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Production of Aluminum-Silicon Alloy and Ferrosilicon and Commercial Purity Aluminum by the Direct Reduction Process

CONS-5089-4

UNCLASSIFIED

UC-95f

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ALCOA

Work Preformed Under
Contract EC-77-C-01-5089

First Annual Technical Report
for the Period 1977 September 01 -
1978 August 31

1978 September

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PRODUCTION OF ALUMINUM-SILICON ALLOY AND FERROSILICON AND COMMERCIAL PURITY ALUMINUM BY THE DIRECT REDUCTION PROCESS

FIRST ANNUAL TECHNICAL REPORT
FOR PERIOD 1977 SEPTEMBER 01 - 1978 AUGUST 31

MARSHALL J. BRUNO

SEPTEMBER 1978

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ALUMINUM COMPANY OF AMERICA
ALCOA LABORATORIES
ALCOA CENTER, PA 15069

PREPARED FOR THE
DEPARTMENT OF ENERGY
OFFICE OF THE ASSISTANT SECRETARY FOR
CONSERVATION AND SOLAR APPLICATIONS
DIVISION OF INDUSTRIAL ENERGY CONSERVATION
UNDER CONTRACT EC-77-C-01-5089

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FORWARD

This is the first annual technical report submitted in accordance with the requirements of Contract No. EC-77-C-01-5089, a three-year cost sharing agreement between the Department of Energy and Alcoa. The report describes work performed in the first year of the program.

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ABSTRACT

Phase A of a three year cost sharing contract between the Department of Energy and Alcoa was started on 1977-08-31. At the end of Phase A the program for Phase A is 97% complete with 80% of the funding expended.

Thermodynamic calculations predicted high metal yields for carbothermic reduction of alumino-silicate ores in a refluxing type vertical shaft reactor. Operation of externally heated bench scale reactors established a three stage reaction mechanism for producing Al-Si alloy in a temperature range of 1500° to 2100°C and indicated that a SiO_2 to Al_2O_3 weight ratio of 0.5 to 1.1 resulted in optimum alloy formation. The effects of impurities on alloy yield including Fe_2O_3, TiO_2, Na_2O and S were determined. Fe_2O_3 increased yield and lowered the third stage temperature. The effects of temperature and heat input rate on reaction kinetics were empirically determined. Also, a computer program was formulated for mathematical modeling of carbothermic reduction kinetics. Analytical procedures and sample preparation techniques were developed for reduction product analyses. Burden preparation methods were established for various ore-coke formulations. High strength agglomerates were made by extrusion, ball forming and briquetting. Self-heated crucible type bench reactors were constructed and operated to evaluate oxygen injection through water cooled tuyeres, raceway formation in the combustion zone and solids charging techniques to avoid bridging. A vertical shaft self-heated pilot reactor was designed and constructed. Preliminary design of a larger, demonstration size reactor was also completed.

Reduction of Si to 15% in simulated reactor product was demonstrated in both a bench scale fractional crystallization unit and an existing pilot crystallizer. Productivity and recovery data for Al-Si alloy refining was also established in the pilot unit. The effects of Fe and Ti impurities on alloy refining were determined. A high temperature bench scale unit was designed, built and operated to study impure alloy concentrations having high liquidus temperatures. Designs were completed for a multipurpose high temperature induction furnace and the pilot crystallizer specific to carbothermic reduction products.

Bench scale tests on purification to commercial grade Al resulted in a product purity of 99.9% and operating efficiencies of 92 to 98% when processing Al-Si-Fe, Al-Si-Ti and Al-Si-Fe-Ti alloys. Compositions of intermetallic compounds in the residue phase were identified. Long term operation was accomplished in a large scale bench unit to evaluate critical materials of construction. The pilot purifier was designed.

Primary activities for the first quarter of Phase B include the following: the vertical shaft pilot reactor installation will be completed and the unit started up; evaluation of process variables will be initiated; externally heated bench reactor operation will continue, using oxygen to evaluate materials of construction and various burden formulations under realistic conditions; development of the computer model for reaction kinetics will continue; design details for the pilot crystallizer will be finalized and component hardware ordered; crystallizer and multipurpose furnace site preparation will be completed; design details for the commercial purity Al unit will proceed; materials testing in long term runs will be continued.

DISCUSSION

The primary objective of the three year program is to demonstrate technical feasibility of a pilot sized direct reduction process for producing aluminum and aluminum-silicon alloy. The process includes three major tasks, reduction to produce impure alloy, alloy purification and purification to commercial grade aluminum. Goals for the first year are to establish the effects of process operating and design variables in bench scale units, to design the three main pilot units plus auxiliary equipment, and to prepare the sites for installation of the pilot units.

Throughout Phase A Alcoa was assisted by three subcontractors on the Reduction task, Koppers Company, Inc., Carnegie-Mellon University and Professor Julian Szekely.

Koppers consulted on a number of thermochemical calculations and bench scale reactor hardware designs. In addition, Koppers made a preliminary design of a demonstration scale reduction reactor including process flow sheet, material balance, plan and elevation drawings, equipment specifications and a cost estimate for preparing complete detailed designs and specifications.

Carnegie-Mellon initiated a project to determine the phase equilibria of the Al-Si-O-C system. To date CMU has procured equipment and nearly completed machining work required to install a high temperature carbon furnace necessary for accomplishing the proposed equilibria studies. Preliminary experiments are underway in a small induction heated furnace to evaluate candidate materials for use at high temperatures without deteriorating or contaminating the test charge.

Professor Szekely consulted for 15 days on various aspects of the Reduction tasks, with emphasis on guiding Alcoa's development of a mathematical model for reaction kinetics.

It is planned to retain the same subcontractors for Phase B.

The multi-coil 100 KVA induction heating system was received at the end of Phase A, approximately 6 weeks late due to a strike at the Ajax Magnethermic Corporation plant. Installation was begun immediately with a goal of completion by mid October, halfway through the first quarter of Phase B.

Progress on the three major tasks of the contract was reported to the Department of Energy Project Manager and Technical Advisor on 1978-07-27.

Progress for the three main tasks is reported by sub-task as identified in the work statement. All sub-tasks for Phase A have been completed except for sub-task no. 10, Reduction, titled "Optimize Yields in Self-Heated Reactor". This sub-task is 30% complete. Therefore, the Reduction task is 94% complete, Alloy Purification 100% complete, and Purification to Commercial Grade Aluminum 100% complete at the end of Phase A. Sub-task no. 10 will be extended to and accomplished under Phase B, sub-task no. 9 under Reduction, titled "Effects of VSR Operating Parameters".

PROGRESS

A. REDUCTION - PHASE I

Task No. 1: Review Literature

Literature surveys were completed and references were reviewed. Twenty-four important references were previously listed, 15 in the First Quarterly Report (1), 6 in the Second Quarterly (2), and 3 in the Third Quarterly (3). The following references are included:

25. E.A. Gulbransen and S.A. Jansson: Oxidation of Metals 4 (1972) 181-201.

26. R.L. Stephenson: Alkalies in Blast Furnaces, McMaster University, Hamilton, Ontario (1973) 3-1 to 3-14.

27. L. Krol and J. Dankemey-Laczny: Alkalies in Blast Furnaces, McMaster University, Hamilton, Ontario (1973) 5-1 to 5-5.

This task is complete.

Task No. 2: Calculate Heat and Mass Balance

This task was revised to include expansion of the computer program data base. An equilibrium, multiphase heat and mass balance process model was developed using NASA program CEP as a basis. The model predicted complete conversion of alumina-silica-carbon feed to aluminum-silicon alloy and carbon monoxide in a refluxing type vertical shaft reactor through several stages of chemical reactions over a temperature range of 1550 to 2368°K.

The computer program was revised to include SOLGASMIX, capable of considering solution interactions. The program was further refined to include thermal efficiencies, sensible heats, heat losses, impurities in the ores and coke, the effects of CO/CO_2 ratio in the exit gas and the effects of pressure on conversion. System variables such as preheated oxygen feed and CO decomposition to CO_2 and C in the shaft top section were evaluated.

Mass and energy balances were calculated for real ores by utilizing experimental results and computer predictions. The overall material balance predicted metal, slag and gas compositions. The energy balance calculations were used to construct an energy flow diagram for the process.

The data base has been improved by replacing estimated thermochemical data for several compounds with new published values, resulting in better agreement between computer predictions and experimental observations.

In a separate study, stage-by-stage heat and mass balances plus temperature profile and pressure differential calculations were completed for a conceptual demonstration reactor. The most critical areas were the high temperature combustion zones at the oxygen inlet locations and the shaft top section where the potential exothermic reaction of CO to CO_2 could occur.

This task is complete.

Task No. 3: Design and Build Externally Heated Reactor

Two externally heated batch reactors were designed and built. Heat was supplied by a 30 KVA, 10,000 cycle induction motor generator with water cooled copper coils. Reaction temperatures were measured with an optical pyrometer. Reaction gases were monitored for flow rate and percent CO.

This task is complete.

Task No. 4: Supply Ores for Bench Reactors

The main criteria for evaluation of feed to the reactor was established. Included are agglomerate size, compressive strength, abrasion resistance and reactivity. Binderless agglomerates were produced from several different mixtures of bauxite, clay and metallurgical coke using three methods, briquetting, extrusion and ball forming. Fired agglomerates were evaluated. The effects of firing conditions on agglomerate strength were determined. Briquetting produced the strongest agglomerates; ball forming the lowest strength. Extrusions maintained integrity up to 1800°C under reducing conditions.

The system bauxite, clay and caking coal was also studied. The effects of particle size and formulation on agglomerate strength and apparent density were determined. Mixtures involving coal were tested as briquettes, balls and "loose charge" agglomeration. Grinding and calcining characteristics were defined. Heat capacities of several bauxites and clay were calculated for use in heat balance determinations.

Burden materials of various formulations were prepared for use in the externally heated and crucible type reactors throughout the phase.

This task is complete.

Task No. 5: Yield Data and Reduction Mechanism in Externally Heated Reactor

This task was revised to include yield data on pure oxides and ores and to establish reduction reaction mechanisms.

Optimization of yields was moved to Tasks 9 and 10 as part of the self-heated reactor program.

A number of runs were made with pure oxides using CO sweep gas to determine the effects of volatility losses and feed charge ratio on product yield. Interrupted runs were also made at various temperatures and retention times to study formation of intermediate compounds and establish reaction mechanism. Test results were compared with predicted mechanisms from computer models. Previously proposed reaction stages were either substantiated or revised. It was found that heat input rate had an effect on the final product made.

A series of runs were conducted to determine the effects of various impurities on the yield and product composition. Iron oxide improved yield and lowered the final reaction stage temperature from 2360°K to 2220°K. Titanium from TiO_2 appeared as a complex Al-Si-Ti solution in the product. Sulfur was detected in all of the reactor output streams. Alkalies were found to concentrate in the cooler portions of the reactor.

Runs made in reactors compartmented by multiple plates demonstrated the location-temperature relationship for various reactions throughout the burden charge, including condensed phases which supports the possibility of operating a refluxing reactor.

This task is complete.

Task No. 6: Develop Analyses and Properties of Critical Compounds

A complex 7-step "wet" analytical procedure was developed to determine Al, Si, C, Al_4C_3, SiC and Al_4SiC_4 in reaction product samples. The procedure was outlined in the First Quarterly Report (1). Development of sample preparation methods was necessary to obtain consistent results from the wet analytical procedure. X-ray diffraction has been used to qualitatively identify phases. Neutron Activation was employed to determine total oxygen. Microprobe checks indicated the presence of elements. Addition of point count analyses following microprobe identification has provided quantitative elemental analyses for the phases. This approach agrees well with the results from the analytical procedure.

Further studies were supported to determine the feasibility of applying Neutron Activation Analysis (NAA) to direct reduction products. It was concluded that routine NAA is useful, primarily for Al, Si, Fe and O. Test results compared favorably with those by wet chemistry. The advantages of NAA include simplified sample preparation and speed of analysis.

Samples of Al_4SiC_4 were synthesized and submitted to several outside testing laboratories to determine thermochemical properties such as heat capacity and heat of formation.

This task is complete.

Task No. 7: Establish Kinetics of Reactions

A series of kinetic experiments were run to determine the effects of heat input rate and temperature for each stage of reaction. Reaction rates for the high temperature reactions increased linearly with heat input rate. Mathematical modeling of kinetics for the predicted reaction mechanism was initiated. A series of rate equations were formulated; an algorithm was selected to simultaneously solve the equations. The computer program was tested on a number of hypothetical situations.

This task is complete.

Task No. 8: Evaluate Materials of Construction

Screening tests were run on a number of candidate materials. Samples were exposed to CO gas in the presence of coke at temperatures up to 2200°C. Samples were evaluated by comparing weight and dimensions of specimens before and after testing. In the reducing atmosphere carbides were best (TaC, TiC, ZrC), followed by TiB_2. Oxides were least promising (ZrO_2, ThO_2, MgO). In several tests involving oxidation resistance, such as oxygen entry pipes, ZrO_2 and Al_2O_3 showed limited capabilities. Oxygen entry pipes required water cooling to eliminate attack of the hot ends. Graphite and SiC have been adequate materials for bench scale reactors above the combustion zone. Blanket type insulating materials were also evaluated, including graphite and carbon felt, Fiberfrax and Cerablanket.

This task is complete.

Task No. 9: Design and Build Self-Heated Reactor

The self-heated bench scale reactor was designed utilizing SiC crucibles inside a gas-fired furnace which provided start-up heat and reduced unit heat losses. Reactor component parts were made from SiC and graphite. The reactor system included the following: water cooled metal tuyeres for oxygen injection to the combustion zone; a charging lock type solids feed entry capable of handling coke or ore particles up to +4 mesh -3/8 inch; an off gas handling train consisting of a water cooled dust collector, hot bag filter, orifice for gas flow rate measurement, sampling ports, flare and exchange ducting; remote automatic/emergency shutdown systems; sight ports and "black body" closed end tubes for pyrometric determination of process temperatures at various locations. Later modifications included an inner "sacrificial" graphite liner to protect the main crucible wall from attack by unburned oxygen and a double crucible assembly with insulation in the annulus to further reduce heat losses. In the last quarter a stockline level probe was incorporated to offset formation of solids bridging in the colder zones of the reactor.

This task is complete.

Task No. 10: Optimize Yields in Self-Heated Reactor

The crucible-type self-heated reactor was operated initially to determine the coke oxidation rate at reaction temperatures. Both metallurgical and petroleum coke were burned. Bridging difficulties were experienced with metallurgical coke due to condensation of reaction products formed from ash constituents. After developing successful water cooled oxygen entries raceway formation was studied. Data indicated a relationship between the oxygen nozzle diameter and the coke particle size on forming the raceway. Raceway flow patterns were defined by the condition of graphite rods set in the grate along tuyere centerlines, and by probing through the nozzles with tungsten rods.

Agglomerated ore materials were charged in a number of runs. Initially the agglomerates were dumped directly into the coke mass. Evidence of first stage reaction was found at a temperature of 1785°C. At 1875°C a small pool of coalesced metal was collected under the grate. In the fourth quarter ore materials were charged into closed end graphite tubes immersed in the hot coke bed to expose the burden to reaction temperatures while eliminating mixture with the combustion coke. Control of the raceway by selective coke particle size and oxygen flow rate averted attack of the graphite tubes. Coalesced metal product was made in a number of runs. Temperatures of reactions were difficult to measure. Also, extreme temperature gradients between the crucible reactor walls and the flame zone deterred accurate interpretation of the extent of reaction. Uniformly heated walls for the pilot reactor should significantly improve reaction zone temperature control.

During the first phase it was determined that the crucible-type self-heated reactors would not produce optimum yields of Al-Si alloy due to lack of proper retention time and reaction staging required to attain reflux and minimize product volatilization losses. Therefore, optimization is to be demonstrated in the pilot vertical shaft reactor scheduled for operation in Phase II as part of Reduction Task No. 9 titled "Effects of VSR Operating Parameters".

This task is 30% complete.

Task No. 11: Design Pilot Reactor

A vertical shaft reactor was designed with an external multi-coil induction heating system to balance heat losses and provide start-up heat prior to oxygen injection. The reactor was designed for continuous operation with separate solids feed systems for coke and ore agglomerates, multiple tuyere oxygen injection, off gas handling equipment, metal product collection hearth, instrumentation and control including emergency shutdown, and safety features such as a Plexiglas enclosure, rupture discs and CO monitor.

A preliminary design of a larger reactor was also completed including process flow diagram, plan and elevation drawings, equipment specifications and rough cost estimates for detailed design.

This task is complete.

Task No. 12: Design Raw Materials Supply System

Preliminary process flow sheets were developed for burden preparation relating to the larger reactor. The raw materials supply system for the pilot reactor was designed.

This task is complete.

Task No. 13: Design Off Gas System

The off gas system was designed for both the larger reactor and the pilot unit.

This task is complete.

Task No. 14: Design Product Removal System

The product removal system was designed for both the larger reactor and the pilot unit.

This task is complete.

Task No. 15: Prepare Site

The site was selected and prepared for the vertical shaft pilot reactor including support platform, work platforms, jib crane, drains and utility headers for natural gas, compressed air, water, nitrogen, oxygen and electricity.

This task is complete.

Task No. 16: Procure Hardware and Materials

Purchased items for the pilot reactor are either on order or have been received.

This task is complete.

A. Alloy Purification - Phase I

Task No. 1: Review Literature

Literature surveys were completed and references were reviewed. Seventeen important references were listed, 6 in the First Quarterly Report (1) and 11 in the Third Quarterly Report (3).

This task is complete.

Task No. 2: Build Apparatus for Measuring Melt Properties

No work was required since all properties required were either found in literature or determined empirically from operation of the bench and pilot crystallizers.

This task is complete.

Task No. 3: Obtain Melt Properties

Densities, surface tensions, viscosities, electrical resistivities and thermodynamic data were obtained for alloys in the system Al-Si-Fe-Ti. The properties were found both as a function of temperature and composition.

This task is complete.

Task No. 4: Build Apparatus for Measuring Crystal Properties

No work was required since the properties required were obtained from literature.

This task is complete.

Task No. 5: Obtain Crystal Properties

Densities and thermal conductivities were obtained for crystals in the system Al-Si-Fe.

This task is complete.

Task No. 6: Build Bench Scale Crystallizer

Two bench scale units were built. The first unit incorporated globar heating elements inserted in a graphite block under the crucible portion of the crystallizer, and was trunion mounted to facilitate melt removal by tilt draining. Melt temperatures up to 980°C were attainable. Refer to Figure 2, First Quarterly Report (1). The second unit was built to provide melt temperatures up to 1500°C. Molten metal was removed through a bottom taphole, eliminating the tilt pour operation used in the first unit. The unit is adaptable for all alloy refining operations including alloy make-up, crystallization and remelt.

This task is complete.

Task No. 7: Operate Bench Scale Crystallizer

The bench scale crystallizers were operated on synthetically produced alloys of Al-Si, Al-Si-Fe, Al-Si-Ti and Al-Si-Fe-Ti to develop techniques for reducing Si, Fe and Ti. The theoretical removal of Si is illustrated by the binary Al-Si phase diagram [Figure 3, First Quarterly Report (1)]. In the process, the Al-Si alloy product is removed as a eutectic liquid. The Si and intermetallics are removed as crystals. For the Al-Si system, remelting of the crystals resulted in higher Si concentration as temperature was increased. Yield and purity results for product alloy indicated that ternary systems containing Al-Si-Fe or Al-Si-Ti did not interfere with the crystallization process. However, in the bench units the quaternary Al-Si-Fe-Ti did restrict the eutectic drain process.

This task is complete.

Task No. 8: Establish Crystal Morphology

Scanning electron microscopy and electron microprobe analyses were used to analyze crystal samples taken from several crystallizer runs. Phases identified included primary and eutectic Si, Al-Fe-Si, Al-Ti-Si and Al. Approximate compositions were indicated. Nonmetallic inclusions were also identified.

This task is complete.

Task No. 9: Evaluate Materials of Construction for Crystallizer

Various materials were evaluated during operation of the bench and pilot crystallizers. Materials selections were made for the pilot unit to be built specifically for refining alloy produced by direct reduction. The primary lining material will be alundum.

This task is complete.

Task No. 10: Evaluate Materials of Construction for Multipurpose Furnace

Consultations with Alcoa ceramics specialists and furnace manufacturers resulted in the selection of a high purity fused alumina castable for the primary furnace lining. Other minor materials were also selected.

This task is complete.

Task No. 11: Operate Existing Pilot Unit

Several runs were made in an existing pilot crystallizer similar to the unit to be built for refining of direct reduction alloy. Synthetic alloys containing 25-28% Si were refined to eutectic alloy containing 14-15% Si. Approximately 60% of the initial charge was recovered as product alloy. Refer to Figure 6 in the First Quarterly Report (1) and Figure 1 in the Second Quarterly Report (2) for graphical representations of the pilot operations.

This task is complete.

Task No. 12: Design Fractional Crystallization Vessel

A 2000 lb capacity pilot crystallizer was designed, including shell, refractory linings, taphole, lid and tilting mechanism.

This task is complete.

Task No. 13: Design Crystallizer Agitation System

The agitation system was designed, including the electrical and pneumatic control circuits.

This task is complete.

Task No. 14: Design Crystallizer Heating System

An induction heating system was designed, including coil and power supply. Coil efficiency was determined as a function of crystallizer height to diameter ratio and alloy crystal physical properties. Calculations predicted good efficiencies for the pilot unit.

This task is complete.

Task No. 15: Design Crystallizer Cooling System

The cooling system was designed. The design provides the flexibility to vary degree and rate of melt surface cooling.

This task is complete.

Task No. 16: Design Product Removal System

Two alternative product removal systems were designed. One system features tilt pouring. The other concept involves lifting out the crystals with a graphite or refractory device. The crystallizer design (Task No. 12) incorporated the flexibility of using either solids removal technique, including auxiliary sidewall heating to reduce crystal adhesion at the walls.

This task is complete.

Task No. 17: Design Multipurpose Holding Furnace

A 2000 lb capacity induction heated furnace was designed, including selection of a manufactured furnace, power supply, control system and cooling water system. The furnace has the capability to attain 1260°C for melting high liquidus point alloys.

This task is complete.

Task No. 18: Prepare Site

The site for the multipurpose furnace and pilot crystallizer was selected and cleared. Layout drawings were made for the main units and auxiliaries. A concrete pad and steel support structure were installed for the cooling tower.

This task is complete.

A. Purification to Commercial Grade Aluminum - Phase I

Task No. 1: Review Literature

A literature survey was made and pertinent literature was reviewed.

This task is complete.

Task No. 2: Obtain Important Physical Properties

Important physical properties of components were obtained from literature and from internal data generated by Alcoa in previous research.

This task is complete.

Task No. 3: Determine Component Phase Diagrams

A number of required phase diagrams were obtained from literature.

This task is complete.

Task No. 4: Determine Theoretical Aluminum Recovery

Theoretical aluminum recovery was calculated for several hypothetical cases involving different Al-Si-Fe-Ti alloy concentrations to be processed in the purification unit. "Worst case" complex formations were assumed. At 800°C the theoretical aluminum recovery was 96%.

This task is complete.

Task No. 5: Build Bench Scale Purification Units

During Phase I a total of 19 small and 2 large bench scale units were built. The small units processed approximately one kg of alloy per run. The large units processed about 4 kg.

This task is complete.

Tasks No. 6 and 7: Operate Bench Scale Units to Study Variables and to Optimize Efficiency and Recovery

The bench scale units were operated to determine the effects of variables such as temperature and feed composition on unit efficiency, Al recovery and purity. Alloys containing Al-Si-Fe and Al-Si-Fe-Ti were purified to 99.9% at unit efficiencies of 97%. Energy requirements for purification were established. Data on unit performance and life was used in design of the pilot unit.

This task is complete.

Task No. 8: Identify Intermetallics in Residue

Residue samples from purification of alloy to commercial grade Al were analyzed by microprobe. The primary phase contained Si crystals. Intermetallics of Al-Si-Fe and Al-Si-Ti were also identified. In the former, the range of Fe concentration was 22-30%; Si was 14-31%. The Ti complexes were predominantly $TiAl_3$ or $TiSi_2$.

This task is complete.

Task No. 9: Obtain Solid State Mass Transfer Coefficients

It was experimentally determined that solid state mass transfer between Al and impurities was not practical. Both Al purity and unit efficiency were poor.

This task is complete.

Task No. 10: Evaluate Materials of Construction for Purification Unit

A series of construction materials were tested. Some key materials were selected on the basis of previous Alcoa experience. Other critical materials were selected on the basis of the test results.

This task is complete.

Task No. 11: Evaluate Concepts for System Design

Calculations were made to correlate Si concentration in the alloy with variables such as temperature, capacity and operating time of the unit [refer to Figure 8, Reference (1)]. Material and construction concepts for the pilot unit were evaluated. Heat transfer and mechanical aspects of the system were defined for the conceptual design.

This task is complete.

Task No. 12: Design Pilot System

The pilot system was designed on the basis of bench scale results, design concept evaluations, residue analyses and materials of construction tests.

This task is complete.

Task No. 13: Prepare Site

The site location was selected and cleared. Layout drawings were made. Existing utilities are adequate to supply the proposed pilot unit.

This task is complete.

PHASE "B" FIRST QUARTER PROGRAM

Administrative

The baseline cost report for Phase B will be submitted.

A request will be made to increase subcontractor expenditure ceilings to cover work planned for Phase B.

Technical

Reduction: Heat and mass balance calculations will be made for the pilot vertical shaft reactor. Mathematical modeling of reaction kinetics will be continued with emphasis on developing an error-free computer program. The externally heated bench scale reactors will be operated to evaluate burden formulations and several newly produced burden agglomerate types, to continue studies on effects of impurities on reaction yield, and to determine reduction reaction mechanisms for a range of operating conditions. Burden materials will be prepared for use in startup and continuous operation of the pilot reactor. Ball forming will be developed further. The pilot reactor installation will be completed and the unit started.

Alloy Purification: Both the standard and the high temperature bench scale units will be operated to continue evaluation of impurity effects on crystallizer performance and alloy purification. Site preparation for the pilot crystallizer and multipurpose furnace will be completed. Pilot crystallizer detailed design will be resolved and hardware ordered.

Purification to Commercial Grade Aluminum: Detailed design of the pilot system will be continued. Critical materials evaluations will be made in both the standard and large scale bench units, with screening done in short runs and definitive tests of promising candidates carried out in long term operation exceeding 100 hours. Hardware revisions will be made to facilitate simultaneous operation of two bench units.

COST SUMMARY

In the fourth quarter the total expenditures were $304,971. Distribution was $229,269 for Reduction, $51,317 for Alloy Purification and $24,385 for Purification to Commercial Grade Aluminum. Total cumulative expenditures for Phase A was $938,808. This total was 80.1% of planned expenditures for the first phase. Actual spending is compared to estimated spending in Figure 1.

ASSIGNED PERSONNEL

The actual man-hours expended by engineers and technicians for the first phase are shown in Table 1 and compared to the estimated man-hours. Engineer man-hours were 16% below estimate. Technician man-hours were 3% below estimate. Cumulative man-hours were 9% below estimate.

REFERENCES

(1) Production of Aluminum-Silicon Alloy and Ferrosilicon and Commercial Purity Aluminum by the Direct Reduction Process, First Interim Technical Report, December 1977, TID #28260.

(2) Production of Aluminum-Silicon Alloy and Ferrosilicon and Commercial Purity Aluminum by the Direct Reduction Process, Second Interim Technical Report, March 1978, TID #28386.

(3) Production of Aluminum-Silicon Alloy and Ferrosilicon and Commercial Purity Aluminum by the Direct Reduction Process, Third Interim Technical Report, June 1978, CONS-5089-3, UC-95f.

TABLE 1

Summary of Man-Hours Expended

	1st	2nd	3rd	4th	Total	Est.	Deviation From Est. %
Engineers	1944	2630	3041	3171	10,786	12,828	-16
Technicians	2789	3534	3608	4629	14,560	14,960	- 3
Total	4733	6164	6649	7800	25,345	27,788	- 9

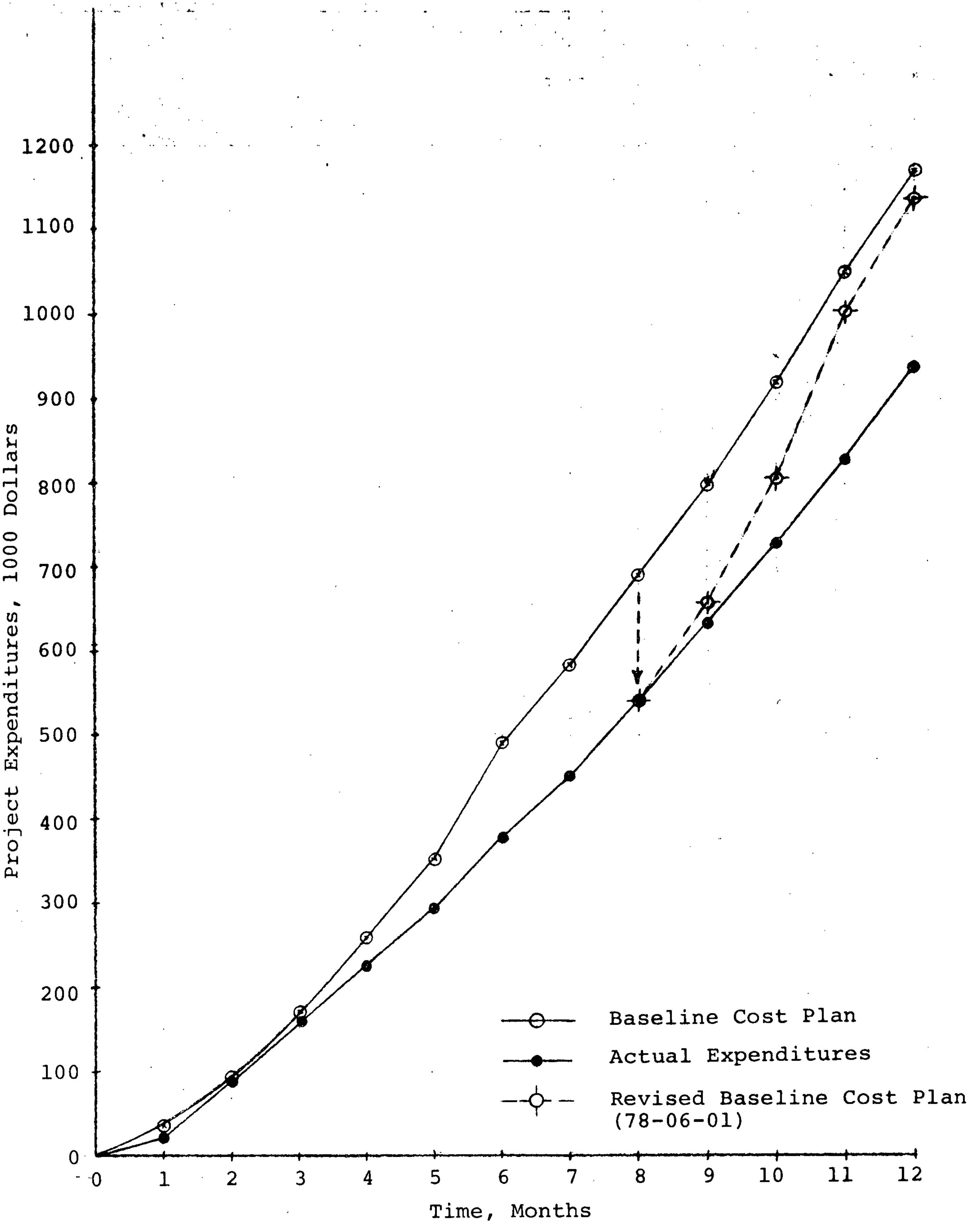

FIGURE 1 - Phase "A" Cost Chart: Total Expenditures vs. Time