UPGRADE SCHEMES FOR GRANULATION PRODUCTS

by

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Presented at the local AIChE meeting
at
Clearwater, Florida

May 1999

DRIVING FORCES BEHIND BETTER FERTILIZER QUALITY

Most of the granulation plants in the US have been upgraded with the objective of increasing capacity and on-stream factors. These upgraded plants found ways to produce more product but often at the expense of reduced product quality. Up until the last five to ten years, very little attention was paid to increasing product quality. New developments in the way fertilizers are blended and used is pressuring producers into taking a more serious look at their product quality.

It should come as no surprise that your customers dictate the need for higher quality. Who are the customers? For the high analysis fertilizer grades generally made in the USA (MAP, DAP, and GTSP) , the customers, for the most part are bulk blenders and a lesser amount is still used directly by the farmer as straight high analysis fertilizers. In the past, these customers would accept anything that met the proper chemical analysis. But in recent years, they have become more sophisticated by using computers to calculate formulations. They have better blenders to turn out custom made fertilizer blends to meet the exact need of every crop. Another change was the demand for more complex blended fertilizers. In the past, formulations were made with a little overage for each nutrient to correct for insufficient blending and to compensate for segragation while in storage or enroute to the user.

Another driving force in the picture is new state laws inforced by state inspectors. Inspectors sample the shipments and if a blended fertilizer has undergone significant segregation while enroute, it could failed to meet the specified grade analysis. This happened frequently in the past and the blenders had to pay the freight to return the shipment.

The bulk blenders have solved segregation problems by simply demanding that all raw materials be more uniformly sized. When this is done, they do not have segregation during shipping, they do not have to over formulate and they pass the state inspectors test. The blenders paid the bill for over formulations to compensate for the wide variation in product quality. The blenders, now want you (the producers) to make the fertilizer so that it will not segregate and so they do not have to over formulate.

A complete fertilizer is typically a blend of some of the following ingredients MAP, DAP, GTSP, ammonium nitrate, ammonium sulfate, potash, urea and many other micronutrients. In general, all of these ingredients have made some improvements in their individual quality and have resulted in better more reliable blended products.

In the past, the bulk blender had to slow things down to accomodate the poor quality of urea or choose not to use urea in a blend. Thus, most of the other fertilizer ingredients received little pressure to improve on quality. Now, the situation has been reversed, most of the fertilizer ingredients have improved their quality and the phosphate fertilizers are the ones that appear to be lacking in uniformity and sphericity.

Basically, the bulk blenders are asking for larger, harder and more uniformly sized granules to prevent segregation which prevents them from having to over formulate. The phosphate producers have made considerable progress in both the size and the uniformity of the granules. However this is not the whole story. It seems that in the last few years, a new farm machine has caught the farmers eye and most of the larger farms are beginning to use this new machine. It is called the Air Seeder. The Air Seeder is ideal for planting seeds and can also be used to apply fertilizer. It has multiply small plows mounted on a beam that spreads out 30 to 60 feet wide. This wide beam mulitple plow system is pulled behind a tractor along with a double hopper on wheels. The bottom of the hoppers are equipped with a pneumatic conveying blower which distributes the seeds and fertilizer to each plow through a series of small hoses. My research into this machine has uncovered certain facts as follows:

- Seeds are easy to handle with the air seeder.
- Fertilizer dust and fines tend to plug up the smaller distribution hoses.

After calling a couple of these air seeder vendors, it was pointed out that the air seeders are sensitive to oversize lumps due to caking caused by humid conditions. What they would like to see in fertilizer quality is more uniformly sized granules, more impact resistances and very near spherical particles. It became evident that the air seeder has emphasized the same properties as the bulk blenders demanded but have added one more property known as sphericity.

Figure 1.0 shows a sphericity apparatus for measuring roundness of granular fertilizer. It was developed by IFDC and can be purchased directly from them. (1) It feeds a sample of granules to an inclined belt conveyor. The rounder particles roll backwards and fall off the lower end of the conveyor while the irregular particles stay on the belt conveyor and fall off the higher end of the conveyor. The sphericity is expressed as a percent of the total sample that is round. Some producers are using this apparatus to determine what variables in the granulation process actually increase the sphericity of the granules.

DEFINITION OF FERTILIZER QUALITY

The first problem with quality of a fertilizer is that it is not well defined. A few years ago, it was acceptable quality if the product had the proper nutrient analysis, less than 1% moisture , the size had to be 95% -4+12 mesh (95% -4.7+1.4mm) and the granules were hard enough to hold up well in bulk storage without much degradation. Today, the term quality varies from producer to producer. Some producers are committed to produce a superior quality product while others are just trying to meet their individual customers specifications.

Who sets the standards for fertilizer quality? The answer to this question is, its the bulk blenders who are trying to please their customers the air seeder users. They do this by notifying the producers that a customer has a complaint.

Where is fertilizer quality measured? It is measured by the producer before it leaves the manufacturing plant, by the bulk blender as he receives the shipment and by the state inspector at its final destination.

What is the current fertilizer quality? Each producer knows the answer to this questiion because it varies with the individual customers. For this reason, the granulation plants need to be capable of varying the product quality to suit each customer.

What is the average fertilizer quality? After taking a poll of local producers and some of the bulk blenders, the overall consensus on this question is, the fertilizer products need to be larger, harder, more spherical and more uniformly sized. Table 1.0 shows a general idea of the current and future quality of MAP/DAP fertilizer. (3)

What can we expect the future quality to be in the next few years? This is just a prediction on the authors part based on what he has learned while preparing this paper. Fertilizer product physical quality in the next 5 to 10 years may have the following properties:

TABLE 1.0
CURRENT & FUTURE MAP/DAP FERTILIZER QUALITY

PROPERTIES	CURRENT (3) AVERAGE	FUTURE PREDICTED
Sign Guide No.	260-315	330-350
Uniformity Index:	45-61	>70
Moisture Content:	1.5 % max	< 1.0%
Hardness:	12-17 lb	20 lb
Sphericity:	55-65%	70-80%

UPGRADE SCHEME FOR IMPROVING QUALITY

The upgrade scheme for improving quality is somewhat different and can be in direct conflict with increasing production. This is not a very popular concept in a phosphate plant and its not surprising why it had to wait until the customers forced the issue. Now, most producers are committed to produce a superior granular product.

The following scheme should provide engineers with some ideas about where to start and how to change our way of thinking to improve product quality.

1. Recycle Rate

The first big decision is what minimum recycle ratio is going to be used for the upgraded plant based on the future production rate. Many plants seem to operate with a recycle ratio of less than 3 : 1 but the product made at these low recycle ratios is not pretty. Quality is a mysterious property that seems to come and go in granulation plants. It generally improves when a plant reduces production rate and quality degenerates when the plant increases production rate. Most operations seem to produce better quality when the recycle rate is above 4 to 1. Based on this information, a minimum recycle ratio of 4.5 : 1 is considered a minimum place to begin the upgrade project. Once you have set the recycle rate you can calculate a production rate and the producer may have to live with it.

2. Recycle Quantity

Besides the recycle rate, there is another more important recycle related factor that must be considered to have a major impact on product quality. Figure 3.0 shows that the recycle system holdup quantity in a typical 100 stph plant, contains only about 97 tons of material. The system retention time based on the production rate (100 stph) is approximately 58 minutes. This means that the plant must grow 100 tons of product size material in 58 minutes. The recycle turnover time is 14.5 minutes. This means that the entire holdup (97 tons) passes through the granulator once every 14.5 minutes. If the recycle rate was higher say 500 tph, the turnover time would decrease to 11.6 minutes. Thus, a lower turnover time, provides more chances for growing the granules in the granulator. Each time this 97 tons of recycle passes through the granulator it gets sprayed at least four times with feed slurry which equates to 16 to 20 sprayings per hour. When you think about this you should be able to explain why higher recycle rates generate better quality products.

3. Recycle Size Distribution

The optimum recycle particle size distribution is the key to growing the particles at a rate that is equal to or more than the production rate. If you want to produce larger particles at higher production rates you must control the size distribution of the recycle stream. Some producers run screen analyses of the recycle to alert them when the system is entering into a fines or oversize cycle. This gives them a chance to take appropriate action without reducing the production rate. More recently, a new technique has been developed by Norsk Hydro called On-line Imaging Photography. (9) This apparatus continuosly samples a stream of solids, then feeds the sample past a strobe light and video camera. The camera takes a picture of the particles when the strobe light fllashes and the resulting picture provides the means to measure the size of all the particles in the sample. When connected to a computer containing the developed software, it will plot a complete screen analysis curve, calculates the size guide number, uniformity index and sphericity of the granules.

With this on-line analyzer installed in a plant, it will be possible to study the variables that really affect the growth rate and sphericity of the granules. When operators gain some experience with this technique, they will be able to plot a curve of the optimum size distribution on the computer and compare it to actual on-line analyses and when the actual curve bulges out to the left of the optimum curve they will know that the system is getting too fine. Likewise, when the actual curve bulges out to the right of the optimum curve, they will know that the system is getting too coarse. Hopefully, by then they will have a means to take appropriate action to make the system return to the optimum size distribution.

4. New Mass Balance

Prepare a new mass balance based on the new production rate and recycle ratio. From this balance start predicting how changes in the acid and ammonia splits affect the properties of the granulator feed slurry, granulator liquid phase, dryer inlet temperature, and determine if each piece of equipment can handle the new flowrates at all of the possible conditions.

5. Identify and List Quality Impacting Equipment

The process of determining if a piece of equipment has an impact on quality is relatively simple. In fact most of the solids handling equipment has some impact on quality. Some tend to improve quality while some tend to decrease quality. And some equipment does both. Sorting the list and prioritizing it should be a helpful approach.

Reactor Slurry
Granulator
Dryer
Screens
Mills
Recycle Flight Conveyor
Fines Return Rate

6. Reactor Slurry

Since granulation theory teaches us that the liquid phase in the granulator controls the granulation rate, the properties of the reactor slurry should be studied in more detail to determine the effects each of its properties has on granule growth rate and shape. In the past attempts have been made to concentrate this slurry to the maximum that can be pumped in order to minimize the water entering the granulator. Perhaps a more dilute slurry will show better handling and distribution properties. A more dilute slurry will be less viscous, have a lower specific gravity, and its temperature will be lower. Some of these variables will have an effect on the spray pattern and its coating characteristics as it is distributed in the granulator.

Another important variable is the degree of ammoniation in the reactor. There is at least one reference reporting that more ammoniation in the reactor and less in the granulator decreases the production of fines. (5)

7. Granulator

The initial birth process of the granule begins inside the rotary drum granulator so it should be considered the most important quality impacting piece of equipment. Many different operations occur simultaneously inside the granulator. The dry recycle material (mixture of fines, product and oversize particles) is sprayed with partially neutralized slurry and then reacted with ammonia. Crystallization occurs as the solubility decreases. The heat of reaction causes moisture to vaporize and all the while, the resulting damp, hot granules are continuously tumbled with each revolution of the granulator. Many attempts have been made to analyze the granulation process with the idea of optimizing the operation. However, due to the large number of variables that are not easy to control, very little progress has been made toward optimization.

There are several key things that need to be done in the granulator as follows:

- The speed of rotation needs to be adjusted so that the peripheral speed is about 320 to 340 fpm. The increase in the peripheral speed will promote better mixing, quicker release of moisture, improved product sphericity and shorten the retention time.

- Granulator ventilation flowrate should be directed to pass through the granulator so that it will assists in removing moisture from the granules and may reduce the buildup in the dryer feed chute. This can be done in two ways, use a small blower to supply air at the feed end of the granulator and vent the discharge end or simply vent the feed end of the granulator and pull air from the discharge end. The latter method seems like the best approach since it is countercurrent to the flow of material but this method tends to pick up a lot more dust and needs to be designed to meet this condition.

- The slope of the granulator encourages the forward motion of the granules and may have a minor impact on product quality.

- The position of the slurry spray nozzles, type of nozzle, and spray pressure all have a significant effect on the granulation process. This is where art comes in to play. Many different type of nozzles have been tried in the past but the hollow cone spray nozzles still comes out as the most practical all around nozzle. The position and angle of spray is critical to absorbing the maximum amount of ammonia and to dry up the bed. Maybe there is another arrangement of the sprays that will improve product quality but may not be optimum for production. There are new more energetic ways to spray liquids such as dual fluid nozzles and ultrasonic spray nozzles. Perhaps these should be studied for their effect on granule growth rate and sphericity.

- The ammonia sparger is buried under the rotating bed of granules and in this position it is detrimental to good granulation. The damp soft granules have to pass under or over the ammonia sparger and this process is damaging to at least some of the granules. The sparger support structure is even more damaging due to the large basketball size buildup that continuously breaks away and rolls around inside the granulator crushing granules under its weight. How can one study the effect of individual variables on granule quality when these lumps are wiping out any good effect that might have occured.

The best thing to do with the granulator ammonia sparger is to eliminate it but unfortunately, it is needed to meet the nitrogen content in the product. Decreasing the size of the sparger and the number of supports is the next best thing to do. However, most of the plants are operating at a rate that requires the sparger to be made of 2 or 3 inch diameter pipe with a minimum of three supports. This is one place where a better design is needed that is less damaging to the granules.

There is at least one good solution to this problem and it lies in the Espindeza's Pipe Reactor process that claims it can completely neutralize the slurry to a 1.95 N/P mole ratio in one step (inside the pipe reactor) and it does not require further ammoniation in the granulator.(10) Thus it does away with the granulator ammonia sparger. The author has witnessed a plant operating in this mode and it does produce a significantly noticable increase in sphericity and it could be due to the lack of an ammonia sparger. The internals of this pipe reactor are different from the TVA type pipe reactors and for this reason, a much higher N/P mole ratio can be achieved with the same ammonia slip as a conventional plant.

- After the reaction is complete, the granules need some time to roll freely inside the granulator to shape the granule and harden the surface so that it does not fall apart inside the dryer. In order to provide this extra space and time, longer granulators would be required. A design with a length to diameter ratio of 2.5 : 1 should be considered for new granulators.

<u>8. DRYER</u>

Most MAP/DAP dryers have a 7-9 minute retention time and during all this time the granules are lifted and cascaded through a hot air stream. The process of drying is important to producing a hard granule and this action in the dryer is beneficial to granule hardness and roundness. Large lumps also are lifted and dropped on to the rolling bed of granules. This action results in damaged granules and is considered non-beneficial to granule quality. Any action that eliminates these large lumps from passing through the dryer would improve quality. Some plants exist that have a lump crusher at the discharge of the granulator to reduce the size of those 6 to 12" lumps before allowing them to pass through the dryer.

Dedusting of the bulk material takes place in the dryer. Most of the dust carried out of the dryer with the air stream is recovered in a cyclone. This fine dust could be used to benefit product quality if it could be accumulated in a bin and continuously fed to the granulator at a controlled rate. Fines added to the granulator are the seeds that agglomerate easily when wetted with the slurry and form the initial small granule that begins to grow by the onion skin growth mechnism.

Dryers have a variety of lifting flight designs and they tend to vary the configuration of the flights along the length of the dryer. Some dryers even have blank sections 10 to 20 feet long with no flights. Any change in the flight configuration tends to change the rate of passage through the dryer. When a change in rate of passage occurs product will accumulate in some areas and thin out in other areas. This produces waves inside the dryer and can cause the recycle rate to vary. This is undesirable because it changes the liquid phase in the granulator and this has been known to interfer with the granule growth process. The elimination of all blank spaces and conversion of all lifting flights to the same "J" shape flight is recommended. This will give maximum air to solids contact and maintain a steady rate of passage throught the dryer.

9. SCREENING

The screens have a direct impact on the Size Guide No. and Uniformity Index (2) and these can be controlled by changing the screen opening size.

The screening requirements for increasing particle size and uniformity may seem to be straight forward but it has some complications. In order to get more larger particles into the product all you have to do is increase the opening size in the top screen deck. This would be acceptable to operations because larger openings do not blind off as easy as the smaller openings. However, when you increase the upper deck opening, it will increases the +4 mm particles in the product and this will reduce the amount of fines that are allowed in the product. For this reason, the opening size must be limited.

In order to increase the Size Guide No. of the product, the average particle size needs to increase and the only way to do this is to reduce the quantity of fines in the product. In order to do this, the bottom screen opening size needs to be increased so as to sift out more fines. Here again, this should be acceptable to operations since it will reduce the frequency of screen blinding problems. The larger screen openings in the bottom deck will return larger particles to the recycle and eliminate a portion of the finer particles in the product. These changes are relatively easy to make and the more open design should be able to increase capacity without reducing efficiency.

Screening problems occur when the recycle stream changes in particle size. In normal steady state operations, granulation plants seem to change the granule growth rate and the particle size of the recycle stream can vary from all fines to all oversize granules. Screening is something concrete that can be altered to increase or decrease its efficiency. The following are some of the things that would be nice to do:

- **HOW TO SEPARATE LARGE LUMPS FROM THE BULK OF THE GRANULES AND REDUCE THEM TO JUST LESS THAN PRODUCT SIZE.**

The average plant is already doing this but when it grinds the large lumps in one pass, it usually fractures the lumps into several smaller irregularly shaped particles. Another complication, is that the inside of these larger lumps are still wet and they need to return to the recycle conveyor without touching metal surfaces. The fractured particles are still larger than product size so they continue to grow larger. With each pass through the chain or cage mill they gradually are reduced to something less than product size particles. This rules out the possiblity of recycling the crushed material to the screen feed elevator and rescreening and recrushing the fractured material. This has been tried before and often resulted in plugged elevator feed and discharge chutes, and frequently blinded the screens. So, the way large lumps are handled now is still the best way to handle them.

- **HOW TO SEPARATE THE GRANULES THAT ARE SLIGHTLY GREATER THAN PRODUCT SIZE AND REDUCE THEM TO A MID SIZE PARTICLE.**

If this could be done, it would rid the plant of oversize conditions. This occurs when the recycle stream has an over abundance of particles just greater than 4 mm. When particles get larger than 4 mm there is no good way to get rid of them. The mills are just not very efficient at grinding this size particle. For the most part they pass through the chain or cage mill untouched and keep recycling until they finally get crushed.

Figure 3.0 is a suggestion for dealing with such a condition. The oversize chute from the screen contains a short section fitted with a fixed coarse mesh screen about 0.25 - 0.375 by 2 inches (6 to 9.5 by 50 mm) openings that would still allow all the larger lumps to roll pass and into the mill. The smaller +4 mm particles would fall through the openings and into a separate chute feeding a small vibrating pan feeder. This feeder would collect the +4 mm from each of two screens and deliver them to a smaller pin mill that would pulverize the +4 mm particles into -2 mm and smaller. This new mill would be sized to handle 5 to 10% of the oversize stream which would keep it under 10 tph. A slide gate would be required to open the flow through this special screen only when the plant gets into an oversize condition.

Figure 4.0 is a simpler method to accomplish the same thing. The last screen panel in the top deck would be replaced with a new coarse mesh screen with 0.25-0.375 by 2 inch (6 - 9.5 by 50 mm) openings. The large lumps would roll pass this screen and into the mill. The smaller +4 mm particles would easily pass into the product stream. The product would then be fed to the product polishing screen where the + 4 mm particles would get removed and delivered to a pin mill that discharges the disentergrated particles and sends them to the recycle conveyor. The oversize in the recycle would gradually decrease and the product would then proceed to the product cooler.

- **HOW TO IMPROVE THE EFFICIENCY OF FINES SEPARATION FROM THE PRODUCT SIZE.**

Figure 5.0 shows a scheme called "Quick Unloading Screens" that provides a way to modify existing screens to handle 20-30% more capacity or simply to increase the size guide number. It basically involves changing out screen cloths with larger openings but using larger openings on the first top deck screen cloth panel and gradually decrease in size on the next two or three top deck screen cloths. On the lower deck, the same gradual decrease in screen cloth openings is used but with smaller openings per screen. This scheme has been used in at least two plants to produce better than 95% -4+2mm product. The more open design near the top of the screen causes rapid unloading of the top deck so that all of the second deck screen are utilized to sift out the fines from the product. The same thing happens on the lower deck, the screen unloads rapidly permitting efficient screening of the product. Another benefit of this scheme is that the larger screen cloth openings do not blind as easily as the smaller openings and they are easier to clean. The product quality advantage is that this arrangement tends to give a product with larger particles closer to 4 mm and less smaller particles (2-2.5 mm). This is exactly what it takes to increase the size guide number and the uniformity index.

- **HOW TO IMPROVE SCREENING EFFICIENCY AT HIGHER FEED RATES.**

Figure 6.0 shows how to increase screening capacity without decreasing the plant's capacity. This scheme is applicable where two single deck screens are used and it is good for a 33% increase in screening capacity. The top screen must be converted into a double deck screen. All oversize particles are removed from the top deck and sent to the mill. The product from the first screen is fed to the second single deck screen where the product is screened a second time at a much reduced rate and removed. The fines from both screens are sent to the recycle system.

If you currently have eight 4' x 20' single deck screens, the maximum total feed should be 480 stph to achieve reasonably good screening efficiency. If the above modifications are made, it is possible to increase the total throughput to 600 stph without loss of efficiency. However, if you are more interested in product quality improvement, this technique will significantly improve screening efficiency at the current screen feed rate.

<u>10. MILLING</u>

The traditional chain mill or double opposed cage mill will handle the large lumps greater than 1/4 inch and reduce them to multiple small particles. However, neither type of mill have a high efficiency on crushing particles slightly larger than + 4 mm . When + 4 mm particles pass through the mill they have a good chance of passing straight through without being touched. This process feeds on itself and continues to produce more large particles until they grow to a size that can be crushed. When they get crushed, they break down into multiple particles that are still greater than 4 mm and the process starts over again. This leads to what operators call an oversize condition. Oversize granules do not do anything good for the granulation process. They need to be reduced in size as soon as this trend occurs. Operators can get out of this condition by shutting off the feed slurry to the granulator and continue to grind up the oversize particles. This may take considerable amount of time and results in loss production.

The choice of mill to reduce oversize particles is between a double opposed cage mill or the double opposed chain mill. Both mills are used extensively in granulation plants and the latest trend is to replace cage mills with chain mills primarily because of lower maintenance with the chain mills. The efficiency to grind down large particles (+0.25 inches) is very high (+90%) for both mills. However, the efficiency to grind smaller particles (+4 mm) has been measured at 30 to 40%. The traditional way to handle this problem is to use two kinds of mills. One for the + 0.25 inch material and one for the +4 mm material. This would require a third deck on the process screens.

<u>11. RECYCLE CONVEYOR</u>

The recycle is normally collected in a drag flight conveyor mainly to contain the dust that results from multiple streams of fines discharging from the screens, mills and cyclones. This conveyor typically is three to five feet wide and 60 to 80 feet long. It moves the product by draging it along with vertical flights and does its best to damage as many granules as it can. This conveyor definitely has a negative impact on quality. Another way to handle this service is to use a special oversize belt conveyor. A regular belt conveyor can be used if it is covered, sealed and ventilated. However, this makes it more difficult to maintain the idlers and belt.

A newer type of conveyor is suggested called the Hi RolleR ® Enclosed Belt Conveyor.(11) This unit has totally different idlers that are maintained from outside the enclosure. It will not damage the granules and it can be purchased for about 20% of the costs of a flight conveyor.

12. FINES RETURN SYSTEM

If it is desirable to control the recycle particle size distributiion, then it will be necessary to control the return of fines from shipping at a controlled rate. This will require a storage bin with a feeder. When the recycle has an abundance of fines we must not compound the problem by adding more fines. If the recycle size distribution is under good control then we should add fines but at a controlled feed rate.

CONCLUSIONS

The intent of these suggestions are to stimulate a different thinking process for people who are working on product quality improvements. After discussing this subject with several producers, it seems that many producers have made considerable progress on improving the Size Guide Number and Uniformity Index but are having trouble doing it consistently 24 hours per day. It is the hope of this paper to provide some ideas that will result in ways to maintain consistent product quality.

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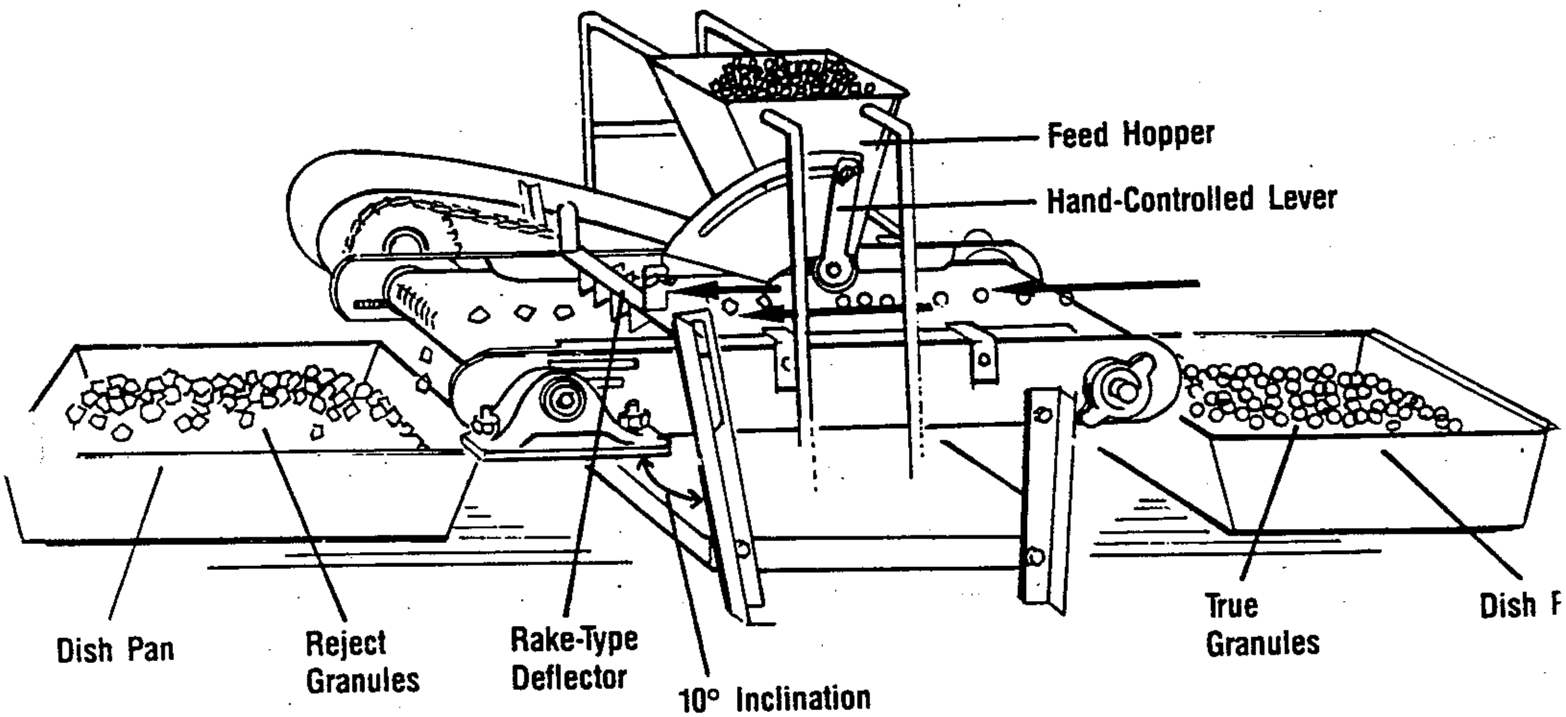


Figure 1. Sphericity Apparatus for Measuring Roundness of Granular Fertilizer.

FIGURE 2.0

RECYCLE HOLDUP QUANTITY

PLANT PRODUCTION RATE = 100 STPH

RECYCLE RATIO = 4 TO 1

RECYCLE RATE = 4 X 100 = 400 STPH

CALCULATE THE HOLDUP IN THE RECYCLE SYSTEM

GRANULATOR	=	12 TONS
DRYER	=	52 TONS
RECYCLE ELEVATOR	=	12 TONS
DRYER ELEVATOR	=	15 TONS
RECYCLE FLT. CONV.	=	4 TONS
CHUTES	=	2 TONS

TOTAL RECYCLE HOLDUP = 97 TONS

RECYCLE SYSTEM RETENTION TIME = 97/100 x 60 = 58 MINUTES

RECYCLE TURNOVER TIME = 97/400 = 14.5 MINUTES

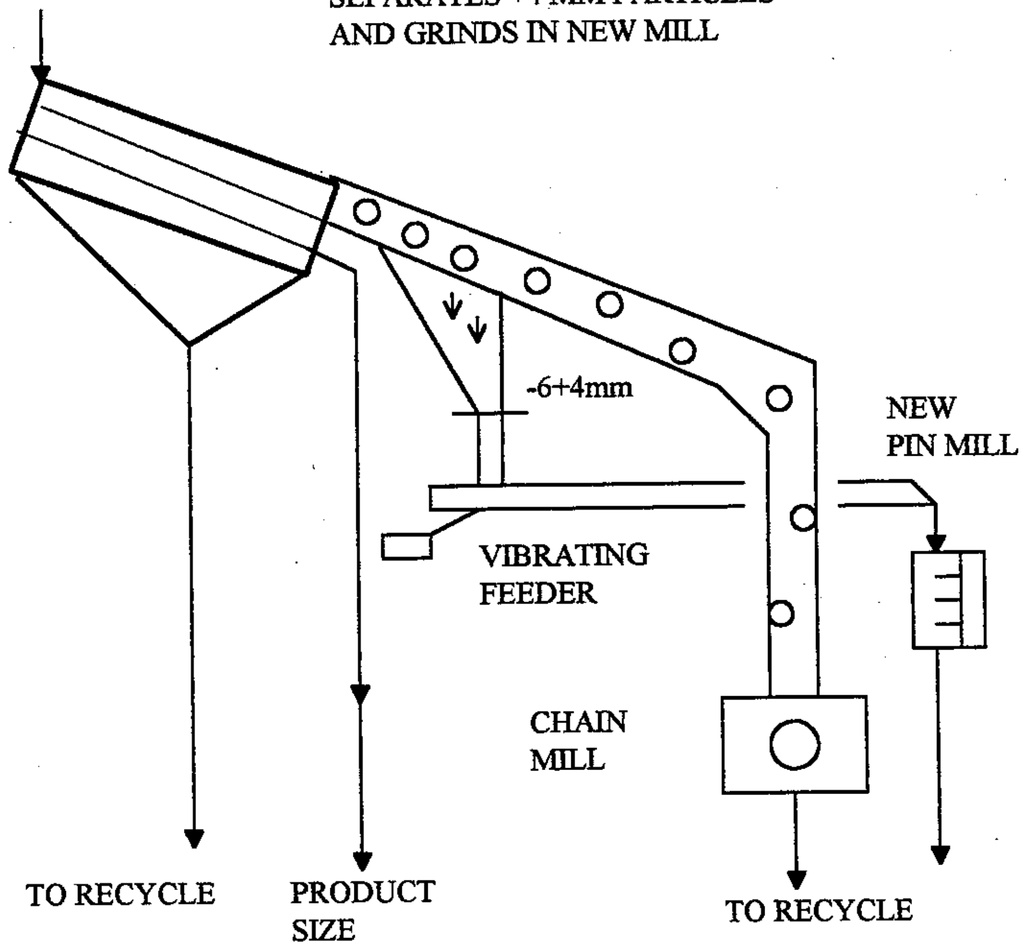
NUMBER OF TIMES GRANULES ARE SPRAYED IN THE GRANULATOR:

assume granulator has 4 slurry spray nozzles.

4 SPRAYS x 4 PASSES / Hr = 16 TIMES / HOUR

WITH A 5 to 1 RECYCLE RATIO THIS WOULLD BE 20 TIMES / HOUR.

FIGURE 3.0
SEPARATES +4 MM PARTICLES
AND GRINDS IN NEW MILL



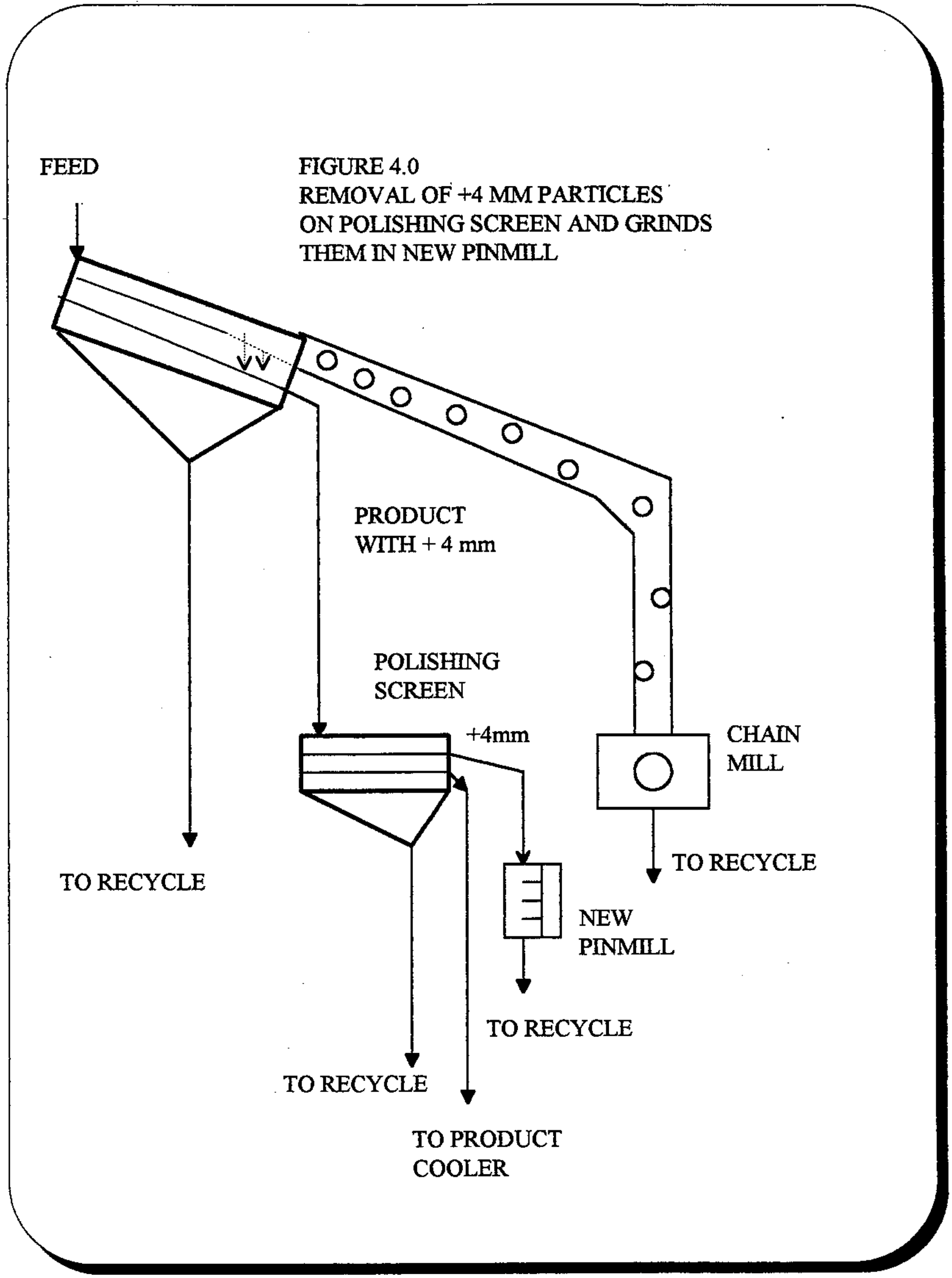


FIGURE 4.0
REMOVAL OF +4 MM PARTICLES
ON POLISHING SCREEN AND GRINDS
THEM IN NEW PINMILL

FIGURE 5.0
QUICK UNLOADING SCREENS

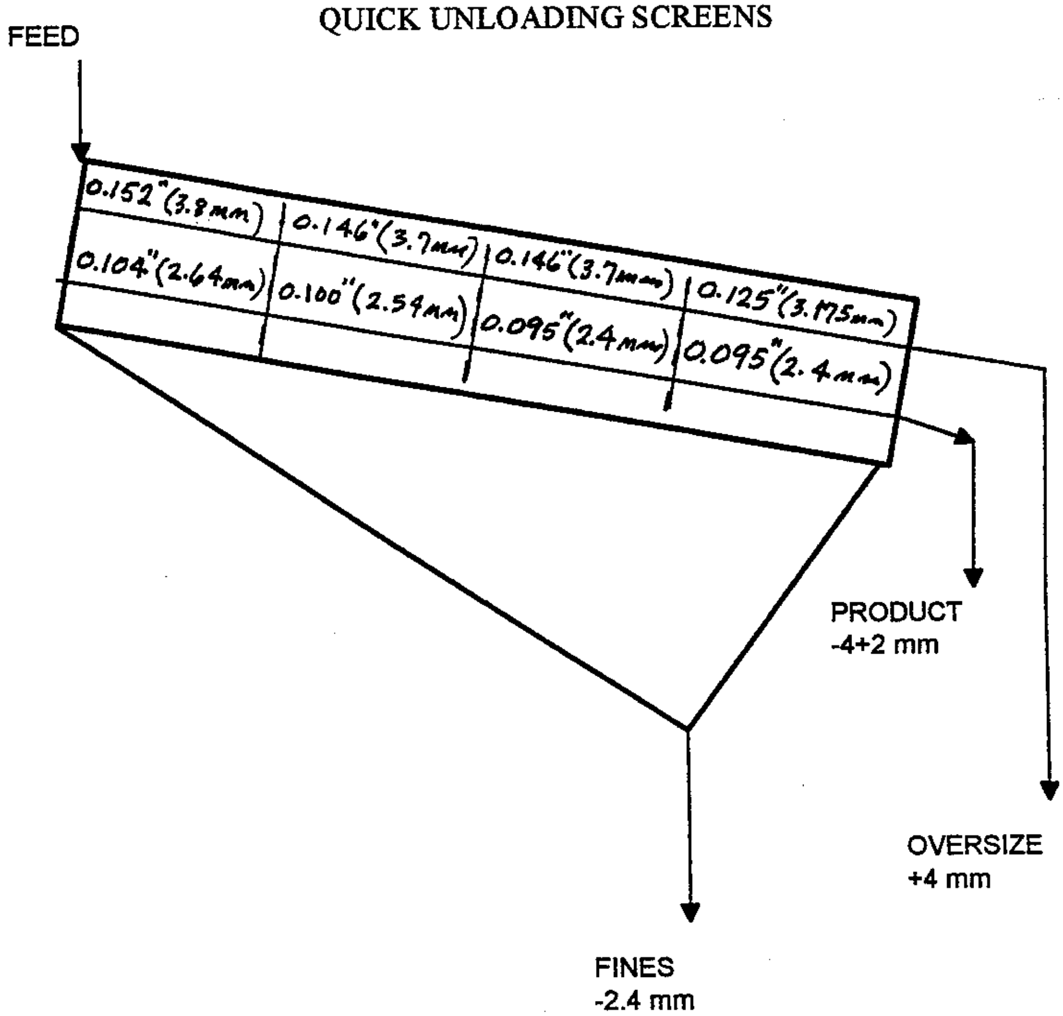
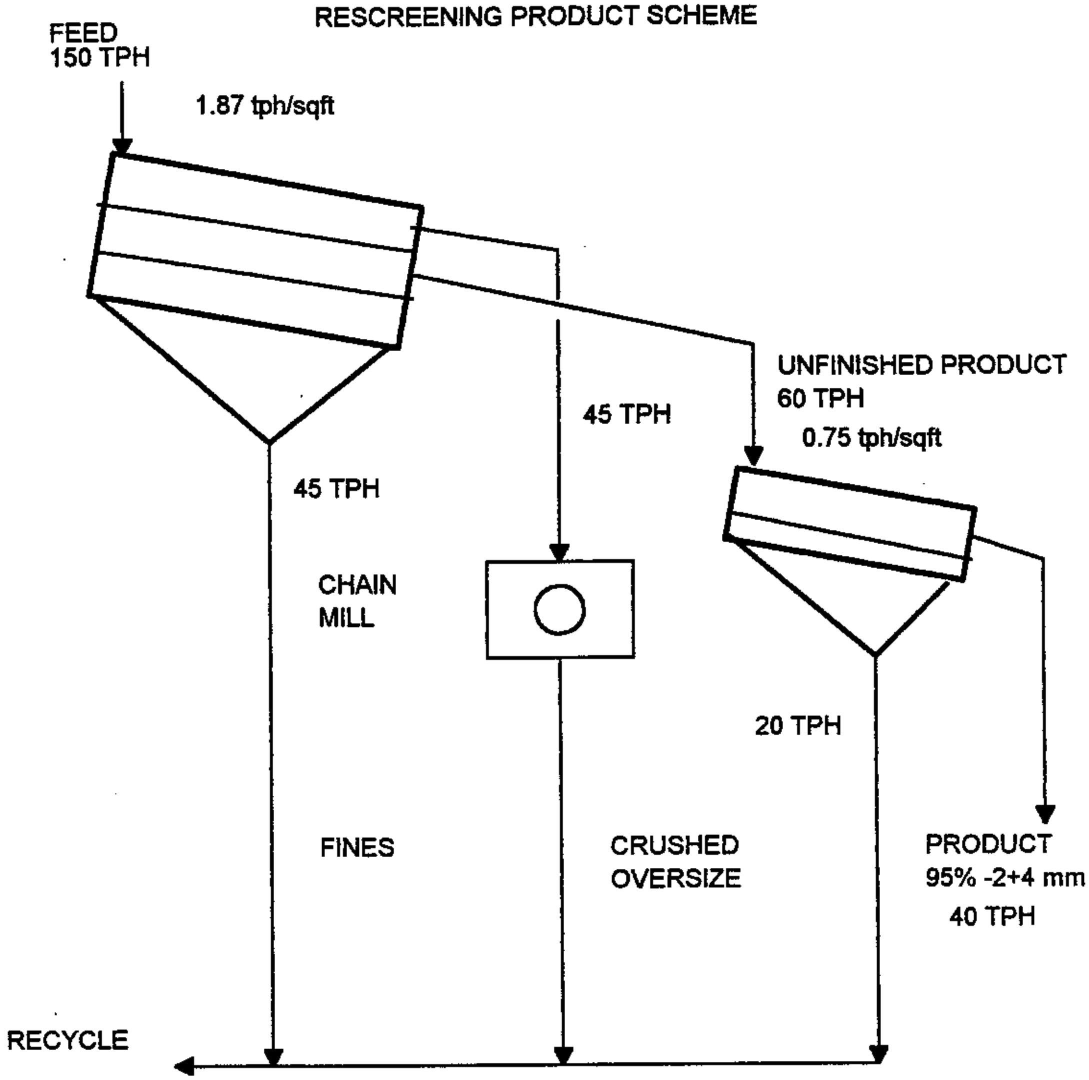


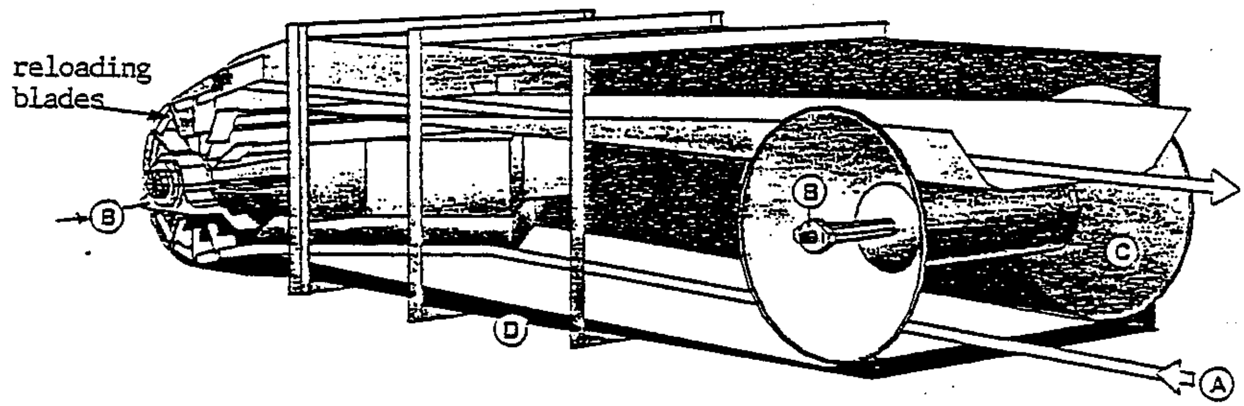
FIGURE 6.0
RESCREENING PRODUCT SCHEME



FOUR SETS OF SCREENS LIKE THIS CAN HANDLE 600 STPH

FIGURE 7.0

ENCLOSED BELT CONVEYOR (side view)



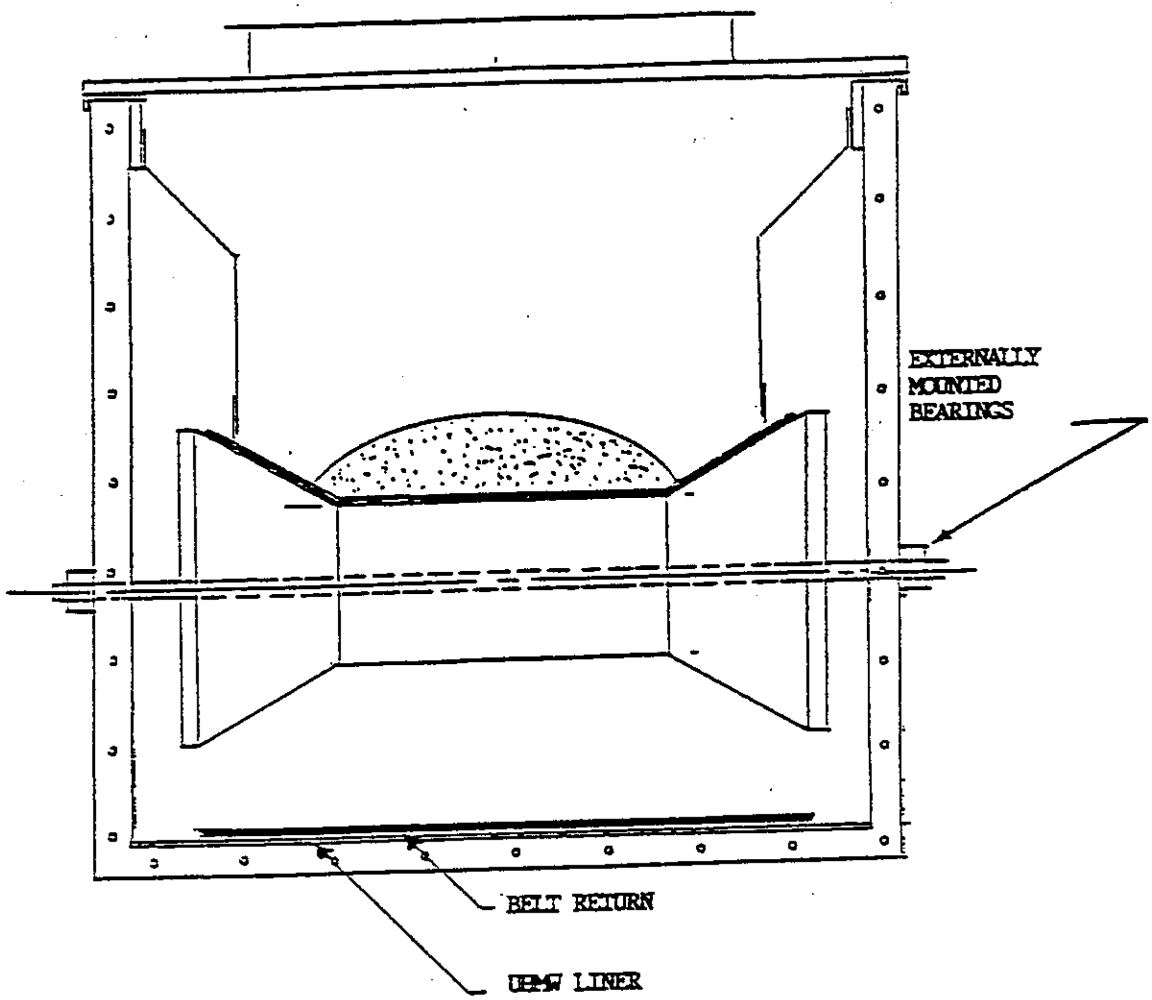


FIGURE 8.0
RECYCLE BELT CONVEYOR

HI ROLLER ®
ENCLOSED BELT CONVEYOR