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ANNUAL TECHNICAL REPORT

TRANSURANIC WASTE PROGRAM

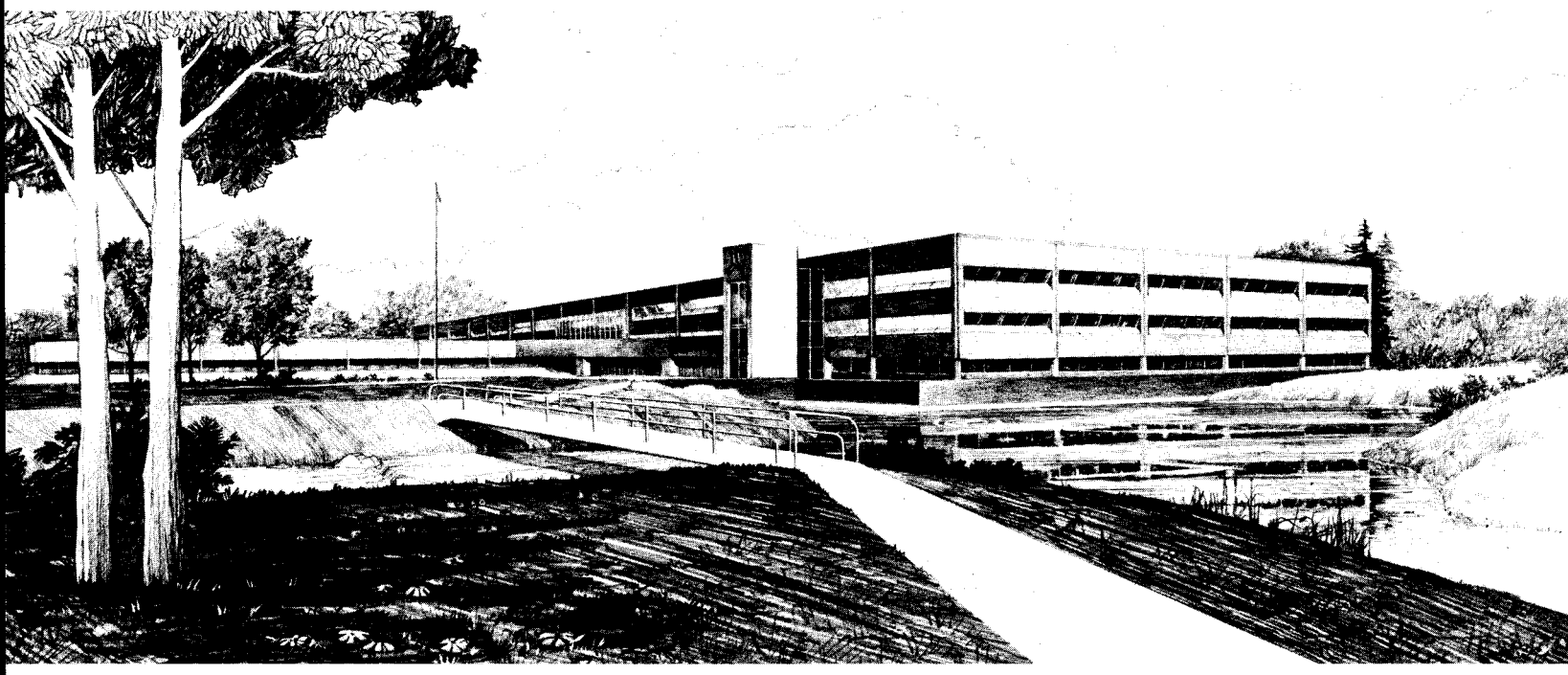
AT EG&G IDAHO, INC.

FY 1980

T. H. Smith
C. R. Tolman

U.S. Department of Energy

Idaho Operations Office • Idaho National Engineering Laboratory



This is an informal report intended for use as a preliminary or working document

Prepared for the
U.S. Department of Energy
Idaho Operations Office
Under DOE Contract No. DE-AC07-76ID01570

EG&G Idaho

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1. INTRODUCTION

This document summarizes the objectives and technical achievements of the transuranic (TRU) waste research and development program conducted at EG&G Idaho, Inc., during fiscal year 1980. EG&G Idaho, Inc., is a prime contractor for the U.S. Department of Energy at the Idaho National Engineering Laboratory (INEL).

This report is in response to the work-element reporting requirement specified in subsection VI.E.2 of the Technical Management Plan for the Transuranic Waste Management Program, Albuquerque Operations Office, U.S. Department of Energy.

The TRU waste activities covered in this report include:

- o INEL TRU Waste EIS (Environmental Impact Statement), including preparation of the EIS, Support Studies, and the Public Participation Program
- o INEL TRU Waste Projects, including System Analysis, Stored Waste projects, and Buried Waste projects
- o Waste Management Materials Studies, including Process Control and Durability studies.

This document does not include the activities of the Transuranic Waste Treatment Facility Project. That project has as its objective the design, construction, and startup of a facility to process INEL TRU waste, prior to shipping the waste to a federal waste repository.

2. INEL TRANSURANIC WASTE EIS

2.1 Preparation of EIS

The TRU waste EIS (Figure 1) is being prepared to provide environmental input to decisions concerning the long-term management of defense-generated solid TRU waste currently located at the Radioacative Waste Management Complex of the INEL. The EIS will comply with the requirements of the National Environmental Policy Act for decisions affecting the environment. When the Final EIS is issued (projected to occur in September 1982), another document, supporting the Record of Decision will be issued. This second document, discussed in 3.1.4, is being prepared under the INEL TRU Waste Project.

2.1.1 Objective

The objective of this activity was to prepare an EIS on the long-term management of INEL TRU-contaminated waste. This was to include issuance of a draft TRU Waste EIS (April 1980) by DOE-HQ for public review and comment, conducting special studies for the draft TRU Waste EIS, and reviewing of the draft by public agencies (July 1980).

2.1.2 Achievements

In mid-December 1979, the scope of the draft TRU Waste EIS was changed to include information on stored waste and on waste processing. As a result, publication of the draft TRU waste EIS for public agency review was delayed.

In April 1980, an internal draft of the EIS was produced for DOE-HQ review. This draft presented alternative methods for managing the buried waste, alternative methods for processing the buried and stored waste before disposal at an offsite geologic repository, and alternative locations for the processing facility. As of September 1980, the draft was still undergoing review at DOE-HQ.

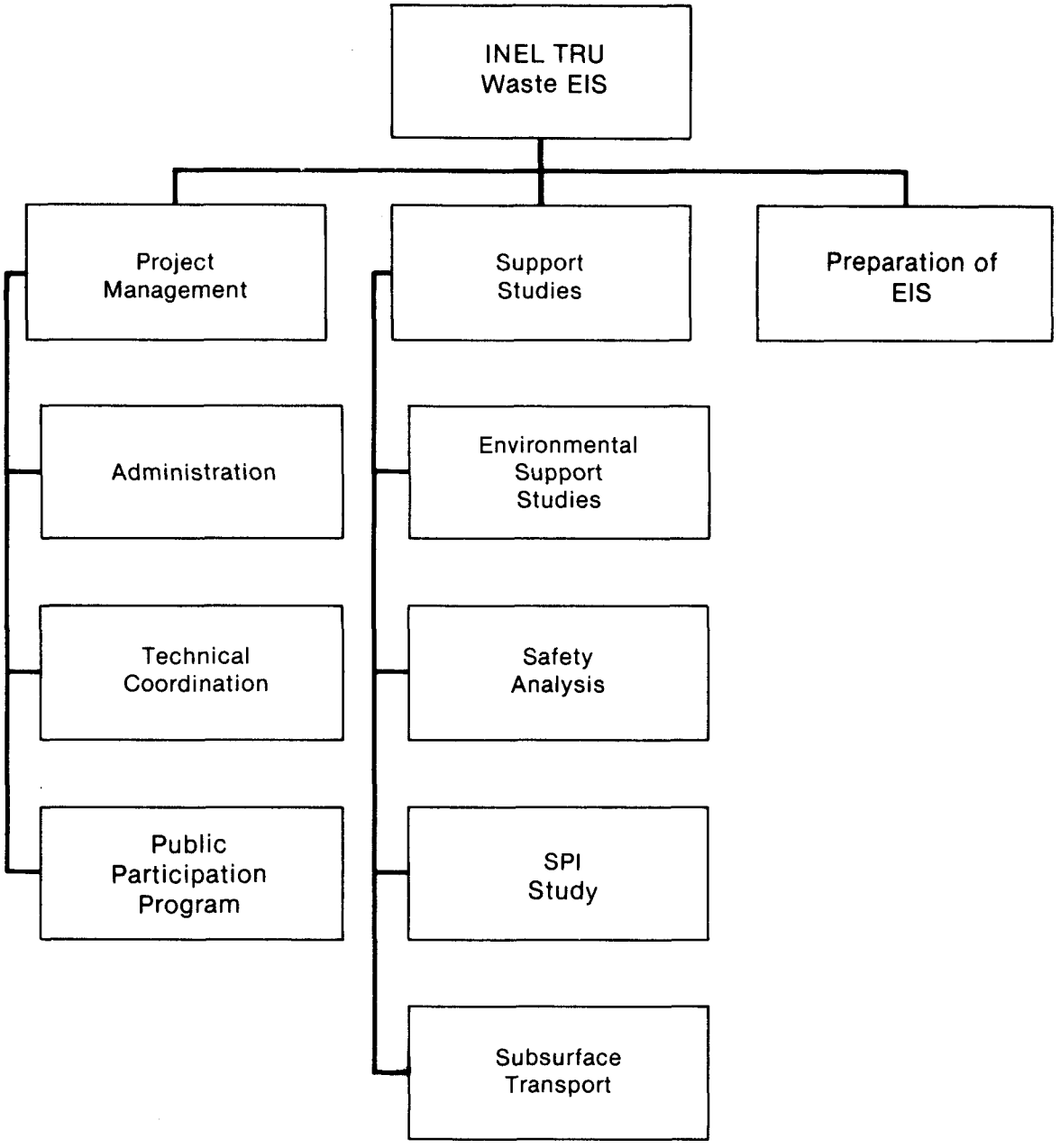

Figure 1. Work breakdown structure for INEL TRU Waste EIS.

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2.2 Support Studies

In conjunction with the TRU Waste EIS, support studies were conducted on environmental and processing (slagging pyrolysis) topics. The support studies are presented in the appendixes to the TRU Waste EIS, and appropriate portions were incorporated into the basic text of the EIS.

2.2.1 Environmental Support Studies

2.2.1.1 Objective. The objective of the environmental support studies was to ensure completeness of the TRU waste EIS in technical and humanistic areas.

2.2.1.2 Achievements. Socioeconomic evaluations were conducted by the University of Arizona. Socioeconomic effects of all phases of alternatives (construction, operation, decontamination and decommissioning) were evaluated and the findings incorporated into the text of the EIS.

A waste-shipment study evaluated the doses received by transport crews and the public during transport. The study considered minimum- and maximum-population routes to a repository by both rail and truck transport modes. Doses from abnormal events (releases from accidents) were also calculated.

A risk analysis of radon gas emission was conducted.

The EIS text was reviewed by humanist experts to ensure multi-disciplinary involvement in preparation of the EIS.

2.2.2 Slagging Pyrolysis Incineration Study

2.2.2.1 Objective. The objective of this study was to evaluate the effects of locating a slagging pyrolysis incinerator at the INEL or at the WIPP repository site.

2.2.2.2 Achievements. The environmental and other effects of locating an incinerator at the INEL or WIPP sites were evaluated. The results were included in the appendix to the TRU waste EIS.

2.3 Public Participation Program

The public participation program was developed for the TRU waste EIS to actively involve the public and state, county, and city officials in decisions for the long-term management of TRU waste at the INEL.

2.3.1 Materials

2.3.1.1 Objective. The objective of this portion of the program was to provide basic materials for understanding radiation, radioactivity, the characteristics of the waste, and possible methods for its long-term management.

2.3.1.2 Achievements. Eleven brochures have been written and are in various stages of completion; three are published and currently available. Brochure topics cover various areas of waste management and waste identification and characterization. A preliminary media kit has been prepared. A basic slide presentation describing the waste, the management method, and the EIS has been prepared.

2.3.2 Public Meetings

2.3.2.1 Objective. Public hearings, seminars, and briefings were to be planned to enable active pubic participation and information dissemination. Both formal and informal settings were to be provided for the public to actively participate in the planning process of the EIS.

2.3.2.2 Achievements. A basic plan has been developed for holding public seminars and hearings within Idaho, related to the issuance of the TRU waste EIS. A public-relations firm assisted in writing the plan, which identifies various audiences and approaches for dealing with the audiences.

3. INEL TRANSURANIC WASTE PROJECTS

The basic objectives of the INEL TRU Waste Projects effort for FY 1980 were to support development of the buried waste EIS and to support design of the SPI Facility (now TWTF). A summary work breakdown structure for this area of effort is given in Figure 2.

3.1 Systems Analysis

3.1.1 Data Management System

3.1.1.1 Objective. The objective of the Data Management System effort was to develop a current, validated short-term data base and data management system to support model development for TRU waste management alternatives.

3.1.1.2 Achievements. The short-term data base was created and a data dictionary that defines the data was written. The data management system was merged with the Query/Update system to provide easier access to the data. Data was entered into the system. A users' guide was issued explaining how to input or change data and how to obtain listings of the current data file.

3.1.2 Program Interface and Integration

3.1.2.1 Objective. The objective of the Program Interface and Integration effort was to provide direction to the Transportation Technology Center (TTC) at Sandia Laboratories to perform a study on the transportation of TRU waste from the INEL to an offsite federal geologic repository (assumed to be in New Mexico).

3.1.2.2 Achievements. TTC provided a draft report on transportation packaging systems and a draft report produced by Battelle PNL that includes operating costs and logistics for transportation of INEL TRU waste to the repository.

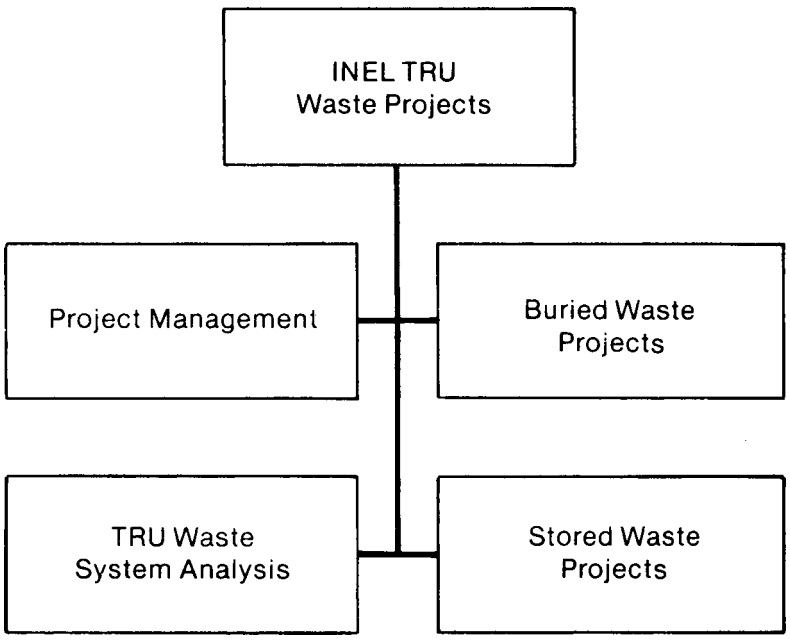

Figure 2. Work breakdown structure for INEL TRU Waste Projects.

3.1.3 Developmental Analysis

3.1.3.1 Objectives. The objectives of developmental analysis effort were to (a) identify functional requirements for each major component of an alternative, including design constraints, useful life, capacity, safety, environment, quality standards, operating characteristics, maintainability, reliability, and support requirements; (b) examine existing modeling capabilities to determine the best system for model construction; and (c) develop for the alternatives a coarse working model that could be used to support design activities and the Recommendation of a Long-Term Strategy (RLTS) document.

3.1.3.2 Achievements. The Decision Analysis section of Information Sciences provided functional requirements, flow diagrams, modeling considerations, and identification of potential problem areas for the alternatives for TRU waste management at the INEL. They performed a study of the oxidation of metals in the TWTF gasifier and wrote a users' manual for an interactive, Fortran-based, steady-state stoichiometric model of the gasifier and secondary combustion chamber. They evaluated a variety of simulation languages and chose the SLAM language for modeling the alternatives. The year-end report described the SLAM models and their results for buried and stored waste retrieval, and their coupling with TWTF and repackaging facility models.

3.1.4 Recommendation of a Long-Term Strategy (RLTS)

3.1.4.1 Objectives. The objectives were to (a) organize and report on a review of the TRU waste EIS by a panel of experts, (b) produce a series of subcontracted and internal studies to provide implementation and cost information for the management alternatives for TRU waste, and (c) begin writing the Recommendation of a Long-Term Strategy document that will combine data from the EIS with implementation-oriented information for decision making and present DOE-ID's recommendation to DOE-HQ.

3.1.4.2 Achievements

1. The EIS review panel was held and a report issued. The findings were incorporated into the current draft of the EIS.

2. Studies were produced on the following subjects:

   a. Alternative designs and their manpower, resource, and cost requirements

   b. Human factors to be considered in systems design and operations

   c. Applicable environmental and safety regulations

   d. The decision process and its estimated duration

   e. Relative merits of different decision-making techniques

   f. Possible land contamination and air activity resulting from accidents

   g. Costs of cleaning up land contamination from accidents and evacuating personnel from affected areas

   h. Evaluation of nontechnical issues related to management of INEL TRU waste

   i. Computer methods for escalating costs and calculating net present value.

3. Writing was begun on the RLTS document.

3.2 Stored Waste

3.2.1 Waste Characterization and Categorization

3.2.1.1 Objective. The objective of this study was to analyze waste from randomly selected 208-liter drums to determine statistical content (at the 95% confidence level) for Transuranic Storage Area (TSA) waste.

3.2.1.2 Achievements. An additional 70 drums were retrieved from the TSA. Thirty-five of the retrieved drums were sent to the Rocky Flats Plant, where the drums were opened and the contents characterized. The results of this activity were compared with current records on container content to validate predicted waste volume versus actual container volume, plus the predicted versus actual physical form. The data obtained will be factored into proposed waste-processing feed mixtures.

3.2.2 Nondestructive Examination

3.2.2.1 Objective. The objective of this study was to perform real-time radiography on the 70 drums of retrieved waste from the TSA to determine the value of X-raying drums prior to opening them in a waste processing facility.

3.2.2.2 Achievements. Seventy waste drums were examined by real-time radiography. The work was performed by Schonberg Radiation Corporation. Tapes of the waste were analyzed and compared with actual contents as established by physical characterization.

3.3 Buried Waste

3.3.1 Nonradiological Hazards Study

3.3.1.1 Objective. The objective of this study was to identify potential nonradiological hazards intermixed with radioactive waste buried in TRU waste disposal areas. Personal contact with offsite waste generator representatives was used to gather the information.

Nonradiological hazards include organic and inorganic chemicals, biological agents, and mechanical hazards, such as pressurized gas cylinders. These materials are not only radiologically contaminated but also represent nonradiological hazards due to associated chemical, biological, or mechanical properties. The study was limited to offsite waste generators no longer shipping waste to the INEL. The majority of offsite-generated waste, other than Rocky Flats, was received for burial during the 1960-1963 period.

3.3.1.2 Achievements. During FY 1980, two studies were made. The first study was an assessment of all available information concerning offsite-generated waste buried in TRU waste disposal areas. The assessments were made by receiving available offsite waste generator records and by interviewing personnel familiar with the offsite generators' operations, material usage, and waste management practices. Information obtained in the study indicates that hazardous materials have been included in radioactive waste shipments to the INEL.

Information obtained from this study will be used to support the RLTS document and to assist in selecting an alternative for management of buried TRU waste. In addition, identification of hazardous materials helps to ensure personnel and environmental protection through adequate engineering design of facilities to be used in accomplishing future waste management alternatives.

Another study, conducted by the Fred C. Hart Associates, Inc., Denver, Colorado, evaluated the risks associated with identified nonradiological hazards.

3.3.2 Encapsulation Studies

3.3.2.1 Objectives. The objectives of this study were to determine the feasibility of (a) in situ immobilization of the buried waste as a method for long-term management and (b) injection of a binding substance into the waste to enhance handling during retrieval and processing.

3.3.2.2 Achievements. A subcontract was awarded to Dames & Moore, Denver, Colorado, to perform the encapsulation studies. The study was conducted in two phases. Phase I was Engineered Containment for Long Term Storage and Phase II was Engineered Containment to Assist in Retrieval and Processing. Both phases were successfully completed. Reports were issued for Phases I and II.

4. WASTE MANAGEMENT MATERIALS STUDIES

Materials studies were to be performed on the development of iron-enriched synthetic basalt (IESB) as a waste form for transuranic (TRU) waste containment. Some of the studies were to address the engineering problems associated with likely systems to process the waste, with special reference to slagging pyrolysis incineration. Other studies were to characterize IESB, attempting to establish its flexibility and effectiveness for TRU containment.

The tests and examinations performed during FY 1980 were to be of the scoping type, aimed at identifying important parameters associated with converting TRU waste into IESB. The high temperature technology associated with waste treatment and the nature of TRU waste results in a waste form the composition of which cannot be closely tailored. Therefore, an envelope of compositions, as well as the structural conditions derived from cooling the melts, were to be examined and tested.

The specific activities to be performed during FY 1980 consisted of two major work elements: (a) assessment of process control and (b) durability (see Figure 3). Process control was comprised of eight activities and durability of two activities.

Composition variations for the waste form studies were mainly associated with the A-series type. The A-series represents compositions obtained by converting average TRU waste stored at the INEL into an oxide-slag form, which has various levels of soil additions. For example, A-40 represents average INEL TRU waste plus 40 weight percent soil. Its composition represents the nominal case and served as the baseline for the studies.

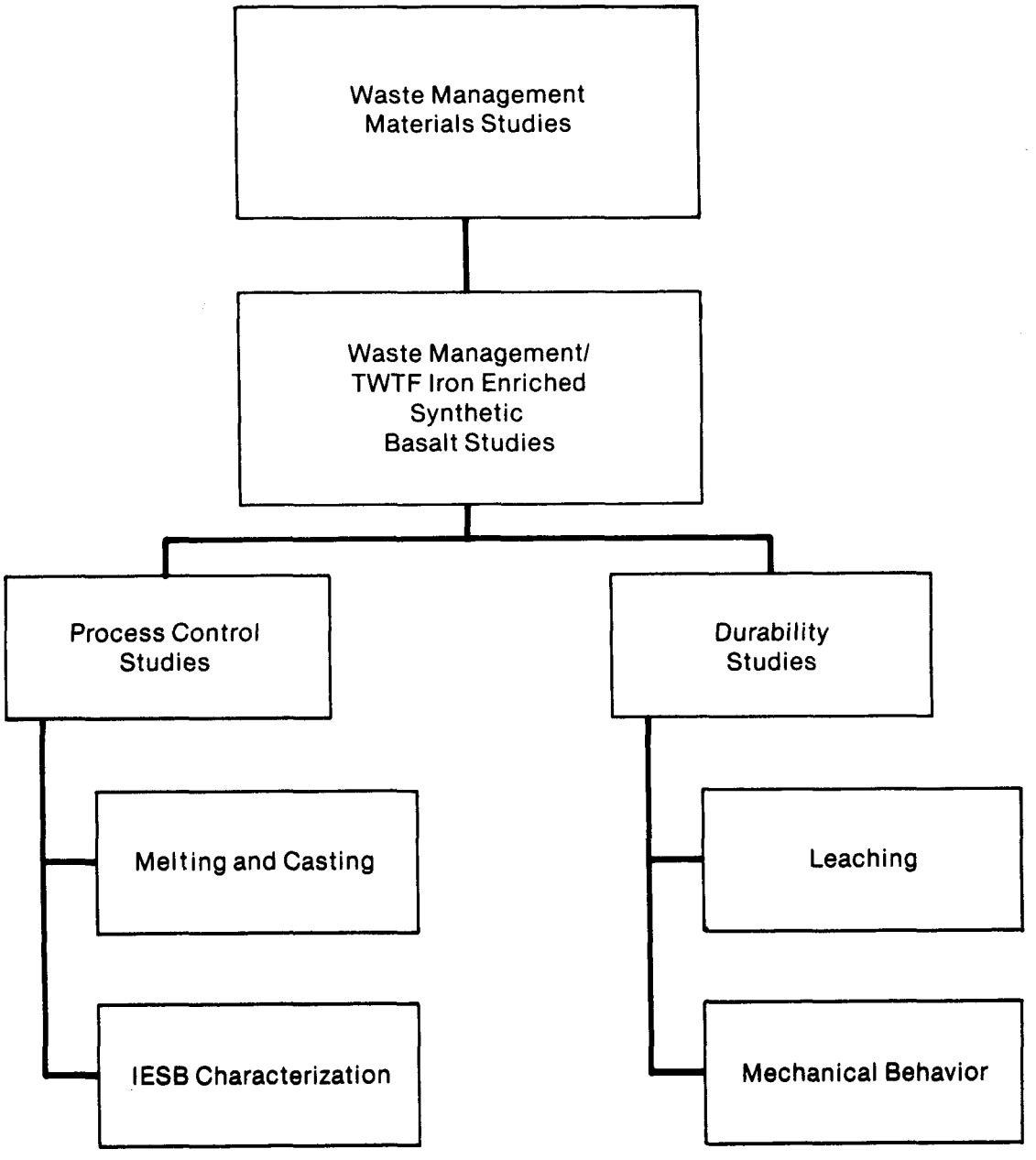

Figure 3. Work breakdown structure for Waste Management Materials Studies.

4.1 Process Control

4.1.1 Melting and Casting

4.1.1.1 Objectives. The objectives of this study were to melt and cast various lab scale and large scale batches of representative waste form compositions, construct an electromelter, and determine if the molten slag can be cast and cooled in mild steel, thin-walled containers.

4.1.1.2 Achievements. Over one hundred lab scale melts, ranging from 50 to 500 g each, were performed. Most of the lab scale melts were doped with U_3O_8. These melts provided specimens for subsequent characterization. Eight large scale melts ($\sim$100 kg each) were produced by electromelting. Four of the castings from the electromelts were evaluated. In addition, several melts were performed using an arc melting furnace. The molten slag was poured and subsequently cooled in 208-liter drums. The castings from the large melts demonstrated that relatively thin-walled mild steel drums will contain the molten slag during cooling. An electromelter, with a 250-kg molten slag capacity, was constructed.

The melter uses molybdenum electrodes and Al_2O_3 - Cr_2O_3 refractories as a liner.

4.1.2 Slag-Refractory Interaction

4.1.2.1 Objectives. The objectives of this study were to conduct static tests on commercial refractories to determine their compatibility with molten uranium-doped slags for migration and to identify the optimum corrosion-resistant refractory for use with anticipated INEL slags.

4.1.2.2 Achievements. Static tests, mainly at 1773 K, were performed on commercial refractories. No preferential migration of the uranium was observed; however, refractories exposed to slags with high iron and/or alkali content showed substantial corrosion rates. For the series of refractories tested, a 10% Cr_2O_3 - 90% Al_2O_3 refractory performed best.

4.1.3 Slag-Frit Assessments

4.1.3.1 Objective. The objective of this study was to characterize municipal frit produced by slagging pyrolysis incineration and to frit small melts of uranium-doped A-series slags to determine uranium content in the quench water.

4.1.3.2 Achievements. Municipal waste frit produced by slagging pyrolysis incineration was characterized. Assessments included particle size analysis, unreacted metallics, and chemical composition. Significant levels of unreacted iron fragments, as well as very high Fe^{2+} content compared to Fe^{3+}, were observed for the frit. Remelting the frit at 1723 K for 1 hour eliminated the iron fragments and changed the Fe^{2+}/Fe^{3+} ratio to $\sim$1. Vibration tests were performed on >2 mm particles of municipal waste frit placed in sealed containers. The tests involved 4 Hz, 15 cm amplitude and a total of 570,000 cycles. After testing, 45 weight percent of the particles were less than 2 mm.

Small melts of uranium-doped A-0 and A-40 slags were fritted. Subsequent analysis included particle size measurements and uranium content in the quench water. Significant levels of uranium were detected.

Cold pressing and sintering studies on municipal waste frit were initiated. A mixture of 40% frit and 10% aluminum enamel was cold pressed and sintered at 1030 K for 3 hours and resulted in a monolith of 2.6 g/cm^3 density and of good strength.

4.1.4 Volatility of Sodium Salts from IESB Melts

4.1.4.1 Objective. The objective of this effort was to determine the volatility of sodium chloride and of sodium sulfates when mixed with A-series melts.

4.1.4.2 Achievements. Salt cake mixtures, including sodium chloride and sodium sulfates, were either mixed with A-40 powders and melted or added directly to A-40 melts. Melts were performed at about 1700 K.

Results showed that chloride and sulfate volatilities were extreme with very small levels detected in the melts after cooling.

4.1.5 Homogeneity

4.1.5.1 Objective. The objective of this study was to assess the distribution of uranium and plutonium in IESB melt after controlled cooling.

4.1.5.2 Achievements. Assessments of the distribution of uranium and plutonium in IESB melts after controlled cooling were performed. For the uranium assessments, melts involving fast cooling (near isothermal) and slow cooling (radial temperature gradients) conditions, as well as subjecting molten slag columns to axial temperature gradients of ∿873 K (1723 K top to 1123 K bottom) for 3 and 9 hours, were examined after cooling by autoradiography and scanning electron microscope (SEM) for evidence of segregation. No segregation was observed. Very small crystallites, ∿1 mm in size, of apparently UO_2 were detected throughout the castings. Molten A-40 slag columns containing 1 weight percent PuO_2 were subjected to both isothermal and large axial temperature gradients (∿873 K) conditions. Alpha autoradiographs and SEM examination disclosed no apparent plutonium separation. Similar to the uranium studies, small crystallites of PuO_2 were observed.

Homogeneity assessments, consisting of chemical analysis and phase and structure examinations, were also performed on the electromelt castings. The results of these evaluations showed the large castings to be generally uniform.

4.1.6 Dissolution

4.1.6.1 Objective. Dissolution investigation of various materials, particularly metallic iron, was to be performed in conjunction with other studies and demonstrations.

4.1.6.2 Achievements. Numerous dissolution investigations of materials in IESB were performed as an integral part of the studies. In

particular, the dissolution of metallic iron in IESB received attention. In addition to the remelting of municipal waste frit containing iron fragments, steel bolts were intentionally inserted into the A-40 1772 K melts. The volume ratio of iron to slag was as high as 1 for some of the tests. The shortest test performed lasted 3 days; subsequent examinations disclosed no evidence of metallic iron in the slags.

4.1.7 Physical Properties

4.1.7.1 Objective. Physical properties of a wide range of representative waste form compositions were to be measured as an integral part of other studies and demonstrations.

4.1.7.2 Achievements. Measurements of viscosity and electrical conductivity as a function of temperature were obtained on slag waste forms over a broad range of compositions. The viscosity measurements on the A-series slags showed that iron additions reduced the viscosity but limited the working range. Also, alkali additions reduced the viscosity but extended the working range. Similarly, both alkali and iron additions were found to significantly increase the electrical conductivity of the slag.

For A-0 slag, the specific heat, C_p, was determined between 423 and 773 K. It was observed that C_p could be described by a second order polynomial in temperature.

4.1.8 Devitrification

4.1.8.1 Objective. Phase and structure development assessments were to be made on the baseline slag to determine the factors that promote devitrification.

4.1.8.2 Achievements. Phase and structure development assessments were performed on the baseline A-40 slag. The parameters involved composition variations, annealing, and controlled cooling to promote devitrification. The composition variations included effects from the iron oxide/silica ratio, Fe^{2+}/Fe^{3+} ratios, and alkali oxide, PbO, ZrO_2,

U_3O_8 and Al_2O_3 additions. It was observed that controlled cooling was more effective than annealing for phase development. Cooling from the melt at about 1573 K, an iron-rich spinel phase, depending on the amount of Fe^{3+} present, is the first to come out of solution. Between 1373 and 1473 K, a pyroxene phase (augite) forms with a general structural formula of $(Ca, Mg, Fe, Al)_2 (Si, Al)_2O_6$. At lower temperatures, estimated to be about 1273 K, feldspar develops.

4.2 Durability

4.2.1 Leaching

4.2.1.1 Objective. Leaching tests were planned to determine leach rates on A-series specimens doped with U_3O_8 using various leachants.

4.2.1.2 Achievements. The leaching tests were performed primarily on A-series specimens doped with U_3O_8. The tests were for short durations, up to 28 days, and used deionized water as the leachant. Test configurations involved static, semistatic (leachant change), and Soxhlet. Temperatures for the tests were 243 and 263 K for the static, 243 K for the semistatic, and 269 K for the Soxhlet. Leaching behavior was measured from weight loss measurements and chemical analysis of the leachants.

Bulk leach rates determined from both methods were comparable. Vitreous A-series specimens (A-0, A-20, A-40, A-60, A-80, and A-100) and devitrified A-40 specimens exhibited leach rates at 243 K of $\sim$0.5 $\mu g/cm^2 \cdot d$. Specimens of A-40 with about 10 weight percent alkali oxide showed leach rates of $\sim$1 $\mu g/cm^2 \cdot d$. Similar specimens with 14 weight percent alkali oxide showed leach rates of 20 to 40 $\mu g/cm^2 \cdot d$. Specimens from the electromelt castings exhibited leach rates ranging from 8 (A-40) to 40 (A-0) $\mu g/cm^2 \cdot d$. For the electromelt specimens, the high leach rates were attributed to the presence of surface defects (e.g., microcracks) and alkali-rich residual glass.

Leach rates at 263 K, observed from weight loss measurements for vitreous A-series specimens, ranged from 6 to 13 $\mu g/cm^2 \cdot d$. For the

Soxhlet tests (3 days at 269 K), the leach rates ranged from 17 to 37 $\mu g/cm^2 \cdot d$.

4.2.2 Mechanical Behavior

4.2.2.1 Objective. The objective of this study was to develop techniques and equipment for determining the mechanical behavior of A-series specimens and to obtain some preliminary data in such areas as splitting tensile strength, fractometry, microindentation, vibration, and impact.

4.2.2.2 Achievements. Some preliminary results were obtained on A-series specimens. The tests developed include splitting tensile strengths, fractometry, microindentation, vibration, and impact on a lab scale impactor. The lab scale impact system consists of a free falling, but guided, projectile which impacts a punch that rests on a specimen housed in a sealed die arrangement. The energy capability of the impact system is 1000 J. Test methods and analyses are still being developed for the lab scale impacts.

The preliminary splitting tensile strengths and fracture toughness measurements showed comparable, respective values for the A-series specimens. Imperfections (e.g., voids and microcracks in the specimens) resulted in lower values for the two tests.

Microindentation tests produced microhardness values and assessment of the crack extensions from the indentations. For the A-series specimens, hardness values were about 700 Dph. Crack extensions were the greatest for specimens from the electromelt castings (partially devitrified) and did not show any dependence on composition. Crack extensions for vitreous A-series specimens were significantly less; however, a devitrified A-40 specimen, subject to controlled cooling from the melt, exhibits the lowest crack extension.

Vibration tests were performed on slow- and fast-cooled A-0 and A-40 melts cast into small, mild steel containers. The test parameters were 4 Hz and a 15.2 cm amplitude for duration of 40 and 50 hours. No discernible degradation to the castings could be attributed to the vibration tests.