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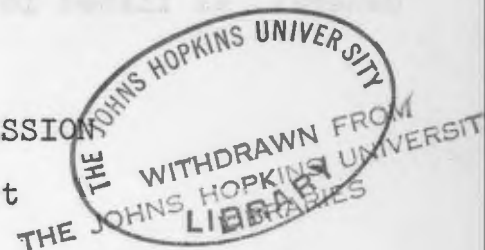
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Research and Development Report



SEMI-ANNUAL SUMMARY RESEARCH REPORT IN ENGINEERING

For July - December, 1957

by

Ames Laboratory Staff

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Ames Laboratory

at

Iowa State College

F..H..Spedding, Director

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SEMI-ANNUAL SUMMARY RESEARCH REPORT IN ENGINEERING

For the Period July - December, 1957

This report is prepared from material
submitted by group leaders of
the Laboratory

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ENGINEERING

Under the direction of F. H. Spedding, G. Burnet, R. W. Fahien, R. W. Fisher, G. Murphy, E. H. Olson, M. Smutz and D. R. Wilder.

Chemical Engineering1. Processing of Monazite Sands (M. Smutz)*

Research has been completed on developing an industrial process for recovering thorium, rare earths and uranium from monazite sands. The final process selected involves a digestion of the sand in hot concentrated sulfuric acid, dissolution of the digested mass in water, precipitation of the thorium and rare earths as oxalates, and removal of uranium by anion exchange. The oxalate ion can be recycled by digesting the oxalates with sodium hydroxide. The thorium and rare earth nitrates can be separated by conventional solvent extraction techniques. A complete description of this work and a cost comparison with other processes are given in ISC-947.

2. Separation of Individual Rare Earths by Solvent Extraction
(M. Smutz)

A 40-stage continuous countercurrent solvent extraction run was carried out using undiluted tributyl phosphate as the solvent. The aqueous phases were maintained at about 5.0N in nitric acid by pre-equilibrating the entering streams. The feed consisted of

*Names in parentheses indicate group leaders in charge of work.

Lindsay Chemical Co. Code 350 rare earth nitrates. The objective was to produce a raffinate product containing greater than 99 per cent lanthanum and cerium.

The extractor was operated for about 300 hours. The actual raffinate contained only about 98 per cent lanthanum and cerium. Failure to obtain a purer product was due to the fact that steady-state was not obtained and stage efficiencies were apparently lower than expected.

Prior to another continuous run, a 30- to 40-stage simulated column run will be made to verify that the calculated operating conditions will produce products of desired quality. The continuous mixer-settler extractor will be modified to permit more precise control of flow rates.

3. Prediction of Continuous Extractor Performance from Simulated Extraction Column Data (M. Smutz)

A paper entitled, "Prediction of Continuous Extractor Performance from Simulated Extraction Column Data" by M. Smutz has been submitted for publication in Ind. Eng. Chem.

ABSTRACT

Simulated continuous extraction experiments are frequently employed to obtain additional equilibrium data and to select operating conditions for process evaluation. Such a method requires only inexpensive laboratory apparatus and a minimum amount of feed, solvent and scrub solutions.

When properly carried out, data for predicting column design can also be obtained by determining the time required to approach equilibrium and time for phases to separate.

Various techniques can be employed in simulated column runs to minimize the time and laboratory manipulations necessary to approach steady state. The column can be preloaded by adding excess feed materials in the initial cycles. The movement of phases can be minimized by renumbering the extraction tubes after aqueous phases have been withdrawn. Checks on the accuracy of the analytical data can be made by comparing the plotted data with known flow rates and feed concentration.

A comparison of the results obtained from a simulated column run and a continuous run using a mixer-settler extractor are shown. The results show that the agreement is excellent if the stage efficiencies are high in the continuous run.

4. Bastnasite Processing (E. Olson)

The process developed for processing bastnasite is based on a nitric acid dissolution of the ground, ignited bastnasite ore followed by filtration to separate the dissolved rare earths from the insoluble residue. The rare earths were removed from the leach liquor filtrate using four co-current extraction stages with tributyl phosphate as the solvent. The combined extracts were

stripped twice with water to remove the calcium which was extracted along with the rare earths into the tributyl phosphate. The aqueous strip solutions containing calcium and some of the rare earths were recycled to the first co-current extraction stage for recovery of the rare earths. The stripped tributyl phosphate phase contained the pure rare earth nitrates. The aqueous raffinate solution from the fourth extraction stage which contained nitric acid, calcium nitrate and other soluble impurities was acidified with sulfuric acid to regenerate nitric acid from the calcium nitrate. The insoluble calcium sulfate was filtered and the filtrate fractionally distilled to recover the nitric acid which was recycled to the ore leaching step.

The optimum processing conditions were determined from small scale experiments and then demonstrated on a larger scale using 5000 grams of bastnasite ore. The over-all rare earth recovery by this method was found to be 99 per cent or greater. A cost estimate for the process is being prepared.

5. Oxidation of Cerium(III) to Cerium(IV) (E. Olson)

It was found that only 25 to 35 per cent of the cerium(III) could be oxidized to cerium(IV) in a reasonable length of time in a 14 to 15N nitric acid solution containing 0.15 to 0.20 moles of cerium per liter. This amount was too low to be of interest in developing a solvent extraction process for separating Ce(IV) from a rare earth nitrate mixture.

We are investigating an alternate method for separating cerium from a rare earth nitrate mixture by a controlled ignition whereby the cerium nitrate is selectively decomposed to the water insoluble ceric oxide. Ignitions of a 1:1 weight ratio of magnesium nitrate to rare earth nitrate mixture at 225, 250, and 275°C for 12 hours, 6 hours and 1 hour, respectively, have indicated that approximately 99.7 per cent of the cerium nitrate was decomposed to ceric oxide. In almost all cases the ceric oxide purity was greater than 99 per cent. In some cases the ceric oxide was found to contain less than 0.01 per cent Pr, 0.01 per cent Nd, and 0.01 per cent Sm.

The use of several other inorganic nitrate salts as replacements for the magnesium nitrate was investigated but sodium nitrate was the only one that resulted in complete decomposition of the cerium nitrate. Even though the use of sodium nitrate requires much longer ignition times, it is still being considered because of lower chemicals cost.

6. Molten Salts as Solvents in a Solvent Extraction Process

(E. Olson)

The purpose of this project is to determine the feasibility of using molten salts as solvents for the removal of metallic impurities from another metal.

The metal-salt system chosen for investigation was a 3 mole per cent magnesium in bismuth metal phase and a 46:54 mole ratio

of $\text{KCl}:\text{ZnCl}_2$ salt phase. According to thermodynamic calculations for free energy changes, the magnesium should react with the zinc chloride and be nearly quantitatively removed from the bismuth. The bismuth should be quite unreactive and the KCl should not react with any of the other materials present. The KCl was added in order to reduce the melting point of the salt phase.

Preliminary extraction runs have been carried out in glass equipment using the above described metal-salt system. In one stirred run, in which the molten magnesium-bismuth metal phase was dispersed into the salt phase continuously for one minute, the magnesium concentration in the bismuth was reduced from approximately 3000 to 15 ppm.

7. Separation of Liquid Metals by Fractional Distillation

(G. Burnet)

A falling-film type column fabricated of low-carbon steel was operated using the lead-bismuth system and batch differential type distillation with reflux. An enrichment equivalent to 4.5 theoretical plates was observed.

8. Uranium Recovery During the Manufacture of Wet Process Phosphoric Acid (G. Burnet)

Samples of raw material, process and waste streams from a commercial fertilizer plant using the Dorr-Oliver process were analyzed for uranium and a balance completed across the plant.

A standard fluorometric analytical method was employed. The Dorr-Oliver process employs a relatively high-temperature digestion of the phosphate rock which tends to increase the uranium losses occurring in this operation. This was confirmed by the analytical results which showed only 75 wt % of the available U in the product compared with 85 wt % for the previously reported Prayon process.

The uranium not appearing in the product acid was accounted for in various plant waste streams. In no instance was the concentration high enough to justify commercial recovery. Hence it was concluded that economical recovery of uranium was possible only from the product acid.

Solvent extraction using an octyl pyrophosphoric acid solvent and ion exchange using Dowex 1 resin are being investigated using run-of-the-plant acid. In each case basic design will be determined.

9. Liquid-Liquid Extraction in Pulse Columns (R. W. Fahien)

Continued progress has been made on the development of a method for the design of pulse liquid-liquid extraction columns. A method has been developed for the prediction of organic and aqueous compositions on each plate of the extractor for conditions following both upstrokes and downstrokes of the pulse generator when the column is operating in the mixer-settler region. By the use of defined stage efficiencies, this method has been extended to the emulsion region where effects of recycle are important.

Future work will be directed toward the simplification of the procedures involved and to the measurement of actual stage efficiencies for typical systems. If successful, the proposed method will permit the estimation of pulse column over-all extraction efficiency without extensive pilot plant testing.

10. Mass Transfer in a Packed Column (R. W. Fahien)

A paper entitled, "Mass Transfer at Low Flow Rates in a Packed Column" by V. P. Dorweiler and R. W. Fahien was submitted for publication in A.I.Ch.E. Journal.

ABSTRACT

Mass transfer in packed columns has been investigated recently for a variety of column and packing sizes, but at flow rates restricted to fully developed turbulent conditions. The present work was undertaken to investigate mass transfer at flow rates for which the conditions of flow could be described as being in the transition and laminar regions.

A dual treatment of experimental data required a knowledge of the variation of concentration and velocity with radial position. A tracer-injection technique was employed which consisted of the introduction of a tracer gas into the center of a bulk gas stream and the measurement of the tracer gas concentration at various radial positions downstream. The velocity distribution for the packed column was determined by means of a five-loop, circular hot-wire anemometer. The

test column was a vertical 4-inch pipe, packed with 1/4-inch spherical, ceramic catalyst support pellets.

Mass transfer diffusivity and Peclet number were determined from two solutions of the differential diffusion equation applied in previous investigations. An analytical solution in terms of Bessel functions was used to calculate values of average diffusivity and Peclet number. A semi-numerical solution in terms of homogeneous linear difference equations was used to calculate values of point diffusivity and Peclet number.

Variation of diffusivity and Peclet number with radial position are shown. Average diffusivity and Peclet number are correlated with Reynolds number. The interaction of molecular and eddy mass transfer mechanisms with decreasing mass velocity is illustrated by defining a "molecular" and "eddy" Peclet number and correlating with Reynolds number. Eddy diffusivity is defined as a function of local flow conditions, and is expressed empirically by the relation

$$E_k = D_M + 7.80 u_k^{1.12} (1 + e^{1.7} - 2e^{3.4}).$$

Nuclear Engineering

1. Slurry Program (G. Murphy)

In an investigation of the head loss encountered in aqueous suspensions of fine spherical glass particles flowing in a vertical

tube, it was observed that in a certain velocity range the solid particles moved toward the center of the tube for upward flow and toward the walls of the tube for downward flow. For upward flow an annulus of clear fluid was easily distinguishable surrounding a core of solid and fluid. It appeared that the "coring" effect was most pronounced near the transition between laminar and turbulent flow, and as the velocity was increased or decreased from the transition velocity the non-uniform distribution of particles began to disappear.

The effect of this phenomenon was also indicated in the head loss measurements. Near the transition region where the coring begins to appear, the head loss for downward flow is higher than for upward flow. The purpose of this study was to determine the reason for the non-uniform distribution of solid and to explain some of the observed effects.

An analysis was made of the forces acting on a spherical particle placed in shear flow. It was shown that the particle will experience a force normal to the main direction of flow of magnitude

$$F = C_L \rho_f A^3 U k$$

where

C_L = unknown coefficient

ρ_f = density of the fluid

A = radius of the sphere

U = constant component of free-stream velocity

k = velocity gradient of free-stream.

Utilization of this expression for the lateral force led to the conclusions that:

(1) For upward flow with $\rho_s > \rho_f$ (ρ_s = density of solid) the particle will move toward the region of higher velocity, whereas for $\rho_s < \rho_f$ the particle will move toward the region of lower velocity.

(2) For downward flow with $\rho_s > \rho_f$ the particle will move toward the region of lower velocity, whereas for $\rho_s < \rho_f$ the particle will move toward the region of higher velocity.

These predicted results were observed experimentally.

An equation was derived for the pressure drop in upward laminar flow with coring. It was shown that the stable configuration for the flowing suspension occurred when the pressure drop per foot was equal to the specific weight of the mixture in the core. The theoretical values for head loss compared satisfactorily with the experimental data.

Two other significant conclusions were drawn from the theoretical study.

(1) The mean concentration in the pipe is less than the measured concentration for flow in which coring is present.

(2) The thickness of the annulus of clear fluid increases as the velocity is increased for a given concentration, and the thickness decreases as the concentration is increased for a given velocity (in the laminar range).

The investigation for downward laminar flow and for flow in the turbulent range is being continued.

Consideration has been given to obtaining some additional design parameters necessary for a feasibility study of a slurry reactor. Both radioisotope and ultrasonic procedures have been employed in obtaining more detailed information regarding the distribution of solids in a slurry flowing through a vertical pipe.

A report (ISC-874) entitled "Flow of an Aqueous Slurry Through a Vertical Tube" by Harold E. Wolfe and Glenn Murphy is being distributed.

ABSTRACT

The upward vertical flow of a slurry was investigated utilizing photographic techniques with the intention of obtaining data on solid phase concentration and velocity distribution and to evaluate the use of photography as a tool in slurry analysis.

An analytical expression for the ratio of the specific weight of the mixture in the tube to the specific weight of the mixture discharged was derived and used to verify certain assumptions indicated in the photographic study.

2. Engineering Properties of Materials (G. Murphy)

A technique of fabricating test specimens and containers for fatigue tests of uranium and its alloys at elevated temperatures

has been developed satisfactorily. An extensive test program is now under way at temperatures up to 600°C.

The equipment for conducting high temperature tests of materials that must be protected at elevated temperatures has been assembled and is being calibrated. Good linearity and hysteresis of the strain-measuring device have been obtained.

Both short-time and long-time creep tests on uranium and on tantalum were conducted during the period. Values of the activation energy for uranium have been obtained from the creep data and these are being studied in an attempt to determine an additional creep parameter. Dimensional considerations indicate that there must exist at least one additional parameter that controls creep rates at various temperatures and stresses.

A report (ISC-839) entitled "Thermal Stress Analysis of a Cylinder of Semi-Plastic Material" by Donald Hunter and Glenn Murphy was distributed.

ABSTRACT

A solution is derived for the thermal stresses in a finite cylindrical solid composed of a material for which the modulus of elasticity decreases linearly with an increase in temperature. The cylinder is assumed to contain a distributed heat source that is radially symmetrical. The solution is applied to evaluate the stresses in a cylindrical uranium fuel slug in which heat is produced by fission. The results are compared with those obtained from a plane strain solution.

3. Molten Metal Experiments (R. W. Fisher)

3.1 Uranium-Chromium in Yttrium

Most of the emphasis during this period has been on the study of the uranium-chromium eutectic in yttrium. Three successful runs were completed: No. 1 for 550 hours at 900°C (static), No. 2 for 1000 hours at 900°C (static), and No. 3 for 1000 hours at 925°C (rocker test). At the conclusion of the various runs the test crucibles were cooled and dissected for study. Examination by photomicrographic techniques showed no attack at the interface.

Yttrium oxidizes very severely at elevated temperatures and must be protected. In order to use yttrium as a container material for the uranium-chromium eutectic it was necessary to find some other material or alloy which would serve as a satisfactory envelope for the yttrium system. The first test run with inconel failed after 60 hours at 1000°C. This test showed that nickel dissolves very readily in yttrium and that alloys containing nickel probably could not be used as an outer sheath for yttrium. To confirm this, various samples of 18-8 stainless steel, Types 304, 316 and 347, were tested. At the end of 48 hours, at temperatures of 1050°C, all of the samples showed appreciable attack and some had failed completely.

A literature survey was made to determine various non-nickel-containing alloys which were oxygen resistant at high temperatures. AISI 446 stainless steel is one of the few alloys meeting the

requirements. Tests were run on both AISI 446 and the regular 446 to determine if a small amount of nickel could be tolerated. The regular 446 contains less than 1% nickel but was considerably attacked at the end of 100 hours. A test using the AISI 446 operated for over 1000 hours at 925°C at which time it was dismantled for analysis. Close examination showed negligible attack and a second test is underway to confirm these results. Preliminary tests show that titanium may be a possible protective material for yttrium.

3.2 Uranium-Bismuth in Niobium

A uranium-bismuth alloy in niobium and pure bismuth in niobium were also tested during this period. Both of these tests failed in less than 100 hours at a temperature of 800°C.

3.3 Uranium-Bismuth in Yttrium

Yttrium was also tested as a container material for the 5% uranium-95% bismuth alloy. After a period of 1100 hours at a temperature of 900°C, a 35 mil attack was noted. It was concluded that yttrium would not be a satisfactory container for this fuel.

3.4 Aluminum-Thorium-Uranium Tests

Aluminum-thorium-uranium eutectic with a melting point at 630°C was tested in a tantalum container which failed after 96 hours at a temperature of 1000°C. This same eutectic was tested in yttrium for 1100 hours at 700°C. At the conclusion of the second test the yttrium container was cut open and photomicrographed.

The walls of the yttrium container were wet by the thorium in the eutectic, but only a small amount of corrosion was noted. A second test has now been in progress for 1346 hours at a temperature of 800°C. A non-destructive radiographic analysis indicates that the yttrium has not failed.

Ceramic Engineering

1. Sintering Phenomena (D. R. Wilder)

The purpose of this investigation is to examine and explain the sintering phenomena observed in ceramic refractories. The oxides are currently being examined, particularly aluminum oxide.

The sintering characteristics of aluminum oxide observed in the temperature range 200° to 1000°C have been found to be closely related to the decomposition of a loosely held surface layer of pseudo-gibbsite which develops on the surface of the otherwise alpha alumina (Corundum). Decomposition temperatures at which this layer changes to alpha alumina have been found to vary reproducibly with the history and the original method of production of the parent oxide. As soon as this layer decomposes, actual cation-anion sintering may begin between the grains. This initiation of sintering accounts for the abrupt loss in slaking characteristics observed in aluminum oxide powders heated to relatively low temperatures. The surface charge, and the change thereof upon heating, grinding, or acid leaching, may be explained by consideration of the above decomposition.

2. Effect of Calcium Fluoride Additions on Magnesium Oxide

(D. R. Wilder)

This study is concerned with addition of calcium fluoride to refractory grades of magnesium oxide, and the observation of the influence of such additives on the refractory properties and sintering characteristics.

A furnace and loading device have been constructed to evaluate cross-bending strength at elevated temperatures. Tests are in progress from 25° to 1450°C on specimens previously sintered under various atmospheres and containing various amounts of calcium fluoride.

A report (ISC-910) entitled "Effect of Calcium Fluoride Additions on the Sintering of Magnesium Oxide" by F. W. Calderwood and D. R. Wilder is being distributed.

ABSTRACT

The effect of additions of calcium fluoride on the sintering of a refractory grade magnesium oxide fired under reducing conditions was studied. Specimens were formed at very low pressures to simulate compaction achieved in the jolt pack technique, and at higher pressures commonly encountered in powder-pressing of ware. Specimens were fired in an induction furnace and held for pre-determined periods at temperatures ranging from 1300°C to 1900°C. Shrinkage, bulk density, and grain-growth factor were determined and are presented as functions of composition and temperature.

Specimens formed with the minimum compaction were found to increase in shrinkage and density with increase of calcium fluoride additive, no maxima occurring over the range 0% to 12 mole %. Specimens formed at higher pressures were found to have maximum density, shrinkage and grain-growth when four mole % calcium fluoride was added. With larger amounts of this additive, bloating occurred, counteracting the sintering forces that tend to consolidate the mass. This mechanism is believed to be a liquid phase formed above a binary eutectic temperature, rather than a solid state reaction. No solid solution or compound formation was found to exist.

3. Oxidation of Ceramic Refractories (D. R. Wilder)

A long range program of investigation into the oxidation behavior of ceramic refractories has been initiated. This study will be concerned both with the tendency of some oxide refractories to gain or lose oxygen while some refractories tend to form oxides and thereby decrease in high temperature utility.

A system for thermogravimetric analysis has been designed and constructed which will permit determination of loss or gain of weight in air at temperatures from 25°C to 1500°C. The apparatus has been fully tested, can accommodate specimens as large as 30 g., and has been found to be sensitive to changes of less than 2 mg. A closed circuit control is employed, giving a continuous record and highly reproducible results.

Study of oxidation phenomena to date has included the UO_2 to U_3O_8 change, and methods to prevent or greatly retard this oxidation.

The oxidation characteristics of molybdenum disilicide have also been examined. With high purity silicide synthesized by reaction of molybdenum and silicon at 1650°C under helium, a gain in weight is observed at about 400°C when heated in air. This gain is followed by a loss at about 700°C , thought to be due to volatilization of the oxides formed. A complete study of the mechanism involved is in progress.

APPENDIX I: LIST OF REPORTS FROM THE AMES LABORATORY

1. Reports for Cooperating Laboratories

- ISC-766 L. L. Knapp, M. Smutz and F. H. Spedding. Solvent Extraction Equilibria for Rare Earth Nitrate-Tributyl Phosphate Systems.
- ISC-781 R. E. Bisque and C. V. Banks. Spectrophotometric Determination of Zinc and Other Metals with α , β , γ , δ -Tetra-phenylporphine.
- ISC-796 J. A. Pierret and H. A. Wilhelm. Caustic Fusion of Columbite-Tantalite Concentrates with Subsequent Separation of Niobium and Tantalum.
- ISC-832 G. E. Bobeck and H. A. Wilhelm. Alloys of Aluminum, Thorium and Uranium.
- ISC-834 Ames Laboratory Staff. Chemistry. Semi-Annual Summary Research Report. July-December, 1956.
- ISC-835 Ames Laboratory Staff. Metallurgy. Semi-Annual Summary Research Report. July-December, 1956.
- ISC-836 Ames Laboratory Staff. Engineering. Semi-Annual Summary Research Report. July-December, 1956.
- ISC-837 Compiled by P. Chiotti. Hanford Slug Program. Semi-Annual Summary Research Report. July-December, 1956.
- ISC-839 Donald Hunter and Glenn Murphy. Thermal Stress Analysis of a Cylinder of Semi-Plastic Material.
- ISC-874 H. E. Wolfe and Glenn Murphy. Flow of an Aqueous Slurry Through a Vertical Tube.
- ISC-893 H. H. Klepfer and P. Chiotti. Characteristics of the Solid State Transformations in Uranium.
- ISC-899 R. W. Vest, M. Griffel and J. F. Smith. Electronic Specific Heat of Sodium Tungsten Bronze.
- ISC-901 Ames Laboratory Staff. Physics. Semi-Annual Summary Research Report. January-June, 1957.
- ISC-904 Ames Laboratory Staff. Engineering. Semi-Annual Summary Research Report. January-June, 1957.
- ISC-905 Compiled by P. Chiotti. Hanford Slug Program. Semi-Annual Summary Research Report. January-June, 1957.

- ISC-906 H. H. Klepfer, H. E. Shoemaker, J. D. Greiner, M. L. Moller and J. F. Smith. Tabulation, Bibliography, and Structure of Binary Intermetallic Compounds. III. Compounds of Copper, Silver and Gold.
- ISC-908 J. E. Frandolig and R. W. Fahien. Mass Transfer in Low Velocity Gas Streams.

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APPENDIX II: LIST OF SHIPMENTS

<u>Destination</u>	<u>Item</u>
University of Arizona Tucson, Arizona	11 gm praseodymium oxide 11 gm neodymium oxide 11 gm samarium oxide 11 gm lanthanum oxide 11 gm cerium oxide 11 gm gadolinium oxide 1 gm yttrium oxide 11 gm dysprosium oxide 11 gm holmium oxide 11 gm erbium oxide 11 gm ytterbium oxide 1 gm thulium oxide 1 gm lutetium oxide 1 gm terbium oxide
H. A. Schimming University of Wisconsin Madison, Wisconsin	50 gm cerium metal
University of California Los Alamos Scientific Laboratory Los Alamos, New Mexico	20 gm terbium metal 100 gm terbium oxide
Argonne National Laboratory Lemont, Illinois	Special discs (1 each) of cerium, neodymium and gadolinium metals
University of Denver Denver, Colorado	50 gm praseodymium metal
Purdue University Lafayette, Indiana	25 gm praseodymium oxide
Dr. James L. Kassner University of Alabama University, Alabama	2 samples of special reagent (1 gm each)
University of California Radiation Laboratory Livermore, California	1 disc each of gadolinium and erbium metals 4.82 gm dysprosium metal 3.63 gm ytterbium metal 4.31 gm holmium metal 4.21 gm terbium metal
Mrs. Mary E. White High Voltage Laboratory Cambridge 39, Massachusetts	100 mg scandium metal

<u>Destination</u>	<u>Item</u>
Bell Telephone Laboratories Murray Hill, New Jersey	2 lb dysprosium metal 2 lb neodymium metal 4.683 gm scandium metal
Dr. Joseph G. Graca Iowa State College Ames, Iowa	200 cc lutetium chloride solution 200 cc of each of the following rare earth solutions in ethylene- diaminetetraacetic acid (equivalent to 5% chloride): lanthanum gadolinium praseodymium samarium
Lincoln Laboratory Lexington, Massachusetts	100 gm yttrium oxide 100 gm samarium oxide
Physics Department Georgetown University Washington, D. C.	1 gm yttrium metal
Huffman Microanalytical Laboratory Wheatridge, Colorado	5 gm special hafnium oxide
Mr. Arnold Gahler Metals Research Laboratories Niagara Falls, New York	3 samples yttrium fluoride
Dr. Frank Benner National Research Corporation Cambridge, Massachusetts	2 samples of niobium metal 4 samples of yttrium metal
State University of Iowa Iowa City, Iowa	10 gm terbium oxide 50 gm praseodymium oxide 2 gm special N ¹⁵ sample
Dr. Henry J. Gomberg Phoenix Memorial Laboratory University of Michigan Ann Arbor, Michigan	2 gm holmium metal 2 gm erbium metal 2 gm thulium metal 2 gm ytterbium
Union Carbide Nuclear Company Oak Ridge, Tennessee	50 gm cerium metal
Carnegie Institute of Technology Pittsburgh, Pennsylvania	4 gm cerium metal 4 gm praseodymium metal
Physikalisches Institut der Technischen Hochschule Munich, Germany	2 gm praseodymium metal 2 gm samarium metal

<u>Destination</u>	<u>Item</u>
General Electric Co.	1 lb praseodymium metal
Cincinnati, Ohio	1 lb erbium metal
	1 lb neodymium metal
	1 lb ytterbium metal
	1 lb dysprosium metal