

RESEARCH PILOT PLANT  
ANNUAL REPORT - YEAR 1959

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Construction of the Research Pilot Plant facilities was started in 1958 and the building was completed early in 1959.

The test operations in the new pilot plant facilities commenced early in 1959.

The purpose of the Research Pilot Plant is to provide facilities for continuous piloting of concentration and agglomeration processes. Prior to construction of the pilot plant, this work had been carried out at the central Research Laboratory in Ishpeming. Limited pilot mill facilities, an inefficient materials handling system, and a more intense diversified pilot mill test program dictated the need for a separate and enlarged pilot plant.

The new pilot plant is divided into two sections, one being devoted to pyrometallurgical processes and the other being utilized for hydrometallurgical flowsheet work.

The pyrometallurgical section started operations with an Allis-Chalmers grate-kiln pilot plant. This system has a capacity of approximately 1200 lbs/hour and is identical to the unit installed at Allis-Chalmers' Carrollville Pilot Plant. Related equipment such as bins, feeders, screens, a balling disc and a balling drum are also incorporated within the grate-kiln pilot plant.

The frame of the 32 square foot Dwight Lloyd sintering machine was erected in the pyro section, however, installation was not completed as test efforts were concentrated on the grate-kiln system.

The hydro section is subdivided into three flowsheets, one being a magnetic separation flowsheet circuit similar to flowsheets that are presently being used for concentrating the magnetic taconites. The two other flowsheets are concerned with flotation processes; one being a prototype of the Humboldt or Republic flowsheet. The other flotation circuit was set up to further explore the regrind-reflotation process which involves regrinding of the flotation concentrates followed by heating of the pulp up to the boiling point and a second stage of flotation separation.

Within the hydrometallurgical section a regrind mill was installed for regrinding of specular hematite concentrates to provide the proper size consist for balling and subsequent pelletizing in the grate-kiln system.

Other facilities at the pilot plant include an unloading station for handling of raw materials, a crushing and screening section and storage bins that have a total storage capacity of 350 tons. A small tailings area to which all tailings are pumped and stocking areas for stockpiling of ores were developed at the outset.

Limited laboratory facilities for testing of circuit products and a chemical laboratory for "on the spot" determinations for iron, ferrous iron, and silica were incorporated in the pilot plant facilities. Extensive batch test studies will still continue to be conducted at the Research Laboratory in Ishpeming.

### PART I

#### GENERAL INFORMATION

##### PERSONNEL AND TIME DISTRIBUTION:

At the end of the year the Pilot Plant was staffed with the following people:

|                             |          |
|-----------------------------|----------|
| Engineers                   | 3        |
| Clerk                       | 1        |
| Technician Leaders          | 2        |
| ACL Section                 | 15       |
| Hydro Section               | 10       |
| Laboratory Testers          | 7        |
| General Helper-Truck Driver | <u>1</u> |
| Total                       | 39       |

The distribution of time as related to projects is presented below.

##### Time Distribution - Research Pilot Plant 1959

| <u>Project</u>      | <u>Hours</u> | <u>%</u>    |
|---------------------|--------------|-------------|
| Empire              | 3,781        | 13.12       |
| Grate-Kiln System   | 20,386       | 70.73       |
| Primary Flotation   | 2,000        | 6.94        |
| Regrind-Reflotation | <u>2,657</u> | <u>9.21</u> |
| Total               | 28,824       | 100.00      |

The number of chemical analyses determined at the plant laboratory during the year are presented below.

1959 ANALYSIS TOTALS - PILOT PLANT CHEMICAL LABORATORY

| <u>Month</u> | <u>Fe</u>    | <u>Fe<sup>++</sup></u> | <u>SiO<sub>2</sub></u> | <u>Totals</u> |
|--------------|--------------|------------------------|------------------------|---------------|
| May          | 134          | 190                    | 64                     | 388           |
| June         | 536          | 418                    | 82                     | 1,036         |
| July         | 598          | 155                    | 73                     | 826           |
| August       | 571          | 274                    | 91                     | 936           |
| September    | 743          | 425                    | 101                    | 1,269         |
| October      | 696          | 334                    | 79                     | 1,109         |
| November     | 601          | 268                    | 51                     | 920           |
| December     | <u>1,354</u> | <u>293</u>             | <u>156</u>             | <u>1,803</u>  |
| Totals       | 5,232        | 2,357                  | 697                    | 8,287         |

Reports or memoranda issued concerning pilot plant test work were assigned Metallurgical Department numbers and issued from the Research Laboratory. Weekly progress reports for the Hydro Section and Pyro Section and monthly reports were issued throughout the year.

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PART IIPYRO SECTION

During the year the ACL pilot unit was operated on a three-shift-per-day basis conducting pelletizing tests on Cleveland-Cliffs specular hematite flotation concentrates. The following lists types of concentrates and approximate quantities tested.

|   | <u>Long Tons</u> |
|---|------------------|
| (a) Humboldt - pilot plant reground               | 663              |
| (b) Republic - Eagle Mills reground               | 143              |
| (c) Republic - Pilot Plant "refloat" concentrates | 6                |

Approximate distribution of operating time was 84.3 per cent, 15.3 per cent, and 0.4 per cent with concentrates a, b, and c, respectively.

OBJECTIVES:Humboldt Concentrates - Pilot Plant Reground:

Testing of reground Humboldt concentrates was pursued as per the following general objectives.

- (a) Determine and define optimum operating conditions with the pilot unit. This information would serve as guide parameters for startup and operation of the commercial plant.
- (b) Operate the system on a continuous basis to bring out any design or materials of construction problems.
- (c) Training of personnel which would greatly aid in startup and operation of the commercial plant.

In accordance with objective (a), the following factors and/or variables were studied.

1. The effect of concentrate size analysis on balling, firing rate (system performance), and final product quality.
2. Correlation of optimum balling moisture with the various levels of regrind.
3. Determination of system performance and final product quality while operating with small (-1/2"), medium (-3/4"+1/2"), and large (+3/4") pellets.
4. Determine final product quality and system performance as correlated to pellets containing only bentonite versus pellets containing bentonite and limestone.
5. Compare product quality and system performance with various indurating (kiln), preheating, and drying temperatures; along with corresponding air flows and system pressures.



6. Analysis of conditions causing ringing and accretion buildup on the kiln lining. The following lists factors studied.

- (a) Preheat temperatures
- (b) Additives
- (c) Velocity of gases in the kiln and kiln feed end temperature as related to the size of the kiln feed end.
- (d) Refractory glaze coatings for the kiln lining.
- (e) Varying flame lengths and spin and no spin flame patterns.
- (f) Elimination of preheated air from the cooler.
- (g) Kiln temperature
- (h) Various ratios of primary and secondary (cooler) air.
- (i) Various levels of air (primary and secondary) and still maintain oxidizing conditions.

Routine quality control tests were conducted on samples of the balling disc, grate, kiln, and cooler product. The following lists properties investigated.

- (a) Crush and drop strengths.
- (b) Size analysis
- (c) Chemical Analysis
- (d) Abrasion resistance
- (e) Bulk density
- (f) Porosity

In addition to analysis of wear, fatigue, and heat resistance of the components of the ACL system as per objective (b), various insulating refractories, castable refractories, firebrick, bonding mortars, and refractory coatings were tested.

Republic - Eagle Mills Reground:

Testing of Republic Eagle Mills reground concentrate was pursued as per the following objective.

- (a) Determine the influence of various preheating and indurating temperatures on product quality and system performance.

Republic - Refloat Concentrates:

A small tonnage of refloat concentrates was processed by the system to obtain some high-grade specular hematite pellets. Routine quality control tests were conducted on these pellets to compare their quality with pellets made from Eagle Mills reground and Humboldt reground concentrates.

FEED PREPARATION:Regrinding:

All of the Humboldt concentrates were ball mill reground in open circuit, brought up to optimum filtering density in a slurry tank, and filtered.

Filtering:

The slurried concentrate was filtered in a 4-foot disc filter. Tests were conducted during the year to determine optimum filtering conditions. The following lists variables tested.

- (a) Density of the pulp in the filter tank.
- (b) Air flows
- (c) Cake thickness as related to disc speed, pickup area, and vacuum.
- (d) Bottom or side feeding of the filter tank.
- (e) Removal of suspended slimes and froth.

Concentrates which did not require regrinding, but whose moisture contents were above or below that desirable for balling, were slurried and refiltered to obtain the proper moisture content.

Balling:

All of the balling was done in a 3-1/2 foot disc. Optimum operating conditions in terms of slope and speed (retention time) were determined for each type of concentrate tested and desired ball size. When the ACL system is operated above 2.0 LT/ft<sup>2</sup>/day the disc becomes overloaded and does not afford the desired surface area for optimum balling. The balling drum circuit was completed except for a tripper on the feed belt to provide steady feed to the drum.

SYSTEM MODIFICATIONS:

The following lists modifications made to the system and its components in order to improve operation.

- (a) The rotating bin feeders were replaced by a B-I-F feeder. The old feeders were a constant source of trouble in terms of material hang-up, inaccurate weighing, and fluctuating feed output. The new feeder affords excellent control of feed rate, gives accurate weights, and delivers the correct proportion of additives.
- (b) Leakage of ambient air into the ACL system required fabrication and installation of new kiln seals which have a grease groove to distribute the lubricant.
- (c) The original curtain wall in the cooler proved to be a constant source of trouble in terms of jamming the cooler. This was replaced by a curtain wall with collapsible buckets.
- (d) The original sideplate casting of the grate machine suffered excessive growth, warpage, and oxidation scaling. This resulted in improper sealing causing hot gases to short-circuit around the pellet bed. After the last run of the year it was necessary to cut 3 inches off the top of each casting. In effect, this removed the area where the castings bind. The refractory sidewalls were lowered to accommodate the lower castings. This change has resulted in very good sealing of the grate-chain.

PART IIIHYDRO SECTIONPRIMARY FLOTATION SECTION:

The objectives for operating the primary flotation were: (1) production of re-grind-reflotation feed and (2) pilot mill testing of Galigher Company's Agitair flotation cells.

1. During September and October of this year this circuit consumed approximately 100 tons of feed and yielded 35-40 tons of 59% Fe regrind-reflotation feed. Two flowsheets were tested; (1) scavenging all flotation tails with the concentrate returned to the head of the circuit and (2) scavenging only the rougher tails with this concentrate and the cleaner and recleaner tails all returned to the head of the circuit. Both flowsheets yielded the desired grade but slightly higher iron recoveries were obtained by scavenging only the rougher tails.

2. During the weeks of October 26th and November 2nd, a representative of the Galigher Company was present to assist in the testing of the Agitair flotation cells. Operation of these cells during this period gave the desired grade of 59% Fe with 90-95% Fe unit recovery based on flotation feed. On isolated shifts, higher grade recleaner concentrates were made but iron unit recovery fell off sharply. Time did not permit a correlation study to enable a comparison of the three cell types on a pilot mill scale.

REGRIND AND REFLOTATION PROCESS:

The substantial degree of upgrading which occurs in the regrind and refloitation process depends largely on the attainment of pulp boiling and the additional liberation achieved by regrinding the rougher flotation concentrates.

Pilot mill studies conducted during the year investigated pulp heating methods and closed or open circuit preconcentrate regrinding.

Pulp heating methods studied were the following:

1. Direct Heating
  - (a) Submerged Combustion
  - (b) Steam Sparging



2. Indirect Heating

- (a) Steam Coils

3. Combination of Direct and Indirect Heating

- (a) Steam sparging and Indirect Steam Coil heating

Evaluation of the heating methods was made based on the BTU input requirements of each method and final refloatation metallurgy.

Closed circuit preconcentrate regrinding was tested studying the following variables:

1. Additional BTU input requirements over open circuit preconcentrate regrinding.
2. Savings in grinding energy requirements.
3. Product size consistability.
4. Final refloatation metallurgy.

Regular Republic concentrate was used for the bulk of the pilot plant test work.

EMPIRE:

Empire flowsheet development testing commenced at the Research Pilot Plant on a one-shift-per-day schedule during June 1959 until November 30, 1959. At this time operations were continued on a two-shift-per-day schedule. The tonnage of crude processed during the total period was approximately 160 long tons.

During November 1959, 1250 tons of crude were obtained from the Empire Area. Approximately 1000 tons was crushed to pass 2 inch for flowsheet development tests and 250 tons crushed to pass 6 inch for future autogenous grinding tests.

The following flowsheet variables were investigated:

1. Cobbing Tests

Cobbing or initial magnetic separation tests were conducted at three rod mill grind size consists.

The purpose of this study was to determine:

- (a) The tonnage of material that could be rejected at each size.
- (b) The grade of cobber concentrate and magnetic iron loss.
- (c) If the material rejected at the three size consists influenced the final metallurgy.

## 2. Open and Closed Circuit Grinding

A series of tests using both open and closed circuit grinding were conducted.

The purpose of the tests was to determine:

- (a) The number of grinding stages necessary.
- (b) The grinding power requirements
- (c) Overall metallurgy.