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Zinc Department Anaconda Reduction Works

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ZINC DEPARTMENT
ANACONDA REDUCTION WORKS

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ANAconda REDUCTION WORKS

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Introduction

The electrolytic zinc department of the Anaconda Reduction Works consists of five divisions, each responsible for one phase in the preparation of electrolytic zinc. These divisions are: (1) The zinc concentrator which produces a high-zinc, low-lead concentrate for further treatment at Anaconda, and a low-zinc, high-lead concentrate which is shipped to East Helena for further treatment. (2) The roasting division wherein the concentrate is roasted to oxides and sulfates. (3) The leaching division which (a) leaches the roasted concentrate to dissolve the zinc, and (b) purifies the leached solution. (4) The electrolytic division which produces pure zinc cathodes by electrowinning from the leach solution, and (5) The casting division wherein the zinc cathodes are remelted and cast into commercial shapes for sale.

This report will be concerned with the five divisions mentioned in the above paragraph. The general chemistry, flow of materials, and some theory will be discussed. Most of the equipment is familiar and will be discussed only when it is necessary.
The Zinc Concentrator

The highline at the zinc concentrator* (Fig. 1) is the starting point for all zinc ore that is processed at the Anaconda Reduction Works. The ore arrives in 50-ton, bottom-door type ore cars. These cars may be dumped into either of two bins that feed two 36-in. Traylor jaw crushers. These crushers are fed by mechanical belt feeders that pass directly under each ore bin. The crushed ore, after leaving the jaw crushers, is then further reduced by three 36-in. Traylor suspended spindle gyratory crushers to about 2-in. in size. When the ore has passed through the primary and secondary crushing stages it is elevated by two 18-in. bucket elevators and passed over two double deck 3/8-1/4-in. hum-mer vibrating screens for sizing.

Fig. 1. General view of concentrator at the Anaconda Reduction Works.

The undersize from the screen is fed into a Dorco rake deslimmer. The slimes, or overflow, go to either the tails or flotation, depending upon their concentration, and the oversize joins the oversize

* See appendix for flow sheet.
from the hum-mer screens. Water is added to the ore that passes over the screens, and when joined by the deslimier, oversize reduces the pulp density to about 80 per cent.

This sluggish ore is fed into a splitter which distributes it to three 9-ft. by 12-ft. rod mills. These rod mills reduce the ore from 2-in. in size to approximately 80 per cent minus 1/4 in. The rod mill discharge is diluted with water to 70 per cent pulp density, and elevated to a distributor that feeds ten Hardinge ball mills operating in closed circuit with Akins classifiers. Lime is added to this closed circuit to prepare the ore for flotation, which requires a pH of about nine. The classifier overflow is approximately 80 per cent minus 150 mesh and has a pulp density between 35 per cent and 40 per cent.

The pulp is pumped into three banks of conditioner cells where the flotation reagents are added. Copper sulfate and mineracl are added and conditioned for 18 minutes. An automatic sampling device is continuously cutting samples out of the conditioner feed. The conditioned pulp is piped to the flotation floor where it is distributed to 15 banks of Agitair flotation cells. Each of these banks has 14 cells and are used as roughers, cleaners, or scavenger cells, as needed. This bulk flotation produces a concentrate that is about 50 per cent zinc sulfide and 30 per cent lead sulfide.

The concentrate from the bulk flotation is transferred by launderers to three Dorr thickeners. The overflow from these thickeners goes to the tails, and the underflow is piped to the zinc-lead flotation separation floor.
Sodium cyanide, zinc sulfate, propyl xanthate, and carbonol are added to the concentrate and conditioned at 140°F for five minutes, to prepare the lead and zinc for separation. When the conditioning is complete, the concentrate is pumped into two flotation banks containing 18 cells each. In these cells the conditioned ore is separated. The zinc is depressed with the aid of sodium cyanide and zinc sulfate and the lead is floated with the aid of the propyl xanthate and carbonol.

The lead concentrate is taken to a Dorr thickener by means of a 12-in. launder. This thickener is used primarily for a storage reservoir and secondarily as a thickener. The overflow from the thickener goes to the tails, and the underflow is piped to an Oliver disc filter. The filtrate from the disc filter goes to the tails, and the thick filter cake is scraped from the leaves onto an 18-in. conveyor belt. The cake is taken to the loading station, on the conveyor, where it is loaded into 50-ton bottom-dump railroad cars and transported to the American Smelting and Refining Company at East Helena, Montana. There it is further treated to recover the lead.

The depressed zinc is piped from the flotation cells to two Dorr thickeners. The overflow from these thickeners goes to the tails, and the underflow is filtered by six Oliver drum filters. The filtrate from these filters goes to the tails, and the cake is discharged onto an 18-in. conveyor belt. This conveyor follows the same course as the lead belt and the concentrate is loaded into bottom-dump railroad cars. Some of this concentrate is shipped to Great Falls to be processed, and the rest is taken directly to the
roasters or stock bins. The concentrate that is taken to the stock bins is usually not stored for over a week or two.

**The Zinc Roasters**

The zinc roasters* at Anaconda are located in the Roaster No. 2 building. This building houses 28 roasters in all, 10 for copper and 18 for zinc. These roasters are all of the 25-ft, eight hearth, McDougall type. Roasting temperatures are usually controlled between 600° and 625° C.

The concentrate that leaves the zinc concentrator is trammed to the stock bin scales, weighed and dumped into the "pit", which is located about ten yards behind the scales. A pneumatic vibrator is placed on the car to assure complete dumping. The concentrate in the pit is fed onto the incline conveyor belt (Fig. 2) by an automatic belt feeder. The 24-in. incline conveyor takes the ore to the top of the roaster building, about 20-ft above the roasters.

* See appendix for flow sheet.
Another belt takes the concentrate in the same direction to the far end of the roaster building, passing between, and above, two rows of roasters, seven in each row. A drag board is used to deflect the ore off the conveyor belt into the different storage bins above each roaster. The four remaining roasters, 3, 4, 7, and 8 are fed by two separate conveyors, one that runs beneath and at right angles to the main belt and the other at right angles to this belt between roasters 7 and 8. The same method, as on the main belt, is used to feed these four roasters (Fig. 3).

**Fig. 3 Plan of the Roasters**

Roasters 1 and 2 are not fed by the main belt. These two roasters roast only flue dust that comes in on a screw conveyor from the Cottrell recovery plant, located outside the building near roaster 4. The ore is fed to each roaster as needed, usually about 25 tons a day. The top hearth is used for drying and each hearth thereafter serves to roast the ore. These wedge type roasters have openings at the centers and edges of alternating hearths from top to bottom. The ore enters at the top and rabbles on the arms are so set to move the ore from the edge of the furnace to the opening.
at the center. The concentrate drops through this opening onto the next hearth and is moved back to the outside and dropped through the outside hole onto the next hearth. This process is continued until the calcine is discharged out of the bottom. Fig. 4 and 5 illustrate an intermediate and top floor of the roaster.

![Image 4: Top floor of roaster](image)

Fig. 4 Top floor of roaster.

![Image 5: Intermediate floor of roaster](image)

Fig. 5 Intermediate floor of roaster

The air is controlled to produce a high oxide roast with just enough sulfate to replace the sulfuric acid loss in the tank
house. The sulfate desired is about 2.5-3 per cent and is easily obtained if the temperature on the first two hearths is kept relatively low. If the temperature is high at the very beginning, the condition for the formation of zinc ferrite is right and there will be a large formation of this compound. Zinc ferrite is very undesirable in the leach because of its insolubility in dilute sulfuric acid and is, therefore, lost in the solid material that is filtered out.

The main reactions in the roasters are as follows:

1. \[ 2 \text{ZnS} + 3\text{O}_2 = 2 \text{ZnO} + 2\text{SO}_2 \]
2. \[ \text{ZnS} + 3\text{SO}_2 = \text{ZnSO}_4 \]
3. \[ \text{ZnO} + \text{SO}_2 + \frac{1}{2}\text{O}_2 = \text{ZnSO}_4 \]
4. \[ 4\text{FeS}_2 + 11\text{O}_2 = 2 \text{Fe}_2\text{O}_3 + 8 \text{SO}_3 \]
5. \[ \text{ZnO} + \text{Fe}_2\text{O}_3 = \text{ZnO} \cdot \text{Fe}_2\text{O}_3 \]

Most of the impurities also oxidize and dissolve in the leach with the zinc. The general reaction for impurities is:

\[ \text{MS} + \text{O} = \text{MO} + \text{SO}_2 \ (\text{SO}_3) \]

When the Calcine reaches the bottom of the roasters, about 15 hours after it has entered, it drops into a temporary storage bin. The bins are emptied periodically into V-shaped rocker dump cars and trammed to the zinc leach department.

**The Zinc Leach**

**A. Leaching**

The ore from the roasters is dumped into bins at the top of the zinc leach building*. From these bins, it passes through two sets of hum-mer vibrating screens. The oversize from these screens is returned to the roasters, and the undersize is carried by launder to the neutral leach. This leach is accomplished in 9 pachuca tanks.

* See appendix for flow sheet.
in series with the leach solution flowing countercurrent to the calcine. The leach solution is composed of spent electrolyte, overflow from the acid thickeners, filtrate from the Moore filters, oxidized iron solution, and manganese dioxide.

The primary purpose of the neutral leach is to neutralize the acid leach overflow and secondarily to dissolve the maximum amount of the zinc oxide possible. The main reaction is:

\[(7) \quad \text{ZnO} + \text{H}_2\text{SO}_4 = \text{ZnSO}_4 + \text{H}_2\text{O}\]

This reaction takes place, in an excess of sulfuric acid, until all the zinc is dissolved. Fresh calcine is added to neutralize the acid in the solution. Other metals that go into solution along with the zinc are, small amounts of copper, cadmium, germanium, nickel, and cobalt. The general reaction is:

\[(8) \quad \text{Mo} + \text{H}_2\text{SO}_4 = \text{MnSO}_4 + \text{H}_2\text{O}\]

The calcine is added in small excess to insure neutralization of the solution, in this case pH 5. When the solution is neutral, the iron precipitates out according to the reactions:

\[(9) \quad 2\text{FeSO}_4 + \text{MnO}_2 + 2\text{H}_2\text{SO}_4 = \text{Fe}_2(\text{SO}_4)_3 + \text{MnSO}_4 + 2\text{H}_2\text{O}\]

\[(10) \quad \text{Fe}_2(\text{SO}_4)_3 + 3\text{ZnO} + 3\text{H}_2\text{O} = 2\text{Fe(OH)}_3 + 3\text{ZnSO}_4\]

The iron hydroxide is assumed to carry out arsenic and antimony by adsorption.

The discharge from the neutral leach enters a ball-mill classifier circuit, to remove the sands. The manganese dioxide is added at this point by a line that comes directly from the tank house. The manganese dioxide is used to convert the ferrous iron into ferric iron in the neutral leach (Reaction 9). The sands are ground in the Hardinge ball mill and carried by launders to the acid leach circuit. The classifier overflow is fed to eight Dorr thickeners.
operating in series, for separation of the dissolved minerals from the undissolved minerals. The overflow from these thickeners goes directly to purification, and the spigot is piped to the acid leach.

The acid leach treats the material in a series of nine pachmica tanks, with sulfuric acid, or spent electrolyte from the tank house. This sulfuric acid dissolves the excess calcines that were added in the neutral leach.

The discharge from this leach is fed into three acid Dorr thickeners in series. The overflow from these thickeners is returned to the neutral leach as part of the leach solution, and the spigot is piped to the Moore filters (Fig. 6).

The Moore filter consists of 35 rectangular filter leaves, suspended from a frame and operates in connection with three baths. The first bath contains the spigot flow from the acid leach, and the second two contain filtrate from the Oliver filters. The solution is in constant flow through the three baths, flowing countercurrent to the direction the cake travels. A complete cycle is as follows:

1st bath  
Cake forming

2nd bath  
Cake discharge
Cake reforming

3rd bath  
Cake discharge
Cake reforming

(Final discharge for Oliver filters)
The filtrate from the Moore filter returns to the neutral leach and the cake is taken to the Oliver filters.

Fig. 6 Moore Filter with leaves submerged in first bath.

The Oliver Drum Filters (Fig. 7) operate in a shallow bath in a four stage cycle: (1) cake forming, (2) cake sucking, (3) cake washing, (4) cake discharge.

Fig. 7. Oliver filter.

The discharge from the drum filter is conveyed to a rotary kiln, (fig. 8) dried and loaded into 50-ton railroad cars and
shipped to East Helena to be processed for the lead. The filtrate is used for washing in the Moore filters.

Fig. 8 Rotary Kiln.

E. Purification

The leach solution from the neutral leach is fed into nine mechanical agitated tanks in the purification building. Three hundred lbs. of zinc dust are added to each tank, 10-ft in diameter and 20-ft. high, full of the leach solution. The solution is agitated for 50 minutes and then discharged into launders leading to a collecting tank. The sequence of filling the tanks, dusting, and agitating is controlled so that filtering is continuous.

The leach solution that enters the purification department contains copper, cadmium, germanium, nickel and cobalt as impurities. The zinc dust is added to remove these impurities by displacement, because the zinc sulfate solution has to be very pure for electrolysis. The chemistry of the purification is as follows:

(1) \( \text{Zn} + \text{Cu}^{2+} = \text{Zn}^{2+} + \text{Cu} \)
(2) \( \text{Zn} + \text{Pb}^{2+} = \text{Zn}^{2+} + \text{Pb} \)

etc.

The purified solution is pumped into the shriver filters under a pressure of 30 psi (Fig. 6).
a pressure of 80 psi (Fig. 9). These filters are cleaned periodically. The residue is dumped into small buggies and pushed outside to sun dry. The filtrate is piped to the tank house storage tanks;

![Shriver Filters](image)

Fig. 9 Shriver Filters

The cake from the shriver filters is loaded into 50 ton railroad cars and shipped to Great Falls for further treatment.

The Zinc Tank House

The purified solution for the tank house* is pumped into two elevated storage tanks (Fig. 10.) from which it is fed directly to the cells.

The tank house (Fig. 11) consists of six units. Each unit has 13 double cascades, of six tanks per cascade, making a total of 156 tanks per unit and 936 cells in all. Each tank has an aluminum cooling coil at the upper end. Cold water is circulated through these coils to maintain the solution at about 35°C.

** See appendix for flow sheet..
The tanks are made of wood, and completely lined with lead. The inside dimensions are as follows: 10-ft 3 in. long, 8-ft 10-in. wide, and 4-ft 9 in. deep. The tanks rest on sills, insulated from lead covered concrete piers by glass insulator blocks.

Fig. 10 Tank house storage tanks.

Fig. 11 Zinc Tank House

Each tank has 27 cathodes and 28 anodes. These are spaced about one-in. apart, alternately throughout the tank. The anodes are made of scrap lead with 0.50 percent silver to prolong their life. A copper bar is cast into the top part of the anode for
contact. The cathode is a high grade aluminum plate with a copper contact bar riveted to the top edge. These contact bars rest on bus bars that run along the side of each tank.

Fresh electrolyte is fed to each cell along with the overflow from the other cells. The solution has about 140 gpl zinc and considerable manganese sulfate along with minor impurities. When an electrical current is applied, zinc plates out on the aluminum cathodes in thin sheets. The manganese dioxide is precipitated, and forms on the anodes and on the lead tank surface. The reactions are:

Cathode:

\[
\begin{align*}
(13) & \quad \text{Zn}^{2+} + 2e = \text{Zn} \\
(14) & \quad 2\text{H}^+ + 2e = \text{H}_2 \\
\text{Anode:} & \\
(15) & \quad 2\text{MnSO}_4 + 2\text{H}_2\text{O} - 4e = 2\text{H}_2\text{SO}_4 + \text{O}_2 \\
(16) & \quad \text{MnSO}_4 + 2\text{H}_2\text{O} - 2e = \text{MnO}_2 + 4\text{H}_2\text{SO}_4 + \text{H}_2
\end{align*}
\]

The spent electrolyte, containing about 50 gpl of zinc and 10 per cent of sulfuric acid, is returned to the tank house.

The cathodes are removed daily and the zinc is stripped from the aluminum sheets manually. The stripped zinc is loaded on small hand cars, weighed, and pushed onto the charge floor in the casting department. The tanks have to be drained of all solution, cleaned, and repaired periodically. The manganese dioxide slime is returned to the neutral leach. All old anodes are replaced with new ones and the cathodes that need replacing are also replaced. The old anodes are returned to the lead casting section for recasting.

The power for this electrolytic operation is supplied by the Montana Power Company from an adjacent sub station. The current for each unit of 156 cells is supplied by a rotary converter of 5,800 K.V., output at 580 volts, and 10,000 amperes maximum capacity.
The current flows through the cell in series, from the anode bus on the outside of an end tank to a cathode-anode on the outside of the tank. With a current of 10,000 amperes, the current density is 29.8 amperes per square foot of cathode surface. (The submerged area of cathode surface is 12.4 sq. ft. per plate.)

ZINC CASTING

After the zinc has been brought to the charge floor from the tank house, it is picked up by a double pronged hook attached to a hoist. These hoists convey the zinc sheets to a chute where they slide into the furnaces.

There are two large furnaces and two smaller ones. One of the small furnaces is used for the mixing of certain batches of zinc. The other small furnace is used for recovery purposes.

Each large furnace has two mold racks with 40 molds per rack. These molds can be changed for the different brands of zinc. When full, each mold will hold fifty pounds of zinc. This can be used for an estimation of the production of zinc at this plant. During a shift one hundred and twenty rounds can be cast. Estimating one ton per round, this is one hundred and twenty eight tons per shift. Zinc is cast on two shifts only, so the production per twenty-four hours is two hundred and fifty six tons.

Every 84 hours the dross, consisting chiefly of zinc oxide, which floats on the surface of the bath, is skinned off. The dross is put into a rotating drum with ammonium chloride, in the ratio of about 1:400, to free the adhering zinc particles from the dross. The freed zinc runs into a small recovery furnace.
When no more zinc runs out of the drum, it is tipped and zinc oxide, and any remaining free zinc runs into a cooler. The cooler is a cylindrical tube that rotates much like a rotary kiln. Water is poured on the zinc oxide and any molten zinc present. The molten zinc solidifies and comes out the end of the cooler, and the zinc oxide falls through a screen into a hopper. The zinc oxide is emptied periodically from the hopper and taken to the zinc leach.

The zinc from the recovery furnace is poured into a small ladling pot and taken to an intermediate floor in the casting building. The zinc dust to be used in the purification of the leach solution is made at this part of the plant. The molten zinc is poured into a reservoir having three small holes in the bottom. The zinc runs from these holes and is intercepted by a blast of air under a pressure of 20 psi. This cold air immediately granulates the zinc which falls into a storage bin. The zinc is taken as needed, from this bin, to the zinc leach.

The cast zinc is stacked and bound with steel bands. It is then loaded into railroad cars and shipped to buyers.
Conclusion

The flow of materials has only been discussed very briefly. Also equipment, chemistry, and theory were only touched upon. It would take a separate and very detailed report to describe each of these as they should be discussed.

Management and labor were not mentioned because it was impossible to obtain any exact figures. To consider the labor force and the jobs, efficiency, and actual positions of these men would take much research.

In general the zinc process at Anaconda is fairly good. The roasting is rather crude and could be improved by using modern roasting methods, such as the FluoSolids of flash roasting. The transfer of materials in certain places could be greatly improved by the installation of conveyors and modern tramming equipment. Of course changes, such as those mentioned, would be very costly but would probably pay for themselves in a matter of a few years.
APPENDIX I

Flow Sheet of Zinc Concentrator

Ore
2 Jaw Crushers
3 Gyratory Crushers
Double Deck Vibrating Screens

Undersize -> Sands
Tails or Flotation

Splitter
3 Rod Mills
10 Ball Mills - Classifiers
Sampler
3 Conditioner Banks

15 Banks of Flotation Cells
Concentrate
3 Dorr Thickeners

CuSO₄, Mineracl

Sodium Cyanide | Zinc Sulfate
Propyl Xanthate | Carbonol

Conditioner (140°C)
3 Banks Flotation cells

Pb Conc. -> Thickeners
Thickeners
Filter
East Helena

Zinc Conc. -> Thickeners
Filter
Roasters
Flow Sheet of Zinc Roasters, Leach, Tank House, and Casting

Zinc Concentrate
  └── Roasters
      └── Dust
          └── Calcines
              └── Gases
                  └── Stack
                      └── Screens
                          └── Oversize
                              └── Undersize
                                  └── Neutral Leach
                                      └── Classifiers
                                          └── Overflow
                                              └── Thickeners
                                                  └── Spigot
                                                      └── Purification
                                                          └── Filters
                                                              └── Residue
                                                                  └── Filtrate
                                                                      └── East Helena
                                                                          └── Storage
                                                                              └── Electrolytic Cells
                                                                                  └── Spent Electrolyte
                                                                                         └── MnO₂
                                                                                             └── Cathode
                                                                                                 └── Zinc
                                                                                                     └── Casting
                                                                                                         └── Dross
                                                                                                             └── Slabs
                                                                                                                 └── Zinc Dust
                                                                                                                     └── Market
                                                                                             └── Acid Leach
                                                                                                             └── Thickeners
                                                                                                                 └── Spigot
                                                                                                                     └── Filter
                                                                                                                         └── Residue
                                                                                                                             └── Filtrate
                                                                                                                                   └── H₂O
                                                                                                                                 └── Filter
                                                                                                                                                  └── Residue
                                                                                                                                                    └── Dry
                                                                                                                                                                                                                      └── East Helena

19.
Appendix II

Bibliography

