



# **Automation of a Diamond Plant**

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Bachelor's Thesis

**Accepted** \_\_\_\_ . \_\_\_\_ . \_\_\_\_ \_\_\_\_\_

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<p><b>Abstract</b></p> <p>In present modern industrializations, automation and machine vision technology are essential in majority of the companies. Automation and machine vision technology can be found in different practical applications such as, space application, hospitals, manufacturing and production industries, robotics and biological systems and many more.</p> <p>The thesis has been carried out to solve the problem faced by Ghana Consolidated Diamonds Ltd at Akwatia in Ghana. The company has been on divesture for the past eight (8) years as result of inefficiencies in their production plant. The company has recently been given to a wholly-owned Ghanaian company, Great Consolidated Diamonds Ltd after winning the bid.</p> <p>The thesis aimed at adopting an innovative approach to build on the existing company production design to design cost-effective and higher productivity automated diamond plant for them using machine vision technology and other automation devices.</p> <p>The method used in solving the problem includes information provided by the company supervisor, De beers Diamond Ltd (South Africa), guidelines provided by the thesis supervisor and interview conducted with Fountain Pumps Ltd (India). This method was utilized to enable an in depth research of the project.</p> <p>The result of the thesis proposed a machine vision technology which has the tendency to reduce losses and increase production at a faster rate. It will help the company to meet their production demand and brings innovation in their way of working.</p>			
<p><b>Keywords</b> Mechanization, Automation, Mining and Machine vision technology.</p>			
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## **DEDICATION**

I dedicate this thesis to the Almighty God, who has brought me this far, I say thank you Lord,

Also to my dear, Asare Rebecca for all your tireless support, physical, spiritual and emotional. And to all my church members (Adventtikirkko), in Varkaus and Hämeenlinna Finland. I say, God bless you all.

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## 1 INTRODUCTION

### 1.1 Background

Ghana is a West African country located on the Gulf of Guinea. The country is well endowed with many natural resources. Ghana covers an area of 238,535 square kilometers with a population of about 23,837,000 (2009 estimate). Ghana's geographical setting is the main reason for its wealth of minerals. Ghana is the leading exporter of bauxite, diamonds and timber.

Ghana is presently the second largest producer of gold in sub-Saharan Africa, only behind South Africa. Between 1983 and 1998, the mining industry brought approximately 4 billion U.S dollars in foreign direct investment to Ghana according to Minerals Commission report, 2000.

Ghana Consolidated Diamonds Limited is the only formal commercial producer of diamonds, using strip mining with Manitowoc draglines. It is the only state owned mining company currently in divestiture.

The company has a total concession area of 185.35 square miles within the Birim Diamond field and Kobriso Gold Concession (GCD, 1999).

The company has produced more than 100 million carats of diamonds mostly industrial grade. It contributes greatly into the country's economy and offers a lot of employment to the youth. Historically, mining operation at Akwatia has brought economic benefits to the city, and a means of employment and poverty alleviation.

Over the past 21 months the company has stopped operation due to the breakdown of its equipment and machinery. The company plant is obsolete and the breakdown of the machinery is what has affected the overall productivity and efficiency of the company.

However, because of unsuccessful divestiture deals, management went ahead to build a new plant (Agyenkwa plant) in the main diamond concession in attempt to gain financial resources to refurbish its production machinery. But many problems are associated with this new plant.

It is against this background that this project has been proposed to modify the system by automating some of the production units to make production smoother, faster, and more cost-effective [1].



## 1.2 **Statement of the Problem**

As the government of Ghana seeks for strategic investor to take over operation of the company, there is the need to improve the working efficiency of the plant to avoid making losses to any investor who takes over the operation. Hence, this calls for a new design which overcomes the problem.

The problem is that, during processing, when the gravel is scrubs and screened in the scrubber, the undersize gravel which contains the diamonds going through the vibrating screens overflow into the Knelson Concentrator (KC) which processes the Gold.

This happens when there is a breakdown in the 0,2mm screen layer. But the most unfortunate thing is that, this is unnoticeable to the human eye. This however calls for a monitoring system that automatically stop the Revolving monitor so that it can stops the oversize conveyor and the scrubber so that there is no feed of gravels in the scrubber to avoid more diamonds going into the waste bin. The revolving monitor is programmed to direct high pressure water onto the gravel in the loading bunker.

To avoid over flooding the vibrating screen should be allowed to keep running whilst this automatic operation is carried out. In this state, a signal can now be sent to the control room to alert the technicians to rectify the fault.

I strongly believe that, if this is done and the employees are trained on how to manage the system, the cost of refurbishing the machinery will be reduced and may save the company from making losses.

However, if this is done, the rejuvenation of the mines would not only bring profit to the investors who take over operation but will also improve the economic life of the people of the region.

## 1.3 **Significance /Need for the Project**

- The project will address the current problem being faced by the company. The system has been carefully designed in such a way that it uses advanced digital system technology in its operation which is found to be a good approach in monitoring the entire plant operation.

- This approach will help any investor who wins the bid of the Divestiture Implementation Committee of the Government of Ghana to implement the idea as a way of finding solution to plant design.
- If the investor expressed interest in this idea, it would give Savonia UAS the opportunity to use their expertise for the implementation of the idea. This would increase their competitiveness at the international educational market.
- Also having an automated plant for the company will increase productivity, reduce hazards, improve efficiency and lower labor costs and human intervention but this should not be seen as a problem since higher production will require more people to work.
- It is also an opportunity for Finnish strategic investors to enter the Ghana market with their advanced technology following the recent bilateral discussions of Finnish Government interested in investing in Ghana according to November 10<sup>th</sup> 2009 Finnish ambassador Anneli Vuorinen discussion with the Ghanaian president.

#### 1.4 **Objective of the Project**

The goal of this project was to adopt an innovative approach to put my combination of skills gained through my studies at the disposal of Ghana Consolidated Diamonds Limited to build on the company idea to design cost-effective and higher productivity automated diamond plant for them using Machine vision technology and other automation devices.

This is an effort to make the company known to investors and also make investors aware of the capability of Savonia University of Applied Sciences.

#### 1.5 **Methodology**

The information for the project was received by;

- discussion with some management personnel of the company
- consultation with the designers of the Agyenkwa Plant
- consultation with top management members of the Debeers group, the biggest diamond mining company in the world in South Africa base
- discussions with Technicians and some employees of G.C.D Ltd

- personal experiences during our time as trainees in the company
- review literature
- consultation with Pulp expert in charge of design in Metso Automation

The facility employed for this research is the use of the internet, field research and Savonia UAS library

### 1.6 **Scope and Limitation**

This project is limited to the problem encountered in the processing of the diamonds and how to improve the working efficiency of the various production units by automation.

However any other problem beyond the processing was not covered in this project due to time and resources. But the best technology and strategy to manage, control, and handle their maintenance material in stock was recommended in the project.

## **2 AUTOMATION AND HISTORY OF THE COMPANY**

### **2. 1 About Ghana Consolidated Diamond Company Limited (GCD)**

According to information from the work supervisor (GCD Ltd) of this project, small scale mining was dated back for more than two thousand (2000) years ago in Akwatia and in the whole country (Ghana) as well.

There is evidence indicating that gold mining in Ghana is going back as far as the seventh and eighth century AD. Because of this GCD Ltd was established and started producing diamonds in smaller quantities before the first president of the republic of Ghana Dr. Kwame Nkrumah started to establish and build big plants for mass production, Before Dr. Kwame Nkrumah started the establishment, the country Ghana was ruled by the British when diamonds were discovered in 1919 in Akwatia.

Akwatia is a small town located in the Kwaebibirem District, Ghana (Eastern Region). Diamonds were first discovered along the Birim River, in an area nineteen miles northwest of Akwatia, in 1919. Over 100 million carats of diamonds have been discovered from the area. Ghana Consolidated Diamonds, Ltd (GCD) is the chief producer of diamonds in the town and the country, having a total concession area of 185.35 square miles within the Birim diamond field and Kobriso Gold concession (GCD 1999). Historically, mining has brought economic benefits to Akwatia, including a means of employment and poverty alleviation.

For many years, GCD's large scale mining production eclipsed artisanal diamond mining in Ghana. While there has been a steady decline in total diamond mining in production in Ghana over the past two decades the number of small scale diamond mining products has increased exponentially. Between 1980 and 1989, the artisanal mining sector produced 207.272 carats of diamonds, in comparison to 5.328.054 carats by GCD (GCD, 2003). In contrast, between 1990 and 1999, small scale diamond mining product drastically increased to 4,637,093 carats, while GCD production declined by about 50% to 2,244,240. In 1980, artisanal mining accounted for less than 1% of total diamond mining product in Ghana, but by 1989 it was 53%, and by 1999. It was approximately 70% of national diamond output. This paralleled a decrease in production by GCD from 99% of national diamond mining production in 1980, to 47% in 1989, and 30% in 1999.

The primary driving force for an increase on artisanal mining activities in Akwatia was that GCD began to sell licenses to small – scale miners to mine its concession. The main small mining site in Akwatia is saltpond, a site on the GCD premises. [1]

## **2.2 Automation and Mechanization**

Industrial Automation is the use of robotic devices to complete manufacturing tasks. Industrial automation is becoming more important in larger, medium and small scale companies for manufacturing process Safety is increased as hazardous and dangerous tasked performed by human workers are automated. Automation plays an increasingly important role in the world economy and in daily experience. Engineers strive to combine automated devices with mathematical and organizational tools to create complex system for rapidly expanding range of applications and human activities.

Mechanization is the providing of human operators with machinery that assists them with the muscular requirements of work. It can also refer to the use of machines to replace automatic labor or animals. A step beyond mechanization is automation. Even the use of hand powered tools is an example of mechanization as it reduces the work of screwing, drilling, inserting nails, punching or even power washing a surface. [4]

## **2.3 Reasons for Automating**

In most modern industrial manufacturing, as the working process is much complex, one or more tasks are performed by the machines before passing it to another for further processing. Automating of the plant will reduce the time taking of work. Which is being done by human labor. Also, at times a task done by human is boring and repetitive of a task and error prone. Because of these, automating a system can perform this work continuously and at high speed, without an error or in some instance small errors and defects.

The control system has the ability to respond quickly to changes when the command is sent. This means, faster decision making which increases production process at a higher speed and fewer delays. Safety is increased as hazardous and dangerous tasks performed by human workers are automated.

Also quality control of production is achieved with precise actuators in automated manufacturing systems. Automated systems reduce costs. The system of operations is more predictable and has more consistent operating costs. The system also provides enhanced control of over consumption and material waste. [3]

## **2.4 AUTOMATION SYSTEMS AND TECHNOLOGY**

### **2.4.1 Supervisory Control and Data Acquisition (SCADA)**

A supervisory control and data acquisition system (SCADA) is a larger industrial control network that is often comprised of smaller sub – systems, including human interface systems connected to remote terminal units, which work to translate sensor signals onto comprehensible data. These systems can work together to control an entire manufacturing site. Or even an entire region by connecting several different manufacturing plants. SCADA systems bear a high resemblance to distributed control systems, and at times it may be difficult to differentiate between the two. The key difference lies in what they ultimately do – SCADA systems do not control each process in real time, rather they coordinate processes. Generally speaking, however, the two systems are highly similar and often used in identical applications.

### **2.4.2 Distributed Control System (DCS)**

A Distributed Control System is one in which there are separate controls throughout the system. The controls are not centrally located, but tend to spread out depending on which region of the system needs monitoring. Each control is connected to the others in a communication network. These kinds of systems are typically used in manufacturing process, especially when the action or production is continuous. The controllers can be specified for a given process, and manipulated to enhance or monitor machine performance. Traffic lights are usually controlled by distributed control systems, and they can also be applied in oil refining and central station power generation.

### **2.4.3 Human Machine Interface (HMI)**

Human machine interface system depends on human interaction with system in order to function. A user will provide the input, and the system in turn will produce output that coincides with the user's intent. In order for this to work users have access to the system and a means by which to manipulate it. ATM's for example, are designed so users can easily dictate what the system is suppose to do while enabling it to easily respond and provide the appropriate results. Buttons that read withdrawal or make deposit provide the user with much easy way to trigger a chain of commands within the internal system. The desired result, either the intake of a deposit or the ejection of cash, can be then be achieved. [4]

### **2.4.4 Programmable Logic Controllers (PLC)**

Programmable Logic Controllers are real time systems, meaning there is a set deadline and time frame in which the desired result must be achieved. The PLC system is essentially a computer that controls manufacturing machines in an industrial production line, so it has multiple capabilities, such as varied temperature range and input and output settings, as well as the ability to weather dust and other unfavorable conditions. Programmable logic controllers can be used to program a variety day – to – day applications, such as amusement park rides [5].

### **3 MACHINE VISION TECHNOLOGY**

Machine vision technology is a process by which a computer - driven device optically sensed external objects and, from its analysis of the sensed data, infers accurate data about those objects. The sensing device is usually a video camera that is linked to a computer that digitizes the captured images and analysis them.

#### **3.1 Machine Vision Background**

As computers and robots have become increasingly capable, the concept of providing them with some ability to "see" objects around them has become more important. Early work on computer vision, dating back to 1967, was done by Marvin Minsky, Seymour Papert, and Thomas Bins ford at MIT. While they began their work with great optimism and expectations of quick results, the problem soon proved to be far more complex and intractable than they had imagined. Considerable progress has been made since those early days and many commercial machine vision systems are now in operation. There is still general agreement, however, that human vision is far more complex process than the early researchers imagined.

Machine vision systems are divided into two broad categories; special purpose (or "dedicated") systems and general purpose systems. A great majority of systems currently in use are dedicated systems.

#### **3.2 Dedicated System**

In a typical dedicated machine vision system, a camera similar to those used in television industry is linked to a computer, which converts imaged captured by the camera into numbers and analyzes them. Special lighting and precise positioning of the object under examination are usually necessary to get an adequate image.

The computer makes a comparison between the captured imaged of the object (represented numerically) and the standard image (held in its memory). It then stores the results for later analysis or reports it immediately to a control processor. The latter may generate a warning signal immediately if a defective part is found, that's if the captured image does not match the standard. The item under inspection might be a valve, a ball bearing, an integrated circuit, or some other parts. [6]



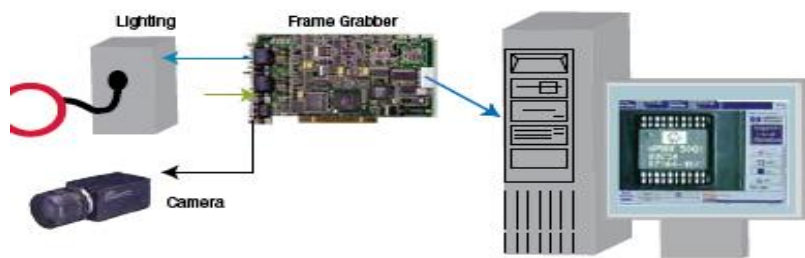


Figure 1 how the information is sent from the machine vision camera to computer in control room.

## 4 COMPANY LAYOUTS (PLANT LAYOUT)

### 4.1 Design

The plant was designed and built by local technicians. The technicians were artisans who know the problems in the company. Agyenkwa plant was built as a backbone for the company because of the inefficiency of the main plant. For the company, the plant is seen as savior, hence the name. Agyenkwa literally means savior. It was built at the bank of the Birim River. The reason for the location was to cater for the distance between the main concession areas and the production plant. Previously, after the extraction of the gravel, the gravel is transported over long kilometers to the main production plant before the final processing: thus it goes through three (3) steps. See figure (2). To save time and maximize production capacity, the new Agyenkwa plant, does the processing and the washed gravel is transported to the main production areas for final sorting of the diamond. Thus, the Agyenkwa plan now combined steps 1 and 2. And it clearly demonstrated how the process has been optimized.

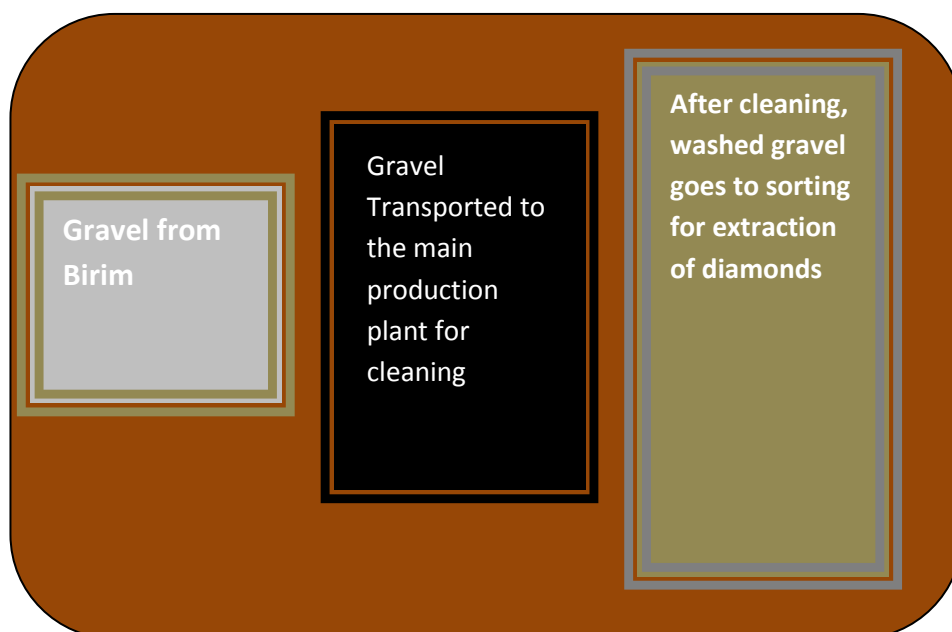


Figure 2 the process steps of the old systems

The Agyenkwa plant is important to the company because Birim is the main concession area. The size of the diamonds in the brim concession area is of high grade and bigger. Hence it is the heart of the company in terms of profit generation.

The reason why the final processing is not done at the Agyenkwa site is that, gold processing cannot be done there. Also it has no sorting place where the final polishing of the diamond can be done.

#### **4.2 Description of the Process**

There are several ways to process diamonds. Before I go ahead to describe the process description of Ghana Consolidated diamond (GCD) mines, I would first give an overview of processing in general.

Diamonds and other precious minerals are extracted from the earth via three main types. This diamond extraction method varies depending on how the materials are deposited within the earth, the stability of the material surrounding the desired mineral, and the peripheral damage done to the surrounding environment. The principle methods of extraction for diamonds are as follows,

#### **4.3 Artisanal Mining**

Artisanal diamond mining (aka 'small – scale mining' figure 3) involves nothing more than digging and sifting through mud or gravel river bank alluvial deposits with bare hands, shovels, or sieves. Laborers who work in artisanal diamond mining are called 'diamond diggers'.

Artisanal diamond mining is a form of 'subsistence based' non – mechanized mining that generates employment and reduces poverty throughout the world. In this form of mining, there are no safety measures that protect the workers, which at times causes many deaths if the pit collapses



Figure 3 Small Scale Mining (Artisanal) [2]

#### 4.4 Open Pit Mining

Open – pit diamond mining or ‘open – cast mining’ is a method of extracting rock or minerals from the earth by removal from an open pit or burrow. Open pit mines are used when deposits of minerals are found near the surface (surface mining). Open pit mining is used when the ‘overburden’, surface material covering the deposit, is relatively thin and / or the minerals are imbedded in structurally unstable earth (cinder, sand or gravel) that is unsuitable for tunneling. ‘Pit lakes’ tend to form at the bottom of open – pit mines as a result of groundwater intrusion.



Figure 4 Open pit mining

#### 4.5 Placer Mining

Placer diamond mining, also known as ‘sand bank mining’ is used for extracting diamonds and minerals from alluvial secondary deposits.

Placer mining is a form of open – pit or open – cast (surface mining) used to extract minerals from the surface of the earth without the use of tunneling. Excavation is accomplished using water pressure (a.k.a hydraulic mining) or surface excavating equipment.



Figure 5 Trommel at potato patch, blue rainbow mine,

#### 4.6 Hard – Rock Mining

The term 'Hard Rock Diamond Mining' refers to various techniques used to mine gems, minerals and ore bodies by tunneling underground and creating underground 'rooms' or 'stopes' supported by timber pillars of standing rock. Accessing the underground ore is achieved via a 'decline' or a 'shaft'. A 'decline' is a spiral tunnel which circles the flank of the diamond deposit or circles around the deposit. A 'shaft' is vertical tunnel used for ore haulage and runs adjacent to the ore. A 'decline' is generally used for personnel and machinery access to the ore.



Figure 6 Hard rock mining [2]

#### 4.7 Marine Mining

Marine mining technology only became commercially viable in the early 1990s. Marine diamond mining employs both 'vertical' and 'horizontal' techniques to extract diamonds from offshore placer deposits. Vertical marine mining uses a 6 to 7 meter diameter drill head to cut into seabed and suck up the diamond bearing material from the sea bed. Horizontal mining employs the use of seabed crawlers (remotely controlled, CAT- tracked underwater mining vehicles) more across the sea floor pumping gravel up to an offshore vessel. [7]



Figure 7 Mining in deep sea [2]



Figure 7.1 Machines at onshore [2]

#### **4.8 Mode of Operation of the company**

With respect to Ghana Consolidated Diamond (GCD) Ltd, the company does not operate on small scale basis. They have all the resources needed for large scale production. Their process goes through different stages in the production chain. This helps them to produce high grade polished diamonds and that is a good reputation for the company in the diamond international market. The difference between GCD diamond and other artisanal mining can easily be distinguished from the appearance and its brightness.

Ghana Consolidated Diamond (GCD) Ltd has land concession area of 185 acres, which is located in Akwatia. Most of GCD diamonds are located in the Brim River, and GCD mines most of its diamonds on a surface. That's surface mining as compared to other mining industries such as gold etc where it goes deep underground to search for the desire product.

Each year a specific area is targeted for production. This task is done by the survey department. Before the mining starts, the surveyors first visit and prepare the ground for prospecting, the prospecting department normally scoop sample of the soil for testing for diamonds. Based on the quantity of the diamonds found it will be determined whether the land is viable for mining.

## 5 FUNCTIONS OF THE MACHINES

The various units of the plant have their specific functions in the production process. The following are the various units and functions of the Agyenkwa plant. Figure 2 shows the layout design of the plant and the various units.

- (i) **Loading Bunker:** The loading bunker is a unit that houses the gravels which contain the diamond for washing. The dump truck loaded with gravels from the Birim River offloads the gravels into the Loading bunker. High pressure of water from the revolving monitor is directed at high pressure and sprayed onto the gravels to soften and flow like a thick fluid into the grizzle feeder.
- (ii) **Revolving Monitor:** The revolving monitor sprays water onto the gravels offloaded by the dump truck into the loading bunker. The revolving monitor is regulated at high pressure by the help of booster pump. The booster pump increases the pressure to an optimal level before spraying. The reason for this is to be able to break lumps of gravels into pieces and also soften it.
- (iii) **Booster Pump:** The booster pump boosts the pressure of the water for the revolving monitor to direct high pressure water to the gravels.
- (iv) **Grizzled Feeder:** The grizzle feeder serves as sieving equipment by vibrating linearly. It receives the gravels from the loading bunker then flow to the washer after sieving the gravels.
- (v) **Knelson Concentrator:** The knelson concentrator is the unit that does the gold processing.
- (vi) **Scrubber:** The scrubber is the unit that grinds the gravels after the revolving monitor has sprayed water onto the gavel and flows like thick fluid. The function of the scrubber is to grind the gravel flowing from the loading bunker. During grinding, the bigger stones in the gravel are directed through a channel (chute) to waste conveyor. The remaining of the gravels (the smooth gravel) goes to the vibrating feeder for further processing.
- (vii) **Vibrating Feeder:** The vibrating feeder functions as a sieve. It separates the sand with diamonds and the sand with Gold. The sand with diamonds goes through different processing for sorting and the sand with Gold goes through the Knelson concentrator.

- (viii) Concentrate Conveyor: The washed gravels with diamonds (concentrate) are conveyed through the conveyor. The concentrate is then offloaded onto a truck for it to be transported to the main plant for sorting and polishing. That ends the process.

### FLOW CHART OF THE PROCESS

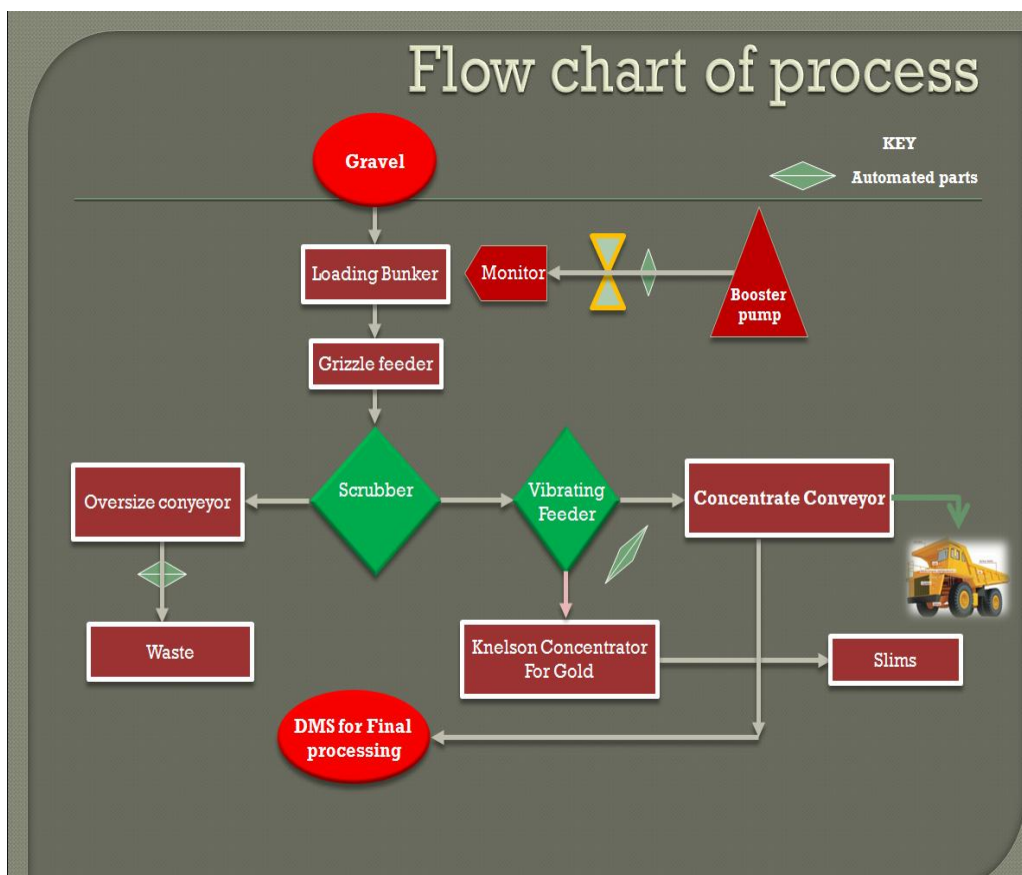


Figure 8 Flow chart of the process [2]



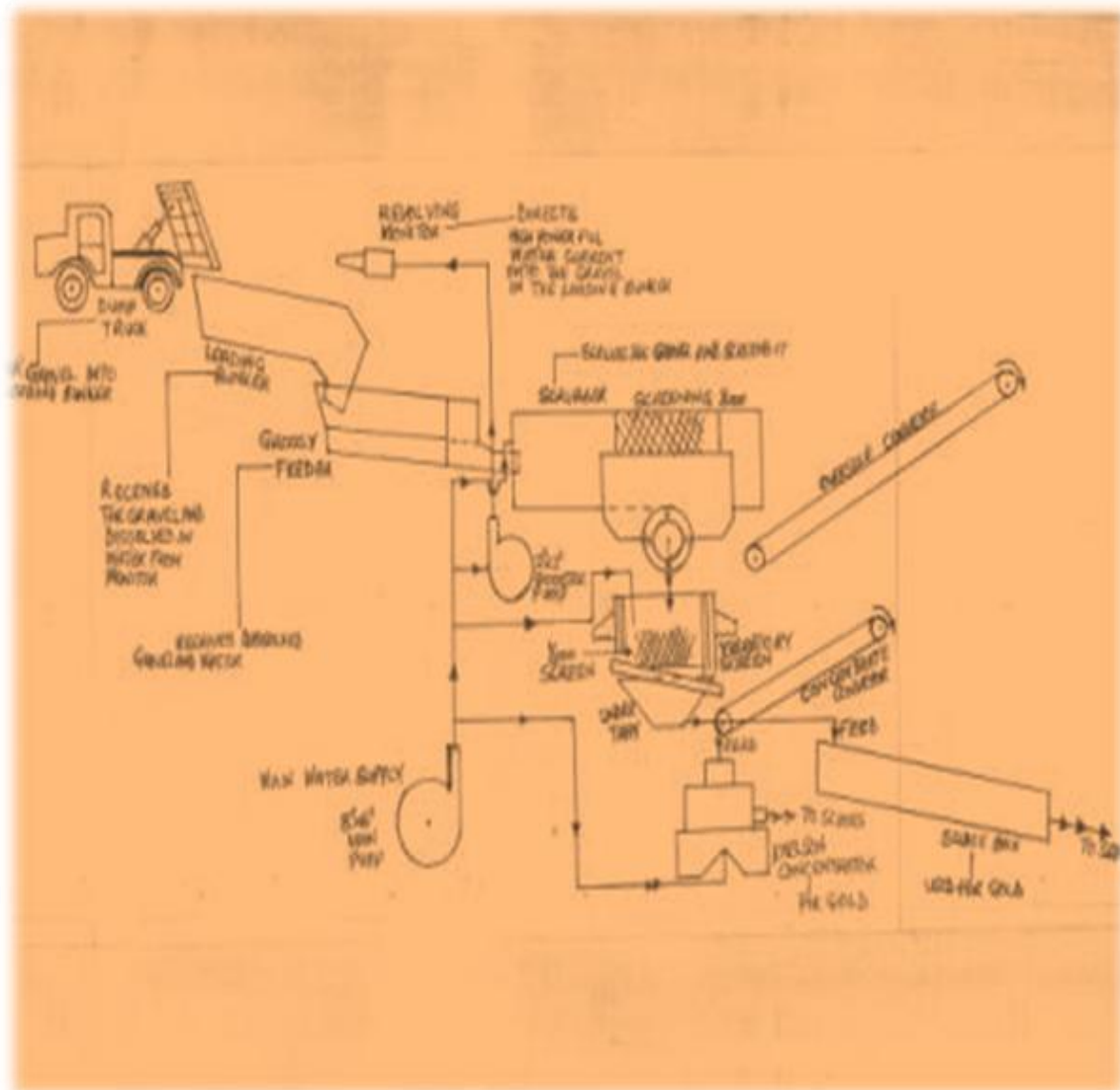


Figure 9 Layout design of Agyenkwa Plan( Ing.Aboagye,GCD Ltd) [2]

### 5.1 Global Research on Diamonds, Diamond Mining and Market

Diamond is one of the precious minerals in the world. Beyond exquisite jewelry, diamonds have many industrial uses. Diamonds are the hardest natural substance known that resists scratching. They are used for their durability to cut through many solid materials, including other diamonds. The beauty of how light passes through and shines upon diamond has made it the favorite choice for jewelry and most popular gem around the world.

Diamonds are easy to identify if observed carefully. Diamond gemstones are very rare. They are composed of carbon atoms that form tight bonds with each other to make the extremely

durable diamond. Diamonds naturally exist 100 miles into the earth mantle. Volcano eruptions would surface large chunks of the xenoliths, or mantle rock. Diamonds are mined from this rock and their sediments.

### 5.1.1 Diamonds as Gems

Diamonds with superior clarity are chosen specifically for jewelry. The value of diamonds is based on their quality, beauty, color, cut and carats. Diamonds are highly sought after for their high sparkle against gold, platinum, silver and other precious metals. Diamonds move light like a prism. The high refractive index and the high dispersion of diamonds cause light to bend and spread, showing all the colors of the rainbow. Most of the diamonds mined are not used for jewelry.

### 5.1.2 Diamonds Used as Abrasives.

Diamonds are used as slurries and as cutting tools. Diamond slurries are a paste made of water and a mixture containing small diamond pieces. These slurries are used to grind down the surface of solid rock and other materials and for polishing their surfaces. Diamond slurries are also used in lapping, where the slurry is sandwiched between two surfaces. These surfaces are then rubbed together, so that the slurry grinds down the surfaces.

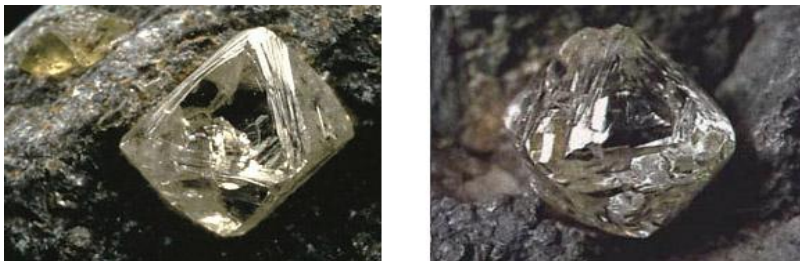


Figure 10 Samples of diamond [2]



Figure 11 different sizes of diamonds [2]

### **5.1.3 Engraving**

Diamonds are used to engrave stones like granite, quartz and other hard materials. These diamonds will not scratch or break against the other stones, so the work can be completed without worrying about replacing the engraving bit.

### **5.1.4 Other Uses**

Diamonds are also used in x-ray machines and lasers, as windows over enclosed parts. Diamonds enhance sounds when made into a very durable speaker dome. In addition to the high refractive index and high dispersion, diamonds also have the highest level of thermal conductivity. Because of this quality, diamonds are used as heat sinks, to prevent heat damage to delicate parts, as in electronic applications.

Diamonds are also used to prevent friction between micro bearings, and to provide more durability to its mechanism parts.

## **5.2 Diamonds and International Trade**

Diamonds are traded all around the world. Many people rely on the diamond industries for their earnings, where jewelers, diamond buyers and diamond miners exchange diamonds for profits. Diamonds are also most notably associated with criminal activity. Many people go to great lengths to possess diamonds, even resorting through theft and other illegal activities.

### **5.2.1 Future Uses**

Future uses of diamonds may extend into medicine for surgical tools, medical devices and for the replacement of joints. Diamonds may also be used in computer parts, communication equipment and for sound material and devices.

## **5.3 World Diamond Mining Companies.**

There are several mining companies operating throughout the globe. But unfortunately few of them have a website and in this thesis there is only information of few top mining companies and about their operations.

Alrosa, is a mining company located at Republic of Sakha (Yakutia), in Russia. Joint Stock Company ALROSA was established under decree of the RF President.

Alrosa is the legal successor of:

- The enterprises, organizations and other units of PNO Yakultamaz (state - owned diamond mining company in the former USSR):
- Some of the units within the structure of the committee for precious Metals and Gems under RSFSR Ministry of Finance (involved in sorting, preparation for shipment and shipments for rough diamonds),
- V/O Almazyuvelirexport. [7]

### **5.3.1 Alrosa Operations**

Within its structure ALROSA incorporates all the technological elements and process components of diamond mining and beneficiation.

Alrosa is a multinational company. The geographical reach of its operations stretches from the Russian arctic to Southern Africa. Alrosa mines rough diamonds from the primary and placer deposits in Russia, mainly using the most efficient open - pit method. This will remain the predominant method in the future, although the proportion off underground mining operations, which commence in 1999 with bringing into service the first underground diamond mining in Russia called the "international", will gradually increase, and by 2015 will account for almost 40% when the new underground mines 'AIKHAL', 'MIR', and UDACHY', are operating full capacity.

Intensive open - pit mining of primary deposits of Yakutia, which are not only high grade but also rich in reserves, provided an annual increase in production.

The bulk of the production was achieved through the development of pipes by open - pit mining method:

- In 1960s - 70s of the 'Mir', 'international', 'Aikhal' open - pit mines.
- In the 1980s of the 'Udachy' and 'Mir' open - pit.
- And in 1990s until the present of the Udachy, Jubilee, Nurba open - pit mines.

In the early 1990s rough diamonds production and sales reached USD 800 million, and over the last decade this has tripled. The company's open - pit mines in the republic of Sakha (Yakutia), in their combined mining and geological characteristics and parameters are unique and have no parallels in the world.[8]



Figure 12 Open pit mining operation in Russia. [2]

### 5.3.2 De Beers Diamond Mining Company

De Beers, established in 1888, is the world's leading rough diamond company with unrivalled expertise in the exploration, mining and marketing of diamonds. Together with its joint ventures partners, De Beers operates in more than 20 countries across six continents employing more than 16,000 people, and is the world's largest diamond producer with mining operations across Botswana, Namibia, South Africa and Canada.

De Beers use several mining methods to extract the desired diamonds from the ground depending on the location. Kimberlite, alluvial and marine mining all use different methods. Kimberlite mines can be underground or open-pit, while alluvial stones may be mined commercially or on a small scale.

Marine mining involves specialized ships, each of which is, in effect, a mine.

Once De Beers detect diamonds, they use different types of mining to extract them, depending on where they have found them.

Most of their diamonds occur in kimberlite pipes and are extracted by:

- **Open-pit mining**, where diamond deposits are on the surface of the ground or
- **Underground mining**, where diamond deposits are below the ground.

Diamonds are also extracted from alluvial deposits, where they are removed from sand, gravel and clay. These can be deposited along the banks of a river, the shoreline or on the bed of the ocean.

This process is called alluvial mining and is undertaken by,

- **Coastal and inland mining**, where sand and soil are removed to find diamonds or
- **Marine mining**, where diamonds are excavated from the seabed. [9]

Besides these two diamond mining companies, there are many diamond companies around the world. Most of the diamond mining companies around the world operate mainly on open-pit and marine mining which needs high-tech equipment and machines. Meanwhile, Ghana consolidated diamond company (GCD) limited, uses coastal and inland mining where sand and soil are removed to find diamonds. Because of these operations, the type of equipment and machines needed for these operations is quite different from the rest of the mining method. In GCD the major work of operations lies on digging and washing the gravels to extract the diamonds.

### **5.3.3 Global Diamond Market**

Diamonds are traded all over the globe, according to the Diamond Trading Company (DTC) and Alrosa. This is how the marketing of diamonds and demand increases. In 2010 the Diamond Trading Company (DTC) focused on increasing its rough diamond sales in the line with sight holder demand as the diamond industry continued to recover from the global economic downturn. The increase business agility introduced by DTC during the downturn was instrumental during 2010 as the speed of recovery was uncertain; effective supply chain planning and flexibility were therefore of paramount importance.

The DTC closed the year with excellent sales of US\$5.08 billion (versus US\$3.24 billion in 2009) as a result of increasing consumer demand for diamond jewellery (with demand particularly strong from emerging markets in the East such as India and China), retail restocking, and retail expansion in China.

The main operational highlight for the DTC was the significant growth in global sales (+57% over 2009 sales). Of the US\$5.08 billion global sales, US\$482 million was sold through

DTCB, US\$225 million through NDTC and US\$470 million through DTC SA (including sales to South Africa's State Diamond Traders (SDT)). [10]

## 6 PROBLEMS AFFECTING PRODUCTION

Time and work efficiency are two special resources that yield higher productivity. They are scarce resources. It can be recalled that inefficiency in production was one of the woes of Ghana Consolidated Diamonds mines. Despite the Agyenkwa plant being the backbone of the company, one would be surprised to know that, most of the activities in the production chain were solely mechanized. This affected productivity. Because the Agyenkwa Plant was built with outdated technology, many activities were done by human beings. It has an effect on one's physical health. This was the case of the revolving monitor. It was made in such a way that, it needs 24hour handling by human. This mean, the loss of time of human control leads to a problem (affects production) which affects the functionality of other units in the production chain. The function of the revolving monitor in the production chain is so crucial that, yet it is above human strength. Holding of the revolving manually to spray high pressure water to soften the gravel, had lot of health implications. It is heavier and since the pressure is unknown due to the outdated technology it made it difficult to regulate to the required pressure. Visual inspection was the means of monitoring and controlling the pressure. Production usually stopped when there was no one for the job since human beings have their limit in maintaining their strength.

An enquired, indicates that many of the operators of the revolving monitor usually suffered from stroke after retirement. This is not medically proven but the personal experience of most of the employees interviewed revealed that. The company always ends up spending thousands of euros on improving their health.

Another problem affecting production was the worn the liner of the vibrating feeder. The frictional force of the vibrating screen causes wear and tear of the liner. When this happened, the undersized gravel with the diamonds goes to the Knelson Concentrator (KC) meant only for gold processing. When this happens, the KC is unable to do the separation and oversized gravel with the diamonds are send to waste by the KC. This means that



anything above 0.2 mm is seen by the KC as waste. But under normal circumstances, anything above 0.2 mm contains diamond. The inconsistencies occur when the liner of the under tray of the vibrating screen wears out.

### **6.1 Ways to Improve Production**

Production can improve if the system is automated using automated devices such as logic gates and machine vision technology. Automation was found to be the best solution to the problem encountered in the company. With automation, all those function above human strength can be controlled by programmable logic controllers (PLC) .This will demand that a controlled roommate is built with all the monitoring devices.

Automating the revolving monitor will improve work efficiency thereby increasing production. In this way, all sickness related to this work will be eliminated to save the company money.

This will also mean that there will be pressure gauges which can be controlled automatically so that required amount of water is directed and spray on the gravels to avoid splitting of the gravels which has been softened.

With regard to the liner of the vibrating screen, the liner worn out when there is friction, machine vision or a system that can display that part on a screen in the control room for visual inspection will solve the problem. This is important because the location is invisible to the human eye. And the only means of noticing the wear is when there is an overflow of water when the system chokes.

## 6.2 Solutions

To ensure continuous production, the revolving monitor problem was solved by providing a mechanical stand to support the weight and the pressure of the water as shown in figure (13). To get high pressure water out of the revolving monitor in turbulent flow rate, the pressure ( $p$ ), the rate of flow ( $Q$ ) and the overall pressure loss ( $\nabla p$ ) in the pipe was calculated or estimated. To be able to control the water flow, regulator was provided to regulate the flow rate at a predetermined time.



Figure 13 overview of the mechanical stand supporting the weight and pressure of the revolving monitor [2]

Turbulent flow is a type of fluid (gas or liquid) flow in which the fluid undergoes irregular fluctuation, or mixing. In turbulent flow the speed of the fluid is continuously undergoing changes both in magnitudes and directions.

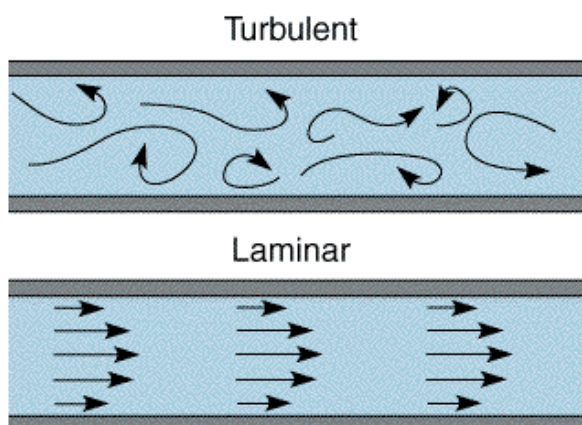


Figure 14 Image of turbulent and laminar flow [2]

### 6.3 New Pump

A new pump was considered in this thesis, since enough information was not available for the project. BLAIR's stainless - steel multistage pump was used to replace the old pump.

The reason was that, the Agyenkwa plant was built by local technicians who just used their technical know - how to design and build based on the principle and design of the old plant.

Hence little technical information about the old pump was available.

#### Old Booster Pump Data Sheet

Pressure: minimum 20bars, maximum 25 - 30 bars

Dimension of the hoses: 6 inches

Length of the pipes: 45m

Location of the pump: Brim river pump station.

### 6.4 SMP (Stainless Steel Multi-Stage Pumps)

BLAIR's stainless - steel multistage booster pump is an equipment to achieve the right water resource/pressure. The automatic pressure systems are designed to automatically start and stop the pump on opening and closing of taps. Pressure booster pump is coupled with a compact designed composed pump, a manometer, a pressure diaphragm tank, a pressure adjustable switch, dry running protector and a 3 or 5 ways connection with a stamped brass.

The pump should be installed in a covered area, protected against the weather. They are very silent and reliable. The pump is designed with advanced features such as the leakage - free design and fully stainless steel materials for rust - free operation without affecting the water quality.



Figure 15 new booster pumps [2]

### 6.4.1 Application

Pumps are suitable for pumping water in Industries, Cooling systems, Aqua farming, Water treatment, Circulation of hot Water, Pumps on Water Treatment Plants, RO, DM Water Plants, Marine Water Handling, Fertilizing - metering & dosing applications.

### 6.4.2 Performance Range.

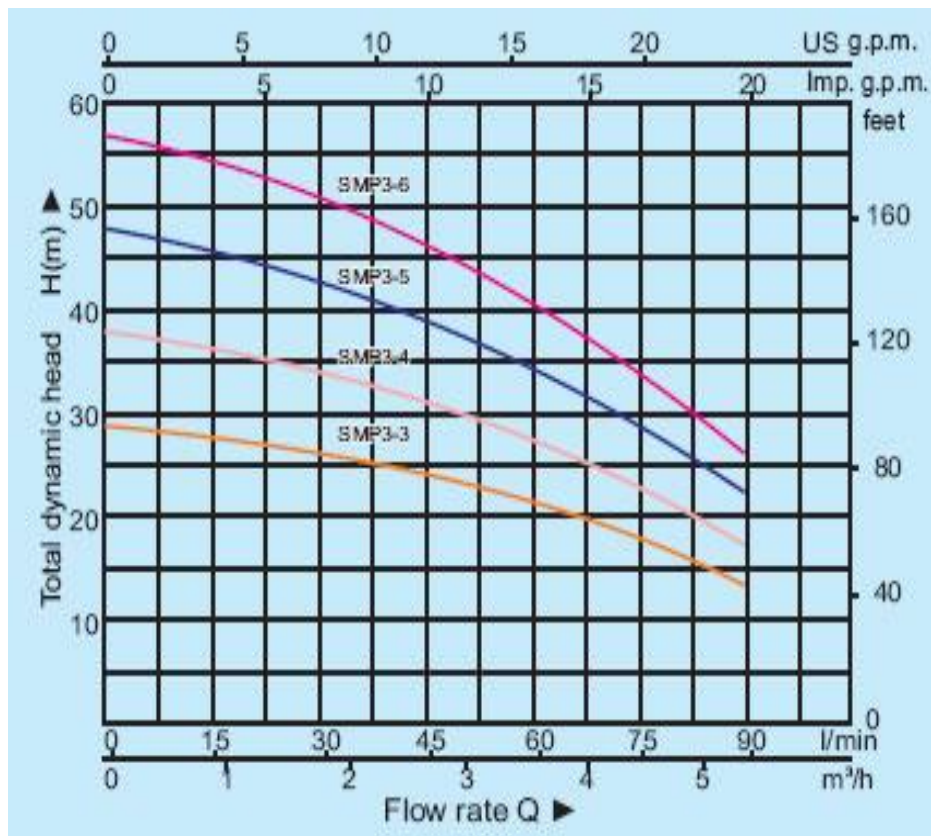


Figure 16 data sheet of the new booster pump [2]

As the pumps are designed with flat curves any application using variable speed can be obtained to increase or decrease the flow of water by keeping head constant. The pumps have a max. Flow rate up to 60 M<sup>3</sup>/hr (1000 ltr/min) and Head max up to 230 M

#### **6.4.3 Operating Limits**

The pumps are also designed to handle a temperature between the ranges of 0° C to +110° C. Pumps are designed with single mechanical seals which are very easy to interchange.  
[11]

## 7 LINER SOLUTION AND DIRECTION OF MACHINE VISION CAMERA

Due to friction, the gravel constantly wears out the liner of the vibrating feeder which causes it to tear. When this happens the system ceases to separate the undersized gravel and goes into the knelson concentrator (KC) which sends the oversized gravel to waste.

As the location of the liner is not visible, a machine vision technology will be used to solve the problem. With machine vision you might be able to detect the tears. The machine vision camera would be fixed in the direction of the liner as shown in figure (17), five (5) meter in diagonal above the position of the liner to provide automatic inspection of the liner in real time. In this case, under abnormal conditions when the liner tears the machine vision camera will sense the tears, analysis it and send the data to the computer in the control room for possible repairs or replacement (7). In many occasions, the liner is repaired when the tear is not beyond repairs. This improves production efficiency because the gravel containing the diamond will not flow to the knelson concentrator as waste.

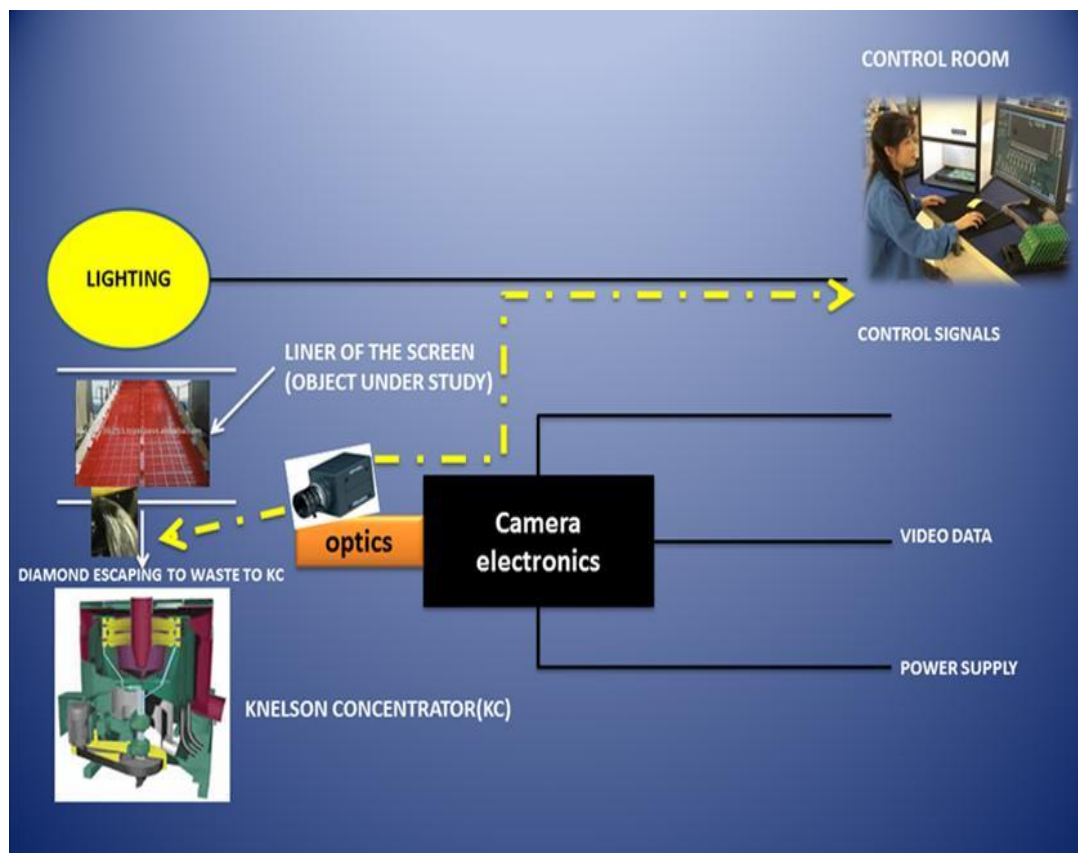


Figure 17 Machine vision cameras detecting the liner [2]

Machine vision systems are divided into two categories, special purpose (dedicated) and general purpose systems. The dedicated system of machine vision was used to solve the problem. With the dedicated system, the camera, connected to the computer in the control room, captured the liner analyze it and send the data to computer. Also if a defective part is found. (See chapter 3)

In machine vision technology, different cameras are used for a specific purpose. As the gravel moves along a conveyor, digital progressive area scan camera was used. The progressive area scan camera has the ability to read the image as a whole. The camera has its own software. The software is installed on the computer; the software is compatible with almost all the windows operating system, e.g. XP, VISTA and Windows 7. All the data sent through the cables to the computer is analyzed by the software. As the data sent is numerical (algorithms), the software that displayed it is in image form to identify the defective part.

There are different types of lens when it comes to digital progressive area scan cameras. The nature of the work determines the type of lens that needs to be installed. As the gravels flow along the conveyor, a specific digital progressive area scan camera with the following features was chosen to perform the duty.

Svs414 1/2" CCD, 640 x480 Pixel, 12 Bit gray level resolution, approx. 30/60 Frames/sec, monochrome and colour version.

### **7.1 Camera Installation**

The camera will be installed in the desired position of the company (5m) in diagonal above the liner. The power supply will be connected to the camera with 12V DC adaptor. Also the camera link cable will be connected to the frame grabber but not exceeding ten meters (10m). [13]

After the implementations, a separate control room will be provided. The control room will serve as a service station where commands will be given by the operator in charge. There

will be a screen or CCTV that will be monitoring all the plants and its environments. The control room will be constructed at the same time when the project is going on. The control room will not cost much; a plot of land for the control room project is already available.

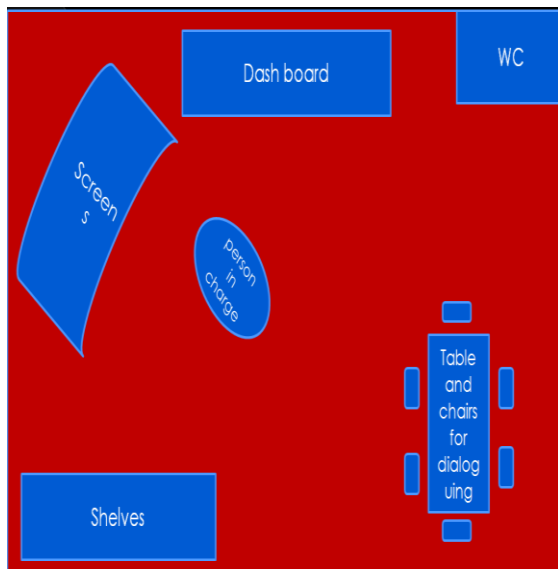


Figure 18 Control room



Figure 18.1 Control room



## 8 TRAINING

After the implementations of the plant, training will be given to skilled personnel who will be in charge of the control room and who will be operating and monitoring all the progress of the work. Special training concerning the functions of the machines and parts, based on this training, if any parts of the plant are not functioning well. The technicians can easily detect the problems and how to solve that particular problem and at the fastest rate. The training will not be just once in a whole year; rather it will be a regular training as some parts will be changed quarterly based on the maintenance schedule.

### 8.1 Cost Estimation

The cost involved for automating the plant was estimated based on the price lists of Pixelink Company, manufacturers and marketing company of machine vision cameras. The cost of the construction of the control room was estimated based on the local standard prices. The reason for this low cost is that the company has its own construction department. Due to this the cost of the personnel will not be included in the labor cost. The personnel are already employees of the company in the construction department. Also a cost of the Blair's stainless steel pump was estimated based on a personal telephone enquiry from Fountain Pump Company. Fountain Pump Company is manufacturers of the booster pump. The price of the mechanical stand was estimated after several enquiries in the local market. Therefore the consultancy and training cost was estimated for the personnel that will fix the machine vision camera and training the local technicians who will be in charge. The cost was estimated after a telephone conversation with Pixelink Company. The two sets of computer cost was estimated after contacting IPMC - GHANA on telephone, The leading IT Company in Ghana.

#### FIXED COSTS

Cost of building control room	= 5,000€
Cost of automation devices	
Mechanical stand	=1,200€
Blair's stainless steel pump	= 2,700€
Computers (two sets)	=1,400€

Machine vision camera =2,000€

Proper lights for machine vision = 599€

#### VARIABLE COSTS

Cost of training personnel per day = 1000€

Labor cost = 3,000€

Cost of consultancy (the application, per project) = 17,500€

Total cost = fixed cost + variable cost = 34,399 Euros

## 9 CONCLUSIONS

The objective of the thesis was to use automation and machine vision technology to solve the problems encountered by Ghana Consolidated Diamonds Ltd. The main problem was inefficiency in their production plant with respect to the vibrating feeder and revolving monitor. The proposed solution will help the employees to adapt to a new face lift from its existing method to innovative and cost effective production.

After intensive research, it was noticed that the booster pump needs to be replaced because much information about the old booster pump was not available. Also to meet the current production rate, the new multi stainless steel pump has the features that are suitable for modern production, the size and length of the pipes.

With regard to the revolving monitor, a mechanical stand was provided supporting the weight of the pipe directing the water to the right position. It will help reducing physical problems face by the personnel who hold the pipe throughout the day when production is going on.

The machine vision technology was essential in this project. The location of the liner is not visible by human naked eyes. Because of this the machine vision technology was adopted to monitor the liner and sense its usability. As the camera captures every movement of the vibrating feeder, at the moment friction wears out the liner, that causes tear. It sends a signal to the control room indicating the condition of the liner for immediate attention.

However, the result of this project was achieved with tight collaboration of the company supervisor and the ideas and guidelines provided by the thesis supervisor. Also little information was gathered from De beers Diamond Company, after several contacts. Fountain Pumps Company also played a major part, the manufacturer of multi stage stainless steel.

In conclusion the project carried out was able to solve the problems faced by the company and a further research can be built upon this project. Funding for the project is one way the other drawback for in-depth research about all the problems faced by the company.

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