INCREASING THE CAPACITY OF THE GRINDING CIRCUITS WITHOUT INSTALLING MORE MILLS

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Abstract

For years urethane screen surfaces have been used in a wide range of wet screening applications where openings from as fine as 100 microns and coarser have been used.

The purpose of this paper is to expose the reader to new developments in both screen surface and screening equipment technologies which allow an end user to consider urethane screen surfaces for fine screening applications. These technologies allow an end user to use the inherent advantages of urethane with regards to wear resistance while also realizing the benefits that a high oper area urethane screen surface can bring. These benefits include non blinding characteristics and feed capacities that which rival that of traditional stainless steel surfaces.

The paper will highlight the features of this patented urethane screen surface technology and the screening machines they are used in conjunction with. There will also be a presentation of case studies of commercial installations where these technologies are utilized. These case studies are from the base metals industry therefore relevance to the conference is direct and not inferred. Included in the paper will also be constraints which must be taken into account when considering urethane screen surfaces such as temperature and chemical attacks.

This paper will expose potential end users to a possibility of using screens to achieve extremely accurate size separations in applications where screens were previously not considered. The paper will explain and demonstrate that prior concerns of screen surface blinding, high screen surface consumption rates and large screen surface area requirements can be eliminated by proper utilization of high open area urethane screen surfaces.

1.- Introduction

The purpose of this paper is to present an analysis of the typical grinding circuits used in the processing of base metals in Peru with an emphasis on classification. This paper shall present historical references to past classification practices, practices used presently and the most up to date technology available. The overall intention is to provide end users the means to increase production capacity while also realizing other benefits as well.

Since the beginning of mineral processing the first phases of liberating and isolating desirable minerals has consisted of grinding mills. In the early phases it was also recognized that some form of size classification associated with the grinding mill would allow for more efficient operation of these grinding mills. We will look at these classification technologies as they've evolved through the years with attention paid to physical and economical limitations of the technologies. Accuracy of the classification is paramount in efficient grinding circuit operation; however accuracy comes at a price. Of course we all recognize that economic considerations must ultimately rule in choosing appropriate technologies.

2.- HISTORY

Traditionally the classification systems used in closed grinding circuits were comprised of rake classifiers, spiral classifiers, hydrocyclones, sedimentation cones, and in some cases rudimentary commodity style vibratory screening machines with steel wire surfaces.

The classification of particles in rakes, spirals, cyclones, and sedimentation cones are made based on settling rate velocities which take into account both particle size and density. In opposition vibratory screening machines utilize particle size only in the classification process. It is this principle difference between hydraulic classifiers, using settling rate velocities and vibratory screens, using particle size differentiation which creates the potential for increased capacity in closed circuit grinding.

In 1925 E.W. Davis conducted tests which made comparison between rake classifiers, spiral classifiers and vibratory screens in the closing of grinding circuits. He concluded that vibratory screens provided both higher capacity and better control over grind size than either rake or spiral classifiers. Grinding mills during this time where comparatively small, therefore some attempts were made to utilize vibratory screens in full scale operations based on this testing. Due to limitations in the weaving of stainless steel wire at the time and the inherent problems with wire cloth relating to blinding, high wear rates and replacement costs these full scale operations proved impractical and uneconomical. In addition the style of screening machines produced at the time had extremely low capacity requiring huge amounts of floor space. This floor space requirement increased installed costs tremendously making vibratory screens impractical.

After WWII, the hydrocyclones became the standard in closing grinding circuits as mill sizes increased. Rake and spiral classifiers became less economically viable due to their large footprint requirements and capital costs. The hydrocyclone on the other hand required very little space, provided high capacity and came with relatively low capital costs. For these reasons and the increased demand for refined minerals, processing plants began to be designed for greater tonnages. With these larger processing facilities becoming the norm, hydrocyclones became the standard device for closing of grinding circuits

According to most operating experiences the separation efficiencies of hydrocyclones fall between 45 – 65%. Throughout the years, hydrocyclone manufacturers have made a series of modification in the design including geometry, materials of construction, cone angles, vortex finder penetration etc.. These changes were made in efforts to improve performance, and in some cases provided marginal improvements but most processing plants never surpassed the 60% separation efficiency level. The end result of closing grinding circuits with this relatively low separation efficiency device is that most mills in the Peruvian base metals industry operate with circulating loads in excess of 200%

Since the early 1950's, Derrick Corporation, a Buffalo, New York based manufacturer of fine screening equipment and screen surface technologies has been at the forefront of pushing screening technology into new applications. One of the objectives of the company is to eliminate mineral processing engineer's typical concerns about screening technology. As mentioned earlier a major concern of processors has been the durability, accuracy and effectiveness of screen surfaces to maintain openings (eliminate blinding) in order to allow for sustainable accurate separations. In the early 1980's Derrick Corporation developed and patented a unique manufacturing process which allows for the manufacture of high open area urethane screen surfaces. These screen surfaces provide high capacities without the downside of woven stainless steel wire screen surfaces. These urethane screen surfaces have open area percentages as high as 45%, will not blind with nearsize material and last 20 to 30 times longer than stainless steel wire cloth. The technology has now evolved to the point where Derrick makes urethane screen surfaces with openings as fine as 75 microns. Remarkably these urethane screen surfaces with 75 micron openings last for 4 to 12 months prior to requiring replacement depending on the abrasiveness of the material.

In the year 2000, Derrick Corporation designed and introduced the Stack Sizer® multi deck fine wet screening machine as illustrated in figure 1. In review of figure 1 we see that a single feed is introduced to the screening machine at five separate feed points by means of a standard flow divider. This is done in order to take advantage of the well known fact that width of screen surface is the most important factor in determining the capacity and efficiency of wet screening machines vs. length or area. It is understood that once free water leaves the mineral slurry on a screen surface - sizing ceases to occur, therefore feeding thin uniform layers of slurry across the entire width of each of the five feed points provides maximum separation efficiencies and tonnage rates. A linear high frequency vibratory motion is supplied to all five screen decks uniformly throughout the entire length and width of each screen deck by means of a pair of TENV (Totally Enclosed Non Ventilated) vibratory motors with a sealed for life bearing design. This vibratory motion induces fluid and undersize solids throughput while also extending the effective fluidized zone for sizing. The vibratory motion is also extremely effective in conveying oversize material to the end of each screen deck making way for the new oncoming feed. A unique hopper and launder assembly allows all undersize to discharge from one outlet and the oversize to discharge from another single outlet.

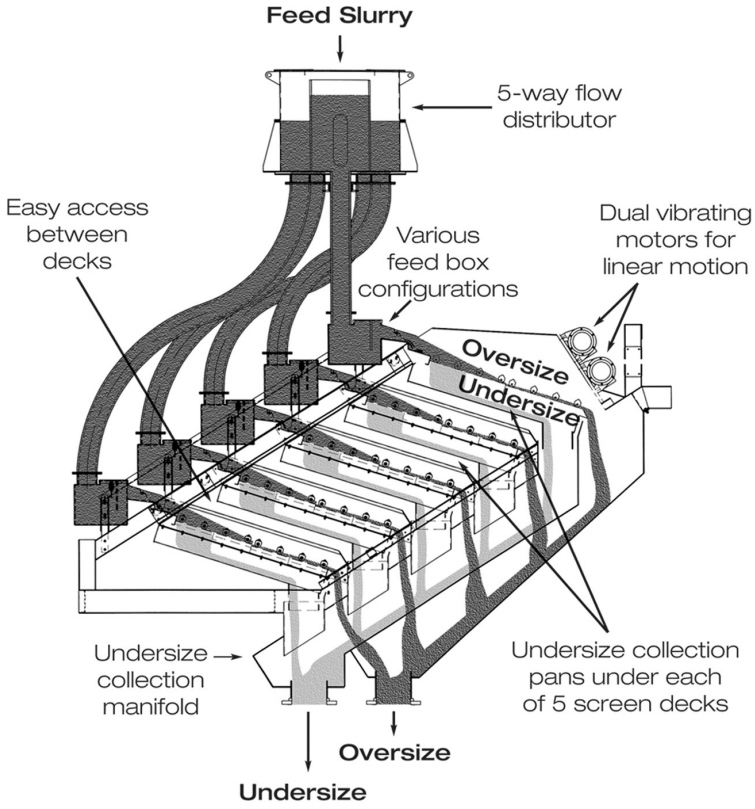


figure 1

The introduction of the Stack Sizer provided end users with an exceptionally high tonnage wet screening system which was previously not available. The Stack Sizer in combination with the high open area urethane screen surfaces basically eliminates all of the prior concerns about the applicability of fine screening technology in closed circuit grinding. The high tonnage rate capabilities reduce footprint requirements dramatically while the patented urethane screen surfaces eliminate wear and blinding issues. It is this combination of technologies from Derrick Corporation that not only makes screening a viable option in closing grinding circuits it also is often the most economical method for base metal grinding circuit closure. At this time it should also be mentioned that this is not experimental technology as over 350 stack sizers have been produced and delivered into applications around the world.

3.-GRINDING CIRCUITS

Grinding is the process of reducing the size of a mineral ore to a point where the desirable mineral is liberated and then presented to further process technologies for efficient separation from the undesirable gangue material. The mills themselves have evolved in size, power draw and durability for over a century but the technologies have remained basically the same. It is in the classification stages that the technology has evolved into visually and functionally different forms through the years. In the Peruvian base metals industry, we can identify four basic types of grinding circuits:

a) Primary Rod Mills followed by Secondary Ball Mills (figure 2)
b) Two Ball Mills in Series (figure 3)
c) Single Ball Mills (figure 4)
d) SAG Mills (semi-autogenous) followed by Secondary Ball Mills (figure 5)

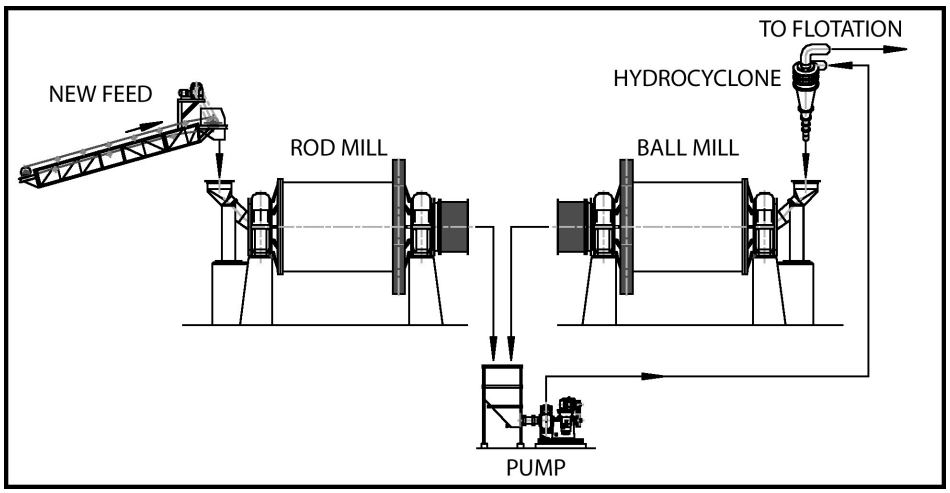
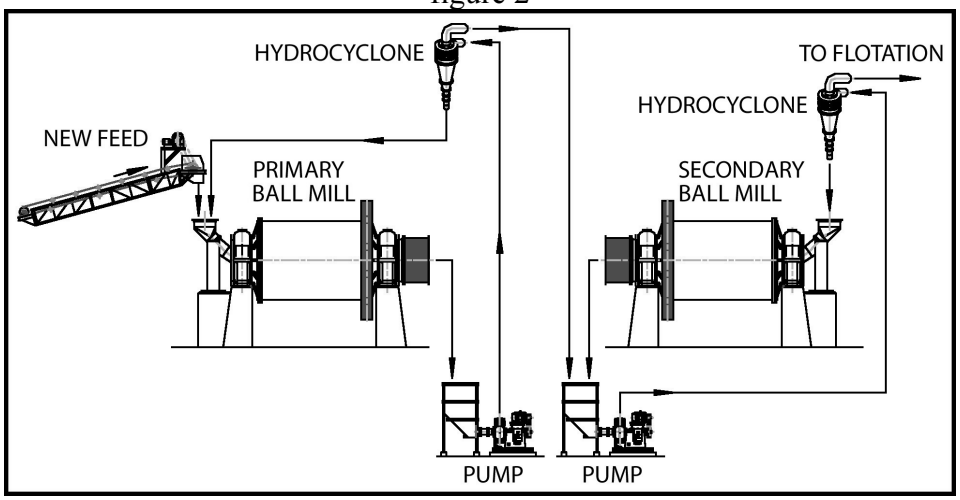


figure 2



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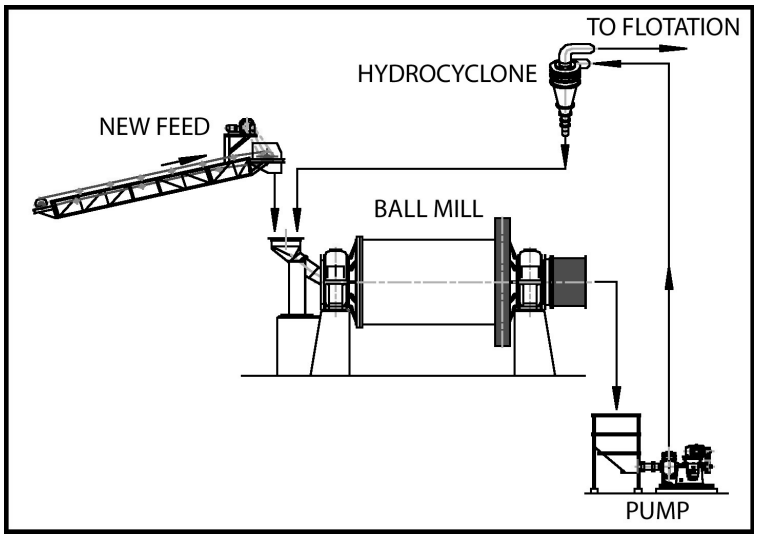

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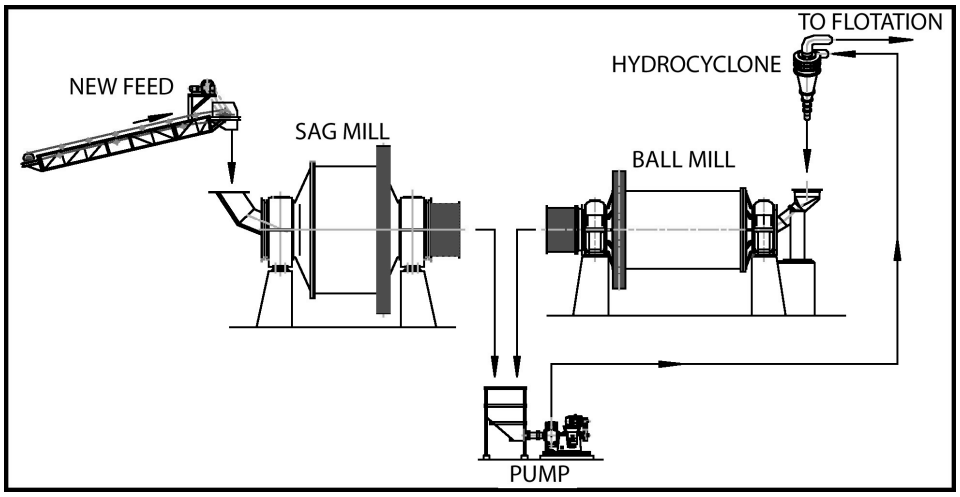

figure 5

Up until most recently the majority of classifiers used in the closing of Peruvian base metals industry grinding circuits have been hydrocyclones (of various models and installation methods). Whether installed vertically or horizontally, no matter the configuration, generally the separation efficiency never surpasses 60%. The end result of these inefficient size separations is that most grinding circuits closed by hydrocyclones operate with high circulating loads that oscillate between 230 – 450%. (See figures 2, 3, 4 and 5 for circuit types)

The grinding operation in a mineral processing facility typically consumes the majority of the energy used. In addition to energy these mills consume special steel rods or balls as well as the steel mill linings. Combining all of these factors we see why grinding is one of the highest costs involved in mineral processing. Keeping these costs in mind it is extremely important that the mills carry out their operation of closed circuit grinding in an efficient manner. Basically we want to ensure that once a particle has been ground to its designated liberation size, it is effectively removed from the milling process as soon as

possible by an efficient classification method. In other words let's consume energy, rods, balls and linings only on the particles which need to be ground further and get liberated particles on their way for separation and refining.

CLASSIFICATION (HYDROCYCLONES vs. STACK SIZER with URETHANE SCREEN SURFACES):

The main objective of a classifier used in closing a grinding circuit is to send liberated mineral particles on their way in order for them to be recovered via mineral concentrating methods. A liberation point for a particular ore is defined by a specific particle size; therefore a classification system which makes the most efficient size separation will be the one that most efficiently reaches the objective of getting liberated particles on their way for recovery. We mentioned earlier that hydrocyclone typically operate with separation efficiencies in the range of 45 to 65%. The Stack Sizer on the other hand typically operates with separation efficiencies in the range of 85 to 92%. The difference between the two technologies does not end at size separation efficiency. Hydrocyclones make their separations based on differences in settling rate velocities while screening machines ignore all other variables with the exception of particle size. Problems with hydrocyclones in grinding circuits are increased further when there are large specific gravity differentials between the desirable mineral and the gangue material. This problem in hydrocyclones causes the heavier liberated minerals to report to the underflow and of course back to the grinding mill while lighter middlings particles report to overflow and on for concentration without the liberation of the desirable mineral. The screen on the other hand recognizes the particle size only and allows for accurate determination of liberation. Below you will find a partial listing of the economic advantages of screens versus hydrocyclones in grinding circuits.

- Typically require less water for operation
- Reduction in slimes generation allows for reduced reagent consumption in floatation
- Reduced energy consumption due to reduced circulating loads
- Increased production rates (typically between 10 to 30%)
- Reduces grinding media consumption
- Reduced Mill maintenance costs
- Increased efficiency in classification devices such as spirals, floatation cells and jigs as they process a narrower size range of particles
- Increased mineral recovery rates
- Reduced concentrate dewatering costs due to coarser liberation and reduction of slimes

CASE STUDY (Sociedad Minera El Brocal)

In 2001 process engineers from the Sociedad Minera El Brocal S.A.A. in Peru visited Derrick Corporation for purposes of conducting full scale testing on the Lead / Zinc ore. The flowsheet at the El Brocal facility appeared as illustrated in figure 6 with three rod mills in open circuit feeding three ball mills which operated in a classic closed circuit grinding operation with hydrocyclones used as the classifying device. Hydrocyclone underflow of course reported back to the ball mills while hydrocyclone underflow reported directly to floatation. The objective of the testing was to determine the screen equipment requirements for replacing the hydrocyclones while also determining the economic benefit of replacing the hydrocyclones with screens. The overall objective of the El Brocal engineers was to determine a way of increasing plant productivity without adding new grinding capacity. With the hydrocyclones closing the Ball Mill circuit these engineers noted circulating loads in excess of 400% and excess slimes production resulting in recovery losses during the floatation process.

Due to it's high tonnage rate capabilities the Stack Sizer was chosen as the screen of choice while due to the already stated benefits of Derrick's patented high open area urethane screen surfaces they were the screen surface of choice for testing. In spite of positive results demonstrated by the testing El Brocal determined that commodity type screening machines fitted with stainless steel wire cloth could be used in place of the Stack Sizer and high open area urethane screen surfaces therefore the decision was made to use the lower cost commodity screen machines and screen surfaces. Placement of the commodity equipment in 2001 proved to be a disaster as the screens blinded over completely. Circulating loads immediately went out of control and the facility was forced to shut down after minutes of operation. Luckily the process engineers at El Brocal did not remove the hydrocyclone circuit from the plant and operation according to the original flowsheet in figure 6 was able to resume within days. Shortly after the failure of the commodity screens and the wire mesh screen surfaces the process engineers of El Brocal revisited Derrick Corporation and performed a second round of confirmation testing. Following that testing the decision was made to purchase two Derrick Model 2SG48-60W-5STK five deck stack sizers fitted with 300 micron urethane screen surfaces and in 2003 the machines were successfully placed in operation according to the flowsheet illustrated in figure 7.

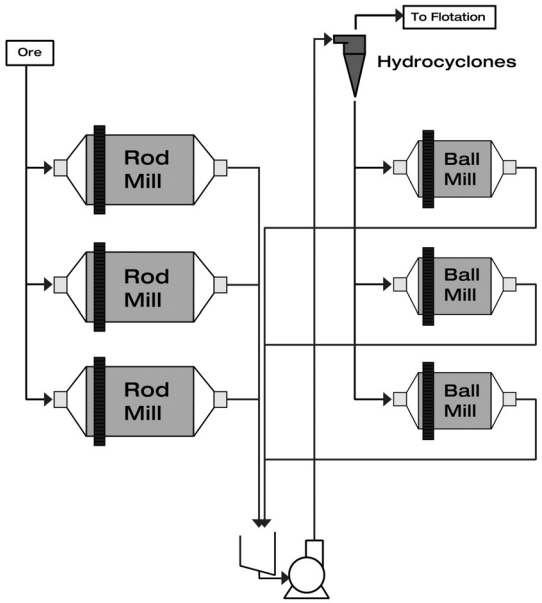

figure 6

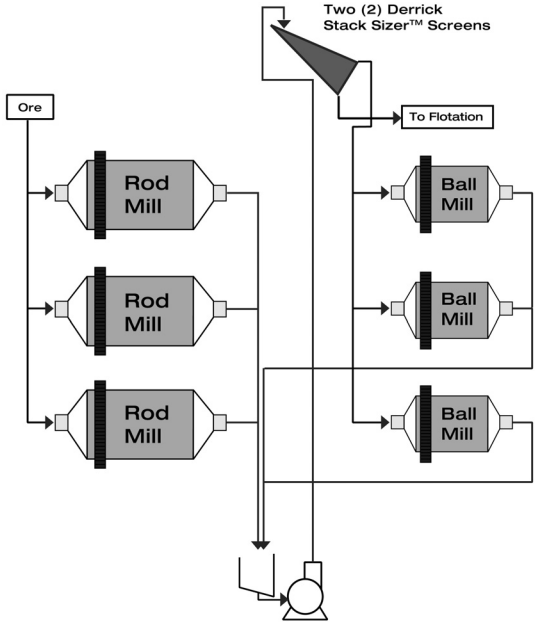

figure 7

With the change in the classifying methodology the process engineers at El Brocal noted that modifications to the grinding circuit were required in order to take advantage of the screens sizing efficiency and indifference to particle S.G. The first thing they noted was that the grinding mills were severely underfed due to the fact that circulating load was decreased to about 100% versus the original 400% with hydrocyclones. Initially one of the ball mills was shut down and then finally two ball mills were shutdown with the resulting flowsheet as illustrated in figure 8. At the same time process engineers also discovered that the screening provided them with a much narrower band of particle size

distribution in the feed to flotation (screen undersize). The effect of this narrower size distribution allowed them to coarsen the grind thereby allowing them to use 500 micron opening screen surfaces in place of the original 300 micron screen surfaces. This change to larger screen openings of course further reduced circulating loads and was the major contributing factor to allowing them to operate with a single ball mill as illustrated in figure 8. Obviously the elimination of two 550 HP ball mills created huge power savings along with maintenance cost elimination.

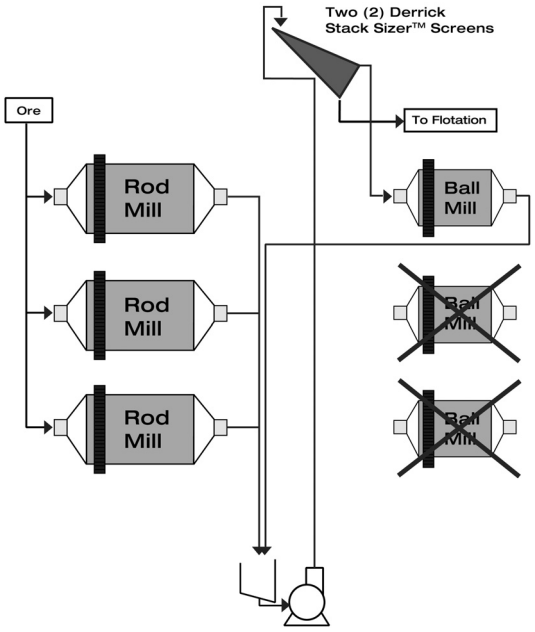

figure 8

The original objective at El Brocal was to increase production throughput for the concentrator. Their original plan was to add a fourth ball mill into the circuit in order to achieve that objective but the results from the test work at Derrick Corporation had convinced them to utilize screens in order to achieve the same objective. Once all of the adjustments had been made in the milling circuit to accommodate the screening efficiency El Brocal realized an immediate production rate increase of 10%. At this time feed limitations in the floatation cells has limited any further production increases but engineers believe that production increases of as much as 30% may be realized due to the change from hydrocyclones to Stack Sizers. In addition to the production gains there have also been additional economic advances related to lead recovery. Lead recovery has increased by 9.0% due to reduced slimes losses. Although data is not readily available at this time it is also believed that reagent consumption within the floatation process has decreased due to reduction in slimes generation in the grinding process.

CONCLUSSIONS:

The gains achieved by El Brocal at their Lead / Zinc operation are not unique to their facility. For years Derrick Corporation has been supplying Stack Sizers fitted with the Urethane screen surfaces in a number of Chinese, USA and Russian iron ore processing facilities with comparable advances in production, recovery, concentrate grade, and decreased power consumption and other operating costs. Lai Wu Steel in the Shandong Province of China has installed Derrick Stack sizers fitted with 100 micron opening urethane screen surfaces at two concentrator facilities where production has increased by 30%, total power consumption dropped by 25% and silica in the final concentrate has dropped by 0.5%. There are over 350 stack sizers operating around the world in a variety of ferrous and non ferrous mineral operations, proving that the technology is ready for widespread use. We also know the advantages of screens versus hydrocyclones in the closing of grinding circuits from both a theoretical and now practical point of view. It is this author's belief that any new processing facility or those considering upgrades in capacity should look at the combination of the Stack Sizer and high open area urethane screen surfaces developed by Derrick Corporation as a more efficient way of obtaining their objectives.

GRATITUDE

The author remains very grateful of the Gerencia de Sociedad Mineral El Brocal and of Derrick Corporation for the authorization to present this work.