public including foundary and fabrication workers. Economic impacts associated with building and operating the facilities to smelt the scrap are also considered. In addition, the energy savings through recycling of these materials back into the commercial marketplace instead of burying them is estimated. The principal alternatives to this proposed action are the sale of surface decontaminated scrap, recycle of decontaminated equipment, burial of contaminated scrap, surface storage of contaminated scrap; and issuance of either a general or specific license for scrap disposal.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

FOREWORD

This Draft Environmental Statement on environmental considerations associated with proposed exemptions for smelted alloys containing low-enriched uranium and technetium-99 was prepared by the U.S. Nuclear Regulatory Commission, Office of Standards Development (the staff) in accordance with the Commission's regulation, 10 CFR Part 51, which implements the requirements of the National Environmental Policy Act of 1969 (NEPA).

The NEPA states, among other things, that it is the continuing responsibility of the Federal Government to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate Federal plans, functions, programs, and resources to the end that the Nation may:

- Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations.
- Assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings.
- Attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences.
- Preserve important historic, cultural, and natural aspects of our national heritage and maintain, wherever possible, an environment which supports diversity and variety of individual choice.
- Achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities.
- Enhance the quality of renewable resources and approach and maximum attainable recycling of depletable resources.

Further, with respect to major Federal actions significantly affecting the quality of the human environment, Section 102(2)(C) of the NEPA calls for preparation of a detailed statement on:

1. the environmental impact of the proposed action;
2. any adverse environmental effects that cannot be avoided should the proposal be implemented;
3. alternatives to the proposed action;
4. the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity;

5. any irreversible and irretrievable commitments of resources which would be involved in the proposed action, should it be implemented.

Pursuant to Section 102(2)(C) of NEPA and to the NRC regulations, the staff prepares a detailed statement on the foregoing considerations with respect to each rule-making proceeding involving amendments of the NRC's regulation "Rules of General Applicability to Domestic Licensing of Byproduct Material," 10 CFR Part 30, concerning the exemption from licensing and regulatory requirements of any equipment, device, commodity, or other product containing byproduct material and any other action which the Commission determines is a major Commission action significantly affecting the quality of the human environment.

When a request for rule making that meets these criteria is filed with the Commission, the staff evaluates the information from the requester. In addition, the staff seeks information from other sources that will assist in the evaluation. On the basis of all the foregoing and other such activities as are deemed useful and appropriate, the staff makes an independent assessment of the considerations specified in Section 102(2)(C) of the NEPA and 10 CFR Part 51.

This evaluation leads to the publication of a draft environmental statement, prepared by the Office of Standards Development, which is then circulated to Federal, state, and local governmental agencies for comment. Interested persons are also invited to comment on the proposed action and the draft statement. Comments should be addressed to the Director, Division of Engineering Standards, at the address shown below.

After receipt and consideration of comments on the draft statement, the staff prepares a final environmental statement that recognizes and discusses any responsible opposing view not adequately discussed in the draft statement, indicating the issues raised, and includes a discussion of questions and objections raised by the comments and the disposition thereof. All substantive comments received on the draft statement (or summaries thereof where the response has been exceptionally voluminous) are attached to the final environmental statement, whether or not each comment is individually discussed in the text of the statement. The final environmental statement also includes a final benefit-cost analysis, which considers and balances the environmental effects of the proposed action and the alternatives available for reducing or avoiding adverse environmental effects with the environmental, economic, technical, and other benefits of the proposed action; and a conclusion as to whether - after the environmental, economic, technical, and other benefits are weighed against environmental costs and after available alternatives have been considered - the action called for, with respect to environmental issues, is the issuance of denial values. The final environmental statement and any comments received accompany the request for rule making through, and are considered in, the Commission's review process.

Mr. James J. Henry is the SD Task Leader for this task. Mr. Henry may be contacted at the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, DC 20555 or at 301-443-5946.

1. SUMMARY

1.1 THE PROPOSED ACTION

By memorandum dated February 12, 1974, to the Director of Regulatory Standards, AEC, the Director of Waste Management and Transportation, AEC, requested assistance in establishing a de minimis quantity of enriched uranium in 10 CFR Part 70.(1)

In a response dated March 28, 1974, the Director of Regulatory Standards agreed to consider an amendment of 10 CFR Part 70 to establish a de minimis quantity for enriched uranium in scrap metal.(2)

In an additional letter dated July 9, 1979, the Director of the Office of Uranium Resources and Enrichment, DOE requested from the Executive Director of Operations, NRC a prompt approval of the aforementioned amendment to 10 CFR Part 70.(3)

The proposed action is the adoption of regulations that would exempt from the Commission's requirements for a license any person to the extent that such person receives, possesses, uses, or transfers Tc-99 or low-enriched uranium as residual contamination in any smelted alloy.

The exemptions would be subject to the following terms and conditions:

- Persons who smelt scrap contaminated with Tc-99 or low-enriched uranium or persons who initially transfer for sale or distribution smelted alloys containing Tc-99 or low-enriched uranium as residual contamination in the smelted alloys would not be exempt from requirements for a specific license.
- The Tc-99 and the low-enriched uranium would be minor constituents less than 5 parts per million and 17.5 parts per million, respectively, of representative samples of the smelted alloys.

The proposed action would also provide specific requirements for licenses to smelt scrap or to initially transfer for sale or distribution smelted scrap for use under the exemptions. Applicants will be required to submit a description of procedures for prior decontamination of the scrap, smelting of the scrap, sampling of the resulting smelted alloys, and the analyses of representative samples for Tc-99 and low-enriched uranium concentrations.

The potential environmental impacts of the distribution, use, and disposal of smelted alloys containing Tc-99 or low-enriched uranium as residual contamination are assessed in this statement.

1.2 ENVIRONMENTAL REVIEW STATUS

In August 1974, the Atomic Energy Act of 1954 was amended to authorize the Commission to establish classes of special nuclear material and to exempt certain classes or quantities of special nuclear material or kinds of uses or users from the requirements for a license set forth in Section 57d. of the Act when it makes a finding that the exemption of such classes or quantities of special nuclear material or such kinds of uses or users would not be inimical to the common defense and security and would not constitute an unreasonable risk to the health and safety of the public.

Under this new authority, the Commission at its own instance initiated rule making to exempt from licensing requirements smelted alloys contaminated with low-enriched uranium.

As part of the public rule making proceeding, the NRC staff is preparing this Environmental Statement pursuant to Section 102(2)(C) of NEPA and pursuant to NRC regulations.

To provide information useful for the preparation of this Statement, the Energy Research and Development Administration by letter dated September 8, 1976, sent to NRC staff an environmental impact assessment concerned with proposed rule making to exempt the sale and use of metal scrap homogeneously contaminated with enriched uranium and technetium-99 (Tc-99) below a specified concentration.(4)

1.3 MAJOR ISSUES

The major issues covered in this Environmental Statement are the following:

- Removability of contamination from the scrap metal involved (Sections 2.2 and 2.3)
- Concentration of contamination in the smelting process and later in the environment (Section 2.3)
- Radionuclides involved: Technetium-99 and low-enriched uranium (Section 2.1 and Appendix A)
- Material (metals) involved: iron (and steel), copper, and nickel (Section 2.1.1)
- Radiation doses to individuals and populations (Sections 4.3 and 7.1)
- Benefits and costs derived from the implementation of this action (Sections 4.5 and 7.4)

1.4 MAJOR CONCLUSIONS

a. Alternatives

The various alternatives to the proposed action that were considered are listed below.

1.	Sale of surface decontaminated scrap	(Section 6.1.1)
2.	Recycle of decontaminated equipment	(Section 6.1.2)
3.	Burial of contaminated scrap	(Section 6.1.3)
4.	Surface storage of contaminated scrap. This is the present method of disposal	(Section 6.1.4)
5.	Issuance of either a general or specific license for scrap disposal	(Section 6.2)

Of these alternatives considered, only the third--burial--was studied in any great detail, since this alternative was the only feasible one of those considered. The others for various reasons as reported in the text were deficient in one way or other.

b. Environmental Impacts and Benefits

The environmental impacts of the proposed action were analyzed--especially the increased radiological dose derived from the smelted metal by the general public including foundry and fabrication workers (Sections 4.3 and 7.1). Table 1.1 summarizes these doses. Economic impacts were analyzed with respect to the building and operation of various smelter facilities including a commercial operation (see Sections 4.5 and 7.4). Table 1.2 shows the comparison of net benefits for various smelting scenarios. All net benefits have discounted the burial of the scrap (Section 7.5).

In addition there would be an energy savings from not having to mine and process an equivalent quantity of ore required to produce the metals contaminated in the scrap (see Section 4.5.3). We have estimated that about 1 x 10^9 megajoules would be saved. This is equivalent to about 170,000 barrels of crude oil or 30,000 Mg of coal.

Table 1.1. Summary of radiological doses derived from the smelting and uncontrolled release of metal alloy generated from the CIP/CUP program

Maximum Individual Total-Body Dose Rate (working 1000 hr/yr inside "vault")	0.01 rem/yr
Maximum Individual Total-Body Dose Commitment (daily ingestion of iron tonic over 1 year)	0.002 rem
Maximum Individual Local Skin Dose (dose to wrist from bracelet worn 50 years)	14.0 rem
Maximum Individual Contact Bone Dose (dose from pin implanted 50 years)	20 rem
Occupational (total scrap smelting [Table 4.13])	0.01 person-rem
General Population (total scrap) Worst Cast Scenario of Transport, Manufacture, Distribution and Use [Table 4.11]	80 person-rem
Health Effects from Population Dose	<1

Table 1.2. Comparison of net benefits in millions of dollars (1977) for three smelting alternatives for iron and steel

	Smelter		
Scrap	Oak Ridge	Commercial	Fernald
Nickel*	34.2	34.2	34.2
Copper**	2.3	2.3	2.3
Iron & Steel	5.1	1.8	0.6
Total	41.6	38.3	37.1

---

*Nickel is assumed to be smelted at Paducah, KY only.

**Copper is assumed to be smelted at Fernald only.

1.5 ISSUES TO BE RESOLVED

The primary issue to be resolved is whether or not the net benefits derived from releasing the CIP/CUP scrap into the commercial market place after smelting it under regulatory control to keep the technetium and uranium contamination levels below those stipulated are greater than the impacts estimated to befall the general public from the unrestricted use of this very slightly contaminated material.

1.6 STAFF RECOMMENDATIONS

On the basis of the analysis and evaluation set forth in this Statement and after weighing the environmental, economic, technical, and other benefits against environmental costs and after considering available alternatives, the staff has concluded that the exemption of smelted alloys assessed herein may be:

a. Appropriately conditioned to protect environmental values; and

b. Acceptable for consideration by the Commission as proposed amendments of 10 CFR parts 30 and 70 under the Commission's rules of practice regarding rule making and the provisions of the Administrative Procedure Act related to rule making.

REFERENCES FOR SECTION 1

1. Memorandum from F. K. Pittman, Director, Division of Waste Management and Transportation, AEC, to L. Rogers, Director of Regulatory Standards, AEC, Subject: Request for Assistance to Establish a De Minimus Quantity of Enriched Uranium in 10 CFR70. Dated February 12, 1974. Available for inspection and copying for a fee at the NRC Public Document Room.

2. Memorandum from L. Rogers, Director of Regulatory Standards, AEC, to F. K. Pittman, Director, Division of Waste Management and Transportation, AEC, Subject: Establishment of a De Minimus Quantity of Enriched Uranium. Dated March 28, 1974. Available for inspection and copying for a fee at the NRC Public Document Room.

3. Letter from William R. Voigt, Jr., Director, Office of Uranium Resources and Enrichment, DOE, to Lee V. Gossick, Executive Director for Operations, NRC. Dated July 9, 1979. Available for inspection and copying for a fee at the NRC Public Document Room.

4. Letter from J. A. Lenhard, Director, Research and Technical Support Division, Oak Ridge Operations, ERDA, to J. Henry, Transportation and Product Standards Branch, NRC, Subject: Transmittal of "Environmental Impact Assessment." Dated September 8, 1976. Available for inspection and copying for a fee at the NRC Public Document Room.

2. SMELTED ALLOY CONTAINING RESIDUAL LOW-ENRICHED URANIUM AND TECHNETIUM-99

2.1 DESCRIPTION OF GENERATED SCRAP

Scrap metal of various radioactive contamination levels has been, is being, and will be generated by the nuclear industry from both government and commercial segments. The metal comes from various sources including the upgrading of equipment, replacement of inoperative or damaged equipment, and the dismantling of obsolete or worn-out facilities.

Presently a large amount of scrap metal contaminated with low-enriched uranium and Tc-99 is being generated by the Cascade Improvement and Cascade Uprating Programs (CIP/CUP) for the Department of Energy (DOE) gaseous diffusion plants.

Other contaminated scrap from previous DOE (AEC-ERDA) operations is located at other locations around the country; a large portion of this scrap resides at the Nevada Test Site. Much of this latter scrap is of undetermined contamination level.

Presently, relatively small amounts of contaminated scrap metals are generated by commercial nuclear facilities; however, in the future a large amount of scrap metal of varying degrees of contamination will become available when the presently operating power reactors and fuels reprocessing plants are dismantled at the end of their useful life (approximately 30 to 40 years). A large portion of this scrap metal could be recycled back into commercial usage through economical and reliable decontamination methods.

Since data on the quantity, classifications, and contamination levels of the other DOE and commercial scrap are unavailable at the present time the cost/benefit portion of this environmental statement will consider only the scrap generated by the CIP/CUP program of the DOE diffusion plants.

2.1.1 Scrap metal from Department of Energy sources

Presently metal scrap contaminated with radioactivity to various degrees has been and is being generated by the many programs sponsored by the DOE. A particular source of scrap contaminated with a relatively low level of radioactivity is that generated by the CIP/CUP programs.

These programs for upgrading the gaseous diffusion plants located at Portsmouth, Ohio; Paducah, Kentucky; and Oak Ridge, Tennessee have generated large quantities of scrap metal such as steel, copper, nickel, and aluminum. This scrap is contaminated with small quantities of uranium and Tc-99 with only minute quantities of neptunium-237 and plutonium at concentrations less than 1 part per billion (ppb). Smelting this scrap will reduce the contamination to such an extent that the resulting metal alloy may be recycled as uncontrolled metal to the marketplace.

Aluminum, however, for reasons stated in Section 2.3.4 will not be considered for smelting in this statement. Table 2.1 shows the quantities of contaminated metal scrap coming out of the diffusion plants in megagrams (Mg).* Future quantities of CIP/CUP scrap have been estimated through the end of the program.

Table 2.1. CIP/CUP contaminated scrap quantities by year generated (Mg)

Year	Steel[(a)]	Copper[(b)]	Nickel
1976	-	640[(c)]	(d)
1977	13,400[(e)]	240	(d)
1978	-	270	(d)
1979	6,500	240	(d)
1980	6,100	210	(d)
1981	4,100	30	(d)
1982	1,700	-	(d)
Total	31,800	1,600	8,400

SOURCE:
(a) Reference 1, P. 5.
(b) Reference 2.
(c) Reference 3.
(d) Actual annual estimates are classified.
(e) Steel generated up to 1978.

A recent survey(4,5) by the National Lead Company of Ohio has determined that approximately 180,000 Mg of metal scrap contaminated with various levels of radioactivity are stored at other DOE sites and at a few Department of Defense (DOD) locations around the country. Table 2.2 shows the locations of the major contributors by state along with the percent of the total. The Nevada Test Site (NTS) near Mercury, Nevada has almost 80% of this scrap (~100,000 Mg) which is all iron and steel.(5) Approximately 30,000 Mg/Yr of primarily ferrous scrap is estimated to be generated at the NTS through 1983.(5)

Although there seems to be a large amount of metal scrap lying around the various DOE sites, the contamination levels of most of it are not too well known. An investigation to develop more information on this scrap as to contamination levels and which portions whould be suitable for smelting is being planned. Until this investigation is completed this non-CIP/CUP scrap will be neglected for the cost/benefit and radiological dose impact portion of this Environmental Statement.

---

*1 Megagram (Mg) = 1,000 kilograms (kg) = 1 metric ton (tonne).

Table 2.2. Major locations of non-CIP/CUP scrap resulting from DOE/DOD programs

Location	Percent of 180,000 Mg
Idaho	4.42
Illinois	1.07
Kentucky	2.32
Maryland	0.08
Nevada	79.31
New Mexico	10.57
Ohio	1.55
Tennessee	0.47
Washington	0.21

2.1.2 Commercial power reactors

The projected amounts of contaminated scrap that would become available through the decommissioning of commercial nuclear power plants, which may be relatively free of radioactive contamination are determined for both a 1 GWe* BWR and a 1 GWe PWR. The quantity of metal available is calculated from projected scrap values(6) for each of these two reactor types. The quantity and type of metals a specific reactor decommissioning is estimated to generate are shown in Table 2.3.

Table 2.3. Scrap metals generated from reactor decommissioning

Types of Scrap	Quantity/Unit (Mg)* BWR	PWR
Steel	20,000	24,000
Stainless Steel	500	800
Copper	600	800

*Based on 1 GWe unit.

---

*1 GWe = 1,000 MWe = 1 x 10^9 watts of electrical power output.

Table 2.4 shows 12 commercial reactors which may be candidates for decommissioning by 2000. From the power capacity of the various plants and the quantities of scrap per unit power, an estimate of metal scrap from commercial reactors up to the year 2000 is shown in Table 2.5. How much of this metal that can be smelted and recycled under this proposed action back into the commercial marketplace is not well known at this time due to the fact that the kinds and levels of radioactive contaminations are not quantitatively known.

Table 2.4. Commercial reactors which may be candidates for decommissioning by the year 2000

	Reactor	Type	Size (MWe)	Year of Start Up
1.	Shipping Port Nuclear Power Station	PWR	90	1957
2.	Dresden Nuclear Power Station, Unit I	BWR	200	1959
3.	Yankee Nuclear Power Station	PWR	175	1960
4.	Big Rock Point Nuclear Plant	BWR	72	1962
5.	Indian Point Station, Unit I	PWR	265	1962
6.	Humbolt Bay Power Plant, Unit 3	BWR	63	1963
7.	Genoa Nuclear Generating Station	BWR	50	1967
8.	San Onofre Nuclear Station, Unit I	PWR	430	1967
9.	Haddam Neck Plant	PWR	575	1967
10.	Ginna Nuclear Power Plant, Unit I	PWR	490	1969
11.	Nine Mile Pt. Nuclear Station, Unit I	BWR	610	1969
12.	Oyster Creek Nuclear Power Plant, Unit I	BWR	650	1969

SOURCE: Reference 7, P.85.

Table 2.5. Quantities of metal scrap available from commercial reactor decommissioning by the year 2000 (Mg)

Type of Scrap	BWR (1.645 GWe)	PWR (2.025 GWe)	Total
Steel	33,000	49,000	82,000
Stainless Steel	800	1,600	2,400
Copper	1,000	1,600	2,600

2.1.3 Fuels reprocessing plant

In reprocessing plants the overall contamination level of most salvageable metals would be high for most sections of the plant. It is presumed that recovery of most of these metals would not be feasible. Scrap of relative low contamination levels which could be recovered is not a large segment of the total scrap generated during decommissioning of such a facility. The following table indicates approximate amounts of "low-level" scrap* generated.(8)

Types of Scrap	Quantity/Plant (Mg)
Stainless Steel	50
Equipment and Piping (steel)	400

2.1.4 Fuels fabrication plants

The quantity of scrap from fuel fabrication plants would, in all probability, be small and would not contribute large quantities of low-level contaminated scrap compared to that expected from reactors and fuels reprocessing plants. These other sources taken into entirety are sufficiently small that it is reasonable to assume that any additional impacts would not significantly affect the already small impact.

2.1.5 Other sources of scrap

There are miscellaneous sources of low-level contaminated scrap such as mining and milling operations. These sources too, would contribute only small amounts of scrap to the total available from reactors and fuels reprocessing plants. However, to the extent that these sources never see low-enriched uranium, they cannot generate scrap covered by this proposed action.

2.2 DECONTAMINATION

Decontamination is the process whereby the quantity of radionuclides adhering to the surface or included within a material is reduced.

A number of factors affect the decontamination of metals. The type of metal, its surface finish and the physical, chemical and radiochemical nature of the contamination. The majority of contaminants are metallic and exhibit characteristics that are quite similar to the contaminated substrate. Because of

---

*The term low-level, when pertaining to radionuclide concentrations has many definitions in the industry. Here "low-level" scrap is defined as that scrap, which could be decontaminated and smelted to meet the levels of contamination stipulated in this environmental statement.

the similarity of contaminants and the metal, it is possible for the contaminating atoms to actually become part of the crystal lattice of the metal and thus decontamination could only be achieved by removing these surface layers. Presently all contaminated scrap being generated at nuclear facilities is decontaminated to some extent using one or more of the following methods.

2.2.1 Chemical decontamination

Chemical methods are one way that contamination can be removed from the surface of metals. In cases where the metal has a protective oxide film much of the contamination can be removed by dissolving this film. Slightly acidic solutions with complexing agents will remove most of the contaminants. Other combinations of acids, bases, and complexing agents are also used for decontamination. Typical surface decontamination of equipment by these methods result in a reduction in contamination levels of a factor of 100; i.e., DF = 100. Internal decontamination of chemical equipment using flushing, spraying of solutions, and agitating systems, can reduce contamination levels by a factor of 1000.(9)

2.2.2 Ultrasonic decontamination

Ultrasonic energy may be used in conjunction with chemical methods for decontamination. Experiments using this method indicate that it increases the rate at which the chemical reactions take place.(10) The method basically introduces the chemical reagents to the surface faster than normal diffusion of the chemicals to the metal surface. The expected DF for ultrasonic decontamination would lie somewhere between 100 and 1000.

2.2.3 Electro-polishing

This method is used to remove the surface of the metal containing the contamination. The metal to be electropolished serves as the anode in a suitable electrolyte; dissolution starts when current is passed, and the anode surface, is slowly dissolved. The dissolving occurs preferentially on the raised portion of surface, and therefore, there is a smoothing action, in addition to a general removal of material from the metal surface. Typical results obtained using this method on steel tools and stainless steel vacuum system components heavily contaminated with plutonium oxides have shown a reduction from more than 1,000,000 dis/min/100 cm^2 to background in less than 10 minutes.(11) This is equivalent to a DF = 200,000.

Although mostly small parts and tools are usually electropolished, there is actually no technical limit to the size of the object. In fact, large plutonium-contaminated components more than 1.4 m^2 (15 ft^2) of surface area have been decontaminated by this technique.(11) The interior of a 95,000 liter (25,000-gal) tank can be electropolished in place using only 8,000 liter (2,000 gal) of electrolyte.(12)

2.2.4 Vibratory decontamination

This method combines chemical cleaning solutions and mechanical cleaning methods. A plastic or ceramic medium containing abrasion particles is vibrated at a high frequency in the presence of a cleaning solution. The abrasive scours the surface of the metal component in contact with the media and the cleaning solution flushes away the spent abrasive and the material removed from the surface.(13) The composition of the solution can be varied as required to promote removal of grease and paint. A DF of 100(14) can be obtained by this method of decontamination.

2.2.5 Other techniques

The following methods can also be used for decontamination.

- High pressure sprays using detergents and other solvents.
- Vapor degreasing with perchlorethylene.
- Wet and dry abrasive blasting using sand.

2.2.6 Summary of surface decontamination methods

The surface decontamination methods described in this section each have some disadvantages. Each item to be decontaminated is processed as a specific item and checked for residual decontamination. These procedures do not make certain that contamination does not exist in cracks and other hard to detect places on the metal. Alpha and beta radiation can be shielded by the metal and therefore may not be detectable on the radiation detecting instruments used for inspection. There are, however, a number of advantages to using these methods. Items decontaminated may in a number of cases be used again directly since they are not destroyed in the process, thus allowing direct recycle. The process is quite rapid and decontamination can be completed in times as short as ten minutes. Capital costs are quite small in comparison to that of more complicated methods such as smelters.

2.3 SMELTING

Smelting is a metallurgical operation for extraction of a metal from its impurities in a fused state. The process involves high temperatures commonly attained by the burning of coal, coke, pulverized fuel, gas or by heat obtained from electrical energy. The pure metal settles to the bottom of the smelter and the impurities are drawn off in the slag that is formed in the smelting process by fluxing agents added to help facilitate separation.

Uranium contaminated iron, nickel and copper metal or alloys, when smelted, produce ingots having a low residual uranium content. However aluminum recovered from uranium contaminated scrap shows only partial decontamination by smelting.

Uranium in contaminated scrap metal will normally occur in the salt form rather than be alloyed with the base metal. It will be deposited in cracks and pores of the metal surface or in adhering corrosion deposits. The total amounts of uranium present as salts and as the metal will be very small in comparison to an alloy of the metal with uranium. The salts formed with uranium from carbon, nitrogen, and sulfur will improve the separation during smelting, thus having some of these elements available to form and maintain the uranium in the salt form will enhance the decontamination process.

The smelting process is basically physical in nature with the uranium and its compounds moving along with the slag to the top surface of the metal. The addition of a suitable salt fluxing agent to the slag on top of the metal will facilitate the removal of the uranium in the slag. Liquation, the separation of substances due to different fusibilities, and settling caused by density differences of the phases may help achieve partial separation. The high density of the uranium may cause it to settle to the bottom of the smelter in the sludge and react with the surface of the furnace refractories. The use of special refractories in the furnace could possibly enhance decontamination of the metal.

Smelting the contaminated scrap does not affect the concentration of Tc-99 in the alloy material to any great extent. If the concentration of Tc-99 is ∿5 ppm* in the scrap the alloy formed after smelting will also contain ∿5 ppm of Tc-99.(15)

Figure 2.1 shows the flow of contaminated scrap from its point of origin through the smelting process and the eventual formation of the metal into new products. A typical electric smelting furnace is shown in Figure 2.2.

2.3.1 Steel scrap

The decontamination by smelting of various steel, stainless steel, and nickel-bearing steel scrap can be very effective. The amounts given in Table 2.6 for these particular types of scrap show an average U content after decontamination of less than 1 ppm and the high cases will have less than 5 ppm uranium. During the smelting process the uranium has little tendency to alloy with steel and is removed in the slag. The slag recovered from this process will contain up to 2% uranium depending on the nature of scrap smelted.

---

*ppm = Parts per million by mass = micrograms per gram (μg/g).

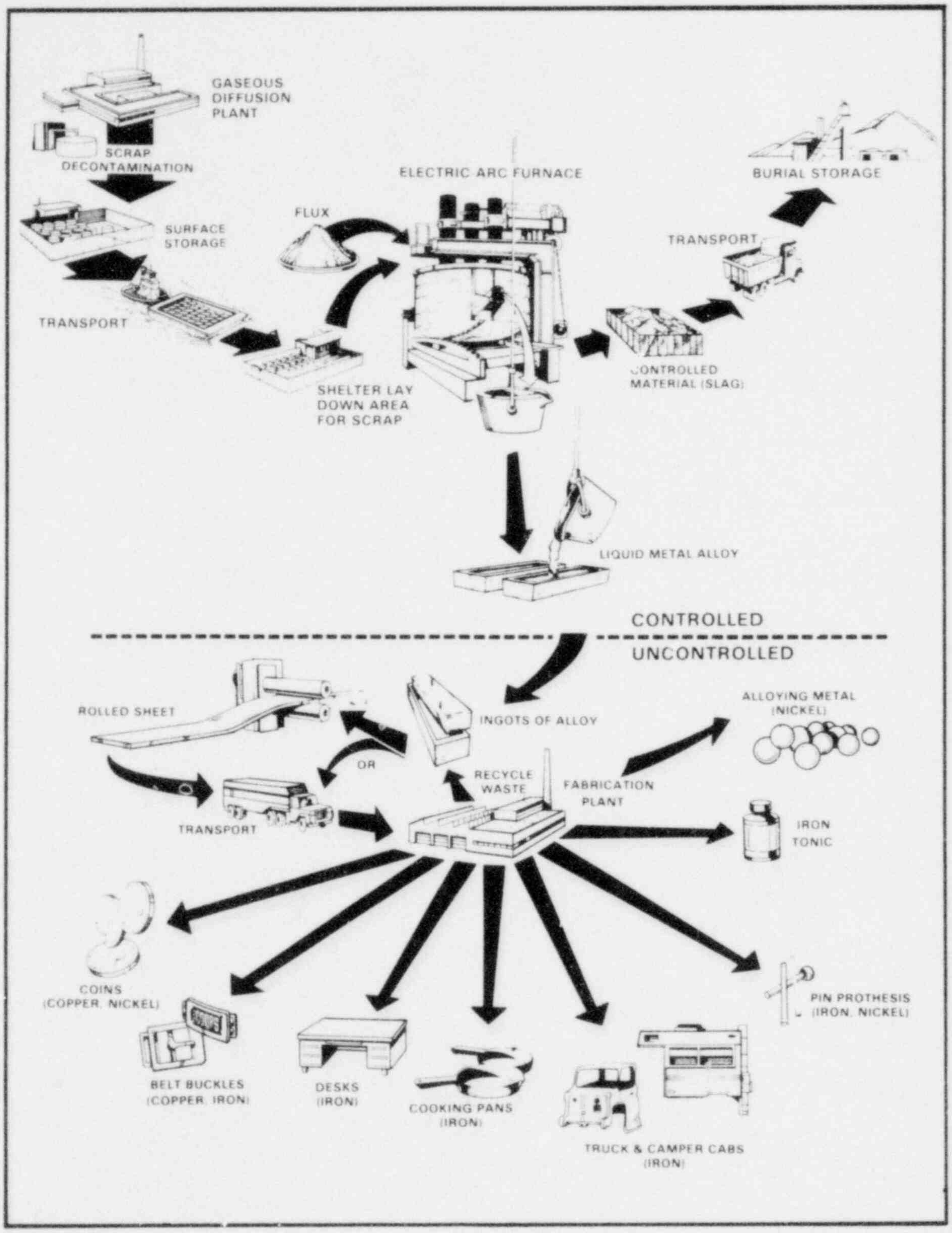

Figure 2.1. Diagram of flow of metal from scrap to consumer product

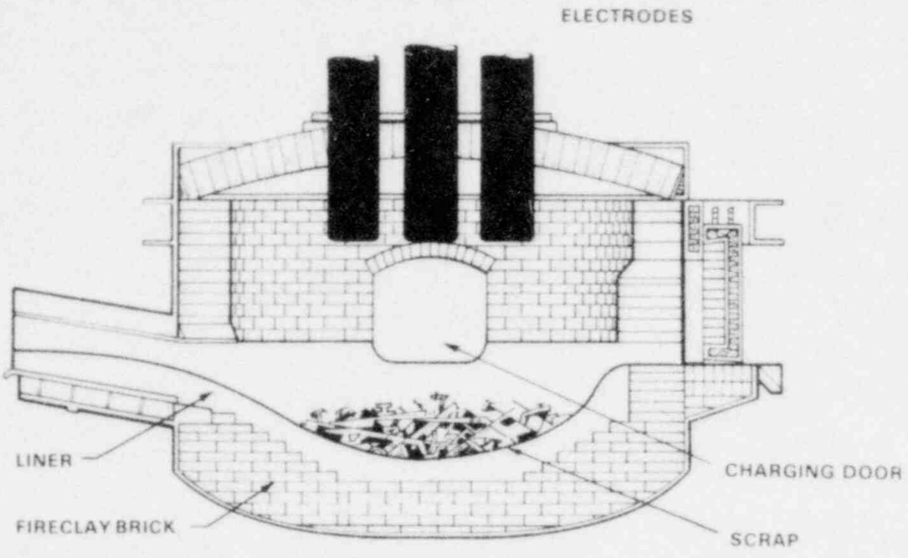

Figure 2.2. Electric steel melting furnace

Table 2.6. Typical plant scale results of smelting uranium-contaminated scrap metals

Material	Product Ingot U Content, ppm(a)			Direct Radiation Alpha d/m/100 cm^2(b)		
	Avg	Low	High	Avg	Low	High
Common Steel	0.4	0.00	3.50	0	--	--
Stainless Steel	0.6	0.01	3.20	100	75	120
Ni-Bearing Steel	0.5	0.02	2.38	<100	<100	<100
Nickel	1.25	0.9	1.6	120	100	200
Monel (Ni Alloy)	0.5	0.01	4.00	--	--	--
Copper	0.4	0.01	2.50	<100	<100	<100
Brass	0.4	0.01	2.50	--	--	--
Yellow Brass	2.1	0.30	3.20	--	--	--
Bronze	0.3	0.04	1.20	--	--	--
Aluminum	200	3	100	3870	2000	6800

(a) Data primarily from Oak Ridge Y-12 plant except for aluminum data from Goodyear Atomic Corporation.

(b) Data primarily from Klevin and Harris, Nucleonics 14, No. 4, pp. 93-6 (April 1956). Caution: Values may not relate directly with ppm column data; values in disintegrations per minute per 100 square centimeters.

SOURCE: Reference 16, p. 5.

Discarded ore concentrate drums and process equipment amounting to 6000 Mg of scrap were smelted by a commercial firm using an electric arc furnace. The ingots produced averaged <6 ppm. The slag amounted to 8.5% of the scrap weight and average 2.12% uranium. The average uranium contained in the scrap before smelting was 0.2% (2000 ppm).(17)

2.3.1.1 Mass balance of steel scrap

Steel scrap is smelted with the addition of a flux such as calcium oxide (lime) to scavenge the contaminants of the scrap, which come out of the mixture as slag. The amount of flux added will depend on the cleanliness and quality of the steel scrap. For one Mg of average scrap approximately 50 kg of Calcium oxide is added as flux. The resulting products would be approximately 1 Mg of steel and 100 kg of slag containing Calcium oxide, silicon oxide (silica), iron oxide, aluminum oxide, magnesium oxide, manganese oxide, and the oxides of the uranium contaminating the original scrap. Of this slag approximately 50% would be calcium oxide; the remainder would be various amounts of the other oxides depending on the carbon content of the steel and variations in the smelting time and temperature.

Table 2.7 describes the mass balance for the test smelting of tube sheet with a uranium contamination level of 87 ppm. The difference between input and output masses of 5 g probably is associated in the fumes released from the smelter in the process.

Table 2.7. Mass balance of smelting of steel tube sheet containing uranium

Item	Amount (g)	Uranium (ppm)
Input to Furnace		
Tube Sheet	4,536	87
Charcoal	50	--
Fluorspar	25	--
Silica	5	--
Total	4,616	
Output from Furnace		
Ingot	4,555	1-4
Slag	56	3,225
Total	4,611	

SOURCE: Reference 15, Table 4.

2.3.2 Nickel scrap

A comparison of the relative decontamination of nickel and its alloys is also shown in Table 2.6. The average contamination of uranium is approximately 1 ppm with the highest sample being 4 ppm (Monel). Nickel responds to smelting similarily to that of steel; the uranium does not alloy readily with the nickel and during smelting is carried off in the slag.

Nickel barrier scrap smelting data is shown in Table 2.8. The results are not quite as low for uranium contamination as the values in Table 2.6. However, the contamination level is still below the 17.5 ppm guideline. The amount of Tc-99 in the scrap metal and alloy ingot are also shown. The experimental results indicate there is only a small reduction in the Tc-99 after smelting but this level of contamination in the alloy ingot is close to the 5 ppm limit for this isotope.

Table 2.8. Ni barrier scrap

Uranium (ppm)		Technetium (ppm)	
Scrap Barrier	Ingot	Scrap Barrier	Ingot
460	3.5		
502	7.0		
418	3.4		
224	2.7		
1645	11	--	6.3
388	5	5.0	4.2

SOURCE: Reference 15, Table 1.

2.3.2.1 Mass balance of nickel smelting process

Nickel scrap is smelted similarly as steel. As a test a sample of the CIP/CUP barrier material was smelted to determine the amounts of contaminants going to the slag and the smelted alloy.(15) In this test, however, a nickel starter rod was melted with the nickel barrier scrap instead of the usual flux. The amounts of the inputs and outputs are given in Table 2.9.

Table 2.9. Mass balance of smelting of nickel barrier material containing uranium and Tc-99

Item	Amount	Uranium		Tc-99	
	(g)	(ppm)	(g)	(ppm)	(mg)
Imput to Furnace					
Barrier Scrap	5,000	388	1.94	4.98	24.9
Ni Starter Rod	332				
Total	5,332		1.94		24.9
Output from Furnace					
Ingot	5,300	5	0.03	4.23	22.4
Slag	400	2,580	1.03	0.110	0.044
Fume Particulates	2.87	8,180	0.02	0.00166	4.6E-6
Total	5,703		1.08		22.44
Recovery, %	99.4		66		90

SOURCE: Reference 15, Table 2.

2.3.3 Copper scrap

Copper scrap contaminated with uranium responds to smelting similarly to nickel and iron. This type of decontamination is quite effective and purity ranges from 0.01 ppm to 2.5 ppm uranium as shown in Table 2.6. Laboratory scale smelting of 20-30 lb of copper scrap in a high frequency induction furnace is summarized in Table 2.10 these results indicate levels of uranium contamination well below the 17.5 ppm limit.

Table 2.10. Uranium content of copper melts

Material	No. Sample	Uranium, ppm		
		Average	High	Low
Scrap Feed	69	1663	3360	5.4
Product Metal	3*	0.37	0.5	0.3
Slag	8	8480	2350	504

---

*Reference 16, Table XII.

2.3.4 Aluminum

Aluminum smelting is different from that of the other metals discussed because of the requirement of special types of fluxes and smelting conditions. A summary of the remaining fractions of uranium and Tc-99 after smelting of aluminum CIP/CUP scrap compressor blades is given in Table 2.11. There is a greater tendency for the uranium to alloy with the aluminum and the amount of uranium still contaminating the metal is shown to be consistently above the 17.5 ppm limit. The Tc-99 level is well within the limit for this metal of <5 ppm. A comparison of the thermodynamic properties of uranium and aluminum indicates that uranium can exist as the metal in molten aluminum, thus reducing the efficiency of decontamination by this method. Further purification could be accomplished by electro-refining.

Table 2.11. Aluminum CIP/CUP scrap test results

Whole Blade Tests	Uranium, (ppm)	Tc, (ppb)*
Whole Blade Scrap	718	26
Ingot Melt No. 47 (holding time 30 min)	686	6
Ingot Melt No. 48 (holding time 5 min)	670	13
Ingot Melt No. 57 (16 g coverall 11 flux)	120	6
Ingot Melt No. 58 ($AlCl_2$ flux)	236	6
Blade Threads Scrap	1810	40
Ingot Melt No. 49 (holding time 5 min)	516	2

---

*ppb = Parts per Billion by mass = nanograms/gram (ng/g).
SOURCE: Reference 15, Table 5.

2.3.5 Summary of smelting

Smelting as a decontamination method requires larger investments in capital equipment, a greater power consumption and cost, and larger, more elaborate equipment than other methods of decontamination. The metal that is obtained after smelting, however, would be homogeneous. Thus smelting greatly reduces the possibility of undetected pockets of contamination. The ability to place all scrap of one type together and process as a unit rather than item by item is a major advantage. Although smelting reduces contamination of uranium in iron, nickel and copper, it is much less effective in this respect for aluminum.

2.4 PRODUCTS OF SMELTING

The primary products that will be formed from this process are the slag and the metal ingots. The ingots of the metal will be exempt from licensing and regulatory requirements and will be ready for processing into the wire, sheet, and other items usually fabricated from normal noncontrolled metal. The slag which can contain significant quantities of uranium will be a controlled special nuclear material and must be handled as such. Recovering uranium for further use from the slag may be a future possibility whenever significant amounts are involved.

Ingots may not be the only metal product. Some metal may be directly cast into finished products. Nickel can be hit with a stream of water to form little buttons for use as alloy additive to stainless steel.

2.5 END USE FOR SMELTED SCRAP

Salvaged decontaminated metals could be made into any number of consumer or industrial products that use these metals at the present time. Examples of consumer products that could be made from the smelted alloy include: automobiles, appliances, furniture, utensils, personal items, and coinage.

This Environmental Statement has considered the impact of some typical metallic articles which would in general come into close contact for long periods of time with people. Such articles are coins, pots and pans, medical protheses such as bone pins, belt buckles, truck and carrier cabs, and desks. In addition, the impact of the intake of iron tonic for relieving anemia will be assessed. Although the probability of this tonic being made from smelted iron is very remote at the present time, the scenario cannot be ruled out.

REFERENCES FOR SECTION 2

1. F. W. Neblett, "Economic Projections for the Decontamination of Steel Scrap by Smelting (Revised)," P. 5, February 10, 1978. Available in file for USNRC Report NUREG-0518.

2. Letter from J. H. Cavendish, National Lead Co. of Ohio, to D. A. Baker, Pacific Northwest Laboratory, Subject: Transmittal of information for Environmental Impact Statement on establishment de minimus limits for special nuclear materials in metals, dated May 5, 1978. Available in file for USNRC Report NUREG-0518.

3. Letter from F. W. Neblett to J. H. Cavendish, Subject: Economic Projection for Processing CIP/CUP Copper Scrap at FMPC, dated, May 12, 1978. Available in file for UNSRC Report NUREG-0518.

4. Letter from R. D. Ohlinger, National Lead Company of Ohio, to J. H. Cavendish, National Lead Company of Ohio, Subject: Scrap Survey Second Generation, dated, October 13, 1977. Available in file for USNRC Report NUREG-0518.

5. Letter from R. D. Ohlinger, National Lead Company of Ohio, to J. H. Cavendish, National Lead Company of Ohio, Subject: Supplement to Scrap Survey, dated, December 14, 1977. Available in file for USNRC Report NUREG-0518.

6. An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives, Tables 3.9 and 3.21, Atomic Industrial Forum, AIF/NESP-009-009SR. Available from the Atomic Industrial Forum.

7. U.S. Department of Energy, "Draft Report of Task Force for Review of Nuclear Waste Management" (Deutch Report), p. 85, DOE/ER-0004/D, February 1978. Available in NRC PDR for inspection and copying for a fee.

8. K. J. Schneider and C. E. Jenkins, Study Coordinators, "Technology Safety, and Costs of Decommissioning a Reference Nuclear Fuel Reprocessing Plant," NUREG-0278, Vol. 1, pp. 7-89 through 7-95, Battelle, Pacific Northwest Laboratory, Richland, WA, 1977. Available for purchase from National Technical Information Service, Springfield, VA 22161.

9. Ibid. P. 7-11.

10. R. V. Amalraj, et al., "Physico-chemical Methods of Decontamination - Evaluation of Some Procedures and Practices Followed in Atomic Energy Establishment, Trombay, India", PP. 206, 207 in Proceedings of the First International Symposium on the Decontamination of Nuclear Installations, Harwell, England, 4-6 May 1966, Cambridge University Press 1967. Available in public technical libraries.

11. R. P. Allen, H. W. Arrowsmith, L. A. Charlot and J. L. Hooper, "Electropolishing as a Decontamination Process: Progress and Applications," PNL-SA-6858, P. 2.1, Battelle, Pacific Northwest Laboratories, April 1978. Available from NRC PDR for inspection and copying for a fee.

12. Ibid. P. 8.1.

13. Ibid. P. 6.2.

14. Ibid. P. 6.4.

15. R. W. Levin, Minutes of Meeting on CIP Scrap Smelting, KY-L-806. Union Carbide Corporation, Nuclear Division, September 17, 1975. Available in file for USNRC Report NUREG-0518.

16. E. W. Mautz, G. G. Briggs, W. E. Shaw, and S. H. Cavendish, "Uranium Decontamination of Common Metal by Smelting--A Review," p. 5, NLCO-1113 Special. National Lead Company of Ohio, February 1975. Available in NRC PDR for inspection and copying for a fee.

17. Ibid, P. 10.

3. MARKET FOR SMELTED ALLOY

The description of the present market for nickel, copper, and iron are discussed along with pricing policy today and into the future in order to assess the economic impact of smelting the CIP/CUP scrap and releasing the ingots to the marketplace. Because the quantities and degree of contamination of metal scrap from other governmental and commercial nuclear projects are unknown at this time, this economic assessment will only include that generated from the CIP/CUP program. However, this assessment can be extrapolated to other metals that might meet the criteria of the exemption.

3.1 NICKEL

3.1.1 Contaminated nickel available for potential reclamation

It is expected that 8,400 metric tons (Mg) of contaminated nickel scrap will become available from the CIP/CUP Program by 1981.(1) Uncontaminated nickel scrap from the CIP/CUP Program is presently being smelted at a recently installed facility at the Paducah, Kentucky, DOE Gaseous Diffusion Plant.(1) The shapes and form of all this nickel is classified. Smelting of the nickel from the CIP/CUP Program eliminates its security classification and allows unclassified handling and burial of the ingots. Therefore, the contaminated nickel will be smelted regardless of the action taken on the proposed change in the regulations to allow unrestricted sale of the smelted product. Additional nickel scrap is expected to become available from the decommissioning of commercial nuclear facilities (see Sections 2.1.2 through 2.1.5). However, the mix of radionuclides and their concentration levels in the scrap are unknown and therefore will not be covered in this report.

3.1.2 Nickel industry

3.1.2.1 Production of nickel

3.1.2.1.1 Primary production of nickel

Canada is currently the world's leading supplier of nickel mining 245,300 Mg of ore and smelting 149,100 Mg(2) of nickel in 1975. Canada is also the major source of nickel for the United States. New Caledonia is the world's second largest nickel supplier with 133,400 Mg of ore mined and 72,200 Mg of nickel smelted in 1975.(2)

The only domestic sources of primary nickel ore are Amax Inc. in Louisiana and the Hanna Mining Co. in Riddle, Oregon. Amax operates a renovated nickel-copper-cobalt refinery which produced 7,300 Mg of nickel in 1975(3) (its first year of operation). Currently, Amax is exploring new nickel ore deposits in Minnesota, and plans on building a test plant near Babbitt. The Hanna Mining Co. produced 15,442 Mg of ferro-nickel from lateritic ore in 1975.(3) Nickel mining and smelting represent only a small portion of Hanna's iron ore mining, processing, and merchandising operations.

A third domestic source of primary nickel is as a by-product of primary copper remining. In 1975, 793 Mg were recovered in this way.

3.1.2.1.2 Secondary production of nickel

A significant source of nickel in the United States is recycled nickel scrap. New scrap is generated as a waste in processing plants (home scrap) or in fabricating plants (prompt scrap). Old scrap is generated from finished goods which have outlived their productive lives. The latter category of scrap is similar to that being generated by the CIP/CUP program.

The amount of nickel recovered from old scrap, has varied from 26% to 59% of total domestic production between 1970 and 1975 (Table 3.1). This secondary nickel production is even more important when the extent of the U.S. dependence of foreign imports is seen by comparing domestic production (Table 3.1) to consumption (Table 3.2).

Table 3.1. U.S. production of nickel

Year	Domestic Production[a] (Primary + Secondary) (Mg)	Nickel from Old Scrap[b] (Mg)	Old Scrap As Percent of Total
1975	29,000	8,000	26
1974	32,000	14,000	43
1973	42,000	24,000	57
1972	47,000	28,000	59
1971	39,000	20,000	51
1970	35,000	15,000	42

SOURCE: (a)Reference 2. p. 1;
Reference 2. p. 871, 1972.
(b)Reference 2. p. 2, 1975
Reference 2. p. 872, 1972
Reference 2. p. 784, 970

Table 3.2. U.S. consumption and prices of nickel

Year	Total U.S. Consumption(a) (Mg)	Cathode* Consumption(a) (Mg)	Unit Price(b) ($/kg) Current $	Unit Price(b) ($/kg) Constant 1977 $(c)
1977	145,000(est.)	93,000(est.)	5.30	5.30
1976	149,000	95,000	4.95	5.71
1975	133,000	90,000	4.55	5.19
1974	189,000	113,000	3.89	4.93
1973	179,000	111,000	3.37	5.19
1972	145,000	100,000	3.08	5.07
1971	117,000	87,000	2.93	5.01
1970	141,000	102,000	2.84	5.01

---

*Cathode is the electro-negative pole of an electrolytic cell upon which material may be deposited by electrolysis.

SOURCE: (a)Reference 3. p. 871, 1972
Reference 2. p. 1, 1975, "NICKEL"
Reference 5. p. 112
(b)Reference 6. p. 110
Reference 6. p. 100, Jan. 2, 1978
(c)Reference 7. p. 46.

3.1.2.2 Domestic consumption of nickel

Domestic consumption of nickel totaled 145,000 Mg in 1977 (Table 3.2) and is predicted to increase at an annual rate of 2.6 percent between 1973 and 2000.(4) Thus, 359,900 Mg of nickel would be consumed domestically in 2000. U.S. produced nickel will only be capable of meeting a portion of this amount, forcing continued dependence on nickel imports unless new domestic nickel deposits are brought into production or recycling of old nickel scrap is greatly increased.

3.1.2.3 Domestic reserves and resources of nickel

The U.S. 1977 reserves* of nickel are estimated to be approximately 181,000 Mg of contained nickel, and low grade resources** contain more than 15,000,000 Mg.

---

*Reserves are defined as that portion of identified resources from which a useable mineral can be economically and legally extracted at the time of determination.

**Resources are defined as a concentration of naturally occurring solid, liquid or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.

Vast quantities of nickel could become available if economical techniques were developed for mining and processing the ore. Based on current reserves and present rate of production, domestic nickel reserves would be exhausted in the next 10-15 years. Thus, the U.S. could become even more dependent on imported nickel and domestic recycling of old nickel scrap.

3.1.2.4 Nickel industry structure and pricing patterns

An examination of monthly nickel prices, listed in Iron Age Annual Statistical Summary, reveals that the price of nickel moves in a step-like fashion. This is in contrast to the sawtoothed price fluctuations exhibited by most metals such as copper. There are two major reasons for this step-like pattern of nickel price changes.

First, the world nickel industry is dominated by a few large producers. Inco (International Nickel Company) of Canada has been the traditional leader in nickel production, controlling over 40 percent of the market. Along with other large nickel producers including Falconbridge, Le Nickel-SLN, WMC, and Sherrit Gordon, Inco periodically assesses what price the market will bear and sets prices accordingly. Since the number of world producers is small, an increase in price by a large producer will easily influence the prices charged by others.

A second source of this pricing pattern is that nickel is not traded on the London Metal Exchange and therefore, is not subject to rapid day-to-day price fluctuations.

Price forecasts in Minerals Facts and Problems(8) estimate the price of nickel to be $4.55/kg (1977 dollars) in 1985 and $4.65/kg (1977 dollars) in 1990 (see Table 3.3 for details). While these price forecasts will be used in the cost benefit analysis (Section 7.4), the accuracy of these or any other price forecasts is open to question.

3.1.3 Nickel uses and substitutes(9)

Due to its ability to resist corrosion and to add strength to other metals, over 90% of nickel used is in the form of metal alloys.

The principal end-users of nickel metal in alloy form are the manufacturers of chemical and allied products, and petroleum refiners. Nickel is used in fabricated metal products such as cutlery and hand tools. Nickel superalloys, which can resist temperatures in excess of 1800°F, are utilized by the aircraft industry. Electroplated nickel trim is used by the automobile industry and some buses and tanker trucks having nickel-bearing stainless steel bodies. Other end-uses of nickel include: electrical machinery, household appliances, building construction, shipbuilding and coinage.

Substitute materials are available to replace nickel in many of its end uses. Columbium, molybdenum, chromium and vanadium could replace nickel in some

Table 3.3. Nickel price forecasts

Year	Unit Price \$/lb[(a)] (1967 \$)	 \$/kg[(b)] (Constant 1977 \$)
1978	1.025	4.40
1979	1.030	4.42
1980	1.035	4.44
1981	1.040	4.46
1982	1.045	4.48
1983	1.050	4.50
1984	1.055	4.53
1985	1.060	4.55
1986	1.065	4.57
1987	1.070	4.59
1988	1.075	4.61
1989	1.080	4.63
1990	1.085	4.65

SOURCE: (a)Reference 3. p. 355, 1970
(b)Reference 7. p. 46, 1975.

steel alloys; cobalt, chromium and columbium-based alloys could replace some nickel super alloys. Use of these substitutes would, however, cause increased production costs and a sacrifice in product performance.

3.1.4 Costs of nickel smelting

The nickel scrap will be smelted anyway prior to burial primarily to declassify (in a security sense) the scrap. Because these costs are common to both burial and sale alternatives, they are not a necessary input to the benefit cost analysis for the proposed regulation.

3.1.5 Impacts of sale of contaminated nickel on nickel industry

If the proposed regulation is approved, it is expected that the 8,400 Mg of contaminated nickel scrap from the CIP/CUP will be smelted and sold between 1980 and 1982. The rate at which the nickel is sold is assumed to be the same as the rate at which it is smelted, namely 2,818 Mg(10) of cathode-grade nickel per year. This is about 3.0% of the nickel cathode consumption in the U.S. in 1977 (see Table 3.2). Therefore, the approval of this regulation is not expected to have a significant impact on the market price of nickel cathodes.

3.2 COPPER

3.2.1 Contaminated copper available for potential reclamation

It has been estimated that 1,600 Mg of unclassified contaminated copper scrap would be generated from the CIP/CUP program between 1976 and 1981.(11) (See Section 2.1.1 for yearly estimates.) This copper is mainly old motor windings from the gaseous diffusion plants and is contaminated with Tc-99 and uranium. These motors are being rebuilt with new windings at National Electric Coil Company in Louisville, Kentucky, and the old motor windings are being transferred to DOE's Feed Material Production Center (FMPC) at Fernald, Ohio.(1) They would be either smelted or stored at FMPC depending on whether or not the proposed regulation is approved. Additional copper scrap is expected to become available from the decommissioning of commercial nuclear facilities. (See Sections 2.1.2 through 2.1.5 for details.)

3.2.2 Copper industry

3.2.2.1 Production of copper

3.2.2.1.1 Primary production of copper

Since 1883 the U.S. has been the world's leading copper producer. In 1975 the U.S. mined 239,094,000(12) Mg of ore and refined 1,169,000(12) Mg of copper (Table 3.4). The principal copper producing states are Arizona (with 59% of the total), Utah (13%), New Mexico (10%), Montana (6%), Nevada (6%) and Michigan (5%).(13)

3.2.2.1.2 Secondary production of copper

Old scrap represented 15 to 24% of total copper production in the U.S. between 1960 and 1975 (Table 3.4). Approximately one half of the old scrap is used in the production of refined copper; the other half is used in the production of brass.

The importance of scrap as a source of copper is expected to increase in the near future. It has been predicted that scrap's portion of the total domestic supply will increase from 20% in 1975 to 25% in 1985.(14)

3.2.2.2 Domestic consumption of copper

In 1976, domestic consumption of copper totaled 1,742,000 Mg (Table 3.5). Domestic consumption is forecasted to be 5,450,000 Mg in 2000.(15) Forecasts of domestic mine production for 2000 indicate that 90%(16) of the quantity demanded in that year will be supplied domestically; the remaining 10% is expected to be met by imports.

Table 3.4. Copper production

Year	Domestic Production (Primary + Secondary) (Mg)	Copper from Old Scrap (Mg)	Old Scrap as Percent of Total (Mg)
1975	2,053,000	336,000	16
1974	2,514,000	439,000	17
1973	2,796,000	442,000	16
1972	2,710,000	417,000	15
1971	2,373,000	405,000	17
1970	2,517,000	458,000	18

SOURCE: (a)For years 1971-1975: Reference 2. p. 1.
(b)For year 1970: Reference 2. p. 473, 1972.

Table 3.5. U.S. consumption and prices of copper

Year	Total U.S.(a) Consumption (Mg)	Cathode(b) Consumption (Mg)	Unit Price ($/kg)	
			Current $(c)	Constant 1977(d)
1977	1,986,000(est.)	891,000	1.45	1.45
1976	1,742,000	781,000	1.52	1.62
1975	1,393,000	445,000	1.39	1.58
1974	1,991,000	526,000	1.69	2.15
1973	2,211,000	482,000	1.32	2.07
1972	2,032,000	386,000	1.12	1.85
1971	1,832,000	281,000	1.14	1.97
1970	1,854,000	224,000	1.28	2.28

SOURCE: (a)For years 1971-1975: Reference 2. p. 2, 1975.
For year 1970: Reference 2. p. 473, 1972.
(b)For years 1974-1975: Reference 2. p. 36, 1975, "Copper"
For year 1973: Reference 2. p. 525, 1974.
For years 1971-1972: Reference 2. p. 499, 1972.
For year 1970: Reference 2. p. 490, 1970.
(c)Reference 6. p. 100, Jan 2, 1978.
(d)Adjusted using Industrial Commodities Wholesale Price Indes, 1967 base from Reference 7. p. 46, 1975.

3.2.2.3 Domestic reserves and resources of copper

The 1976 U.S. copper reserves are estimated to be 82,000,000 Mg of contained copper. U.S. identified copper resources are 190,000,000 Mg.

3.2.2.4 Copper industry structure and pricing patterns

The domestic copper industry is dominated by a few large firms. In 1974, four companies accounted for 64% of domestic mine production.(17) Many of these firms are vertically integrated with smelting and refining operations.

U.S. investments in foreign copper operations were common until the early 1970s when many foreign countries nationalized U.S. interests. The Council Intergouvernmental des Pays Exportateurs is an international organization comprised of Chile, Zambia, Zaire and Peru, which now controls over 70% of the western world's copper reserves. The purpose of this organization is to stimulate their countries' copper production by fostering foreign trade.

In the world copper market there exists a two tiered pricing system: the London Metal Exchange (LME) price and the U.S. Producers price. The LME price is established by daily copper trading activity. The U.S. producers' price is set by leading domestic copper producers based on market conditions. However, the U.S. producers' price is set at less than the market clearing price (here assumed to be the LME price), which forces the non-price rationing of copper to domestic consumers. This two-tiered pricing system exists because the U.S. producers fear that their U.S. customers would turn to foreign suppliers and that a higher price would stimulate the search for copper substitutes.

The price of copper is forecasted to be $2.77/kg (1977 dollars) in 1985 and $2.92/kg (1977 dollars) in 1990.(18) (See Table 3.6 for details.) While these price forecasts will be used in the cost benefit analysis (Section 7.4), the accuracy of these or any other price forecasts is open to question.

3.2.3 Copper uses and substitutes(19)

Copper is used primarily in electrical equipment and parts. Electric motors, power generators, motor-generator sets, dynamotors and blowers all utilize copper. Electronic navigation and communication systems that require all weather dependability rely heavily on copper. Copper also finds wide-spread use in nonelectrical applications such as commercial airconditioning, farm machinery, automotive parts, shell casings, coinage, and household water piping.

In recent years, aluminum, plastics, steel and other materials have replaced copper in some of its traditional uses. Aluminum is copper's principal competitor in limited electrical and heat exchanger applications. Currently, 40%(20) of insulated power cables and more than 90%(20) of bare conductors are produced with aluminum. Heat exchangers in household refrigerators and freezers, and automotive airconditioners are now made almost exclusively from aluminum.

Table 3.6. Copper price forecasts

Year	Unit Price ($/lb) Constant 1967 $[(a)]	Unit Price ($/kg) Constant 1977 $[(b)]
1978	$0.596	$2.55
1979	0.603	2.59
1980	0.610	2.62
1981	0.617	2.65
1982	0.624	2.68
1983	0.631	2.71
1984	0.638	2.74
1985	0.645	2.77
1986	0.652	2.80
1987	0.659	2.83
1988	0.666	2.86
1989	0.673	2.89
1990	0.680	2.92

SOURCE: (a) Reference 4. p. 546.
(b) Adjusted using the Industrial Commodities Wholesale Price Index. Reference 7. p. 46.

One of the prime determinants of the price elasticity of demand for a good is the availability of substitutes, because price of the good will encourage some consumers to substitute other available goods.

An examination of the price elasticity of demand for copper, measured as the percentage change in the quantity of copper demanded divided by the percentage change in the price of copper, provides an indication of the substitutability of other metals for copper. If the absolute value of the price elasticity demand for copper is greater than one (i.e., the percentage decrease in the quantity demanded is greater than the percentage increase in price), the demand for copper is said to be elastic. Likewise, if the absolute value of the price elasticity of demand for copper is less than one (i.e., the percentage decrease in the quantity of copper demanded is less than the percentage increase in the price) it is said that the demand for copper is inelastic.

Testimony given by Dr. James C. Burrows before the Congressional Subcommittee on Economic Growth(21) indicates that the long run price elasticity of demand for copper is greater than one. That is, the long run demand for copper is elastic, and substitution of other materials for copper is likely if the relative price of copper rises. This in turn is expected to restrain the increases in copper prices.

3.2.4 Costs of copper smelting

Copper scrap is to be smelted in existing furnaces at the FMPC in Fernald, Ohio. Each of these twenty-six year old furnaces has a smelting capacity of 60 Mg per week.(22) Additional capital costs for a shredder and other modifications to the existing furnaces are estimated to be $126,600 in 1977 dollars. Operating costs are estimated to be $1037/Mg in 1977 dollars.(23)

3.2.5 Impacts of sale of contaminated copper on copper industry

If the proposed regulation is approved it is expected that the 1,600 Mg of contaminated cathode grade copper scrap from the CIP/CUP will be smelted and sold in 1980 and 1981. This total amount of smelted copper is about 0.1% of the U.S. cathode grade copper consumption in 1977. Therefore, the approval of this regulation is expected to have little or no effect on the market price for cathode-grade copper.

3.3 IRON AND STEEL

3.3.1 Contaminated iron and steel available for potential reclamation

It is estimated that 31,800 Mg of iron and steel scrap will become available from the CIP/CUP Program (See Section 2.1.1 for details). The smelting operation is assumed to take place at either a new facility to be built at DOE's Oak Ridge Gaseous Diffusion Plant in Oak Ridge, Tennessee, or at FMPC in Fernald, Ohio.(24) Additional iron and steel scrap is expected to become available from the decommissioning of commercial facilities (see Sections 2.1.2 through 2.1.5). However, the mix of radionuclides and their concentration levels in the scrap are unknown and therefore will not be covered in this report.

3.3.2 Iron and steel industry

3.3.2.1 Domestic production of iron and steel

Until 1973, the United States was the world's leading producer of iron and steel. The USSR has since taken and held the lead, with Japan third. In 1975, the U.S. produced 72,474,000 Mg of pig iron in 201 blast furnaces operated by 22 companies(25) and 114,636,000 Mg of raw steel (Tables 3.7 and 3.8). The technology used to produce raw steel has changed over time. In 1960, 88.5 percent of the raw steel produced in the U.S. came from

Table 3.7. U.S. production of pig iron

Year	Total Production Pig Iron (Mg)
1975	72,474,000
1974	86,797,000
1973	92,106,000
1972	80,796,000
1971	73,984,000
1970	83,830,000

SOURCE: For years 1971-1975:
Reference 2. p. 2.
For 1970: Reference 2.
p. 641, 1972.

Table 3.8. U.S. raw steel production by furnace

Year	Openhearth Percent of Total Output*	Basic Oxygen Process Percent of Total Output	Electric Arc Percent of Total Output	Total Production of Raw Steel (Mg)
1977	--	--	--	114,636,000(est.)
1976	18.3	62.4	19.3	116,364,000
1975	19.1	61.5	19.4	106,038,000
1974	24.3	56.0	19.7	132,473,000
1973	26.4	55.2	18.4	136,090,000
1972	26.2	56.0	17.8	121,128,000
1971	29.5	53.1	17.4	109,494,000
1970	36.6	48.2	15.2	119,558,000

---

*Includes Bessemer process' share of total output.
SOURCE: Reference 6. p. 93, January 2, 1978.

openhearth furnaces, 3.3 percent from basic oxygen furnaces, and 9.2 percent from electric arc furnaces. By 1976, openhearth furnaces' share decreased to 18.3 percent. The share from basic oxygen furnaces and electric arc furnaces increased to 62.4 percent and 19.3 percent respectively. For each Mg of pig iron produced domestically approximately 1.5 Mg of metalliferous materials (including iron ore) was consumed in blast furnaces.

3.3.2.2 Domestic consumption of pig iron

In 1975, 69,662,000 Mg of pig iron (Table 3.9) were consumed in domestic blast furnaces to produce raw steel.(26) Domestic consumption of pig iron is estimated to increase at an average annual rate of 1.6 percent from 1975.(27 Thus, domestic consumption in 2000 is expected to total approximately 103,595,000 Mg compared to domestic production of 151,744,000 Mg (assuming an average annual increase in production of 3 percent).(27)

Table 3.9. Consumption of pig iron

Year	Total U.S. Consumption(a) (Mg)	Unit Price ($/kg)	
		Current $	Constant 1977 $(b)
1977	71,550,000(est.)	0.21	0.21
1976	76,090,000(est.)	0.21	0.22
1975	69,662,000	0.21	0.24
1974	84,633,000	0.14	0.18
1973	88,744,000	0.09	0.14
1972	78,387,000	0.09	0.15
1971	71,410,000	0.08	0.14
1970	78,697,000	0.08	0.14

SOURCE: (a)For years 1973-1975: Reference 2. p. 16.
For years 1970-1972: Reference 2. p. 660, 1972.
(b)Adjusted by the Industrial Commodities Wholesale Price Index. Reference 7. p. 46.
(c)Reference 6. p. 98, January 2, 1978.

3.3.2.3 Domestic reserves and resources of iron ore

The 1976 U.S. iron reserves were 3,600,000,000 Mg (3.6 Petagrams) of contained iron. Domestic identified iron ore resources are approximately 16,300,000,000 Mg (16.3 Petagrams) of contained iron. It is expected that most of the iron and steel consumed in the U.S. through the year 2000 will be produced from domestic reserves.

3.3.2.4 Iron and steel industry structure and pricing patterns

In 1975 there were 175 companies producing a variety of iron and steel products. In 1974, 20 of these firms were vertically integrated with blast furnaces, steelmaking furnaces and finishing mills and 10 firms producted 80% of the raw steel in the U.S. in 1967. (See Table 3.10)

The majority of the iron and steel industry in the United States is located near the lower Great Lakes parts in Illinois, Indiana, Michigan, Ohio, and western Pennsylvania. The large vertically integrated steel mills are in northern New York, eastern Pennsylvania, eastern Maryland and Alabama.

Table 3.10. Raw steel production in the United States in 1967

Company	Production (Mg)	Percent of Total
U.S. Steel	28,000,000	24.3
Bethlehem	9,000,000	16.1
Republic	8,500,000	7.3
National	8,700,000	6.7
Armco	7,800,000	5.9
Jones and Laughlin	6,300,000	5.4
Inland	6,200,000	5.3
Youngstown	5,100,000	4.4
Wheeling-Pittsburgh	2,900,000	2.5
Kaiser	2,600,000	2.3
Total*	93,000,000	80.2
Total Industry	116,000,000	

*Top ten steel producing companies
SOURCE: Reference 28.

The iron and steel industry has had a history of administered pricing policies. A few large firms, such as U.S. Steel,(29) called "price leaders" set the prices of iron and steel products at fixed plus marginal costs and a target rate of return. These announced price increases are generally followed by other iron and steel companies, but these price increases are subject to certain constraints. Foreign producers in Japan and Europe, which are partly subsidized by their respective governments, provide a constraint on U.S. producers' price increases by not generally following the U.S. price leaders. A second constraint is the federal government's investigations of iron and steel producers' pricing policies.

Iron and steel scrap was produced by 3,700 firms in 1975. In 1974, 90 percent of iron and steel scrap was produced by 1,300 firms. Thus, it may appear that the iron and steel scrap market is more perfectly competitive than the rest of the iron and steel industry. However, the cost of transporting a Mg of iron and steel scrap from the processor to the customer represents a significant portion of the delivered price of low valued scrap. This, in turn, limits the geographical extent of the market in which the scrap processors can compete, and may enable some processors to establish local scrap monopolies.

The price of pig iron is forecasted to remain at $0.21/kg (in constant 1977 dollars) from 1978 until 2000 (Table 3.11). This forecast is based on price forecasts contained in *Mineral Facts and Problems*(30) for iron-in-ore, and it agrees with price forecasts made in "Economic Projections for the Decontamination of Steel Scrap by Smelting"(31) for pig iron.

Table 3.11. Price forecasts for pig iron

	Unit Price		
Year	($/Mg) Constant 1968 $(a)	($/Mg) Constant 1977 $(b)	($/kg) Constant 1977 $
1978	107.01	208.67	0.21
1979	107.08	208.81	0.21
1980	107.15	208.94	0.21
1981	107.22	209.08	0.21
1982	107.29	209.22	0.21
1983	107.36	209.35	0.21
1984	107.43	209.49	0.21
1985	107.50	209.63	0.21
1986	107.57	209.76	0.21
1987	107.64	209.90	0.21
1988	107.71	210.03	0.21
1989	107.78	210.17	0.21
1990	107.85	210.31	0.21

SOURCE: (a)Reference 4. p. 302, 1970
(b)Reference 7. p. 46.

3.3.3 Iron and steel uses and substitutes(32)

The primary use of pig iron is in the production of raw steel. Steel scrap is the primary substitute for pig iron in this use. Pig iron is combined with steel scrap in Openhearth furnaces (usually 40-45% steel scrap) and in basic oxygen furnaces (usually 30% steel scrap). Steel scrap is normally the only raw material used in electric arc furnaces to produce raw steel.

A few of the principal uses of iron and steel products include: frame and housing for automobiles, rails for railroads, sheet and plate for office furniture and ships, reinforcing bars for concrete buildings, drilling rods and pipes for oil and gas wells, and sheet for the body of cans and containers. Substitutes exist for iron and steel products in certain applications. Alloys of nonferrous metals such as aluminum, copper, titanium and zirconium, can replace steel in wire, rods, bars and piping. Reinforced concrete is used to replace some structural steel. Aluminum, copper and plastics can replace steel in some cans and containers. The extent to which these other materials can replace iron and steel products would be reflected by the price elasticity of demand for iron and steel if this information were available.

3.3.4 Costs of iron and steel scrap smelting(33)

Contaminated iron and steel scrap from the CIP/CUP is expected to be smelted at a new facility to be built at the Oak Ridge Gaseous Diffusion Plant in Oak Ridge, Tennessee. This new 10-Mg size, 4000-kVA electric arc furnace will be operated by three shifts per day, five days per week and smelting 10,910 Mg of iron and steel scrap per year.

The total capital cost for this facility is estimated to be $6,450,000 (in constant 1977 dollars). Operating costs are estimated to be $120.05 per Mg of saleable output (in constant 1977 dollars).

The total capital costs of building a smelter at Fernald, Ohio is $3,771,000 (in constant 1977 dollars) and the operating costs are $119.74 per Mg of saleable output (in constant 1977 dollars).

3.3.5 Impacts of sale of contaminated from and steel on iron and steel industry

If the proposed regulation is approved it is expected that the 31,800 Mg of contaminated iron and steel scrap will be smelted and sold between 1982 and 1984. The rate at which the iron (or semi-steel) pigs will be sold is assumed to be the same rate at which it is produced through this smelting process, namely 10,910 Mg per year. This is about 0.01% of the U.S. pig iron consumption in recent years (see Table 3.9). Therefore, the approval of the proposed regulation is expected to have little or no effect on the market price of pig iron.

REFERENCES FOR SECTION 3

1. Letter from J. H. Cavendish, National Lead Company of Ohio, to D. A. Baker, Pacific Northwest Laboratory, Subject: Transmittal of information for Environmental Impact Statement on establishment of de minimus limits for special nuclear materials in metals, dated May 5, 1978. Available in file for USNRC Report NUREG-0518.

2. Minerals Yearbook. Preprint from the 1975 Vol. 1, Bureau of Mines, U. S. Department of the Interior, Washington, DC, p. 9. Available in public technical libraries.

3. Mineral Facts and Problems. Bureau of Mines, U.S. Department of the Interior, Washington, DC, p. 735, 1976. Available in public technical libraries.

4. Ibid. p. 745.

5. Mineral Commodity Summaries 1978, Bureau of Mines, Dept. of Interior, Washington, DC, p. 112. 1978. Available in public technical libraries.

6. Iron Age Annual Statistical Review, p. 100, January 1978. Available in public technical libraries.

7. Business Statistics, p. 46, U.S. Dept. of Commerce, Washington, DC, 1975. Available in public technical libraries.

8. Op. Cit., Ref. 3, p. 355, 1970.

9. Op. Cit., Ref. 3, pp. 742-743.

10. Letter from E. W. Richardson, Union Carbide to S. A. Smith, Pacific Northwest Laboratory, Subject: "Smelting of Contaminated Nickel Scrap," dated August 8, 1978. Available in file for USNRC Report NUREG-0518.

11. Letter from R. W. Neblett to J. H. Cavendish, Subject: "Economic Projection for Processing CIP/CUP Copper Scrap at FMPC," dated May 12, 1978. Available in file for USNRC Report NUREG-0518.

12. Op. Cit., Reference 2, p. 1.

13. Ibid., p. 2.

14. Op. Cit., Reference 3, p. 294, 1970.

15. Ibid., p. 306, 1976.

16. Ibid., p. 308.

17. Ibid., p. 294.

18. Ibid., p. 546, 1970.

19. Ibid., p. 297-298, 1976.

20. Ibid., p. 301.

21. "Testimony of Dr. James C. Burrows before the Subcommittee on Economic Growth of the Joint Economic Committee of the Congress of the United States," p. A20, Charles Rivers Associates, Inc., p. 22, 1974. Available in file for USNRC Report NUREG-0518.

22. Op. Cit., Reference 1, p. 3.

23. Op. Cit., Reference 11, exhibit B, p. 2.

24. Engineering Feasibility Report for a Smelting Facility for Processing Uranium Contaminated Ferrous Scrap, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN, p. 2, 1975. Available in file for USNRC Report NUREG-0518.

25. Op. Cit., Reference 5, p. 84, 1976.

26. Op. Cit., Reference 2, p. 3.

27. Op. Cit., Reference 3, pp. 543.

28. E. W. Mautz, "The Ferrous and Common Nonferrous Metals Industries and Associated Scrap - Metals - A Review," p. III.39, National Lead Company of Ohio, NLCO 1128, 1975. Available in file for USNRC Report NUREG-0518.

29. F. M. Scherer, Industrial Market Structure and Economic Performance, p. 168-170, Rand McNally & Company, Chicago, 1973. Available in public technical libraries.

30. Op. Cit., Reference 3, p. 302, 1970.

31. F. W. Neblett, "Economic Projections for the Decontamination of Steel Scrap by Smelting (Revised)," p. A-21, National Lead Company of Ohio, February 10, 1978. Available in file for USNRC Report NUREG-0518.

32. Op. Cit., Reference 3, p. 553.

33. Op. Cit., Reference 31, p. 9.

4. PREDICTED IMPACTS OF SMELTED ALLOY

4.1 INTRODUCTION

Reclamation of metals contained in obsolete or discarded industrial equipment and consumer products is a significant source of feed material for the secondary metals industry. The reclaimed metal scrap may be contaminated with materials used in the industrial processes or in the consumer products. Metal scrap recovered from uranium handling or processing equipment will likely be contaminated with uranium and other radionuclides derived from the uranium. This chapter considers the potential impacts, radiological and nonradiological, on man and his environment from the sale and unrestricted reuse of reclaimed alloys contaminated with small quantities of technetium-99, uranium, and uranium decay products.

The potential impacts associated with the unrestricted reuse of uranium contaminated alloys must take into consideration the identities and quantities of the contaminative radionuclides. These characteristics cannot be specified rigorously, because the potential sources of scrap are varied, as is the radionuclide content of any batch even if from only one source. In addition, complete determinations of isotopic concentrations are generally not made of scrap metals. Therefore, calculations of the impacts of recycled metal are based on the upper limits of the proposed exemption; 17.5 ppm of uranium isotopes, 5.0 ppm of the fission product technetium-99, and daughter nuclides assumed to have built up from 20 years decay of the parent nuclides. The radiological effects are dependent not only on the absolute quantity of uranium but also on the isotopic composition. The concentrations of uranium isotopes U-238, U-236, U-235, U-234, and U-232 and their daughter nuclides are given in Appendix A for uranium enriched to 1.5 wt% U-235, which is used in all following analyses.

Reclaimed scrap in general is used as a feed material by the secondary metals industry. The released metal alloy under consideration in this assessment is likely to be treated in the same manner as is all scrap. Thus, the metal may be recycled into the manufacture of a wide variety of products. A complete assessment of all potential uses for the metal is not feasible. Therefore, several scenarios which are representative of the many potential uses are selected and assessed in detail. The results of the selected examples can be extrapolated to other uses and should present a conservative picture of the potential environmental impacts associated with the proposed exemption.

Figure 2.1 of Chapter 2 depicts the flow of the recyclable metals considered in this assessment. The inventory of each metal is decontaminated and smelted into salable ingots at a licensed private or government-owned facility. Bulk quantities of the smelted metal alloy ingots are transported from the facility directly to the users by rail or truck shipment. The smelted alloy is then manufactured into a wide variety of industrial and consumer products. It is impossible to assess all potential products made from recycled alloy.

Therefore, a representative sample of product types are investigated at various stages of the consumer cycle. The points of assessment are presented in Table 4.1. Population doses at these points are conservatively calculated assuming the entire proposed inventory of recycled CIP/CUP smelted alloy is used in each product (see Table 2.1 of Chapter 2). The population doses for manufacture, distribution, and use of products made from the smelted alloy would be the same whether the metal inventory were all released at one time or released over a period of years. Therefore, the doses are calculated as if the material is all used in manufacture at once. Separate doses for individuals are presented for products used for population doses as well as products thought to be of a critical nature to show the range of doses an exposed individual might be expected to receive. The doses given are meant as examples. Since the population doses are calculated assuming all the material goes into each product, they are not additive; the total dose to the population from unconditional release of the smelted alloys is not the sum of the various population doses.

Table 4.1. The operations for which doses are assessed for the selected representative products

	Operation				
	Bulk Transport	Manufacture	Distribution	Use	
Product	(Population)	(Population)	(Population)	(Population)	(Individual)
Iron:					
Bulk	X				
Sheet		X			
Slag		X	X	X	X
Pans		X	X	X	X
Structures				X	X
Furniture					X
Buckles					X
Prostheses					X
Tonic					X
Copper:					
Bulk	X				
Pennies		X	X	X	X
Bracelets					X
Nickel:					
Bulk	X				
Nickels		X	X	X	X
Sheet				X	X

Separate groups of people are involved with each step of the products' life cycles. The potential radiological effects of transport of the bulk alloy, and manufacture, distribution, and use of the selected products made from it, are summarized in Section 4.3 for the human populations described in Section 4.2. Nonradiological impacts and societal impacts are given in Sections 4.4 and 4.5, respectively.

4.2 ENVIRONMENTS AND POPULATIONS AFFECTED

All of the recycled smelted metal alloy follows a similar life cycle. From a government or commercial smelter, bulk alloy is transported to the manufacturers. Products are fabricated and distributed to consumers. When the product wears out or becomes obsolete, it is either discarded or recycled back into the secondary metal industry.

4.2.1 During bulk transport

Bulk quantities of recovered smelted alloy will be shipped from the licensed smelting facility to manufacturers via either rail or truck. Rail transportation would be preferred for long-distance shipments [greater than 800 km (500 miles)] and truck transportation for shorter distances. Those environments that would be impacted include the transport vehicles, freight terminals, and service facilities normally used in bulk transport. Members of the public affected include transport workers and service personnel. Incidental exposure to shipments would be experienced by members of the general public located along the shipment routes. Detailed descriptions of exposure conditions for transport workers, service personnel, and the general public are presented in Appendix B.

4.2.2 During manufacture

The environments affected by the reuse of slightly contaminated metal alloys in manufacturing processes would include almost all of those associated with the use of basic unformed metals. A representative sample of industries which might use recycled alloy is discussed in the following paragraphs. The results from the selected examples can be extrapolated to other manufacturing processes and should present a conservative picture of the potential impacts of recycling potentially contaminated metals.

The recovered alloy in ingot form could be used immediately to manufacture products or it could be resmelted. Steel making is an example process which could use a large quantity of alloy as feedstock. The reference steel mill has the capacity to process 400 Mg of iron per day, therefore, the entire CIP/CUP inventory of iron discussed in Chapter 3 represents 80 days of feed stock. The iron would probably not all be released at one time, so that individual doses would be smaller, but the population doses would be the same, therefore, the doses are calculated based on an 80 day mill run.

Steel workers involved in unloading the smelted alloy ingots, charging and tending furnaces, pouring and handling new ingots, milling and storing finished steel sheets would be exposed to direct irradiation and to inhalation of and air submersion in air containing particulate iron. Exposure scenarios for steelworkers are provided in detail in Appendix B.

Slag is generated as a byproduct in steelmaking. For the purpose of placing an upper limit on dose estimates the residual uranium isotopes present in the smelted iron alloy are assumed to concentrate in the slag when the ingots are resmelted for steelmaking even though there is no conclusive evidence that this can happen.* Resmelting the entire CIP/CUP inventory of recycled iron would result in up to 3,200 Mg of slag. The slag could be used in any of several ways; e.g., as a base for paving a highway. Persons driving over such a highway could be exposed to direct irradiation from the slag. Erosion of the roadbed into a body of water used as a local drinking water supply would result in ingestion of a small amount of contaminated slag.

The recycle iron need not be made into steel. An alternative use would be to manufacture cast-iron frying pans. The CIP/CUP inventory of recycle alloy would be sufficient to make 9 million cast-iron frying pans.

The frying-pan manufacturing plant employs workers to operate furnaces, run ladles, and pour, cast, grind and package pans. The factory workers are immersed in air containing iron particulates, and thus receive air immersion and inhalation doses as well as direct radiation doses from handling the contaminated alloy. The exposure scenarios to frying pan makers are described in detail in Appendix B.

Pennies and nickels are minted from copper and nickel. Many operations are performed in the mints. Mint workers involved in working with furnaces, ingots, blanks and finished coins would be exposed not only to direct irradiation from the copper and nickel, but also to air containing particulates. Details of exposure conditions during mint operations are given in Appendix B.

4.2.3 During product distribution

Cast-iron frying pans represent items with a typical consumer product distribution system. Frying pans are typically distributed through warehouses and retail stores. Truck drivers, service attendants, and persons along the route are exposed during transport, and warehouse workers, retail clerks, checkers, and customers are exposed during distribution and sale of the pans. Exposure conditions are summarized in Appendix B.

Coins are distributed from the mint to local banks by armored car. The driver and two guards ride in the truck. Persons along the distribution route are also incidentally exposed. Detailed exposure conditions are presented in Appendix B.

---

*See Appendix B, page B-6.

The distribution of other products made from the recycled alloy would be similar to one of these modes, or similar to the distribution of bulk metal alloy (e.g., transport of slag from resmelting recycled iron), and the associated populations would resemble these.

4.2.4 During product use

Sheet steel is used in manufacture of many products. Small buildings, vehicles, office furniture and home appliances are among the products the recycled alloy could be used in. Persons using these items would be exposed to low levels of radiation from the contaminative radionuclides.

The 9 million cast- iron frying pans are assumed to be distributed two per family to 4 1/2 million families, effecting about 18 million persons. These people would be exposed directly to the pans during cooking and cleaning, and also would be subject to ingesting a small amount of iron from corrosion of the pan during cooking.

Many people would receive incidental exposure to various small metallic items. Several use situations are assumed for coins. Details for coin use are given in Appendix B. Individuals could wear personal jewelry made from recycled metal. Individual doses from steel belt buckles and copper bracelets are considered. A few people may be exposed to a surgically implanted steel bone prosthesis for stabilizing fractures. Individual doses are considered. Finally, as an example of iron salts as a food ingredient, the pharmaceutical compound ferrous sulfate (an iron supplement), normally administered in daily doses as a tonic or pill, is considered. Individual doses and dose commitments from ingestion of daily doses of iron sulfate are considered in the exposure scenario. As an extreme case, the radiological effects of ingesting an entire bottle of ferrous sulfate tonic, as a small child might do, are considered in Chapter 5. It is assumed that no chemical purification of the iron and its contaminants occurs in processing.

4.2.5 Due to disposal or during recycle

Obsolete or discarded articles made of metals with trace amounts of uranium and Tc-99 will either be recycled or disposed of. Recycled metal will be collected and reenter the product cycle. Places and groups affected will be similar to those just discussed. Discarded metal will likely be deposited in landfills. Measurable effects from such disposal will be negligible, because relatively few contaminated items would be buried at any one location. The dose rate from individual items made from recycle alloy is so low that doses to trash collectors or landfill operators will be negligible.

4.3 RADIOLOGICAL IMPACTS

In the assessment of the potential radiological impacts associated with unrestricted distribution, use, and disposal or recycle of enriched-uranium contaminated alloys, the exposure pathways illustrated in Figure 4.1 are considered. The pathways relate to exposure by direct radiation and by the potential loss of radionuclides from the metals.

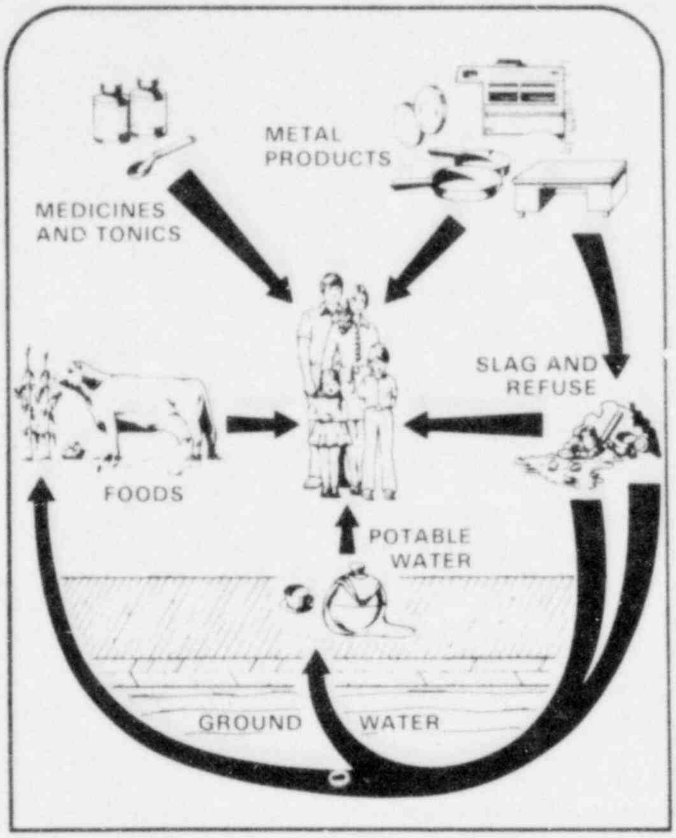

Figure 4.1. Generalized exposure pathways to man from radioactive material contained in or released from consumer products

Except for direct contact with the metals and internal deposition of released radionuclides, radiation exposure from beta particles should be negligible, since most beta particles would be absorbed in the metal. Throughout this assessment, the assumptions are made that, when taken into the body, the radionuclides behave independently of the scrap metal in which they are incorporated and are in the form (soluble or insoluble) that delivers the maximum dose for the exposure pathway under consideration.

For this report doses from external irradiation of the body (direct and immersion) are the doses received during the postulated duration of exposure. Doses from internal exposure (ingestion and inhalation) are the cumulative doses that will be received during the 50 years following the postulated intake (50-year dose commitments).

It should be noted that the units used in this report for activity and ionizing radiation are curie, rad, rem, and person-rem.* The new SI units for these quantities are as follows:

---

*Person-rem or man-rem are expressions for the summation of total-body doses to individuals in a group. Thus, if each member of a population group of 1,000 people were to receive a dose of 0.001 rem (1 millirem), or if 2 people were to receive a dose of 0.5 rem (500 millirem) each, the total population or collective dose in each case would be 1 person-rem.

Quantity	New Named Unit and Symbol	In Other SI Units	Old Special Unit and Symbol	Relationship New to Old Units
Absorbed dose	Gray (Gy)	J/kg*	Rad (rad)	1 Gy = 100 rad
Dose Equivalent	Sievert (Sv)	J/kg	Rem (rem)	1 Sv = 100 rem
Activity	Becquerel (Bq)	dis/sec**	Curie (Ci)	1 Bq ≈ 27 pCi

---

*Joule per kilogram.
**Disintegrations per second.

The potential doses are all based on conservative, yet reasonable, assumptions applicable to the situation being evaluated. As a result, the estimated doses are conservative; i.e., they are maximized. However, the assumptions used in constructing exposure situations limit the accuracy of the reported doses.

Average doses to the total body are estimated in all cases considered. Except for doses to skin and bone, the total-body dose is a conservative estimate of potential doses to organs by external radiation. This is not true for radionuclides taken into the body by inhalation and ingestion. Doses to most internal organs will exceed those to the total body if the radionuclides are inhaled or ingested in the form (either soluble or insoluble) that results in uptake in a specific organ. In situations where airborne radionuclides are present, inhalation is the critical exposure pathway.

4.3.1 Radiological effects on man

4.3.1.1 Due to bulk transport

Bulk quantities of recovered alloy could be shipped from the licensed recovery facility to manufacturers by either rail or truck. Tables 4.2* and 4.3 summarize the potential total-body radiation doses to transportation workers and the general public for the populations described in Section 4.2.1 exposed according to the scenarios of Appendix B for rail and truck transport, respectively. The doses are those reported by ERDA in a recent Environmental Impact Assessment(1), which assumed 5 ppm uranium and 5 ppm Tc-99. Doses would total 2×10^{-4} person-rem if the entire (all metals) CIP/CUP scrap inventory (see Table 2.1 of Chapter 2) was smelted, and the resulting alloys were shipped by train or 3×10^{-3} person-rem if these were shipped by truck.

---

*In the tables for this section the "E format" notation is used to represent very small and very large numbers. For example: 6E+3 = $6 \times 10^{+3}$ = 6,000 and 6E-3 = 6×10^{-3} = 0.006.

Table 4.2. Potential radiation doses from transport by railcar of bulk quantities of recycled smelted alloy

Metal*	Population Group	Population Exposed	Population Dose (Person-rem)
Fe	Brakemen	70	2E-5
	Yard Workers	70	7E-5
	Passersby	700	1E-5
	Persons along Route**	2.3E+7	9E-5
Ni	Brakemen	18	4E-6
	Yard Workers	18	2E-5
	Passersby	180	3E-6
	Persons along Route**	5.9E+6	2E-6
Cu	Brakemen	4	1E-6
	Yard Workers	4	4E-6
	Passersby	40	7E-6
	Persons along Route**	1.3E+6	4E-7
All Metals	Total		2E-4

---

*Shipments of total CIP/CUP inventory.

**The number of persons along the route is the product of 130 persons per square kilometer and the total number of train-kilometers traveled by all 10-car trainloads.

4.3.1.2 Due to manufacture

The dose to the workers in a mill which may melt the smelted alloy for a second time was estimated. A steel mill is assumed to run for 80 days to process the entire CIP/CUP inventory of recycle iron. Workers in the steel mill would be subject to radiation doses from direct radiation from the metal, and immersion in and inhalation of air contaminated with metal particulates. Potential direct radiation doses to the workers in a mill producing rolled steel sheet from recycled alloy are summarized in Table 4.4 for the circumstances described in Section 4.2.2 and Appendix B. The direct radiation doses to the total body or workers would total 1×10^{-4} person-rem.

Table 4.3. Potential radiation doses from transport by truck of bulk quanties of recycled smelted alloy

Metal*	Population Group	Population Exposed	Population Dose (Person-rem)
Fe	Truck Drivers	1,400	2E-3
	Service Attendants	2,800	9E-5
	Passersby	14,000	1E-4
	Persons along Route**	2.3E+8	3E-5
Ni	Truck Drivers	370	4E-4
	Service Attendants	740	2E-5
	Passersby	3,700	3E-5
	Persons along Route**	6.1E+7	6E-6
Cu	Truck Drivers	72	7E-5
	Service Attendants	144	4E-6
	Passersby	720	6E-6
	Persons along Route**	1.2E+7	1E-6
All Metals	Total		3E-3

---

*Shipments of total CIP/CUP inventory.

**The number of persons along the route is the product of 130 persons per square kilometer and the total number of shipment-kilometers traveled by all truck shipments.

In addition, the 50-year total-body dose commitments from immersion in and inhalation of air in the mill would be 1×10^{-8} person-rem and 2×10^{-3} person-rem, respectively. All workers are assumed exposed to the same air concentration of particulates. Dose commitments to the lungs of workers from inhalation would be over 200 times the total-body dose: 0.5 person-rem over 50 years.

The dose from the slag from the resmelting operation was estimated. Assuming that all the slag generated by resmelting the recycled smelted-iron ingots is used to pave a segment of highway as described in Section 4.2.2, doses to travelers on the highway would be no more than 3×10^{-7} rem/yr per trip to the total body. Assuming 1000 people taking 250 trips per year, this could

Table 4.4. Total-body direct radiation doses to steel mill workers for an assumed 80-day exposure period

Worker Description	Population Exposed	Dose (Person-rem)
Scrap Crane Operator	3	6E-6
Furnace		
Charger	3	3E-6
Operator	6	2E-5
Pouring Crane Operator	3	9E-6
Casting Operator	3	5E-6
Ingot Removal	3	6E-6
Slab Mill Workers	3	2E-6
	9	2E-5
Slab Storage	3	3E-5
Hot Strip Mill Workers	9	1E-6
	9	1E-6
	3	4E-7
	18	4E-5
	21	1E-6
	3	6E-7
Slag Handler	3	6E-6
Total		1E-4

result in a population dose of 7×10^{-2} person-rem/yr. The roadbed is considered to be an infinite strip source and an attenuation factor of 0.5 from paving and automobile is assumed. Erosion of the roadbed into a water-supply reservoir could result in ingestion of 0.10 mg of slag per day by a person drinking 1.5 liters per day. This person could receive a 50-year dose commitment from both uranium and Tc-99 of 2×10^{-9} rem to the total body per day of ingestion. Therefore, for one year of continuous intake this person would receive a 50-year dose commitment of 2×10^{-4} rem. If 10,000 people drank from this reservoir, a population dose of 2.0 person-rem would result.

A factory is assumed to be involved in the manufacture of the entire inventory of CIP/CUP iron into 9 million cast iron frying pans. Workers in the factory would be exposed to direct radiation from the pans, and to immersion in and inhalation of air contaminated with metal particles. Potential doses to workers from direct radiation are summarized in Table 4.5 for the exposure scenarios outlined in Section 4.2.2 and Appendix B. The direct radiation doses would total 9.1 person-rem to the total body of workers. In addition, the 50-year total-body dose commitments from immersion in and inhalation of the air in the factory would be 2×10^{-7} and 4×10^{-2} person-rem, respectively. The dose commitment to lungs from inhalation would be 9.9 person-rem.

Table 4.5. Total-body doses from direct irradiation to frying-pan makers for one year of operation

Operation	Population Exposed	Dose (Person-rem)
Unload	9	2E-2
Charge Furnace	18	5E+0
Operate Furnace	27	2E-1
Large Ladle	9	2E-1
Pouring Ladle	36	2E-1
Remove Castings	18	9E-2
Cut and Rough Grind	36	1E-1
Grit Blast	9	4E-1
Clean Dust	9	3E-2
Inspect	18	8E-1
Package	27	3E-1
Store	9	1E+0
Total		9E+0

The entire CIP/CUP inventory of recycle smelted copper is assumed to be made into pennies. Mint workers would be subject to direct exposure to the metal, and to immersion in and inhalation of air containing copper particulates. Potential direct radiation doses to mint workers are summarized in Table 4.6 for the exposure conditions outlined in Section 4.2.2 and Appendix B. The direct radiation doses to the total body of mint workers would total 0.7 person-rem. In addition, the 50-year dose commitments to total body from immersion in and inhalation of air in the mint would be 6×10^{-9} person-rem and 1×10^{-3} person-rem, respectively. The dose commitment from inhalation to the mint workers' lungs would be 0.3 person-rem.

Table 4.6. Total body doses from direct irradiation of mint workers involved in making pennies

Operation	Population Exposed	Dose (Person-rem)
Charge Furnace	9	7E-2
Operate Furnace	1	8E-3
Ladle	2	4E-3
Remove and Clean Ingots	4	9E-3
Roll	2	4E-3
Check	1	9E-4
Slit	2	3E-3
Coil	2	2E-3
Punch Blanks		
Load	40	3E-2
Punch	80	4E-2
Package	40	5E-2
Recycle	2	9E-4
Anneal	1	5E-3
Clean	2	4E-3
Upset		
Load	20	8E-2
Roll	20	6E-4
Collect	20	8E-2
Press Coins		
Load	20	8E-2
Press	80	2E-1
Collect	20	8E-2
Test	1	1E-3
Count	1	6E-3
Bag	1	3E-4
Store	1	2E-4
Total		7E-1

The dose scenario for nickel would be the same as pennies if the inventory of CIP/CUP nickel were made into coins. Since there is about five times as much nickel recycled as copper, the manufacturing doses could be about five times those from minting pennies.

4.3.1.3 Due to product distribution

Potential radiation doses to individuals during distribution of cast iron frying pans with slightly contaminated alloy are presented in Table 4.7, based on the exposure conditions of Section 4.2.3 and Appendix B.

Table 4.7. Potential direct radiation doses to the total body due to distribution of 9 million cast-iron frying pans

Individual	Persons Exposed (Thousands)	Dose (Person-rem)
Truck Driver	47	4E-2
Truck Loader	47	5E-4
Service Attendant	94	1E-3
Passersby	467	2E-3
Public along Distribution Route	1,490	5E-5
Warehouse Worker	1	3E-3
Warehouse Packer	1	3E-3
Retail Clerk	375	2E-1
Retail Checker	375	3E-4
Retail Customer	375,000	2E-1
Total		4E-1

Distribution of pennies could result in the doses summarized in Table 4.8 for the exposure conditions of Section 4.2.3 and Appendix B. A bag of coins is represented as a point source. At one meter, a bag of pennies has a dose rate of 4.0×10^{-11} rem/hr and a bag of nickels has a dose rate of 2.0×10^{-11} rem/hr. Thus the dose to the driver, guard or excort delivering nickels would be about half that given in Table 4.8 for pennies, but the population dose could be 50 times as much since more shipments are required if the entire nickel inventory is made into coins.

Table 4.8. Potential direct radiation doses to total body due to distribution of pennies

Individual	Persons per Exposure	All Shipments* Population Dose (Person-rem)
Driver	1	7E-6
Guard	1	7E-6
Escort	1	7E-6
Public (Country)	46,000	1E-8
Public (City)	14,950	3E-8
Total		2E-5

---

*Distribution of 550 shipments of pennies.

4.3.1.4 Due to product use

Structures fabricated of steel sheet rolled from the smelted alloy could be widely used. The dose rate at the center of a 3 m x 3 m x 3 m sheet metal room made of 1.6-mm-thick metal containing 17.5 ppm uranium, 5 ppm technetium, and daughters would be 5 x 10^{-8} rem/hr. A person working within this structure 1000 hr/yr could receive a total-body dose rate of about 5 x 10^{-5} rem/yr. If the entire inventory of CIP/CUP iron were made into these structures, a population dose rate of 1.3 person-rem/yr would result. A person standing a distance of 3 meters from such a structure would receive about 3 x 10^{-9} rem/hr, with a resultant annual population dose of 4 x 10^{-1} person-rem. This structure can represent an office, a truck cab, or numerous large metal appliances.

The alloy could possibly be used for a steel "vault" type of structure such as a submarine, bank vault, diving bell, etc. Assuming the dimensions of the above sheet-metal room (a cube 3 meters on a side), but with a wall thickness of 10 cm, the total-body dose rate to a person located at the center would be approximately 1 x 10^{-5} rem/hr. Thus, assuming a person spends 1000 hr/yr in such a vault, his dose rate would be 0.01 rem/yr to his body.

Sheet steel could also be manufactured into office furniture. The dose rate to the total body and gonads of a person seated at a steel desk made of slightly contaminated sheet steel could be 2.4 x 10^{-9} rem/hr and 2.6 x 10^{-9} rem/hr, respectively, resulting in dose rates of 5 x 10^{-6} rem/yr to total body and 6 x 10^{-6} rem/yr to gonads.

Potential doses to users of cast-iron frying pans are summarized in Table 4.9 for the exposure conditions given in Section 4.2.4 and Appendix B. The ingestion doses and the beta particle dose to hands are the largest, but both are still very small.

Table 4.9. Potential total-body radiation doses to individual users of cast-iron frying pans

Activity	Dose Per Year of Use	Population Dose (Person-rem)
Meal Preparation	1.5E-6 rem/yr	6.8
Cleaning Pan	1.1E-8 rem/yr	0.1
Beta dose to hands	5.5E-4 rem/yr	
Ingestion Dose Commitment	2.3E-7 rem/50 yr	4.1
Other	1.9E-7 rem/yr	3.4

Skin doses from wearing steel belt buckles and copper bracelets for 16 hours/day for 1 year would be 3.7×10^{-4} and 0.29 rem respectively. The skin dose over 50 years would be 0.019 and 14 rem respectively. The skin dose from the bracelet would be higher than that from the belt buckle since no intervening cloth is assumed to halt beta particles. Although the above skin dose rate of 290 mrem/yr is relatively high, it would be localized to the area in contact with the bracelet.

The doses to persons handling pennies made of contaminated copper alloy are estimated for the unlikely situation that all pennies to which one person might be exposed during one year are made of the recycle metal. Potential doses resulting from the exposure conditions given in Section 4.2.4 and Appendix B are summarized in Table 4.10.

The average dose rate to the total body at 30 cm from a penny made of recovered copper is 8×10^{-12} rem/hr. Doses to an average person can be approximated by weighting the estimated doses in Table 4.10 with the probability that the coins will be those made from recovered alloy. For pennies the probability is about 8×10^{-3} and thus the doses to the average individual could be about 0.8% of those given in Table 4.10. The population doses in Table 4.10 have already been modified by the probability.

The doses to people handling nickels made of recycled nickel alloy are considered under the same circumstances as pennies. The dose rate to the total body at 30 cm from a nickel containing recovered nickel is about 3×10^{-12} rem/hr, thus individual doses from nickels could be about 40% of those from pennies. The population dose from nickels could be 25 times as great, however, since the probability a nickel made from recycled metal would be involved in an event is greater than for a penny (5×10^{-1} versus 8×10^{-3}). It is unlikely that this much of the recovered nickel would be used to mint coins.

Nickel is a common ingredient of many corrosion-resistant alloys. The inventory of recovered nickel could be used in making stainless steel (10 wt% nickel). About 910,000 pieces of 3 m x 3 m x 0.0016 m stainless-steel sheet could be made from 8,400 Mg of nickel. The dose rates from the stainless

Table 4.10. Maximum potential radiation doses to users of pennies

Population Group	Population Subgroup	Number of Members	Individual Dose to Total Body (rem/yr)	Beta Dose to Hands (rem/yr)	Population Dose* (Person-rem/yr)
Non-carrier	All	2.1E+8	9.1E-9	0.0	1E-2
Carriers	Men	7.3E+7	3.9E-9	4.9E-4	2E+0
	Women	8.0E+7	2.3E-8	4.9E-4	1E-2
	Children	5.3E+7	1.2E-7	9.0E-3	5E-2
Banks	Tellers	2.1E+5	3.9E-6	8.7E-4	6E-3
	Head Tellers	4.1E+4	3.5E-5	6.8E-4	1E-2
	Customers	8.0E+6	1.8E-11	0.0	1E-6
Small Stores	Cashiers	8.8E+5	6.0E-7	3.4E-3	4E-3
	Customers	4.4E+7	3.2E-12	8.0E-5	1E-6
Large Stores	Cashiers	8.8E+5	3.4E-6	7.0E-3	2E-2
	Customers	4.4E+7	1.9E-11	8.0E-5	6E-6
Total					2E+0

---

*The population doses have been modified by the probability that a penny made of contaminated copper will be involved in interaction, 8.1×10^{-3}.

sheet would be about 11% of that from regular steel sheet made from the iron smelted alloy only. Dose rates to people from structures made of this stainless steel would thus be 11% of those from similar structures made of recycled iron, as discussed above. Since there are nearly 3 times as many stainless sheets postulated using recycled nickel as were postulated using recycled iron, the population dose would be 29% of those postulated for the regular sheet steel products.

The dose rate to the bone of a person surgically fitted with a stainless steel pin prosthesis would be 0.44 rem/yr (20 rem/50 yr) at the surface of the pin, mostly from beta particles, and decreasing rapidly to 1.1×10^{-5} rem/yr at one centimeter, due primarily to gamma rays. Dose rates external to the body of the person with the pin would be on the order of 6×10^{-11} rem/hr, essentially negligible.

A person ingesting 6 teaspoons per day of ferrous sulfate iron tonic derived from the smelted alloy would receive a 50-year dose commitment of 6×10^{-7} rem per day of ingestion, or 0.002 rem/50-yr per year of ingestion. It is assumed that the chemical processing of the iron used in manufacturing the ferrous sulfate does not alter the radionuclide contaminant concentration. This example shows that, while it is undesirable and certainly not intended, even direct consumption of metals contaminated with uranium and technetium would not result in undue doses to the general public.

4.3.1.5 Due to recycle or disposal

The fate of the enriched uranium is the primary problem for consideration in the disposal of products manufactured from slightly contaminated metals.

The recovery and reuse of metal products will involve collection and blending of contaminated metals with virgin or recycled metal having no prior association with low-enriched uranium. The overall effect will be further dilution in the characteristics imparted by the low-enriched uranium. The radiological impacts would likely be no worse than those previously estimated. Individual doses would be decreased in proportion to the degree of mixing with uncontaminated recycle material. Population doses would also decrease in proportion to the quantity of radionuclides lost from the recycle flow.

The metal lost from the recycle flow would likely be discarded in landfills. Discarding metal items should not result in measurable doses to any individuals. Refuse collectors would only be exposed to individual items for short periods, and would at most receive doses on the order of those received by retail checkers in the distribution of frying pans (Table 4.7). Few items would be buried at any one location. Transport of the uranium, Tc-99 or daughters into the atmosphere is likely only in the form of dusts from decomposing products. Any localized concentrations from such uranium and Tc-99 are considered unlikely, and even if occurring, would produce radiological impacts much smaller than those incurred by manufacturing plant workers. Since most of the uranium and Tc-99 in the metal is in the form of insoluble oxides, a reasonable situation cannot be envisioned whereby the concentration in a body of water of radionuclides released from discarded products would exceed that assumed to result from slag erosion (Section 4.3.1.2). As noted, a person drinking such water for an entire year would receive a 50-year dose commitment to the total body of about 2×10^{-4} rem, mostly from the soluble Tc-99 released.

4.3.1.6 Summary of radiological doses to general population

Tables 4.11 and 4.12 present a summary of the radiological doses from the use of metal slightly contaminated with uranium and technetium, for the few example products assessed. Many other types of products and different exposure conditions can be postulated. The products considered in Tables 4.11 and 4.12 are considered to be representative of many products, as are the exposure conditions. The dose estimates are considered to be representative of those that could potentially be received by the general public. However, because of self shielding, if the smelted metal alloys were used in objects having large surface areas, such as truck cabs, desks, buildings, etc., the radiation doses to individuals could be higher than those shown. In other words, if the smelted alloy was used in objects with high surface to volume ratios, the individual doses would be larger, and the population doses would be increased.

4.3.1.7 Occupational doses to the workers smelting the CIP/CUP scrap

Before it is released for unrestricted sale and use, scrap metal contaminated with various radionuclides must be smelted to get the uranium concentrations below the exemption limits. Workers in the smelter would be subject to radiation doses from direct radiation from the scrap and from inhalation of and immersion in air contaminated with metal oxide particulates. Potential direct radiation doses to the workers smelting contaminated iron, nickel, and copper scrap are summarized in Table 4.13 for the circumstances described in Appendix B. The direct radiation doses would total 4×10^{-3} person-rem for iron scrap, 5×10^{-3} for the nickel scrap, and 2×10^{-3} for the copper scrap. In addition, the total-body dose for workers immersed in air around the smelter would be 2×10^{-6} person-rem for iron, 2×10^{-8} person-rem for nickel, and 5×10^{-9} person-rem for copper. Also, the 50-year total-body dose commitments from inhalation of particulates would total 3×10^{-1}, 3×10^{-3}, and 6×10^{-4} person-rem for smelting the iron, nickel, and copper scrap, respectively. The 50-year dose commitments to the lungs of smelter workers would be about 330 times the total-body dose commitments for each metal.

4.3.1.8 Health effects

The relationship of radiation dose to observable "health effects" is well studied[2,3,4,5] but ill-defined. At the low dose rates observed, immediate health effects will not be seen. The amounts of radionuclides are very small, and the radiation dose to any individual is small, thus the effects to be considered are long delayed somatic and genetic effects. The effects that must be considered are cancers that may result from whole-body exposure and genetic effects, reflected in future generations, due to exposure of the germ cells.

Table 4.11. Summary of potential population radiation doses from release of smelted metal alloy* containing 17.5 ppm uranium and 5 ppm Tc-99

	Operation			
Product	Bulk Transport Population Dose (Person-rem)	Manufacture Population Dose (Person-rem)	Distribution Population Dose (Person-rem)	Use Population Dose (Person-rem)
Iron:				
Bulk	2E-4 (rail) or 2E-3 (truck)			
Sheet		2E-3		
Slag Roadbed**		6E-6		7E-2
Eroded Slag**		6E-6		2E+0
Pans		9E+0	4E-1	1E+1
Sheet Structures				1E+0
Copper:				
Bulk	2E-5 (rail) or 8E-5 (truck)			
Pennies		7E-1	2E-5	2E+0
Nickel:				
Bulk	3E-5 (rail) or 4E-4 (truck)			
Nickels		4E+0	4E+0	5E+1
Sheet Structures				3E-1

---

*The population doses are not additive. The entire inventory of each metal is used to maximize the population dose for each product. Actual doses would be reduced by the fraction of recycle metal going to the manufacture of each product.

**Assumes all uranium in the metal concentrated in slag at 175 ppm (10% of volume) and the Tc-99 concentration in the slag remains the same as in the alloy (see page B-3).

Table 4.12. Summary of potential individual doses from the release of smelted alloy containing 17.5 ppm uranium and 5 ppm Tc-99

Product	Dose* (rem)	Remarks
Iron:		
Slag Roadbed**	3E-7	per trip
Eroded Slag**	2E-4	50-yr commitment
Pans	2E-6	primarily external dose
Structures:		
0.16-cm-sheet	1E-1	spending 1000 hr/yr inside
10-cm-"vault"	1E-5	spending 1000 hr/yr inside
Desk	5E-6	using 2000 hr/yr
Buckles	4E-4	beta skin dose to local area from wearing 5840 hr/yr
Bone Pin	2E-1	dose to bone in contact with pin carried 50 yr
Tonic	2E-3	50-yr commitment from 1-yr intake
Copper:		
Pennies	4E-5	
Bracelets	3E-1	beta skin dose to local area from wearing 5840 hr/yr
Nickel:		
Nickels	2E-5	
Sheet Structures	2E-6	spending 1000 hr/yr inside

---

*Annual dose to total body from one year exposure to external radiation unless otherwise noted.

**See footnote ** of Table 4.11.

Estimates of the risk of cancers and genetic effects per unit of radiation exposure vary greatly.(2,3,4,5) The risk factors employed in this study are taken from a recent Environmental Impact Statement on the Management of Commercially Generated Radioactive Waste.(4) These risk factors are presented in Table 4.14. We believe that these risk factors are appropriate for estimating health implications from radiation. Without discussing the merits,

Table 4.13. Total body direct radiation doses to workers smelting contaminated scrap

Worker Description	Population Exposed	Dose (person-rem)		
		Iron Scrap	Nickel Scrap	Copper Scrap
Scrap Crane Operator	3	3E-4	4E-4	3E-4
Furnace Charger	3	3E-5	4E-5	2E-5
Furnace Preparer	6	1E-5	2E-5	1E-5
Furnace Operator	6	7E-5	1E-4	6E-5
Pouring Crane Operator	3	1E-5	3E-6	5E-7
Casting Operator	3	5E-6	1E-6	2E-7
Ingot Remover	3	6E-5	2E-5	3E-6
Slag Handler	3	3E-3	4E-3	2E-3
Ingot Storage	3	9E-5	2E-5	6E-6
Furnace Reliners	4	1E-4	1E-4	6E-5
Totals		4E-3	5E-3	2E-3

or lack of merit, of larger risk factors, the simple expedient of multiplying the numbers presented in Table 4.14 by 5 will include most other factors that have been used.(4)

The relative risk of cancer to the population from unrestricted use of smelted metal alloy contaminated with low levels of uranium and technetium-99 is given in Table 4.15 for the various products discussed.* Risk for population only is given since risk for individuals is so small. These risks are believed to be representative of those for a multitude of products represented by this sample. It can be seen that the risk of causing any cancers at all is less than one for release and unrestricted use of the entire inventory of smelted CIP/CUP alloy.

If, in addition to the smelted alloy from the CIP/CUP program, the inventory of reusable metals from decommissioning of light water reactors given in Table 2.5 is considered using the same scenarios, the resulting cancer risk to the public is increased in proportion to the increased amount of metal. This is of course based on the assumption that the reactor alloys would be smelted to contain nothing other than 17.5 ppm uranium and 5 ppm technetium-99. The cancer risk from iron and iron products given in Table 4.15 would be increased by about a factor of 3.6, and the risk from copper products increased by about 2.6. It can be seen that even with the increased amount of recycled material, the risk to the public of any cancers is still less than one.

---

*The basis of the risk calculation is the assumption that the general public is exposed to the contaminated smelted metal or derivative products for one year. For scenarios with ingestion or inhalation exposure pathways, the 50-year dose commitment from one year of exposure is used.

TABLE 4.14. Health effects risk factors[(a)]

Type of Risk	Predicted Incidence Per 10^6 Man-rem
Cancer from:	
Total Body Exposure	50
Lung Exposure	5
Skin Exposure	1[(b)]
Specific Genetic Effects to all Generations from:	
Total Body Exposure	50

SOURCE: (a) Reference 4, Appendix E, p. E.8.
(b) Reference 5, p. 171, under "all other cancer".

4.3.1.9 Comparisons to normally occurring uranium concentrations

To put the potential doses from unrestricted sale and distribution of slightly contaminated metal into perspective, the estimated annual doses to the general public from various sources are given in Table 4.16. The limits for dose from ionizing radiation to the individual members of the general public and to the total population are given in the National Council on Radiation Protection and Measurement (NCRP) Report No. 39(6):

> "The dose limit for the critical organs (whole body) of an individual not occupationally exposed shall be 0.5 rem in any one year, in addition to natural and medical and dental exposures.
>
> The dose equivalent to the gonads and the critical organs (whole body) for the population of the United States as a whole from all sources of radiation other than natural radiation, and radiation from the healing arts, shall not exceed a yearly average of 0.17 rem (170 mrem) per person."

It can be seen that the increments to total dose brought about by the recycle of slightly contaminated alloy are a negligible portion of actual amounts of recommended limits.

Table 4.15. Summary of potential health effects from release of slightly contaminated smelted metal alloy*

Product	Operation				Occupational**
	Bulk Transport	Manufacture	Distribution	Use	
Iron:					2E-5
Bulk	1E-8 (rail) or 1E-7 (truck)				
Sheet		1E-7			
Slag Roadbed†		3E-10		4E-6	
Eroded Slag†		3E-10		1E-4	
Pans		4E-4	2E-5	5E-4	
Structures				5E-5	
Copper:					4E-7
Bulk	1E-9 (rail) or 4E-9 (truck)				
Pennies		4E-5	9E-10	1E-4	
Nickel:					1E-7
Bulk	2E-9 (rail) or 2E-8 (truck)				
Nickels		2E-4	2E-4	3E-3	
Structures				2E-5	

---

*Note: The health effects are not additive. The entire eventory of each metal is used to maximize the population dose for each product. Actual effects would be reduced by the fraction of recycle metal used in the manufacture of each product.

**To workers in controlled smelter processing the CIP/CUP scrap.

†See footnote ** of Table 4.11.

Table 4.16. Average dose rates to the United States population (1970)

Source	Average Dose* Rate (rem/yr)	Population Dose (Person-rem)
Environmental		
Natural	1.0E-1	2.1E+7
Global Fallout	4.0E-3	8.2E+5
Nuclear Power	3.0E-6	7.0E+2
Subtotal	1.0E-1	2.2E+7
Medical		
Diagnostic	7.2E-2	1.5E+7
Radiopharmaceuticals	1.0E-3	2.0E+5
Subtotal	7.3E-2	1.5E+7
Occupational	8.0E-4	1.6E+5
Miscellaneous	2.0E-3	5.0E+5
Total	1.8E-1	3.7E+7

---

*Note: The numbers shown are average values only. For given segments of the population, dose rates considerably greater than these may be experienced.
SOURCE: Reference 2, p. 19.

Uranium is a commonly occurring constituent in many products. Table 4.17 presents estimates of concentrations of uranium in common building materials.(7). Dental porcelain, used in making false teeth, has been found(8) to contain from 10 to 990 ppm uranium. The uranium in false teeth is used to provide natural-looking color properties. The USNRC upper limit on unimportant quantities of uranium is 500 ppm.(9) These same limits allow uranium concentration in decorative porcelain glazes up to 20% by weight, and in glassware up to 10% by weight. There are at this time no allowances for exempt concentrations of Tc-99.

4.3.2 On other biota and the environment

Any potential environmental releases of radionuclides contained in scrap metals should have only small effects on the environment. Existing concentrations of the radionuclides should not be appreciably increased by scrap disposal except possibly at the point of disposal.(10). Uptake by terrestrial plants of uranium released to the environment should be negligible.(10) In

Table 4.17. Estimates of concentration of uranium in building materials

Material	Uranium (ppm)
Granite	4.7
Sandstone	0.45
Cement	3.4
Limestone Concrete	2.3
Sandstone Concrete	0.8
Dry Wall Board	1.0
Manufactured Anhydride (by-product gypsum)	13.7

SOURCE: Adapted from Reference 7, p. 30.

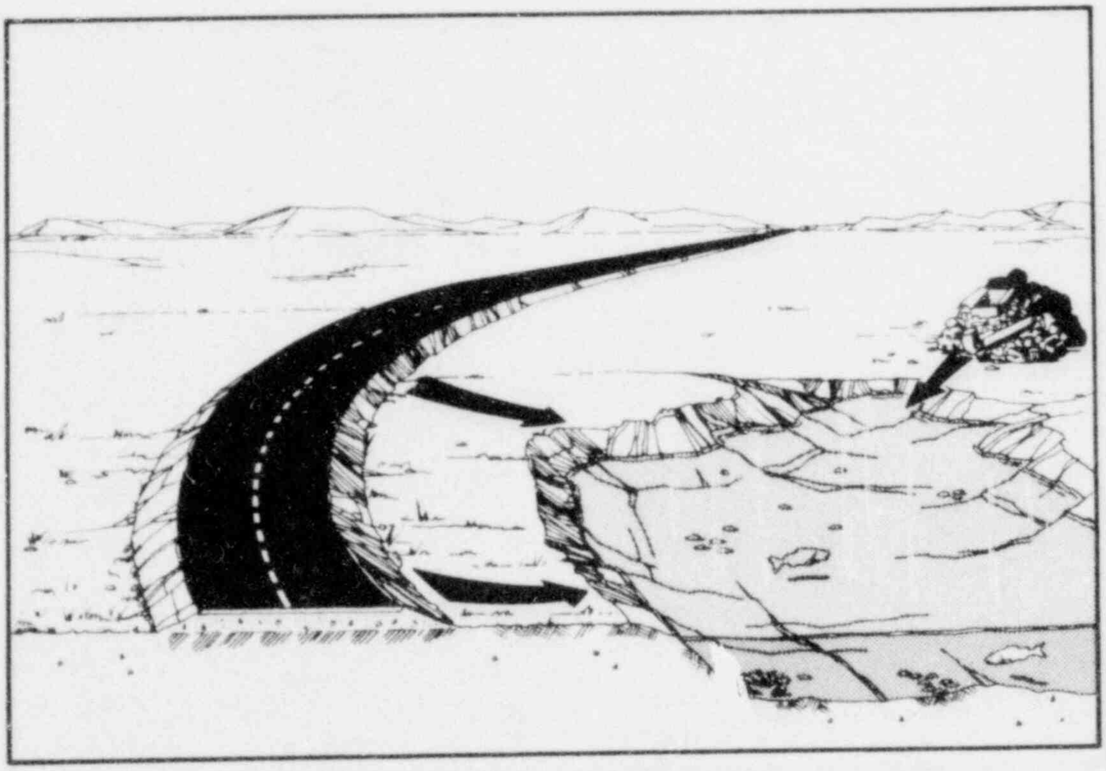

Figure 4.2. Generalized exposure pathways to organisms other than man

aquatic environments, radionuclides may be dispersed in the water or deposited in sediments. The dispersed nuclides are more significant, they could be taken up by aquatic plants and aquatic invertebrates, fish, and mammals dependent on the aquatic food chain. Doses to biota are from Reference 1, modified for 17.5 ppm uranium, 5.0 ppm Tc-99, and associated daughters, calculated based on the pathways shown in Figure 4.2.

For the postulated case of 1 Mg of slag eroding from the roadbed (see Section 4.3.1.2), aquatic plants could receive 3.5 x 10^{-4} rad/year, invertebrates could receive 1.3 x 10^{-4} rad/year, fish could get 1.4 x 10^{-4} rad/year, and muskrats (or similar mammals) could receive 4.8 x 10^{-4} rad/year. The preponderance of the doses are from the Tc-99. These doses are dominated by the internal exposure pathways. It can be seen from the trend of the biota doses that, contrary to the behavior of many pollutants (e.g., DDT), uranium does not concentrate along the food chain to higher animals.(2,10) Doses to biota derived from the erosion of refuse areas containing articles made from the smelted alloy would be infinitesimal.

Radiation doses to biota other than man should not exceed those given for the aquatic environment in other potential release situations. Few studies have been conducted to determine the impact of low-level radiation on aquatic and terrestrial organisms, but the philosophy is generally accepted that the limits established for man are also conservative for other species.(2)

4.4 NONBIOLOGICAL IMPACTS

The small quantities of radionuclides assumed to be present in the smelted metal will largely preclude the possibility that detectable nonbiological effects would occur. There will be some positive social benefits, described in Section 4.5.

4.4.1 Nonradiological

Some studies have been done(11,12,13) of the impacts of uranium in industrial products. The effects of low levels of uranium contamination on the physical properties of iron, copper, and nickel are discussed, as are the use of these metals in products like photographic film cannisters.

Contractor and Munroe(11,12) have investigated the effects of uranium on the properties of steel. Most of their investigations have been with macroscopic uranium fractions, however, they do present results for uranium concentrations less than 0.35 wt% (3,500 ppm). These are:

1. the critical transformation temperatures are unaffected, especially in medium carbon steels;

2. the hardenability is unaffected in medium carbon steels;

3. there is some evidence that uranium doping tends to result in a coarser grain structure in very low carbon steels, but only if added in large quanties;

4. there is no effect on tempering or on as-quenched hardness;

5. the tensile strength and yield point are superficially improved;

6. the fatigue limit is moderately improved for uranium concentrations between 1,000 and 4,000 ppm, and

7. the impact strength is "drastically" reduced for uranium contents above 1,500 ppm.

It can be seen that the low levels of uranium concentration possible with the proposed exemption (17.5 ppm) result in little adverse effects on the normal properties of steel.

Thomson and Edwards(13) have studied the effects of uranium contaminants on nickel and copper. They specifically studied the use of uranium as a deoxidant in copper processing. They found that for up to 0.8% uranium in copper (8,000 ppm), there was no effect on the fabricability, conductivity, or softening characteristics of copper, and there was only a small effect on copper's as-cast mechanical properties, machinability, corrosion resistance, and abrasion resistance. They also found for nickel with between 0.3% and 0.8% uranium (3,000-8,000 ppm), that there were no hardness changes, and no other detrimental effects. Thus, the small increase in uranium concentration proposed should have no noticable nonradiological affects on the properties of either copper or nickel.

4.4.2 Radiological

A number of investigators have examined the potential effects of radiation on stored photographic films.(14,15,16) Blatz(14) reports that a steel sample containing 74 ppm uranium would require about six months of direct contact to produce observable fogging of x-ray film. While the maximum anticipated level of 17.5 ppm uranium in recycled metal could produce only a minor amount of film fogging, the presence of Tc-99 is expected to cause a more noticable effect. Blatz(14) cites an estimate of about 10^5 beta particles/mm^2, relatively independent of electron energy, as producing a pronounced darkening of fast x-ray film. This exposure could result from direct contact with a steel film cannister contaminated with 5 ppm of Tc-99 in only a few days. The energy of the Tc-99 beta is fortunately low enough that a thin layer of paint, paper, or plastic coating between the film and film housing would be sufficient to eliminate the effect. Since most technical and medical films come packaged in paper or foil packets, there should be little problem with them. Standard commercial 35 mm photographic film comes in steel cannisters. Unless the cannister material has been diluted by mixing with other uncontaminated metal, the film would be subject to darkening on the edges and outer layers. Since the amount of contaminated metal to be recycled is a small fraction of that recycled every year, substantial dilution is expected and no problem with film darkening is anticipated.

4.5 IMPACTS ON COMMUNITIES

4.5.1 Economic

Economic impacts will be concentrated on communities near the controlled facilities used to smelt the contaminated scrap. The extent of these impacts depends on the number and wages of employees hired for construction and/or operation of the smelters if the proposed regulation is approved.

A nickel smelter has been constructed and is in operation at Paducah, Kentucky. This facility is currently smelting only the uncontaminated classified nickel scrap from the CIP/CUP program. The contaminated nickel scrap will be smelted to destroy its security classification whether it is sold or not. No changes in employment at Paducah are expected to occur as a result of approval of the proposed regulation.(17) Therefore, no incremental community impacts are expected in connection with the nickel smelter.

The CIP/CUP copper scrap is expected to be smelted at facilities at DOE's FMPC in Fernald, Ohio. However, this work could be completed in about six months of operation,(18) and no new workers are expected to be hired.(19) Also most workers are expected to commute from larger communities such as Cincinnati, Ohio rather than living in Fernald. Thus, the economic impacts on the local communities from copper smelting are expected to be minimal.

Several alternatives for smelting of the CIP/CUP iron and steel scrap have been discussed.(20) It is currently expected that a new facility would be built at Oak Ridge, Tennessee if the proposed regulation is approved. Construction of this facility is expected to cost $6.45 million in 1977 dollars and is expected to occur in 1981.(20) However, it is assumed that only $2.1 million (one third of $6.45 million) will be spent in the Oak Ridge area. Employment and income multiplier effects of this construction in the Oak Ridge/Knoxville area are expected to be small due to its short duration. Operation of the steel smelter at Oak Ridge is expected to cost $1.3 million per year for 1972-83 and $1.2 million in 1984 (all in 1977 dollars); smelting of the CIP/CUP iron and steel scrap is expected to be completed in 1984.(20,21) The size of employment and income multipliers varies among industries, regions, and over time for given locations, but a value of about 2.0 is generally used.(22) Thus, as a result of construction and operation of a new iron and steel smelter at Oak Ridge, total income in the local Oak Ridge/Knoxville area is expected to be increased by about \$4.3 million in 1981 and \$2.6 million in 1982-83 and \$2.4 million in 1984 (all in 1977 dollars).

These economic impacts of constructing and operating a new iron and steel smelter at Oak Ridge must be balanced against those avoided by not hiring workers to bury the contaminated iron and steel scrap. These burial costs avoided are estimated to be about \$700,000 per year in 1977 dollars for the 1981-83 period.(20,23) Thus, this would bave generated about \$1.4 million per year for 1981-83 in the Oak Ridge/Knoxville area if the contaminated iron and steel scrap were buried at Oak Ridge.

In conclusion, the only significant net economic impacts on local communities of a decision to approve the proposed regulation are expected to result from the employment and income effects of construction and operation of a new iron and steel smelter in Oak Ridge, Tennessee. Net economic activity in the Oak Ridge/Knoxville area is expected to increase by about \$2.9 million in 1981 and by about \$1.0 million in 1982 and 1983 and by about \$2.4 million in 1984 (all in 1977 dollars) as a result of the approval of the proposed regulation (see Table 4.18).

4.5.2 Societal

Societal community impacts include increases in population and demand for housing and social services that may be expected to occur as a result of the employment and income increases discussed in Section 4.5.1. Assuming the national averages of 1.46 workers per family and 3.3 persons per family gives a population multiplier of 2.25 which can be applied to these labor force estimates.(22)

No increases in population or demand for housing and social services are expected in the Fernald and Paducah areas. Since existing furnaces will be used, no additional smelter operators will be hired.

The construction of the iron and steel smelter at Oak Ridge is expected to last 2½ years and require 50 construction workers.(21) Assuming the population multiplier of 2.25, the Oak Ridge area will experience an increase in population of about 113 people during the 2½ year period.

The operation of the smelter will require 70 workers for 3 years (1982-1984).(21) This means that the Oak Ridge area will experience an increase in population of about 158 people during the 3 year period.

The effects of these increases in the Oak Ridge area population on the demand for housing and social services well be minimal.

Table 4.18. New community impacts for the Oak Ridge smelter in 1977 dollars

Year	Smelter Construction Costs	Smelter Operating Costs	Local Income Generated**	Income Lost†	Community* Income Lost	Net Community Income from Approval of the Regulation
1981	$6.45 x 10^6		$4.3 x 10^6††	$700,000	$1.4 x 10^6	$2.9 x 10^6
1982		$1.3 x 10^6	$2.6 x 10^6	$700,000	$1.4 x 10^6	$1.2 x 10^6
1983		$1.3 x 10^6	$2.6 x 10^6	$700,000	$1.4 x 10^6	$1.2 x 10^6
1984		$1.2 x 10^6	$2.4 x 10^6			$2.4 x 10^6

---

*Assumes an income multiplier of 2.0.

**From construction and operation of the Oak Ridge smelter.

†Income lost from not hiring workers to bury the iron and steel scrap.

††Assuming that one-third of the construction costs ($2.12 x 10^6) are labor costs and that the income multiplier is 2.0.

4.5.3 Ecological and aesthetic

The manufacture, distribution, use and disposal of the products containing recycled contaminated alloy should require no additions to the facilities used by those sectors of society normally engaged in those activities. Thus there should be negligible impacts associated with these areas. Recycle of these materials will, however, mean a possible reduction in the amount of the various ores that would be mined in order to supply metal equivalent to that used. To supply metal equivalent to that generated by the CIP/CUP program, the following ore would have to be mined:

Ore	Quantity (Mg)
Iron Ore (Taconite)	159,000
Nickel Ore (Pendlandite)	840,000
Copper Ore (Chalcopyrite)	164,000

Mining operations, both surface and deep, cause serious solid waste and water pollution problems. Solid wastes are created by the dumping of overburden and the conversion of low-grade ores to concentrates by techniques such as floatation.(24) Water pollution occurs from run off, from mine drainage, and from the formation of sulfuric acid by air oxidation of sulfides exposed in mining.(25)

The processing of fresh ores has a significant environmental impact. Production of metals from their ore creates air pollution both from the metal extraction process and in the generation of power used in the extraction process. The roasting of sulfide concentrates produced from copper and nickel ores produces large quantities of both SO_2 and dust, which can contain toxic compounds such as the oxides of mercury, arsenic, and lead. The smelting of fresh iron ore has similar impacts.

The processing of fresh ores also requires the use of more energy input than does recycle of metals. For instance the recycling of iron would save approximately 30 to 2000 kW-hr/ton (100 to 8000 J/g) of energy depending on the type of ore and iron concentration. Table 4.19 summarizes the energy savings which could result from the recycle of CIP/CUP generated metals. The generation of this much energy would require the equivalent of 30,000 Mg of coal.

The fraction of total mining of these metals and of coal represented by the CIP/CUP numbers is small compared to the total,(27) but the effect will become more significant as the nuclear industry expands and more recycle metals are placed on the market.

Table 4.19. Energy savings resulting from the recycle of CIP/CUP metal

Metal	Quantity (Mg)	Energy Saved/unit (MJ/Mg)	Energy Saved (MJ)
Iron	31,300	100-8000(a)	4E+6 - 2E+8
Nickel	8,400	86,000(b)	7E+8
Copper	1,600	52,000(c)	8E+7
Total			8E+8 - 1E+9

SOURCE: (a)Reference 26, p. 25.
(b)Reference 1, p. II.7.
(c)Reference 26, p. 34 (1% ore).

REFERENCES FOR SECTION 4

1. U.S. Energy Research and Development Administration, "Environmental Impact Assessment Concerning Proposed Rulemaking, Exemption from Licensing Requirements for the Sale and Use of Metal Scrap Homogeneously Contaminated with Enriched Uranium and Technetium-99 Below a Specified Concentration," Oak Ridge National Laboratory, July 1976. Available in NRC PDR for inspection and copying for a fee.

2. National Academy of Sciences, National Research Council, "The Effects on Population of Exposure to Low Levels of Ionizing Radiation," pp. 25-34, Report of the Advisory Committee on the Biological Effects of Ionizing Radiations, Washington, DC 20006, November 1972. Available in NRC PDR for inspection and copying for a fee.

3. U.S. Nuclear Regulatory Commission, "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," Appendix VI, Sections G and I. USNRC Report WASH-1400 (NUREG 75/104), October 1975. Available for purchase from National Technical Information Service, Springfield, VA 22161.*

4. U.S. Dept. of Energy, "Draft Environmental Impact Statement, Management of Commercially Generated Radioactive Waste," Vol. 2, Appendix E, USDOE Report DOE/EIS-0046-D, April 1979. Available in NRC PDR for inspection and copying for a fee.

5. National Council on Radiation Protection and Measurements, "Review of NCRP Radiation Dose Limit for Embryo and Fetus in Occupationally Exposed Women," pp. 12-27, NCRP Report 53, NCRP Publications, Washington, DC, 1977. Available in public technical libraries.

6. National Council on Radiation Protection and Measurements, "Basic Radiation Protection Criteria," pp. 95-96, NCRP Report 39, NCRP Publications, Washington, DC, 1971. Available in public technical libraries.

7. National Council on Radiation Protection and Measurements, "Radiation Exposure from Consumer Products and Miscellaneous Sources," pp. 29-31, NCRP Report 56, NCRP Publications, Washington, DC, 1971. Available in public technical libraries.

8. D. L. Thompson, "Uranium in Dental Porcelain," p. 8, HEW Report (FDA)76-8061, September 1976. Available for purchase from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

9. U.S. Code of Federal Regulations, "Unimportant Quantities of Source Material," 10 CFR 40.13 Available in public libraries.

---

*Also available free upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

10. W. E. Hanson, "Ecological Consideration of Depleted Uranium Munitions," pp. 2-5, LA-5559, Los Alamos Scientific Laboratory, 1974. Available for purchase from National Technical Information Service, Springfield, VA 22161.

11. G.P. Contractor and D. A. Munro, "Some Observations on the Tempering Response of Low-Carbon Uranium-Bearing Steel," *Trans. Metallurgical Soc. of AIME* 236, 447-454, (April 1966). Available in public technical libraries.

12. G. P. Contractor, "Some Properties of Plain Carbon Steels Containing Uranium," *Can. Mining Met. Bull.* 56, 199-208 (1963); *Trans. Can. Inst. Mining Met.* 66, 113-122 (1963). Available in public technical libraries.

13. R. Thomson and J. D. Edwards "Uranium in Non-Ferrous Metals," Department of Mines and Technical Surveys, Mines Branch Research Report R 97, Ottawa, Canada. Available in public technical libraries.

14. H. Blatz, "Sale of Uranium Contaminated Steel Scrap Recommended," pp. 125-127, *Iron Age*, September 25, 1952. Available in public technical libraries.

15. D. H. O. John, *Radiographic Processing in Medicine and Industry*, pp. 247-249, London, Focal Press, 1967. Available in public technical libraries.

16. T. Franke, "Experience in Monitoring Artificial Radioactivity in the Photographic Industry," *Atompraxis* 10, 522-526 (December 1964)(in German). Available in file for USNRC Report NUREG-0518.

17. Letter from E. W. Richardson, Union Carbide, to S. A. Smith, Pacific Northwest Laboratory, Subject: Personnel hiring to operate Paducah, KY, nickel smelter. Dated August 24, 1978. Available in file for USNRC Report NUREG-0518.

18. Letter from F. W. Neblett, National Lead Company of Ohio, to J. H. Cavendish, National Lead Company of Ohio, Subject: Economic Processing CIP/CUP Copper Scrap at FMPC, Dated May 12, 1978. Available in file for USNRC Report NUREG-0518.

19. Letter from J. H. Cavendish, National Lead Company of Ohio to S. A. Smith, Pacific Northwest Laboratory, Subject: Personnel to be hired by National Lead to Operate a Smelter, Dated August 21, 1978. Available in file for USNRC Report NUREG-0518.

20. F. W. Neblett, *Economic Projections for the Decontamination of Steel Scrap by Smelting*, internal report of National Lead Company of Ohio, February 10, 1978. Available in file for USNRC Report NUREG-0518.

21. Letter from R. J. Ryburn, Department of Energy, Oak Ridge, TN, to S. A. Smith, Pacific Northwest Laboratory, Subject: Smelter Construction at Oak Ridge, TN. Dated August 15, 1978. Available in file for USNRC Report NUREG-0518.

22. Technical, Environmental, and Socioeconomic Factors Associated with Dry-Cooled Nuclear Energy Centers, pp. 121 & 122, BNWL-1985, prepared for NRC by Pacific Northwest Laboratory, April 1976. Available for purchase from National Technical Information Service, Springfield, VA 22161.

23. J. H. Cavendish, editor, Feasibility Study of a Portable Smelter for Scrap Metals, pp. 26-31, NLCO-1132, prepared for Oak Ridge Operations Office, USERDA, by National Lead Company of Ohio, June 1976. Available in file for USNRC Report NUREG-0518.

24. W. H. Dennis, Metallurgy of the Non-Ferrous Metals, Ch. 2 and Ch. 7, London, Sir Isaac Pitman & Sons Ltd., 1954. Available in public technical libraries.

25. C. Bagge, "Coal Industry Faces Environmental Problems,: pp. 56-57, Pollution Engineering, September 1977. Available in public technical libraries.

26. J. C. Bravard, H. B. Flora II, C. Portal, Energy Expenditures Associated with the Production and Recycle of Metals. Available in NRC PDR for inspection and copying for a fee.

27. U. S. Dept. of the Interior, Bureau of Mines, Status of the Mineral Industries, 1977, p. 2. Available in public technical libraries.

5. POSSIBLE ENVIRONMENTAL IMPACTS OF POSTULATED ACCIDENTS AND MISUSE

Accidents involving recycle metal alloy may occur at any point in the manufacture, distribution, use, or disposal of products made from it. However, the occurrence of accidents in which the uranium, Tc-99, and daughter isotopes could produce measurable impacts is improbable. Impacts due specifically to recycle smelted metal involved in an accident would be negligible compared with the impacts of the accident itself.

Misuse of products containing recycle smelted alloy is possible. A scenario involving acute ingestion of recycle metal is discussed.

5.1 ACCIDENTS INVOLVING RADIOACTIVE MATERIALS

An extreme case of ingestion of contaminated iron alloy cay be hypothesized. The pharmaceutical compound ferrous sulfate is commonly used as a dietary iron supplement. Undiluted recycled smelted iron is assumed to be used to make a batch of ferrous sulfate. No chemical purification of the iron is assumed during processing. A person, such as a small child, is assumed to consume an entire 355 ml bottle of ferrous sulfate tonic, containing 3,124 mg of iron,(1) at one time. Acute ingestion of this amount of iron containing 17.5 ppm uranium, 5.0 ppm Tc-99, and associated daughters, would result in a total-body dose commitment of 1.8×10^{-5} rem. and a G.I.-tract dose commitment of 2.7×10^{-3} rem to the individual.

Possible "heavy-metal poisoning" from the uranium in the ferrous sulfate was also considered. However, the very small concentrations of uranium in the iron ($\leq$ 17.5 ppm), which on the basis of 3,124 mg of iron per bottle,(1) results in a concentration of 150 μg/ℓ, would have in all probability no toxic effect on the recipient. Effects of uranium poisoning are observed at much higher concentrations.(2)

5.2 ACCIDENTS NOT INVOLVING RADIOACTIVE MATERIALS

The possibility that recycle smelted alloy could be involved in conventional accidents (those in which the presence of radioactive materials is not a factor) has been considered. Although many such accidents are possible, the likelihood is negligible that a significant adverse environmental impact attributable to the use of smelted alloy would occur. The impacts of the accident would be the same whether this proposed action was approved or not.

REFERENCES FOR SECTION 5

1. Label from a bottle of "Feosol Elixer," Smith Kline and French Laboratories, Division of Smith Kline Corporation, Philadelphia, PA 19101. Available in file for USNRC Report NUREG-0518.

2. Jack Edward McKee and Harold W. Wolf, Ed., "Water Quality Criteria," Second edition, pp. 291-292, The Resources Agency of California, State Water Resources Control Board, 1963. Available in file for USNRC Report NUREG-0518.

6. ALTERNATIVES

6.1 ALTERNATIVES RELATED TO SMELTED SCRAP

Various other methods have been devised for dealing with the contaminated scrap generated by DOE and the commercial nuclear industry. The alternatives to smelting which will be examined are:

- Sale of surface decontaminated scrap
- Recycle of decontaminated equipment
- Burial of contaminated scrap
- Surface storage of contaminated scrap

6.1.1 Sale of surface decontaminated scrap

Scrap, which has been contaminated only on the surface, may be released for uncontrolled use under strict limits as to the amount of residual contamination that may be left after decontamination. The methods of surface decontamination summarized in Section 2.2 may be used. After decontamination, the surface of the object is then carefully measured for any residual contamination following the strict procedures outlined in the proposed American National Standard.(1) If the object in question meets the criteria of this standard, the object may be released for uncontrolled use.

However, because of the impossibility at this time of detecting cryptic deposits of alpha radioactivity which may be lodged in small cracks and crevasses in the surface of the object, the ANSI standard has issued a disclaimer which states: "Where potentially contaminated surfaces are not accessible for measurement (as in some pipes, drains, and ductwork), such property shall not be released pursuant to this standard, but shall be made the subject of case-by-case evaluation."(2)

6.1.2 Recycle of decontaminated equipment

Some of the scrap metal in the form of still serviceable equipment, tools, etc., may be decontaminated to the extent that it could be reused. The surface of the object may not be decontaminated sufficiently to be released under the rigid ANSI Standard mentioned in Section 6.1.1; however, the object still could be used again in a radiation controlled area. This method is being used at present for small tools and parts which do not have to undergo refabrication.

Another form of recycle is that of "captive recycle" whereby the unusable metal tool or device is refabricated at a government-owned-plant to be used again and again. For example, the Reduction Pilot Plant operated by International Nickel at Huntington, West Virginia was built to refabricate the used nickel barriers from the diffusion plants into new devices, thus recycling the material.(3) However, because of the unfavorable economics of the process the plant is not in operation and is now being dismantled.

6.1.3 Burial of contaminated scrap

Materials only slightly contaminated with radioactivity are considered low-level waste. These wastes may be buried a few feet below the ground surface (in trenches 200 to 300 m long, 15 m wide and 8 m deep) within special restricted areas called shallow land burial facilities. These sites are restricted to unauthorized intrusion by an 8-foot chain-link fence. Surrounding this fence is an undisturbed buffer zone to insure physical isolation of the central restricted zone. Where the burial facility is on a DOE reservation, the reservation serves as a buffer zone. To protect the general public from any radioactivity unintentionally released from the facility, routine radiation monitoring of the air and water associated with the site and periodic environmental surveillance is carried out to detect inadvertent contamination of biota and persons residing in the region of the facility.

Scrap containing low levels of uranium and technetium which is suitably prepared by compaction and containerizing could be buried in this type of facility. Presently, shallow-land burial facilities for government-generated low-level waste are located at most major DOE installations (Figure 6.1).(4)

Figure 6.1. Burial site locations (source: reference 4. p. 6)

Only three* facilities licensed to accept commercial waste are presently in operation. These sites are located near Barnwell, South Carolina, Beatty. Nevada, and Richland Washington (Figure 6.1). Tables 6.1(5) and 6.2(6,7) summarize operations at the various burial facilities.

The total capacity of the presently operational commercial sites can be estimated. From Table 6.2, the total capacity of the sites is:

$$(2 \times 10^6) + (7 \times 10^5) + (9 \times 10^5) = 3.6 \times 10^6 \text{ m}^3$$

Using an average scrap density value of 800 kg/m^3,(8) the total capacity would be

$$800 \times (4 \times 10^6) = 2.9 \times 10^9 \text{ kg} \quad \text{or} \quad 3 \times 10^6 \text{ Mg}$$

Thus the shallow land burial of the total CIP/CUP scrap (Table 2.1) at the presently operating commercial sites would require only a little over 1% of their total burial capacity.

The burial option for unsmelted scrap metal would result in some radiation exposure to the scrap handlers and to the public. CIP/CUP scrap would probably be buried at the Oak Ridge site since it is located near the diffusion enrichment plants. Because the distance is short, scrap would probably be shipped by truck. Radiation doses can be calculated assuming an average of 100 ppm uranium and 5 ppm technetium-99 in the unsmelted scrap,(9) with no other special nuclear material, an average shipping distance of 300 km through country with an average population density of 130 persons per square kilometer, and using dose methodology similar to that used for smelted metal in Section 4.3.1.1 and Appendix B. Scrap crane operators would receive about 7×10^{-4} man-rem while loading and unloading shipments. Bystanders in contact with the shipment could receive 3×10^{-4} man-rem, with persons living along the route of the shipment getting another 7×10^{-5} man-rem. The highest potential doses would go to truck drivers, who for all shipments might receive 1×10^{-2} man-rem. All of these doses are very small.

6.1.4 Surface storage of contaminated scrap

For material contaminated with very low levels of radioactivity storage above ground is sometimes used. The prevailing philosophy is that this mode of storage is only temporary (less than 100 years). However, since the material is placed above ground and thus not strictly isolated from the environment as in burial, stricter operational controls are required to provide adequate security. Material may be placed directly in the reserved area as is, or placed in some type of container. The area is fenced off from the public as at the burial site to control access. A more elaborate method of above-ground

---

*However, the actual number of commercial facilities actually open for operation at any future date is highly unpredictable.

Table 6.1. DOE waste burial ground operations

	Savannah River	Oak Ridge	Los Alamos	Idaho	Hanford
Burial trench/ pit size	6 wide x 6 deep x variable length	3 wide x 15 long x 3-4.5 deep	8-30 wide x 120-180 long x 8 deep	Trench: 2-3 wide x 275 long x 4 deep Pit: 30 side x 4 deep, variable length	1.5-5 wide (bottom width) x 4-8 deep x variable length
Provisions for water collection and containment	None; trenches have monitoring wells	Trenches sloped to one end; 15 cm metal casing as monitoring well	None	None	None
Waste disposal procedures	Random placement in trenches	Trench filled to 1 m of surface	Pits filled in layered fashion; final waste layer 1 m below surface	Pits/trenches filled to 1 m of surface	Trench filled from one end
Waste covering frequency	Covered after disposal for fire, contamination, radiation control	When trench is filled	Combustibles covered day of delivery; others as required for contamination control and layering	As trench/pit is filled	Daily after deliveries
Type of final cover	Excavated fill to ground surface; mounded as necessary	Excavated material, to ground surface few experimentally sealed; ~0.5 m below surface; reseeded	Excavated tuff fill with compaction by heavy earth moving equipment	Excavated soil fill; reseeded	Excavated fill to surface; mounding necessary
Depth of final cover	Minimum 1.2 m cover, or that needed to reduce dose to <6 mR/hr at surface	Minimum 1 m to ground surface	Minimum 1.5 m total excavated tuff cover with mounding to 0.5-1 m above grade	Minimum 1 m to ground surface	Minimum 2.5 m total, or that needed to reduce dose to <1 mR/hr at surface
Other		Minimum 1.5 m between trenches	Minimum 4.5 m between pits at surface; minimum 15 cm crushed, compacted tuff in pit bottom prior to waste fill	Minimum 0.6 m soil in pit/trench bottom to underlie wastes	

SOURCE: Reference 5. p. 24.16.

Table 6.2. Commercial waste burial ground operations

Operation	West Valley, NY[a]	Morehead, KY[a]	Barnwell, SC	Sheffield, IL[a]	Beatty, NV	Richland, WA
Burial Trench Size (meters)	180-210 x 10 x 6 deep	60-150 x 24 x 6-8 deep	140 x 15 x 5-7 deep	150 x 15-18 x 6-8 deep	260 x 12-15 x 8 deep	90 x 8 x 6 deep
Provisions for Water Collection and Containment	Trench sloped 2° to provide a low end away from waste; sump with riser pipe at low end	Bottom slopes 1° min., 0.6 x 0.6 x 0.6 m pit at low corner; standpipe; (2 x 0.6 m) clay berm around trench	0.6 x 0.6 m drain field, with stand-pipes in center bottom; 1° slope to end; 1 m minimum of sand in bottom of trench	Bottom slopes to centerline at one end, 0.6 x 0.6 m ditch, filled with broken brick; sump and stand pipe	None required	None required
Waste Disposal Procedures	Trench filled beginning at one end; filled to original grade level at center	Random dumping beginning one end; filled to 0.6 m of surface	Trench filled to 1 m of surface	Packages randomly emplaced; filled to 0.6 m of surface	Entire trench filled to 1 m of surface	Entire trench filled to 0.6 m of surface
Waste Covering Frequency	Daily	Daily	Daily	Daily	When trench is filled	When trench is filled
Type of Final Cover	Excavated earth fill; compacted; topsoil added	1 m compacted clay; mounded; reseeded	0.6 m of clay between waste and ground surface; additional mounded cover	Compacted clay cover; surface reseeded	Excavated earth fill, no compacting	Excavated earth fill; no compacting
Depth of Final Cover	Minimum of 3 m cover; mounded 1.5 m min. above grade	1 m cover mounded 0.6 m above grade	3 m cover at centerline, 1.5 m at trench edge	Minimum 1 m final cover; mounded	Minimum 2 m total; mounded 0.6 m above grade	Minimum 2 m total; mounded 1 m above grade
Capacity (m^3)(*)	2×10^5	3×10^6	2×10^6	2×10^5	7×10^5	9×10^5
Other	Trench dug as filled. Packages must be self-supporting. Min. 3 m between trenches at surface	Trench pumped dry following final covering	2.5 m dirt separates wastes from different generators. Min. 3 m between trenches at surface.	Min. 3 m at surface between trenches		

(a) Presently not in operation.
Source: Reference 6, p. 24.8 and (*) Reference 7, p. 19.

storage is to place the material inside fire-proof buildings. This covered storage system would provide an added measure of protection from the weathering effects of outside storage and security against unauthorized access.

Surface storage of the contaminated scrap is the method used at present to store the CIP/CUP scrap. The classified scrap (nickel) is further placed in a closed building for further security. The part of this nickel scrap, which has not been contaminated, has been smelted and the resulting ingots are piled on a concrete pad at the Paducah facility. Since all this scrap is classified, plans are to smelt the contaminated scrap and store it in the same manner indefinitely. It is assumed however, that if this contaminated nickel alloy cannot be sold, it will eventually be placed in shallow land burial grounds for ultimate disposal. These sites are within DOE reservations and thus are well "insulated" from the general public. There are no specifically licensed commercial above-ground waste storage facilities at present; however, radioactive waste is stored temporarily above ground at most commercial nuclear facilities.

6.2 ALTERNATIVES RELATED TO LICENSING REQUIREMENTS

6.2.1 General licenses

One alternative to the proposed action would be issuance of general licenses for the possession, use, and transfer of low-enriched uranium and Tc-99 as residual contamination in smelted alloys. (Any general license issued by the NRC is effective without the filing of applications with the NRC or the issuance of licensing documents to particular persons.)

Depending on the level of regulatory authority desired to be exercised, the NRC could issue general licenses to industrial and commercial firms to use the smelted alloys for industrial and commercial purposes or the NRC could issue general licenses to any person or federal, state, or local agency holding an NRC or Agreement State specific license to use the smelted alloy for operational purposes. Under these general licenses, private individuals could not possess, use, or transfer smelted alloys nor could the general licensees manufacture the smelted alloys into consumer products for widespread uncontrolled use.

Other types of general licenses could be issued with the overall objectives of identifying the users, foreseeing end uses, and prohibiting abandonment or disposal of low-enriched uranium or Tc-99 as residual contamination in smelted alloys. However, when account is taken of the efficiency of smelting processes to keep residual contamination at very low levels, neither the consumer-users nor the foreseeable end uses of smelted alloys need be identified. Thus, establishment of general licenses is not needed.

6.2.2 Specific licenses

Another alternative to the proposed action would be issuance of specific licenses to named persons upon applications filed with the NRC to possess, use, and transfer low-enriched uranium and Tc-99 as residual contamination in smelted alloys. (This would maintain the status quo which is the basis for the request for relief from regulatory controls.)

The levels of regulatory control called for in specific licenses (reporting, recordkeeping, restricting disposal of radioactive material, requiring compliance with standards for protection against radiation) and fees for licenses, amendments, and inspections are neither necessary nor appropriate in view of NRC authority to exempt special nuclear and byproduct material from licensing requirements if the exemption is not inimical to the common defense and security and the health and safety of the public.

6.2.3 Exemptions from licensing requirements

During the development of the text of the proposed exemptions and specific license conditions, the staff chose among various alternatives. The original request by the Director, Division of Waste Management and Transportation on February 12, 1974, was for assistance in establishing a de minimus quantity for enriched uranium in scrap metal.

That request raised several problems for the regulatory staff. There was no basis for establishing any quantity, de minimus or otherwise, for a commodity as open-ended as scrap metal. The term "enriched uranium" could potentially result in unlicensed persons receiving high-enriched or fully enriched uranium-235. The use of the term "scrap metal" could be construed to cover scrap metal with loosely adhering, easily separable uranium compounds in cracks, crevices, and other recesses.

With enactment of Public Law 93-377 in 1974 authorizing the Commission to exempt special nuclear material, the regulatory staff could begin resolving the first problem by considering an exemption from licensing and regulatory requirements for any person receiving, possessing, using, or transferring an exempt concentration of special nuclear material.

Upon learning that essentially all of the scrap metal covered by the original request had been exposed to uranium with a maximum uranium-235 concentration of 6 percent, the regulatory staff could resolve the second problem by limiting any proposed action to cover low-enriched uranium (defined in 10 CFR 70.51(a)(2) as that uranium whose isotope content is less than 20 percent uranium-235 by weight).

Further, upon learning that all scrap metal covered by the original request would be smelted prior to initial transfer, the regulatory staff could begin resolving the third problem by limiting any proposed action to cover scrap metal melted or fused into smelted metal. Smelting would provide an additional decontamination procedure and would disperse the residual contamination throughout the smelted metal.

Early in the review of the original request, the regulatory staff considered alternatives for specifying either the sources of the metal scrap or the smelted metals to be covered by the proposed action. The staff determined that the best course would be to avoid any implication that the proposed action would confer special benefits on a single source of metal scrap or on a single metal. Accordingly, the proposed action would cover any source of metal scrap that would produce any smelted alloy meeting contamination and other appropriate limitations. Still unresolved was the problem of setting limits on the residual contamination in the smelted alloy.

With regard to establishment of the uranium limit, the staff's primary concern was physical protection of materials. There were two reasons for this: 1) the proposed action involved special nuclear material; and 2) low-enriched uranium would be dispersed in smelted alloy at the parts-per-million level (which eliminated essentially all radiological health concerns). The remaining step was to select the magnitude of the uranium limit that was consistent with existing policy.

First, the staff reviewed 10 CFR 40.13(a) which exempts from licensing requirements source material in any alloy in which the source material is by weight less than one-twentieth of 1 percent (0.05 percent) of the alloy. When the source material is natural uranium, the alloy contains 0.05 percent natural uranium, x 0.711 percent uranium-235 = 0.00035 percent (or 3.5 parts per million) uranium-235 as the base for calculating a concentration limit of 3.5 x 1/20(percent) = 17.5 parts per million low-enriched uranium in smelted alloy. Under this consistency, exempt persons could receive no high concentration of uranium-235 in smelted alloy containing low-enriched uranium than in any alloy containing natural uranium.

Finally, the staff considered the alternative to lower the limits for the uranium element concentration in smelted alloy. Careful analyses of residual uranium in smelted alloy indicate that contamination levels of a few parts per million can be achieved in plant scale smelting tests. ERDA, in an Environmental Impact Assessment dated July 1976, used a value of 5 parts per million uranium in nickel and iron ingots for purposes of estimating ionizing radiation doses from smelted alloy. However, a 5 parts per million value would require chemical analyses that have an accuracy of about 3 parts per million with a precision of about ±2 parts per million. This exceeds the routine, quick turnaround capabilities of production laboratories of smelters. The laboratories are more likely to be able to report analytical results as equal to or less than 10 parts per million with a precision of ±5 parts per million.

Based on the factors involved, the staff believes that the residual uranium value of 17.5 parts per million is appropriate from the viewpoints of consistency with existing policy and practicality of laboratory analysis. After further consideration and data collection, ERDA by letter dated September 8, 1976, transmitted to NRC an environmental impact assessment in which ERDA proposed:

1) An exemption of smelted metal contaminated with uranium enriched up to 20% uranium-235 providing the total uranium content in the metal does not exceed 17.5 parts per million; and 2) The addition of technetium-99 at a concentration of 8.6×10^{-2} microcuries/gram (equivalent to 5 parts per million) to Column II, Schedule A, 10 CFR 30.70, "Exempt Concentrations."

Neither proposal was acceptable from a regulatory control viewpoint.

The first proposal did not clearly exclude source material or other special nuclear material from the proposed exemption and did not indicate whether alloys (such as steel, brass, Zircaloy) would be covered by the proposed exemption.

The second proposal would have authorized the introduction of technetium-99 into any commodity or product. It also attempted to add to Schedule A, 10 CFR 30.70 a byproduct material concentration that would meet neither the schedule's criterion for concentration (the lowest value for a radionuclide given in Table I of the National Bureau of Standards Handbook 69 for continuous occupational exposure) nor the criterion for byproduct material half-life (less than 3 years).

With regard to establishment of the technetium-99 limit, the staff took into account the factors that result in the concentration of fission product technetium-99 on or in enrichment plant scrap. During the enrichment process, technetium deposits on all materials that come in contact with uranium hexafluoride. In the case of scrap metal generated in the Cascade Improvement Program and Cascade Upgrading Program, the combination of feed material specification (maximum technetium-99 beta particle activity only 10 percent of the beta activity of aged natural uranium), deposition rates, and mechanical and chemical decontamination results in scrap metal contaminated with a maximum of 5 parts per million technetium-99.

There is essentially no removal of technetium from metal during smelting processes. Accordingly, the staff has proposed for smelted alloy a concentration of 5 parts per million technetium-99 which is achievable by mechanical and chemical decontamination techniques prior to smelting scrap metal. The production laboratories of smelters can confirm the level of residual technitium-99 contamination after the smelted alloy has been poured into billet or ingot molds or made into semi-finished products.

The staff believes the 5 parts per million technetium-99 limit will cover scrap from uranium hexafluoride conversion plants, uranium production plants, and other plants having parts that come in contact with uranium hexafluoride and/or fission products of uranium.

Not readily apparent from the language of the proposals was the problem that, absent specific licensing requirements for smelting scrap, any person possessing contaminated metal scrap could melt or fuse the metal scrap and transfer smelted metal to exempt persons for uncontrolled use.

The task before the regulatory staff was to develop two exemptions with accompanying limitations and specific license conditions that would be consistent with findings that the exemptions would not be inimical to the common defense and security and would not constitute an unreasonable risk to the health and safety of the public.

The text developed by the staff is set out on page 1-1 of the Summary. Key words and phrases, discussed below, are designed to inform all persons (exempt persons, applicants for specific licenses, and license reviewers) of the terms conditions, and limitations of the proposed exemptions.

1. "Low-enriched uranium." This term is defined in 10 CFR 70.51(a)(2) and is short-hand for "uranium whose isotope content is less than 20 percent uranium-235 by weight." It is used consistently to reduce the potential that any person might acquire smelted alloy requiring physical protection for safeguards purposes.

2. "Residual contamination." This phrase is used to indicate that the contamination is that which remains in scrap after it has been subjected to a smelting process to produce smelted alloy. It indicates that the exemptions do not apply to smelted alloy that may have acquired additional loose contamination after being produced in a smelter.

3. "Any smelted alloy." The phrase is designed to indicate that any commodity or product that can be classed as an alloy and characterized as having been melted or fused to separate the alloy is covered by the proposed exemptions, if it meets the conditions of the exemptions. As indicated earlier, the phrase was developed to avoid any implication that the NRC staff was tailoring exemptions that would confer special benefits on enrichment plant metal scrap (particularly Cascade Improvement Program - Cascade Upgrading Program scrap) not available to other sources of contaminated scrap. By proposing exemptions for the class "any smelted alloy," the NRC staff could evaluate the CIP/CUP scrap as the principal source, consider nuclear power plant decommissioning scrap as the second source, and note that there are other lesser known sources for producing smelted alloys for use under the exemptions.

4. "Minor constituent." This phrase is primarily intended to forestall any interpretation that natural uranium or depleted uranium are covered by the phrase, "any smelted alloy" and thereby are relieved from the licensing and regulatory requirements of 10 CFR Part 40.

5. "Less than 17.5 parts per million" is discussed above in connection with establishing a numerical limit for the uranium in any smelted alloy consistent with the uranium limit in any alloy exempted under 10 CFR 40.13(a).

6. "Less than 5 parts per million" is discussed above in connection with establishing a numerical limit for the technetium in any smelted alloy. Use of the dimension "parts per million" is intended to indicate that the technetium-99 was not introduced into smelted alloy for its radioactive properties and remains as technological contamination after decontamination processing.

7. "Representative sample of the smelted alloy." This phrase is designed to indicate to exempted persons, applicants for specific licenses, and license reviewers that samples of smelted alloys for analyses should be taken as samples representative of the composition of the alloys and not as samples biased towards the lowest residual contamination levels.

The proposed exemptions would not authorize the transfer of smelted alloy containing byproduct material other than technetium-99 as residual contamination source material, or special nuclear material other than low-enriched uranium as residual contamination. This limitation is intended to make clear that smelted alloy meeting the requirements of the proposed exemptions would not be granted relief from other licensing and regulatory requirements in 10 CFR Parts 30, 40, and 70. The provisions and requirements of the proposed rule changes are in addition to, and not in substitution for, other requirements of 10 CFR Chapter I. For example, a hypothetical smelted alloy consisting of depleted uranium containing 17 parts per million low-enriched uranium and 4 parts per million technetium-99 as residual contamination would still be subject to all the licensing and regulatory requirements of 10 CFR Part 40.

Finally, requirements for specific licenses to smelt scrap or to initially transfer smelted alloys containing technetium-99 or low-enriched uranium specify that the applicant must submit a description of decontamination and smelting procedures, sampling procedures, and analytical procedures. The requirements, in effect, make the persons initially transferring smelted alloys responsible for providing such alloys that meet the specifications of the proposed exemptions.

REFERENCES FOR SECTION 6

1. Draft American National Standard, "Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to be Released for Uncontrolled Use," ANSI N13.12 1978. Available from American National Standards Institute, 1430 Broadway, New York, NY 10018, Copyrighted.

2. Ibid., p. 4.

3. Letter from R. J. Hart, U.S. ERDA, to R. G. Romatowski, U.S. ERDA, Subject: Disposal of the Reduction Pilot Plant - Huntington, West Virginia, October 21, 1976. Available in file for USNRC Report NUREG-0518.

4. National Academy of Sciences, "The Shallow Land Burial of Low-Level Radioactively Contaminated Solid Waste," p. 6, National Academy of Sciences, Washington, DC, 1976. Available in public technical libraries.

5. U.S. Energy Research and Development Administration, "Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle," ERDA Report ERDA-76-43, Vol. 4, p. 24.16, May 1976. Available for purchase from the National Technical Information Service, Springfield, VA 22161.

6. Ibid, p. 24.8.

7. J. A. Adam and V. L. Rogers, "A Classification System for Radioactive Waste Disposal - What Waste Goes Where?," USNRC Report NUREG-0456, p. 19, June 1978. Available for purchase from the National Technical Information Service, Springfield, VA 22161.

8. U.S. Nucle[illegible]latory Commission, "Techno[illegible] Safety, and Costs of Decommissioning a Reference Nuclear Fuel Rep[illegible]essing Plant," USNRC Report NUREG-0278, Vol. 2, p. E-87, October 1977. Available for purchase from the National Technical Information Service, Springfield, VA 22161.

9. U.S. Energy Research and Development Administration, "Environmental Impact Assessment Conserning Proposed Rulemaking, Exemption from Licensing Requirements for the Sale and Use of Metal Scrap Homogeneously Contaminated with Enriched Uranium and Technetium-99 Below a Specified Concentration," p. II.1, Oak Ridge National Laboratory, July 1976. Available in NRC PDR for inspection and copying for a fee.

7. OTHER CONSIDERATIONS

7.1 UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

The primary adverse effects on man would be the slight increase in radioactivity that he may come in contact with in the products fabricated from the smelted alloy. The radiological doses that may be received are slight compared to background radiation and would not be expected to produce one health effect in the whole population exposed to products produced from the smelted CIP/CUP scrap metal. The workers smelting the CIP/CUP scrap metal would in general each receive slightly larger doses, but here again, these doses are expected to be much below normal background radiation. A few individuals could hypothetically receive higher doses from the intake of iron tonic, carrying an implanted bone prosthesis, or wearing bracelets or jewelry which contain smelted alloy. These latter two doses would be quite local in nature and not expected to effect the recipients in any measurable degree. Adverse effects to biota from the radionuclides released into the environment from this action are expected to be nil.

Some air pollution is expected from typical smelter activities but this will be expected to be kept below federal and state air pollution limits in effect at the time.

See Table 7.1 for summary of contemplated impacts from the smelting and uncontrolled release of metal alloy generated from the CIP/CUP program.

7.2 RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY OF THE ENVIRONMENT

It is expected that this action will have little or no adverse impact on the productivity of the environment in either the long or short term.

7.3 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

All resources used to smelt the CIP/CUP scrap could be retrieved except the energy used to melt the scrap. However, the energy required to mine, process, and smelt an amount of ore to produce the same amount of metal alloy would be larger so that a net energy savings would be had if this action is approved (see Table 7.2). The fluxing materials making up the slag could probably be reclaimed if economically justified. If this action is not approved, the CIP/CUP scrap (except nickel) would eventually be buried in a shallow-land burial site although it could be easily retrieved for future use if desired.

Table 7.1. Summary of impacts from the smelting & uncontrolled release of metal alloy generated from the CIP/CUP program

Radiological	
Maximum Individual Total-Body Dose Rate (working 1000 hr/yr inside "vault")	0.01 rem/yr
Maximum Individual Total-Body Dose Commitment (daily ingestion of iron tonic over 1 year)	0.002 rem
Maximum Individual Local Skin Dose (dose to wrist from bracelet worn 50 years, 16 hr/day)	14 rem
Maximum Individual Contact Bone Dose (dose from pin implanted 50 years)	20 rem
Occupational (total scrap smelting [Table 4.13])	0.01 person-rem
General Population (total scrap) (worst case scenario of transport, manufacture, distribution, and use [Table 4.11])	80 person-rem
Health Effects from Population Dose	<1
Nonradiological	
Similar to Noncontaminated scrap metal	

Table 7.2. Energy saved in recycling the CIP/CUP scrap through smelting

Metal	Energy (MJ)
Iron	4E+6 - 2E+8
Nickel	7E+8
Copper	8E+7

7.4 EXPECTED BENEFITS AND COSTS

In this section the incremental costs and benefits arising from the smelting and sale of the CIP/CUP contaminated nickel, copper, and iron and steel scrap will be investigated. The "tool" used to evaluate these costs and benefits is the net present value technique. The basic formulas are:

$$\text{PVB (or C)}_i = \sum_{t=1}^{n} \frac{\text{B (or C)}_{i,t}}{(1+r)^t} \quad (1)$$

where,

PVB (or C)_i = the present value of the ith benefit or cost in 1977 constant dollars. (i.e., the effects of inflation have been removed.)

$\text{B (or C)}_{i,t}$ = the value in constant 1977 dollars of the ith benefit or cost in year t.

r = the real rate of discount assumed to be 2.5% for this analysis.(1)

and,

$$\text{NPV} = \sum_{i=1}^{n} \text{PVB}_i - \sum_{i=1}^{m} \text{PVC}_i \quad (2)$$

where,

NPV = net present value

Equation 1 is used for discounting the stream of benefits or costs by the real rate of interest (assumed to be 2.5% for this analysis). This discount rate represents the opportunity cost of money to the government.

Once the stream of benefits and costs has been discounted, equation 2 is used to find the difference between the benefits and costs. This difference is called the net present value.

The costs and benefits included in this analysis are only those resulting from the smelting and sale of the CIP/CUP contaminated scrap.

The contaminated copper scrap would eventually have to be placed in a shallow-land burial ground and would remain there indefinitely if the proposed regulation were not approved. Approval of the regulation would allow the smelting (at National Lead Company of Ohio facilities) and the sale of the contaminated copper scrap. Benefits resulting from the sale would include: burial costs avoided and revenue from the sale of the copper ingots. Costs would include: the costs of smelting the copper scrap, and the burial of the contaminated copper slag (a byproduct of the smelting process).

Three alternatives are examined in the case of the contaminated iron and steel scrap: smelting at Oak Ridge, Tennessee, smelting at Fernald, Ohio and smelting by a commercial operator. For the Oak Ridge and Fernald alternatives the costs and benefits associated with the smelting and sale of the iron and steel scrap will be similar to those for the contaminated copper scrap case (with the exception of community impacts).

In the commercial smelter alternative, the contaminated iron and steel scrap would be either sold or given to the commercial smelter operator by the government. The benefit associated with this alternative would be the scrap burial costs avoided. (For this analysis it is assumed that the scrap is given to the commercial smelter operator.) The main cost associated with this alternative would be the contaminated slag burial costs.

The contaminated nickel scrap will be smelted whether or not the proposed regulation is approved or disapproved in order to destroy its security classification. Therefore, the costs of smelting the contaminated nickel scrap will not be included in the cost/benefit analysis. The revenue generated from the sale of the nickel ingots and any burial costs avoided would be included as benefits.

Preliminary experiments at the National Lead Company of Ohio in Fernald, Ohio indicate that the recovery of uranium from the contaminated copper, and iron and steel slag is not economically feasible at the present time and therefore will not be included in the analysis.(2)

7.4.1 Nickel

7.4.1.1 Benefits

The nickel from the CIP/CUP will all be smelted to destroy the security classification whether it is sold or not. The nickel scrap is assumed to have no value prior to smelting. If the proposed regulation to allow sale of smelted contaminated nickel is approved, benefits from the sale of nickel ingots include revenues to the government. The present (1977) value of contaminated nickel ingots made from CIP/CUP scrap that is expected to be sold in 1980-82 is estimated to be over $34 million in constant 1977 dollars (see Table 7.3 for details). No disposal/burial costs would be avoided, because storage of nickel ingots would be above ground on a concrete slab at Paducah, Kentucky, that would be otherwise unused and additional security will be minimal.(3) Also, no community impacts are expected because no new workers would be hired (see Section 4.5 for details).

7.4.1.2 Costs

The costs of smelting the nickel would be incurred whether or not the proposed regulation is approved; smelting is necessary for security reasons.

7.4.1.3 Net benefits

Net benefits (benefits minus zero costs) of approval of the proposed regulation to allow sale of smelted nickel CIP/CUP scrap are expected to exceed a present value of $34 million in constant 1977 dollars.

Table 7.3. Revenues expected from sale of smelted contaminated nickel

Year	Quantity of Nickel (Mg)	Forecasted Price (1977 $/Mg)**	Current Year* Value	Present Value†
1980	2,818(a)	$4,440	$12,512,000	$11,619,000
1981	2,818	$4,460	$12,568,000	$11,386,000
1982	2,818	$4,480	$12,625,000	$11,159,000
Totals	8,455(b)			$34,164,000

---

*In 1977 dollars.

**Table 3.3 in Section 3.1.2.4.

†Present (1977) value in 1977 dollars at 2.5% real rate of discount.

SOURCE: (a) Reference 3.
(b) Reference 4.

7.4.2 Copper

7.4.2.1 Benefits

If the proposed action is adopted, benefits are expected to include: revenues from the sale of copper ingots, burial costs of scrap avoided, and net community impacts. The present (1977) value of revenues from the sale of copper ingots in 1979-81 are expected to be about $4.0 million in constant 1977 dollars (see Table 7.4 for details). The present (1977) value of burial costs of contaminated copper scrap avoided in 1979-81 are expected to about $31,000 in 1977 dollars (see Table 7.5 for details). It is assumed that the contaminated copper scrap has no value prior to smelting. Net community impacts are expected to be negligible because no new workers are expected to be hired if the proposed regulation is approved (see Section 4.5 for details).

7.4.2.2 Costs

Costs are expected to be largely costs of smelting the contaminated copper scrap. These costs are expected to include over $125,000 in capital costs in 1977 dollars; these costs are projected to occur in 1979 and are primarily for a shredder to remove insulating material from the copper wire and to size it prior to smelting.(5) Operating costs are expected to be $1036.65/Mg in 1977 dollars. Assuming that operating costs escalate at the same rate as inflation, the present (1977) value of the costs of smelting the contaminated copper scrap is expected to be about $1.7 million (see Table 7.6 for details).

The present (1977) value of the cost of disposing the contaminated copper slag is about $500 in constant 1977 dollars (see Table 7.7 for details).

Table 7.4. Revenues expected from sale of smelted contaminated copper

Year	Quantity of Copper (Mg)**	Forecasted Price (\$/Mg)†	Current Year* Value	Present Value††
1979	327	\$2,500	\$847,000	\$806,000
1980	655	\$2,620	\$1,716,000	\$1,593,000
1981	655	\$2,650	\$1,736,000	\$1,573,000
Totals	1,600			\$3,972,000

---

*Value in current year in 1977 dollars.

**Reference 5, p. 2.

†Table 3.6 in Section 3.2.2.

††Present (1977) value in 1977 dollars at 2.5% real rate of discount.

Table 7.5. Contaminated copper scrap burial costs avoided

Year	Quantity of Copper (m^3)	Volume of Copper (m^3)*	Unit Costs $(\$/m^3)$	Current Year Costs**	Present Value of Costs†
1979	327	3.65	\$1,800	\$6,570	\$6,300
1980	655	7.32	\$1,800	\$13,176	\$12,200
1981	655	7.32	\$1,800	\$13,176	\$11,900
Totals	1,600††				\$30,400

---

*Reference 6, p. A-25, \$19.58/ton in 1978 dollars converted to \$20.59/Mg in 1977 dollars using wholesale price index (195.1/204.1), in 1977 dollars.

**Cost in current year in 1977 dollars.

†Present (1977) value of costs in 1977 dollars at 2.5% real rate of discount.

††Reference 5, p.2.

Table 7.6. Expected costs of smelting contamirated copper scrap

Year	Capital Costs* (1977 dollars)	Operating Costs ($/Mg) (1977 dollars)	Total Costs in Current Year**	Present Value of Total Costs†
1979	$126,572	$1,036.65	$466,000	$444,000
1980		$1,036.65	$679,000	$631,000
1981		$1,036.65	$679,000	$615,000
				$1,690,000

---

*Derived from Reference 5, p. 3.

**In 1977 dollars.

†Present (1977) value of total costs in constant 1977 dollars discounted at 2.5% real rate.

Table 7.7. Copper contaminated copper slag burial costs

Year	Quantity of Copper Slag* (Mg)	Volume Copper Slag (m^3)	Slag Burial Costs**	Present Value of Costs†
1979	3.27	1.09	$109	$104
1980	6.55	2.18	$218	$202
1981	6.55	2.18	$218	$198
Totals	16.37			$504

---

*Assumes that 1% of the Copper scrap (by weight) is slag.

**Assumes cost of contaminated slag burial to be $100/$m^3$ in constant 1977 dollars.

†Present (1977) value of slag burial costs in constant 1977 dollars discounted at 2.5% real rate.

7.4.2.3 Net benefits

The present (1977) value of the net benefits (benefits less costs) expected to result from approval of the proposed regulation for copper is about $2.3 million in 1977 dollars (see Table 7.8).

Table 7.8. Net benefits for copper (present 1977 value in 1977 dollars)

Revenues	+$3,972,000
Scrap Burial Costs Avoided	+ $30,400
Smelting Costs	-$1,690,000
Slag Burial Costs	- $500
	$2,311,900

7.4.3 Iron and steel

7.4.3.1 Benefits

The benefits from the sale of smelted contaminated iron and steel scrap are expected to include: revenues from the sale of pig iron, burial costs of scrap avoided, and net community impacts. The present (1977) value of revenues from the sale of pig iron in 1982-84 are expected to be about $6 million in constant 1977 dollars (see Table 7.9 for details). The present (1977) value of burial costs of contaminated iron and steel scrap avoided in 1980-83 are expected to be over $1.8 million in 1977 dollars (see Table 7.10 for details). The present (1977) net community impacts in 1977 dollars from the construction and operation of the Oak Ridge iron and steel smelter will total about $7.0 million (see Table 7.11 for details).

Table 7.9. Revenue expected from sale of smelted contaminated iron and steel

Year	Quantity of Iron (Mg)*	Price ($/Mg)**	Current Year Value†	Present Value††
1982	10,900	$209.22	$2,282,000	$2,017,000
1983	10,900	$209.35	$2,284,000	$1,970,000
1984	10,000	$209.49	$2,095,000	$1,762,000
Totals	31,800			$5,749,000

---

*Reference 6, p. 5.

**Table 3.11 in Section 3.3, in 1977 dollars.

†In 1977 dollars.

††Present (1977) value in 1977 dollars discounted at 2.5% real rate of interest.

Table 7.10. Contaminated scrap iron and steel burial costs avoided

	Scrap				Current Cost in 1977 Dollars			
	Quantity (Mg)*		Volume (m^3)**					
Year	Classified	Unclassified	Classified	Unclassified	Classified at $144.8/$m^3$	Unclassified at $172.3/$m^3$	Total	Present value†
1980	1,818	3,636	526.8	1512.3	$ 76,000	$261,000	$337,000	$313,000
1981	3,636	7,273	1053.5	3018.9	153,000	520,000	673,000	610,000
1982	2,727	8,182	784.5	3398.4	114,000	587,000	701,000	620,000
1983	909	3,636	263.4	1512.3	38,000	261,000	299,000	258,000
Totals	9,090	22,727						$1,801,000

---

*Reference 6, Appendix Exhibit P.

**Reference 7.

†Present (1977) value in 1977 dollars discounted at 2.5% real rate.

Table 7.11. Net community impacts for the Oak Ridge smelter in 1977 dollars

Year	Smelter Construction Costs	Smelter Operating Costs	Local Income Generated*	Income Lost**	Community Income Lost†	Net Community Income from Approval of the Regulation	Present Value of Net Community Income††
1981	$\$6.45 \times 10^6$		$\$4.3 \times 10^6$‡	\$700,000	$\$1.4 \times 10^6$	$\$2.9 \times 10^6$	$\$2.62 \times 10^6$
1982		$\$1.3 \times 10^6$	$\$2.6 \times 10^6$	\$700,000	$\$1.4 \times 10^6$	$\$1.2 \times 10^6$	$\$1.06 \times 10^6$
1983		$\$1.3 \times 10^6$	$\$2.6 \times 10^6$	\$700,000	$\$1.4 \times 10^6$	$\$1.2 \times 10^6$	$\$1.03 \times 10^6$
1984		$\$1.2 \times 10^6$	$\$2.4 \times 10^6$			$\$2.4 \times 10^6$	$\$2.02 \times 10^6$
Total							$\$6.73 \times 10^6$

---

*From construction and operation of the Oak Ridge Smelter.

**Income lost from not hiring workers to bury the iron and steel scrap.

†Assumes an income multiplier of 2.0.

††Present (1977) value of Net Community Income at 2.5% real rate of discount.

‡Assuming that one-third of the construction costs ($\$2.12 \times 10^6$) are labor costs and that the income multiplier is 2.0.

7.4.3.2 Costs

Costs resulting from approval of the proposed regulation for iron and steel are expected to be largely costs of smelting the contaminated iron and steel scrap. The iron and steel scrap is assumed to have no value prior to smelting. These costs depend on which of the possible smelter options is selected.(6) Currently a new smelter to be built at Oak Ridge, Tennessee, seems the most probable option. Capital costs in 1981 for the Oak Ridge smelter are estimated to be $6.45 million in 1977 dollars.(8) It is assumed that the iron and steel smelter will be totally depreciated in three years due to the uncertainty as to the future amounts of contaminated iron and steel scrap that will become available after the completion of the CIP/CUP program. This assumption can be viewed as the conservative scenario. Operating expenses are expected to be $120.05/Mg in 1977 dollars,(9) for Oak Ridge. They are assumed to escalate at the same rate as inflation. The total present (1977) value of capital and operating costs in 1981-84 for the iron and steel smelter at Oak Ridge, Tennessee, are expected to be about $9.1 million in 1977 dollars (see Table 7.12 for details).

Table 7.12. Contaminated iron and steel smelting costs (1977 dollars) at Oak Ridge

Year	Capital Costs*	Operating Costs at $120.05/Mg in 1977 Dollars*	Current Year Total Costs**	Present Value of Total Costs†
1981	$6,450,000		$6,450,000	$5,843,000
1982		$1,309,625	$1,310,000	$1,158,000
1983		$1,309,625	$1,310,000	$1,130,000
1984		$1,200,500	$1,201,000	$1,010,000
Total				$9,141,000

---

*Reference 6, p. 11.
**In 1977 dollars.
†Present (1977) value of costs in 1977 dollars discounted at 2.5% real rate.

The present (1977) value of the costs of disposing the contaminated iron and steel slag is about $9,200 in constant 1977 dollars (see Table 7.13 for details).

Table 7.13. Contaminated iron and steel slag burial costs

Year	Quantity of Iron and Steel Slag (Mg)	Volume of Iron and Steel Slag (m^3)*	Slag Burial Costs**	Present Value of Costs†
1982	110	36.7	\$3670	\$3244
1983	110	36.7	\$3670	\$3165
1984	100	33.3	\$3330	\$2801
Totals	320			\$9210

---

*Assumes that 1% of the iron and steel scrap (by weight) is slag.

**Assumes cost of contaminated slag burial to be \$100/m^3 in constant 1977 dollars.

†Present (1977) value of slag burial costs in constant 1977 dollars discounted at 2.5% real rate.

7.4.3.3 Net benefits

7.4.3.3.1 Oak Ridge smelter

The present (1977) value of the net benefits (benefits - costs) expected to result from approval of the proposed regulation for iron and steel is about +\$5.1 million (see Table 7.14).

Table 7.14. Net benefits for iron and steel assuming smelting at a new Oak Ridge, TN, facility

Revenues	+\$5,749,000
Scrap Burial Cost Avoided	+\$1,801,000
Capital and Operating Costs	-\$9,141,000
Net Community Impacts	+\$6,730,000
Slag Burial Costs	-\$ 9,200
	+\$5,129,800

7.4.4 Iron and steel commercial smelter option

This section examines the possible alternative of having the contaminated iron and steel scrap sold or given (by the government) to a licensed commercial operation for smelting.

7.4.4.1 Benefits

The benefits to the government of the commercial smelter alternative are the burial costs of scrap avoided. The iron and steel scrap is assumed to have no value prior to smelting, a conservative assumption. The present (1977) value of the burial costs of contaminated iron and steel scrap avoided are expected to be about $1.8 million in 1977 dollars (see Table 7.10 for details).

7.4.4.2 Costs

The costs of this alternative are mainly the costs of disposing the contaminated slag from the smelting of the scrap. This assumes that the contaminated slag is returned to the DOE for disposition. The present (1977) value of the cost of contaminated slag burial is expected to be about $9,200 in 1977 constant dollars (see Table 7.13). The NRC would incur the additional costs of licensing and inspecting the commercial facility. However, these costs will be minor with respect to the scrap burial costs avoided.

The commercial smelter operators will incur the costs of smelting the contaminated iron and steel scrap and will receive any profits from their sale. Since these costs and benefits are incurred and received by the commercial smelter operators and not by the government, they are not appropriate to include in this analysis.

7.4.4.3 Net benefits

The present (1977) value of the net benefit (benefits - costs) of the commercial smelter alternative is about +$1.8 million (see Table 7.15 for details).

Table 7.15. Net benefit of commercial smelter alternative

Scrap Burial Costs Avoided	+$1,801,000
Slag Burial Costs	-$ 9,200
	+$1,791,800

7.4.5 Iron and steel Fernald, Ohio option

This section examines the possible alternative of smelting the contaminated iron and steel scrap at the National Lead Company of Ohio (NLCO) plant in Fernald, Ohio.(10) This option would require the construction of an iron and steel smelter that would be in operation by 1982. As was assumed in the Oak Ridge Case, the Fernald smelter will only be used to smelt the contaminated iron and steel scrap from the CIP/CUP program. This assumption is very conservative since it is quite likely that the smelter will be utilized to smelt other metals after the completion of the CIP/CUP program.

7.4.5.1 Benefits

The benefits of this option include: the revenue generated from the sale of smelted iron and steel (see Table 7.9) and scrap burial costs avoided (see Table 7.10). The net economic impacts from the construction and operation of the Fernald smelter will not be as significant as in the case of the Oak Ridge smelter. The majority of the construction equipment and workers will be from the Cincinnati area (approximately 40 miles from Fernald) and the income generated from the construction will have a relatively minor impact on the Cincinnati economy. Also, NLCO is not planning to hire additional personnel to operate this smelter.

The present (1977) value of the revenue from the sale of smelted contaminated iron and steel and the burial costs avoided are $7,550,000.

7.4.5.2 Costs

Costs are expected to be the costs of building and operating an iron and steel smelter at Fernald, Ohio, and slag burial costs. These costs are summarized in Table 7.16 and Table 7.13. The present (1977) value of these costs are $6,904,200.

Table 7.16. Contaminated iron and steel smelting costs at Fernald, Ohio

Year	Capital Costs*	Operating Costs at $119.74/Mg* **	Total Costs in Current Years**	Present Values of Total Costs
1981	$3,771,000		$3,771,000	$3,416,340
1982		$1,306,243	$1,306,243	$1,154,528
1983		$1,306,243	$1,306,243	$1,126,369
1984		$1,197,350	$1,197,350	$1,007,289
Total				$6,895,000†

---

*Reference 6, p. 13.

**In 1977 dollars.

†Numbers may not add due to rounding.

7.4.5.3 Net benefits

The present (1977) value of the net benefits (benefits - costs) from the smelting of contaminated iron and steel scrap at Fernald, Ohio and their sale is about +$645,800 (see Table 7.17).

Table 7.17. Net benefits for iron and steel assuming smelting at Fernald, Ohio facility

Revenues	+$5,749,000
Burial Costs Avoided	+$1,801,000
Capital and Operating Costs	-$6,895,000
Slag Burial Costs	-$ 9,200
	+$ 645,800

7.5 SUMMARY OF RESULTS

The present (1977) value of the overall net benefits of approval of the proposed regulation for all metals are expected to be over $40 million in 1977 dollars (see Table 7.18), assuming an Oak Ridge smelter, for iron and steel. The most significant benefit is the revenue from the role of 8,400 Mg of nickel ingots. The most significant cost is the capital cost of the Oak Ridge smelter that would have to be invested and then charged against the gross sales of the smelted iron and steel.

Table 7.18. Present (1977) value of total net benefits in 1977 dollars (Oak Ridge alternative)

Nickel	+$34,164,000
Copper	+$ 2,312,000
Iron and Steel	+$ 5,130,000
Total	+$41,606,000

The present (1977) value of the overall net benefits of approval of the proposed regulation with the iron and steel scrap smelted commercially is about +$38 million in 1977 dollars (see Table 7.19 for details).

Table 7.19. Present (1977) value of total net benefits in 1977 dollars (commercial smelter alternative)

Nickel	+$34,164,000
Copper	+$ 2,312,000
Iron and Steel	+$ 1,792,000
Total	+$38,268,000

The present (1977) value of the overall net benefits of the approval of the proposed regulation with the smelting of the iron and steel at Fernald, Ohio is about +$37 million dollars (see Table 7.20 for details).

Table 7.20. Present (1977) value of total net benefits in 1977 dollars (Fernald, Ohio alternative)

Nickel	+$34,164,000
Copper	+$ 2,312,000
Iron and Steel	+$ 645,000
Total	+$37,121,000

REFERENCES FOR SECTION 7

1. H. Ashley, R. L. Rudman, and C. Whipple, eds., Energy and the Environment, A Risk-Benefit Approach, p. 118, Pergamon Press, New York, 1976. Available in public technical libraries.

2. Letter from J. H. Cavendish, National Lead Co. of Ohio, to S. A. Smith, Pacific Northwest Laboratory, dated January 11, 1979. Available in file for USNRC Report NUREG-0518.

3. Letter from E. W. Richardson, Union Carbide Corp., to S. A. Smith, Pacific Northwest Laboratory, dated August 8, 1978. Available in file for USNRC Report NUREG-0518.

4. Letter from J. H. Cavendish, National Lead Co. of Ohio, to D. A. Baker, Pacific Northwest Laboratory, Subject: Transmittal of Information for Environmental Impact Statement (EIS) on Establishment of De Minimus Limits for Special Nuclear Materials in Metals, dated May 5, 1978. Available in file for USNRC Report NUREG-0518.

5. Letter from F. W. Neblett, National Lead Co. of Ohio, to J. W. Cavendish, National Lead Co. of Ohio, Subject: Economic Projection for Processing CIP/CUP Copper Scrap at FMPC, dated May 12, 1978. Available in file for USNRC Report NUREG-0518.

6. F. W. Neblett, "Economic Projections for the Decontamination of Steel Scrap by Smelting (Revised)," February 10, 1978. Available in file for USNRC Report NUREG-0518.

7. P. R. Vanstrum, "Ferrous Scrap Smelter Facility Review of ERO-ORO's Summary of Comments," K-BD-646, Attachment 6, November 10, 1975, as cited in Reference 4. Available in file for USNRC Report NUREG-0518.

8. Op. Cit., Ref 6, A-11.

9. Ibid, p. 11.

10. Ibid, p. 12.

8. LIST OF CONTRIBUTORS

The following persons contributed to this Environmental Statement:

DAVID A. BAKER, P.E., Senior Environmental Engineer, Environmental Analysis Section, Ecological Sciences Department, Pacific Northwest Laboratory

Education

B.S.	Electrical Engineering, University of Colorado	1959
M.S.	Physics, University of Colorado	1964

Experience and Qualifications

Mr. Baker specializes in estimating environmental radiation doses to people due to releases from nuclear facilities. His professional experience includes mathematical modeling and computer calculations of doses to individuals and populations through various pathways. He has directed or contributed to major programs in the following areas:

- Environmental Impact Statements and Assessments. At Battelle-Northwest Mr. Baker has had major responsibilities related to the environmental consequences of nuclear power plant operation and specifically to estimating chronic doses to individuals and populations from both projected and measured releses of radioactive materials in gaseous and liquid form from commercial power reactors and other nuclear facilities.

- Meteorological Data Acquisition. While employed by Douglas United Nuclear (now UNC Nuclear Industries, Inc.), Mr. Baker set up and managed a meteorological data acquisition system for monitoring temperature, wind direction, and wind speed at the N-Reactor site. This data was eventually used as the basis for diffusion factor estimates for hypothetical atmospheric releases from the N-Reactor site.

- Professional License. Mr. Baker is a registered Professional Engineer in the State of Washington.

Mr. Baker has had overall responsibility for the contributions from the staff of the Pacific Northwest Laboratory as well as contributing to Chapters 1, 2, 4, 5, and 6 of this statement.

LEE E. ERICKSON, Senior Research Economist, Economic Analysis Section,
Energy Systems Department, Pacific Northwest Laboratory,
Presently Assistant Professor, Taylor University, Upland, IN

Education

B.A.	Economics, University of Washington	1968
M.A.	Economics, University of Washington	1970
Ph.D.	Economics, University of Michigan	1975

Experience and Qualifications

Dr. Erickson's education emphasized the fields of public finance, natural resource economics, urban/regional economics, and industrial organization. His primary interests are "market failures," where the private market does not produce socially optimal resource allocations without governmental constraints or incentives. These market failures include externalities such as pollution, congestion and other public goods and common property problems, and imperfect competition, which may be caused by economies of scale or spatially separated markets. His work experience includes:

- Benefit-Cost Analysis of Health and Safety Standards. Dr Erickson has let a project to assist the Nuclear Regulatory Commission's Office of Standards Development (NRC-SD) in improving their standards setting decision process. This effort focused on possible applications of benefit cost analysis. It included review of 1) analysis techniques used in support of health and safety standards decisions at other Federal agencies, 2) the available approaches to valuing health and life-saving benefits of standards, and 3) ways of incorporating risk and uncertainty and their value to people into benefit cost analyses.

- Assessing Environmental Externalities. For an EPA/ERDA project Dr. Erickson has developed a procedure for estimating the dollar value of visual pollution from power plants in all the air quality control regions in the West by generalizing from survey results for the Four Corners area. As a further contribution to this effort to assess the social costs of electrical energy developments in the Western U.S., Dr. Erickson led a comparison of benefit-cost and multiattribute utility approaches to integrative assessments as public decision aids.

- Socio-economic Impact Studies. Dr. Erickson has led the socio-economic impact analysis portion of a feasibility study on a dry-cooled nuclear energy center for the Nuclear Regulatory Commission. Prior to joining the staff of Battelle-Northwest he participated in studies of the socio-economic effects of alternative freeway locations in the North Bend and Mercer Island areas for the Washington State Highway Department.

- Fish as Common Property Resources. Dr. Erickson has studies the economics of the Geoduck clam and Dungeness crab fisheries in Washington. Two contract reports on these investigations have been published by the Washington Department of Fisheries. His doctoral thesis, based primarily on this work, reviewed the theory of common property resources and compared the externalities found in fisheries with other market failures. He used new techniques to measure the extent and value of effort in excess of the socially optimal level employed in the Dungeness crab fishery. He evaluated the existing management policies in this fishery and suggested improvements.

- Northwest Energy Impact Modeling. Dr. Erickson participated in an extensive, multidisciplinary effort to forecast and assess the long term economic, social, and environmental impacts of alternative energy development options for the Northwest region using a simulation modeling framework. His primary contributions to this project were summarized in a paper suggesting a methodology to be followed. While this approach was developed independently from that of the Federal Energy Administration (FEA), it is very similar to thier PIES methodology.

- Energy Demand Analysis and Consumption Forecasts. Dr. Erickson has studied regional electrical energy use trends and reviewed the applied econometric work of other researchers on the relationships between electricity use and other variables. He suggested alternative regional electrical use forecasts and directions for further demand analysis efforts. Prior to joining the Battelle staff Dr. Erickson prepared a summary of forecasts of energy consumption in the U.S. for the years 1980 and 2000 for the American Association for the Advancement of Science.

Professional Affiliations

American Economic Association
Western Economic Association

Dr. Erickson has contributed to Chapters 3,4, and 7 of this statement.

BRUCE A. NAPIER, Scientist, Environmental Analysis Section, Ecological Sciences Department, Pacific Northwest Laboratory

Education

B.S.	Nuclear Engineering, Kansas State Usiversity	1975
M.S.	Nuclear Engineering, Kansas State University	1977

Experience and Qualifications

Mr. Napier works with the development and operation of computer models concerned with the calculation of radiation doses to people from releases from nuclear facilities. His professional experience includes mathematical modeling and calculations of doses to individuals and populations through various pathways. He has contributed to projects in the following areas:

- Computer Programming. Mr. Napier has written and operates computer programs in FORTRAN IV and BASIC languages.
- Environmental Analysis. At Battelle-Northwest, Mr. Napier has performed dose calculations and provided other support for Environmental Impact Statements and Safety Analyses.
- Isotopic Safeguards. At Battelle-Northwest, Mr. Napier developed a set of isotopic correlations for detecting diversion of special nuclear material from spent fuel reprocessing plants.

Mr. Napier is a member of the American Nuclear Society, Tau Beta Pi, and Phi Kappa Phi.

Mr. Napier has contributed to Chapters 4 and 5, and the appendices of this statement.

STANLEY E. NUNN, Technical Consultant, Columbia Engineers Services, Inc.

Education

B.S.	Mathematics, Whitworth College	1961
M.S.	Chemistry, Washington State University	1966

Experience and Qualifications

Mr. Nunn has had considerable experience with various aspects of the nuclear industry. His professional experience includes the development of safety analysis reports for various nuclear facilities. He has contributed to major programs in the following areas:

- Development of the safety analysis reports for the Purex Plant and Z Plant at Hanford. Also served as administrative assistant in the publication of the Final Safety Analysis Review (FSAR) for the FFTF Project.

- Development of analytical methods for the rapid analysis of fuel pellets for fast breeder reactors.

- Participated in an economic study of availability of neptunium quantities through 1980 from reprocessing of commercially available reactor fuels and the fuel cycle parameters of sodium-cooled fast breeder reactors and their effect on power costs.

- Dealt with the development of a computerized information retrieval system for nuclear data.

Mr. Nunn has contributed to Chapters 2 and 6 of this statement.

STEVEN A. SMITH, Research Economist, Advanced Energy Section, Energy Systems Department, Pacific Northwest Laboratory

Education

B.A.	Economics, Washington State University	1975
M.A.	Economics, Washington State University	Pending

Experience and Qualifications

Mr. Smith has a strong background in micro- and macro-economic theory and quantitative methods. Applied areas include Industrial Organization and air, water and rail transportation. Specific examples of projects in which he has participated are:

- Transportation Economics. Mr. Smith assessed the economic impacts of Burlington Northern's proposed abandonment of a 10-mile line in southeastern Washington state. This project involved the gathering and evaluating of primary data from proponents and opponents of the abandonment.

  Mr. Smith also developed a qualitative assessment of the potential costs and benefits associated with the establishment of a regional airport near Lewiston, ID.

- Economic Feasibility. Mr. Smith investigated the economic and technical feasibility of using power plant waste heat in various agricultural applications including: swine enclosures, polyculture ponds and algae basins. In the case of swine enclosures, the technical evaluation included whether power plant waste heat would provide adequate heating of the nurseries and farrowing houses during winter months. The economic evaluation included an investigation of the savings in heating bills due to the use of the power plant waste heat versus conventional heating methods.

- Mineral Economics. Mr. Smith is currently involved in investigating the market structure of several metal industries. In an environmental statement, sponsored by the Nuclear Regulatory Commission, he investigated the market structure, the degree of competitiveness and the pricing behavior of the nickel, copper, and iron and steel industries.

- Materials Resource Assessments. Mr. Smith is involved in identifying material constraints to the implementation of various solar energy technologies. He has developed various portions of the methodology used in evaluating material constraints and the large data base used in this project.

Since 1975, Mr. Smith has been a member of Phi Beta Kappa, and was the past chapter president of Omicron Delta Epsilon.

Mr. Smith has contributed to Chapters 3,4, and 7 of this statement.

9. LIST OF AGENCIES, ORGANIZATIONS, AND PERSONS TO WHOM COPIES OF THE STATEMENT ARE SENT

The following Federal agencies and states are being asked to comment on this Draft Environmental Statement:

- Department of Agriculture
- Department of Commerce
- Consumer Produce Safety Commission
- Department of Energy
- Environmental Protection Agency
- Department of Health and Human Services
- Department of Education
- Department of the Interior
- Department of Transportation
- All Agreement States

10. INDEX

APPENDIX A

THE RADIONUCLIDES IN SMELTED ALLOY

The specification of the isotopic composition of the total uranium in the recycle smelted alloy is not possible. However, since a large portion of uranium contaminated metal will result from the CIP/CUP gaseous diffusion plant upgrading programs, a reasonable estimate of the abundance of each minor uranium isotope (MUI) relative to the abundance of U-235 can be obtained.(1) The following relationships between weight percent of MUI and total U-235 are assumed to be valid for U-235 enrichments as high as 6%:

Percent of MUI by weight normalized to the percent of U-235 weight in total uranium

MUI	Through FY-80	Trend After FY-89	FY-92
U-232	5.0E-8	Slight increase through FY-88; rapid increase thereafter.	1.3E-7
U-234	9.0E-3	Very slow increase	1.0E-2
U-236	4.2E-1	Slow increase reaching equilibrium	5.6E-1

Based on FY-80 estimates and the above consideration, the following quantities of parent radionuclides are assumed to be present in smelted metal alloy containing 17.5 ppm total uranium and 5.0 ppm Tc-99.

U-235 Enrichment (wt% in U)	Radionuclides in Scrap (wt%)					
	U-238	U-236	U-235	U-234	U-232	Tc-99
1.0	1.7E-3	7.4E-6	1.8E-5	1.6E-7	8.8E-13	5.0E-4
1.5	1.7E-3	1.1E-5	2.6E-5	2.4E-7	1.3E-12	5.0E-4
2.0	1.7E-3	1.5E-5	3.2E-5	3.2E-7	1.8E-12	5.0E-4
5.0	1.6E-3	3.9E-5	8.8E-5	8.1E-7	4.6E-12	5.0E-4
10.0	1.5E-3	7.4E-5	1.8E-4	1.6E-6	8.8E-12	5.0E-4
20.0	1.3E-3	1.5E-4	3.5E-4	3.2E-6	1.8E-11	5.0E-4

The average U-235 enrichment of the uranium present in metal scrap from gaseous diffusion plant systems is between 1.0 and 1.5%. All scrap metals considered in this assessment are assumed to be contaminated with 1.5% enriched material, as above. The 1.5% enrichment is used because the average U-235 enrichment of the uranium in the CIP/CUP scrap is between 1 and 1.5%.(1)

However, since the proposed action applies to scrap containing enriched uranium up to 20% U-235, estimates of doses resulting from this enrichment were made. The doses are sensitive to the MUI concentration in the metal, increasing as the MUI concentration increases. For example, for 20% enriched uranium at 17.5 ppm and Tc-99 at 5 ppm, ingestion doses are higher by a factor of 3.7 than those from metal with only 1.5% U-235. For the same case, air immersion doses are increased by a factor of 12 and inhalation doses are increased by a factor of 13 over those of metal containing residual 1.5% enriched uranium. Therefore, if a large quantity of metal contaminated with uranium of greater than 1.5% enrichment is released, doses to the public could be up to an order of magnitude higher than those reported in Chapter 4.

The radionuclides potentially present in the alloys have a pronounced effect on the dose estimates. The complete source term acounts for the buildup of daughter radionuclides by assuming that the uranium isotopes have decayed for 20 years. The daughters considered and activity relative to the parent nuclide are presented in Table A.1 for scrap contaminated with the proposed limits of 1.5% enriched uranium and technetium.

The resulting photon yield per gram of smelted metal alloy and beta yield per gram of metal by nuclide decay chain are given in Tables A.2 and A.3 for materials contaminated with 17.5 ppm uranium and 5.0 ppm Tc-99. The energy spectrum for each case is broken into 25 intervals for convenience.

The potential radiological effects of manufacture use, and disposal of products containing these isotopes is discussed for the human populations described in Appendix B.

For comparison purposes some concentrations of background radioisotopes (both natural and man-made) occurring in two metals discussed in this environmental statement are presented in Table A.4.

Table A.1. Decay chain data

	U-238	U-236	U-235	U-234	U-232	Tc-99
Specific Activity of Parent per Gram of Scrap (dps/g)	0.214	0.259	0.021	0.525	0.011	3200
Specific Activity of Daughters per Gram of Scrap (dps/g)	0.214 Th-234 0.214 Pa-232	None	0.021 Th-231	None	0.011 Th-228 0.011 Ra-224 0.011 Rn-220 0.011 Po-216 0.011 Pb-212 0.011 Bi-212 0.007 Po-212 004 Tl-208	None

Table A.2. Photon yield per gram of recycled metal contaminated with 17.5 ppm of uranium and 5 ppm of Tc-99 (photons/s-g)

Energy (MeV)	Decay Chain				
	U-238	U-236	U-235	U-234	U-232
0.01					1.9E-3
0.015	2.4E-2	2.1E-2	2.2E-2	4.6E-2	2.3E-3
0.02	1.6E-3	1.4E-3	7.7E-3	3.0E-3	1.2E-4
0.03			2.6E-3		
0.04	2.0E-6		1.2E-4		1.1E-4
0.05	1.3E-4	2.1E-4		8.8E-4	
0.06	2.0E-3		9.5E-5		2.1E-5
0.07			4.9E-5		1.1E-3
0.08			1.8E-3		1.9E-3
0.09	1.4E-2		2.0E-3		8.1E-4
0.10	7.4E-4		1.6E-3	3.1E-4	7.0E-5
0.15			3.2E-3		4.2E-5
0.2			1.2E-2		5.3E-3
0.3	9.8E-5				6.3E-4
0.4					3.3E-6
0.5					9.1E-4
0.6					3.2E-3
0.7	7.4E-4				7.4E-4
0.8	8.1E-4				9.8E-5
0.9					4.9E-4
1.0					1.0E-4
1.5					2.2E-4
2.0					
3.0					3.9E-3

Table A.3. Beta particle yield per gram of recycled metal for each decay chain (particles/s-g)

Eβ (MeV)	U-238	U-236	U-235	U-234	U-232	Tc-99	Total
0.1	6.3E-1	1.7E-2	1.6E-2	3.5E-2	7.4E-3		7.1E-1
0.2	1.7E-1		6.3E-3		1.8E-3		1.8E-1
0.3			1.5E-2		8.8E-3	3.2E+3	3.2E+3
0.4					1.8E-4		1.8E-4
0.5					2.6E-4		2.6E-4
0.6					1.8E-3		1.8E-3
0.7	8.4E-4				1.5E-4		9.9E-4
0.8	2.0E-4				5.3E-5		2.5E-4
0.9					1.1E-5		1.1E-5
1.0					3.9E-4		3.9E-4
1.1							
1.2							
1.3	1.6E-3				2.6E-3		4.2E-3
1.4							
1.5	1.5E-3				2.2E-3		3.7E-3
1.6					5.3E-4		5.3E-4
1.7					1.1E-5		1.1E-5
1.8					5.3E-3		5.3E-3
1.8							
2.0							
2.1							
2.2							
2.3	2.1E-1				6.0E-3		2.2E-1
2.4							
2.5					2.1E-5		2.1E-5

Table A.4. Some background concentrations (parts per million) of radionuclides in iron and copper

Material	K-40	CO-60	Ra-226	U-238	Th-232
Iron					
Various Samples(a)	--	2 to 4E-11	4E-9 to 3E-8	0.03*	0.014
Plate(b)	6E-4	--	--	0.007	0.01
304 Stainless(b)	0.004	--	--	0.009	0.02
304-L Stainless(b)	0.001	--	--	0.007	0.02
Copper					
Sheet(b)	0.01	--	--	0.008	0.2
Rod(b)	0.006	--	--	0.04	0.08

---

*Isotope not specified, but assumed to be U-238.
--Not measured.
SOURCE: (a) Reference 2, PP. 11, 17.
(b) Reference 3.

REFERENCE FOR APPENDIX A

1. U.S. Energy Reserach and Development Administration, "Environmental Impact Assessment Concerning Proposed Rulemaking, Exemption from Licensing Requirements for the Sale and Use of Metal Scrap Homogeneously Contaminated with Enriched Uranium and Technetium-99 Below a Specified Concentration," p. III.5, Oak Ridge National Laboratory, July 1976. Available in NRC PDR for inspection and copying for a fee.

2. James R. DeVoe. Consultant, "Radioactive Contamination of Materials Used in Scientific Research," Prepared for AEC by National Academy of Sciences--National Research Council, 1961. Available in public technical libraries.

3. N. A. Wogman, Pacific Northwest Laboratory, "Natural Radioactivity in NaI(Tℓ) and Ge (Li) Gamma-ray Spectrometer Construction Materials", February 22, 1978. Available in file for USNRC Report NUREG-0518.

APPENDIX B

DOSE SCENARIOS FOR ENVIRONMENTS AND POPULATIONS*

B.1 DURING INITIAL SMELTING

The accumulated metal scrap from the CIP/CUP program is assumed to be smelted before release in the Oak Ridge, Tennessee, smelter described in Section 3.3.4. The smelter is assumed to smelt during two shifts per day with a third shift for maintenance and cleanup. During active smelting, two charges of 10 Mg each are melted per shift. Thus 3,180 charges are required to smelt all the iron, 840 for all the nickel, and 160 for all the copper.

The threshold limit value (TLV) for particulate iron in air is 5 mg/m^3.(2) Those for nickel and copper are 0.2 mg/m^3.(2) Besides being exposed to direct radiation, workers unloading scrap, tending the smelter, and handling the ingots would also be exposed to inhalation of and immersion in air contaminated with particulates.

It is assumed that the insulating lining of the smelter will have to be replaced every 200 melts. Four workers each are assumed to work one shift removing the slag-lined inner floor of the smelter. They are assumed to wear respirators so the only exposure pathway is direct radiation.

The unsmelted scrap can have fairly high levels of uranium concentration. Iron is assumed to contain 100 ppm(3) uranium and daughters, nickel to contain 500 ppm,(3) and copper 1,500 ppm.(3) (See Tables 2.8 and 2.10 for a further discussion of these figures). Slag (3) from the smelting of these metals is assumed to contain 1,000 ppm uranium for iron, 5,000 ppm for nickel, and 10,000 ppm for copper. Once the metals leave the smelter, the uranium concentration is assumed to be 17.5 ppm. Since technetium-99 does not translocate much during smelting, it is assumed to remain at 5 ppm in all steps.

Direct radiation doses to workers in the smelter are determined based on the exposure conditions calculated in Table B.1.

B.2 DURING BULK TRANSPORT

Bulk quantities of recovered alloy will be shipped from the licensed recovery facility to manufacturers via either rail or truck. Rail would be preferred for long-distance shipments (greater than 800 km) and truck for shipments of shorter distances.

---

*The dose scenarios discussed are taken primarily from Reference 1 unless otherwise noted.

Table B.1. Exposure conditions for scrap smelter workers

Operation	Workers per Melt	Time per Operation (hr)	No. of Operations Iron	No. of Operations Nickel	No. of Operations Copper	Distance from Source (m)	Shields	Source
Unload Scrap	1	8.0	30	8	2	4.8	1.3 cm steel	5 Mg load 14,000 Mg pile
Charge Furnace	1	1.0	3,180	840	160	3.0	1.3 cm steel	10 Mg in bucket
Prepare Furnace	2	0.7	3,180	840	160	2.5	2.5 cm steel 33 MgO*	10 Mg metal
Operate Furnace	2	7.3	3,180	840	160	5.0	2.5 cm steel 33 cm MgO*	10 Mg metal
Pour Ingot	1	2.2	3,180	840	160	6.1	1.3 cm steel	iron-filled ladle
Cast Ingot	1	1.3	3,180	840	160	6.1	1.3 cm steel	iron-filled ladle
Remove Ingot	1	4.0	3,180	840	160	4.5	none	9 Mg ingot
Handle Slag	1	8.0	3,180	840	160	4.5	none	1 Mg slag
Store Ingots	1	8.0	30	8	2	4.5	none	ingot pile
Reline Furnace	4	4.0	16	4	1	1.0	none	furnace walls

---

*Magnesium Oxide.

Exposure conditions for transport workers, service personnel, and the general public are summarized in Table B.2. Exposed persons living along the route of the shipments are assumed to live between 30 and 1,600 meters from the centerline of the railroad or highway right of way, with a constant population density of 115 persons per square kilometer.

Each rail car is assumed to travel 1,600 km in 8 days. Truck shipments are assumed to travel 800 km in 2 days. There are 368 persons affected per kilometer along the route of the shipment.

B.3 DURING MANUFACTURE

The environs affected by the reuse of slightly contaminated metal alloys in manufacturing processes would include almost all of those associated with the use of basic unformed metals. A representative sample of industries which might use recycled scrap are discussed in detail. The results from the selected examples can be extrapolated to other manufacturing processes and should present a conservative picture of the potential impacts.

- Steel making

  Steel making is an example process which could use large quantities of contaminated alloy. The released iron ingots could be resmelted and made into sheet steel. The doses to steel workers have been extensively analyzed in Reference 1 for this scenario, using iron containing 5.0 ppm uranium, 5.0 ppm Tc-99, and associated daughters.

  The assumed steel mill has a capacity to process 4.0×10^2 Mg of iron per day. Therefore, the entire CIP/CUP inventory of recycled iron represents an 80-day stock of feed for the mill. Approximately 320 melts would be required to process the metal. The mill operates around the clock, in three shifts of eight hours' duration.

  The threshold limit value (TLV) for particulate iron in air is 5 mg/m^3.(2) Besides being exposed to direct irradiation, steelworkers involved in unloading scrap, charging and tending furnaces, pouring and handling ingots, milling, and storing the finished steel sheets would also be exposed to inhalation of and immersion in air contaminated with particulates. Doses to steel workers are determined based on the exposure conditions summarized in Table B.3.

- Slag disposal

  The resmelting of the iron alloy during steel making would result in the generation of byproduct slag. The radionuclides and other impurities present in the alloy could concentrate in the slag when the metal is resmelted. The amount of slag generated depends on the amount of impurities present and the amount of slagging material used. For the purposes

Table B.2. Exposure conditions to persons affected during bulk transport

Population	Persons per Exposure	Number of Exposures*	Duration of Exposure	Distance to Source (m)	Source Description
Rail					
Brakeman	1	93	5 min/shipment	1.0	10 rail cars
Yard Workers	1	93	1 hr/yr	2.0	10 rail cars
Passersby	10	93	3 min	1.0	1 rail car
Persons Along Route	589,000	93	---	30 to 1,600	10 rail cars
Truck					
Drivers	1	1,840	12.5 hr	1.0	1 truck load
Service Attendants	2	1,840	10 min	1.0	1 truck load
Passersby	10	1,840	3 min	1.0	1 truck load
Persons Along Route	294,000	1,840	---	30 to 1,600	1 truck load

---

*There are assumed to be 70 train loads or 1,400 truck loads of iron, 4 train loads or 72 truck loads of copper, and 19 train loads or 371 truck loads of nickel. A train load consists of 10 cars.

Table B.3. Exposure conditions for steelworkers

Operation	Workers per Shift	No. of Shifts	Time per Shift (hr)	Distance to Source (m)	Shields	Source
Unload Scrap	1	29	8	4.8	1.3 cm steel	5 Mg load and 14,000 Mg pile
Charge Furnace	1	320	1	3.0	1.3 cm steel	50 Mg in bucket
Prepare Furnace	2	320	0.7	2.5	2.5 cm steel 33 cm MgO*	100 Mg iron
Operate Furnace	2	320	7.3	5.0	2.5 cm steel 33 cm MgO*	100 Mg iron
Pour Ingots	1	320	2.2	6.1	1.3 cm steel	iron-filled ladle
Casting	1	320	1.3	6.1	1.3 cm steel	iron-filled ladle
Remove Ingots	1	320	4.0	4.5	--	9 Mg ingot
Operate Mill	1	320	0.7	1.5	1.3 cm steel 15 cm MgO*	9 Mg ingot
Scarf, Shear, Pile	3	320	2.9	3.0	0.6 cm steel	9 Mg ingot
Hot Strip Mill						
Pusher	3	10	8	3.0	1.3 cm steel	9 Mg ingot
Slab Extraction	3	10	8	3.0	1.3 cm steel	9 Mg ingot
Scale Breaking	1	3	8	3.0	1.3 cm steel	9 Mg ingot
Mill Slab	6	65	8	3.0	--	9 Mg rolled steel
Finish Milling	7	26	8	3.0	--	9 Mg rolled steel
Coil	1	3.6	8	3.0	--	9 Mg coil
Store	1	12	8	4.5	--	ingot pile

---

*Magnesium Oxide.

of dose calculations, it is assumed that the slag generated is about one-tenth the mass of alloy processed. Experimental evidence with neptunium, plutonium, and americium(4,5), which are chemically similar to uranium has indicated that even at low initial concentrations, uranium could concentrate in the slag. The technetium, however, would probably not come to more than an equilibrium concentration. Therefore, for dose calculation purposes, it is assumed that the slag has a concentration of 175 ppm uranium and 5 ppm Tc-99. It is felt that this is a conservative assumption, and that some uranium would remain in the resmelted alloy.

The slag generated in the resmelting of the recycled iron could be discarded or used in any one of the ways steel slag is currently used. The main uses for slag in the U.S. are as follows:(6)

	Amount % of Total 1972
1. Railroad Ballast	13.1
2. Highway Base and Shoulders	35.2
3. Paved Area Base	17.5
4. Miscellaneous Base of Fill	18.9
5. Bituminous Mixes	5.5
6. Agricultural Liming	1.1
7. Other Uses	8.7
	100.0

The total quantity of slag produced from resmelting the inventory of CIP/CUP iron would be only about 3,200 Mg. All the slag is assumed to be used in paving a segment of highway. The roadbed is assumed to be 0.15 m thick, 6 m wide, and 1,280 m long, and to be covered with several centimeter of concrete or asphalt. A population of 1,000 persons is assumed to travel over this segment of road 250 times per year each at a speed of 65 km/hr.

The uranium in the slag will be in an oxide form and will be almost completely insoluble in water. The technetium, however, will partially be in the form of the soluble pertechnetate anion. The roadbed paved with the slag is assumed to physically erode. Rain water is assumed to carry 50% of the technetium and 1 Mg of slag to a public water supply reservoir covering 2.6 km^2 to a depth of 6 m. Assuming uniform mixing, the concentration of eroded slag should not exceed 5.8×10^{-5} g/ℓ as suspended solids in the water. The technetium concentration would be about 5.1×10^{-7} g/ℓ, or 8.7×10^{-9} Ci/ℓ. The maximally exposed individual is assumed to drink 1.5 ℓ/d of this water.

- Frying pan manufacture

A cast-iron frying pan manufacturing plant is assumed to have the capacity to process the entire inventory of CIP/CUP iron into nine million frying pans per year. A pan is assumed to be 27 cm in diameter, 9 cm deep, 0.25 cm thick, and to have a 15 cm handle. It weighs 3.6 kg. A pan is represented by a point source in all exposure situations except direct contact.

Many operations are carried out in the factory. The workers could be immersed in air containing up to the TLV of 5 mg/m^3 of iron particles.(2) Inhalation and air immersion doses received are similar to those of steelworkers. The indrect exposure conditions assumed for frying pan makers are summarized in Table B.4.

- Minting of coins

  Copper and nickel are used in minting pennies (95 wt% Cu + 5 wt% Zn) and nickels (75 wt% Cu + 25 wt% Ni). A penny weighs 3.1 g and is 1.9 cm in diameter and 0.12 cm thick. Approximately 5.3 x 10^8 pennies could be minted from entire inventory of CIP/CUP copper--8.6% of the number minted and 0.81% of the number in circulation in 1972.(7) A nickel weighs 5.0 g and is 2.2 cm in diameter and 0.15 cm thick. Approximately 6.7 x 10^9 nickels could be minted from 8,400 Mg of nickel--12 times the nickels minted and almost as many as were in circulation in 1972.

  Assessment is given for the manufacture of pennies. Doses from nickels during manufacture, assuming they contain only recovered nickel, could be five times those from manufacture of pennies.(1)

  A mint is assumed to process 2.7 x 10^4 kg of copper (or of copper plus nickel) per eight-hour shift. Sixty shifts would be required to process the entire inventory of copper. The important direct radiation exposure conditions and source representations used are given in Table B.5. In addition, mint workers would be immersed in air containing up to the TLV of 0.2 mg/m^3 of copper particulates,(2) with attendant inhalation and immersion doses for 60 eight-hour shifts.

B.4 DURING PRODUCT DISTRIBUTION

Sheet steel would normally be shipped in bulk. Populations and environments affected would resemble those of bulk alloy shipment, and the radiation doses would be similar.

Cast-iron frying pans represent items with a typical consumer product distribution system. Frying pans are typically distributed to the general public either through warehouses or through retail stores. Reference 1 presents a detailed scenario of frying pan distribution. Pans are trucked 800 km from factory to ware house. Truck drivers, service attendants, passersby, persons along the route and truck loading workers are exposed in a manner similar to those exposed during the truck shipment of bulk scrap. At the warehouse, packers and handlers are assumed to be in contact with the frying pans. The exposure conditions and source representations associated with the distribution of nine million cast-iron frying pans are given in Table B.6.

Table B.4. Exposure conditions to the total body from frying pan makers

Operation	Workers per Shift (no.)	Shifts (no.)	Duration of Exposure per Shift (hours)	Distance to Source	Absorbers	Source Description (dimensions in cm) and Representation
Unload	9	3	8	4.5	1 cm steel	5-Mg crane, load (R=65.1)
				4.5	1 cm steel	1,800 Mg pile, (R=380.5), hemisphere
Charge Furnace	18	471	2	1	1 cm steel	1,800 Mg pile, above
				1	1 cm steel	4 Mg load, (R=53.8, H=107.7), cylinder
					none	25-kg ingot (R=4.5, H=47.5), cylinder
Operate Furnace	27	471	2.5	1.5	2.5 cm steel 20 cm brick	7.7 Mg load (R=67.8, H=135.7), cylinder
Large Ladle	9	471	3	0.5	2.5 cm steel 20 cm brick	7.7 Mg load, above
Pouring Ladle	36	471	0.5	0.5	none	275 kg load (R=25.5) hemisphere
Remove Castings	18	471	0.5	2	none	75 pans, point source
Cut Off and Rough Grind	36	471	2	0.5	none	1 pan at a time, source
Grit Blast	9	471	2	1	none	75 pans, point source
Clean Dust	9	471	0.5	0.5	none	5 pans, point sources
Inspect	18	471	2	0.3	none	5 pans, point sources
Package	27	471	2	0.3	none	1 pan, point source
				1	none	1 carton-12 pans in stack (R=13.3, H=09.9), cylinder
Store	9	94	6	2	none	1,728 cartons, 12 x 12 x 12 array-144 exposed, above

Table B.5. Exposure conditions to the total body of mint workers involved in minting pennies

Operation	Workers per Shift (no.)	Shifts (no.)	Duration of Exposure per Shift (hours)	Distance to Source	Absorbers	Source Description (dimensions in cm) and Representation
Charge Furnace	2	60	4	1	none	240 Mg pile, (R=234) hemisphere
				0.6	1 cm	load, (R=62.4, H=124.8), cylinder
Operate Furnace	1	60	7	0.6	3 cm steel	14 Mg cylinder, above
Ladle	2	60	1	0.6	1 cm steel	14 Mg cylinder, above
				0.6	none	Stream of metal (L=61, H=30.5), point
Remove and Clean Ingots	4	60	8	0.6	none	9-kg ingot, (R=3.3, H=30.5), cylinder
Roll	2	60	6	1.2	none	s-kg ingot, above
				1.2	none	sheet, (304.8 x 25.4 x 0.15), 10 point source
Check	1	60	4	1 2	none	sheet, above
Slit	2	60	6	1.2	none	sheet, above
Coil	1	60	4	0.6	none	35-kg coil, (R=11.1, H=10.2), cylinder
Punch Blanks						
Load	40	60	3	0.6	none	35-kg coil, above
Punch	80	60	6	0.6	none	sheet, 152.4 x 10.2 x 0.153), 5 point source
Package	40	60	4	0.6	none	35-kg bag, as coil above
Recycle	2	60	4	2	none	350-kg coil, above
Anneal	1	60	4	0.6	1 cm steel	35-kg cylinder, above
			8	2	1 cm steel	2-Mg furnace load (R=13.3, H=365.8), cylinder
Clean	2	60	6	0.6	1 cm steel	2-Mg batch, (R=32.6, H=65.2), cylinder
Upset						
Load	20	60	6	0.6	1 cm steel	1-Mg load, (R=H=32.6) cylinder
Roll	20	60	6	0.6	none	sheet, (30.48 x 30.48 x 0.153), point source
Collect	20	60	6	0.6	1 cm steel	1-Mg load, above
Press Coins						
Load	20	60	6	0.6	1 cm steel	1-Mg load, above
Press	80	60	6	0.6	none	sheet, as above
Collect	20	60	6	0.6	1 cm steel	1-Mg load, above
Test	1	60	4	1.2	none	9,000 coins, point sources
Bag	1	60	6	1	none	6 bags of pennies
Store	1	60	8	2	none	5 x 5 x 5 array of bags 25 contribute

Table B.6. Exposure conditions during the distribution of frying pans

Worker	Persons per Exposure	No. of Exposures	Duration of Exposures (hr)	Distance to Source (m)	Absorbers	Source Description
Truck Driver	1	46,900	12.5	1.0	truck cab	16 cartons of pans in truck (12 pans/carton)
Truck Loader	1	46,900	0.25	0.3	none	16 cartons of pans
Service Attendant	2	46,900	0.167	1.0	truck	16 cartons of pans
Passerby	10	46,900	0.05	1.0	truck	16 cartons of pans
Public	104,000	46,900	---	30-760	none	truck, point source
Warehouse Worker	104	2,250	1	1.5	none	7 cartons of pans
Warehouse Packer	104	86,400	0.004	contact	none	1 pan in hands
Retail Clerk	37,500	250	8	3-15	none	6 pans on display
Retail Checker	37,500	24	1.3-3	contact	none	1 pan in hands
Retail Customer	37,500	1,000	0.5	15	none	6 pans on display

Coins distributed from the mint to banks represent a product with a specialized distribution system midway between those represented by bulk steel sheet and individual frying pans. Delivery to local banks is commonly by armored car. A bank is assumed to receive weekly shipments of 80,000 pennies and 20,000 nickels, and an armored car is assumed to service 12 banks per trip. Thus, 550 shipments of pennies and 28,000 shipments of nickels would be required to distribute coins made from recovered scrap metal. Exposed personnel in the truck are assumed to be a driver, a guard, and an escort. The exposure conditions associated with the distribution of coins are given in Table B.7.

Distribution of other products would follow patterns similar to those described above.

Table B.7. Exposure conditions during distribution of coins

Population	Persons per Exposure	No. of Exposures*	Duration of Exposure (hr)	Distance to Source (m)	Source
Driver	1	28,500	4	1.0	12 bags of coins
Guard	1	28,500	6	1.0	6-12 bags of coins
Escort	1	28,500	2	1.0	12 bags of coins
Escort	1	28,500	4	1.0	6 bags of coins
Escort	1	28,500	3	0.3	1 bag of coins
Population (country)	115/km	28,500	---	30 to 760	truck moving 80 km/hr for 400 km
Population (city)	115/km	28,500	---	3 to 760	truck moving 15 km/hr for 130 km

---

*Distribution of 550 shipments of pennies and 28,000 of nickels.

B.5 DURING PRODUCT USE

Sheet steel of a thickness of 1.6 mm is assumed to be used in the manufacture of metal structures. The postulated structure is a 3-m x 3-m x 3-m room. Enough sheet steel is produced from recycled alloy to produce 66,000 such structures. One person per structure is assumed to spend four hours per day, 250 days per year, working inside the metal room. Two persons per structure are assumed to spend the same amount of time outside the structure at a distance of 3 m. The steel room could also be taken to represent several kinds of home appliances, and the people outside the structure could represent appliance owners.

Sheet steel is also used in the fabrication of office furniture. A worker is assumed to sit 8 hours per day, 250 days per year, at a steel desk made of recycled materials. Only individual doses are considered.

A typical home might use two frying pans. Both are assumed to be made from recovered scrap. Thus, the 9 million pans could be distributed to 4½ million families, affecting about 18 million persons. Four and one-half million people are assumed to use the pans in cooking. Kitchen activities and other exposure mechanisms are listed in Table B.8. The ingestion route is from an assumed pan corrosion rate of 0.127 cm/yr, or 16.7 g/yr per pan, 1% of which is ingested by family members.

Several use situations for coins are assumed to illustrate the potential radiological impact of use of coins made form the contaminated metals. The exposure conditions assumed to represent the everyday activities of persons are given in Table B.9.(1)

Table B.8. Exposure conditions for frying pan users

Activity	Time Spent (hr/yr)	No. of Pans	Distance (m)
Meal Preparation	60	1 (on stove)	0.3
	60	1 (stored)	1.0
	45	2 (stored)	0.6
	770	2 (stored)	2.0
Cleaning	10	1 (sink)	contact
Ingestion	---	---	ingestion
Other	6,126	2 (stored)	8.0

Individual doses are considered for several personal products. Use of stainless steel for a surgically implanted bone prosthesis is considered. the prosthesis is a 0.6 cm by 7.5 cm right circular cylinder implanted in cortical bone. Doses to persons wearing belt buckles made of recycled metal are considered. Several layers of intervening cloth are assumed to eliminate the beta particle dose from the buckle. Skin doses to wearers of copper bracelets made from recycled copper are considered. Beta doses are considered using the Loevinger(8) methodology for a thick disk source. Ingestion doses to persons consuming ferrous sulfate iron supplement are considered. The ferrous sulfate elixor is assumed to contain 44 mg per teaspoon of contaminated recycled iron containing 17.5 ppm uranium, 5 ppm technetium, and daughters. The user is assumed to consume 6 teaspoons of ferrous sulfate elixor per day over a year.(9) In addition this annual supplement would require about 15 bottles of tonic, the likelihood of them all containing contaminated iron is very small.

Table B.9. Assumed exposure conditions for persons using pennies

Population Group	Population Subgroup	Persons in Subgroup (millions)	Exposure Event	Number of Coins Involved	Average Distance from Coins (m)	Duration of Exposure (hr/yr)	Attenuation Factor	Duration of Contact (hr/yr)
Non-carrier	all	205	living	24-80	3-30	4,380	0	0
Carriers	men	73	carry	8	0.1	5,840	0	0
			transact	3	1.1	10	0	10
	women	80	carry	10	0.4	2,920	0	0
			transact	3	1.1	10	0	10
	children	53	carry	2	0.4	182	0	182
			store	200	1.5	3,500	0.5	0
Banking	tellers	0.21	transact	3	1.1	17	0	17
			at window	500-2,000	0.4-3.0	1,750	0.25-0.5	0
	head tellers	0.04	transact	50	1.1	14	0	14
			at window	5,000-2,000	0.4-3.0	1,750	0.25-0.5	0
	customers	9	in bank	2,500	3.0	0.33	0.25	0
Small Stores	cashiers	0.80	transact	1	1.1	69	0	69
			at register	125-125	0.45-3.0	1,500	0.25	0
	customers	44	in store	250	9.1	0.5	0.5	0
			check-out	250	3.0	0.17	0.25	0.17
Large Stores	cashiers	0.88	transact	1	1.1	140	0	140
			at register	540-2,170	0.45-4.5	2,000	0.25	0
	customers	44	in store	2,700	9.1	0.5	0.5	0
			check-out	2,700	4.5	1.7	0.25	1.7

REFERENCES FOR APPENDIX B

1. U.S. Energy Research and Development Administration, "Environmental Impact Assessment Concerning Proposed Rulemaking, Exemption from Licensing Requirements for the Sale and Use of Metal Scrap Homogeneously Contaminated with Enriched Uranium and Technetium-99 Below a Specified Concentration," Oak Ridge National Laboratory, July 1976. Available in NRC PDR for inspection and copying for a fee.

2. American Conference of Governmental Industrial Hygenists, "TLV's--Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1974," pp. 38-43, A.C.G.I.H., 1974. Available in NRC PDR for inspection and copying for a fee.

3. E. W. Mautz, G. G. Briggs, W. E. Shaw, and S. H. Cavendish, "Uranium Decontamination of Common Metals by Smelting--A Review," NLCO-1113 Special, National Lead Company of Ohio, February 1975. Available in NRC PDR for inspection and copying for a fee.

4. R. W. Levin, "Minutes of Meeting on CIP Scrap Melting," KY-L-806, Union Carbide Corporation, Paducah, KY, September 17, 1975. Available in file for USNRC Report NUREG-0518.

5. M. G. Seitz, T. J. Gerding, and M. J. Steindler, "Decontamination of Metals Containing Plutonium and Americium," p. 25, ANL-78-13, prepared for DOE by Argonne National Laboratory, June 1979. Available in NRC PDR for inspection and copying for a fee.

6. H. J. Drake, "Slag-Iron and Steel," Minerals Yearbook - 1972, Volume I (Metals, Minerals, and Fuels), U.S. Bureau of Mines, pp. 1143-1145 (1974). Available in public technical libraries.

7. U.S. Department of Commerce, Statistical Abstract of the United States: 1973, p. 456, Washington, DC, 1973. Available in public libraries.

8. R. Loevinger, E. M. Japhu, and G. L. Brownell, Radiation Dosimetry, (G. J. Hine and G. L. Brownell, eds), Academic Press, NY, 1956, Chapter 16. Available in public technical libraries.

9. Label from bottle of "Feosol Elixir," Smith-Kline and French Laboratories, Division of Smith-Kline Corp., Philadelphia, PA 19101. Available in file for USNRC Report NUREG-0518.

APPENDIX C

INDIVIDUAL AND COLLECTIVE DOSE CALCULATIONS

External radiation doses to the individuals and population described in Appendix B were calculated using standard techniques. Doses from the transport of bulk materials were calculated using the methodology developed for a USNRC assessment of the potential radiation doses associated with transportation of radioactive materials.$^{(1)}$ Direct irradiation doses from manufacture, distribution, and use of products were calculated using either the CONDOS$^{(2)}$ methodology or the ISOSHLD$^{(3)}$ shielding code. Both methods provide gamma ray shielding calculations for a wide variety of source and shield configurations. Source and shield descriptions are provided in Appendix B. Direct irradiation of skin from direct contact with metal containing radionuclides was calculated using the Loevenger finite disk source formulation.$^{(4)}$

Internal radiation doses from ingestion of metals contaminated with radionuclides were calculated using the dose factors in Table C.1. Doses resulting from inhalation of particulate metal were calculated using the dose factors in Table C.2. The dose factors in Table C.3 were used to calculate the external exposure from immersion in air contaminated with particulate metal. All dose factors are taken from Killough and McKay$^{(5)}$ to maintain consistency with the previous Environmental Impact Assessment$^{(6)}$ on unconditioned release of metals slightly contaminated with low-enriched uranium and technetium-99.

An example of the use of these dose factors is given for the case of a person immersed in and breathing air contaminated with 1 $\mu\text{Ci/m}^3$ of U-235 in equilibrium with its daughter Th-231. This person is assumed to spend 8 hours per day, 200 days per year in this environment. The total body dose from immersion in this air is thus:

$$\left[\left(1\ \frac{\mu\text{Ci}}{\text{m}^3}\ \text{235-U}\right)\left(1.1\ \frac{\text{rem/yr}}{\mu\text{Ci/m}^3}\right) + \left(1\ \frac{\mu\text{Ci}}{\text{m}^3}\ \text{231-Th}\right)\left(0.12\ \frac{\text{rem/yr}}{\mu\text{Ci/m}^3}\right)\right] \times \left[\left(\frac{8\ \text{hr/d}}{24\ \text{hr/d}}\right)\left(\frac{200\ \text{day/yr}}{365\ \text{day/yr}}\right)\left(1\ \text{yr}\right)\right] = 0.22\ \text{rem}$$

Similarly, for a person breathing this air at a rate of 10 m^3 for an 8-hour working day, 200 days per year:

$$\left[\left(1\ \frac{\mu\text{Ci}}{\text{m}^3}\ \text{235-U}\right)\left(1.2\ \frac{\text{rem}}{\mu\text{Ci}}\right) + \left(1\ \frac{\mu\text{Ci}}{\text{m}^3}\ \text{231-Th}\right)\left(5.0\text{E-}5\ \frac{\text{rem}}{\mu\text{Ci}}\right)\right] \times \left[\left(10\ \frac{\text{m}^3}{\text{day}}\right)\left(200\ \frac{\text{day}}{\text{year}}\right)\left(1\ \text{year}\right)\right] = 2{,}400\ \frac{\text{rem}}{\text{year.}}$$

This number is a 50-year dose commitment. These examples show the dominance of the internal exposure pathways for radiation dose.

Table C.1. Organ-dose conversion factors for ingestion of radionuclides - 50 year dose commitment (rem/μCi)

Radionuclide	Whole Body	Lungs	G.I. Tract
U-238	4.5E-2	4.5E-2	4.9E-2
Th-234	2.3E-6	2.3E-6	9.7E-2
Pa-234m	3.2E-8	3.2E-8	3.2E-8
U-236	4.9E-2	4.9E-2	6.5E-2
U-235	4.2E-2	4.2E-2	6.5E-2
Th-231	2.0E-8	2.0E-8	9.7E-3
U-234	5.1E-2	5.1E-2	6.5E-2
U-232	2.9E-1	2.9E-1	6.5E-2
Th-228	1.7E-2	1.7E-2	1.9E-1
Ra-224	2.0E-1	2.0E-1	3.9E-1
Rn-220	0	0	0
Po-216	2.1E-8	2.1E-8	2.1E-8
Pb-212	3.0E-3	3.0E-3	9.7E-3
Bi-212	3.6E-5	3.6E-5	4.9E-3
Tl-208	8.5E-7	8.5E-7	8.5E-7
Po-212	1.3E-14	1.3E-14	1.3E-14
Tc-99	4.9E-5	1.6E-5	9.7E-3

Table C.2. Organ-dose conversion factors for inhalation of radionuclides - 50 year dose commitment (rem/μCi)

Radionuclide	Whole Body	Lungs	G.I. Tract
U-238	1.2E-0	4.7E-1	3.6E-2
Th-234	5.7E-3	2.0E-1	7.1E-2
Pa-234m	8.1E-5	1.5E-3	8.1E-5
U-236	1.2E-0	5.2E-1	3.6E-2
U-235	1.2E-0	5.1E-1	4.3E-2
Th-231	5.0E-5	1.1E-3	5.3E-3
U-234	1.3E-0	5.4E-1	3.6E-2
U-232	7.3E-0	2.3E-0	4.3E-2
Th-228	4.2E-1	1.0E-3	1.1E-1
Ra-224	2.7E-1	9.1E-0	2.4E-1
Rn-220	1.1E-2	6.0E-3	7.1E-3
Po-216	9.8E-8	2.1E-6	9.8E-8
Pb-212	1.1E-2	3.3E-1	7.1E-3
Tl-208	9.0E-7	9.3E-6	9.0E-7
Po-212	6.2E-14	2.0E-12	6.2E-14
Tc-99	4.9E-5	1.0E-1	7.1E-3

Table C.3. Organ-dose conversion factors for immersion in contaminated air $\left(\frac{\text{rem/year}}{\mu\text{Ci/m}^3}\right)$

Radionuclide	Whole Body	Lungs	G.I. Tract
U-238	1.6E-3	4.8E-1	4.9E-4
Th-234	5.2E-2	4.3E-2	2.7E-2
Pa-234m	2.0E-3	1.8E-3	1.3E-3
U-236	1.6E-3	3.5E-4	4.3E-4
U-235	1.1E+0	9.4E-1	5.9E-1
Th-231	1.2E-1	8.8E-2	5.5E-2
U-234	2.5E-3	1.0E-4	8.6E-4
U-232	3.5E-3	1.6E-3	1.2E-3
Th-228	1.8E-2	1.5E-2	9.5E-3
Ra-224	7.3E-2	6.5E-2	4.1E-2
Rn-220	2.6E-3	2.5E-3	1.9E-3
Po-216	0	0	0
Pb-212	1.1E+0	9.1E-1	5.6E-1
Bi-212	8.1E-1	7.7E-1	6.1E-1
Tl-208	2.5E+1	2.4E+1	2.0E+1
Po-212	0	0	0
Tc-99	0	0	0

REFERENCES FOR APPENDIX C

1. U.S. Atomic Energy Commission, "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants," App. D, WASH-1238, December 1972. Available for purchase from National Technical Information Service, Springfield, VA 22161.

2. F. R. O'Donnell, L. R. McKay, O. W. Burke, and F. H. Clark, "CONDOS - A Model and Computer Code to Estimate Population and Individual Radiation Doses to Man from the Distribution, Use, and Disposal of Consumer Products that Contain Radioactive Materials." pp. 1-28, ORNL-TM-4663, May 1975. Available for purchase from National Technical Information Service, Springfield, VA 22161.

3. R. L. Engel, J. Greenborg, and M. M. Hendrickson, "ISOSHLD - A Computer Code for General Purpose Isotope Shielding Analysis," BNWL-236, June 1966. Available for purchase from National Technical Information Service, Springfield, VA 22161.

4. G. J. Hine and G. L. Brownell, eds., *Radiation Dosimetry*, Chapter 16, Academic Press, New York, 1956. Available in public technical libraries.

5. G. G. Killough and L. R. McKay, "A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment," Tables 3-8, 4-2, and 4-3, ORNL-4992, March 1976. Available for purchase from National Technical Information Service, Springfield, VA 22161.

6. U.S. Energy Research and Development Administration, "Environmental Impact Assessment Concerning Proposed Rulemaking, Exemption from Licensing Requirements for the Sale and Use of Metal Scrap Homogeneously Contaminated with Enriched Uranium and Technetium--99 Below a Specified Concentration," Oak Ridge National Laboratory, July 1976. Available in NRC PDR for inspection and copying for a fee.