Appendix "B"

Argonne National Laboratory
Statement of Work
Estimating the Cost of a Manufacturing Plant for NMCA Cathode Materials
01/20/2023

1.0 Background

Argonne National Laboratory has been working on the development of lithium-ion batteries (LIB) for several decades with noteworthy contributions in the advancement of the technology. Technoeconomic analysis is an integral part of the technology development to evaluate new technologies and to identify the potential for technology commercialization. The Laboratory has a growing interest in the techno-economics of all points within the supply chain of lithium-ion batteries. This work is targeted at the manufacturing of lithium nickel manganese aluminum oxide (NMCA) cathode materials.

2.0 Scope

This work is expected to provide the Laboratory with a design of the physical and chemical processing steps necessary in the production of NMCA materials.

Each processing step necessarily requires capital equipment, floor area, and supporting labor. The process must be designed with redundancies (such as parallel lines or standby equipment to prevent a complete shutdown of production). Each processing step typically has multiple identical units that operate in series or parallel to match the production rate. It is important to match the number of these units with their capacity and identify their installed cost, the man-hours of labor required to operate them per 24-hour basis, their energy (heat or electricity) demand (usually listed on the equipment), the amount of water (process or cooling) needed, and the floor space required for each equipment. These process equipment (reactors, furnaces) are supported by unit operations (pumps, heat exchangers, mills/grinders, filters, separators, dryers, etc.) and these need to be identified as capital equipment (may be lumped as for example, heat exchangers with the total heat transfer load, or pumps with their processing loads, total number of filters indicating the number of stages, etc.

A high-level estimate of the cost of production is also expected. The output should resemble stage 2 of a feasibility analysis – *i.e.*, preliminary equipment designs, preliminary plant layout, and preliminary costs estimated within 15-20% of a complete design. The Laboratory is looking for the level of detail that could be produced by 150-250 person-hours of a process design engineer familiar with such a plant.

3.0 Objectives

The objective of this study is to estimate the design and cost of setting up and operating a large-scale plant in the United States to produce NMCA materials. Estimates for three plant sizes should be provided: 100, 175, and 250 MT/yr. The plants should be capable of producing powders that incorporate state-of-the-art materials in anticipation of demand in ~5 years. The design and cost estimates will be incorporated into ongoing techno-economic analyses at Argonne National Laboratory.

4.0 Tasks

<u>Main Deliverables</u>

This work should yield estimates for the design and cost of NMCA plants built in the United States. The salient features of the study are as follows:

- Three design and cost estimates should be presented for three production volumes of 100, 175, and 250 MT/yr.

- The plants will produce "state-of-the-art" NMCA materials with the ability to change the Ni:Mn:Co:Al ratios in different lines.
- Assumptions for the composition and morphology (e.g., single crystal, core/shell, coating layers, etc.) of these materials should be provided
- The design estimate should include:
  - Plant layout chart
  - Flow diagram showing material, energy flows for each type of equipment
  - Rated capacity of each type of equipment and the number of units in the plant
  - Plant area required per each type of equipment
  - Rated energy (heat or electricity) consumption for each type of equipment
  - Labor required per year for each type of equipment
  - Processing rates for batch and continuous reactors, furnaces, etc.
  - Operating conditions (temperature, pressure, pH, residence time, environment[1]) of each type of equipment. The operating condition profile / history for units with long residence time (>1 hour) or changing conditions should be included
  - Footprint area of the production floor and infrastructure (maintenance, warehouse, shipping, utility, recycle facility, water processing)
  - Quantity breakdown of annual electric, natural gas, cooling water, and process water demands of the plant
  - Assumptions for yields and overall equipment effectiveness (OEE) at each stage in the process
- The cost estimate should include:
  - Quantity and price of purchased materials (raw materials, supplies)
  - Capital equipment for the plant with breakdown of equipment and installation (USA)
  - Building construction cost for production area and infrastructure (maintenance, warehouse, shipping, utility, recycle facility, water processing)
  - Building operation cost for production area and infrastructure (maintenance, warehouse, shipping, utility, recycle facility, water processing)
  - The total investment cost
  - The estimated cost of the product and the methodology used

Additional Information

The design should be for a plant of very high efficiency to be built ~5 years in the future. Therefore, the plant will likely be highly automated with high-speed production per units of plant area, capital equipment cost, and labor cost. It should be assumed that the appropriate R & D to establish the feasibility of the plant design have been successfully completed.

The unit operations (*e.g.,* pumps, heat exchangers, mills/grinders, filters, separators, dryers, etc.) required to support the process equipment (*i.e.,* reactors and furnaces) should be identified as capital equipment. The unit operations should also depend on manufacturing rate. For example, heat exchangers depend on the total heat transfer load, pumps depend on the processing loads, and total number of filters depend on the number of stages.

The proposal should include a template of the final report (Table of Contents) to reflect that the needed information identified in Section 4.0 will be included.

5.0 Delivery

A final report and presentation will be presented to the technical team at Argonne. Additional materials used in the analysis (*i.e.,* spreadsheets, word documents, etc.) must also be provided upon request.

[1] Furnaces may use oxygen-rich or inert-rich gas.

6.0 Government-Furnished Property

n/a

7.0 Security

n/a

8.0 Place of Performance

n/a

9.0 Period of Performance

The final report will be due 6 months after contract signing.