Light Metals

## UTILIZATION OF HORIZONTAL BELT FILTERS FOR

## WASHING FINE ALUMINA SEED AND KILN FEED PRODUCT

### BY

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### Introduction

In the processing of bauxite to produce alumina ($Al_2O_3$) for ultimate production of aluminum by electrolysis, the product must have a high purity and a closely controlled size distribution. As the entire alumina flowsheet involves fluids of high caustic concentration, one of the critical measures of product purity is the sodium content. This should be a maximum of 0.04 Wt% soluble $Na_2O$. In the United States, smelters are based upon sandy alumina. Generally, sandy alumina trihydrate ($Al_2O_3 \cdot 3H_2O$) prior to calcining should have a size distribution in the range of 95% +44 microns and only a very small amount of -20 micron material to meet final alumina product size requirements.

While product quality is mandatory in alumina processing, other factors which significantly influence operating cost, must be considered. First, any water introduced into the flowsheet must be thermally evaporated either in specially designed flash tanks and evaporators or in the product calciners. The alumina industry employs evaporation units which generally remove approximately four pounds of water for every pound of steam. With today's increasing energy costs, it is very desirable to reduce water inputs for filter cake washing in order to reduce evaporation energy consumption.

Secondly, moisture content of product kiln feed should also be minimized. Additional energy must be added over that required for the calcination reaction as the feed moisture increases.

Third, caustic soda must be recovered efficiently for obvious economic reasons. Thus, the final product purity of 0.04 Wt% soluble $Na_2O$ maximum reflects this necessity as well as aluminum reduction plant requirements. It is stressed again, however, that $Na_2O$ recovery should be achieved while minimizing wash water input.

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Finally, organic material in the bauxite and from other inputs converts partially to sodium oxalate in the high pressure/temperature leach and the following processing steps. If the oxalate is not removed, serious processing problems occur. If oxalate concentration is too high, particle size distribution control is adversely affected in the alumina precipitation process. Yield will also decrease and this increases energy consumption and cost. Sodium oxalate concentration on the hydrate seed in the precipitation section should be held to a maximum of 0.1%.

Improving the efficiency of both the oxalate removal and the kiln feed deliquoring and washing steps can reduce process energy consumption and improve product quality.

The oxalate removal step can be achieved by deliquoring the fine alumina trihydrate used as seed for crystal growth in the precipitators, displacing the filter cake liquor with cold water to recover caustic values and then washing the cake with hot water to solubilize the oxalate. This filtrate can then be processed to remove the oxalate. This can also increase the capacity of the precipitators by removing an appreciable quantity of spent liquor.

The deliquoring step prior to the product kiln must achieve both the required purity and minimize wash water input. Additionally, the moisture content must be lowered to a maximum of 10 Wt%.

It is felt both steps can be improved over present practice through the use of horizontal belt filters. The Eimco-Extractor®, which is a horizontal belt filter, is shown schematically in Figure 1. The unit consists of an elastomer drainage belt which slides over a vacuum box. By proper construction, the drainage holes through the rubber belt are confined to the vacuum box opening. Low friction coefficient fluorocarbon plastic slide plates are employed to reduce horsepower drive requirements. A filter media rides on top of the drainage belt on the upper portion of the filter. Synthetic fiber cloths are employed. Because of the design, all filtrates (strong, first wash, second wash, etc.) are isolated by vertical baffles in the vacuum box so they can be separated. Accordingly, countercurrent washing can be practiced. This is very important in reducing water consumption in kiln feed dewatering. This feature also permits the segregated hot and cold water washes for oxalate removal. In addition, the filter cloth is returned to the head end of the filter where it can be washed to prevent blinding. This maintains high filtration rates and minimum moisture content.

Some of the design advantages of horizontal belt filters are:

1.  Good feed distribution. Because of the belt principle, feed can be more evenly divided across the width of the filter as compared to a circular disc shape.

2.  Efficient multi-stage washing of the cake. An even cake thickness is presented for cake washing and the washing fluids can be isolated by cylindrical rolls or flood dams riding on the cake surface.

3.  Variations in feed flow rate and solids concentration can be handled by these units. Cake thickness can be measured and controlled by automatic belt speed variations. Such flexibility is important to maintain product quality.

4.  Operator visual analysis of the entire filter operation. The horizontal surface is entirely exposed so that any upset may be quickly observed and the operation can be "fine-tuned".

5.  Effective washing and chemical cleaning of the filter media. By use of headers with appropriate spray nozzles, the cloth, which is returned to the head end in a separate path from the drainage belt, can be washed as required. If scaling occurs, the cloth can be washed with appropriate chemicals.

6.  Because of the rectangular construction, floor space efficiency is increased. Also, spare filters can be more economically employed to increase availability and improve operating factors.
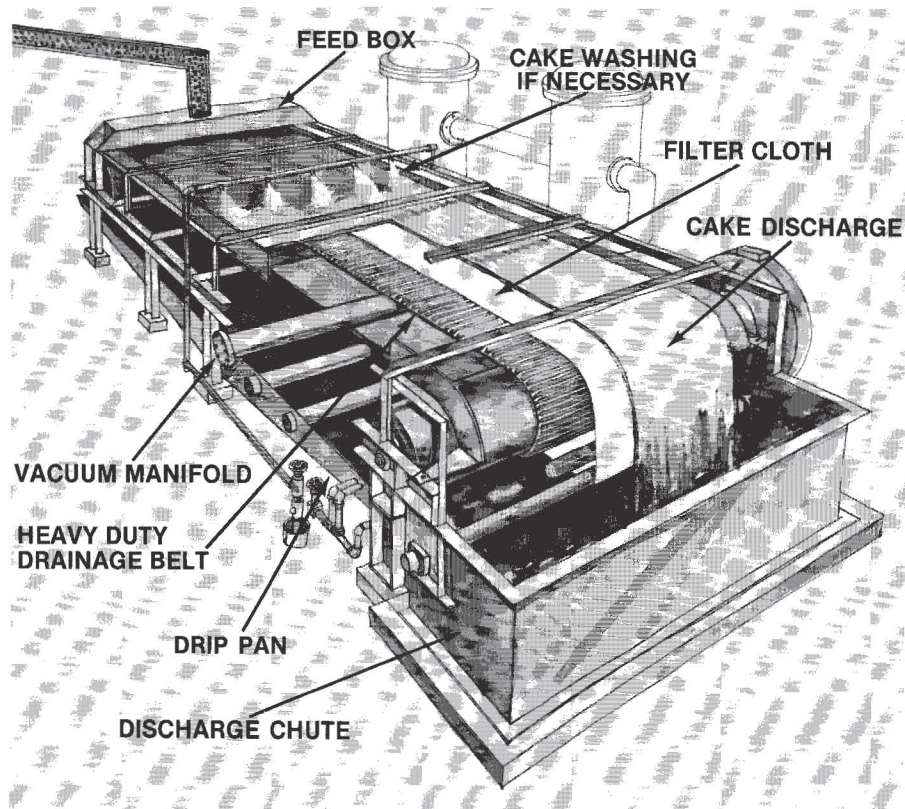


Figure 1
Schematic of an Eimco-Extractor

### Application Development

#### Seed Washing

In precipitation, alumina trihydrate is recovered from the sodium aluminate liquor. A major operating objective in the precipitation process is to obtain the maximum yield consistent with the required particle growth. Since the undersize hydrate is recycled as seed, particle growth must be controlled to obtain a balance between the seed produced and that required to obtain a specified product. This requirement is particularly critical in plants producing coarse alumina.

Contamination of process liquor impairs both yield and particle growth. Sodium oxalate in sufficient concentration in the liquor coprecipitates with alumina hydrate. The solid oxalate tends to concentrate with the fine seed hydrate and can further generate a large amount of very fine hydrate during the precipitation cycle. Removal of oxalate crystals from the seed circuit is sometimes necessary. This can be accomplished by seed heating, seed washing, or selective oxalate crystallization.

Kaiser developed a patented process for oxalate control which employs filtration and washing of fine seed. Facilities utilizing this oxalate removal system have been incorporated into alumina plants worldwide.

The use of the horizontal belt filter was proposed for this application since it had the potential to improve both the installation and operating costs of the seed washing operation.

#### Kiln Feed

The final unit operation in the Bayer process is calcination, where hydrate is converted to alumina. The function of the hydrate filters is to deliquor the hydrate slurry and recover soluble soda prior to calcination.

The soda content of the filter cake directly affects product quality and the amount of wash water required for soda recovery affects plant evaporation requirements. The moisture content of the filter cake influences calcination fuel requirements.

The use of horizontal belt filters for kiln feed service was proposed as a potential method of improving both installation and operating costs.

#### Pilot Scale Testing

A development project was carried out at Kaiser Aluminum & Chemical Corporation's Baton Rouge Works in 1970 to evaluate horizontal belt filters in seed washing and kiln feed filtration operations. Pilot scale tests were conducted using an Eimco-Extractor having 0.98 $m^2$ (10.5 $ft^2$) of effective filtration area.

A total of 70 pilot scale tests were run. The seed washing studies encompassed 57 tests and the remainder evaluated operation in kiln feed service. Conclusions based on these studies included:

Seed Washing - Oxalate removal could be accomplished effectively on a single-stage horizontal belt filter with a fine seed handling capacity of 1220 - 1464 Kg dry solids/hr-$m^2$ (250 - 300 lbs/hr-$ft^2$) of filter area under vacuum.

Kiln Feed - Efficient kiln feed filtration could be accomplished using a horizontal belt filter operating with a hydrate capacity of 5855 Kg dry solids/hr-$m^2$ (1200 lbs dry solids/hr-$ft^2$) of filter area under vacuum.

Operation - With comparable feed rate and feed properties, the horizontal belt filter could provide better control and require less wash water than other methods.

## Laboratory Scale Testing

Bench scale testing and analysis is commonly performed on many different applications to predict full-scale results. By proper correlation methods (developed from basic theory) filter station requirements can be reliably develped for such important items as discharged cake moisture percent, content of cake with respect to solubles, required wash fluid volume and number of wash stages to achieve desired solubles recovery, and filtration rate per unit area. Furthermore, performance results over a wide range of operating conditions can be predicted.

Many times, it is essential to conduct such experiments in the operating plant. This is the case in alumina processing. Properties of alumina trihydrate slurries can change significantly when samples are shipped to a different location. It is also more convenient, because representative feeds can easily be obtained, difficult analytical procedures are routine, and normal wash fluids with respect to chemical concentration for solubles recovery tests are readily available. Accordingly, bench scale test work has been done in several operating alumina plants on red mud, hydrate seed and product alumina filtration and cake washing, as well as countercurrent sedimentation for separation of red mud and pregnant liquor.

In addition to pilot scale test programs, many bench scale filtration tests have been run to obtain data necessary to size Eimco-Extractors for specific applications. A brief description of the laboratory test procedure which simulates each of the component steps of a commercial Extractor using a test filter apparatus follow:

Equipment - The basic equipment (refer to Figure 2) for bench scale testing of horizontal belt filter application consists of a small drainage grid covered with filter cloth and surrounded by a shim. This filter leaf is supported vertically by a vacuum flask. All system pipes and tubing are of large bore to minimize hydraulic restrictions. A second vacuum flash (not shown in the sketch) is filled with cool water to maintain the vacuum system air at a standard temperature. A gas meter is attached at the discharge side of the vacuum pump to measure airflow though the filter cake.
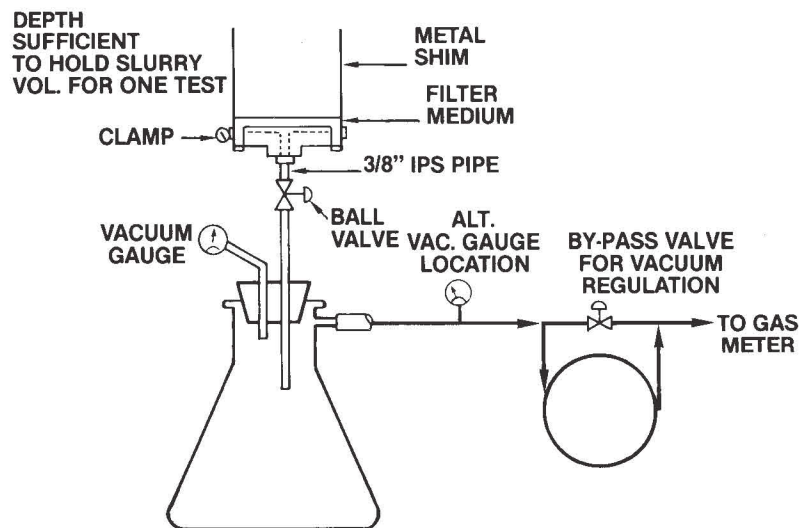


Figure 2
Bench Scale Extractor Test Arrangement

Feeding - A premeasured weight of slurry containing the specified dry cake weight is poured onto the filter leaf surface. Vacuum is immediately applied at the desired level. The time required to form the filter cake (when the last free liquor disappears from the cake surface) is recorded.

Washing - In tests simulating single stage washing, a known volume of solute free wash water is applied after a specified prewash drying period, and the wash time recorded. Countercurrent washing is simulated by using a first wash of known volume and soda concentration, following a drying period, and then applying the final wash using a known volume of solute free water.

Drying - The cake is then allowed to dewater for a predetermined drying period. After releasing the vacuum, the cake is removed from the filter leaf into a container which is sealed immediately and saved for laboratory analyses.

Data from the laboratory filtration tests are reduced, correlated, and usually presented graphically. Correlations developed include:

1.    Cake dry solids weight and filter cake thickness relationship

2.    Filter cake weight and cake formation time

3.    Percent solubles removed and cake wash displacements

4.    Cake moisture and dry time correlation factor

5.    Air flows and dry times

Scale-up factors between bench and full-scale operation have been evaluated. The factors developed in the laboratory tests have proven reliable for sizing Extractors and vacuum systems.

Laboratory tests conducted in this manner have been utilized to size the Extractors for Kaiser's plants as well as for other services.

### Design Considerations

From the previous experimental work and analysis, the Extractors were designed for the two applications. It should be noted that the six advantages of the horizontal belt filter cited in the Introduction were essential to improving the two applications over previous methods. The particular design considerations for the two applications will be considered separately.

## Seed Filtration and Oxalate Removal

Feed slurry design conditions were:

Suspended solids concentration - 35 Wt%

Oxalate concentration on dry solids basis - up to 2.5 Wt%

Solids size distribution         - 12 – 25% +200 mesh
                                  - 40 – 70% +325 mesh

Feed temperature - 68°C (155°F) max.

Caustic concentration in liquor as NaOH - 12 – 15 Wt%

The first cold water wash should be no more than 0.33 Kg wash/Kg dry solids. It should be noted that this is approximately a 1.0 wash displacement (volume of wash/volume of liquor in the cake prior to wash) in order to maximize the caustic strength in the filtrate. The remaining caustic left in the seed will be recovered from the oxalate filtrate (hot water wash) after the oxalate is removed from the liquor. Thus, the cold wash filtrate will be combined with the strong or mother liquor filtrate with minimum dilution.

Hot water wash should range from 82 - 93°C (180 - 200°F) and 0.85 - 1.0 Kg wash/Kg dry solids, as it is essential to obtain a low concentration of oxalate in the final solids. This is about a four-displacement wash.

The discharged cake should have a maximum moisture of 20 Wt% with no more than 0.05 Wt% of oxalate on a dry solids basis. Another important factor is the suspended solids content of the strong and cold wash filtrates. This liquor will eventually return to digestion, and any solids will be resolubilized. As this consumes additional energy, a filtrate suspended solids content of only 20 mg/liter is desirable.

The flowsheet for the Extractor station is illustrated in Figure 3. It will be noted that the hot water wash is split into two parallel parts to ensure efficient oxalate removal. Also, this filtrate is segregated from the strong and cold wash filtrates by a separation baffle within the vacuum box. As this seals against the drainage belt, a different vacuum from the previous section can be applied if necessary.
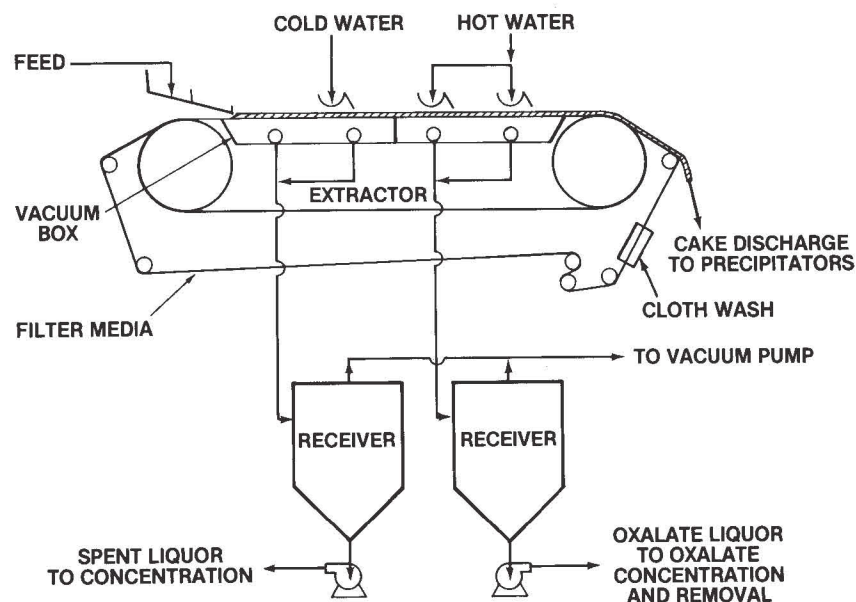


Figure 3
Extractor Flowsheet
Seed Filtration and Oxalate Removal

It is essential that the feed be spread evenly across the width of the Extractor. Thus a special double cascade sawtooth weir is employed to ensure an even cake thickness for most effective cake wash.

Cake wash is practiced with open type weir wash boxes with an elastomer impingement skirt. This ensures an even "gentle" addition of wash water without disturbing the cake.

Side plates on the top of the vacuum box are constructed of a low friction coefficient special fluorocarbon plastic. The slide plates are lubricated by injection of water to further minimize the friction between the traveling drainage belt and the stationary slide plate. The vacuum box is also fitted with protected screw activators, which lower the boxes for easy maintenance. As the caustic liquors are scaling in nature, it is essential to provide for easy and frequent descaling to maximize availability.

The special filter cloth required for good filtrate clarity can be washed continuously if necessary on one or both sides to prevent blinding. High impact spray nozzles are used. This is also true of the elastomer drainage belt.

A drip pan underneath the body of the filter extending the full length of the extractor is also employed to capture any spillage plus the cloth and belt washes.

Belt speed was made variable over a seven : one speed range so that the unit can accommodate available feed slurry. As the feed fluctuates, the speed can be tuned to the feed rate to optimize cake thickness.

Materials of construction in direct contact with the feed, filtrate or cake are stainless steel 316, fiberglass, reinforced polyester, polypropylene plastic (EimcoMet), neoprene covered steel on rolls and pulleys, and Ethylene Propylene Terpolymer drainage belts. These specifications are mainly influenced by the caustic and high temperature.

The Extractors have 25.6 m$^2$ (275 ft$^2$) of effective area under vacuum. Design is based on 843.5 metric tons/day (930 short tons/day) of dry solids maximum to each unit.

Product Kiln Dewatering and Washing

As the plant produces sandy alumina, the feed solids are 96 - 99% +325 mesh with 2 - 10% +100 mesh. The feed solids concentration varies between 45 - 47 Wt% with a caustic content in the liquor of approximately 7% as NaOH.

A two stage countercurrent wash is employed to achieve a leachable $Na_2O$ content in the final product of 0.02 - 0.04 Wt%. Because of the high caustic concentration in the feed liquor, a very high recovery of $Na_2O$ must be achieved. The countercurrent wash minimizes input water. Wash water rate to the second wash is between 0.3 and 0.4 Kg wash/Kg dry solids.

Feed temperature is 74 - 85°C (165 - 185°F). Input hot water wash is 85 - 96°C (185 - 205°F). The strong filtrate and first wash filtrate are combined and returned eventually to digestion as spent liquor.

The flowsheet for the Extractor filter station for product kiln feed is similar to Figure 3 except that there are only two wash boxes and the second stage wash filtrate is returned to the first stage wash.

Materials of construction are similar to those employed for seed filtration. This is also true for the design of vacuum boxes, feed and wash boxes, cloth and belt wash systems and filter media. However, flood dams are also included. These are elastomer membranes which ride on the cake and prevent mixing or run-back between feed and first and second washes on the surface of the cake.

Extractors of 94 ft$^2$ of effective area each under vacuum were employed to process 26.7 - 32.2 MTPH (29.4 - 35.5 STPH) of dry solids and produce a cake moisture of 10 Wt% maximum. However, they are designed to process up to 45.8 MTPH (50.9 STPH) at a discharged cake moisture of 12 Wt% maximum for peak demands.

### Plant Experience

Kaiser Aluminum & Chemical Corporation has purchased several Eimco-Extractors for use in the Baton Rouge and Gramercy plants. Applications are detailed in Table I.

### TABLE I

### EIMCO-EXTRACTOR APPLICATIONS

### BATON ROUGE AND GRAMERCY PLANTS

|  | Extractors | | | | |
|---|---|---|---|---|---|
|  |  |  | Individual Filtration Area | | Date |
| Service | Number | Model | Ft$^2$ | M$^2$ | Installed |
| Substrate Alumina (gel) | 2 | 828 | 212 | 19.7 | 1970 |
| Fine Alumina Filtration | 1 | 4624 | 101 | 9.4 | 1972 |
| Kiln Feed | 1 | 4624 | 101 | 9.4 | 1975 |
| Sodium Dawsonite | 1 | 9630 | 256 | 23.8 | 1977 |
| Seed Washing | 3 | 6945 | 275 | 25.6 | 1982 |
| Substrate Alumina (gel) | 2 | 6945 | 275 | 25.6 | 1982 |
| Kiln Feed | 7 | 4624 | 94 | 8.8 | Delayed |

#### Seed Washing

Three Model 6945 Extractors were installed for use in seed washing service at the Baton Rouge Plant in 1982. Figures 4 and 5 show the feed and discharge portions of one of the Extractors. The distinct color difference between these two points with the white color of the discharged seed is readily apparent. The requirements for these filters included:

Capacity - 77,500 pounds of fine seed solids per hour per filter (1340 Kg/hr-m$^2$ - 275 lbs/hr-ft$^2$) with a feed solids concentration of at least 35 Wt%.

Filter Cake - Oxalate content of 0.05% or less on a dry basis and a moisture content of no more than 20 Wt%.
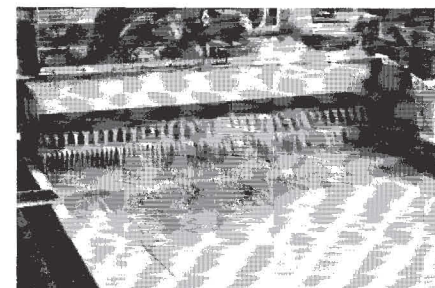


Figure 4
Feed End of Extractor
Seed Filtration - Oxalate Removal

Performance of these filters was satisfactory during the period they were in operation. However, production at the Baton Rouge Plant was curtailed before operation was completely optimized.
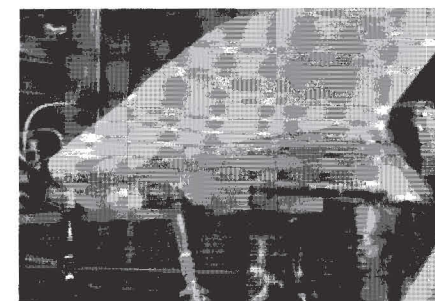


Figure 5
Discharge End of Extractor
Seed Filtration - Oxalate Removal
Note Color Difference from Feed

During start-up, problems were experienced with liquor dripping on the cloth alignment devices and the method of cloth connection. These were solved by design changes.

Problems remaining when production was curtailed included:

Capacity - Above 80% of design capacity had been demonstrated with a feed solids concentration of 30 - 32%. Efforts to increase the feed solids concentration were in progress. It is felt that design conditions would have been achieved.
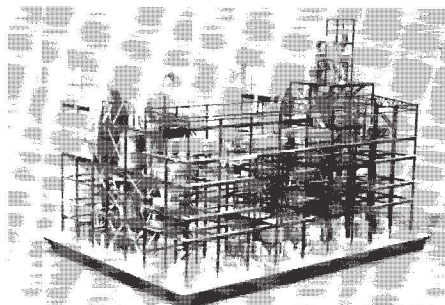
Figure 6
Calcination Plant Model
Fluid Bed Calciner Plant
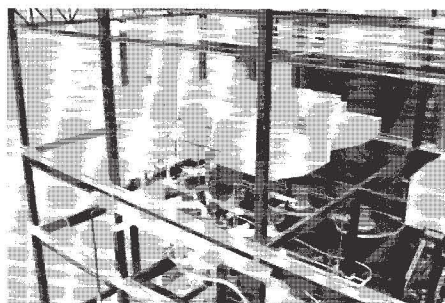Six Extractors in Foreground



Figure 7
Calcination Plant Model
Two Extractor Stations Close-Up

Cloth Alignment   - A program to address the problems of maintaining alignment over the entire filter length was being developed when production was curtailed.

The three major operations associated with seed washing are bulk liquor removal, liquor displacement with cold water, and a final hot water wash to remove sodium oxalate. Performance of these filters showed that these three operations can be satisfactorily accomplished in a single unit without repulping between stages.

### Kiln Feed

A Model 4624 Extractor was installed for use in kiln feed service at the Gramercy Plant in 1975. Performance of this unit has shown:

Capacity   - Up to 5855 Kg dry solids/hr-m$^2$ (1200 lbs dry solids/hr-ft$^2$) with cake moistures of about 13% and satisfactory soda control. Lower cake moistures are obtained at lower operating rates.

Maintenance   - Lower maintenance costs and better operating factors than other methods for this service.

Wash Water   - Lower specific wash water consumption than other methods.

Because of the successful application of the extractor to kiln feed service at Gramercy, Extractors were selected for the new filtration facility connected with the installation of fluid bed calciners at Baton Rouge. Operating data is not available since construction has been delayed due to the production curtailment of the Baton Rouge Plant.

Design of the Baton Rouge fluid bed calcination facility consisted of four calciners and seven Model 4624 Extractors. Figure 6 shows the model constructed for design purposes with six Extractors positioned on an upper floor. Figure 7 is a close-up of two of the Extractor stations. One filter was dedicated to the "special alumina" calciner. The remaining six filters were designed as a multiple filter arrangement with two filters feeding each reduction grade calciner. Each filter was capable of supplying approximately two-thirds of its calciner's hydrate requirement. The requirements for these filters included:

|  | | Normal | Maximum |
|---|---|---|---|
| Solids | - lbs/hr-ft$^2$ | 625 - 756 | 1074 |
|  | - Kg/hr-m$^2$ | 3050 - 3690 | 5240 |
| Free Moisture (% by Wt.) | | 8 - 10 | 12 |
| Leachable Na$_2$O (%) | | 0.02 - 0.04 | 0.065 |
| Wash Water Rate (Kg/Kg Dry Cake) | | 0.3 - 0.4 | 0.5 |

Final evaluation of these filters will be made when they have been installed and operated for a sufficient period of time.

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