A NEW CONCEPT ON SAMPLING SYSTEMS BY AIR CANNON APPLICATION

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

UFUK YÜNEL

IN PARTIAL FULLFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF
MASTER OF SCIENCE
IN
THE DEPARTMENT OF MINING ENGINEERING

JANUARY 2004

Approval of the Graduate School of Natural and Applied Sciences

Prof. Dr. Canan Özgen
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. M. Ümit Atalay
Head of the Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Cahit Hiçyılmaz
Supervisor

Examining Committee Members:

Prof. Dr. Cahit Hiçyılmaz
Prof. Dr. Ümit Atalay
Prof. Dr. Çetin Hoşten
Prof. Dr. Ali İhsan Arol
Assoc. Dr. Özcan Gülsoy

ABSTRACT

A NEW CONCEPT ON SAMPLING SYSTEMS
BY
AIR CANNON APPLICATION

Ufuk, Yünel
M.Sc., Department of Mining Engineering
Supervisor: Prof. Dr. Cahit Hiçyılmaz
January 2004, 114 Pages

The most important criterion in industrial production processes is to control the required product quality and comply with the standards pre-described for the application during any stage of the process. This control begins from the entry of raw material to the plant and continues with pre-determined points.

Mainly two different types of inspection and analyses are used to examine the material quality and content. These are physical and chemical analysis.

In most of the production plants above mentioned analyses are made in related laboratories of the plant. Therefore, it is necessary to have "sample" to be analyzed.

This “sample” should have a real “representative” property, which must carry all of the physical and chemical characteristics of the material at the point where this “sample” is taken.

The present methods and systems used to take samples from any required point have some disadvantages and present some problems especially for not being “representative”. These problems are discussed in detail within this thesis study and aimed to reach a new concept and system with:

- Low cost of investment
- Low cost of operation
- Less requirement of maintenance and calibration
- The achievement of “correct” and “representative” sample

As a result of the theoretical studies together with practical application works and experiments, a new concept in sampling, namely “Sampling System with Air Cannons” was introduced. The new system of sampling was tested to give better performance and practical use.

Keywords : Air Cannons, Sampling, Quality Control, Sample Increment, Size Distribution

ÖZ

HAVA PATLAÇLARI UYGULAMASI
İLE
NUMUNE ALMA SİSTEMLERİNDE YENİ BİR YAKLAŞIM

Ufuk, Yünel
Yüksek Lisans, Maden Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Cahit Hiçyılmaz
Ocak 2004, 114 Sayfa

Endüstriyel üretim sistemlerindeki en önemli kriter, üretim işleminin her kademesinde istenilen ürün kalitesinin bulunup bulunmadığının veya önceden tespit edilmiş standartlara uyulup uyulmadığının kontrolüdür. Bu kontrol hammaddenin tesise girdiği noktadan başlayıp, tespit edilmiş belirli test noktalarında devam ederek sürer.

Esasen, malzemenin kalitesini ve içeriğini incelemek için yapılan iki tür kontrol ve analiz yöntemi vardır. Bunlar fiziksel ve kimyasal analizlerdir.

Üretim yapan birçok kuruluşta bu analizler o tesisin ilgili laboratuarlarında gerçekleştirilir. Bu işlemlerin yapılabilmesi için elde test yapılacak bir “numune” (örnek) olmalıdır.

Bu "numune", alındığı noktadaki tüm malzemenin bütün kimyasal ve fiziksel özelliklerini taşıyan gerçek "temsil niteliği" özelliği bulunan bir örnek olmalıdır.

Bugün istenilen bir noktadan numune almakta kullanılmakta olan metot ve sistemler bazı dezavantajlar taşımakta ve alınan bu numunenin gerçek "temsil niteliği" olmayan bir numune olması gibi problemler doğurmaktadır. Bütün bu problemler tezimizde detayları ile incelenmiş, tartışılmış ve yeni bir yaklaşım ile:

- Düşük yatırım maliyeti olan
- İşletme masrafı da düşük olan
- Çok daha az bakım ve kalibrasyona ihtiyaç gösteren
- "Doğru" ve "temsil niteliği" olan numunelere ulaşan

bir sistem ortaya çıkartabilmek hedef alınmıştır.

Teorik çalışmalarla birlikte pratik uygulama işlemleri ve testler yaparak numune almada yeni bir fikir olan "Hava Patlaçları ile Numune Alma Sistemleri" ortaya çıkmıştır. Numune alma konusundaki bu yeni sistem ile daha iyi performansa ve pratik uygulamaya sahip bir "numune alma" sistemine ulaşılması hedeflenmiştir.

Anahtar Kelimeler : Hava Patlaçları, Numune Alma, Kalite Kontrol, Numune Kesiti, Tane Boyu Dağılımı

To My Dear Family,

For giving me life and joy

ACKNOWLEDGEMENTS

The writing of this thesis has been a challenging but most rewarding experience. This would not have been possible without the support of my advisors, colleagues, friends and family.

First and foremost, I would like to express my deepest gratitude to Prof. Dr. Cahit Hiçyılmaz for his invaluable guidance and advice as the research and thesis progress. His suggestions have enabled constant improvement and refinement of the thesis and his encouragement has helped me brave the rough times when things do not seem to go in the right direction. I also express my special thanks to Prof. Dr. Ümit Atalay for his valuable advice.

I gratefully acknowledge the close interest and help of Mr. Cengiz Göçer, General Manager of Adana Cement, Mr. Fuat Akın Erdem, The former director of Yozgat Cement and Mr. Ertuğrul Sandıkçıoğlu, Technical Manager of Baştaş Cement together with other personnel and labor of these Cement Factories for providing their continuous support and interest during my research project.

Most of all, I would like to thank my parents, Mustafa Kemal and Gülen and my sister Aslı for the freedom support and love they showered me with throughout these years, in good times and in hard times. They have given me the strength and courage to reach to greater heights and pursue my dreams.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

CHAPTER I

INTRODUCTION

One of the main problems of the industries dealing with solid material handling and processing is to be able to take representative samples from different points of production. The vital importance of the correct sampling is very well defined by all of the operation people of the plants,but it is not possible to choose a correct sampling system every time. The quality of the end product is coming from the control of process by continuous monitoring of the material throughout the production line.

The work in this thesis was initiated to design a new sampling system. Therefore, various cement factories were visited to have a general idea for already existing sampling systems. In Turkey, there are more than 57 cement factories and 31 of them have rotary kilns. Their cement production is reasonably high than those of other countries. Turkey exports clinker and different quality standard cement. The total cement production in 2002 was 32.800.000 tons and 5.958.000 tons of this cement were exported. The total production is expected as 34.400.000 tons in the year 2003. Cement is the main product in the construction of buildings, dams, bridges, roads etc. For that reason, the quality of the clinker or cement must be within the ranges, determined by the standards.

The studies carried on present sampling systems in four cement factories showed that they have some common problems with their sampling systems. These are:

1. The harsh environmental conditions were affecting these electromechanical systems and causing early failures.
2. The collected sample with these electromechanical systems generally was not representing the total lot. Because these systems could not be able to take samples completely from cross-section instead they received only some part of it.
3. The sampling pattern of these electromechanical sampling devices during their operation in a continuous flow is not correct. Because the speed of these devices are limited.

Therefore, the studies were concentrated on finding a new system, which will not have above problems or at least to decrease these negative effects. In this study, a pneumatic air shock system was applied to take representative samples from a belt conveyor by using air cannon mechanism.

Air cannon give an air shock by speeding air more than 1 Mach, the speed of sound, known as 340 m/sec. The force applied by air cannon is 1500kg at 10 kg / cm^2 air vessel testing pressure.

The other expected advantage of using air cannons as sampling device is the control of the shock value by adjusting the air pressure.

The practical application of this thesis was to reach a sampling system with the following properties.

1. Low investment cost
2. Low operational cost
3. Resist to any harsh environmental conditions
4. Needs low maintenance and repair
5. The sample taken by this system will have all qualifications to represent the material.
6. Easy to apply on conveyor belt construction, air slides and similar locations

1.1. OBJECTIVES OF THE THESIS

This thesis entailed development of a new “sampling system” by evaluating theoretical information as well as practical measures.

The new idea is to choose air shock cannon mechanism instead of currently used conventional mechanical cutters for increment sampling. This mechanism will be triggered to receive exact representative units from conveyed material.

Different vessel capacities such as 12 liters, 20 liters, and 36 liters, are used. Other parameters are conveyor belt speed, size distribution of conveyed material, different air pressure levels, different nozzles and the distance from the conveyor belt.

As it is seen from the following chapters of this study, the aim is to find an applicable value by testing the above mentioned parameters for conveyor belt. The findings and further studies to reach this result will give birth to the utilization of this new system to any conveyor belt or any conveying mechanisms in process.

There is no equivalence of air shock cannon system in sampling in the world till now.

CHAPTER II

BACKGROUND

2.1. SAMPLING TERMINOLOGY

2.1.1. General Overview

Sample and sampling are universal concepts that take place in statistics, natural sciences, research, and other fields of science. The definition of ‘‘sample’’ has been used by Statistics and Industrial Applications frequently (Lapin, 1987). Definitions can be given as follows:

‘A sample is a finite part of a population (in industry: lot) often obtained by the reunion of several increments or fractions extracted from the lot, and meant to represent it in further operations’ (Webster, 1985). In mining and industrial applications, sampling can be stated as the proportion and the distribution of critical component such as set of minerals when estimating the chemical and mineralogical composition of the lot, a set of size fractions when estimating the size analysis of the lot …etc. are the same in both the whole and the increment taken (sample) (Gy, 1982).

Sampling procedures are realized to evaluate mineral deposits and to have the general information about the end product. The aim is to receive representative quantities of test materials either in the form of slurry or bulk ore as a part of process evaluation. Sampling is one of the fundamental duties that cannot be discarded throughout the life of the process. If the solids are not sampled in a representative manner then process and product control will not be reliable (Taggart, 1945).

Sampling should be observed as two sided phenomena. One side is the user, whose main concern is to receive accurate and/or reproducible results. The other side is the manufacturer, whose main concern is to design and manufacture correct or applicable devices.

2.1.2. Incremental Sampling

Incremental sampling is the procedure of collecting a group of particles from the lot in a single operation of a sampling device, usually from the conveyor. In industries, many conveyor systems have been used such as the general sense applies to belt conveyors, chutes for solids, air slide systems for fine particles, pipe and launders for slurry or other conveyances for the continuous transport. The methods of taking samples from these systems will be mentioned in the following sections.

2.1.3. Lot Modeling

Lot modeling is the expression defined according to the geometry of the lots for a sampling point of view (David, 1977).

2.1.3.1. Three – Dimensional Modeling

In three dimensional modeling, all lots having irregular shape, which cannot be reduced to degenerate models of two, one or zero dimensional models. An example can be given as an irregular pile of ore that is represented by a three dimensional model.

2.1.3.2. Two – Dimensional Modeling

In two dimensional modeling, one of the dimensions of the lot usually thickness is small and uniform. Some examples are flat piles and metallurgical products under the form of plates.

2.1.3.3. One – Dimensional Modeling

One dimensional modeling will be the point of concern, which constitutes the elongated piles or the material that is transported on the belt conveyors.

2.2. SAMPLING ERRORS

Sampling is the *science*, which should be taken in consideration with intensive care and it should be handled seriously (Keller and Warrack, 1997). The importance of sampling is most of the times underestimated. The weight of the analysis or assay sample may be as small as one gram or a few decigrams in a mason jar whereas the batch may reach to several hundred thousand tons (Gy, 1982). Is it that easy to receive accurate, reproducible and representative sample increment from great amount of material? The answer will not be positive. The obstacles that the engineer or any authorized people encounter will be the sampling errors. The process of sampling encompasses several steps such as (1) Taking a gross sample S from bulk material B, (2) Preparation of sample S for testing, and finally (3) Testing. Each of these steps contributes errors to the final result.

The sampling problem is studied by recapitulation of the sampling errors that can be encountered. A design of the sampling scheme is necessary for eliminating or minimizing certain number of errors (Gy, 1992).

2.2.1. Splitting Overall Sampling Error (OE)

It is made up of Total Sampling Error (TE), which is known as the numerous composite errors in each stage of bulk reduction stages and Analysis Error (AE) that is caused during analytical operations. However, in our daily life Analysis Errors are minimized by reducing the human factor through which the analysis of critical content a_S is investigated through X – Ray Devices and Fusion Analysis (Kanmaz, 2000).

$$OE = TE + AE \tag{1}$$

2.2.2. Splitting Total Sampling Error (TE)

Total sampling error is divided into two series of errors as Preparation Errors (PE) such as errors resulting from contamination, losses, alterations generated from the chemical composition and physical composition, unintentional mistakes, frauding or sabotage. Sampling and preparation should be realized by specialized staff under the supervision of another control department. In sampling, it will be focused on prevention of the formation of preparation errors together with sampling error.

The Sampling Error (SE) is defined simply as the difference between a_L 'unknown critical content of the lot L' and a_S 'unknown critical content of the sample S'. a_S is the estimator of a_L.

$$TE = PE + SE \tag{2}$$

$$SE = \frac{(a_S - a_L)}{a_L} \tag{3}$$

2.2.3. Splitting Sampling Error (SE)

Sampling Error is splitted into Continuous Selection Error (CE) which is made up of four consecutive errors that are complex and don't have practical meaning. Other type of error called Increment Materialization Error (ME) has practical meaning. This error should be suppressed or minimized during the sampling equipment design stage.

$$SE = CE + ME \tag{4}$$

2.2.4. Splitting Continuous Selection Error (CE)

It is constituted from Short – Term, Long – Term Quality Fluctuation Errors together with Periodic Quality Fluctuation Error (QE1, QE2 and QE3). Quality Fluctuation Errors are caused by the changes in the quality.

Increasing the number of increments in the sampling process will be useful to cope with this error. Weighing Error (WE) is another determinant for Continuous Selection Error, which compromises the changes in weighing. It is equal to the difference of CE and QE.

$$CE = QE1 + QE2 + QE3 + WE \quad (5)$$

2.2.5. Splitting Materialization Error (ME)

It will be the main concern for sampling device design since Delimitation and Extraction Errors (DE and EE) affect the reproducibility as well as the accuracy of sampling. The increment delimitation is the operation of receiving a particulate geometrical boundary of the material. If some disconformities occur during this operation then increment Delimitation Error takes place (DE). In cutter edge type sampling systems there is a problem of loosing the material by bouncing and by falling within the boundaries of extended increments by center of gravity. If these phenomena occur during sampling then increment Extraction Error will be inevitable. The details will be given during the evaluation of sampling systems.

$$ME = DE + EE \quad (6)$$

A designer should pay attention to dispose the three major sources of error as:

- Increment Delimitation Error DE = 0
- Increment Extraction Error EE = 0
- Preparation Errors PE = 0

An ideal sampling procedure should be reached by referring the conditions given above (Gy, 1982). Sampling is an error-generating operation and hardly few applications in the world are obeying the rules of correct sampling. Unfortunately, it can be seen that most of the well–known sampling device producers are manufacturing incorrect devices. Moreover, the technical and administrative failures cause misleading results and errors in sampling. The error classification is as follows:

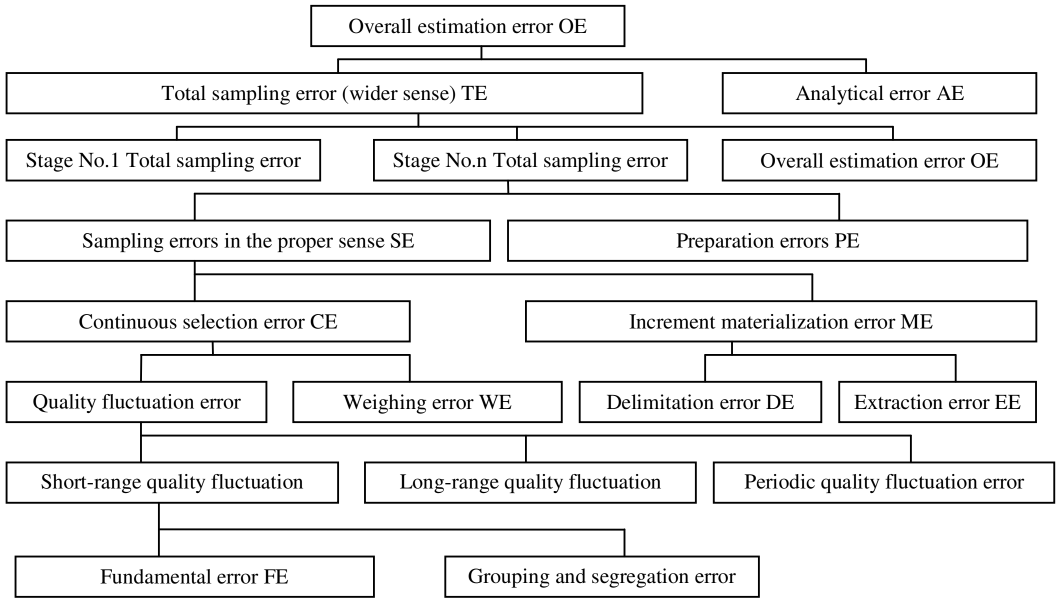


Figure 1. A schematic illustration of sampling errors.

2.3. INDUSTRIAL SAMPLING SYSTEMS

Industrial centers are utilizing various designs of equipment. Even though a multitude of functional machine designs has been developed at operating properties for sampling systems historically, most of them have been discarded in favor of commercially made equipment meeting established standards of operating reliability and sampling accuracy. Theory of sampling states accuracy of sample taking that is how much sample to take and how to take to meet the accuracy specification. In industries electromechanical sampling techniques are utilized. The application is mostly to receive a sample increment with a cutter that follows a path through or traverse a flowing system. Two frequently used sample extraction methods in flow regime are employed. First method is sample extraction from material in gravity free fall such as from trajectory discharge of a conveyor or from a chute. Second method is sample extraction from the material on a moving conveyor with a cutter traverse through the complete material (Gy, 1982).

2.3.1. Air Slide Sampler

The air slide samplers are designed for continuous or intermittent sample extraction of dry, non – sticky powdered material transported via air slides.

Air slides are closed conveying channels through which a fabricated cloth is placed. The fine material travels over that cloth by means of pneumatic action and with the inclination of channel. Since very fine particles are carried via air slide mechanisms, the sampling device is mainly made up of an external stationary tube having a 4mm standardized slot. This slot rotates within the stationary tube thus creating moving hole in the assembly extending over the full conveyor height.

System is not covering all cross section of the material flow. On the contrary, it collects spot increments. The slot needs to be cleaned with pressurized air to prevent any built up from previous sampling procedure. These are some drawbacks of air slide samplers.

In most of the factories, it is regarded as secondary or tertiary sampling process (M&W Jawo Handling, 1999).

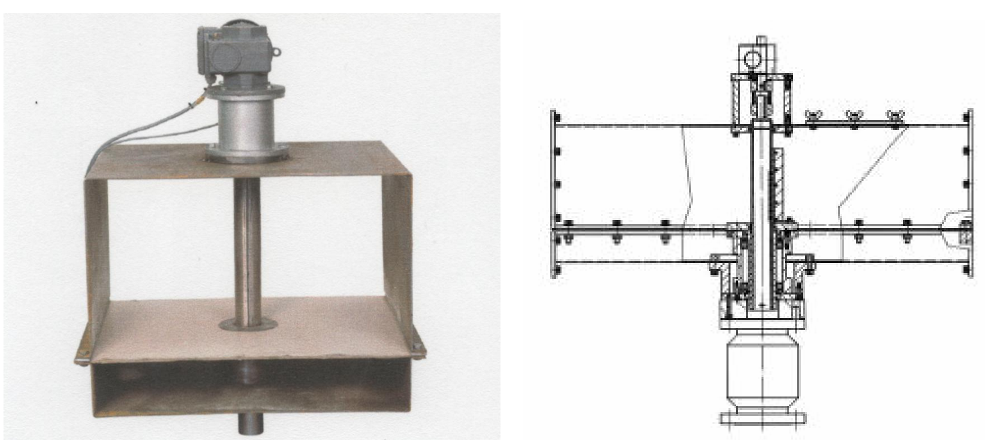


Figure 2. Air Slide Sampler

2.3.2. Linear Cross Stream Samplers

Some variations of linear cross stream samplers have been used in industries. The variations are caused by using different kinds of driving mechanisms. These driving mechanisms are electric motor, pneumatic, hydraulic or magnetic drives. Among these, electric drives are by far the most usual because they are cheap, convenient and highly reliable. It should be compulsory for a sampling system to achieve uniform cutter velocity during cutter's travel across the stream. It is hard to achieve constant speed with other driving mechanisms except electric motors (Gy, 1982). The linear cut model is preferred in industries because during the sample increment extraction it covers all the flowing material from trajectory and receives a representative portion. However, this procedure should be implemented by taking some important issues into consideration. These are the location, the dimensions, the material of construction and the speed of the cutter. On the other hand, careful inspection and continuous cleaning of the cutter mechanism are needed to avoid residues of previous sample increments.

Generally this type of cross belt bucket samplers are used to take out a representative sample of powdered material or lumps up to 100 mm from free falling flow of materials. These are mostly the products obtained from crushing stage of the process.

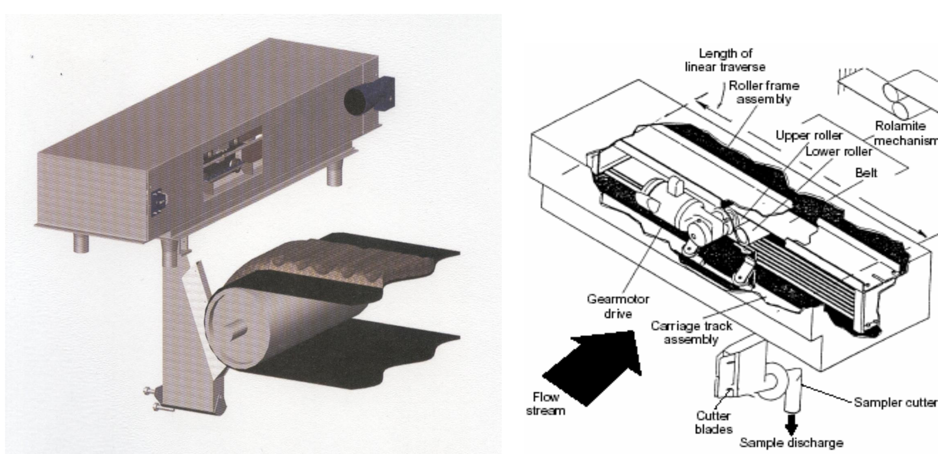


Figure 3. Linear Cross Stream Sampler

2.3.3. Rotating Arch Path Samplers

Rotating arch path samplers can be classified as horizontal arch path samplers and inclined arch belt samplers. The former is used for small capacity sampling of fine size material and used for both slurry and solid sampling from a falling stream. The latter utilizes mostly 30º to provide an inclination to achieve hard to handle applications in moist and adhering materials. Reject material from the individual sample increments are returned to the main out-going stream of material, usually by gravity.

However, there are some difficulties in mounting the scoop, since the scoop should scan all the cross section of the flowing material in order to take a representative portion. The scoop should be designed in such a way that the material received should be neither flooded from the bottom plate nor bounced from the side plates. Moreover, the rotating arch path samplers have some drawbacks in taking representative portions because most of the time the cutter does not traverse the entire stream and does not project an equal cutter opening across the flowing material being sampled.

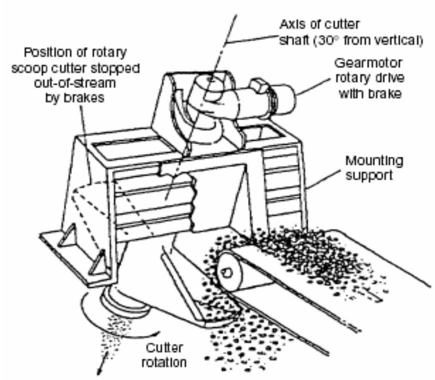


Figure 4. Rotating Arch Path Sampler

2.3.4. Swing Arm Cross Belt Sampler

Swing arm cross belt sampler is designed to take out representative sample of powdered material and lumps up to 200 mm from material on an operating rubber belt conveyor without stopping the belt. The sampler pivots on an axis parallel to the centerline of the belt (M&W Jawo Handling, 1999). This system is used for primary sampling, where the material size is bigger. However, this system brings about some careful monitoring of operation together with a proper design. If the gap between belt and back plates cannot be adjusted properly then there will be a direct contact with the sampler and belt. This will give consequential damage to the belt. Moreover some additional features such as brushes and resilient skirts have to be added so as to avoid any residual fine particles on the belt, even though it is hard to achieve. The profile of the belt should be adjusted to suit the curvature of path of scoop. Problems arise due to segregation of the fines at the bottom of the burden next to belt.

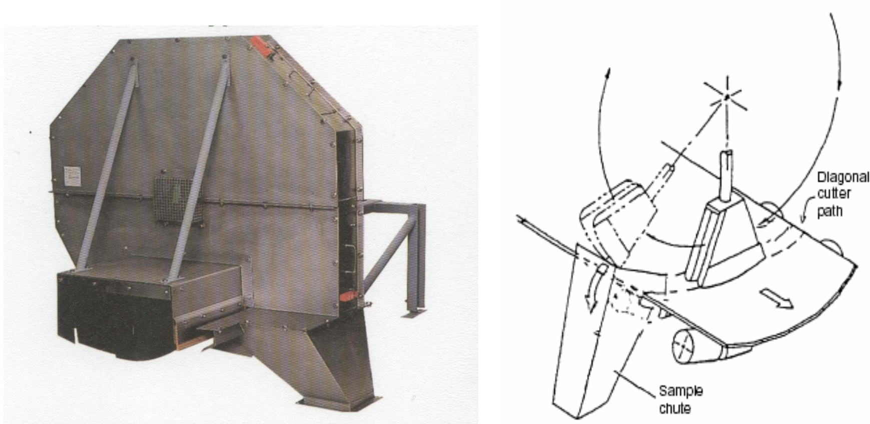


Figure 5. Swing Arm Cross Belt Sampler

2.3.5. Slotted Belt Linear Sampler

Sampler simply relies on a slot opened on the surface of a conveyor belt. It moves over the belt and when comes on a chute, the material falls down. Its design is simple but the applications are awkward when material discharge trajectories occur at higher speeds (Perry, 1999).

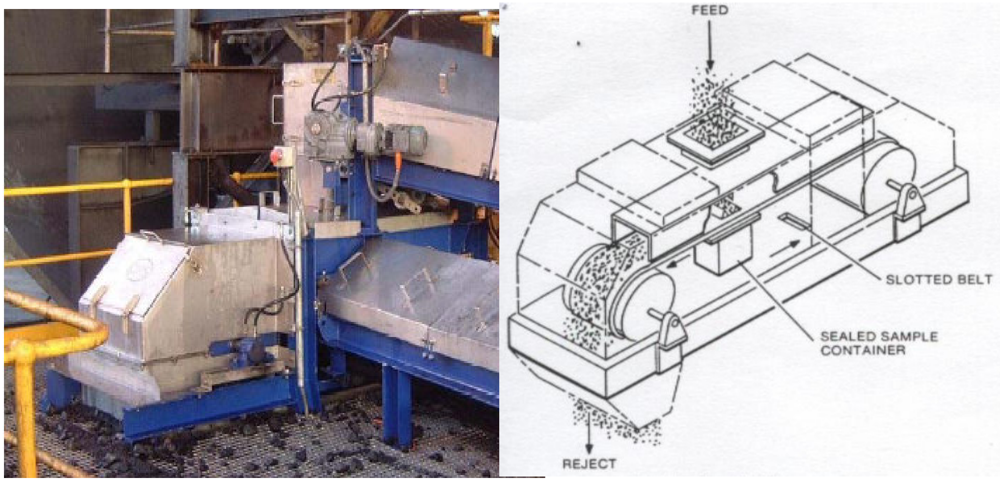


Figure 6. Slotted Belt Linear Sampler

2.3.6. Flap Gate Sampler

These samplers are designed as single edge cutters. They cut trapezoidal increments and causing wrong sample because the material falling from the chute or conveyor closest to the out of stream position of the gate is better represented in the sample than the material farther away. These devices are always incorrect and all the sample manufacturers avoid producing it since the concept is basically wrong (Perry, 1999).

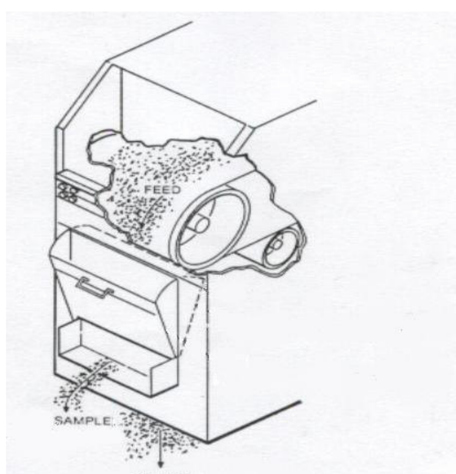
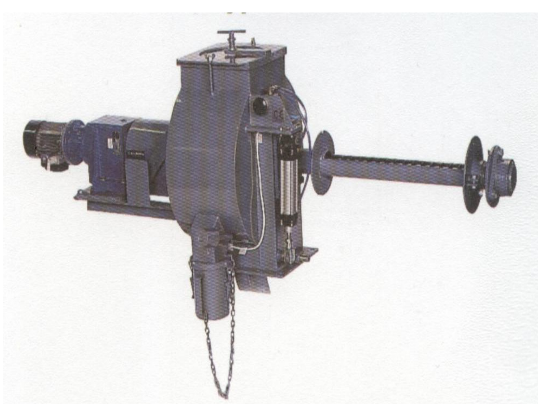


Figure 7. Flap Gate Sampler

2.3.7. Screw Sampler

The screw sampler systems are utilized frequently in fine material – dry, non-sticky powdered material – process to extract continuously or periodically depending on the application. The system operates as a screw conveyor system having a slot at the top, driven by a geared motor. The screw transports the material to a mixing tank or to a discharge chute depending on the application. The system is used in vertical chutes and restricted with inclined chutes with maximum inclination of 30º. These systems are not suited for installation of pneumatic conveying systems (M&W Jawo Handling, 1999).

The slot opening should be designed according to the maximum particle size criteria. The slot should be appropriate for the flow cross sectional distance. It is preferred to open the slot throughout the diameter of the chute in order to take a representative portion from the lot. The design of the screw conveyor is so important here, because the sticky or humid material can cause blocking inside the conveyor. It should be cleaned periodically via pressurized air or the screw conveyor should work idle for a period to prevent any occurrence of residual material from previous increment extraction.



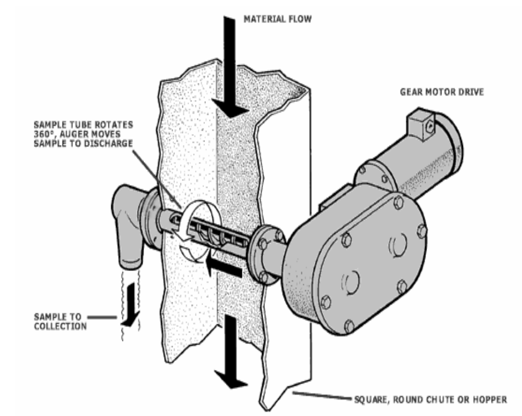


Figure 8. Screw Sampler

2.3.8. Probe Samplers

Probe Samplers are made up of a probe, which extracts a cylindrical portion of the material from the bulk material transported with trucks, railcars, ships and other vessels (Gy, 1992). However, one obvious drawback of these systems is to maintain correct delimitation. It is hardly possible to achieve this because it is required to take all portions from the uppermost level down to the bottom of the vessel. Several slots are opened on the probe but still it is often difficult and sometimes impossible for the sampler to penetrate the material down to the bottom of the vessel.

One example can be given as the trucks carrying humid loads and traveling on very rough tracks. The large part of the water slips towards the bottom due to the gravitation and vibration whereas the top layer dries in the sun. The probe sampler fails to sample correctly that part of concentrated load. The samples actually extracted have an average critical content much lower than the actual critical content to be estimated.

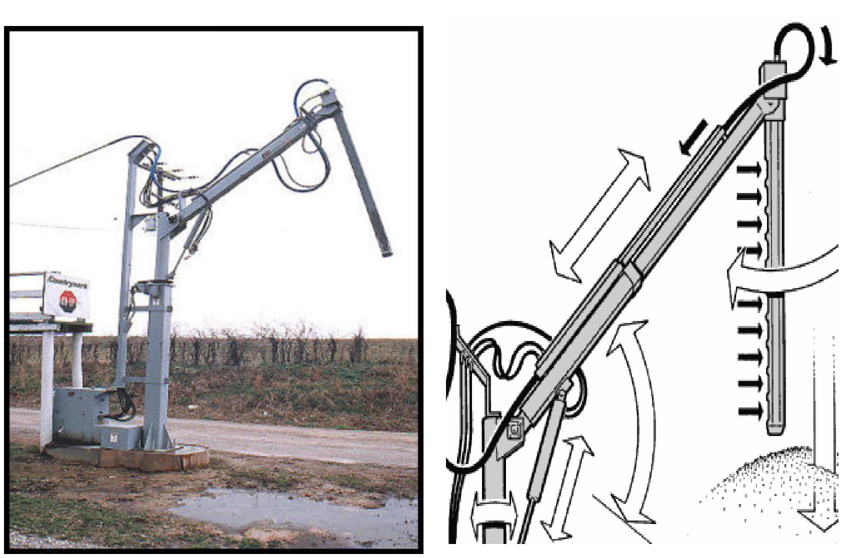


Figure 9. Probe Sampler (http://www.intersystems-inc.com/prime/html/products/probe_sampling)

2.4. SAMPLING SYSTEM DESIGN CRITERIA

2.4.1. Cutter Width and Speed

ISO Quality Certificate Criteria are looking forward to 'have a correct sample due to the cutting speed in relation to the speed of the belt conveyor is in consideration'. The speed of the cutter should not be so high to knock away pieces that should go into the sample in electromechanical samplers. This is caused by the restriction of the cutter structure (Gy, 1982).

The experience shows that the economical optimum regarding the speed and the width of the cutter can be expressed with the following relation:

$W = W_0$ and $V_C = 0.6$ m/s where;

W: width of the cutter of desired equipment,

W_0: critical width as a reference

- If $W \geq W_0$: all particles belonging to the increment eventually fall in the actual increment.
- If $W < W_0$: some of the particles belonging to the increment have the hazard of rebounding from the side plates of the cutter and these are lost by spinning over the extracting edge of the cutter (Gy, 1992).

The data show that critical speed of the cutter can be taken as 0.6 m/s for electromechanical samplers. On the other hand, the width of the cutter should be larger than three times of the diameter of the largest particle in the lot. This formulation became as 'a rule of thumb' in mechanical sampling equipment design (Perry, 1999).

There are dozens of wrong designs operating in various parts of industries. It is really a costly procedure not to think of extraction correctness at the designing stage of the sampling plant. The outcomes are most of the times irreversible. It is necessary to obey the simple rules of cutter width and speed design in electromechanical sampling procedures.

2.4.2. Correct Increment Delimitation

In industry most of the devices are ineligible to provide correct increment delimitation, which is the first step that should be realized in sample increment extraction. Incorrect increment delimitation causes to have unrepresentative sample increments. This phenomenon must be avoided. Correct increment delimitation is related with the geometry of the cutter mechanism together with the operation measures.

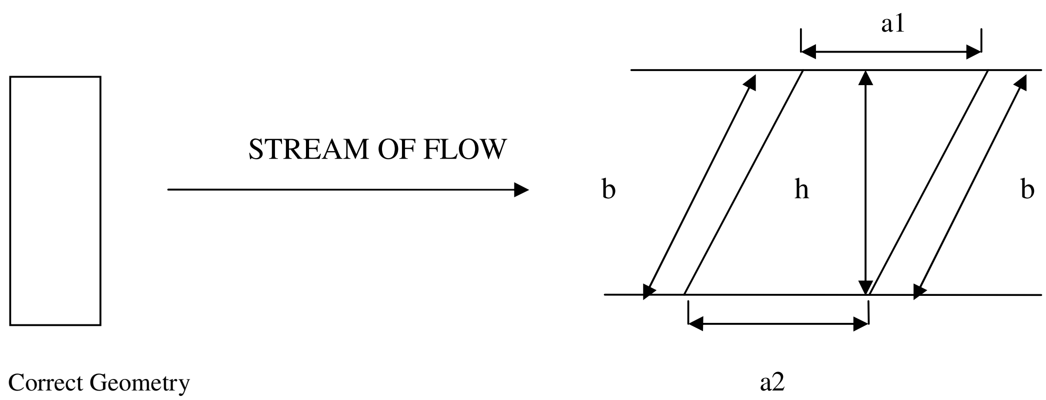


Figure 10. Correct Increment Delimitation (a1 = a2)

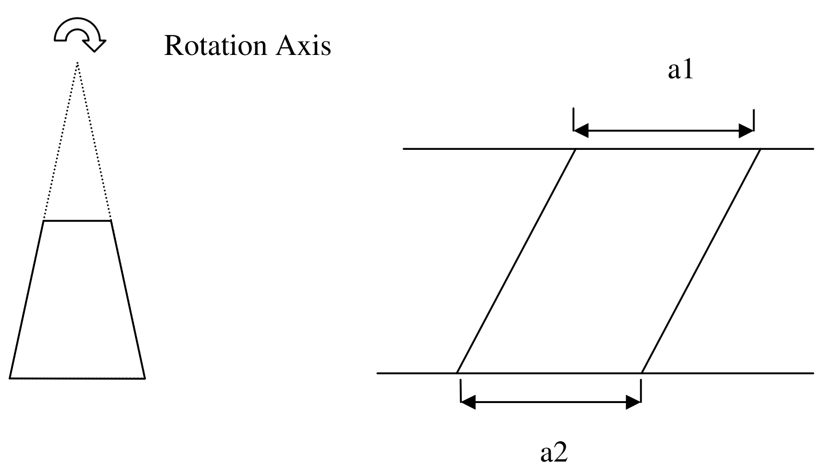


Figure 11. Circular Path Cutters – Correct Increment Delimitation

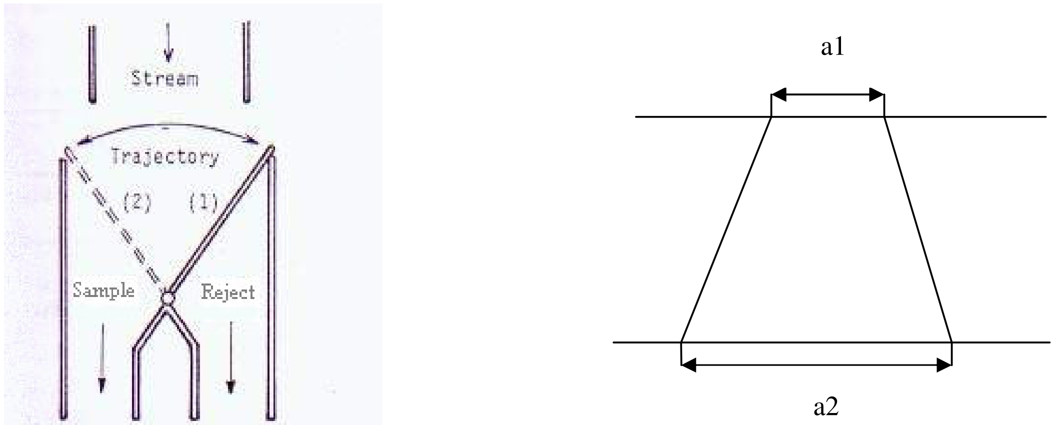


Figure 12. Flap Gate Sampler – Incorrect Increment Delimitation (a1 ≠ a2)

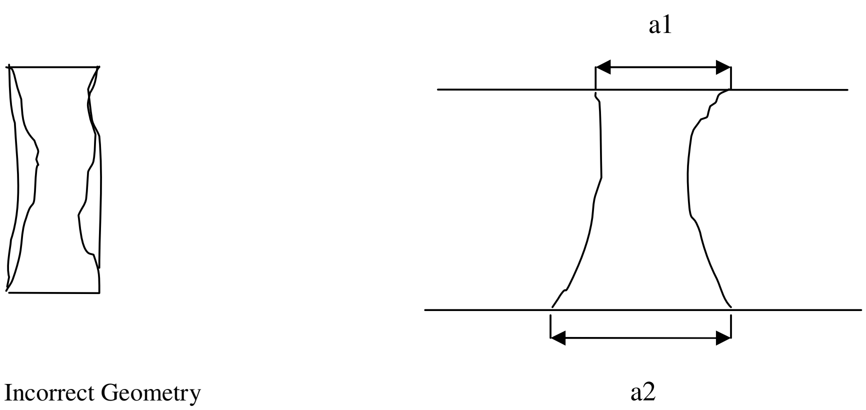


Figure 13. Mechanical Cutter Partly Obstructed – Incorrect Increment Delimitation

- Straight Path Cutters: The geometry is correct if and only if the cutter edges are parallel, regardless to their angle with the stream. This is given in Figure 10.
- Circular Path Cutters: The geometry is correct if and only if the cutter edges are radial, such as intersecting on the revolution axis of the cutter, regardless to their angle with the axis. This is given in Figure 11.
- Other Cutters: Most of the cutter mechanisms do not maintain correct trajectory from the material stream due to incorrect geometry, since the correct geometry of a cutter depends on the trajectory. Non-straight and non-circular mechanical path cutters have that difficulty of having correct increment delimitation (Pitard, 1989).

Flap Gate Sampler is a good example for incorrect increment delimitation. This is shown in Figure 12.

Correct increment delimitation and extraction should be obeyed so as to take a representative portion from the entire stream. The cutter openings should be periodically checked for deformation and wear due to the impact of the particles and their material characteristics such as abrasion. This is shown in Figure 13.

2.4.3. Driving Mechanism

Cutter velocity should remain unchanged during the travel of the cutter throughout the stream to give the same probability of extraction of each particle in the stream. This should be maintained by electric drives and it is hard to obtain constant speed with hydraulic, pneumatic, magnetic and manual drives (Avallone and Baumeister, 1996).

2.4.4. Sampler Lay – Out

The cutter opening should be arranged in such a way that the stream should pass through a well delimited area without letting any part of the stream escape. The correct lay – out of the opening is partially maintained. In addition to this, the idle or reversing position of the mechanical cutter should be far away from the stream. It can be 0.2 to 0.3 meter from the leading end of the stream (Gy, 1992).

The top of the cutter should be covered with protecting cap to prevent dust settlement inside the mechanical cutter.

2.4.5. Cutter Design

In mechanical cutters; the sampled material can be accumulated on any part of cutter walls or bottom. The mechanical cutter needs an intensive inspection after each respective increment extraction.

In mechanical cutters, a minimum depth equal to about three times the maximum diameter d_M at the shallowest point of the cutter should be maintained in order to avoid any problem of bouncing back of the particles inside of it (Gy, 1982).

In mechanical cutters, it should be useful to have U – shaped inclined trough with no welding, nuts, bolts or rivets and no sharp folding in order to avoid any material built up.

Professional manufacturers should be attentive in selection of the construction material of mechanical cutters and components. Stainless steel is suitable as a construction material. Ordinary steel is abstained to have any formation of rust from contaminating the increments.

The angle of the inner walls of the cutters should be larger than 60˚ for wet material and 45˚ for dry material. The walls of the cutter should be heated if possible. The surface tension should be overcome by means of the inclination. Heating process should be realized with great care to avoid any problems in moisture sampling.

In bucket type mechanical cutters, the bucket capacity should be at least three times larger than the volume of the largest possible increment. The cutter mechanism should be equipped with bottom opening or overall tilting to allow all particles depart from the bucket (Gy, 1982).

These measures should be neither neglected nor underestimated during the design of *electromechanical* sampling equipment. The data given above will be useful for evaluation of sampling equipment. Unfortunately, it is not easy to rehabilitate an already existing and operating system in industries.

It was given as almost 80 % of the sampling equipment in the industry had suffered from wrong design at the initial stage. Generally the increments received by these samplers do not represent the whole lot (Gy, 1982).

CHAPTER III

MATERIAL, EQUIPMENT AND METHOD

3.1 MATERIAL

In this research, two synthetic lots were prepared by known quantity and size fraction. The material was received from a quarry near Akyurt – Ankara. The procedure was as follows:

The lots were in different size fractions and called as LOT A (80% passing 19.71 mm), and LOT B (80% passing 15.01 mm). These are illustrated in Figure 14.

These special lots were conserved in dust proof plastic covers to prevent any impurity entrance from outside.

3.1.1. Preparation of Lots to the experiments

Two – dimensional slab cake is a method practiced in laboratory for lots up to a few hundred kilograms. It was primarily LOT A to be mixed for homogenization. The lot was laid on a smooth and clean surface. It was prevented from any material settlement due to environment. The rectangle was formed and divided into a matrix (2 x 5) of approximate squares. Grooves were formed by a hand shovel between each square to prevent any interference. The center of each square was extracted with respecting to particle segregation. This is a sensitive process of splitting

After receiving 50 kg lot by previous method, true fractional shoveling method was realized. True fractional shoveling method with a splitting ratio of 1 / 5 was implemented to take 10 kg of representative sample from 50 kg lot. This representative sample was carefully painted with a special dark gray EPOXY Industrial Paint. It was considered to make a new lot with a predetermined weight of gangue and valuable mineral from each size fraction. The valuable minerals were represented with dark colored paint (10 kg). In contrast, the gangue minerals remained unpainted (40 kg).

A proportion with a known quantity from valuable and gangue mineral was gathered to form a 50 kg new lot, so called the synthetic lot of the experiment. This procedure was implemented to LOT A and LOT B separately.

3.1.2. Sieve Analysis of Synthetic Lot

Sieve analysis was applied to LOT A and LOT B separately. These lots are 50 kg each. First tests were implemented on LOT A. As it is mentioned above, LOT A was made up of particles having coarser size. During the analysis, 6 sieves were used. These sieves were prepared according to the International Standards. Besides, all portions of sieve analysis were carefully weighed in few grams basis by means of a balance scale. Each size fraction is listed to show the general distribution of the lot.

LOT A and LOT B are synthetic lots formed by mixing known proportions of pure components. These two components are the valuable minerals (painted) together with gangue minerals (unpainted). The main concern should be the conformity of the accuracy towards the assay and the size distribution between the valuable minerals and the entire lot. These are represented in Figure 15 and Figure 16. It is desired that the extracted sample increment should have the same assay and size distribution characteristics with the entire lot. The lot was carefully blended to maintain homogeneity at each stage of operation.

Physical analysis of LOT A is stated as follows:

Table 1. Size and Weight Fraction of LOT A

Size Fraction (mm)	Weight (g)	Weight (%)	Cum. Wt % Ret.	Cum. Wt % Pass.
+ 22 mm	1710	3.43	3.43	96.57
- 22 mm + 20 mm	7490	15.04	18.47	81.53
- 20 mm + 16 mm	10560	21.21	39.68	60.32
- 16 mm + 8 mm	29450	59.14	98.82	1.18
- 8 mm + 4 mm	290	0.58	99.40	0.60
- 4 mm + 2 mm	80	0.16	99.56	0.44
- 2 mm	220	0.44	-	-
Accuracy	200	-	-	-
Total	50000	100.00	-	-

Table 2. Sieve Analysis of valuable minerals (painted) in LOT A

Size Fraction (mm)	Weight (g)	Weight (%)	Cum. Wt % Ret.	Cum. Wt % Pass.
+ 22 mm	300	2.99	2.99	97.01
- 22 mm + 20 mm	1560	15.53	18.52	81.48
- 20 mm + 16 mm	2020	20.12	38.64	61.36
- 16 mm + 8 mm	6020	59.96	98.60	1.40
- 8 mm + 4 mm	50	0.50	99.10	0.90
- 4 mm + 2 mm	40	0.40	99.50	0.50
- 2 mm	50	0.50	-	-
Accuracy	40	-	-	-
Total	10000	100.00	-	-

In this step, the valuable mineral that was carefully selected from the lot by careful monitoring was recorded with respect to the size fraction. The requirement is to receive a representative portion from the lot. The material is generally segregated from top to bottom, so the shovel should move from bottom to top in favor of receiving from all size fractions.

Although they seem negligible, it is preferred to record the accuracy of reading since there may have been some differences occurred due to some reasons such as misreading of the weight of the material in weighting balance. It is not an electronic scale so the measurements mostly depend on eye. It can be measured with 10 grams accuracy.

On the other hand, these are partially caused by the inefficient collection of the particles from the surface. The material may have lost during the transport from one side to another, although it was spent so much effort to prevent any material accumulation on the surface. Physical analysis of LOT A is stated as follows:

Table 3. Size and Weight Fraction of LOT B:

Size Fraction (mm)	Weight (g)	Weight (%)	Cum. Wt % Ret.	Cum. Wt % Pass.
+ 22 mm	5	0.01	0.01	99.99
- 22 mm + 20 mm	243	0.49	0.50	99.50
- 20 mm + 16 mm	3290	6.57	7.07	92.93
- 16 mm + 8 mm	45720	91.33	98.40	1.60
- 8 mm + 4 mm	232	0.46	98.86	1.14
- 4 mm + 2 mm	90	0.18	99.04	0.96
- 2 mm	480	0.96	-	-
Accuracy	60	-	-	-
Total	50000	100.00	-	-

Table 4. Sieve Analysis of valuable minerals (painted) in LOT B

Size Fraction (mm)	Weight (g)	Weight (%)	Cum. Wt % Ret.	Cum. Wt % Pass.
+ 22 mm	0	0	0.00	100.00
- 22 mm + 20 mm	50	0.50	0.50	99.50
- 20 mm + 16 mm	810	8.05	8.55	91.45
- 16 mm + 8 mm	8990	89.45	98.00	2.00
- 8 mm + 4 mm	80	0.80	98.80	1.20
- 4 mm + 2 mm	20	0.20	99.00	1.00
- 2 mm	100	1.00	-	-
Experimental bias	50	-	-	-
Total	10000	100.00	-	-

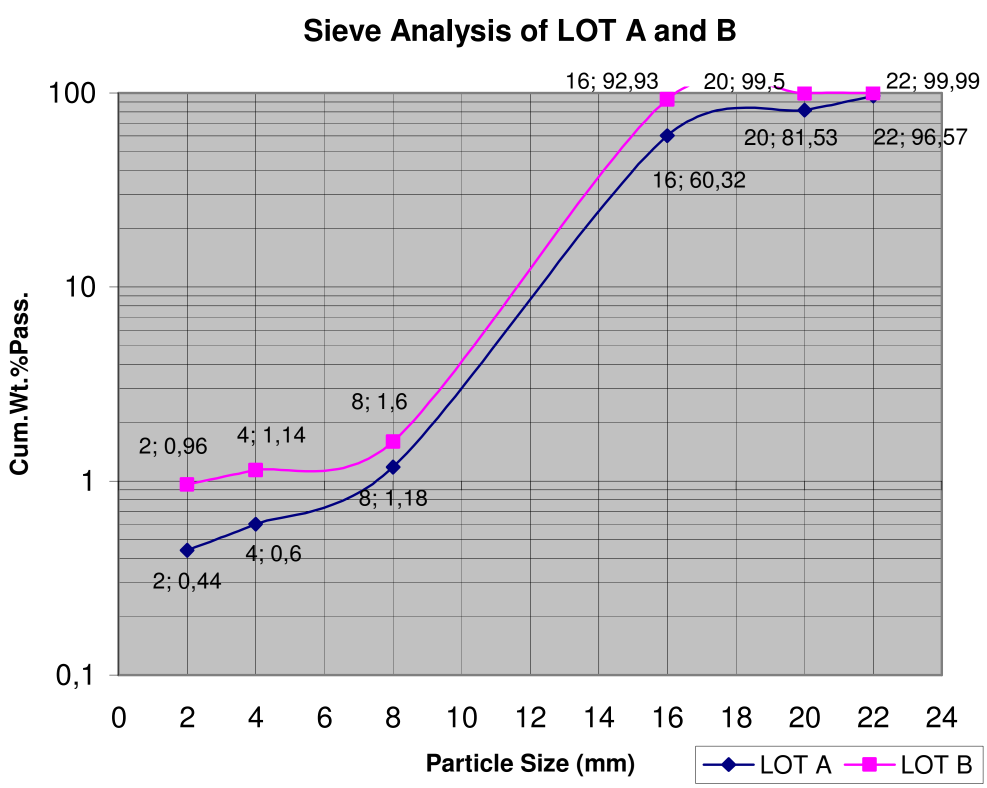


Figure 14. Sieve Analysis of LOT A and LOT B

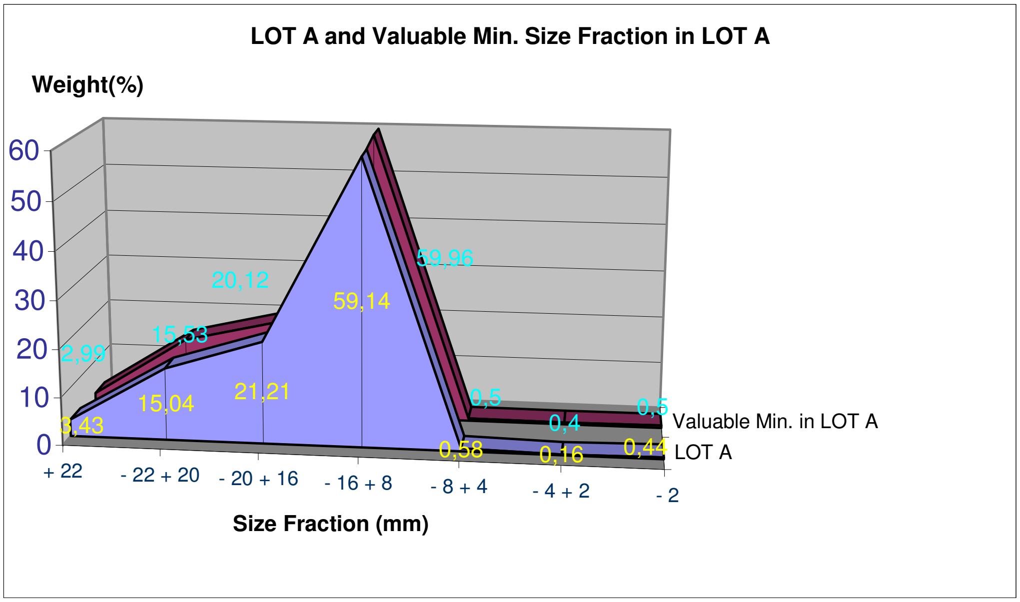


Figure 15. Size Fraction of LOT A versus Valuable Mineral in LOT A

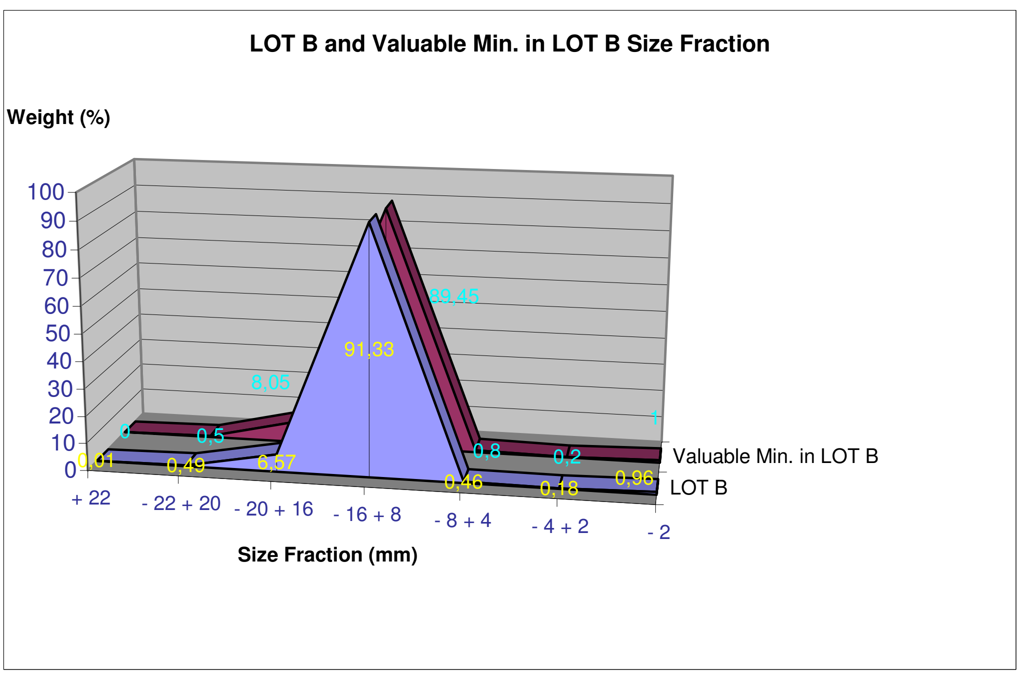


Figure 16. Size Fraction of LOT B versus Valuable Mineral in LOT B

There are many ways of showing the results. Although arithmetic graph paper can be used, it suffers from the disadvantage that points in the region of finer aperture sizes tend to become congested. A semi-logarithmic plot avoids this, with a linear ordinate for percentage passed or retained material and a logarithmic abscissa for particle size (Wills, 1985).

The sieve analysis of valuable material both in LOT A and LOT B are close to the fractions in sieve analysis of the entire lot. It is for sure that 100 % similarity in the sieve analysis of both cannot be reached. However, these results would be representative for following experiments.

The chemical compositions of LOT A and LOT B were analysed in Turkish Cement Manufacturer's Association's quality control laboratories. Two analyses were realized for CaO and MgO content of these lots.

Table 5. Chemical Composition of LOT A and LOT B

	% CaO	% $CaCO_3$	% MgO	% $MgCO_3$
LOT A	53.67	95.84	0.61	1.28
LOT B	52.74	94.18	1.10	2.31

After having the sieve analysis, their size and weight fractions were analyzed so as to enlighten the experimental procedures and to have an idea whether the sample extracted was representative and reproducible for the entire lot.

The material used in the experiments is limestone having the specific gravity of 2.67.

3.2. EQUIPMENT

3.2.1. Belt Conveyor

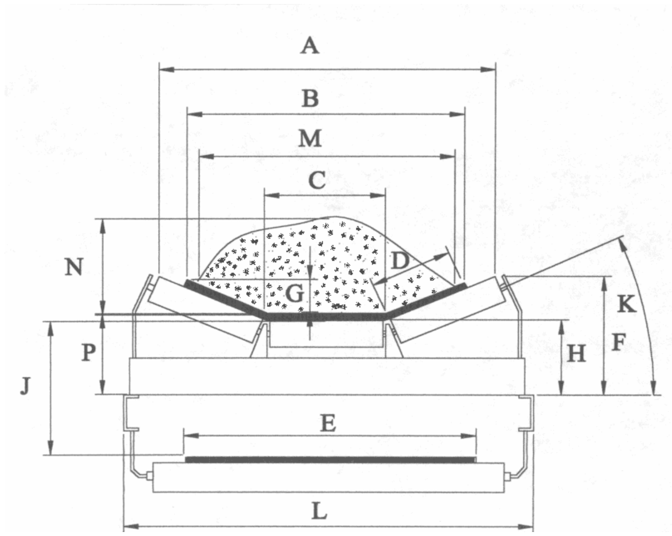


Figure 17. Technical specifications of testing belt conveyor

Table 6. Dimensions of testing belt conveyor

A	**950 mm**	**Across Wing Roll Tips**
B	**780 mm**	**Working Belt Width**
C	**315 mm**	**Center Belt Width**
D	**205 mm**	**Side Belt Width**
E	**800 mm**	**Flat Belt Width**
F	**490 mm**	**Wing Roll Tip Height**
G	**12 mm**	**Belt Center Sag**
H	**385 mm**	**Center Roll Height**
J	**240 mm**	**Distance to Return Belt**
K	**18.5°**	**Outer Roll Angle**
L	**1170 mm**	**Width Over Stringers**
M	**580 mm**	**Product Width on Belt**
N	**50 mm (max.)**	**Product Height on Belt**

The pneumatic air shock sampling device was installed on a testing belt conveyor. The belt conveyor has a driving pulley and a head pulley, having diameters 420 mm and 280 mm, respectively. The belt is vulcanized and has 3 – plies with inner clothing. The conveyor chasis is ordinary steel profile. The length of the chasis is 7.92 meters from the centers of the pulleys. In total the length of the belt conveyor is 8.27 meters. The belt specifications and other dimensions are shown in Figure 16. The driving mechanism has 50 rev. / min with power 1.5 kW. It has a reduction rate of 1 / 30.

3.2.2. Frequency Converter

Frequency Converter Motor Speed Integrator was installed to carry out the experiment with different conveyor belt speeds. The speed of the conveyor can be adjusted by changing the frequency up to 50 Hz manually. The maximum belt speed reached is 1 m / sec. These frequency values represent the values for the speed of the conveyor.

3.2.3. Start – Stop Box

Start – Stop Box was used to send signal to the frequency converter to operate the conveyor or to stop the movement of the conveyor. An operator was on charge to use the Start – Stop box in order to prevent the flooding of the material from the discharge end.

3.2.4. Channel, Chute, Bunker and Bucket

The sample increment has to be carried through a channel towards the chute and finally to a bucket for picking up. For that reason a closed structure was constructed from the initial point of sample extraction till the final destination of sample. These were constructed over the conveyor to form a path for the sample increment and to prevent the scattering of the material. Three structures were welded together to form an assembly. These were constructed from 3 mm thick steel. The material coming through the bunker was falling down to bucket. It is shown in Figure A1 and A2.

3.2.5. Alignment Table

Alignment table was installed to keep the Air Cannon Sampling System stationary during operation. Alignment table has a special grooved surface. The sampling mechanism was placed on that surface with another support plate. Distance of sampling mechanism can be adjusted by moving support plate on that grooved surface by means of bolts and nuts.

3.2.6. Air Cannon Sampling System

Air Cannon Sampling System is the major component of Industrial Sampling Station. Air Cannon is a pressure resistant air tank having different volumes. It is designed to resist to 10 kg / cm^2 air pressure. The system is designed as R2" and R4" outlet flanges, meaning 2 and 4 inches outlet diameter. Inside, there is piston mechanism and chrome plated cylinder housing with recompression spring. (Working principle of the system will be given in Section 3.3. Method).

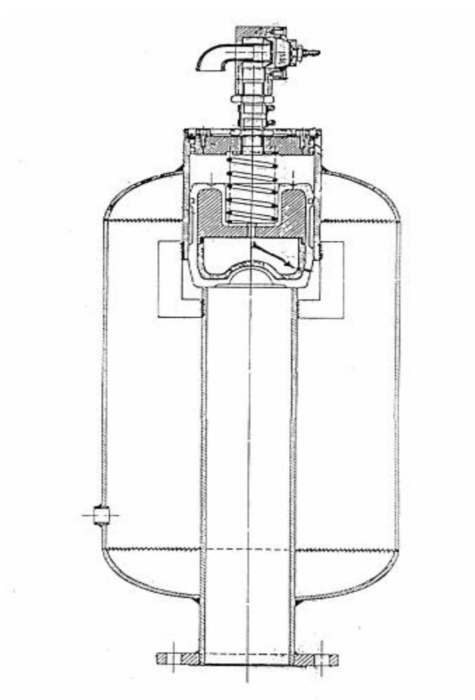


Figure 17. Technical cross–sectional drawing of Air Cannon.

3.2.7. Quick Exhaust Valve (Q.E.V) and Connections

It is an excessive air-releasing valve placed at the top of the Air Cannon having inlet and outlet as 1/4" - 3/4". It has fittings and flexible connecting hose to connect the valve to air cannon tank.

3.2.8. Nozzles

Nozzles are the connection parts placed at the outlet of the Air Cannons to give a direction to the discharged air through surface by a controlled release. Different types of nozzles can be used depending on the operation. The nozzle types used are Y – Type Nozzles and Pipe – Type Nozzles. Y – Type Nozzles are designed to give a spreading effect to the discharged air due to their geometry. Pipe – Type Nozzles are designed to give a punctual effect to the discharged air that tends to follow up a cylindrical path.

3.2.9. Hose System

Pressure resistant hose and fittings were lined up between the air compressor and the Air Cannon to form a network for the pressurized air.

3.2.10. Air Regulator

Air Regulator was connected to adjust the air pressure coming from the air compressor to the Air Cannon. The air pressure can be read for the air given inside the Air Cannon from the gauge of the regulator.

3.2.11. 3 / 2 Way Valve

Air Cannon can be activated manually by 3 / 2 Way Valve. An operator was sufficient to adjust the air pressure with Air Regulator and operate 3 / 2 Way Valve. The valve works for opening and closing the path of air through the Air Cannon.

3.2.12. Compressor

Compressor produces the pressurized air necessary for the system.

3.3. METHOD

Air Cannon Sampling System releases compressed air stored inside the cannon with a velocity. It kinetically activates the stationary material that is adhered on a surface or in another condition. The compressor generates the pressurized air for cannon. The compressed air is discharged from the outlet of air cannon which has different diameters such as 2" (50.8 mm) and 4" (101.6 mm). The air is introduced with a flexible hose to Quick Exhaust Valve through which it fills inside the Air Cannon. The air moves inside the Air Cannon via a hollow opening inside the piston. Air fills the free volume inside the air cannon by passing through a very small opening located at the bottom of the piston (This is shown with an arrow in Figure 17). The air fills inside cannon and air feeding stops.

The Air Cannon is activated by using 3 / 2 Way Valve for sampling. The excess air leaves from the outlet of the Quick Exhaust Valve, which causes the rubber seal pulling backwards after initiating the operation. The rubber seal is a mobile component inside the Quick Exhaust Valve. Air is primarily located at the top of the piston. A pressure difference (Δp) is generated by the release of air over the piston. The air inside the cannon will apply a pressure towards both sides of the piston. This pressure causes the piston to move upwards towards the compression spring. The cylinder housing opens with the movement of the piston. Air stored inside the cannon passes through the cyclinder housing. It moves towards the outlet of the Air Cannon and leaves the system from the nozzle. The air from the nozzle is active along the conveyor belt together with the sample increment.

The sudden but controlled release of compressed air into the material is faster than the material can absorb it; thereby causing the material to get dislodged and move. The moved particles can be gathered as sample increments from the dynamic lot over the conveyor.

The tests were conducted for two types of lots, namely LOT A and LOT B. These lots were prepared as synthetic lots. These lots were homogenized throughout each consecutive procedure before testing. Their physical and chemical properties are presented from Table 1 till Table 5 respectively.

As a first step, LOT A was spreaded on the conveyor belt without leading any groupings on specific parts of the belt. The surface of the lot was leveled with a polyamide sheet. It is required to prevent any sampling errors generated from misalignment of the lot. This lot was conveyed to the sampling station, where the sampling increment was received. There were different parameters for testing.

The objective of the experiment is to find out the most effective way of operating this new system of sampling technology by applying different parameter variations. This objective is realized by comparing the results of each consecutive analysis of sample increment extraction with the tabulated data of the specified lot. The geometry of the increment extracted from the sampling procedure should carry the model increment extraction motive as shown in Figure 10. Partially taken sample increments can not be considered as representative increments although the methodology matches with the methodology of the entire lot.

As a second step, the most feasible constraint of these parameters were found by trying each data of a parameter. The technique used is ‘one variable at a time’. This procedure was followed up until all parameters were evaluated.

3.3.1. Parameters:

– Speed of the Belt Conveyor:

Three different belt speeds were tested. Speed variations were adjusted by frequency converter. The tests were carried out with maximum frequency of 50 Hz that offsets 1 m / sec, medium frequency of 25 Hz that offsets 0.5 m / sec and a low frequency of 8.48 Hz that offsets 0.17 m / sec. The next parameter - the difference in feeding air pressure - was monitored, after finding the most appropriate speed for the conveyor.

– Air Shock Pressure:

Test were realized in various air shock pressure values. The initial pressure value was 3 kg / cm². It was followed up by 4, 5, 5.5, 6 and ended up with 7 kg / cm².

– Distance of Air Cannon from the Conveyor Belt
(Position of the air nozzle from the Conveyor Belt)

The alignment table was designed to give movement capability to air cannon on a grooved surface. The initial location of the air cannon was recorded as 365 mm from support plate till the entrance of the channel. Other testing positions were 315 mm and 415 mm respectively. These values are 365 ± 50 mm.

(In other words; initially 100 mm portion of the nozzle was driven inside the belt. It was followed up 50 mm and 150 mm portion of nozzle that were in the belt).

– Angle of the Nozzles

The nuts and bolts were used to change the height of the nozzle on to the belt. The difference in height leads to losing the parallelism of the nozzle with the surface of the belt.

– Type of the Nozzles

Y – Type and Pipe – Type Nozzles were used in testing of air cannon sampling system. Y – Type nozzle has 60º angle to spread the air coming from the cannon. It is given in Figure C1. It has a shape of truncated half cone. Pipe – Type nozzle has a cylindrical shape, having 2" (50.8 mm) outlet diameter. It is given in Figure C2. Both nozzles have an inclination of 22º.

– Type of Air Cannons

Three different types of air cannons were manufactured for tests. First air cannon was manufactured as 12 liters capacity with 4" (101.6 mm) outlet pipe. Second air cannon was manufactured as 20 liters capacity with 2" (50.8 mm) outlet pipe. Third air cannon was manufactured as 36 liters capacity with 4" (101.6 mm) outlet pipe.

The above mentioned parameters were used in testing of the air cannon sampling system for LOT A and LOT B. These lots have different size fractions and weight distributions. The effects of those parameters were carefully monitored so as to receive a correct geometry and representative sample increment extraction. All findings were presented as experimental data. In general, each tests were carried out twice to see experimental reproducibility. It will be seen below that the belt speed tests were initially conducted with 0.17 m / sec and repeated once again to have reproducible results.

3.3.2 Methodology of evaluation the results

The results of the succeeding experiments are compared according to the following evaluation criteria:

- Sampling Increment Geometry: It should be referred to correct increment extraction procedure that was stated in Section 2.4.2. The values of a1, a2, b and h are examined as given in Figure 10. b and h can be different from each other if the increment extraction is diagonal. a1 and a2 is required to be close or ideally same.
- $|\Delta d|$: It is the absolute cumulative difference between the weight percent of the lot and weight percent of the test in each size fraction. (%)
- V / G: It is the ratio of the valuable minerals to gangue minerals
- Amount of Sample Increment Extracted: The quantity of the sample increment received from the entire crosscut of stream of flow is important.
- Amount of Material Lost: The lost material is not received inside the bucket instead spreaded on a controlled area during the sample extraction The amount of lost material and its valuable mineral content are one of the factors for evaluation.

CHAPTER IV

EXPERIMENTAL RESULTS AND DISCUSSION

4.1. EXPERIMENTS WITH LOT A

4.1.1. Parameter: Speed of the Belt Conveyor

In first set of the experiments, belt conveyor speed was considered as variable while other parameters remain constant. 6 subsequent tests were performed in three groups. Each number indicates the specific experiment with one parameter. The letters a and b show that the experiment was repeated for reproducibility.

Table 7. Tests with Parameter: Speed of the Belt Conveyor for LOT A.

Experiment No	Variable Parameter: Speed of the Belt Conveyor
I – a	0.17 m / sec with 8.48 Hz. and 240 rev / min
I – b	0.17 m / sec with 8.48 Hz. and 240 rev / min
II – a	0.50 m / sec with 25 Hz. and 707 rev / min
II – b	0.50 m / sec with 25 Hz. and 707 rev / min
III – a	1.00 m / sec with 50 Hz. and 1414 rev / min
III – b	1.00 m / sec with 50 Hz. and 1414 rev / min

The initial experiments were performed with 20 liters capacity air cannon. The air pressure was initially set as 3 kg / cm². The distance of the air cannon from the support plate to the entrance of the channel was 365 mm or in other words the nozzle was located 100 mm inside the side belt. Y – Type nozzle was initially used. The angle of nozzle was equal to outer roll angle K given as 18.5° in Figure 16.

Test I – a: (0.17 m / sec)

Table 8. Size and Weight Fraction of Test I – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT A}$ (%)	Δ d $C_{LOT A} - C_{TEST}$
+ 22 mm	40	4.05	3.45	- 0.60
- 22 mm + 20 mm	350	35.35	15.11	- 20.24
- 20 mm + 16 mm	180	18.18	21.30	3.12
- 16 mm + 8 mm	410	41.42	59.40	17.98
- 8 mm + 4 mm	5	0.50	0.58	0.08
- 4 mm + 2 mm	5	0.50	0.16	- 0.34
Total Weight	990	-	-	|Δ d| = 42.36

Table 9. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT A}$ V_{LOTA}/G_{LOTA}
740	250	990 (Test)	0.34	0.25
35	5	40 (Lost)	0.14	-

The values for extracted increment are:

a1	60 mm
a2	110 mm
b	315 mm
h	300 mm

Test I – b: (0.17 m / sec)

Table 10. Size and Weight Fraction of Test I – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	60	6.49	3.45	- 3.04
- 22 mm + 20 mm	275	29.73	15.11	- 14.62
- 20 mm + 16 mm	170	18.38	21.30	2.92
- 16 mm + 8 mm	380	41.08	59.40	18.32
- 8 mm + 4 mm	30	3.24	0.58	- 2.66
- 4 mm + 2 mm	10	1.08	0.16	- 0.92
Total Weight	925	-	-	$\lvert\Delta d\rvert = 42.48$

Table 11. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
705	220	925 (Test)	0.31	0.25
65	15	80 (Lost)	0.23	-

The values for extracted increment are:

a1	60 mm
a2	110 mm
b	300 mm
h	280 mm

Test II – a: (0.50 m / sec)

Table 12. Size and Weight Fraction of Test II – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	95	12.58	3.45	- 9.13
- 22 mm + 20 mm	110	14.57	15.11	0.54
- 20 mm + 16 mm	110	14.57	21.30	6.73
- 16 mm + 8 mm	430	56.96	59.40	2.44
- 8 mm + 4 mm	5	0.66	0.58	- 0.08
- 4 mm + 2 mm	5	0.66	0.16	- 0.5
Total Weight	755	-	-	$\lvert\Delta d\rvert = 19.42$

Table 13. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ (%) V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ (%) V_{LOTA}/G_{LOTA}
590	165	755 (Test)	0.28	0.25
40	5	45 (Lost)	0.13	-

The values for extracted increment are:

a1	60 mm
a2	120 mm
b	310 mm
h	300 mm

Test II – b: (0.50 m / sec)

Table 14. Size and Weight Fraction of Test II – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	80	10.81	3.45	- 7.36
- 22 mm + 20 mm	125	16.89	15.11	- 1.78
- 20 mm + 16 mm	135	18.24	21.30	3.06
- 16 mm + 8 mm	390	52.70	59.40	6.70
- 8 mm + 4 mm	5	0.68	0.58	- 0.10
- 4 mm + 2 mm	5	0.68	0.16	- 0.52
Total Weight	740	-	-	$\lvert\Delta\ d\rvert = 19.52$

Table 15. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
590	150	740 (Test)	0.25	0.25
65	5	70 (Lost)	0.08	-

The values for extracted increment are:

a1	65 mm
a2	120 mm
b	300 mm
h	280 mm

Test III – a: (1.00 m /sec)

Table 16. Size and Weight Fraction of Test III – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A}$ - C_{TEST}
+ 22 mm	35	4.64	3.45	- 1.19
- 22 mm + 20 mm	70	9.27	15.11	5.84
- 20 mm + 16 mm	130	17.22	21.30	4.08
- 16 mm + 8 mm	510	67.55	59.40	- 8.15
- 8 mm + 4 mm	5	0.66	0.58	- 0.06
- 4 mm + 2 mm	5	0.66	0.16	- 0.50
Total Weight	755	-	-	|Δ d| = 19.82

Table 17. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
630	125	755 (Test)	0.20	0.25
80	10	90 (Lost)	0.13	-

The values for extracted increment are:

a1	60 mm
a2	140 mm
b	300 mm
h	280 mm

Test III – b: (1.00 m /sec)

Table 18. Size and Weight Fraction of Test III – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A}$ - C_{TEST}
+ 22 mm	15	1.75	3.45	1.70
- 22 mm + 20 mm	90	10.53	15.11	4.58
- 20 mm + 16 mm	160	18.71	21.30	2.59
- 16 mm + 8 mm	580	67.83	59.40	- 8.43
- 8 mm + 4 mm	5	0.59	0.58	- 0.01
- 4 mm + 2 mm	5	0.59	0.16	- 0.43
Total Weight	855	-	-	$\lvert\Delta$ d$\rvert$ = 17.74

Table 19. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
710	145	855 (Test)	0.21	0.25
65	5	70 (Lost)	0.08	-

The values for extracted increment are:

a1	55 mm
a2	130 mm
b	300 mm
h	280 mm

4.1.1.1 Discussions on Belt Conveyor Speed Parameter Tests

1. It was observed that the increment received did not represent the entire stream of the transversal cross section. The smaller is the amount of the increment, the harder the sample to be representative for the entire lot. In each test, the sample increment weights should be monitored. The sample increments weighed less than 1 kg for all tests.

It was seen that the differential conveyor belt speeds are not in correlation with the amount of extracted material. Therefore another constraint should be investigated for the amount of the sample collected. This is the air shock pressure and it will be given accordingly.

2. The sieve analysis were done for the entire lot and for the sample increment individually to find the distribution among these specific size fractions. It was expected to have identical size distribution between the entire lot and the sample increment received after testing. It is almost impossible to receive the identical size distribution because of various factors that can affect the accuracy of the testing. However, Δ d was defined to show the difference in distribution of the same size fraction between the entire lot and the sample increment. The smaller is the Δ d, the more accurate the size distribution analysis of the sample to the lot. These Δ d values were added up to find the absolute cumulative difference among each size fraction. It is used to compare each test. It is denoted by | Δ d|. The data showed that Test II with 0.50 m / sec and Test III with 1.00 m / sec had very close | Δ d| values.

3. The main lot was formed as 20 % valuable mineral and 80 % gangue mineral. The ratio of lot is 0.25. It was expected from the sample increment tests to be close to that ratio. This result was reached only in Test II – b with 0.50 m / sec as 0.25.

4. The lost material is carefully monitored to return the material to the lot. In Test III the lost material reached to its maximum. The relation can be formed as the lost material quantity increases as the belt speed increases. On the other hand, there is no big difference in lost material quantity among the tests.

5. Unfortunately, some portion of the material remained on the belt conveyor during speed tests. The possible reason for this outcome is insufficient air shock pressure to take out the increments. In both tests, the b and h value varies between 280 mm and 300 mm. The total width of the material on the belt is 580 mm. Therefore, 300 mm and 280 mm of the material remained on the belt. The geometry of the correct delimitation was not obeyed in these test increments.

The geometry of correct delimitation is to keep the same width of extraction throughout the increment extraction width. The cross sectional width of the increment should be the same from the entrance of the cutter till the location, where the increment is dumped into the chute.

The conveyor belt speed was selected as 0.50 m / sec for the following tests referring to the above given results.

4.1.2. Parameter: Air Shock Pressure

The first parameter used in testing was the belt conveyor speed variables. All results were evaluated for speed analysis. 0.50 m / sec was selected as the speed of testing with 20 lt. Air Cannon for 800 mm width conveyor belt. The nozzle portion inside the conveyor belt is 100 mm and Y – Type Nozzle is used. The nozzle was installed parallel to the side belt.

In second part of the experiments, the belt speed was selected as 0.50 m / sec and this kept constant throughout the following tests. The tests were conducted by applying the following pressure values as: 4 kg / cm^2, 5 kg / cm^2, 5.5 kg / cm^2, 6 kg / cm^2 and finally 7 kg / cm^2.

Table 20. Tests with Parameter: Air Shock Pressure for LOT A.

Experiment No	Variable Parameter: Air Shock Pressure
II – a	3 kg / cm²
II – b	3 kg / cm²
IV – a	4 kg / cm²
IV – b	4 kg / cm²
V – a	5 kg / cm²
V – b	5 kg / cm²
VI – a	5.5 kg / cm²
VI – b	5.5 kg / cm²
VII – a	6 kg / cm²
VII – b	6 kg / cm²
VIII – a	7 kg / cm²
VIII – b	7 kg / cm²

These experiments were performed with 20 liters capacity air cannon. The speed of the belt conveyor is 0.50 m / sec. The distance of the air cannon from the support plate to the entrance of the channel was 365 mm. Y – Type nozzle was used. The angle of nozzle with the horizontal was equal to Outer Roll Angle: K given as 18.5°.

Various pressure values are tested to find the value of pressure.

Test IV – a: (4 kg / cm²)

Table 21. Size and Weight Fraction of Test IV – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Content LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	100	6.56	3.45	- 3.11
- 22 mm + 20 mm	190	12.45	15.11	2.66
- 20 mm + 16 mm	270	17.70	21.30	3.60
- 16 mm + 8 mm	950	62.30	59.40	- 2.90
- 8 mm + 4 mm	10	0.66	0.58	- 0.08
- 4 mm + 2 mm	5	0.33	0.16	- 0.17
Total Weight	1525	-	-	|Δ d| = 12.52

Table 22. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
1175	350	1525 (Test)	0.30	0.25
75	15	90 (Lost)	0.20	-

The values for extracted increment are:

a1	60 mm
a2	140 mm
b	400 mm
h	380 mm

Test IV – b: (4 kg / cm²)

Table 23. Size and Weight Fraction of Test IV – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOTA $C_{LOT\,A}$ (%)	Δ d $C_{LOT\,A} - C_{TEST}$
+ 22 mm	95	8.05	3.45	- 4.60
- 22 mm + 20 mm	120	10.17	15.11	4.94
- 20 mm + 16 mm	200	16.95	21.30	4.35
- 16 mm + 8 mm	750	63.56	59.40	- 4.16
- 8 mm + 4 mm	10	0.85	0.58	- 0.27
- 4 mm + 2 mm	5	0.42	0.16	- 0.26
Total Weight	1180	-	-	|Δ d| = 18.58

Table 24. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\,A}$ V_{LOTA}/G_{LOTA}
920	260	1180 (Test)	0.29	0.25
85	35	120 (Lost)	0.41	-

The values for extracted increment are:

a1	65 mm
a2	150 mm
b	360 mm
h	380 mm

Test V – a: (5 kg / cm²)

Table 25. Size and Weight Fraction of Test V – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A}$ - C_{TEST}
+ 22 mm	130	4.81	3.45	- 1.36
- 22 mm + 20 mm	350	12.94	15.11	2.17
- 20 mm + 16 mm	445	16.45	21.30	4.85
- 16 mm + 8 mm	1740	64.32	59.40	- 4.92
- 8 mm + 4 mm	30	1.11	0.58	- 0.48
- 4 mm + 2 mm	10	0.37	0.16	- 0.19
Total Weight	2705	-	-	|Δ d| = 13.97

Table 26. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ (%) V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ (%) V_{LOTA}/G_{LOTA}
2145	560	2705 (Test)	0.26	0.25
40	5	45 (Lost)	0.13	-

The values for extracted increment are:

a1	65 mm
a2	150 mm
b	530 mm
h	510 mm

Test V – b: (5 kg / cm²)

Table 27. Size and Weight Fraction of Test V – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\,A}$ (%)	Δ d $C_{LOT\,A} - C_{TEST}$
+ 22 mm	180	6.94	3.45	- 3.49
- 22 mm + 20 mm	410	15.80	15.11	- 0.69
- 20 mm + 16 mm	520	20.04	21.30	1.26
- 16 mm + 8 mm	1470	56.65	59.40	2.75
- 8 mm + 4 mm	10	0.39	0.58	0.19
- 4 mm + 2 mm	5	0.19	0.16	- 0.03
Total Weight	2595	-	-	$\lvert\Delta d\rvert = 8.41$

Table 28. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\,A}$ V_{LOTA}/G_{LOTA}
2055	540	2595 (Test)	0.26	0.25
125	35	160 (Lost)	0.28	-

The values for extracted increment are:

a1	65 mm
a2	150 mm
b	540 mm
h	520 mm

Test VI – a: (5.5 kg / cm²)

Table 29. Size and Weight Fraction of Test VI – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	330	7.91	3.45	- 4.46
- 22 mm + 20 mm	625	14.99	15.11	- 0.12
- 20 mm + 16 mm	750	17.99	21.30	3.31
- 16 mm + 8 mm	2440	58.51	59.40	0.89
- 8 mm + 4 mm	15	0.36	0.58	0.22
- 4 mm + 2 mm	10	0.24	0.16	- 0.08
Total Weight	4170	-	-	$\lvert\Delta d\rvert = 9.08$

Table 30. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
3350	820	4170 (Test)	0.25	0.25
150	40	190 (Lost)	0.27	-

The values for extracted increment are:

a1	150 mm
a2	155 mm
b	610 mm
h	580 mm

Test VI – b: (5.5 kg / cm²)

Table 31. Size and Weight Fraction of Test VI – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	145	4.66	3.45	- 1.21
- 22 mm + 20 mm	450	14.47	15.11	0.64
- 20 mm + 16 mm	675	21.70	21.30	- 0.40
- 16 mm + 8 mm	1800	57.88	59.40	1.52
- 8 mm + 4 mm	30	0.96	0.58	- 0.38
- 4 mm + 2 mm	10	0.32	0.16	- 0.16
Total Weight	3110	-	-	$\lvert\Delta d\rvert = 4.31$

Table 32. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
2450	660	3110 (Test)	0.27	0.25
170	40	210 (Lost)	0.24	-

The values for extracted increment are:

a1	155 mm
a2	160 mm
b	610 mm
h	580 mm

Test VII – a: (6 kg / cm²)

Table 33. Size and Weight Fraction of Test VII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	360	9.14	3.45	- 5.69
- 22 mm + 20 mm	530	13.45	15.11	1.66
- 20 mm + 16 mm	600	15.24	21.30	6.06
- 16 mm + 8 mm	2400	60.91	59.40	- 1.51
- 8 mm + 4 mm	40	1.01	0.58	- 0.43
- 4 mm + 2 mm	10	0.25	0.16	- 0.09
Total Weight	3940	-	-	$\lvert\Delta d\rvert = 15.44$

Table 34. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
3160	780	3940 (Test)	0.25	0.25
30	170	200 (Lost)	0.18	-

The values for extracted increment are:

a1	180 mm
a2	220 mm
b	610 mm
h	580 mm

Test VII – b: (6 kg / cm²)

Table 35. Size and Weight Fraction of Test VII – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT A}$ (%)	Δ d $C_{LOT A} - C_{TEST}$
+ 22 mm	280	8.81	3.45	- 5.36
- 22 mm + 20 mm	480	15.09	15.11	- 0.02
- 20 mm + 16 mm	410	12.89	21.30	8.41
- 16 mm + 8 mm	1990	62.58	59.40	- 3.18
- 8 mm + 4 mm	15	0.47	0.58	- 0.11
- 4 mm + 2 mm	5	0.16	0.16	0.00
Total Weight	3180	-	-	$\lvert\Delta d\rvert = 17.08$

Table 36. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT A}$ V_{LOTA}/G_{LOTA}
2480	700	3180 (Test)	0.28	0.25
170	50	220 (Lost)	0.29	-

The values for extracted increment are:

a1	210 mm
a2	240 mm
b	610 mm
h	580 mm

Test VIII – a: (7 kg / cm²)

Table 37. Size and Weight Fraction of Test VIII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A}$ - C_{TEST}
+ 22 mm	230	5.88	3.45	- 2.43
- 22 mm + 20 mm	600	15.35	15.11	- 0.24
- 20 mm + 16 mm	560	14.32	21.30	6.98
- 16 mm + 8 mm	2470	63.17	59.40	-3.77
- 8 mm + 4 mm	30	0.77	0.58	- 0.19
- 4 mm + 2 mm	20	0.51	0.16	- 0.35
Total Weight	3910	-	-	|Δ d| = 13.96

Table 38. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
3210	700	3910 (Test)	0.22	0.25
190	50	240 (Lost)	0.26	-

The values for extracted increment are:

a1	180 mm
a2	230 mm
b	610 mm
h	580 mm

Test VIII – b: (7 kg / cm²)

Table 39. Size and Weight Fraction of Test VIII – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	140	3.96	3.45	- 0.51
- 22 mm + 20 mm	450	12.71	15.11	2.40
- 20 mm + 16 mm	630	17.80	21.30	3.50
- 16 mm + 8 mm	2250	63.56	59.40	- 4.16
- 8 mm + 4 mm	60	1.69	0.58	- 1.11
- 4 mm + 2 mm	10	0.28	0.16	- 0.12
Total Weight	3540	-	-	$\lvert\Delta d\rvert = 11.08$

Table 40. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
2920	620	3540 (Test)	0.21	0.25
185	35	220 (Lost)	0.18	-

The values for extracted increment are:

a1	220 mm
a2	200 mm
b	610 mm
h	580 mm

4.1.2.1. Discussions on Air Shock Pressure Tests

1. It had been observed that the correct increment extraction was received after applying air pressure as 5.5 kg / cm². This will be illustrated in Figure 21. These pictures were taken during the experiments. It was not possible to take a correct increment at 3, 4 and 5 kg / cm² pressure values. The air pressure energy applied was not sufficient to extract a complete increment. Therefore, it can be expressed that air pressure values higher than 5.5 kg / cm² represented the entire stream of the transversal cross section. Correct increment extraction geometry was almost received. The sample increment weight increase should be monitored as the pressure value increases. There is a direct correlation between the quantities of the sample extracted with the air pressure applied.

2. The smaller is the Δ d, the more accurate the size distribution analysis of the sample to the lot. The absolute sum of these values should be recorded. The ideal is to have 0 in absolute sum. However, the uniform distribution and small $\Sigma |\Delta d|$ values have been reached in Test V – b with 5 kg / cm² air pressure value, Test VI – a and Test VI – b with 5.5 kg / cm² air pressure value as 8.41, 9.08 and 4.31 respectively.

3. The ratio of valuable minerals to gangue minerals in entire lot is 0.25. It was expected from the sample increment tests to have this value. All the air pressure value tests in LOT A were recorded to have 0.25 in these tests. Finally, in Test VI – a with 5.5 kg / cm² and Test VII – a with 6 kg / cm², the valuable to gangue ratio is 0.25.

4. As the air pressure increases, the amount of the lost material increases. These increases can be monitored starting from Test IV with 4 kg / cm² air pressure value to the preceding tests. The lost material amount has its peak value in Test VII – a with 6 kg / cm² with 240 grams.

The air pressure was selected as 5.5 kg / cm² for the following tests referring to the above given results.

4.1.3. Parameter: Distance of Air Cannon from the Conveyor Belt (Position of the air nozzle from the Conveyor Belt)

In third part of parameter application, the distance of air cannon from the conveyor belt was changed to find the optimum distance for sample extraction. Universally, it can be emphasized as the position of the air nozzle inside the conveyor belt was another matter of concern. The belt conveyor speed was selected as 0.50 m / sec and the air pressure value was 5.5 kg / cm². Now, the tests were conducted by adjusting the distance of the support plate to the entrance of the channel from its initial position of 365 mm to 315 mm and 415 mm. In this situation, the nozzles were located as 100 mm in the initial position, then 50 mm and 150 mm portion of the nozzle was driven inside the belt. The distance was not randomly appointed. The explanation related with the above statement will be given in 1 of Sec. 4.1.3.4.

Table 41. Tests with Parameter: Distance of Air Cannon from the Belt for LOT A. (Position of the air nozzle from the Conveyor Belt)

Experiment No	Variable Parameter: Distance of Air Cannon (Position of nozzle)
VI – a	365 mm (100 mm of nozzle portion in belt)
VI – b	365 mm (100 mm of nozzle portion in belt)
IX – a	315 mm (150 mm of nozzle portion in belt)
IX – b	315 mm (150 mm of nozzle portion in belt)
X – a	415 mm (50 mm of nozzle portion in belt)

These experiments were performed with 20 lt. Capacity Air Cannon. The air pressure was selected as 5.5 kg / cm² after evaluating other pressure values. The distance of the air cannon from the support plate to the entrance of the channel was adjusted. The nozzle was Y – Type nozzle. The angle of nozzle was equal to outer roll angle K given as 18.5° in Figure 2 of the conveyor belt. This location is parallel to the side belt.

Test IX – a: (150 mm of nozzle portion in belt)

Table 42. Size and Weight Fraction of Test IX – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A}$ - C_{TEST}
+ 22 mm	160	4.49	3.45	- 1.04
- 22 mm + 20 mm	520	14.61	15.11	0.50
- 20 mm + 16 mm	650	18.26	21.30	3.04
- 16 mm + 8 mm	2200	61.80	59.40	- 2.40
- 8 mm + 4 mm	20	0.56	0.58	0.02
- 4 mm + 2 mm	10	0.28	0.16	- 0.12
Total Weight	3560	-	-	$\lvert\Delta d\rvert = 7.12$

Table 43. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
2690	870	3560 (Test)	0.32	0.25
255	35	290 (Lost)	0.14	-

The values for extracted increment are:

a1	150 mm
a2	120 mm
b	610 mm
h	580 mm

Test IX – b: (150 mm of nozzle portion in belt)

Table 44. Size and Weight Fraction of Test IX – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A}$ - C_{TEST}
+ 22 mm	110	3.43	3.45	- 0.02
- 22 mm + 20 mm	640	19.97	15.11	- 4.86
- 20 mm + 16 mm	670	20.90	21.30	0.40
- 16 mm + 8 mm	1770	55.23	59.40	4.17
- 8 mm + 4 mm	10	0.31	0.58	0.27
- 4 mm + 2 mm	5	0.16	0.16	0.00
Total Weight	3205	-	-	$|\Delta d| = 9.72$

Table 45. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
2475	730	3205 (Test)	0.30	0.25
270	50	320 (Lost)	0.18	-

The values for extracted increment are:

a1	150 mm
a2	120 mm
b	610 mm
h	580 mm

Test X – a: (50 mm of nozzle portion in belt)

Table 46. Size and Weight Fraction of Test X – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT A}$ (%)	Δ d $C_{LOT A}$ - C_{TEST}
+ 22 mm	90	11.18	3.45	- 7.76
- 22 mm + 20 mm	105	13.04	15.11	1.94
- 20 mm + 16 mm	180	22.36	21.30	- 1.24
- 16 mm + 8 mm	420	52.18	59.40	6.72
- 8 mm + 4 mm	5	0.62	0.58	- 0.04
- 4 mm + 2 mm	5	0.62	0.16	- 0.46
Total Weight	805	-	-	$\|\Delta d\| = 18.16$

Table 47. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT A}$ V_{LOTA}/G_{LOTA}
580	225	805 (Test)	0.21	0.25
5	0	5 (Lost)	Undefined.	-

The values for extracted increment are:

a1	40 mm
a2	160 mm
b	200 mm
h	180 mm

4.1.3.1. Discussions on Distance of Air Cannon from the Conveyor Belt Tests (Position of the air nozzle from the Conveyor Belt)

1. The 100 mm portion of the nozzle was initially inside the side belt then 150 mm and 50 mm were applied. Further movement of the nozzle towards the belt allow that portion of the material under the nozzle on the belt without taking it as an increment. On the other hand, taking the sampling device away from the conveyor belt ended up taking only very small portion of the material on the belt and not taking the complete increment. Therefore, 50 mm and 150 mm were selected after these trials.

2. 150 mm gave better results than 50 mm. The increment was not extracted properly from a distance of 50 mm. It was an unsatisfactory experiment because of its poor increment extraction. The b was only 200 mm out of 580 mm.

3. The increment extracted from 100 mm (the original position of the air cannon) has a better increment extraction geometry than that of 150 mm, although complete increment was extracted with 150 mm nozzle entrance.

4. The lost material from 100 mm has the values of 190g and 210 g respectively whereas these are 290 g and 320 g for 150 mm. This is the comparison of the amount of lost materal in Test VI with 100 mm and Test IX with 150 mm.

5. Test VI – a and Test VI – b with 100 mm have V / G ratio as 0.25 and 0.27, whereas in Test IX – a and Test IX – b with 150 mm, the ratio is 0.32 and 0.30.

The portion of nozzle inside the belt (air cannon distance) was selected as 100 mm (365mm) for the following tests referring to the above given results.

4.1.4. Parameter: Angle of the Nozzles

The tests were followed up by having different angles of nozzles after determining belt speed as 0.50 m / sec and the air pressure as 5.5 kg / cm² together with the nozzle portion inside the side belt as 100 mm.

4.1.4.1. Discussions on Angle of the Nozzles Tests

The nozzle angles were adjusted by means of nuts and bolts located on the grooved surface of the support plate. The reference angle is K° as 18.5° which is the outer roller angle of the conveyor. The initial position of the nozzle was 18.5°.

As the angle of the nozzle adjusted smaller than K°, the increment received became less. The air coming from the nozzle just took the increment from the top of the material, although it should have received a complete increment from the cross cut in normal alignment conditions.

As the angle of the nozzle adjusted larger than K°, the discharge outlet of the nozzle became higher strict angle to the surface of the belt, instead of sweeping the material from the surface. Small portion of the increment was extracted. The increments of these two angle allignments were not representative. The most proper allignment of the nozzle was to keep the angle K° , in which the nozzle is parallel to the side belt. In this allignment, correct increment extraction was realized.

4.1.5. Parameter: Type of the Nozzles

The next step was to switch off to pipe type nozzle application and keep the results. The belt speed was determined as 0.50 m / sec and the air pressure as 5.5 kg / cm² together with the portion of the nozzle inside the belt as 100 mm, having the nozzle angle parallel to the side belt angle,

Table 48. Tests with Parameter: Type of the nozzles for LOT A.

Experiment No	Variable Parameter: Type of the nozzles
VI – a	Y – Type Nozzle Application
VI – b	Y – Type Nozzle Application
XI – a	Pipe – Type Nozzle Application
XI – b	Pipe – Type Nozzle Application

Test XI – a: (Pipe – Type Nozzle)

Table 49. Size and Weight Fraction of Test XI – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A}$ - C_{TEST}
+ 22 mm	250	8.05	3.45	- 4.60
- 22 mm + 20 mm	390	12.56	15.11	2.55
- 20 mm + 16 mm	550	17.71	21.30	3.59
- 16 mm + 8 mm	1900	61.20	59.40	-1.80
- 8 mm + 4 mm	10	0.32	0.58	0.26
- 4 mm + 2 mm	5	0.16	0.16	0.00
Total Weight	3105	-	-	$\lvert\Delta d\rvert = 12.8$

Table 50. Weight Distributions of Valuable and Gangu e

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
2555	550	3105 (Test)	0.22	0.25
155	35	190 (Lost)	0.23	-

The values for extracted increment are:

a1	190 mm
a2	150 mm
b	620 mm
h	580 mm

Test XI – b: (Pipe – Type Nozzle)

Table 51. Size and Weight Fraction of Test XI – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\,A}$ (%)	Δ d $C_{LOT\,A} - C_{TEST}$
+ 22 mm	85	3.85	3.45	- 0.40
- 22 mm + 20 mm	230	10.41	15.11	4.70
- 20 mm + 16 mm	425	19.22	21.30	2.08
- 16 mm + 8 mm	1440	65.16	59.40	- 5.76
- 8 mm + 4 mm	25	1.13	0.58	- 0.55
- 4 mm + 2 mm	5	0.23	0.16	- 0.07
Total Weight	2210	-	-	$\lvert\Delta d\rvert = 13.56$

Table 52. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\,A}$ V_{LOTA}/G_{LOTA}
1710	500	2210 (Test)	0.29	0.25
170	40	210 (Lost)	0.24	-

The values for extracted increment are:

a1	190 mm
a2	160 mm
b	620 mm
h	580 mm

4.1.5.1. Discussions on Type of the Nozzles Tests

Two different types of nozzles were used namely Y – Type and Pipe – Type. The results obtained from tests seemed applicable for the Pipe – Type nozzles and the air cutter sweeps the surface of the belt without leaving any residues. However, the increment did not have a correct geometry of extraction. It enlarges through the discharge end of the side belt by having a1 wider than a2.

4.1.6. Parameter: Type of the Air Cannons

All the tests were carried out with 20 liters air cannon tank till now. Different capacity air cannon systems with 12 and 36 liters were tested. The results were not anticipated before the tests were conducted.

Initially, it was observed that 12 liters air cannon became insufficient for generating enough air to extract the sample from the surface of the conveyor belt. This volume was extremely small to generate enough air for increment extraction even a small portion. No additional tests were conducted with that capacity of air cannon. The results were tabulated as 'zero' in Table 54.

36 liters air cannon tank was tested with two different air pressure values, 6 kg / cm² in Test XII – b and Test XIII – a and 7 kg / cm² in Test XIII – b.

Table 53. Tests with Parameter: Type of the Air Cannon for LOT A.

Experiment No	Variable Parameter: Type of the Air Cannon
VI – a	20 lt. free volume capacity Air Cannon
VI – b	20 lt. free volume capacity Air Cannon
XII – a	12 lt. free volume capacity Air Cannon (Unsatisfactory test)
XIII – a	36 lt. free volume capacity Air Cannon
XIII – b	36 lt. free volume capacity Air Cannon
XIV – a	36 lt. free volume capacity Air Cannon (7 kg / cm²)

Test XII – a: (12 liters air cannon)

Table 54. Size and Weight Fraction of Test XII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT A}$ (%)	Δ d $C_{LOT A} - C_{TEST}$
+ 22 mm	0	0.00	3.45	3.45
- 22 mm + 20 mm	0	0.00	15.11	15.11
- 20 mm + 16 mm	0	0.00	21.30	21.30
- 16 mm + 8 mm	0	0.00	59.40	59.40
- 8 mm + 4 mm	0	0.00	0.58	0.58
- 4 mm + 2 mm	0	0.00	0.16	0.16
Total Weight	0	-	-	$\lvert\Delta d\rvert = 100$

Table 55. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT A}$ V_{LOTA}/G_{LOTA}
0	0	0 (Test)	0.00	0.00
0	0	0 (Lost)	0.00	-

The values for extracted increment are:

a1	0 mm
a2	0 mm
b	0 mm
h	0 mm

Test XIII – a: (36 liters air cannon)

Table 56. Size and Weight Fraction of Test XIII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	345	9.21	3.45	- 5.76
- 22 mm + 20 mm	510	13.62	15.11	1.49
- 20 mm + 16 mm	730	19.39	21.30	1.91
- 16 mm + 8 mm	2120	56.61	59.40	2.79
- 8 mm + 4 mm	40	1.07	0.58	- 0.49
- 4 mm + 2 mm	0	0.00	0.16	0.16
Total Weight	3745	-	-	$\lvert\Delta d\rvert = 12.6$

Table 57. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
2930	815	3745 (Test)	0.28	0.25
410	115	525 (Lost)	0.28	-

The values for extracted increment are:

a1	120 mm
a2	270 mm
b	460 mm
h	430 mm

Test XIII – b: (36 liters air cannon)

Table 58. Size and Weight Fraction of Test XIII – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT A}$ (%)	Δ d $C_{LOT A}$ - C_{TEST}
+ 22 mm	210	6.97	3.45	- 3.52
- 22 mm + 20 mm	660	16.44	15.11	- 1.33
- 20 mm + 16 mm	710	17.68	21.30	3.62
- 16 mm + 8 mm	2500	60.75	59.40	- 1.35
- 8 mm + 4 mm	30	0.73	0.58	- 0.15
- 4 mm + 2 mm	5	0.12	0.16	0.04
Total Weight	4115	-	-	$\lvert\Delta$ d$\rvert$ = 10.01

Table 59. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT A}$ V_{LOTA}/G_{LOTA}
3345	770	4115 (Test)	0.23	0.25
420	80	500 (Lost)	0.19	-

The values for extracted increment are:

a1	180 mm
a2	280 mm
b	450 mm
h	420 mm

Test XIV – a: **(36 liters air cannon with 7 kg / cm²)**

Table 58. Size and Weight Fraction of Test XIV – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT A $C_{LOT\ A}$ (%)	Δ d $C_{LOT\ A} - C_{TEST}$
+ 22 mm	195	4.15	3.45	- 0.70
- 22 mm + 20 mm	620	13.19	15.11	1.92
- 20 mm + 16 mm	680	14.47	21.30	6.83
- 16 mm + 8 mm	3175	67.55	59.40	- 8.15
- 8 mm + 4 mm	25	0.53	0.58	0.05
- 4 mm + 2 mm	5	0.11	0.16	0.05
Total Weight	4700	-	-	$\lvert\Delta d\rvert = 17.7$

Table 59. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ A}$ V_{LOTA}/G_{LOTA}
3720	980	4700 (Test)	0.26	0.25
545	130	675 (Lost)	0.24	-

The values for extracted increment are:

a1	110 mm
a2	340 mm
b	510 mm
h	480 mm

4.1.6.1. Discussions on Type of the Air Cannon Tests

1. The experiment was not successful because the air cannon with 12 liters volume was not capable of receiving any sample increment. This stored air was not sufficient to create enough air shock.

2. Another air cannon was designed with 36 liters capacity. It was tested with two different pressure values of 6 kg / cm² and 7 kg / cm² respectively. The observed pressure value of 6 kg / cm² gave the similar effect of 4 kg / cm² in 20 liters. This statement was addressed regarding to identical geometrical patterns of increment extraction in these two specific applications. No complete increment was extracted. However, if the same effect was obtained with a higher pressure value, then the system with lower pressure value should be operated.

3. A higher air pressure value was tested with 36 liters capacity air cannon. The system was operated with 7 kg / cm². Dust formations were seen with this pressure value. The sample increment was studied. The EPOXY painted minerals represented valuable minerals. The valuable material did not abrade easily with impacts previously. In this particular test, some new surface formations were observed due to the air shock strength and the capacity of the air cannon. As a result, few materials were exposed to size reduction and small chips were formed.

In Cement Industry, the particle size is not primary consideration rather chemical composition should be known. The increment received with a mechanical cutter is generally introduced to a small crusher for size reduction.

It can be concluded that the bigger sample increments were received with air cannons of higher capacities. The geometrical pattern of increment was larger in size but the correct increment was not received in 36 lt with 6 kg / cm². Some of the material remained unextracted on the belt. The increase of air pressure to 7 kg / cm² caused chipping of the particles. Therefore the optimum volume of air cannon was selected as 20 liters.

4.2. EXPERIMENTS WITH LOT B

4.2.1. Parameter: Speed of the Belt Conveyor

The same belt conveyor speed values were tested for LOT B as done in LOT A. The results were recorded as follows:

Table 62. Tests with Parameter: Speed of the Belt Conveyor for LOT B.

Experiment No	Variable Parameter: Speed of the Belt Conveyor
XV – a	0.17 m / sec with 8.48 Hz. and 240 rev / min
XV – b	0.17 m / sec with 8.48 Hz. and 240 rev / min
XVI – a	0.50 m / sec with 25 Hz. and 707 rev / min
XVI – b	0.50 m / sec with 25 Hz. and 707 rev / min
XVII – a	1.00 m / sec with 50 Hz. and 1414 rev / min
XVII – b	1.00 m / sec with 50 Hz. and 1414 rev / min

It was started with 20 liters capacity air cannon as in LOT A. The air pressure was initially set as 3 kg / cm². The distance of the air cannon from the support plate to the entrance of the channel was 365 mm or in other words the nozzle was located 100 mm inside the side belt. Y – Type nozzle was initially used. The nozzle was located parallel to the side belt. The angle of nozzle was equal to outer roll angle K given as 18.5°.

– 2 mm size fraction was excluded in preceeding tests because of not having the possibility of counting valuable and gangue minerals.

Test XV – a: (0.17 m / sec)

Table 63. Size and Weight Fraction of Test XV – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\,B}$ (%)	Δ d $C_{LOT\,B} - C_{TEST}$
+ 22 mm	0.00	0.00	0.01	0.01
- 22 mm + 20 mm	20	3.64	0.49	- 3.15
- 20 mm + 16 mm	50	9.09	6.64	- 2.45
- 16 mm + 8 mm	470	85.45	92.21	6.76
- 8 mm + 4 mm	5	0.91	0.47	- 0.45
- 4 mm + 2 mm	5	0.91	0.18	- 0.73
Total Weight	550	-	-	$\lvert\Delta d\rvert = 13.55$

Table 64. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\,B}$ V_{LOTB}/G_{LOTB}
415	120	535 (Test)	0.29	0.25
40	10	50 (Lost)	0.25	-

The values for extracted increment are:

a1	50 mm
a2	110 mm
b	220 mm
h	200 mm

Test XV – b: (0.17 m / sec)

Table 65. Size and Weight Fraction of Test XV – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	5	0.65	0.49	- 0.16
- 20 mm + 16 mm	30	3.92	6.64	2.72
- 16 mm + 8 mm	720	94.11	92.21	- 1.90
- 8 mm + 4 mm	5	0.65	0.47	- 0.18
- 4 mm + 2 mm	5	0.65	0.18	- 0.47
Total Weight	765	-	-	$\lvert\Delta d\rvert = 5.44$

Table 66. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ V_{LOTB}/G_{LOTB}
610	150	760 (Test)	0.25	0.25
28	2	30 (Lost)	0.07	-

The values for extracted increment are:

a1	50 mm
a2	120 mm
b	240 mm
h	220 mm

Test XVI – a: (0.50 m / sec)

Table 67. Size and Weight Fraction of Test XVI – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\,B}$ (%)	Δ d $C_{LOT\,B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	25	3.25	0.49	- 2.76
- 20 mm + 16 mm	60	7.79	6.64	- 1.15
- 16 mm + 8 mm	670	87.01	92.21	5.20
- 8 mm + 4 mm	10	1.30	0.47	- 0.83
- 4 mm + 2 mm	5	0.65	0.18	- 0.47
Total Weight	770	-	-	$\lvert\Delta d\rvert = 10.42$

Table 68. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ (%) V_{TEST}/G_{TEST}	Ratio $_{LOT\,B}$ (%) V_{LOTB}/G_{LOTB}
610	160	770 (Test)	0.26	0.25
55	25	80 (Lost)	0.45	-

The values for extracted increment are:

a1	50 mm
a2	120 mm
b	250 mm
h	220 mm

Test XVI – b: (0.50 m / sec)

Table 69. Size and Weight Fraction of Test XVI – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	5	0.79	0.49	- 0.30
- 20 mm + 16 mm	50	7.87	6.64	- 1.23
- 16 mm + 8 mm	570	89.76	92.21	2.45
- 8 mm + 4 mm	5	0.79	0.47	- 0.32
- 4 mm + 2 mm	5	0.79	0.18	- 0.61
Total Weight	635	-	-	$\lvert\Delta d\rvert = 4.92$

Table 70. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ V_{LOTB}/G_{LOTB}
635	155	790 (Test)	0.25	0.25
25	5	30 (Lost)	0.20	-

The values for extracted increment are:

a1	50 mm
a2	120 mm
b	230 mm
h	210 mm

Test XVII – a: (1.00 m / sec)

Table 71. Size and Weight Fraction of Test XVII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT B}$ (%)	Δ d $C_{LOT B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	5	0.75	0.49	- 0.26
- 20 mm + 16 mm	60	9.02	6.64	- 2.38
- 16 mm + 8 mm	590	88.73	92.21	3.48
- 8 mm + 4 mm	5	0.75	0.47	- 0.28
- 4 mm + 2 mm	5	0.75	0.18	- 0.57
Total Weight	665	-	-	$\lvert\Delta d\rvert = 6.98$

Table 72. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT B}$ $V_{LOTB}/G_{LOT B}$
495	170	665 (Test)	0.34	0.25
60	20	80 (Lost)	0.33	-

The values for extracted increment are:

a1	60 mm
a2	130 mm
b	260 mm
h	240 mm

Test XVII– b: (1.00 m / sec)

Table 73. Size and Weight Fraction of Test XVII – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	5	0.63	0.49	- 0.14
- 20 mm + 16 mm	100	12.58	6.64	- 5.94
- 16 mm + 8 mm	680	85.53	92.21	6.68
- 8 mm + 4 mm	5	0.63	0.47	- 0.16
- 4 mm + 2 mm	5	0.63	0.18	- 0.45
Total Weight	795	-	-	$\lvert\Delta d\rvert$ = 13.38

Table 74. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOTB}/G_{LOT\ B}$
595	200	795 (Test)	0.34	0.25
90	30	120 (Lost)	0.30	-

The values for extracted increment are:

a1	60 mm
a2	140 mm
b	300 mm
h	280 mm

4.2.1.1 Discussions on Belt Conveyor Speed Parameter Tests

1. Three different speed variables were tested. However, the amount of the increment extracted was not the whole cross section of the material transported on the belt. The increment weighed less than 1 kg as in LOT A testing. Therefore, the main concept would be the applicability of the other constraints such as air pressure.

2. The $|\Delta d|$ values were evaluated for belt conveyor speed tests. It was 4.92 for Test XVI – b with 0.50 m / sec, 6.98 for Test XVII – a with 1.00 m / sec and 5.44 for Test XV– b with 0.17 m / sec. Test XVI – b has the closest $|\Delta d|$ value among these.

3. The ratio of the valuable and gangue minerals as 0.25 was reached in Test XV – b with 0.17 m / sec and Test XVI – b with 0.50 m / sec.

4. All lost material were collected carefully and then weighed. The results were recorded as given in above tables. It was recorded that the minimum amount of loss occurred as 30 grams both in Test XV – b with 0.17 m / sec and Test XVI – b with 0.50 m / sec. On the other hand, the lost material was highest in Test XVII – b with 1.00 m / sec. It was 120 grams.

5. In these tests, it was not possible to extract complete increment. The remaining material on the belt had dimensions between 300 mm and 380 mm.

The geometry of correct delimitation is to keep the same width of extraction throughout the increment extraction width. The cross sectional width of the increment should be the same from the entrance of the cutter till the dumping point of the increment.

Five points of evaluation methodologies were studied and six tests were evaluated. As a result, conveyor belt speed was selected as 0.50 m / sec for the following tests referring to the above given results.

4.2.2. Parameter: Air Shock Pressure

Six tests were realized with three different belt speed variables. In LOT B, the belt speed was selected as 0.50 m / sec. After testing the belt conveyor speed variables, with 20 liters air cannon for 800 mm width conveyor belt with the given specifications.

In second part of the experiments, the belt conveyor speed was 0.50 m / sec, whereas the air shock pressure was adjusted as 4 kg / cm², 5 kg / cm², 5.5 kg / cm², 6 kg / cm² and finally 7 kg / cm². The results were tabulated as follows:

Table 75. Tests with Parameter: Air Shock Pressure for LOT B.

Experiment No	Variable Parameter: Air Shock Pressure
XVI – a	3 kg / cm²
XVI – b	3 kg / cm²
XVIII – a	4 kg / cm²
XVIII – b	4 kg / cm²
XIX – a	5 kg / cm²
XIX – b	5 kg / cm²
XX – a	5.5 kg / cm²
XX – b	5.5 kg / cm²
XXI – a	6 kg / cm²
XXI – b	6 kg / cm²
XXII – a	7 kg / cm²
XXII – b	7 kg / cm²

These experiments were performed with 20 liters capacity air cannon. The speed of the belt conveyor is 0.50 m / sec. The distance of the air cannon from the support plate to the entrance of the channel was 365 mm. Y – Type nozzle was used. The angle of nozzle was equal to Outer Roll Angle: K given as 18.5°.

Test XVIII – a: (4 kg / cm²)

Table 76. Size and Weight Fraction of Test XVIII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	30	2.37	0.49	- 1.88
- 20 mm + 16 mm	100	7.91	6.64	- 1.27
- 16 mm + 8 mm	1120	88.53	92.21	3.68
- 8 mm + 4 mm	10	0.79	0.47	- 0.32
- 4 mm + 2 mm	5	0.40	0.18	- 0.22
Total Weight	1265	-	-	$\lvert\Delta d\rvert = 7.38$

Table 77. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ V_{LOTB}/G_{LOTB}
1065	200	1265 (Test)	0.19	0.25
100	10	110 (Lost)	0.10	-

The values for extracted increment are:

a1	130 mm
a2	150 mm
b	390 mm
h	360 mm

Test XVIII – b: (4 kg / cm²)

Table 78. Size and Weight Fraction of Test XVIII – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\,B}$ (%)	Δ d $C_{LOT\,B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	0	0.00	0.49	- 0.49
- 20 mm + 16 mm	50	4.08	6.64	2.56
- 16 mm + 8 mm	1160	94.69	92.21	- 2.48
- 8 mm + 4 mm	10	0.82	0.47	- 0.35
- 4 mm + 2 mm	5	0.41	0.18	- 0.23
Total Weight	1225	-	-	$\lvert\Delta d\rvert = 6.12$

Table 79. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\,B}$ V_{LOTB}/G_{LOTB}
980	230	1210 (Test)	0.23	0.25
90	10	100 (Lost)	0.11	-

The values for extracted increment are:

a1	120 mm
a2	150 mm
b	390 mm
h	370 mm

Test XIX – a: (5 kg / cm²)

Table 80. Size and Weight Fraction of Test XIX – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	30	1.07	0.49	- 0.58
- 20 mm + 16 mm	170	6.05	6.64	0.59
- 16 mm + 8 mm	2570	91.45	92.21	0.76
- 8 mm + 4 mm	35	1.25	0.47	0.78
- 4 mm + 2 mm	5	0.18	0.18	0.00
Total Weight	2810	-	-	$|\Delta d| = 2.72$

Table 81. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ (%) V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ (%) V_{LOTB}/G_{LOTB}
2240	580	2825 (Test)	0.25	0.25
40	5	45 (Lost)	0.13	-

The values for extracted increment are:

a1	150 mm
a2	140 mm
b	580 mm
h	580 mm

Test XIX – b: (5 kg / cm²)

Table 82. Size and Weight Fraction of Test XIX – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	10	0.39	0.49	0.10
- 20 mm + 16 mm	300	11.58	6.64	- 4.94
- 16 mm + 8 mm	2250	86.87	92.21	5.34
- 8 mm + 4 mm	25	0.97	0.47	- 0.50
- 4 mm + 2 mm	5	0.19	0.18	- 0.01
Total Weight	2590	-	-	$\lvert\Delta d\rvert = 10.90$

Table 83. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOTB}/G_{LOT\ B}$
2055	540	2595 (Test)	0.26	0.25
175	55	230 (Lost)	0.31	-

The values for extracted increment are:

a1	180 mm
a2	170 mm
b	490 mm
h	470 mm

Test XX – a: (5.5 kg / cm²)

Table 84. Size and Weight Fraction of Test XX – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	60	1.80	0.49	- 1.31
- 20 mm + 16 mm	190	5.69	6.64	0.95
- 16 mm + 8 mm	3050	91.32	92.21	0.89
- 8 mm + 4 mm	35	1.04	0.47	- 0.57
- 4 mm + 2 mm	5	0.15	0.18	- 0.03
Total Weight	3340	-	-	$\lvert\Delta d\rvert = 3.76$

Table 85. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOTB}/G_{LOT\ B}$
2600	740	3340 (Test)	0.28	0.25
210	50	260 (Lost)	0.26	-

The values for extracted increment are:

a1	170 mm
a2	120 mm
b	590 mm
h	590 mm

Test XX – b: (5.5 kg / cm²)

Table 86. Size and Weight Fraction of Test XX – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	20	0.65	0.49	- 0.16
- 20 mm + 16 mm	250	8.16	6.64	- 1.52
- 16 mm + 8 mm	2760	90.05	92.21	2.16
- 8 mm + 4 mm	30	0.98	0.47	- 0.51
- 4 mm + 2 mm	5	0.16	0.18	- 0.02
Total Weight	3065	-	-	$\lvert\Delta d\rvert = 4.38$

Table 87. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ V_{LOTB}/G_{LOTB}
2370	710	3110 (Test)	0.30	0.25
100	20	210 (Lost)	0.20	-

The values for extracted increment are:

a1	160 mm
a2	120 mm
b	590 mm
h	590 mm

Test XXI – a: (6 kg / cm²)

Table 88. Size and Weight Fraction of Test XXI – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	80	2.03	0.49	- 1.54
- 20 mm + 16 mm	300	7.62	6.64	- 0.98
- 16 mm + 8 mm	3510	89.20	92.21	3.01
- 8 mm + 4 mm	40	1.02	0.47	- 0.55
- 4 mm + 2 mm	5	0.13	0.18	0.05
Total Weight	3935	-	-	$\lvert\Delta d\rvert = 6.14$

Table 89. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOT\ B}/G_{LOTB}$
3130	810	3940 (Test)	0.26	0.25
170	30	200 (Lost)	0.18	-

The values for extracted increment are:

a1	190 mm
a2	190 mm
b	610 mm
h	580 mm

Test XXI – b: (6 kg / cm²)

Table 90. Size and Weight Fraction of Test XXI – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$(%)	Δ d $C_{LOT\ B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	30	0.88	0.49	- 0.39
- 20 mm + 16 mm	300	8.76	6.64	- 2.18
- 16 mm + 8 mm	3060	89.34	92.21	2.10
- 8 mm + 4 mm	30	0.88	0.47	- 0.42
- 4 mm + 2 mm	5	0.15	0.18	0.03
Total Weight	3425	-	-	$\lvert\Delta d\rvert$ = 5.13

Table 91. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOT\ B}/G_{LOTB}$
2750	680	3430 (Test)	0.25	0.25
150	30	180 (Lost)	0.20	-

The values for extracted increment are:

a1	200 mm
a2	200 mm
b	610 mm
h	580 mm

Test XXII – a: (7 kg / cm^2)

Table 92. Size and Weight Fraction of Test XXII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	- 0.01
- 22 mm + 20 mm	40	1.09	0.49	- 0.60
- 20 mm + 16 mm	340	9.31	6.64	- 2.73
- 16 mm + 8 mm	3200	87.67	92.21	3.77
- 8 mm + 4 mm	60	1.66	0.47	- 1.20
- 4 mm + 2 mm	10	0.27	0.18	- 0.09
Total Weight	3650	-	-	$\|\Delta d\| = 8.40$

Table 93. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOT\ B}/G_{LOTB}$
3060	580	3640 (Test)	0.19	0.25
190	50	240 (Lost)	0.26	-

The values for extracted increment are:

a1	240 mm
a2	240 mm
b	610 mm
h	580 mm

Test XXII – b: (7 kg / cm²)

Table 94. Size and Weight Fraction of Test XXII – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	40	1.05	0.49	- 0.56
- 20 mm + 16 mm	250	6.53	6.64	0.11
- 16 mm + 8 mm	3500	91.38	92.21	0.83
- 8 mm + 4 mm	30	0.78	0.47	- 0.31
- 4 mm + 2 mm	10	0.26	0.18	- 0.08
Total Weight	3830	-	-	$\lvert\Delta d\rvert = 1.90$

Table 95. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOTB}/G_{LOT\ B}$
3210	620	3830 (Test)	0.19	0.25
185	35	220 (Lost)	0.19	-

The values for extracted increment are:

a1	200 mm
a2	230 mm
b	610 mm
h	580 mm

4.2.2.1. Discussions on Air Shock Pressure Tests

1. The air shock pressure was gradually increased so as to determine the pressure value test, in which the correct increment extraction was received. As it was noted that no complete increment was received in 3 kg / cm² with belt speed tests. Further, in 4 kg / cm² and 5 kg / cm², no complete increment extraction was received. First time a clean complete increment was extracted in Test XX with 5.5 kg / cm². However, the extracted increment geometry is getting larger towards the dumping side in Test XX (a1 is larger than a2). In Test XXI with 6 kg / cm², the cleanest sample increment was received and the shape was a parallelogram (a1 is equal to a2). It was the ideal condition. In Test XXII with 7 kg / cm², complete increment was extracted but the extracted increment geometry is getting larger towards the dumping side likewise in Test XX (a1 is larger than a2).

The sample increment amount increases, as the air shock pressure increases. The minimum sample weight was received in Test XVIII – b with 4 kg / cm². The sample increment values were reached ranging between 3000 to 4000 grams in following tests of air shock pressure.

2. As an overall, $\Sigma|\Delta\ d|$ values were smaller in air shock pressure testing in LOT B than in LOT A. Some examples can be stated as Test XIX – a with 5 kg / cm² having 2.72, Test XX – a with 5.5 kg / cm² having 3.72 and Test XXII – b with 7 kg / cm² having 1.90. These are some best examples but in other tests, the distribution was uniform and the values were closer to those in the lot.

3. The valuable to gangue mineral ratio of 0.25 was reached in two tests in LOT B air pressure testing. These are namely Test XIX – a with 5 kg / cm² and Test XXI – b with 6 kg / cm². In Test XX with 5.5 kg / cm², the valuable to gangue mineral ratio values were 0.28 and 0.30, greater than 0.25.

4.The lost material varies between 45 and 260 grams. It should be emphasized that the amount of lost material was fewer in tests with pressure values of 4 kg / cm² and 5 kg / cm² because the increments were not completely received.

Therefore the lost material values should be considered among tests with pressure values 5 kg / cm², 5.5 kg / cm², 6 kg / cm² and 7 kg / cm². The fewer amount of loss material received during Test XXI with 6 kg / cm².

As a result, air shock pressure was selected as 6 kg / cm² for the following tests referring to the above given results.

4.2.3. Parameter: Distance of Air Cannon from the Conveyor Belt (Position of the air nozzle from the Conveyor Belt)

The belt conveyor speed and the air pressure values for LOT B were determined as 0.50 m / sec and 6 kg / cm² respectively. In third part of the experiments the tests were conducted by adjusting the distance of the support plate to the entrance of the channel from its initial position of 365 mm to 315 mm and 415 mm. In other words, the nozzle had initally 100 mm portion inside the side belt. Other data were collected by adjusting the nozzle as 50 mm and 150 mm inside the belt.

Table 96. Tests with Parameter: Distance of Air Cannon from the Belt for LOT B.

Experiment No	Variable Parameter: Distance of Air Cannon (Position of nozzle)
XXI – a	365 mm (100 mm of nozzle portion in belt)
XXI – b	365 mm (100 mm of nozzle portion in belt)
XXIII – a	315 mm (150 mm of nozzle portion in belt)
XXIII – b	315 mm (150 mm of nozzle portion in belt)
XXIV – a	415 mm (50 mm of nozzle portion in belt)

These experiments were performed with 20 liters capacity air cannon. The air pressure was selected as 6 kg / cm² after evaluating other pressure values. The nozzle portion was adjusted to 50 mm and 150 mm starting with tabulating the data for 100 mm entrance given as Test XXI. Y – Type nozzle was used. The angle of nozzle was equal to 18.5°, which was parallel to the surface of the belt.

Test XXIII – a: (150 mm of nozzle portion in belt)

Table 97. Size and Weight Fraction of Test XXIII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT B}$ (%)	Δ d $C_{LOT B} - C_{TEST}$
+ 22 mm	5	0.17	0.01	- 0.16
- 22 mm + 20 mm	65	2.14	0.49	- 1.65
- 20 mm + 16 mm	175	5.80	6.64	0.84
- 16 mm + 8 mm	2750	91.06	92.21	1.15
- 8 mm + 4 mm	20	0.66	0.47	- 0.19
- 4 mm + 2 mm	5	0.17	0.18	0.01
Total Weight	3020	-	-	$\lvert\Delta d\rvert = 4.00$

Table 98. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT B}$ $V_{LOT B}/G_{LOTB}$
2330	690	3020 (Test)	0.30	0.25
195	35	230 (Lost)	0.18	-

The values for extracted increment are:

a1	50 mm
a2	220 mm
b	420 mm
h	400 mm

Test XXIII – b: (150 mm of nozzle portion in belt)

Table 99. Size and Weight Fraction of Test XXIII – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	20	0.67	0.49	- 0.18
- 20 mm + 16 mm	200	6.73	6.64	- 0.09
- 16 mm + 8 mm	2730	91.76	92.21	- 0.45
- 8 mm + 4 mm	20	0.67	0.47	- 0.20
- 4 mm + 2 mm	5	0.17	0.18	0.01
Total Weight	2975	-	-	$|\Delta d| = 0.94$

Table 100. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOT\ B}/G_{LOTB}$
2475	730	3205 (Test)	0.30	0.25
170	40	210 (Lost)	0.24	-

The values for extracted increment are:

a1	180 mm
a2	240 mm
b	400 mm
h	380 mm

Test XXIV – a: (50 mm of nozzle portion in belt)

Table 101. Size and Weight Fraction of Test XXIV – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	30	6.06	0.49	- 5.57
- 20 mm + 16 mm	40	8.08	6.64	-1.50
- 16 mm + 8 mm	420	84.85	92.21	6.59
- 8 mm + 4 mm	5	1.01	0.47	- 0.55
- 4 mm + 2 mm	0	0.00	0.18	- 0.18
Total Weight	495	-	-	$\lvert\Delta d\rvert = 14.40$

Table 102. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOT\ B}/G_{LOTB}$
415	80	495 (Test)	0.19	0.25
25	5	30 (Lost)	0.20	-

The values for extracted increment are:

a1	80 mm
a2	120 mm
b	100 mm
h	80 mm

4.2.3.1. Discussions on Distance of Air Cannon from the Conveyor Belt Tests (Position of the air nozzle from the Conveyor Belt)

1. The increment extraction geometry were initially studied. It was adjusted as initially the nozzle was 150 mm inside the belt. The increment was extracted by leaving some portion of material from the side towards the middle of the belt. The material towards the dumping side was swept into chute. The increment was received partially with 150 mm allignment. Secondly, the nozzle was adjusted as 50 mm inside the side belt. In that case, material extracted was so small to be representative.

2. The increment extraction was better when the nozzle was driven as 150 mm inside the belt rather than 50 mm inside the belt. The quantity of extraction was higher in 150 mm as 3020 and 3205 grams. However, it was only 495 grams in 50 mm.

3. Although $|\Delta d|$ value was small in Test XXIII with nozzle portion of 150 mm and it was the best among other tests, the increments were not complete. Test XXIV – a with 50 mm nozzle portion, has far away an acceptable value for $|\Delta d|$ as 14.40. Therefore, tests with nozzle portion of 150 mm gave better $|\Delta d|$ values (4.00 and 0.94) than with nozzle portion of 50 mm. $|\Delta d|$ values are 6.14 and 5.13 for 100 mm.

4. Test XXI – a & b with 100 mm nozzle portion inside the belt have the valuable and gangue mineral ratio as 0.26 and 0.25, whereas the ratio is 0.30 for Test XXIII – a and XXIII – b with 150 mm nozzle portion, which is higher than 0.25. The ratio is 0.19 for Test XXIV – a with 50 mm nozzle portion. Therefore previous tests with nozzle portion of 100 mm (original position) have better valuable over gangue mineral ratio than other tests of nozzle portion.

5. The correct increment extraction was initial priority in sample extraction. It was not maintained in Test XXIII with 150 mm nozzle portion and Test XXIV with 50 mm nozzle portion.

The portion of nozzle inside the belt (air cannon distance) was selected as 100 mm (365mm) for the following tests referring to the above given results.

4.2.4. Parameter: Angle of the Nozzles

Test were conducted by adjusting the angles of the nozzles, after determining the belt conveyor speed as 0.50 m / sec and the air pressure as 6 kg / cm^2 together with the portion of the nozzle inside the belt as 100 mm.

4.2.4.1. Discussions on Angle of the Nozzles Tests

The nozzle angles were adjusted by means of nuts and bolts located on the grooved surface of the support plate. The reference angle is K° as 18.5° which is the outer roller angle of the conveyor. The initial position of the nozzle was 18.5°.

As the angle of the nozzle adjusted smaller than K°, the increment received became less. In this case, the air coming from the nozzle just took the increment from the top of the material. The increment was not received completely from bottom to top.

As the angle of the nozzle adjusted larger than K°, the discharge outlet of the nozzle came perpendicular to the surface of the belt, instead of sweeping the material from the surface. Small portion of the increment was extracted. The increments of these two angle allignments were not representative. The most proper allignment of the nozzle was to keep the angle K° as in the original allignment.

4.2.5. Parameter: Type of the Nozzles

In this part of the experiments, Y – Type nozzle was replaced by Pipe – Type nozzle.

Table 103. Tests with Parameter: Type of the nozzles for LOT B.

Experiment No	Variable Parameter: Type of nozzles
XXI – a	Y – Type Nozzle Application
XXI – b	Y – Type Nozzle Application
XXV – a	Pipe – Type Nozzle Application
XXV – b	Pipe – Type Nozzle Application

Test XXV – a: (Pipe – Type Nozzle)

Table 104. Size and Weight Fraction of Test XXV – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT B}$ (%)	Δ d $C_{LOT B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	20	0.67	0.49	- 0.18
- 20 mm + 16 mm	245	8.18	6.64	- 1.54
- 16 mm + 8 mm	2680	89.48	92.21	2.73
- 8 mm + 4 mm	45	1.50	0.47	-1.03
- 4 mm + 2 mm	5	0.17	0.18	0.01
Total Weight	2995	-	-	$\lvert \Delta d \rvert = 5.50$

Table 105. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT B}$ V_{LOTB}/G_{LOTB}
2385	610	2995 (Test)	0.26	0.25
215	25	240 (Lost)	0.12	-

The values for extracted increment are:

a1	220 mm
a2	100 mm
b	610 mm
h	580 mm

Test XXV – b: (Pipe – Type Nozzle)

Table 106. Size and Weight Fraction of Test XXV – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	30	1.01	0.49	- 0.52
- 20 mm + 16 mm	170	5.74	6.64	0.90
- 16 mm + 8 mm	2710	91.55	92.21	0.66
- 8 mm + 4 mm	40	1.35	0.47	- 0.88
- 4 mm + 2 mm	10	0.34	0.18	- 0.16
Total Weight	2960	-	-	$\lvert\Delta d\rvert$ = 3.13

Table 107. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOT\ B}/G_{LOTB}$
2380	580	2960 (Test)	0.24	0.25
300	70	370 (Lost)	0.23	-

The values for extracted increment are:

a1	240 mm
a2	100 mm
b	610 mm
h	580 mm

4.2.5.1. Discussions on Type of the Nozzles Tests

It was switched to Pipe – Type nozzle application after having the belt speed as 0.50 m / sec and the air pressure as 6 kg / cm² together with the portion of the nozzle inside the belt as 100 mm, having the nozzle angle parallel to the side belt angle as in original position.

Pipe – Type nozzles are capable of receiving a complete increment. The air cutter sweeps the surface of the belt without leaving any residues. However, this increment geometry enlarged to the dumping side towards the chute (a1 is larger than a2).

4.2.6. Parameter: Type of the Air Cannons

All the tests were carried out with 20 liters air cannon tank till now. 12 liters and 36 liters air cannons were installed and tested.

As in the previous experiment with LOT A, it was proven that 12 liters air cannon was not sufficient for generating enough air to extract the sample from the surface of the conveyor belt. The volume was too small to generate enough air for extraction. 12 lt. air cannon was not operative. The results were not tabulated. 36 liters air cannon tank was tested with two different air pressure values. These were 6 kg / cm² in Test XII – b and Test XIII – a and 7 kg / cm² in Test XXVIII – a. The results were given below:

Table 108. Tests with Parameter: Type of the Air Cannon for LOT B.

Experiment No	Variable Parameter: Type of Air Cannon
XXI – a	20 liters free volume capacity Air Cannon
XXI – b	20 liters free volume capacity Air Cannon
XXVI – a	12 liters free volume capacity Air Cannon (Unsatisfactory test)
XXVII – a	36 liters free volume capacity Air Cannon
XXVII – b	36 liters free volume capacity Air Cannon
XXVIII – a	36 liters free volume capacity Air Cannon (7 kg / cm²)

Test XXVII – a: (36 liters air cannon)

Table 109. Size and Weight Fraction of Test XXVII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	95	2.46	0.49	- 1.97
- 20 mm + 16 mm	350	9.07	6.64	- 2.43
- 16 mm + 8 mm	3390	87.80	92.21	4.41
- 8 mm + 4 mm	20	0.52	0.47	- 0.05
- 4 mm + 2 mm	5	0.13	0.18	0.05
Total Weight	3860	-	-	$\lvert\Delta d\rvert = 8.92$

Table 110. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOTB}/G_{LOT\ B}$
3035	825	3860 (Test)	0.27	0.25
380	90	470 (Lost)	0.24	-

The values for extracted increment are:

a1	130 mm
a2	280 mm
b	460 mm
h	430 mm

Test XXVII – b: (36 liters air cannon)

Table 111. Size and Weight Fraction of Test XXVII – b

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B}$ - C_{TEST}
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	40	1.26	0.49	- 0.77
- 20 mm + 16 mm	230	7.26	6.64	- 0.62
- 16 mm + 8 mm	2880	91.00	92.21	1.21
- 8 mm + 4 mm	10	0.32	0.47	0.15
- 4 mm + 2 mm	5	0.16	0.18	0.02
Total Weight	3165	-	-	$\|\Delta d\| = 2.78$

Table 112. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOTB}/G_{LOT\ B}$
2465	700	3165 (Test)	0.28	0.25
260	50	310 (Lost)	0.19	-

The values for extracted increment are:

a1	120 mm
a2	260 mm
b	390 mm
h	360 mm

Test XXVIII – a: (36 liters air cannon with 7 kg /cm²)

Table 113. Size and Weight Fraction of Test XXVII – a

Size Fraction (mm)	Weight (g)	Weight C_{TEST} (%)	Weight LOT B $C_{LOT\ B}$ (%)	Δ d $C_{LOT\ B} - C_{TEST}$
+ 22 mm	0	0.00	0.01	0.01
- 22 mm + 20 mm	50	0.99	0.49	- 0.50
- 20 mm + 16 mm	580	11.53	6.64	- 4.95
- 16 mm + 8 mm	4370	86.88	92.21	4.56
- 8 mm + 4 mm	25	0.50	0.47	- 0.04
- 4 mm + 2 mm	5	0.10	0.18	0.08
Total Weight	5030	-	-	-

Table 114. Weight Distributions of Valuable and Gangue

Gangue Mineral G (g)	Valuable Mineral V (g)	Total Weight (g)	Ratio $_{TEST}$ V_{TEST}/G_{TEST}	Ratio $_{LOT\ B}$ $V_{LOTB}/G_{LOT\ B}$
3980	1050	5030 (Test)	0.27	0.25
770	150	920 (Lost)	0.19	-

The values for extracted increment are:

a1	120 mm
a2	340 mm
b	480 mm
h	460 mm

4.2.6.1. Discussions on Type of the Air Cannon Tests

1. All previous tests for LOT B were carried out with 20 liters air cannon. Two different air cannons were designed. 12 liters air cannon was installed but no increments were received.

The testing pressure was 6 kg / cm² for Test XXVII – a and XXVII – b with 36 liters air cannon while the testing pressure was 7 kg / cm² for Test XXVIII – a again with 36 liters air cannon. The outcome would be the same with the same constraints applied for LOT A testing. In this particular test, some new surface formations were observed due to the air shock strength and the capacity of the air cannon. Small chippings were formed.

2. Tests with 36 liters air cannons were carefully monitored from the incremental point of view. The higher pressure value was tested to reach a complete increment extraction. The increment got broader and likewise the quantity of extracted material increased. However, no complete increments were extracted. The highest pressure value was 7 kg / cm². It was physically almost impossible to test higher pressure values with the given testing parameters. The reasons are further formation of chippings for the material extracted and a dusty condition while testing. The value of a2 got larger as the pressure value increased with 36 liters air cannon.

3. The ratio of valuable to gangue mineral was higher than 0.25 in both these three tests. However, Test XXI – b with 20 liters air cannon have the value of 0.25.

It can be concluded that the bigger sample increments were received with air cannons of higher capacities. The geometrical pattern of increment was larger in size but the correct increment was not received in 36 lt with 6 kg / cm². Some of the material remained unextracted on the belt. The increase of air pressure to 7 kg / cm² caused chipping of the particles. Therefore the optimum volume of air cannon was selected as 20 liters as in previous lot testing.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from this work:

1. Air Cannon System was utilized in sample extraction process. The effect of the air shock, which is the operational principle of the cannon system, on the sample increment was carefully monitored.

It was observed that the system reached to correct increment extraction geometry in the selected operating conditions with previous testings. Some electromechanical sampling devices are not able to maintain cutter speed throughout the stream of flow as stated in cutter speed and width section. On the contrary, the increments with air cannon sampling systems has a regular shape, because of instant sample increment extraction without encountering any delay as in electromechanical sampling systems.

It was seen that the system was also capable of removing the residual fine material from the surface of the conveyor, whereas in mid-belt cutter mechanisms some fines remain on the belt.

The system uses only air as a cutter mechanism. Therefore the material did not have any interaction with any mechanical cuttter mechanism to have any built up or blockage problem.

2. Two different lots were tested to see the performance of air cannon sampling system: LOT A and LOT B.

Different parameters were tested as belt speed, air shock value, position of the nozzle from the conveyor, angle of nozzle, type of nozzle, type of air cannon.

These parameters were evaluated with different methodologies as sample increment geometry, $|\Delta\ d|$, valuable over gangue mineral, amount of sample increment extracted and amount of material lost. First three methodologies were initial concern for selection. The best results obtained in this research are given as follows:

The selected system for LOT A is having a belt speed of 0.50 m / sec. The system operates with a pressure of 5.5 kg / cm^2 (20 liters air cannon with Y – type nozzle). Nozzle is located 100 mm inside the side belt and has an angle equal to the outer roll angle that is 18.5˚.

The selected system for LOT B is having a belt speed of 0.50 m / sec. The system operates with a pressure of 6 kg / cm^2. 20 liters air cannon with Y – type nozzle. Nozzle is located 100 mm inside the side belt and has an angle equal to the outer roll angle that is 18.5˚.

The following recommendations can be given as:

a. During the tests it was seen that the system can be operated more efficiently by making some modifications. A return idler (an idler that has the same width with the belt) can be placed before the entrance of the product to the sampling unit. This will ease the operation of the sampling unit by spreading the material.

b. The channel and chute construction design can be improved. The system can be modified by replacing the corners with the curvatures and round shapes without any joints. This will avoid possible built ups and sample losses.

The sampling system with air shock cannon is a new concept. It is thought to be utilized as commercial product in the industrial applications. The system is in prototype stage and it is planned to be improved in future. The system has low initial and operating cost. The electromechanical sampling systems have higher cost figures including the overall maintenance cost and the cost of repair. The electromechanical systems are equipped with many movable parts such as pistons, chain drives, pulleys, screw conveying mechanisms, motors, probes, hydraulic parts …etc. Air cannon mechanism movable parts are only as piston and compressor

Turkish Patent Institute had received the application with all necessary documentations prepared for air shock sampling system.

REFERENCES

Avallone, Eugene A.; Baumeister, Theodore., 1996. “ Marks Standard Handbook for Mechanical Engineers ”, 10 th Edition by McGraw – Hill.

David, Michel., 1977. “ Geostatic Ore Reserve Estimation ”, Elsevier Scientific Publishing Company, Amsterdam, Oxford and New York.

Gy, Pierre M., 1982. “ Sampling of Particulate Materials: Theory and Practice ”, Elsevier Scientific Publishing Company, Amsterdam, Oxford and New York.

Gy, Pierre M., 1992. “ Sampling of Heterogeneous and Dynamic Materials: Theories of Heterogeneity, Sampling and Homogenizing ”, Elsevier Scientific Publishing Company, Amsterdam, Oxford and New York.

Keller, Gerald.; Warrack Brian., 1997. “ Statistics for Management and Economics ” , 4 th Edition by Brooks / Cole Publishing Company, A Division of International Thompson Publishing Inc.

Konmaz, Vedat., 2000. “ Çimento Sanayinde Hammadde ve KST analizi ”

Lapin, L. L., 1987. “ Statistics for Modern Business Decisions ” , Harcourt Brace Johanovich, Inc

M & W Jawo Handling., 1999. “ Material Handling Systems – Quality Control, Sampling Equipment ”

Perry, Robert H.; Green, Don W., 1999. “ Perry’s Chemical Engineer’s Handbook ” by McGraw – Hill Companies., Inc.

Pitard, F.F., 1989. “ Pierre Gy’s Sampling Theory – Sampling Practice ” by CRC Press, Boca Raton, Florida. 2 Vol.

Taggart, A.F., 1945. “ Handbook on Mineral Dressing ” by J. Wiley & Sons, New – York.

Webster, M., 1985 “ Webster’s New Collegue Dictionary ” , Marian Webster Inc

The electromechanical sampling systems in the production line of Intersystems Inc.
http://www.intersystems.com

APPENDIX A

SAMPLING STATION

Figure A1. Sampling Station installed on 800 mm. Conveyor Belt

Figure A2. Sampling Station ready for consecutive testing procedure

APPENDIX B

EXPERIMENTS

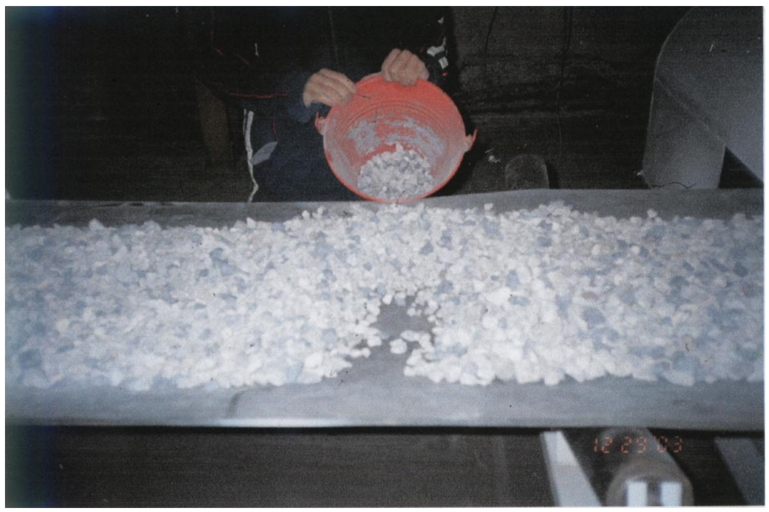


Figure B1. Incorrect increment extraction in low air pressure application.

Figure B2. Correct Increment extraction in higher air pressure application.

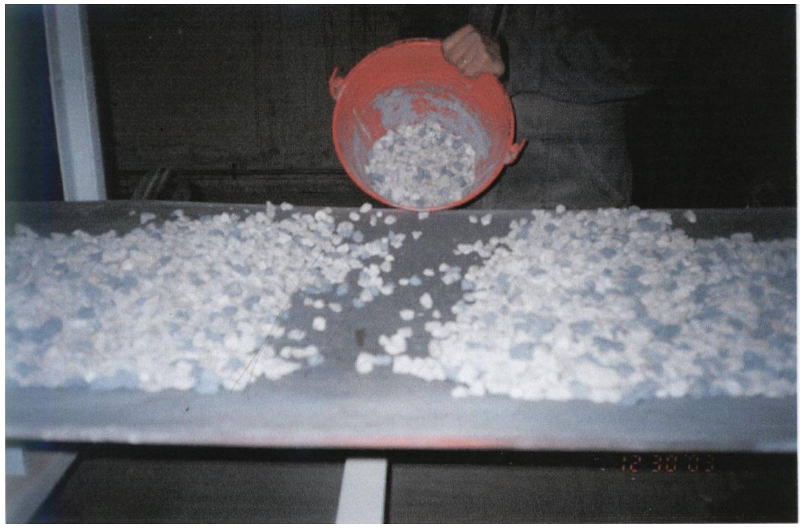


Figure B3. Better and Cleaner increment extraction was achieved

Figure B4. The increment is defined as in a1, a2, b and h

APPENDIX C

VARICAD DRAWINGS

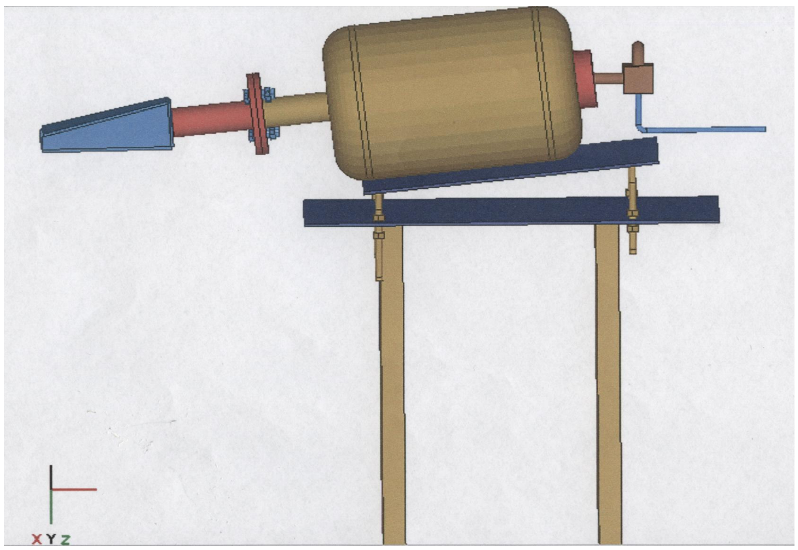


Figure C1. Air Cannon Drawing with Y– Type Nozzle Application

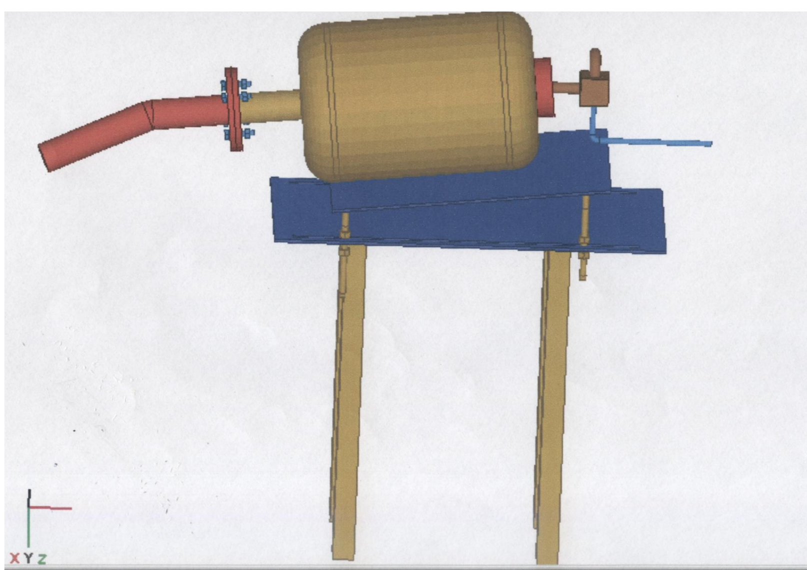


Figure C2. Air Cannon Drawing with Pipe – Type Nozzle Application