University of Southern Queensland
Faculty of Engineering and Surveying

Design and Review of Millmerran Coal Handling Plant

A dissertation submitted by

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towards the degree of

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Abstract

Millmerran Power Company generates 850 MW (mega watt) and produces electricity to about 1.1 million houses in the south-east Queensland. The Power Station consists of two generating units. The Coal plant at Millmerran Power Station has been experiencing difficulties with the transfer of wet coal in the plant. These problems have led to a reduction in the availability of coal plant and blockages in the silos. This blockage caused by wet coal has led to a considerable amount of unit trips.

The identification and reduction of problems with wet coal is vastly advantageous as it would result in a reduction in the number of unit trips. Therefore Millmerran Power Station which operates as a private investor would benefit significantly from this improvement..

A detailed review of the coal handling plant, conveyors and chutes was carried out. The solution was to connect the Reclaim conveyor to the Stacker conveyor system through a Re-blending conveyor system. By using this method the coal can be stacked in the emergency area until it is dry enough for handling.

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Chapter 1 : Introduction

> *"When you can measure what you are talking about, and express it in numbers, you know something of your subject. But if you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."*

As quoted by Lord Kelvin, renowned for his work on the molecular motion who worked as a Scottish physicist and mathematician from 1849-1899.

The understanding of the properties and the handling characteristics of liquids and gases is an essential requirement for most of the practising engineers. Over the years there has being a remarkable amount of development and literature dealing with the fundamentals of fluid flow, fluid mechanics, hydraulics and related topics. Despite the fact that Queensland is one the main exporters of bulk material, there has been no parallel development of the related discipline Bulk Solids Handling. Bulk material handling is based on the design of equipment used for the transportation of materials such as coal and consisting of machinery like conveyors, chutes, hoppers, stackers and reclaimers.

1.1 Aim

This dissertation is an industry project for Millmerran Power Company. My aim for this project is to develop a system without any DEM software that will benefit for Millmerran operating conditions. It is not economical for Millmerran to purchase expensive software for one particular project only. The aim is to make use of the company's available resources in order to develop a custom made result and to produce the most efficient and economical outcome. Furthermore, transfer chutes are very important devices in materials handling. Therefore, my aim is to design a simple, user-friendly practical device which will be economical for the company on a long term basis. I have all the confidence that my highly experienced engineering manager, particular in this industry, will supervise and advise me to achieve the best practical outcome for Millmerran.

1.2 Background

Millmerran Power Company generates 850 MW (mega watt) which produce electricity to about 1.1 million houses in the south-east Queensland.

The coal which acts as a fuel source for the power plant must supply coal to the power plant at a constant rate.

The high amount of clay content in coal causes difficulties at Millmerran Coal Plant. Any small amount of moisture causes blockages in the coal silos. These blockages and wet coal affects the units which in turn can trip and go off line. Any un-planned outages cost Millmerran a considerable amount of money and should be avoided at all times.

With the current drought condition that we face, Millmerran has the responsibility to solve this problem for the future.

1.3 Project Objectives

The scope of work for this project is listed below;

1. Define and describe current Millmerran Power Station coal handling system and the operation of the power station.
2. Review of bulk materials handling and the characteristics of bulk material.
3. Review of conveyor design and conveyor belts.
4. Review of chute design.
5. Propose a design to solve Millmerran Power Station problems including any control requirements.
6. Formally report the findings to the project sponsor.
7. Write a dissertation of the project work.

1.4 Dissertation overview

This dissertation begins with an introduction which outlines the project objectives and the methodology undertaken to meet these objectives.

Chapter 2 provides a background into Millmerran coal plant and the layout of the coal plant with different configurations.

Chapter 3 provides an explanation of Risk Management from an Occupational Safety Health Perspective.

Chapter 4 provides further background into power plant layout and the different auxiliary plants.

Chapter 5 explains the characteristics of bulk material and the different tests performed on the product.

Chapter 6 and 7 describes and explains the different conveyor structure, configurations and different types of conveyor belt.

Chapter 8 gives insight into the portray chutes and the path that the material follows inside the chute.

The outcome and results is displayed in Chapter 9, where Chapter 10 discusses further work and recommendations on the project.

Finally, a conclusion to the project is presented in Chapter 11.

Chapter 2 : Background on Millmerran's Coal Plants

2.1 Coal Transport

Coal is delivered to the ROM (run-of-mine) by means of mine trucks and unloaded into the unloading hopper. From the unloading hopper, the run-of-mine (ROM) coal is withdrawn by a feeder-breaker, which reduces the coal from a maximum 1000 mm to a nominal 200 mm at a rate of 1,500 ton per hour (tph).

The coal then discharges from the feeder breaker into a chute which feeds a secondary crusher which reduces the coal to nominal 100 mm product. The coal is then discharged onto the unloading conveyor, which conveys and discharges the coal onto the overland conveyor to the coal plant in figure 2.1.

Figure 2. 1: Millmerran's Coal Transport Plant

The 1500 tph overland conveyor transports coal to transfer tower number two over a distance of nearly two kilometres. A diverting gate provided at the head end of the overland conveyor allows the option of either discharging coal onto the stacking conveyor or discharging onto the crusher feed conveyor. Coal that is diverted to the stacking conveyor is discharged onto the active pile by a travelling linear stacker rated at 1500 tph. Coal from the active pile is reclaimed using a full portal scraper reclaimer, dual rated at 750 tph or 1500 tph.

The reclaim conveyor transports coal at up to 1500 tph back to transfer tower number two for discharging onto the crusher feed conveyor. The 1500 tph crusher feed conveyor transports coal to the crusher tower where the coal passes under a magnetic separator before being discharged into the 100 metric ton surge bin. Each of the two outlets of the surge bin are provided with isolation gates. Coal is discharged into two 50% capacity crushers rated at 750 tph via the crusher feeders. Each crusher reduces the coal feed size from 100 mm to a maximum of 45 mm. From the crusher tower, coal is transferred via two power block feed conveyors; each rated at 750 tph, to the unit one silo bay. At the power block, a diverting gate is used to discharge coal to either the unit one silo feed conveyor or to the transfer conveyor, which transports coal to the unit two silo feed conveyor at 1500 tph. Each silo feed conveyor includes a travelling tripper, which is used to discharge coal to the silos. The total capacity of the silos for each unit is 2750 metric tons to accommodate approximately 10 hours of boiler operation.

2.2 Stacker and Reclaimer Systems

The stacker and reclaimer systems are designed for heavy duty operation and accept products from all types of crushing installations. They are suitable for raw materials in the cement, coal, pulp and paper (figure 2.2), mining and other industries as well as power plants and ports.

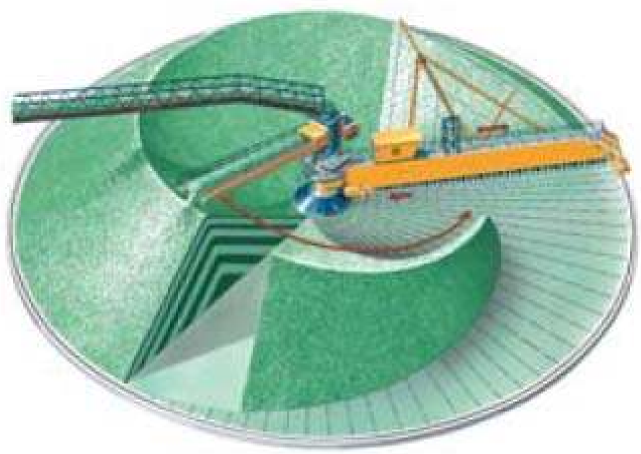
Figure 2. 2: Raw Materials

The stacker and reclaimer systems are used for both pre-homogenisation and buffer storage of raw materials like coal. When planning which stacker and reclaimer system to use, you will need to consider various questions before selecting type and size:

- open or roofed store
- mill feed system
- weather conditions
- the chemical characteristics of the materials to be handled

Over the years the industry has developed different storage types for various types of materials that have to be handled. In the following table 2.1, diverse types have been used in the industry and are classified into two main categories, homogenizing and non-homogenizing stores. Homogenizing is then divided further into three categories:

- Circular bridge scraper store (CBS)
- Longitudinal bridge scraper store (BS)
- Bucket chain excavator store (BE)

Homogenizing stores	
CBS type • High constant effect • No cone problems • Maximum use of space • Fully automatic	

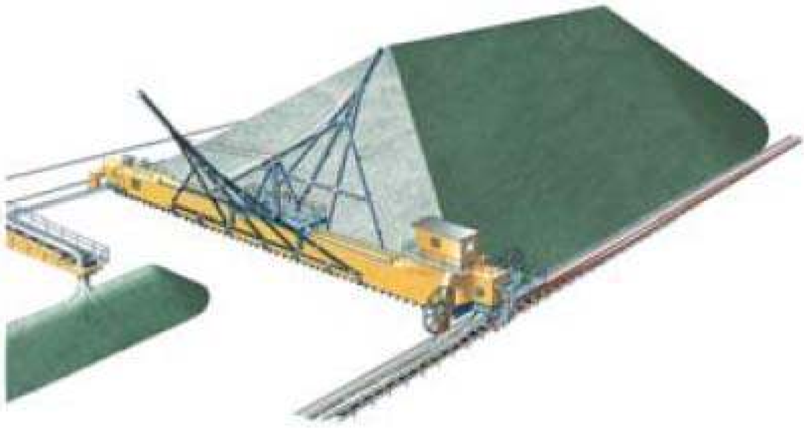
BS type • Dry to sticky materials • Direct feed • Store can easily be expanded	
BE type • Very sticky materials • Direct feed for large stores • Roofing easy to install	 *Courtesy of FEMSA*

Table 2. 1: Homogenizing Stores

Non-homogenizing stores are divided into two categories in table 2.2;

1. Portal scraper store (PS)
2. Side scraper store (SS)

Non-homogenizing	
PS type • Used for wide variety of materials • Different materials can be stacked and reclaimed • Low cost • Easy to expand storage	
SS type • Sticky materials • Different materials can be stacked and reclaimed • Easy to expand storage	 *Courtesy of FEMSA*

Table 2. 2: Non-Homogenizing Stores

2.3 Stacking methods

Stacking methods used in longitudinal stores include the following which are displayed in figure 2.3;

- Chevron
- Windrow
- Windrow- open pile
- Continuous chevron
- Cone shell

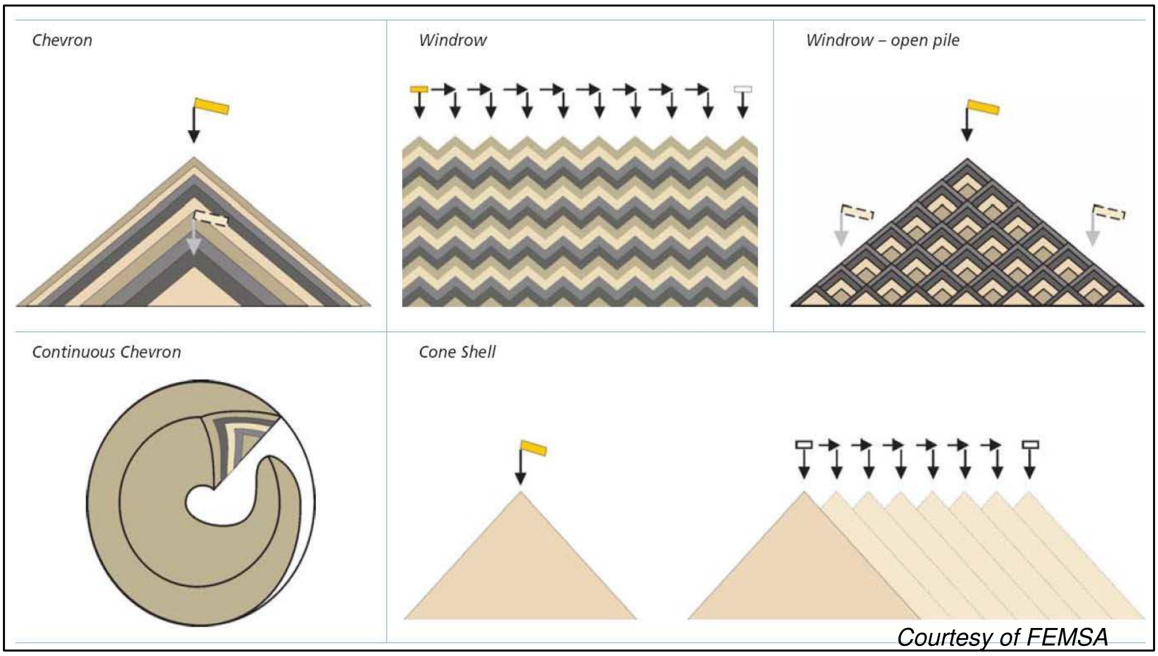


Figure 2. 3: Stacking Methods

These methods involved stacking a large number of layers on top of each other in the longitudinal direction of the stack pile.

2.4 Reclaiming methods

The reclaimer operates on an automated on/off system. Constant speed motors drive the reclaimer, whereby the material is carried by belt conveyors. The conveyor belt moves at a constant velocity and discharge the material into a feed bin. Reclaiming capacity is higher than the mill requirements and the reclaimer therefore operates on maximum and minimum silos levels.

Chapter 3 : Risk Management from an Occupational Safety Health Perspective

3.1 Introduction

In order to formulate policies and procedure it is necessary to define the word accident.
Let us examine a case of four men tripping over the same obstruction. The first man stumbles over the obstacle and remains on his feet, the second falls over and stands up with no injuries, the third cuts his hand, the fourth break his arm on an adjacent table.
The results differ widely. While the accidents are identical the consequences vary. What caused the men to trip in the first place rather than the consequences is what should concern the investigation as well as what corrective action needs to be taken.

"An accident is any unplanned, uncontrolled, unwanted or undesirable event, or sudden mishap which interrupts an activity or function." according to Alan (et al.)

Operations, maintenance and safety are closely related in the engineering industry. Well designed conveyors are reliable and robust machines. However, there is no room for complacency. Unless safety procedures are strictly adhered to where conveyor belts are concerned there is a danger of failure and serious accidents. The biggest safety concerns in the coal industry are explosions which can lead to fatal accidents.

3.2 Hazard identification

The most important and first step in risk management is to identify hazards which may result in injuries.

3.3 Elimination of potential ignition sources

If all possible ignition materials could be eliminated, an explosive atmosphere could not occur under any circumstances. The potential list of ignition sources is long and includes flames, static electricity, electricity sparking, mechanically generated sparks, heated surfaces and thermal decomposition of dust.

However, elimination of all potential ignition sources is unrealistic and the best safeguard lies in ensuring personnel have good knowledge of plant, equipment and process.

Explosive dust clouds can be ignited if the energy available to the source is adequate to set off a self-sustaining ignition. When the energy in the ignition source is below the critical value, the explosive atmosphere will not ignite. To ensure a safe plant and working environment these critical values of the potential ignition sources must not be exceeded at all costs. The key to all of this is prevention of potential ignition sources.

3.3.1 Ignition by electrical discharges

Electrical discharges are possible ignition sources for dust clouds and, therefore the discharge must be capable of releasing adequate energy into the explosive atmosphere if an ignition is to occur. The minimum energy depends on the dust clouds and how the discharge is produced, either through static electricity or electrical circuitry. Some circuits will produce ignitions at low energy while others like capacitive electrical circuits produce a specified ignition energy data for specifications.

3.3.2 Ignition by static electricity

Ignition is made easier when the duration of the spark can be increased by the installation of a suitable induction in the circuit. Standard test of the inductance of the discharge circuit are performed at two levels, 1-2 mH and 20µH. The addition of the 1-2mH inductance in the discharge generating circuit is for measuring the minimum ignition energy in this test, and should not be used in the assessment of the electrostatic hazards. Ignition energy that is applicable to electrostatic discharges is measured around 20µH in the discharge generating circuit.

Several different types of electrostatic discharge exist. The spark occurs between two conductive objects, and the spark is capable of igniting dry, flammable dust. When a brush discharge occurs the conductive, grounded object is subject to a high electrical field. Corona discharge occurs when the radius of curvature is very small.

3.3.3 Ignitions due to electrical equipment

Sparks produced when live currents are broken are classified as transient inductive sparks, given by the equation as;

$$\frac{1}{2} L I^2 \qquad (3.1)$$

where L is the circuit inductance [H];
I is the current in the circuit [A].

The discharge from components with a significant inductance or resistance produce a discharge with a longer duration than purely capacitance discharges, and therefore this results in a lesser amount of total energy which is needed to ignite a specific dust. Boyle and Llewelyn (1950) proved that by including a series resistance in the circuit. The minimum capacitor energy that is capable of igniting a dust source decreased considerably.

3.3.4 Hot surface ignition

Potential ignition sources for dust and gases are hot surfaces and bodies. The most common characteristics of hot ignition sources at conveyor belts are bearings that failed. There are several ignitable characteristics required for the elimination of hot surface sources;

- the minimum ignition temperature of an explosive atmosphere surroundings,
- the minimum ignition temperature of a dust layer.

3.4 Risk assessment

Risk management process should involve the methodical identification, analysis, assessment, treatment, monitoring and communication of risk. People take risks on a daily basis with hazards and most survive. Thus, risk can be seen as the measure of harm that can result from a hazard. The most effective way to combat safety in a process plant is through HAZOP (Hazard and Operability) assessment which includes the following;

- health, safety and environmental policy
- safety organization
- formal safety studies
- incident and accident reporting

- formal operating procedures
- maintenance work permit system
- plant modification procedures
- safety training programs
- allowance for human factor aspect

Therefore the most important factor is to control the risk based on sound hazard identification and quality risk assessment techniques. Effective risk control usually centres on a recognized hierarchy of controls, which offer a logical sequence of handling the hazard and reducing the risks.

During the risk assessment process the main elements are;

- establishment of context
- identification of risk
- assessment of risk
- controlling of risk
- monitoring and
- reviewing of risk

Risk engineering is the application of engineering to eliminate and reduce hazards and relies on the conduct of risk assessment to identify potential hazards.

3.5 Safety with conveyor belts

Conveyor belts and transfer points can be dangerous. Such mechanical equipment applies large amounts of energy to what is basically a loaded rubber band. Operations and maintenance personnel should always be aware of the danger of conveyors and maintain a healthy respect for its potential to kill or injure any unwary individual.

3.5.1 General safety guidelines

There are certain safety-guidelines that should be observed regardless of the design of the conveyor operations;

- Lock out all energy sources to the conveyor belt before beginning to work. Use a lock with a single key which should be kept by the person doing the work.
- Personnel should be properly trained on the material handling system, before they are allowed to work on the equipment.
- An inspection and maintenance schedule should be developed. This should include emergency switches, wiring, horns, lights and warning labels.
- Employees should learn all applicable company, state and safety rules.
- Recommended speed and capacity should never be exceeded.
- A permit system should be employed on the conveyor system.
- After any work is completed, all tools and equipment should be removed from the conveyor belt.
- Never allow personnel to sit on, cross over, or ride on a conveyor belt.

The above guidelines are not intended to replace the more detailed safety guidelines of the Australian Standards.

Chapter 4 : Background on Power Station Operations

Millmerran Power Station (figure 4.1) is an 850 MW coal-fired, base load power station. It is located 14km from Millmerran and approximately 100 km south-west of Toowoomba.

Figure 4.1: Millmerran Power Station

Millmerran transports up to 20 000 tons of coal per day for the generation of electricity supply for 1 million homes in Queensland. This section describes the power plant and the different operation involved.

4.1 Thermal Power Plant types

In thermal power stations, mechanical power is produced by a heat engine, which converts thermal energy, often from combustion of a fuel, into rotational energy. Most thermal power stations produce steam, and these are called steam power stations. Not all thermal energy can be changed to mechanical power, according to the second law of thermodynamics. Therefore, there is always heat lost to the surroundings. If this loss is employed as functional heat, for industrial processes, the power plant is referred to as a cogeneration power plant. In countries where district heating is general, there are dedicated heat plants called “heat-only boiler plants”.

Thermal power plants are classified by the type of fuel and the types of prime mover installed are described below in table 4.1.

Type of power plant	**Prime mover installed**
Nuclear power plants	use a nuclear reactor's heat to operate a steam turbine generator.
Fossil fuel powered plants	use a steam turbine generator or in the case of natural gas fired plants may use a combustion turbine.
Geothermal power plants	use steam extracted from hot underground rocks.
Renewable energy plants	fuelled by waste from sugar cane, municipal solid waste, landfill methane, or other forms of biomass.
Steam turbine plants	use the pressure generated by expanding steam to turn the blades of a turbine
Gas turbine plants	use the heat from gases to directly operate the turbine. Natural-gas fuelled turbine plants can start rapidly and so are used to supply "peak" energy during periods of high demand, though at higher cost than base-loaded plants.
Combined cycle plants	use the exhaust gas from the gas turbine to produce electricity. This greatly increases the overall efficiency of the plant, and most new base load power plants are combined cycle plants fired by natural gas.
Internal combustion and reciprocating engines	used to provide power for isolated communities and are frequently used for small cogeneration plants. Hospitals, office buildings, industrial plants, and other critical facilities also use them to provide backup power in case of a power outage. These are usually fuelled by diesel oil, heavy oil, natural gas and landfill gas.
Micro turbines, Stirling engine and internal combustion reciprocating engines	low cost solutions for using opportunity fuels, such as landfill gas, digester gas from water treatment plants and waste gas from oil production.

Table 4.1: Types of Power Plants

4.2 Electricity Generation

Power stations are used in the industry to generate electricity, a suitable form of energy which can be transmitted from the power stations to the load centres.

Electrical energy is converted from different types of energy into electrical energy in most power stations and includes;

- heat energy produced by the combustion of coal,
- heat energy produced by the combustion of fossil fuels,
- energy contained in water stored at high levels,
- wind

4.3 Power Stations in Queensland

Queensland's electricity generation is provided by power stations owned by the Government and by a number of private companies.

Listed below in table 4.2 are the main power stations in Queensland alongside the owners. The generating capacity for each is specified by the megawatt (MW) value.

Government owned	**Location and megawatt produced**
Stanwell Corporation	Stanwell 1,440 MW (4 X 360 MW) - coal-fired, steam cycle Kareeya - 84 MW (3 X 18 MW, 1 X 22 MW) - hydro Barron Gorge - 60 MW (2 X 30 MW) - hydro Windy Hill - 12 MW (20 x 0.6 MW) - wind Koombooloomba - 7 MW (1 unit) - hydro Mackay - 34MW (1 unit) - gas turbine
Tarong Energy	Tarong 1,400 MW (4 x 350 MW) - coal-fired, steam cycle Wivenhoe - 500 MW (2 X 250 MW) - hydro, pumped storage
CS Energy	Callide A 120 MW (4 X 30 MW) - coal-fired, steam cycle (in storage) Callide B 720 MW (2 x 360 MW) - coal-fired, steam cycle Swanbank B 480 MW (4 x 120 MW) - coal-fired, steam cycle Swanbank E - 385 MW (1 unit) - gas-fired, combined cycle gas turbine Mica Creek - 325MW - CCGT, gas turbine, steam
Privately owned	**Location and megawatt produced**
Comalco/NRG	Gladstone, 1680 MW (6 x 280 MW) - coal-fired, steam cycle
InterGen	Millmerran, 860 MW (2 x 430 MW) - coal-fired, supercritical steam cycle
Transfield	Collinsville, 188 MW (2 x 30 MW, 2 X 31 MW, 1 x 66 MW) - coal-fired , steam cycle
Transfield	Yabulu, 220 MW (1 unit) - gas-fired
Origin Energy	Mount Stuart, 288 MW (2 x 144 MW) - liquid fuel, open cycle gas turbine
Origin Energy	Roma, 70 MW (2 x 35 MW) - gas-fired
Oakey Power Holdings	Oakey, 320 MW (2 x 160 MW) - liquid/gas fuel
Energy Equity	Barcaldine, 53 MW (1 unit) - gas-fired

Part government/part privately owned	Location and megawatt produced
CS Energy/InterGen	Callide C, 914 MW (2 x 457 MW) - coal-fired, super critical steam cycle
Tarong Energy/Mitsui/Tokyo Electric	Tarong North, 443 MW (1 unit) - coal-fired, supercritical steam cycle

Table 4.2: Main Power Station and Owners

Queensland is well supplied with peaking plants that can be quickly brought on line to meet peak demands. These are mainly quick start gas turbines, several of which are powered by natural gas with the remainder using liquid petroleum based fuels.

The domination of coal-fired power stations connected to the eastern grid is due to the abundant supplies of low cost coal in the coastal hinterland from south to north Queensland. Many of the power stations, for example Callide A, B and C, Collinsville, Tarong, Tarong North and Millmerran are located adjacent to their coal suppliers to reduce coal transport costs.

Natural gas is being increasingly used to generate electricity. The Swanbank E power station uses coal seam methane. The Mica Creek power station is fully natural gas fuelled. The Queensland Government is implementing a range of measures to increase the proportion of electricity generated from gas, including the 13% Gas Scheme.

Bagasse (the fibre residue from crushed sugar cane) is used as a fuel in the generation of electricity at many of the sugar mills in northern Queensland, and in a smaller number of mills in south east Queensland. The sugar mills use most of this electricity in the production of sugar, but an increasing proportion of surplus power is sold to the network.

A large 'wind farm', utilising wind generators to produce electricity, is located at Windy Hill in far north Queensland. Additional sites in Queensland are being investigated for suitability as to their future use for wind farm electricity production.

An experimental solar thermal collector has been constructed at the Stanwell power station in central Queensland. This is expected to improve the power station's thermal efficiency. Photovoltaic cells are increasingly being used in remote area power supplies.

More than 200 small power stations provide electricity to remote communities. These are not connected to the east coast or the Mt Isa networks. Diesel engines are predominantly used in these power stations.

Diesel engine powered generators are also used to increase the reliability of supply to rural communities which are connected to the east coast grid by power lines which are prone to damage, particularly during cyclones.

4.4 Processes used in Thermal Power Plants

There are three distinct stages through which the conversions of chemical energy from coal into electrical energy must pass:

Stage 1 - The chemical energy is converted to heat energy in the furnace. The heat energy is then changed into steam in the boiler.

Stage 2 - The heat energy from the steam transforms into rotational energy in the steam turbine.

Stage 3 - The rotational energy of the turbine transforms into electrical energy through the alternator.

The arrangement of a power plant items are illustrated in figure 4.2

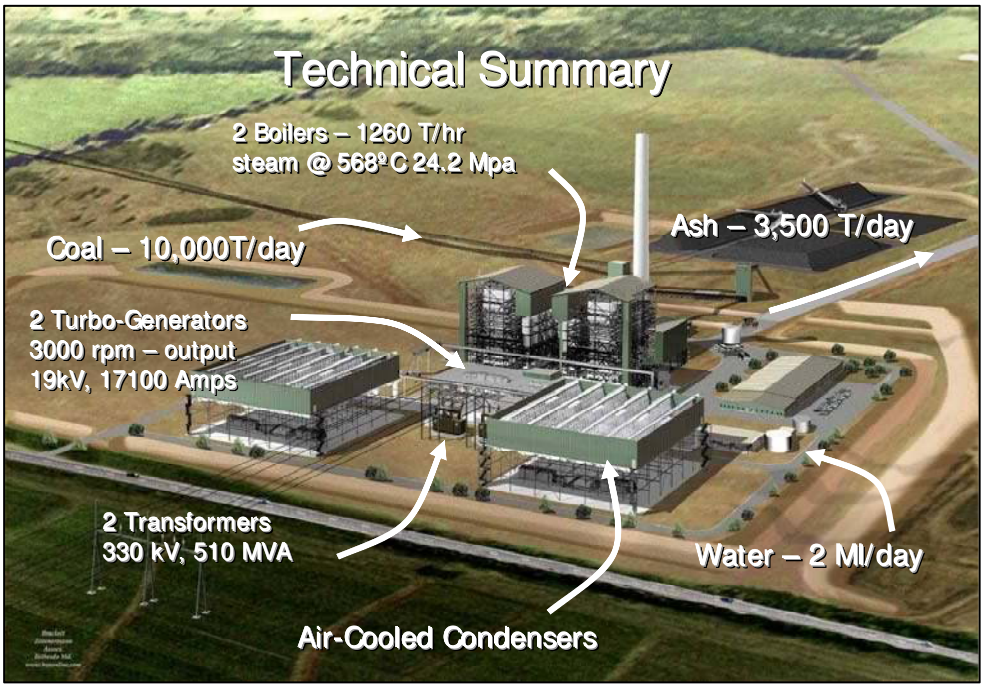


Figure 4.2: Arrangement of the plant equipment in thermal power plant

The principle items of the power plant consist of the following:

- coal handling plant
- boiler
- turbine and generator set
- ash plants
- circulating water system
- auxiliary equipment

4.4.1 Coal handling plant

Coal can be recovered from different mining techniques like:

- shallow seams by removing the overburden to expose the coal seam
- under-ground mining.

Once the coal is received the size reduction operations at the power plant are confined to crushing. Coal particle size degradation occurs in transport and handling and must be taken into account for size specifications. For pulverized coal fired boilers there is a maximum delivery size with no limitation on the percentage of fines.

The coal handling plant is used to store, transport and distribute coal which comes from the mine. The coal is delivered either through a conveyor belt system or by rail or road transport. The bulk storage of coal at the power station is important for the continuous supply of fuel. At Millmerran power station 10 000 tons of coal are required per day. The coal handling plant at Millmerran power station stores 150 000 tons of coal, which consist of three stockpiles and an emergency stockpile. Usually the stockpiles are divided into three main categories;

- live storage
- emergency storage
- long term compacted stockpile

When coals from different sources are used, blending is required to supply the boiler with a uniform feed of coal.

4.4.2 Boiler

Millmerran use Babcock & Wilcox (figure 4.3) Universal Pressure (UP) boilers. These boilers are referred to as UP-Spiral boilers and are a once through type steam generators. The developments of Universal Pressure boilers originate with the design to operate the boiler at variable pressure with higher low load power cycle efficiency. A more common name for this design is called supercritical boilers.

The design dates back to 1950's when the first 125MW supercritical boiler was build for American Electric Power's Philo station. The design evolved in later years with 1300MW units. Today there are still nine units in operation which are amongst the largest fossil fuel boilers in the world.

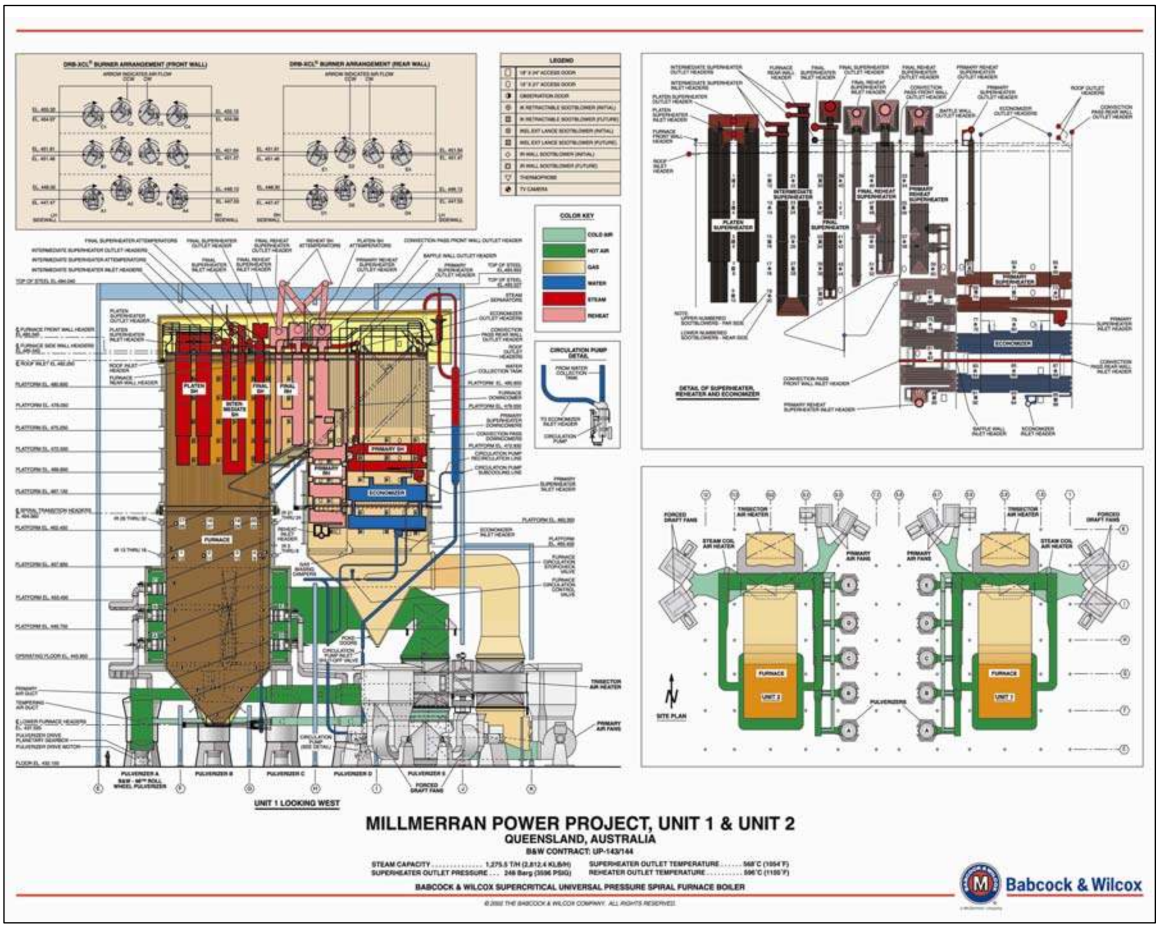


Figure 4.3: Boiler

The principle of operation is that of a Benson cycle also described as a once-through boiler cycle. This operates on the principle of above the minimum Benson cycle. The high pressure water enters the economizer and high pressure superheated steam leaves the super heater while no recirculation of water or steam appears within the boiler system.

The spiral design allows for furnace cooling, especially at minimum loads and when shared with the start-up and recalculating system.

Supercritical coal fired power plants with efficiencies of 45% have much lower emissions than sub critical plants for a given power output. The paper reviews the major technical and performance aspects of a coal fired plant using this technology. These include the turbine-generator set, the once-through boiler and operational issues such as load change, fuel flexibility and water. Early experience with supercritical plants in the US indicated that they had poor availability i.e. forced outages were greater than with sub critical plants. However experience that takes account of plant performance in Japan and Europe as well as in China and South Africa (where these once through-boilers plants are common) shows that these plants are just as reliable as sub critical plants.

Worldwide, more than 400 supercritical plants are in operation.

Reviewing the possibilities for the design and manufacture of components for supercritical-fired plants in developing countries, the paper notes that the differences between sub critical and supercritical power plants are limited to a relatively small number of components; primarily the feedwater pumps and the high-pressure feedwater train equipment. All the remaining components that are common to sub critical and supercritical coal-fired power plants can be manufactured in developing countries.

4.4.3 Turbine

A Turbine can be described as a rotary heat engine comprising a number of cylinders with rotors. Every rotor is supported within its respective cylinder on journal bearings.

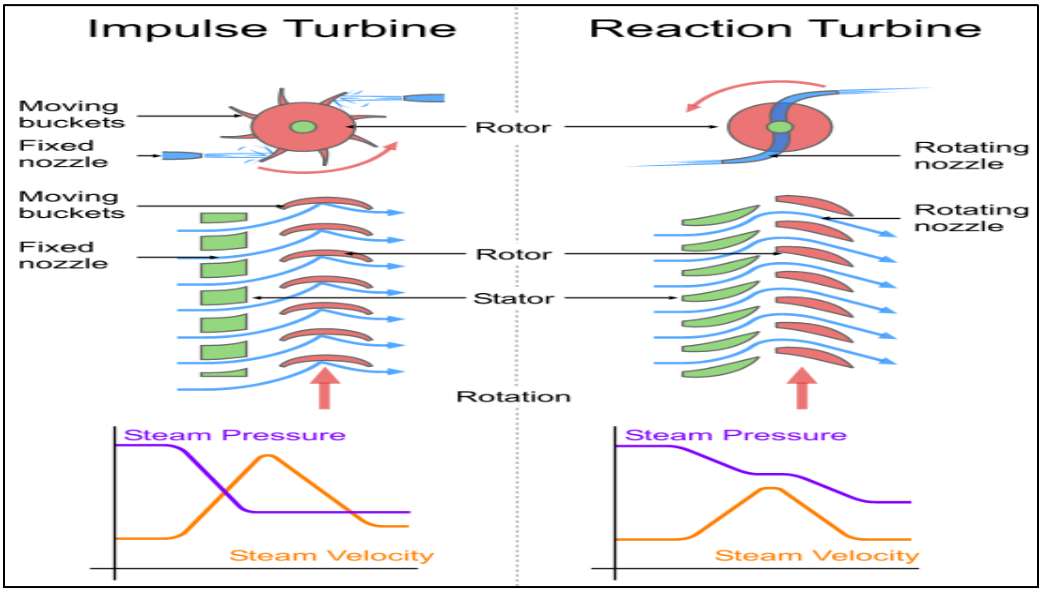
Each cylinder is fitted with alternate rows of rotating and stationary blades. Stationary blades are fitted into the cylinder casing where they redirect the steam onto the next row of rotating blades of the rotor. Steam governor valves control the turbine. At the low pressure end of the turbine is the condenser which receives and condenses the exhaust steam which returns to the boiler. In the case of Millmerran super critical system this is a once off cycle and the condensate does not return to the boiler.

Turbines are classified in the following groups:

- cylinder arrangement
- type of blading
- type of flow

Turbines can be either axial or radial flow. Impulse turbines change the direction of flow of a high velocity steam jet. The resulting impulse spins the turbine and leaves the steam flow with a reduced kinetic energy. There is no pressure variation of the fluid in the turbine rotor blades. Before reaching the turbine the steam pressure head is changed to velocity head by accelerating the steam with a nozzle. Pelton wheels and de Laval turbines use this process fully. Impulse turbines do not require a pressure casement around the runner since the steam jet is prepared by a nozzle prior to reaching turbine. Newton's second law explains the transfer of energy for impulse turbines.

Reaction turbines develop torque by reacting to the steam pressure or weight. The pressure of the steam changes as it passes through the turbine rotor blades. A pressure casement is needed to contain the working fluid as it acts on the turbine stage or the turbine must be fully immersed in the steam flow. The casing contains and directs the working steam and, for water turbines, keeps the suction imparted by the draft tube. Most steam turbines use this concept. Both reaction and impulse blades are shown below in figure 4.4.



Courtesy of Sulzer

Figure 4.4: Impulse and Reaction Blades

4.4.4 The Turbine Generator Set

There are several turbine designs available for use in supercritical power plants. These designs need not fundamentally differ from designs used in sub critical power plants. However, due to the fact that the steam pressure and temperature are more elevated in supercritical plants, the wall-thickness and the materials selected for the high-pressure turbine section need reconsideration. Furthermore, the design of the turbine generator set must allow flexibility in operation. While sub critical power plants using drum-type boilers are limited in their load change rate due to the boiler drum, supercritical power plants using once-through boilers can achieve quick load changes when the turbine is of suitable design.

4.4.4.1 High Pressure (HP) Turbine

In this section, the steam is expanded from the live steam pressure to the pressure of the reheat system, which is usually in the order of 4 to 6 Mpa. In order to cater for the higher steam parameters in supercritical cycles, materials with elevated chromium content which yield higher material strength are selected. The wall thickness of the HP turbine section should be as low as possible and should avoid massive material accumulation (e.g. of oxides) in order to increase the thermal flexibility and fast load changes.

4.4.4.2 Intermediate Pressure (IP) Turbine Section

The steam flow is further expanded in the IP turbine section. In supercritical cycles there is a trend to increase the temperature of the reheat steam that enters the IP turbine section in order to raise the cycle efficiency. As long as the reheat temperature is kept at a moderate level (approximately 560°C) there is no significant difference between the IP turbine section of a supercritical plant and that of a sub critical plant.

4.4.4.3 Low Pressure (LP) Turbine Section

In the LP turbine section the steam is expanded down to the condenser pressure. The LP turbine sections in supercritical plants are not different from those in sub critical plants.

4.4.5 Generator

The generator consists mainly of two parts; stator and rotor.

The rotor consists of a rotor body with coupling flanges, excitation windings, retaining wings, ventilator fan and the current leads.

The rotor of a generator is the rotating part of the generator. The rotor is driven by the prime mover which in our case is a turbine. Depending on the type of generator, this type of component may be the armature or the magnetic field. The rotor will be the armature if the voltage output is generated there, or the rotor will be the field if field excitation is functional.

The stator is mainly the casing, core, stator windings, terminals and the hydrogen coolers.

Therefore the stator is stationary. In our case the stator is the armature because voltage is applied there, and the stator will be the field.

4.4.5.1 Field

The field in an AC generator consists of coils of conductors within the generator that receive a voltage from a source (called excitation) and produce a magnetic flux. The magnetic flux in the field cuts the armature to produce a voltage. This voltage is ultimately the output voltage of the AC generator.

4.4.5.2 Armature

The armature is the part of an AC generator in which voltage is produced. This component consists of many coils of wire that are large enough to carry the full-load current of the generator.

4.4.5.3 Prime Mover

The prime mover is the component that is used to drive the AC generator. The prime mover may be any type of rotating machine, such as a diesel engine, a steam turbine, or a motor.

4.4.5.4 Rotor

The rotor of an AC generator is the rotating component of the generator, as shown in figure 4.5. The rotor is driven by the generator's prime mover, which may be a steam turbine, gas turbine, or diesel engine. Depending on the type of generator, this component may be the armature or the field. The rotor will be the armature if the voltage output is generated there; the rotor will be the field if the field excitation is applied there.

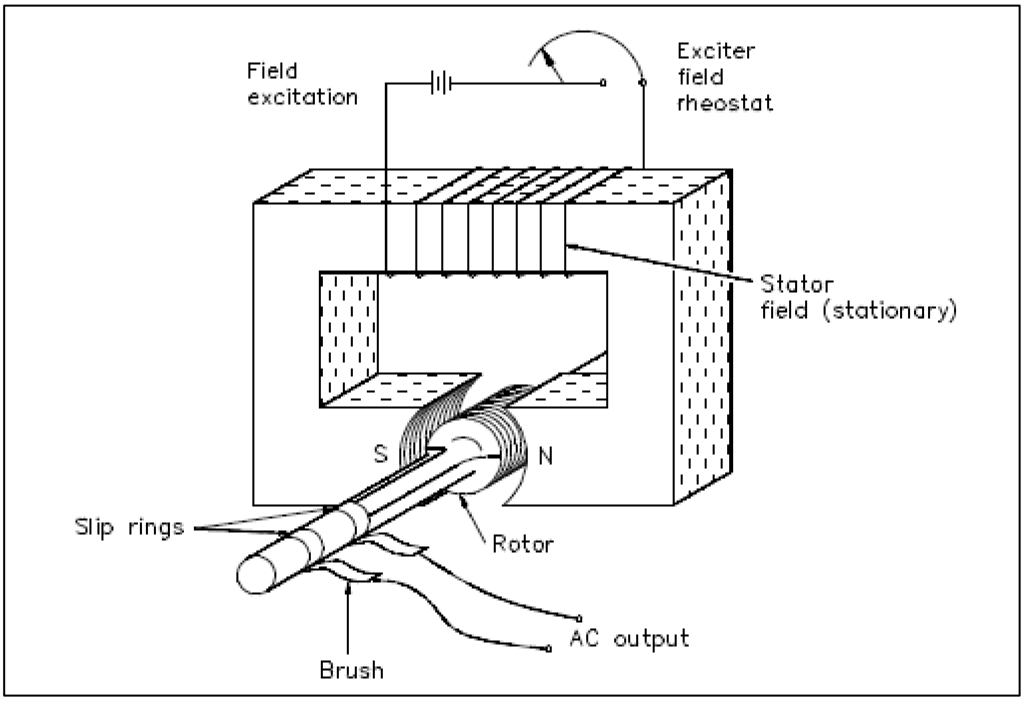


Figure 4.5: Basic AC Generator

4.4.5.5 Stator

The stator of an AC generator is the part that is stationary. Like the rotor, this component may be the armature or the field, depending on the type of generator. The stator will be the armature if the voltage output is generated there; the stator will be the field if the field excitation is applied there.

4.4.5.6 Slip Rings

Slip rings are electrical connections that are used to transfer power to and from the rotor of an AC generator. The slip ring consists of a circular conducting material that is connected to the rotor windings and insulated from the shaft. Brushes ride on the slip ring as the rotor rotates. The electrical connection to the rotor is made by connections to the brushes. Slip rings are used in AC generators because the desired output of the generator is a sine wave. In a DC generator, a commutator was used to provide an output whose current always flowed in the positive direction, as shown in figure 4.6. This is not necessary for an AC generator. Therefore, an AC generator may use slip rings, which will allow the output current and voltage to oscillate through positive and negative values. This oscillation of voltage and current takes the shape of a sine wave.

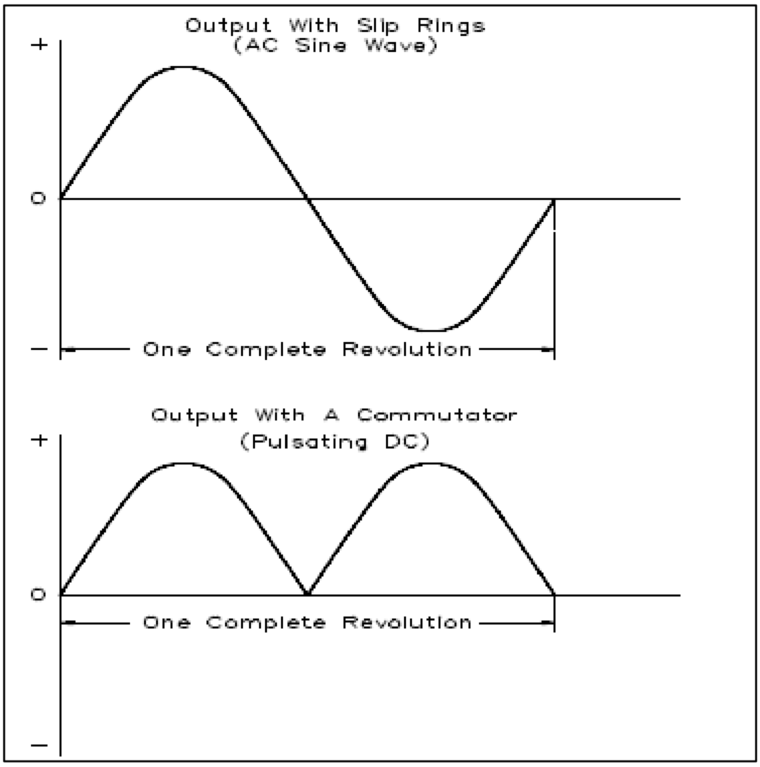


Figure 4.6: Comparison of DC and AC Generator Outputs

4.4.6 Ash plants

Millmerran's coal contain up to 35% ash. The ash content is divided up into the bottom ash and the fly ash. During the process the heavier ash gravitates to the bottom of the boiler, where it is cooled and collected in a water-filled hopper. This type of ash is referred to as bottom ash. The bottom ash is then removed from the boiler ash hopper and transferred to the mine for back fill.

The ash that is collected by the bag house is dry-stored in hoppers beneath the collecting plant and then transferred to silos. This ash is referred to as fly ash. In both the fly ash and bottom ash systems the ash is mixed with water and then transported through various methods back to the mine.

4.4.6.1 Bottom Ash

The boiler bottom ash which is too heavy to flow with the hot flue gases, falls under gravity past the boiler throat to the water filled hopper underneath. This hopper is sectionalized into a number of compartments which depend on the boiler size. These compartments allowed better control of ash and water into the sluiceway as each section is emptied.

This system is classified as a wet system where the water is used as a convenient means of cooling and collecting the glowing furnace ash.

4.4.6.2 Fly Ash

In the boiler approximately 10% of the ash particles fuse and form larger particles, which is bottom ash. The remaining 90% of the ash, called fly ash, is entrained as fine dust particles in the flue gasses and carried with the gasses through to the boiler passes. Fly ash particle sizes range from sub-microns to 200 microns.

4.5 Circulating water system

The purpose of the circulating water system is to distribute large quantities of cooling water required to condense the exhaust steam from the turbine after it has done the work on the turbine blades.

Cooling water is pump by large capacities low pressure pumps through condensers and other equipment related to the turbine.

4.6 Auxiliary equipment

The auxiliary equipment is necessary for a sufficient and proper operation of the boiler and the turbine alternator unit and includes the following:

- fuel supply and ignition system
- air heaters to heat up the air before entering the furnace
- forced draft fans for air flow
- induced draft fans to extract the hot gasses from boiler
- boiler feed pumps to supply water to the boiler
- turbine barring gear
- turbine oil pumps
- turbine condensate pumps
- turbine circulating pumps
- generator rotor and stator cooling system
- generator seal for the hydrogen gas
- hydrogen supply and generation

Chapter 5 : Characteristics of Bulk Materials

5.1 Introduction

Bulk materials are stored, handled and processed in various manners throughout the industry. The behaviour of these materials is influenced by the composition as well as the ambient conditions. To secure a reliable performance from these materials we have to understand the behaviour and take into account the characteristics in the equipment design. A major problem for the industry is that poorly designed equipment result in a disastrous reduction of flow and production losses.

Analysis of the characteristics of bulk materials in granular form is limited by the nature of the particulate system. Difficulties arise from the great number of variables, and the different systems of stress to which the materials are subjected.

Further difficulties occur from the contact with diverse ambient process conditions and their variations, second stage effects from the void content and any other changes which take place due to thermal, chemical, electrostatic or other factors which affect the condition, stability or the characteristics of the bulk material which is displayed below in table 5.1.

There are three major areas of interest in the bulk material handling characteristics-health and safety, plant performance and the product quality.

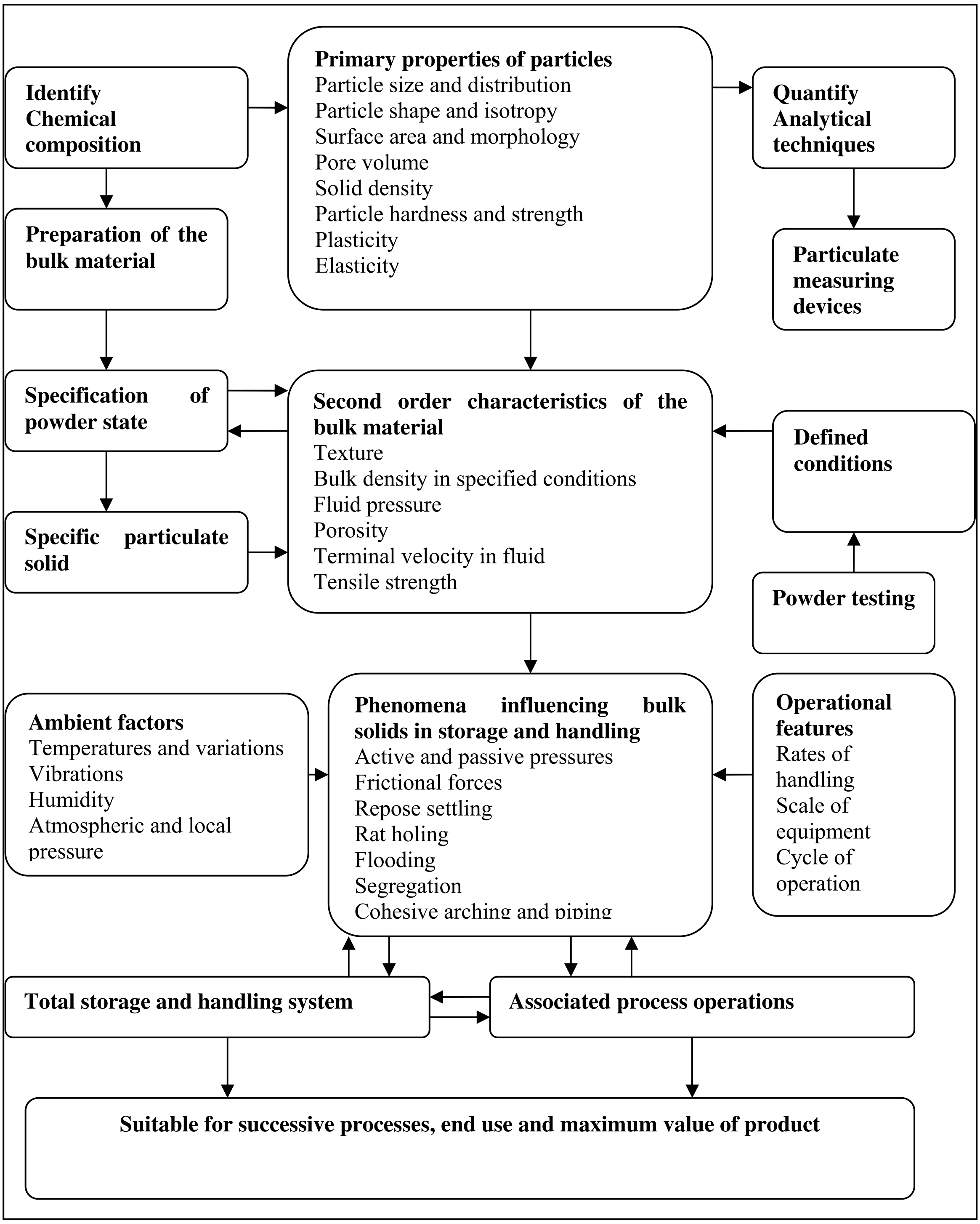


Table 5.1: Aspects of bulk solids relating to storage and handling

5.2 Bulk density

Bulk density is the most common used in bulk characteristics. It is used in chute design to estimate flow ability. Bulk density is simply the mass of the material divided by the volume that it occupies.

5.3 Angle of response

The angle of response is used as another parameter to measure the flow ability of a bulk solid. There are three angles which are important in bulk material;

1. Angle of response
2. Drained angle of response
3. Dynamic angle of response

5.4 Aspects of powder behaviour

The behaviour of a particulate material cannot be predicted from knowledge of the primary properties of which the material is composed. Different secondary properties of the bulk are therefore measured to evaluate the mechanical characteristics of the mass.
Chutes are designed to take account of these measured values as how the material breakdown under stress and the knowledge of slip properties on a contact surface.
Testing in appropriate conditions reveals how these properties are affected by changes in the bulk condition of the material.

5.4.1 Selection for testing

The first stage is to determine what forms of variation may exist in the material. These are divided into three sections;

1. Uniformity. Is the material homogeneous?
2. Consistency. Is the material similar in daily operations?
3. Stability. Will changes take place due to material ageing?

The second stage is testing now particular conditions. This is best done using worst-case scenarios. The last stage is to prepare a sample under normal conditions, where the material is analysed for friction and flow conditions.

5.4.2 Reason for testing

There are different reason why the powder material is tested;

- Product research and development
- Registration of a material
- Behaviour evaluation

- Contractual specification
- Quality control
- Equipment testing
- Specification

5.4.3 Range of tests

A two stage approach exits for any new investigation;

5.4.3.1 Simple tests

These are quick tests which are low cost, crude and would give an initial feel for the new material,

- Snowball test
- Wall ‘stiction’ – for damp or cohesive materials
- Cliff test – for fine, uniform materials
- Agitated bottle
- ‘Flung bottle’
- Poured repose
- Tapped density test

5.4.3.2 Measured value tests

This is a more advanced test which cost more and has more merit,

- Wall friction
- Tensile strength
- Cohesion
- Unconfined failure by strength
- Maximum principle stress
- Integral angle of friction
- Permeability

Chapter 6 : Conveyors Structures

6.1 History of conveyors

The most important advance in modern history is the development of conveyor belts; which are capable of transporting any bulk material at thousands of tons per hour in a continuous and consistent stream. The history of conveyers dates back to 1830 in the sawmill industry. Sawmills used flat belts sliding in steel troughs to move sawmill refuse and other materials away from the milling operations. The grain industry developed the first conveyor design, in 1850, to reduce friction of rubber sliding in a steel trough. They replace the trough with a series of pulleys to shape a cup for a troughing leather belt.

During 1891 the rubber belt conveyors were applied to the handling of heavy bulk materials. Earlier on, ore processing plants were always built into the side of a hill and therefore eliminating the need for horizontal transport.
Thomas Edison experimented with flat belt conveyors in the same year. The belts he used were simply a cotton duck material with wooden pulleys, and could not transport the abrasive ore. Replacement of the belt and idlers became essential on a one month cycle.

In the same year, Thomas Robins Senior convinced Thomas to try a cotton duck belt with a 1/8″ rubber coat. The next change was to try a troughed belt configuration using spool shaped idlers to form a trough, which failed. Robins suggested that they divide the spool into three independent cylindrical pulleys, which is supported by a bearing on the end shaft.
This configuration of the rubber belt covers and the three roll idlers became the foundation of modern belt conveyor design. In the following years, the demand for higher capacities, longer runs, steeper conveying angles and the energy efficiencies has led to new technologies.
In today’s emerging technologies conveyors carry up to 20 000 tons per hour over a distance of 45 kilometres and in different configurations like, horizontal curves and inclinations from horizontal to vertical.

6.2 General applications

6.2.1 Variety of materials

The size of materials that can be conveyed over a distance is restricted by the belt width. Different material can be transported which can range from lump ore, stone, coal, to very fine dusty chemicals. Rubber belts are well resistant to corrosion and abrasion, therefore maintenance costs are fairly low when these corrosive materials are handled. Materials that can cause sticking if transported can be effectively transported on belt conveyors. Heat resistance belts are used for the transportation of hot material such as, foundry shake out sand, coke, sinter and iron pellets.

6.2.2 Wide range of capacities

Belt conveyors are capable of handling any capacities and therefore they are used economically in plants for transporting materials between process units at a wide range of rates. A belt conveyor operates continuously, without loss of time during unloading or empty return trips. There is no need to schedule as the material is loaded automatically onto and from the conveyor belt. In the industry the operating labour cost differs little, despite the capacity rating. The overall costs per ton decrease significantly, while the yearly tonnage handled increases. With these advantages belt conveyors are capable of handling a large amount of bulk materials that would be more cost effective and often not viable to transport by any other means. Different methods of conveyor handling are used in the industry today.

6.2.3 Path of Travel

The means of transporting materials via the shortest distance between the loading and unloading points are conveyor belts, which can follow the existing terrain on grades 30 to 35 percent. In comparison to trucks hauling the same material are limited to a steepness of 6 to 8 percent. Material can be conveyed down hill and electricity can be generated through this process for general plant and equipment use.

6.2.4 Steep angle conveying

Factors that dictate the maximum incline angle in which materials can be conveyed without having the material roll back or slip on the belt are the density, effective angle of internal friction, lump size and shape.
The maximum angle to convey materials ranges from 10-20 degrees and this depend on the material being conveyed. Beyond these angles of incline, the material will tend to;

- slide down the belt
- slide internally on top of itself
- lumps will roll down the belt
- lumps will roll down over on top of the fines

The coefficient of friction between the belt and the material will determine the limits of incline which can be achieved. Material that is heavy and consists of large lumps allows an increased inclination compared to finer materials.
The latest developments in steep angle conveying increase the angle and therefore enhance the flexible path that standard conveyors now can negotiate. Therefore, as the angle increases the conveying belt capacity drops significantly. Large cleats can be bolted or bonded to the belt, which allow the angle to increase approximately to 45 degrees. Cleated belts are restricted to short distances where few or no return idlers are necessary. As a result material used on the belt does not stick to the belt surface.

6.3 Design considerations

The main objective behind conveyor design is to introduce common configurations and a combination of belt conveyors generally selected for the use in bulk material handling, and to discuss the related design consideration that effect the overall effectiveness of belt conveyor systems. A main aspect in the designing of a conveyor system is the trade off between various options and their effect on the total cost of ownership.

6.4 Conveyor arrangements

Belt conveyors can be arranged in a variety of configurations to follow an infinite number of profiles. Conveyors can be horizontal, inclined or declined, with the addition of concave, convex or horizontal curves in any trend.

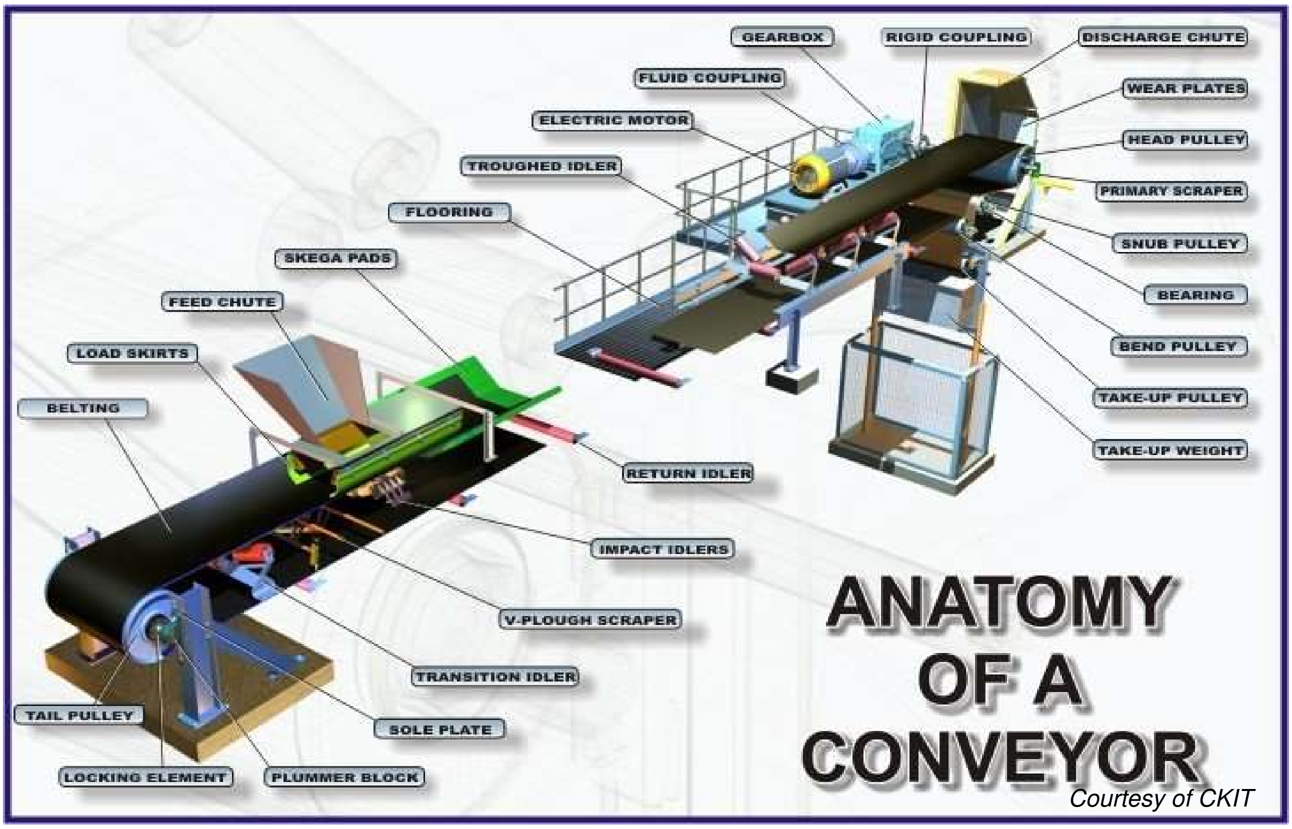


Figure 6.1: Anatomy of a Conveyor

Figure 6.1 describes the arrangement of a typical conveyor system. Most of the configurations and resulting calculations start off from combinations of these basic arrangements. Belt conveyors can be linked to a mainline conveyor to stockpile material several metres on either side, into piles of preferred length, or a stacker-reclaimer can be used to stockpile material or to reclaim material and return it to the main belt conveyors.

Belt conveyors can be designed for any preferred path of travel, limited only by the strength of the belt, angle of incline/decline or accessible space. Some arrangements are more preferred than others, e.g. the transfers between conveyors should be avoided due to possible wear of loading points and possible plugging of transfer chutes.

6.5 Conveyor structures

The following sections describe the general guidelines for the design of the support structures of belt conveyors. All support structures should be designed to allow for proper operation of belt conveyors while addressing many issues like the economy, fabrication, shipping, installation, alignment, deflection, loads, safety, access, clearances, corrosion and maintenance.

6.6 Structure widths

There are two general categories for the spacing of the main support elements for conveyer components;

1. structure supporting the carrying and return run of the conveyor
2. structure supporting main pulleys and drive components.

6.6.1 Carrying and return structure

There are two idler base designations, standard and wide. The location of the support will be determined by the structural shape and the practical location for the idler mounting holes. The idler clearance dimension can be used as a guide for the outside dimensions for the support structures.

6.6.2 Main pulley and drive structure

The main pulley and drive structure spacing is determine by the size and shape of the structural elements based on design loads and the bolt pattern of the main bearings. However, the engineering pulleys of traditional dimensions are often required for the main pulleys. No standard clearance dimension is given between the pulley edge and the chute wall and therefore it is common practice to allow a minimum of a pulley face width plus 100 mm for the inside dimension of the chute.

6.6.3 Other considerations for structure spacing

The benefit of belt conveyers is their ability to be adapted to almost any type of design limitation. There are numerous factors that influence the spacing of conveyor structures and include integral walk ways for access. Structures are design to accommodate key process equipment and therefore conveyor structures are less important.

6.7 Stringers

A conveyor that is supported by stringers is often found at or near a gradient, with short beam that support sections of the conveyor. The beams used here are often standard steel channel section.

A stringer supported conveyor belt system is not limited to short segments design at a gradient. Longer spans can be achieved without the in-between supports by using wide steel flange sections. By using shapes other than normal channel sections, the spacing may vary from the standard channel spacing to accommodate the bearing and idler bolt-hole patterns. Pre-cast concrete has being used to construct longer span sections.
When the engineer is designing the stringer and foundations, he must be aware that the foundation must support all of the forces acting on the conveyor system.

6.8 Trusses

Steel trusses have been used in designs to support conveyor belts over longer spans. When stringers and trusses are compared the latter type is considerably lighter and less expensive. The truss is fabricated from steel members and various configurations have been used in the industry. The 'Pratt' truss is most used where the vertical members are typically in compression, while the longer diagonal members are in tension. Cold formed steel joists can be used for long span conveyor support trusses.

Two types of steel trusses are used to support conveyors;

- box truss
  Box trusses are used for intermediate length spans or used where the depth of the structure below the belt limit is difficult.
- deck truss
  When a longer span is required the deck or gallery truss is employed. The best case for selecting a deck truss is when the belt and walkway is enclosed.

With the design of belt trusses one of the major considerations is the need for properly designed lateral forces in the resisting system. Box trusses often have diagonal bracing across the section of the truss and therefore in-plane bracing is used in the top and bottom chord of

the truss. Both types of trusses will require a stiffened portal section because of the transfer of lateral forces.
Trusses are typically designed using a typical assumption of pinned connections. Under these assumptions, members at a point connection should be arranged so that the lines of action of the members intersect at a common point. Additionally, the eccentricity of individual truss members should be limited.

6.9 Tubular galleries

Enclosed tubular structures may also be used to support and surround a belt conveyor. Custom designed and manufactured systems are offered. The shell provides the supporting conveyor structure and the conveyor enclosure. A major design consideration should take into account the possibility of spillage occurring and collecting at the bottom of the tube. Such occurrence would create a large unplanned weight that must be supported.

One concern about tubular galleries is that the supports can create concentrated loads, which must be distributed into the thin shell tube without the distortion. The tube must be held round to properly transfer the stress. This can be solved by stiffeners around the tube placed at an appropriate spacing around the tube. These stiffeners can be from plate, bar or rolled angle.

6.10 Portals

Conveyors at an elevation can be constructed from stringers, trusses or enclosed galleries. These structures can be supported directly on foundations or towers. Loads that are being placed on the stringers, trusses and galleries are transferred to the towers, from there on to the foundations. For transverse, longitudinal, horizontal and vertical loads these load transfers occur.
Portals, a stiffened section, are usually required at a point where the horizontal forces act on the full height of a truss and must be transferred to the bottom of a structure. Therefore, it is used to prevent a truss from racking or twisting out of alignment. A stiffened collar is usually provided with the use of an enclosed tubular gallery.

6.11 Towers and bents

The vertical structure elements that hold up the elevated belt conveyor are classified as towers and bents. The bents and towers can be constructed from structural steel or reinforced concrete.
A tower structure provides lateral support in transverse and longitudinal direction to the conveyor. These towers are placed at transfer points and belt take-up locations and are used in a four legged configuration.
A bent, used in a two legged configuration, is a vertical member that supports the conveyor vertically and provides lateral load resistance perpendicular to the belt. The bent therefore depends on the longitudinal stiffness of the truss to provide stability.

6.12 Frames and bases

Frames and bases form the support structure of the conveyor belt with the mechanical equipment. Therefore, the structural design must not only account for the loads, but also resist movement and torque induced by the moving parts.

6.13 Foundations

External loads, i.e. dead loads must all be finally supported to the ground. The foundation that is placed under the conveyor belt system will depend on ground stability and formation. A qualified geotechnical engineer will investigate the ground formation and the type of foundation to be used for the appropriate site and conveyor belt loadings.

6.14 Design

As the design and configuration of the conveyor system take place the supports must be evaluated to ensure that the structure is both stable and economical. During the design, the layout of the structure is first generated by using estimated structural member sizes. These layouts provide a basis when determining the loads of the structure. The most important feature is to identify all the loads acting on the structure under the guidelines of applicable codes and the Australian Standards.

6.15 Stress design

Allowable stress design or ASD is a traditional method for evaluating structural members when placed under loads. Loads acting on the structural members are converted into stress values through the ASD method, and then compared with allowable stress values. The allowable stresses are determined by the nominal strengths divides by the factor of safety. When a member stress value is lower than the actual allowable stress the member receives a ‘pass’.

6.16 Load and factor design

Load and resistance factor or LFRD is an alternative method for evaluating structural members under load. The same method applies as before where the loads acting on the structural members are compared to the predicted strength of the members. Detach factors are applied to each load to reflect degrees of doubt, load combinations, safety and accuracy of predicted strengths.

6.17 Vibration

Apart from load and stress concerns, structural supports must incorporate vibration analysis. The natural frequency of the structure must be greater then any applied frequency of any vibrating machinery or the belt. This applies to supports for the screens, crushers, and feeders. Damping devices can be used on vibrating equipment and the vibration, due to wind, can be avoided by using minimum values of slenderness ratios set by codes or standards. The slenderness ratio of a member is defined as the ratio of its effective length to its radius of gyration.

6.18 Deflection

Any structure will deflect under loads. The important factor is to limit these deflections with belt training, tripper operation, or general structural interferences. The most effective method to minimize deflection is to design a camber into a beam support, and therefore sufficient curvature is built into the structure so that the structure deflects to a desired position.

6.19 Buckling

With the design of conveyors the engineer must be aware of the boundaries due to buckling. Compressive loads and bending loads can cause a member to buckle or twist. With these limitations in mind the carrying capacity of the members can reduce drastically, especially with the use of high strength steels. The buckling capacity which is a function of the modulus of elasticity is reduced while the strength is increased, when using high strength steels.

6.20 Loads

The following load considerations need to be included in the design which has to be carried by the structure of the conveyor;

- dead loads
- material live loads
- piping and conduit
- spillage loads
- walkway and ladder live loads
- plugged chute loads
- belt tension loads
- expansion loads
- wind loads
- seismic loads
- dynamic loads
- stockpile loads

6.21 Corrosion protection

Conveyor belts are exposed to different environments like weather, salt water, corrosives and other elements that can deteriorate the structure. The design of the conveyor system should take account of the conditions under which the system will operate.

6.21.1 Paint

Paint is the most common method to protect conveyor structures from corrosion. Different paint processes vary from a wire brush to sand blasting, acid etching and epoxy paint systems. The expected life of the conveyor and the corrosive environment determine the method of paint application. One of the advantages of paint is the availability in most areas and cost is minor compared to other corrosion applications. The disadvantage of paint is any scratches that may develop speed up the deterioration of the structure.

6.21.2 Galvanizing

The structure is dipped in molten zinc or zinc alloy to form a corrosion barrier coating on the surface. This coating applied to the structure will resist corrosion and the structure will last longer than painted. The galvanizing protection will provide a better long term solution to corrosion and will also protect areas which cannot be reached with painting. A disadvantage of galvanizing is the heat from the process can distorts thinner members.

6.21.3 Corrosion resistance steels

Different corrosion resistant steels can be used such as stainless steels, aluminium and weathering steel. Excellent corrosion steel which is not affected through the thickness or by scratches is stainless steel. The cost is very high for the construction. It is available in many grades and grade selection should be based on use, cost and availability.

With the use of weathering steels if the top layer rusts it creates a protective oxidation to protect the rest of the steel. When the surface is scratched, the steel create another corrosion resistance layer of oxidation.

Aluminium is useful for smaller and lighter conveyor members and is corrosion resistance in many environments. Most of the aluminium alloys are heat treated and proper detailing of welding specification must be given to welding connections to avoid loss in critical areas.

6.22 Capacities

The belt width and capacity of the belt conveyor increase together, at a given speed. The main factor about belt widths is that the material must not load to close to the edge where spillage can result which is displayed in figure 6.2.

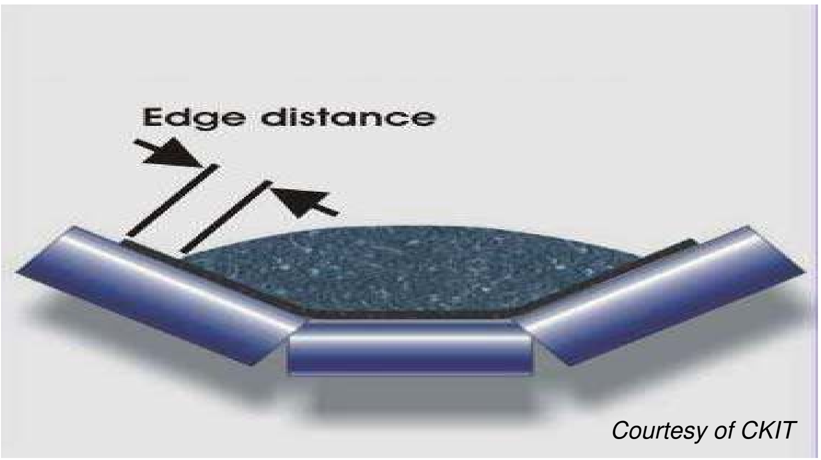


Figure 6.2: Edge Distance

6.23 High belt speeds

Higher belt speeds may be appropriate when;

- conveyor length is over 1.5 kilometres
- the loading and unloading chutes are well designed and the material is directed onto the belt in the same direction and speed
- the material consist of smaller lump sizes
- the tension in the belt is suitable to limit sag levels

The following disadvantages of high belt speeds must be weighed against the above;

- increased belt wear
- wind losses
- material degradation
- the material lump size impact on the idlers
- more maintenance on the loading and unloading chutes
- overall more wear on the conveyor components

6.24 Lower belt speeds

The use of lower belt speeds could be applied for special material such as;

- to minimize the dust created by powder materials especially at loading and unloading points
- for fragile material decrease belt speeds
- for sharp and heavy materials
- to reduce the danger associated with hazard material spillage

Therefore, it is important that conveyors should not be load to their maximum capacity. A typical capacity design factor of 1.25 is acceptable. The belt conveyor power output should always be calculated at 100% of the theoretical value to accommodate starting condition under heavy loads.

6.25 Belt conveyor idlers

On important aspect for the material carried on the belt is the loaded requirement for the idlers (figure 6.3). There are two basic types of idlers that are used in the conveyor belts. The carrying idler is used to support the load while the return idler support the empty run of the conveyor belt.

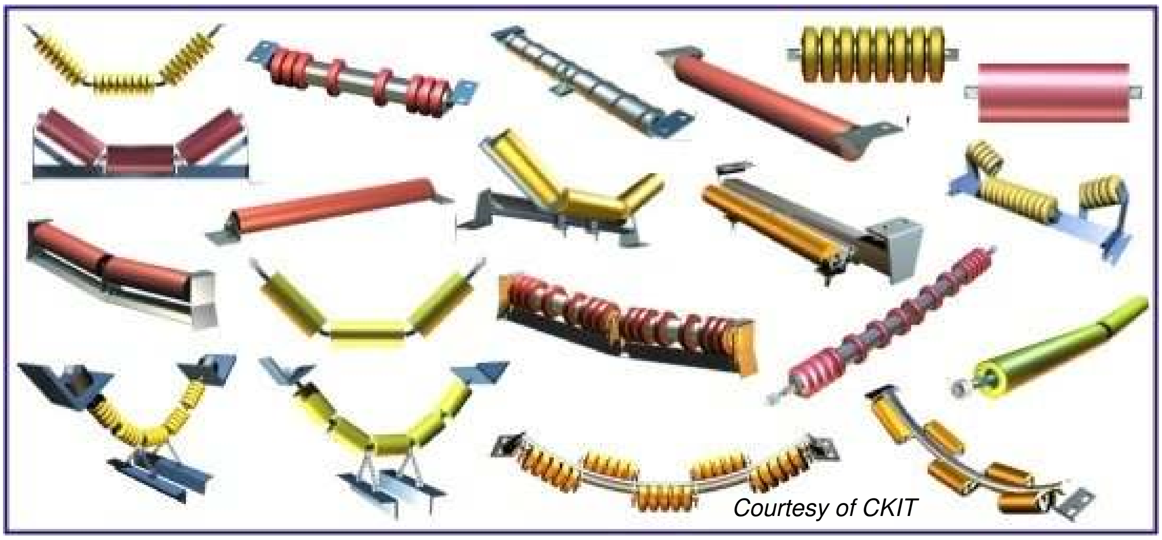


Figure 6.3: Types of Conveyor Idlers

6.25.1 Carrying idlers

There are two common carrying idlers, one is used for troughed belts and has three rolls. The centre roll is horizontal while the two outer rolls are inclining upwards (figure 6.4).

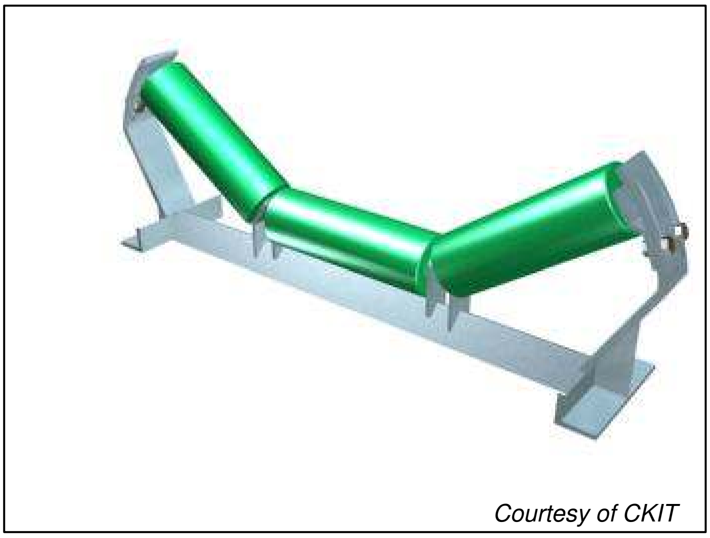


Figure 6.4: Carrying Idler

The other type is a single roll, used for flat belts, which is horizontal between brackets which are attached to the conveyor structure (figure 6.5).

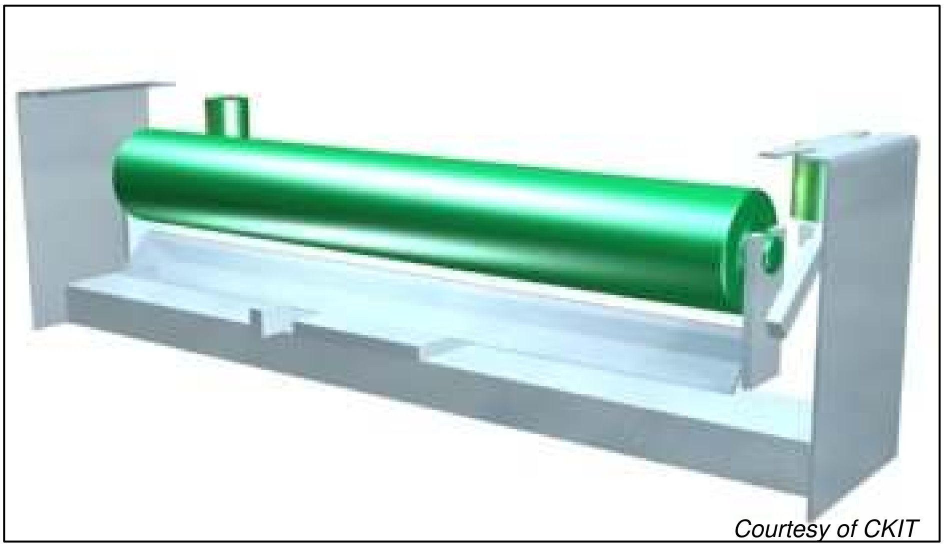


Figure 6.5: Carrying Idler

6.25.2 Troughing idlers

Troughing carrying belts are also referred to as carriers and are the most general kind of idlers used. Due to their increase cross section load these belts can carry more tonnage than flat belts. The idler rolls are made up of steel tubing with the end disc, also named bearing housing, welded to the tube ends (figure 6.6).

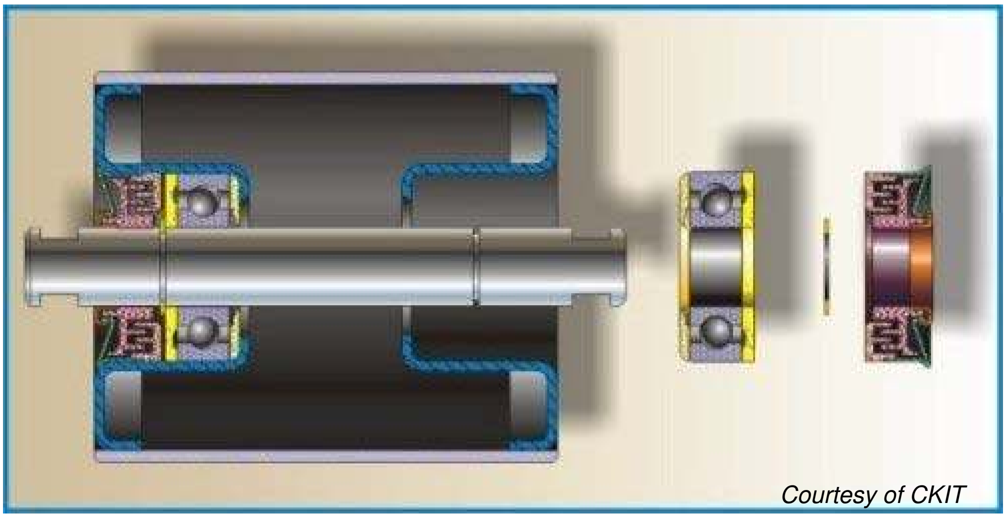


Figure 6.6: Idler

The idler rolls are made from high molecular weight polyethylene material that can withstand abrasion, material build-up and corrosion.

A 20-degree angle was mostly used in the industry until 35-degrees was introduced. Today a 45-degree idler configuration exists. These idlers are made up as either in-line or offset centres, while the three roll in-line are most commonly used to carry a maximum load cross section (figure 6.7).

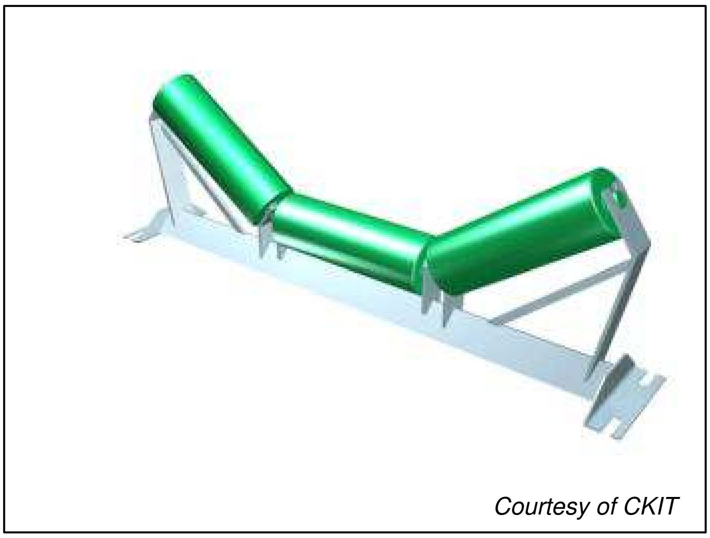
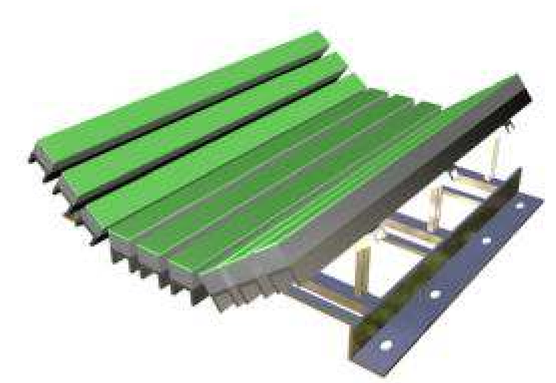


Figure 6.7: Trough Idler

6.25.3 Impact idlers

Impact idlers also referred to as cushion idlers, take the impact from the material load in the transfer chutes (figure 6.8). The impact load is a result of the material that is used and loads may vary through different materials, density, lump size and the height from which the material free falls. If the belt is not supported with correct idler spacing under the load, the belt could be heavily damaged.

Different types of impact idlers exist on the market today such as; using pneumatic tyres, semi-pneumatic tires or heavy rubber covers vulcanized to steel rolls. A flat belt impact idler has the same load rating as a single roll.



Courtesy of CKIT

Figure 6.8: Impact Idler

6.25.4 Training idlers

The training idlers are the main device that controls the belt alignment. Well designed conveyors that are precisely assembled and constructed do not need self alignment idlers. Due to brief conditions that cause conveyor belts to become misaligned, therefore conveyor manufacturers install belt trainer idlers to help control belt alignment in difficult conditions (figure 6.9).

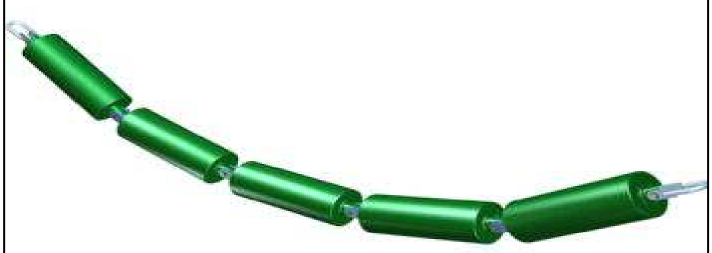
Figure 6.9: Training Idlers

When the conveyor belt is run in the opposite direction, the self-aligned idlers must be of a type that will swing around their pivot in a corrective direction regardless of their direction. A different type of idler that works on friction of the off centre belt to shift the idler will work in both directions of the belt movement.

When belt training idlers are required the spacing should be 30 to 45 metres apart and not used in areas of belt transition. With the design of conveyors belts, the greater the tension in the conveyor belt the less effective the training idlers will be.

6.25.5 Garland idlers

Garland idlers are also referred to as Suspended idlers and usually consist of three roll configurations for carrying, two for return and five for impact idlers, displayed in figure 6.10. This idler has the ability to adapt to load conditions, in both longitudinal and transverse directions, due to its flexibility. Garland provides extra cushioning and the carrying and impact idlers are made up from a steel shell construction.



Courtesy of CKIT

Figure 6.10: Garland Idler

Garland idlers can be used on a rigid frame or wire rope supported conveyor system.

6.25.6 Return idlers

These idlers are used to support the belt on the return run, and usually are suspended below the lower flanges of the stringers that support the carrying idlers.

6.25.7 Flat idlers

The flat return idler is a single long roll which is fitted at each end with a mounting bracket (figure 6.11). The idler length, bracket design, and the spacing for mounting holes should allow the belt for crosswise movement without the belt edges coming into contact with any stationary part of the conveyor frame.

Courtesy of CKIT

Figure 6.11: Flat Idler

6.25.8 Self Cleaning idlers

One of the important factors of the returning belt is for the purpose of cleaning the belt. Material that is conveyed on the belt is abrasive and might wear the shell of the return idlers. The build-up of material may be sticky and stay on the return idler rolls. When this build-up of material occurs it may cause the misalignment of the belt.

Courtesy of CKIT

Figure 6.12: Self-cleaning Idler

Different types of self cleaning idlers are available to conquer this problem. With the use of rubber or urethane discs the sticky material is solved (figure 6.12), while disc with helical rolls can also reduce the trend for material build-up. A common name for these idlers is belt cleaning idlers.

6.25.9 Training idlers

Belt idlers can be pivotally mounted to align the belt conveyors (figure 6.13). The return training idlers are more effective than trough training idlers, due to the lower belt tension on the bottom return run.

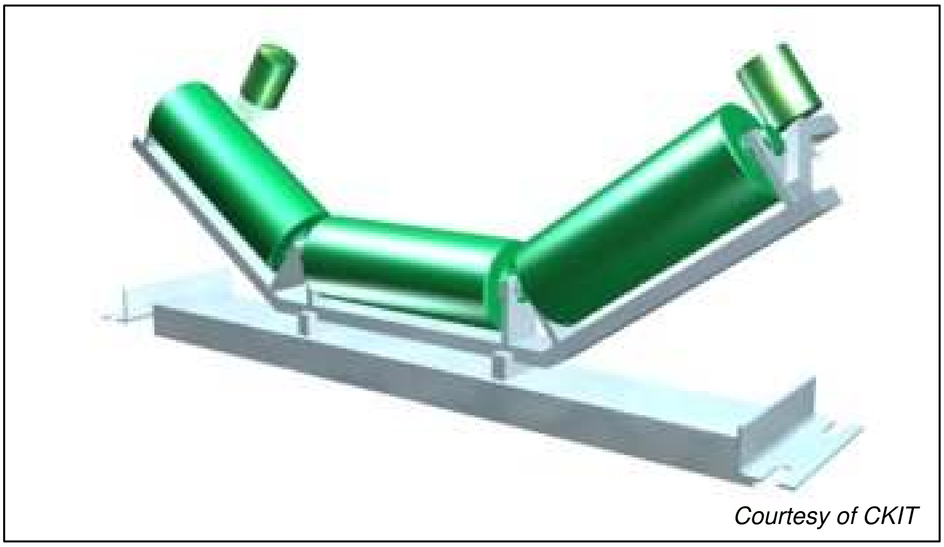


Figure 6.13: Training Idler

6.25.10 Vee idlers

Vee idlers consist of two roll, which can have a five, ten or fifteen degree angle (figure 6.14). This idler is used with the increase of heavy, high tension fabric and steel cable belts, where a better support and training of the belts is required.

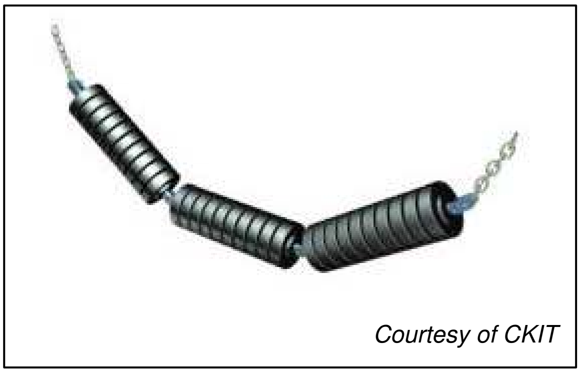


Figure 6.14: Vee Idler

6.26 Idler selection procedure

The following conditions determine which idlers can be used;

- type of material used
- load on idlers
- bearing life
- belt speed

- roll diameter
- environment and maintenance

6.27 Belt tension and selection

According to CEMA, in order to determine the effective tension, the designer needs to identify and evaluate each of the individual forces acting on the conveyor belt. These forces contribute to the tension required to drive the belt at the driving pulley and are forces produced by the belt tension as follow;

- gravitational load to lift or lower the material
- frictional resistance of the conveyor components and all the equipment while operating at design capacity
- frictional resistance of the material that is being conveyed
- force required to accelerate the material as the material is fed onto the conveyor by a chute

6.28 Pulleys and shafts

Conveyor pulleys and shafts are considered together because they form composite structures which are commonly related (figure 6.15). Therefore, it is discussed in one section of conveyor design and construction.

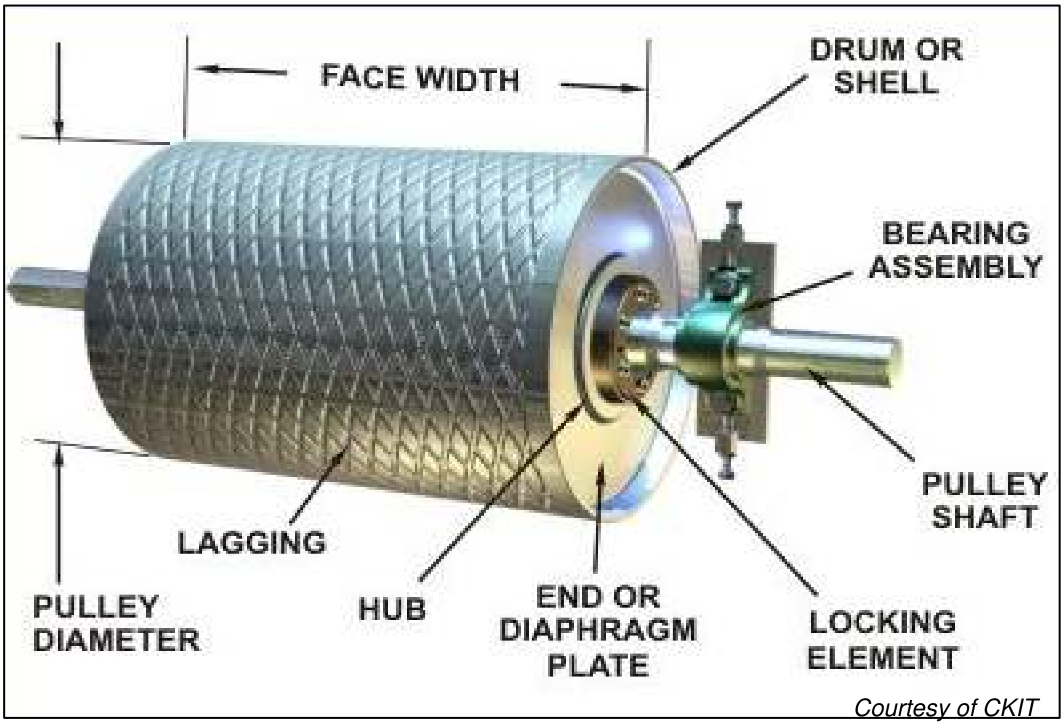


Figure 6.15: Pulley Assembly

6.28.1 Conveyor pulleys

The pulley has undergone several changes over the years from its earlier fabrication out of wood through cast iron construction up to the present day of welded steel fabrication. The increased used of pulleys has led to the development of a standard steel pulleys with a universally established size range, construction similarities and uniform load carrying capacities. Different types of pulley are used and manufactured in a wide range of sizes.

Several factors need to be included in the design and the following information is required for a reliable and economical conveyor pulley system;

- diameter and face width
- bearing centres
- pulley location
- type of belt take-up
- type of conveyor belt
- transient belt tension on pulley
- belt wrap angle
- shaft diameter
- horsepower

- belt speed
- environment and operations condition
- starting mechanism

6.28.2 Mine pulleys

The use of standard size drum and wing pulleys are used in mine duty construction. The mine pulley design is different from the others. Its material thickness has been increased to a rigid, conservative design. The mine industry uses these pulleys in their underground operations where the abusive environment and high cost of installation demanded a more conservative design. This conservative design include frequent starting and stopping, overloads which exceed 150% of running tensions and where the increased of reliability is needed.

6.28.3 Conveyor shafts

The shaft and the pulley cannot be selected separately. The designer has to keep in mind that the load capacity of a given pulley is a function of the shaft that is installed in that pulley. The shaft and pulley have to be treated as a combined structural assembly.
Strength and deflection is a function of the shaft diameter required for a pulley. With a pulley assembly, either strength or deflection can be the determining factor for the shaft diameter selection.

6.28.4 Shaft materials

The design of pulleys is based on the use of any commercial or standard shafting material. When higher strength shafts are required the load does not necessarily change.

6.28.5 Resultant radial load

The resultant radial load can be calculated by the vector summation of the belt tension, pulley weight and the weight of the shaft.

Chapter 7 : Conveyor Belt Selection

7.1 Introduction

With the continuing developments in the field of elastomers and synthetic fibres, this chapter will discuss only the basic types and grades of conveyor belts (figure 7.1) that apply to the majority of conveyor applications. Sometimes the belt will meet the specified circumstances, but it may not always be the most economical available.

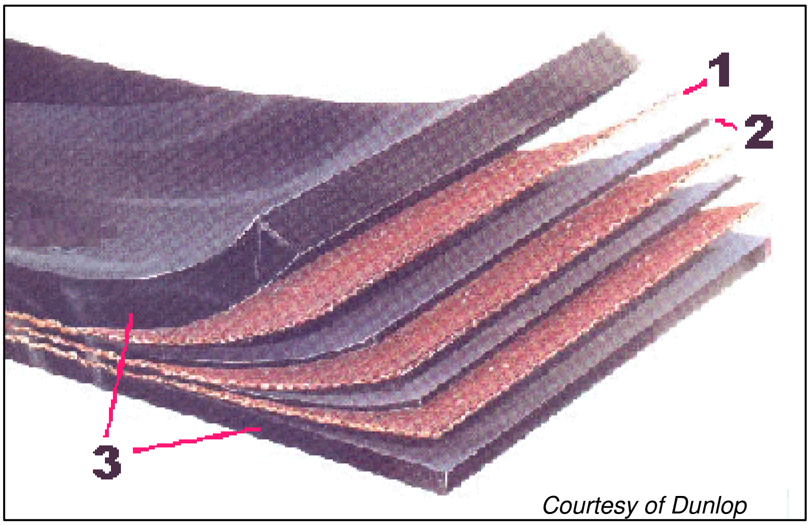


Figure 7.1: Conveyor Belts

7.2 Determining belt specifications

In the industry the conveyor belt applications needs to be analyzed before the development of the final design and operating conditions need to be looked at. The analysis of the conveyor system that will determine the belt specification of the design follows;

- material conveyed: general explanation, density, lump size of material, oils or chemical presence, requirements for fire resistance
- required maximum capacity
- belt width
- belt speed
- shape of the conveyor
- drive configuration, single or double pulley system
- pulley diameter
- take-up

- idlers type used
- loading arrangement
- temperature
- type of belt splice to be used
- types of belt cleaners to be used

7.3 Conveyor belt characteristics, composition and design

Conveyor belt are available in a wide range of types and construction. Choices of belting should be made on the basis of material to be conveyed, different operating conditions and to conform to a specific design criterion.

When conveyor belts were first introduced natural rubber and cotton fibre reinforcement were the only options. The development of synthetic rubbers, polymers, elastomers and fibres over the past forty years has led to an increase in the service life of the conveyor belt.

The compounds that are used in today's conveyor belts consist of natural rubbers, styrene-butadiene rubber blends of natural and other synthetics, nitriles, butyl, ethylene propylene based polymer and the record continues to grow.

There are two distinct categories: - general purpose belting and special purpose belting. Each of these two groups should be further defined by the definite end use.

1. General purpose belting
2. Special purpose belting.

7.4 Loading considerations

The frequency factor is the number of minutes for the belt to make one complete revolution and the formula is;

$$F_f = \frac{2L}{V} \qquad (7.1)$$

where L is centre to centre length of the belt conveyor

V is belt speed frequency factor

If the frequency factor is 4.0 or over, the minimum top cover thickness can be considered based on the loading conditions. When the frequency factor is 0.2 then the top cover thickness should be increased to twice the minimum amount.

7.4.1 Loading conditions which would result in normal wear;

- material feed is in the same direction as the belt travel
- free fall of the material does not exceed 1.2 meters
- loading area of the belt is horizontal, or has a slope less than eight degrees
- chutes that are properly designed where the load would settle in the middle of the belt
- temperature range between -1°C to 65°C
- materials that are transported on belt are not corrosive.

7.4.2 Loading conditions which will result in minimum wear;

- during the loading of the material the material travel at the same speed as belt
- design of the loading area to reduce impact is good
- fines of material are placed on the belt first
- spoon chutes used in the transfer points

7.4.3 Loading conditions which will result in maximum wear;

- material load 90° to the belt direction
- material load exceeds 90° to the belt direction
- loading area has a slope which exceeds eight degrees
- free fall of the material exceeds 1.2 meters
- material has a negative velocity in the direction of belt travel

7.5 Belt carcass

The cover that protects the conveyor belt is called the carcass. The purpose of the carcass is to carry the load and is the key reinforcement for the resistance to tear, impact and for the mechanical fasteners retention. The belt carcass consists of one or more plies of woven fabric. In the application of high tension carcasses cabled steel cord are also employed.

7.6 Carcass Types

A different carcass depends on the type and the life expectancy of the belt. The introduction of high strength synthetic fibres has changed the conveyor industry and the way the system is designed. Multi-ply cotton carcass is still used today but the main stream has gone to multi-ply polyester and nylon belting.

During the early 1980's, straight warp carcass designs became available which introduced the concept of reduced ply thereby reducing the weight of conveyor belts. This design has high impact and tears resistance and the demand was high. Carcass design is listed in table 7.1 below that is used in belting reinforcements.

Name	Composition	Comments
Cotton	Cellulose(natural)	High moisture incorporation. Prone to mildew attack and loss of strength.
Glass	Glass	High strength, low elongation. Used in very high temperatures.
Kevlar	Aramid	Low elongation, high strength. Decay in high temperatures, does not melt
Nomex	Aramid	High strength, high elongation. Good high temperature properties
Nylon	Polyamide	High strength, high elongation. Good resistance to abrasion, fatigue and impact. Reasonable moisture absorption.
Polyester	Polyester	High strength, high elongation. Good abrasion and fatigue resistance.
Steel cord	Steel	Very high strength, very low elongation. Excellent heat resistance. Good fatigue and abrasion resistance.

Table 7.1: Carcass Designs

7.6.1 Textile reinforcements

The most commonly used materials for reinforced plies in conveyor belts are textile fabrics. These fabrics are also used for conveyor belt breaker plies. The fabric properties are directed by the yarn material, size and the fabric construction and weave. These heavy duty multi-ply belt fabrics are dip treated with Rescorcinol-Formaldeyde-Latex coating to provide adhesion with rubber products.

7.6.2 Non-woven fabric

This non-woven fabric is a mat of fibres that are bonded together chemically thus providing a flexible and strong belt.

7.6.3 Woven fabric

This is the most common and least complicated fabric pattern used for flat belts. In the construction, the warp and filling yarns cross each other. When the belt has two or more layers it is known as a multi ply belt.
Other common constructions include broken twill; basket and leno weave which has an open mesh and used as a breaker fabric.

Woven cord is used to hold the warp yarns in position and consist of very fine filling yarns. Solid woven makes use of interwoven multiple layers of warp and filling yarns. Straight warp fabrics hold basic tension bearing yarns which are straight. Mechanical fastener holding strength is applied through the binder warp yarns which are interwoven with the filling yarns.

7.6.4 Fibre content

The most commonly used belting fabrics known by their major fibre content are:-

- Cotton, (fabric with cotton in both warp and filling yarns).
- Cotton-Synthetic, (fabric with cotton warp yarns and synthetic filling yarns. Nylon and polyester are the most common used synthetics).
- Polyester, (fabric with polyester fibre warps yarns and filling yarns).
- Nylon, (fabric with nylon fibre warp and filling yarns).
- Polyester-Nylon, (fabric with polyester warp and nylon filling yarns).

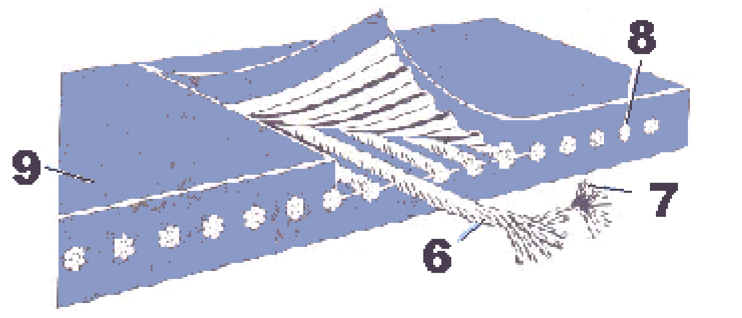
Solid woven fabrics are composed of spun and filament yarns. These spun yarns can be either cotton or synthetic or a combination of both. The filament yarns consist of nylon or polyester.

7.6.5 Steel reinforcements

Steel cord is used in belting where it is better able to satisfy the requirements of the service conditions. The steel cord supplies a high strength, superb length stability, minimum bending stresses and provides superior troughing characteristics. Wires used inside the conveyor belt are usually made of high carbon steel and have a surface finish which reduces corrosion during use.

7.7 Steel cord carcass

The steel cord conveyor belts are fabricated with a single layer of parallel, homogeneous tensioned steel cords that serves as a load bearing member inside the belt. These steel cords are imbedded in elastometric compound shown in figure 7.2.



Courtesy of Dunlop

Figure 7.2: Steel Cord Belt

This method is preferred for high tension fabric belts with heavy gauge fabrics and for belts with aramid cords.

Steel cord belting is made of two different types;

- gum compound structure with steel cords and elastometric compounds
- reinforced construction with one or more plies of rubberized fabric.

7.7.1 Other wire components

There are several other forms of wire used in belting for special purposes for rip resistance and transverse stiffness. Some of them are pierce tape, flat wire braid, tire tread wire and wire tire cord.

7.8 Belt splices

Conveyor belts are joined by two methods; vulcanized splices or mechanically fastened belts. Vulcanized fabric belt splicing is illustrated in figure 7.3.

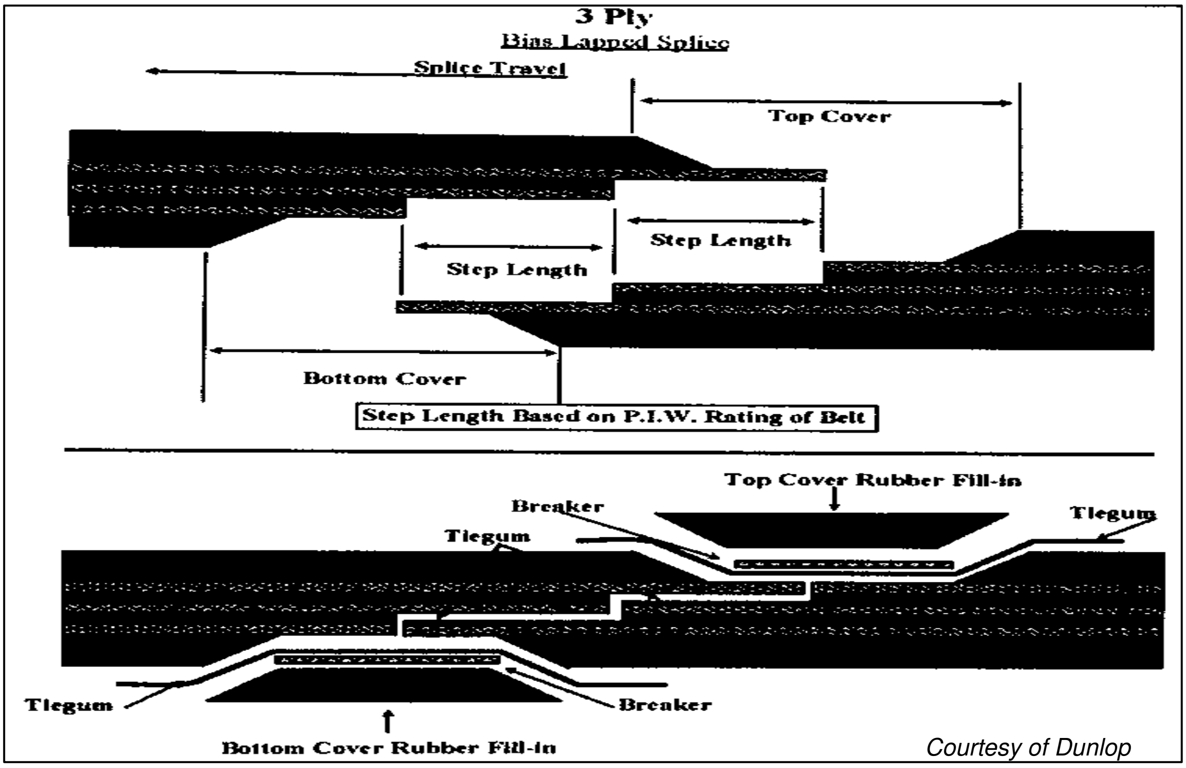


Figure 7.3: Belt splicing

Advantages of vulcanized splicing;

- strength
- a very long service life
- the splicing is clean, smooth and continuous.

Disadvantages of vulcanized splicing;

- more expensive than mechanically fastened belt
- longer travel take-up must be allowed for
- replacing a vulcanized belt is time consuming and costly
- process for splicing is quite complex

Advantages of mechanically fastened belts

- quick process to join a belt,
- cost is low,
- take up problems are minimum,
- great complexity.

Disadvantages of mechanically fastened belts

- moisture and cuts expose the belt carcass,
- rough surface where the belt joins,
- when used in high temperature, the fasteners retain the heat and transmit it directly to the belt,
- difficult to produce a mechanically fastened belt that can be leak-proof where fine materials are conveyed.

7.9 Belt and system concerns

7.9.1 Load support

Most bulk material carrying conveyors operate in a troughed configuration to prevent spillage over the edges. The angle of these troughed rolls will range from 20 degrees to 45 degrees.

When the belt conveys no material, it must have sufficient lateral flexibility to keep in contact with the centre of the troughed roll. If the belt does not have enough lateral flexibility it will drift from side to side and cause substantial edge damage.

Equally, when the belt has a full load, there must be enough lateral stiffness to support the load and bridge the gap between the centre and troughing rolls. If the belt has too much flexibility or the idler gap is too big this will lead to premature belt failure.

7.9.2 Transition distance

As the conveyor completes each cycle the belt edges are stretched and tension increases at the outer edges as the belt passes through the last troughing idler to the terminal pulley. The belt edge will be stretched permanently if the stress exceeds the elastic limit of the carcass. Spillage is likely to occur on the other hand if the troughing idlers are placed too far from the terminal pulleys. If the transition and geometry distances are not correct, the belt will buckle and cause belt damage. Two, three or more idlers can be used to support the belt between the last standard troughing idler and the terminal pulley. These idlers can be used at a fixed or variable angle.

The distance is important in the transition zone which is from the trough to flat form. Therefore it is recommended;

- to use metal rollers in the transition zone,
- start the loading of the belt after the first fully troughed idler,
- use the half trough transition arrangement displayed in figure 7.4.

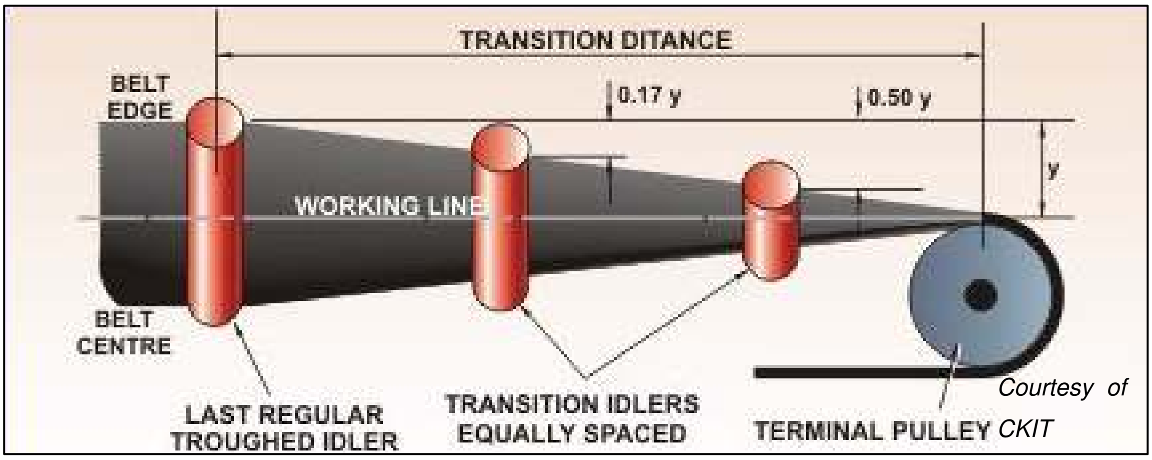


Figure 7.4: Transition Distance

7.10 Elongation

Elongation for multi ply belts at the normal tension for the complete belt should be less than four percent. At breaking tension the longitudinal elongation for the belt is usually bigger than ten percent.

7.11 Impact resistance

With the loading of bulk material onto a conveyor system the material creates an impact force on the belt. This arises from the effect when the material is dropped from a height above the belt surface, and the belt speed may be different from the velocity of the material.
A problem does not occur when the material consists of fines where the impacting is spread over a wide belt surface area. The carcass damage is minimal with the transporting of fine materials.

Major damage is caused by lumps of material that have sharp edges and fall over great distances. When these lumps fall onto the belt they tend to rupture the belt or, when an impact is directly over an idler, the carcass can be damaged.

To minimize this impact damage, careful design consideration should be looked at. The fines should fall onto the belt first followed by the lumps. The following equation can be used to calculate the equivalent free fall;

$$H_e = H_f + H_r(\sin^2 \Delta) \quad (7.1)$$

where H_e is the equivalent free fall [ft]

H_f is the total free fall [ft]

H_r is the vertical height on loading chute [ft]

7.12 Tension ratings

The tension rate of a belt can be described as the maximum safe working stress that should be applied to a belt. The belt tension is referred to as the force applied to the belt per unit of belt width, such as kilo-newtons per meter width. These belts or textile fabrics are frequently rated for their maximum safe working stress.

The important points to look at when assessing difference manufacturers are:

Quality of

- fibre, polyester and nylon used for the fabric
- safe working load
- ratio of belt braking strength.

Chapter 8 : Chutes

8.1 Introduction

The function of a transfer chute in the handling of materials is to regulate the flow of bulk material from a discharging conveyor onto a receiving conveyor. The main purpose of a transfer chute is to regulate the material so that it behaves in a controlled and predictable manner. Transfer chutes are transfer points in a materials handling plant. They often demand more attention and can be the source of more downtime than the conveyors that precede or follow them. Ideally the chutes are designed first, and then the plant equipment and structures are planned around them. The nature and characteristics of the equipment before and after the chute are clearly defined. A couple of important questions arise with regard to transfer chutes:

- what is the belt width,
- belt speed,
- loaded material profile,
- material trajectory,
- what is the height through which the material must fall,
- does the material have a single flow path, or
- are there alternative flow paths?

8.2 Principles of transfer chute design;

There are five basic designs for a transfer chute;

1. to guide material on to a conveyor belt, at the speed of the belt, in the direction of belt travel.
2. to eliminate material spillage.
3. to enclose material dribbles.
4. to enclose material from operating personnel.
5. to eliminate dust liberation.

8.3 Flow of Bulk Solids in Transfer Chute Design

Flow through a chute is a transient phenomenon mostly taking about one second. However, with a longer chute of some twenty metres the passage of the product could take two seconds.

Some of the main considerations are what happens to the material once it leaves the belt surface:

- a “small amount” of the fines float into the surrounding air stream.
- a “small amount” of the product sticks to the sides of the chute.
- a “small amount” of the product gets carried back on the return belt.
- a “small amount” of the product escapes from the chute and settles on the floor.
- at times product will block the chute and cause overflow.
- some of the fines end up in the head pulley and bearings.
- the balance of the product continues the journey to the next transfer point (figure 8.1).

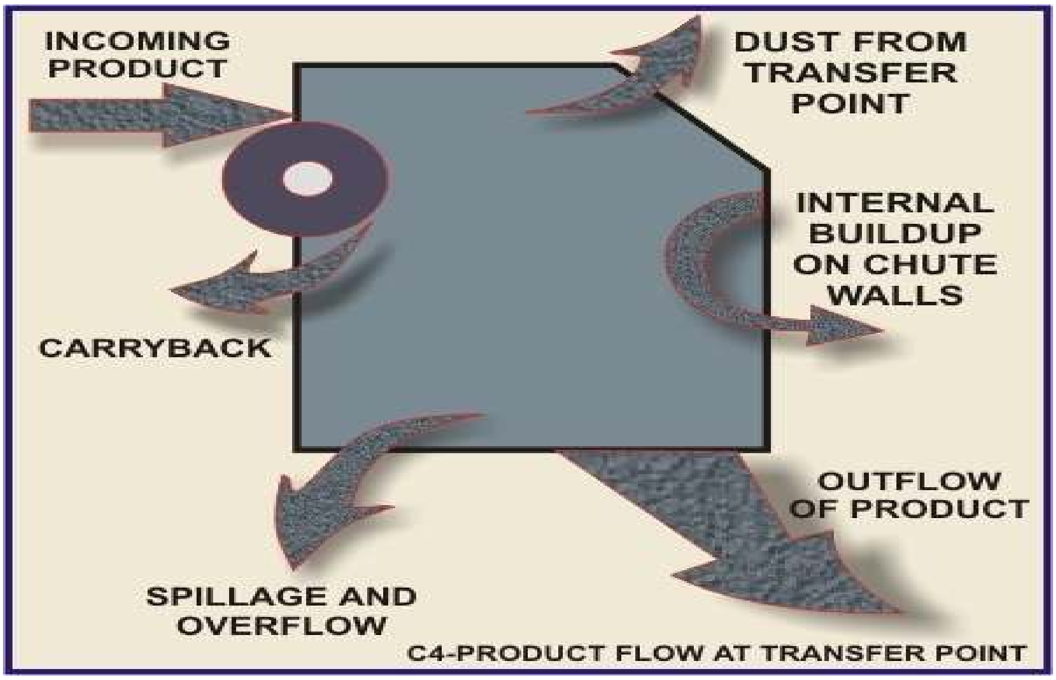


Figure 8.1: Material Flow in Chutes

The essential aim of good transfer chute design is to successfully transfer as much of the incoming product as possible from one point to the next transfer point.

8.4 The Primary Trajectory

The simplest process for discharge from a conveyor belt is to let the product pass over an end pulley and fall onto a pile, which is called the trajectory of the material. By adding a suitable transfer chute the discharge may be directed as desired- to a stockpile, a bin, or to another conveyor. A fork at the discharge chute will permit the product to flow simultaneously in two directions.

Whenever the belt is discharged over an end pulley, the speed of the belt, diameter of the end pulley and material properties are what determine the path of the discharged material. The shape displayed in the following figure 8.2 of the discharged product trajectory is important when designing chutes.

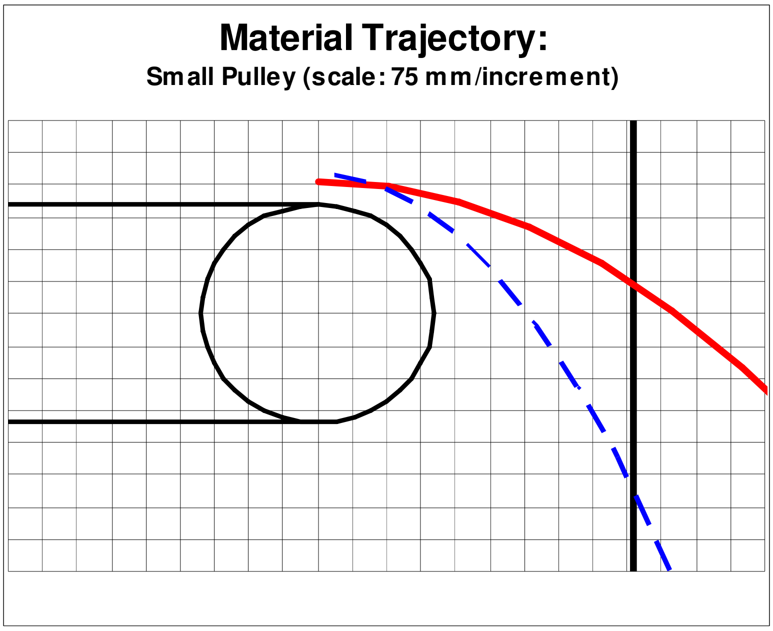


Figure 8.2: Material Trajectory

Chapter 9 : Conveyor blending solution/problem

9.1 Different systems solutions

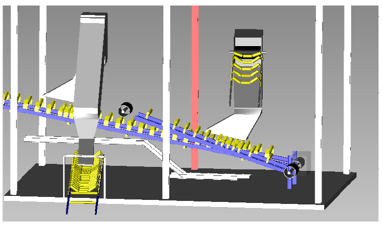
<table>
<tr><th>Different systems</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>V-Plough
</td><td>• Simple design
• Easy installation</td><td>• Belt wear
• Chutes complex
• Coal too heavy for removal</td></tr>
<tr><td>Change of belt
</td><td>• Simplicity of operation</td><td>• Will not fit into transfer tower
• Change of conveyor structure</td></tr>
<tr><td>Re-blending conveyor
</td><td>• Fit into transfer tower
• Automatic operation
• Minimum downtime for installation
• Reliable system</td><td>• Expensive system</td></tr>
</table>

Table 9.1: Different Solution

The above table 9.1 displays the different option for Millmerran power station. Shutting down the coal plant for long periods of time, when no power is being generated, is one of the major problems. As Millmerran is under private management a shut down would cause an enormous financial loss. The implemented system should have a minimum effect on the deliver of coal to the power station. This modification would also have to happen inside transfer tower number two. The transfer tower station has dimensions of 16 x 9.7 meters, which would place a constraint on the different design options for this project.

The first option was to install a V-plough onto the existing crusher feed conveyor, which would be easy to operate automatically. The disadvantage of this option was the wear that the V-plough could have on the crusher feed conveyor. This conveyor belt has a length of 136 metres and to replace would be costly. To place transfer chutes at the sides of the crusher feed conveyor and the automatically control of those chutes would be a considerable task.
The idlers at the bottom of the conveyor belt have to drop from 35 degrees to zero degrees and the amount of spillage has to be kept at a minimum.
The V-plough design and the automatic control the system would be a challenging and complicated task.

The second option was to turn the crusher feed conveyor 90 degrees clockwise while entering transfer tower number two. Over a distance of forty metres it would turn 90 degrees to dump the coal and return to normal. This system would be straightforward to control, although the biggest disadvantage would be the enormous distance required for this to occur.

The third option was to transfer the coal from the reclaim conveyor to the stacking conveyor within the transfer tower. With this design a new conveyor system would be parallel to the crusher feed conveyor and run at an incline where the coal is dumped into the chute through to the stacking conveyor. With this design there would be a minimum down time period for the coal plant. Any interruption caused by the construction process could happen over several days. This re-blending conveyor system would be control by a diverter gate valve which would be installed in the reclaim transfer chute. Two transfer chutes have to be modified where impact plates have to be installed to change the flow of coal (Appendix D).

9.2 Re-blending conveyor inside transfer tower

The re-blending conveyor would consist of the following components:

- Conveyor
- Idlers
- Transfer chute
- Diverter gate valve

The following section would give an insight into the design of a conveyor system.

9.3 Conveyor calculations

Conveyor calculations can be divided into five main categories:- slippage, impact forces, belt tension, and transfer points.

9.3.1 Effect of the incline on belt

With an incline conveyor belt, gravity dictates that the actual cross section of the material load is to be measured in a vertical load. To retain the total width of the coal load on the conveyor belt the cross section of the section must be less than that of the horizontal belt. Some precautions need to be taken with inclined conveyor belts. Lumps tend to roll off the edge more than horizontal belts. In the case of constant slope conveyor belts, spillage of material is more likely to occur after the point of loading.

The critical correlation between the belt velocity, material conveyed, and the conveyor belt set-up must be retained to avoid spillage and slip-back of the material on inclined conveyor belts. Therefore, the following two equations (9.1 and 9.2) for the maximum belt velocities that can be reached before material slip or spillage occurs on inclined conveyor belts are given by maximum belt speed before material slippage occurs;

$$Vslip - \max = 60\, x \sqrt{\frac{Si}{2\, x\, \pi\, x\, \Delta Ys}\, x\, (g\, x\, (\cos(\theta_{belt}) - \frac{1}{\mu_e}(\theta_{belt})) + \frac{\sigma_0}{\rho\, x\, h})} \qquad (9.1)$$

where $Vslip - \max$ is the maximum belt speed [fpm];

Si is the idler spacing [ft];

ΔYs is the belt sag [ft];

g is the acceleration [ft/ s^2];

θ_{belt} is the belt angle [degrees];

μ_e is the friction between belt and material

σ_0 is the adhesive stress between belt and material

ρ is the density [lbf/ ft^3];

$$h = (b_{wmc} \bullet \sin(\beta) + \frac{(b_c + 2 \bullet \cos(\beta)) \tan(\Phi_s)}{6} (\frac{1}{2})$$

b_{wmc} is length of belt on wing roller in contact with material [ft];

b_c is length of belt on centre roller in contact with material [ft];

BW is belt width [ft];

β is idler wing roll inline [degrees];

Φ_s is surcharge angle of the bulk material [degrees].

and the maximum belt speed before material spillage occurs.

$$Vspill - \max = 60\, x \sqrt{\frac{Si}{2\, x\, \pi^2\, x\, \Delta Ys}(g\, x(\cos(\theta_{belt}) + \frac{\sigma_0}{\rho\, x\, h})} \quad (9.2)$$

Where Si is the idler spacing [ft];

ΔYs is the belt sag [ft];

g is the acceleration [ft/ s^2];

θ_{belt} is the belt angle [degrees];

μ_e is the friction between belt and material [-];

σ_0 is the adhesive stress between belt and material [-];

ρ is the density [lbf/ ft^3];

$$h = (b_{wmc} \bullet \sin(\beta) + \frac{(b_c + 2 \bullet \cos(\beta))\tan(\Phi_s)}{6}(\frac{1}{2})$$

b_{wmc} is length of belt on wing roller in contact with material [ft];

b_c is length of belt on centre roller in contact with material [ft];

BW is belt width [ft];

β is idler wing roll inline [degrees];

Φ_s is surcharge angle of the bulk material [degrees].

9.3.2 Idler selection

There are many circumstances that have an effect on idler life. Some of those considered in the selection procedure are;

- type of material conveyed
- idler load
- impact forces
- load on predicted bearing L_{10} life

- conveyor belt speed
- idler diameter
- maintenance conditions

Appendix D gives a detailed selection procedure for idler selection.

9.3.3 Impact forces

Impact forces are important at conveyor loading points when selecting idlers. Impact forces should be calculated whether the conveyed material contains large lumps or even when there are no lumps in the material.

When large lumps are conveyed in the material equations xxx should be used, if there are no lumps larger than 150 mm equation xx should be used.

$$F = W + (2\, x\, k\, x WH)^{\frac{1}{2}} \quad (9.3)$$

$$F = 0.1389\, x\, Q\, x\, H^{\frac{1}{2}} \quad (9.4)$$

Where F is the impact forces [lbf];

W is the weight of lump [lbf];

Q is the capacity [tph];

WH is the impact idler energy [lbf-ft];

k is the spring constant of idler [lbf/ft].

9.3.4 Tension and power

The effective tension (Te) is described by Conveyor Equipment Manufactures Association (CEMA) as the forces acting on the conveyor belt and contributing to the tension required to drive the belt at the driving pulley. The Te is produced by the following forces;

- The gravitational force used to lift the material on the belt
- Frictional resistance of the conveyor belt, drive, and all the equipment at operating conditions
- Frictional resistance of material
- Force required to accelerate the material as it is fed onto the belt by a chute

The formula used to calculate effective tension, Te, is;

$$T_e = L\,x\;K_t\,(K_x + K_y\;x\;W_b + 0.015W_b) + W_m\,(L\,x\,K_y + H) + T_p + T_{am} + T_{ac} \qquad (9.5)$$

Where L is the conveyor length [ft];

H is the vertical lift [ft];

Wb is the gravity load on belt [lbf/ft];

Wm is the load of bulk material on belt [lbf/ft];

Kx is the idler resistance factor [-];

Ky is the belt resistance factor [-];

Kt is the temperature correction factor [-];

Tp is the tension due to belt flexure [lbf];

Tam is the tension resulting from force due to acceleration [lbf];

Tac is the tension from accessories [lb/ft].

9.3.5 Shaft deflection

Shaft sizes are determined by using the Stress Limit and Deflection Limit. The Stress Limit is first used and then the Deflection Limit. Whichever gives the larger shaft size governs. The diameter of the shaft is then increased to the next standard shaft size. Equation 9.6 is used for the diameter of a pulley shaft loaded in bending and torsion;

$$D = \sqrt[3]{\frac{32\,x\,FS}{\pi}\sqrt{(\frac{M}{S_r})^2 + \frac{3}{4}x(\frac{T}{S_y})^2}} \qquad \textbf{(9.6)}$$

Where D is the shaft diameter [in];

FS is the factor safety [-];

Sf is the corrected shaft fatique limit $k_a k_b k_c k_d k_e k_f k_g \bullet S_{f^*}$ [-];

k_a is the surface factor [-];

k_b is the size factor [in];

k_c is the reliability factor [-];

k_d is the temperature factor [-];

k_e is the duty cycle [-];

k_f is the fatigue stress [-];

k_g is the miscellaneous factor [-];

S_{f^*} is the tabulated ultimate tensile strength [psi];

S_y is the yield strength [psi];

M is the bending moment [in-lbf];

T is the torsional moment [lbf].

The pulley assembly is a structural unit, while the strength of different components is treated independently. Pulley construction and shaft attachment components vary, therefore only pulley manufacturers can determine the actual interaction between components. The manufactures design pulleys for the particular demand of particular applications. The following formula 9.7 is used to determine the shaft size based on the deflection on a straight shaft,

$$\tan\theta = \frac{R\,x\,A\,x\,(B-2A)}{4E_y\,x\,I} \qquad (9.7)$$

Where R is the resultant pulley load [lbf];

A is the moment arm for the pulley [in];

B is the bearing centres [in];

Ey is the Young's modulus [psi];

I is the area of moment of inertia of the shaft [in^4].

9.3.6 Discharge trajectories

The path of the material as it leaves the conveyor belt is known as the trajectory. This curvature path is determined by the rotational velocity, radius of the pulley, force and gravity. The crucial design of transfer chutes depends on this trajectory path, and must be calculated as accurately as possible.

9.4 Chutes calculations

Many research papers have been written about chute design. Nowadays, most of the approach to chute design is by the use of software packages. In Australia, Professor Alan Roberts of TUNRA Bulk Solids Handling Division has done numerous studies and implementation on the design of transfer chutes. Today he is an expert consultant in materials handling and is renowned over the world for his work.

The following figure 9.1 displays a cross-sectional view of an inline transfer chute.

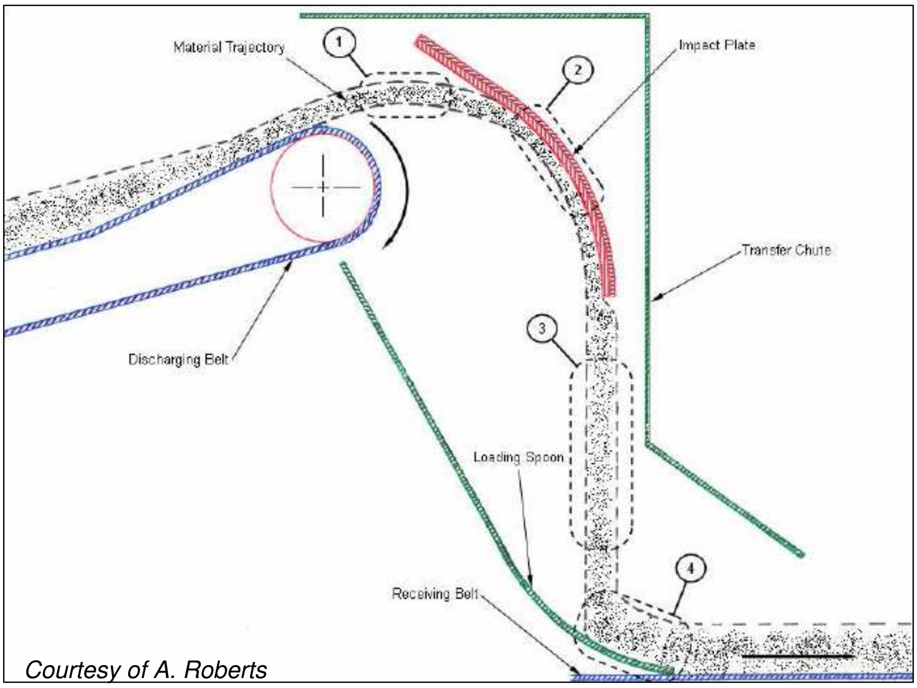


Figure9.1: Cross section view of Transfer Chute

The four main concerns in material transfer are;

1. Material discharge
2. Impact, flow down impact plate
3. Freefall of coal
4. Impact, flow down loading spoon

With this calculation the air resistance is neglect because of the low rate of flow. The four parts above will be investigated in the following section.

9.4.1 Material discharge

The following figure 9.2 displays a two dimensional illustration of a simple projectile motion. Take into account a single particle that moves on the outer edge of the stream of material flow.

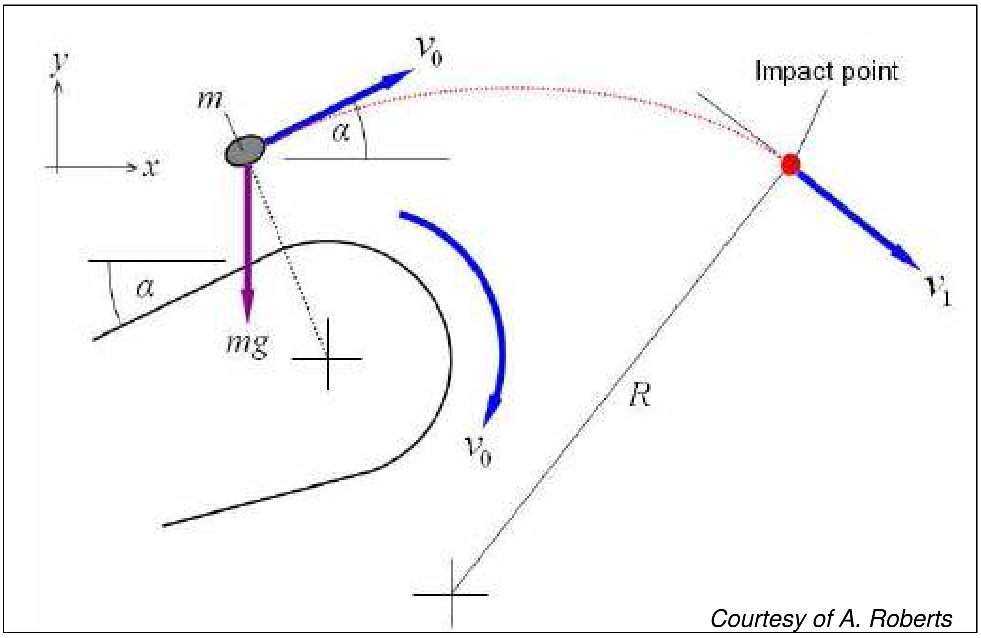


Figure 9.2 Material discharge

The important aspect is that the particle is assumed to travel at the same velocity v_o as the belt. By this assumption the radius of curvature of the impact plate can be calculated through the particle trajectory and the radius of curvature of this trajectory.

This trajectory can be calculated by equation 9.8. This particle is expressed by the vertical position as a function of the horizontal position.

$$y(x) = x \tan\alpha - \left(\frac{g x^2}{2 v_0^2 \cos^2 \alpha}\right) \qquad (9.8)$$

where x is the horizontal distance [m];

$\tan\alpha$ is the angle of conveyor [degrees];

g is the gravitational force [m/s^2];

$v_0^2 \cos^2 \alpha$ is the velocity of particle with angle [m/s, degrees].

The radius of curvature R(x) of the trajectory curve is determined by the following equation 9.9.

$$R(x)=\frac{v_0^2\cos^2\alpha}{g}[1+(\tan\alpha-\frac{g\,x}{v_0^2\cos^2\alpha})^2]^{1.5} \qquad (9.9)$$

where R is the radius of curvature [m];

x is the horizontal distance [m];

$\tan\alpha$ is the angle of conveyor [degrees];

g is the gravitational force [m/s^2];

$v_0^2\cos^2\alpha$ is the velocity of particle with angle [m/s, degrees];

9.4.2 Impact, flow down impact plate

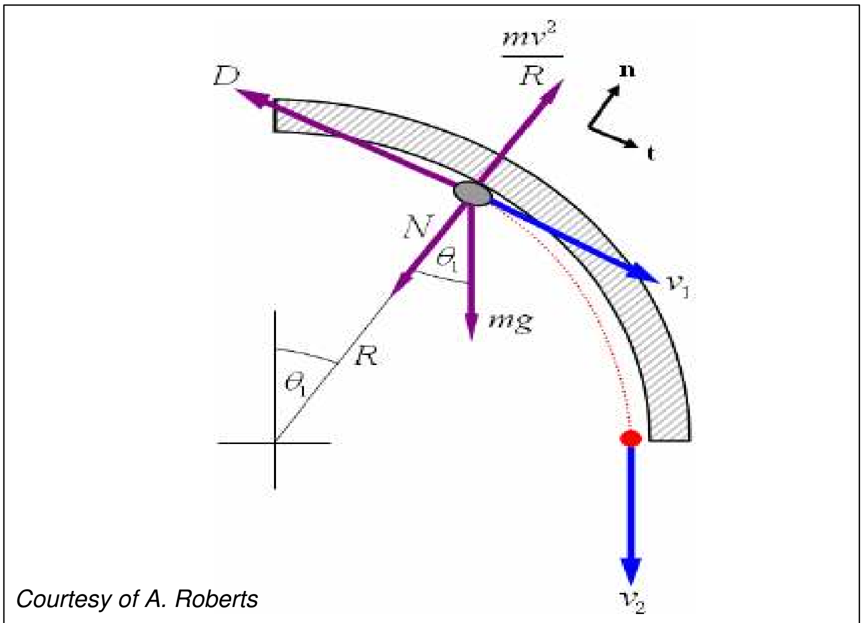


Figure 9.3 Impact along plate

The radius of curvature R is used to determine the radius of the impact plate for a smooth transition along the impact point. This implies that the radius of the impact plate matches up with the radius of curvature at the impact point. Therefore the material is actually guided into the impact plate. The velocity is given in the following equation 9.10.

$$v(\theta)=\sqrt{\frac{2\,g\,R}{4\mu^2+1}[3\,\mu\sin\theta+(2\mu^2-1)\cos\theta]+v_1^2-\frac{2\,g\,R}{4\mu^2+1}(3\mu\sin\theta_1+(2\mu^2-1)\cos\theta_1)} \quad (9.10)$$

Where g is the gravitational force [m/s^2];

R is the radius of curvature [m];

μ is the friction coefficient [-];

9.4.3 Freefall of coal

After the material particle leaves the impact plate it is for a certain time in freefall until it impacts with the loading spoon. The impact velocity v_3 is determined by equation 9.11.

$$h = \frac{v_3^2 - v_2^2}{2g} \qquad (9.11)$$

where h is the height [m];

v_3^2 is the impact velocity [m/s];

v_2^2 is the entry velocity [m/s];

g is the gravitational force [m/s^2].

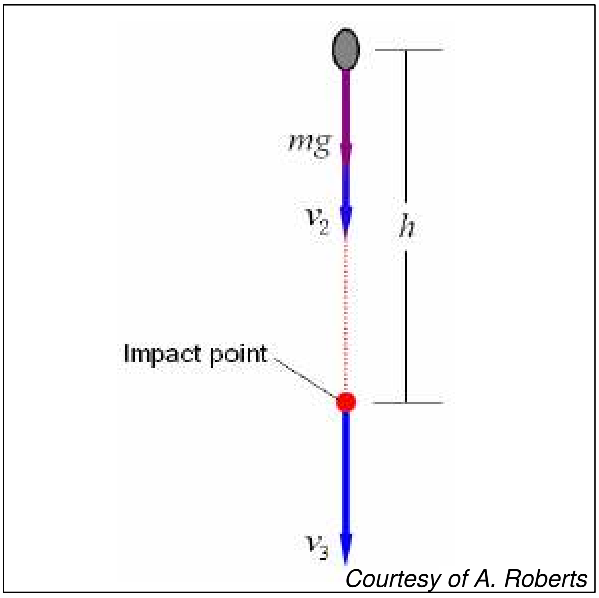


Figure 9.4 Freefall

9.4.4 Impact, flow down loading spoon

The radius of curvature R is used to determine the radius of the spoon plate. Therefore the material is actually guided into the spoon plate.

The velocity is given in the following equation 9.11.

$$v(\beta)=\sqrt{\frac{2gR}{4\mu^2+1}[3\mu\sin\beta+(1-2\mu^2)\cos\beta]+[v_5^2-2gR(\frac{1-2\mu^2}{4\mu^2+1})]e^{2\mu\beta}} \qquad (9.11)$$

Where g is the gravitational force [m/s^2];

R is the radius of curvature [m];

μ is the friction coefficient [-];

v_5^2 is the exit velocity [m/s].

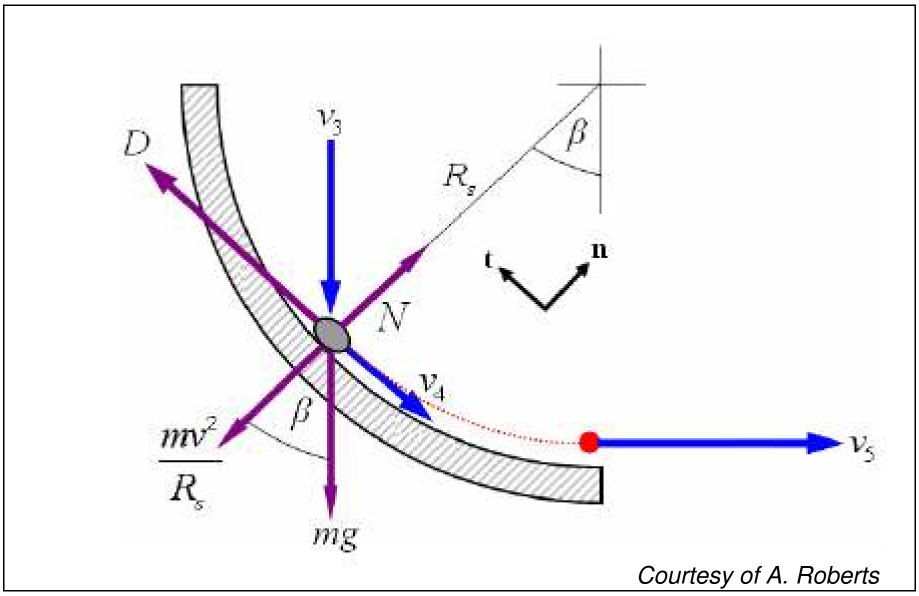


Figure 9.5 Flow along Spoon

9.5 Computer control system

A computer control system involves real time control by a microprocessor based system with an input section, a processing section and an output section.

There are different types of computer control systems which include the following:-

- programmable logic controllers (PLC),
- distributed control system (DCS),
- personal computers (PC), and
- single board custom microcontrollers (SBCM).

Throughout the industry, the PLC is the most common platform. Computer control provides a programming-logic working environment where individual changes and features may be set up to match each conveyor belt application. The computer control system is tough, dependable, cost effective, and flexible. The input sensors are the conveyor belt and equipment protection switches and transducers. Inputs are digitals or analogue signals. Digital inputs depend on two conditions, “on” or “off”, and are normally powered by a low level power source such as 120 VAC or 24 VDC.

Analogue transducers measure the physical property and convert the measurement to a linear electrical input range. Examples of analogue transducers inputs are bin levels, vibration and bearing temperatures. The most common analogue signals are 4 – 20 ma, 1 – 5 VDC, and 0 - 10 VDC.

The computer control system evaluates the inputs. It also applies the control logic, rules, and algorithms, and control the output section. The drawing of the control system for the diverter gate valve is displayed in Appendix J.

The output devices are the main elements controlled by the conveyor belt computer control system. The output can also be either digital or analogue, while the digital outputs are usually powered by low voltage AC or DC. Examples of digitals outputs are starters, solenoids and valves. Analogue output devices take an electrical signal and provide some physical action. Examples are valve positioners, feeder rate controls, belt speed control devices, and gate actuators.

9.6 Conclusion

This particular design is only suitable for Millmerran Power Station. The work that Professor Alan Roberts of TUNRA Bulk Solids Handling Division has done for the industry is enormous. From the author’s viewpoint, the above calculation for transfer chutes can be used as a point of reference and from there onwards the condition of the power station specific design needs to be taken into account and adjustments made.

At this stage of the project the cost analysis can only be an estimate. To implement this project would be significant, and the cost analysis can only be done via the tender process. Costing will not be undertaken in this project as the magnitude of this task is enormous.

Chapter 10 : Future Work

10.1 Commissioning, Testing and Maintenance

Three main sections exist after the completion of the construction phase;

1. Commissioning
2. Testing
3. Maintenance

The four stages of commissioning are the following:

1. Construction and engineering checks
2. Pre-commissioning
3. Process commissioning
4. Completion of commissioning and start of production

Stage 1: as each phase of construction is completed, the engineer is intended to confirm that the plant has been constructed according to the design and adheres to standards. Any faults found during the engineering checks shall either be corrected at the time or listed

Stage 2: this stage involves further engineering checks. Engineering errors found during this stage shall either be corrected at the time or recorded.

Stage 3: process materials are introduced into the plant for the first time. The responsibilities are the same as for stage 2, with the addition of the requirement for the commissioning manager to write procedures covering the new plant extension.

Stage 4: completion of commissioning and start of production

Maintenance, in general, affects all aspects of operational achievement and risks, not just system availability and cost. Maintenance has an influence on safety, operational efficiency, energy efficiency, product quality, and environmental reliability.

Managing conveyor life is a broad and important concern from the day a system is commissioned until the day it is retired from service.

Like maintenance for many other systems, the maintenance of conveyor systems is split into three broad categories:

1. predictive,
2. preventive, and
3. corrective.

The obvious advantage of predictive and preventive maintenance is that downtime surprises can be avoided, and when action needs to be taken, all of the parts, materials, and timing can be in order for operational ease.

Successful management of conveyor life begins with the choice of a system that matches the application for which it's being used. Different applications require relatively different system components and configurations, especially as they apply to load requirements, operational conditions, cycles-of-use, materials conveyed, operational speeds, and handling period.
Also, idlers with poor quality components in frame, seals, and bearings can quickly fail under load due to the intrusion of various types of contaminants, such as dust and moisture. This reduces not only the value received from the individual idler but, if undetected, a resulting bearing failure could cause a roll to seize, which cause belt damage. Pulleys that are not designed to standard for the loads they are carrying can deflect and cause premature failure, and the results can be costly.

Improperly designed impact areas can also result in belt and structural damage and system failure. An under-built structure can be a factor in misalignment, which, if left unresolved, can hassle an operation throughout its useful life.

10.2 Wear on Chute liners

The transfer chute should be lined on the flow surface with a good abrasive wear resistance material, so that the chute does not wear out. The type of liner used to protect the chute must be compatible with the bulk material used. The selection of the wear material is always a compromise between cost and ease of attachment to the chute walls. Table 10.1 below shows a range of wear materials currently used as chute linings. This table is from MHEA's "The Design of Transfer Chutes & Chute linings".

*Scale: - Poor * Good ** Very Good *** Excellent*						
Lining material	**Initial cost**	**Sliding resistance**	**Impact resistance**	**Temp. resistance**	**Low friction**	**Ease of fabrication**
Alumina tile	High	***	*	***	**	*
AR plate	Low	**	*	**	-	*
Carbon steel	Medium	**	*	**	-	***
Chromium Clad plate	High	***	***	**	-	*
Corrosion Stainless steel	Medium	*	*	**	**	*
High Cr cast iron tiles	High	***	***	**	**	**
Mild steel	Low	*	*	**	-	***
Polyurethane	High	**	***	-	-	***
Quarry tiles	Low	*	-	*	*	**
Rubber	High	*	***	-	-	**
Stainless steel	High	*	*	***	**	**
UHMW	Medium	*	-	-	***	***
Vitrified tiles	Low	**	-	**	**	***

Table 10.1: Wear on Chute liners

Wear in transfer chutes is a combination of abrasive and impact wear. Abrasive wear caused by the steam of continuous material and is caused by the normal pressure and rubbing velocity. The following equation 10.1 can be used to calculate the abrasive factor W_C.

$$W_C = \frac{Q_m K_C \tan\theta}{B} N_{WR} \qquad (10.1)$$

Where Q_m is the mass flow rate [kg/s]

K_C is the average stream velocity/ rubbing velocity [m/s]

$\tan\theta$ is the friction angle for bulk solid

B is the chute width

N_{WR} is the abrasive wear number [non dimensional]

Chapter 11 : Conclusion

The scope of work for this project has been achieved, as well as all the individual tasks.

A good grasp of Millmerran Power Station coal handling plant was achieved during the research into the operation of the coal handling plant.

During the review of the bulk material system the understanding of testing each individual material that can be used in the bulk handling system was achieved. Furthermore, the basics of conveyor design and belt selection was achieved in the review process.

During the review with transfer chutes the most important goal was to design without any software package or DEM that is available on the market. Although this was a tedious and time consuming task it was very interesting and rewarding.

Finally, a design was chosen that would fit into the Millmerran operating conditions. Overall a good framework for this project was achieved.

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APPENDIX A - Project Specification

Faculty of Engineering and Surveying

Courses ENG4111/4112 RESEARCH PROJECT Part 1 & 2

Project Specification 2007

Student:	Claudius Kleynhans
Student No.:	0050017480
Supervisor:	R. Fulcher
Sponsor:	Millmerran Power Station
Industry Advisor:	David Hunt, Engineering Manager.
Title:	Design and review of Millmerran coal plant
Aim:	Design of a conveyor system to transfer coal from the reclaim conveyor to the stacker conveyor
Issue:	A 19 March 2007

Objectives:

1. Define and describe current Millmerran Power Station coal handling system and the operation of the power station.
2. Review of bulk materials handling and the characteristics of bulk material.
3. Review of conveyor design and conveyor belts.
4. Review of chute design.
5. Propose a design to solve Millmerran Power Station problems including any control requirements.
6. Formally report the findings to the project sponsor.
7. Write a dissertation of the project work.

If time allows

8. Report on any implement solutions.

Student: Claudius Kleynhans **Signature**: ________________ **Date**: ____________

Supervisor: R Fulcher **Signature**: ________________ **Date**: ____________

APPENDIX B – Permission to use Rulmeca Program

Rulmeca Motorized Pulley Power Calculation Program - metric 5.37 Page 1 of

Kleynhans, Claude

From: Mike Gawinski [mgawinski@rulmecacorp.com]
Sent: Friday, 9 February 2007 11:39 PM
To: Kleynhans, Claude
Subject: FW: Rulmeca Motorized Pulley Power Calculation Program - metric 5.37

Dear Claude, I'd be delighted if you used our program in your project. As a Motorized Pulley "expert", I wrote the program in 1993 for the US market (in imperial units) and then in 2004 converted the input page and the output page to metric for th convenience of the rest of the world. If you need to make any programming changes the password is mjg. My wife and I had the pleasure of living in Australia in Mackay in 1973-74 when I served as Erection Advisor at the Hay Point coal loading facility during the Saraji Expansion. I wish you all of the best as you finish your degree. Please let me know if there is anyway I can help you (e.g. explaining an equation or assumptions in the program.)
Best regards,
Rulmeca Corporation
Mike Gawinski
President

From: Denis Zucchinelli [mailto:denis.zucchinelli@rulmeca.it]
Sent: Friday, February 09, 2007 2:53 AM
To: Mike Gawinski (E-mail)
Subject: I: Rulmeca Motorized Pulley Power Calculation Program - metric 5.37

-----Messaggio originale-----
Da: Kleynhans, Claude [mailto:CKleynha@INTERGEN.com]
Inviato: venerdì 9 febbraio 2007 1.11
A: rulmeca@rulmeca.it
Oggetto: Rulmeca Motorized Pulley Power Calculation Program - metric 5.37

Hi,

I am a mechanical engineering student studying in Australia at University of Southern Queensland.
I am busy with my final year project and would like to have Rulmeca's permission to use the software that is available on the website for conveyor belt calculations from the CEMA book.

Regards
Claude Kleynhans
ckleynha@intergen.com

APPENDIX C – Rulmeca Program

Rulmeca Motorized Pulley Power Calculation Program - Metric Version 5.37

Specifier Sheet and Recommendation Summary

Millmerran Power Station

08/15/07
Date

www.rulmecacorp.com
www.rulmeca.com
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Telephone | Telefax | e-mail

Go to Design Parameters

Re-Blending Conveyor
Project Name

Conveyor Reference

Go to Trajectory Sheet

Standard Loading Conditions:

Conveyor Length (m)	10
Tonnage Rate (metric tons/hour)	700
Belt Speed (m/s)	5.2
Material Lift Height (m)	
Ambient temperature (°C) Min	-10
Ambient temperature (°C) Max	40
Initial Velocity of Material (m/s)	
Number of Belt Cleaners	1
Number of Return Belt Scrapers	1
Length of Skirt Zone (m)	1.5
Depth of Mat'l in skirt zone (mm)	25
Number of Non-driven Pulleys	1
Elevation Above Sea Level	1.0 Km
Material, fric coeff	Coal, bitum. mined, 0.075
Belt Width	900 mm
Belt Carcass Type	Fabric
Idler Roll diameter	159 mm
CEMA Type	C
Troughing Idler Spacing	1.2 meters
Angle of Wrap**	420 degrees (dual)
Type of Lagging	Full Lagging
Type of Take-up	Manual
Type of Belt	3 ply, 330 piw
Bulk Density (Kg/m³)	Coal, bituminous, 880
Condition of Idlers & Pulleys	well maintained

** This parameter is for either single or dual drive arrangement.

REQUIRED POWER: 17.3 kW

BELT PULL SUMMARY:	Force (N)
Standard Loading Belt Pull	3,016
Extra pull for Hopper (if any)	
Extra pull for Slider Bed (if any)	
Extra pull for Diverter or Tripper (if any)	
TOTAL Required Belt Pull (Te):	3,016

RECOMMENDED OPTIONS:

SPECIAL NOTES (if any):

Go to Design Parameters

RECOMMENDED "SINGLE DRIVE" MOTORIZED PULLEY:

Power: 18.5 kW		Models Available:
Belt Speed: 4.5 m/s		Not Available at this speed.
Face Width: 950 mm		

RECOMMENDED "DUAL DRIVE" MOTORIZED PULLEY:

Power: 11 kW/ea		Models Available:
Belt Speed: 4.5 m/s		Not Available at this speed.
Face Width: 950 mm		

Power savings - 1 shift and 3 shift per day:

(Motorized Pulley compared to exposed conveyor belt drives)

Save: 3965 Kw-Hrs/Yr, 1 shift/day or 11894 Kw-Hrs/Yr, 3 shifts/day

Save: 345 €/Yr, 1 shift/day or 1035 €/Yr, 3 shifts/day @ 0.087 €/Kw-Hr

Minimum Acceptable Diameter is 355 mm

*A smaller pulley diameter may cause belt carcass or fastener damage.
This calculation does not check pulley/belt traction.

Rulmeca Motorized Pulley Power Calculation Program - Metric Version 5.37
Model Selector

Millmerran Power Station

08/15/07
Date

www.rulmecacorp.com
www.rulmeca.com

Telephone | Telefax | e-mail

Re-Blending Conveyor
Project Name

Conveyor Reference

REQUIRED POWER: 17.3 kW

Select Model

630M

BELT PULL SUMMARY:	Force (N)
Standard Loading Belt Pull	3,016
Extra pull for Hopper (if any)	
Extra pull for Slider Bed (if any)	
Extra pull for Diverter or Tripper (if any)	
TOTAL Required Belt Pull (Te):	3,016

Check Radial Load (to prevent internal damage to pulley)	Force (N)
Maximum Allowable Radial Load	46,000
Estimated Maximum Radial Load	4,825

Selected model is appropriate for estimated radial load.

RECOMMENDED OPTIONS (if any):

Check Pulley Diameter (to prevent belt damage.)
Minimum Acceptable Diameter is 355 mm
Selected Diameter is 630 mm
Selected diameter is appropriate for specified belt.
(This calculation does not check pulley/belt traction.)

SPECIAL NOTES (if any):

Check Belt Tension	Force (N)
Maximum Belt Tension (T1)	3,920
Allowable Belt Tension	52,384

Go to Design Parameters

RECOMMENDED "SINGLE DRIVE" MOTORIZED PULLEY:

Power:	18.5 kW	Models Available:
Belt Speed:	4.5 m/s	Not Available at this speed.
Face Width:	950 mm	

RECOMMENDED "DUAL DRIVE" MOTORIZED PULLEY:

Power:	11 kW/ea	Models Available:
Belt Speed:	4.5 m/s	Not Available at this speed.
Face Width:	950 mm	

Rulmeca Motorized Pulley Power Calculation Program - Metric Version 5.37
Design Parameter Summary

Millmerran Power Station	08/15/07 Date		
Telephone	Telefax	e-mail	
Re-Blending Conveyor Project Name		Conveyor Reference	

Power Calculation Summary

Return to Specifier Sheet

Calculated power to drive conveyor belt:	15.7 kW
Drive pulley bearing friction:	0.5 kW
Power at motor:	16.2 kW
Gear loss in motorized pulley:	1.0 kW
Calculated power	17.2 kW
Derate for high elevation	kW
Derate for high temperature	kW
Required Power for motorized pulley:	17.2 kW

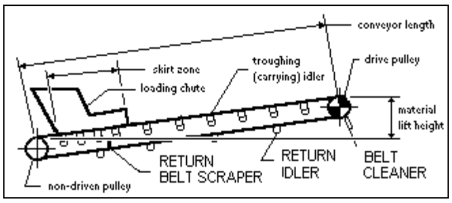
Return to Specifier Sheet

Symbol	Value	Definition of Terms
Te	3016 N	Te = effective belt tension at drive.
ang	420 degrees	ang = angle of belt wrap around drive pulley(s).
Cw	0.3	
T2	905 N	T2 = estimated "slack-side tension" required to keep belt from slipping on pulley surface.
T1	3920 N	T1 = Te + T2
T1 + T2	4825 N	T1 + T2 = Sum of belt forces on drive pulley. NOTE: This is not a vector sum.
T_L	Full Lagging	T_L = type of lagging specified for drive pulley(s).
Tatype	Manual	Tatype = type of take-up specified to apply "slack-side tension".
Beltype	3 ply	Beltype = type of belt carsass specified.
w	900 mm	w = belt width
str	11693 N	str = tensile strength of specified belt.
pstr	8 %	pstr = percentage of available belt tensile strength used.
btr	8 to 14 mm	btr = thickness range of specified belt
Ai	6.672 N	Ai = belt tension required to overcome frictional resistance and rotate idlers.
Cs	0.0754	Cs = skirtboard friction factor.
H	0 m	H = vertical distance that material is lifted or lowered.
Kt	1.06	Kt = ambient temperature correction factor.
Kx	0.6kg/m	Kx = factor to calculate frictional resistance of the idlers and the sliding resistance between belt and idler rolls.
Ky	0.03	Ky = factor to calculate resistance of belt and resistance of load to flexure as they move over idlers.
L	10 m	L = length of conveyor.
Q	700 mtph	Q = tons per hour conveyed. Return to Specifier Sheet
Si	1.2 m	Si = troughing idler spacing.
Tac	1709 N	Tac = total of the tensions from conveyor accessories.
Tam	1010 N	Tam = tension required to accelerate the material continuously as it is fed onto belt.
Tb	0 N	Tb = tension required to lift or lower the belt.
Tbc	788 N	Tbc = tension required to overcome belt cleaner drag.
Te	3016 N	Te = effective belt tension at drive.
Tm	0 N	Tm = tension required to lift or lower conveyed material.
Tp	86 N	Tp = tension required to overcome resistance of belt to flexure around pulleys and resistance of pulleys to rotate on their bearings.
Tpl	788 N	Tpl = tension required to overcome belt plow drag.
Tsb	133 N	Tsb = tension required to overcome skirtboard drag.
Ttr	0 N	Ttr = tension required to overcome special loading condition(s.)
Tx	62 N	Tx = tension required to overcome carrying and return idler friction.
Tyb	45 N	Tyb = total of tensions due to resistance of belt to flexure as it rides over carrying and return idlers.
Tyc	29 N	Tyc = tension due to resistance of belt to flexure as it rides over carrying idlers.
Tym	103 N	Tym = tension due to resistance of material to flexure as it rides over carrying idlers.
Tyr	16 N	Tyr = tension due to resistance of belt to flexure as it rides over return idlers.
V	5 m/s	V = design belt speed.
Wb	10 kg/m	Wb = weight of belt per unit of length of conveyor. Return to Specifier Sheet
Wm	37 kg/m	Wm = weight of material per unit of length of conveyor.

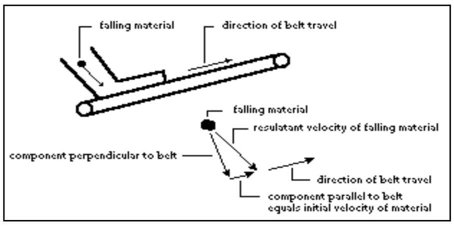
Rulmeca Motorized Pulley Power Calculation Program - Metric Version 5.37

Bulk Handling Belt Conveyor Terminology

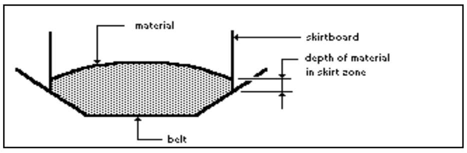
www.rulmecacorp.com   Return to Specifier Sheet   www.rulmeca.com



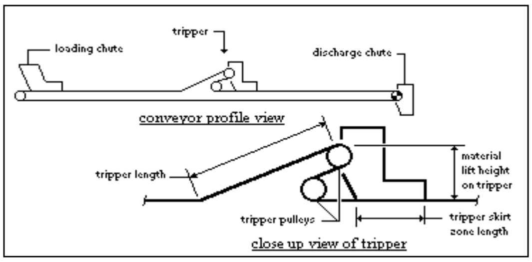
Conveyor Profile   Return to Specifier



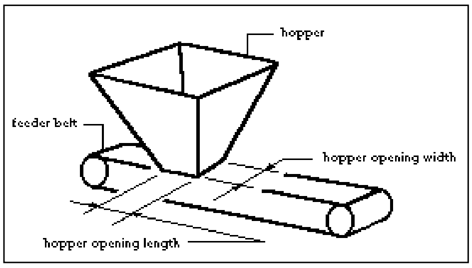
Initial Velocity of Material   Return to Specifier



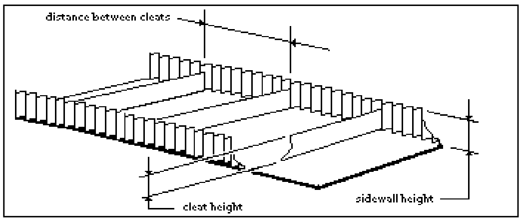
Conveyor Cross Section in Skirt Zone   Return to Specifier



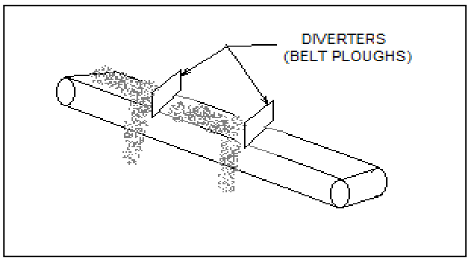
Belt Conveyor with Tripper   Return to Specifier



Hopper Feeder Conveyor   Return to Specifier



Cleated Belt with Sidewalls   Return to Specifier



Belt Conveyor with Two Diverter(s)

"CEMA" Idler Type Definitions

Return to Specifier

(Based on Conveyor Equipment Manufacurters Association Manual)

Belt Width	Idler Load Ratings* (kg)														
Idler Type >	A			B			C			D			E		
Idler (deg) >	20	35	45	20	35	45	20	35	45	20	35	45	20	35	45
460	136	136	136	186	186	186	408	408	408	-	-	-	-	-	-
610	136	136	131	186	186	186	408	408	408	544	544	544	816	816	816
760	136	127	122	186	186	186	408	408	408	544	544	544	816	816	816
915	125	116	112	186	186	180	408	380	367	544	544	544	816	816	816
1070	-	-	-	177	165	159	386	359	347	544	544	544	816	816	816
1220	-	-	-	172	160	155	363	337	327	544	544	544	816	816	816
1370	-	-	-	-	-	-	340	317	306	544	506	490	816	816	816
1525	-	-	-	-	-	-	318	295	286	522	485	469	816	816	816
1830	-	-	-	-	-	-	-	-	-	476	443	429	816	816	816
2130	-	-	-	-	-	-	-	-	-	-	-	-	816	759	735
2440	-	-	-	-	-	-	-	-	-	-	-	-	794	738	714

*These ratings are for three-equal-roll idlers and are based on a 30,000 hour minimum BU bearing life at 500 RPM. BU bearing life represents the statistical point in hours where a minimum of 90% of the bearings will still be functional with no increase in torque or noise.

Return to Specifier
Return to Trajectory Sheet

Material Surcharge Angle Guide

(Based on Conveyor Equipment Manufacurters Association Manual)

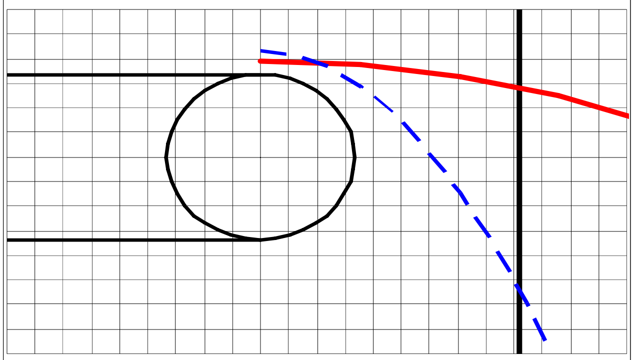
Surcharge Angle	Angle of Repose	Description of Material
5	0 to 19	Uniform size, very small rounded particles, either very wet or very dry; such as dry silica sand, cement, and wet concrete.
10	20 to 29	Rounded, dry polished particles, of medium weight, such as whole grain and beans.
20	30 to 34	Irregular, granular or lumpy materials of medium weight, such as anthracite coal, cottonseed meal, and clay.
25	35 to 39	Typical common materials such as bituminous coal, stone, and most ores.
30	40+	Irregular, stringy, fibrous, interlocking material, such as wood chips, bagasse, and tempered foundry sand.

Project Name	Re-Blending Conveyor	Return to Specifier
Conveyor Ref.		

System Design Parameters:

Belt Width	900 mm
Troughing Idler Angle	35°
Diameter Pulley (mm)	500
Lagging Thickness (MM)	5
Belt Speed	4.59 m/s
Surcharge Angle (degrees)	25
Tonnage Rate (MTPH)	700
Material Density (Kg/m³)	880
Belt Thickness (mm)	8
Distance to Chute Plate (mm)	700
Angle of Conv. Inclination (deg)	
Alternate Belt Speed (m/s)	1.4

Material Trajectory:
Small Pulley (scale: 75 mm/increment)



Design Trajectory - solid red line; Alternate speed - dotted blue.

Print This Sheet

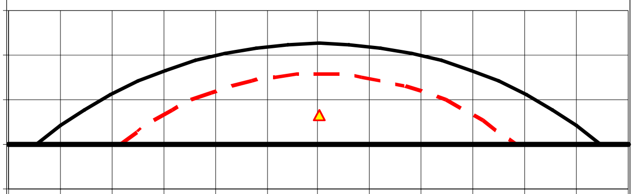
Go to Large Pulley Sheet

Go to Overview Sheet

Calculated Results:

Calc'd mat'l height at centerline	120 mm
Calc'd actual height of C.O.G.*	49 mm
Calc'd actual mat'l cross section	4.8 sq m
CEMA Max Allow. height at center	168 mm
CEMA Max Height of C.O.G.*	69 mm
CEMA Max Allow. cross section	9.8 sq m

Mat'l Cross Section at Pulley Face:
Small Pulley (scale: 75 mm/increment)

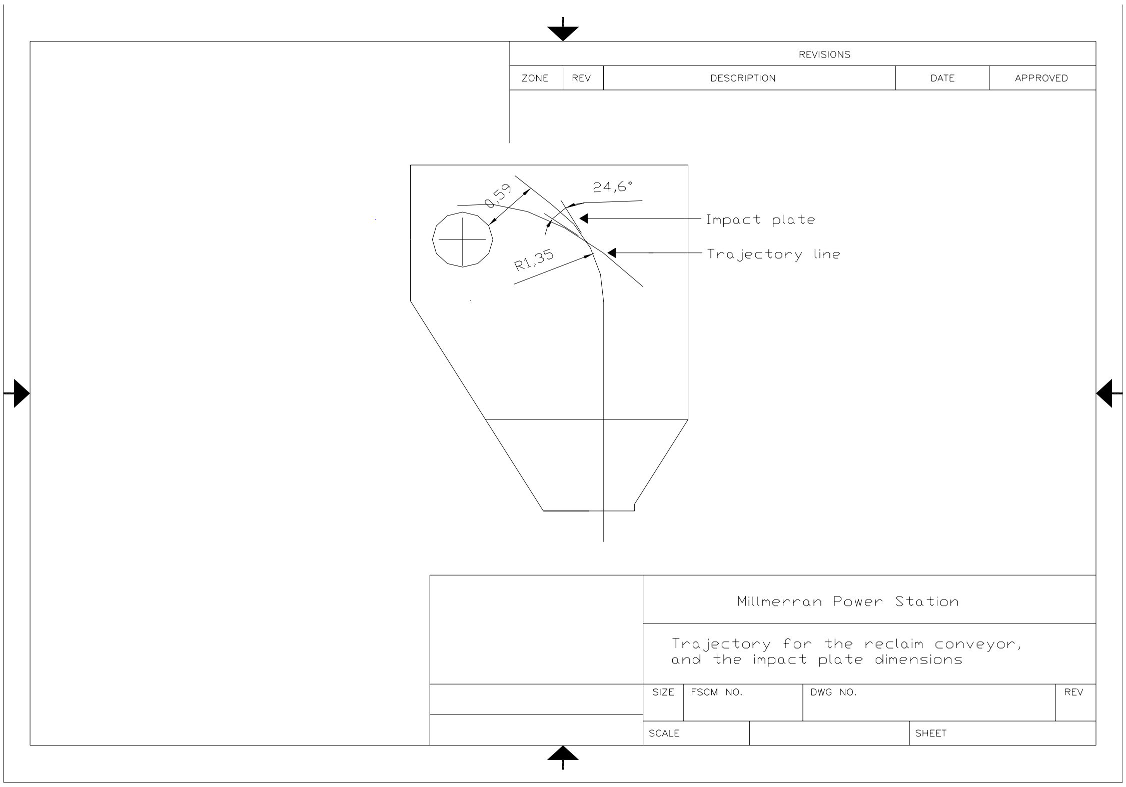


Note:
This program uses actual C.O.G.* height above top of belt (based on actual cross section) to plot trajectory. Height of C.O.G. for CEMA max. allow. cross section is given for ref. only.

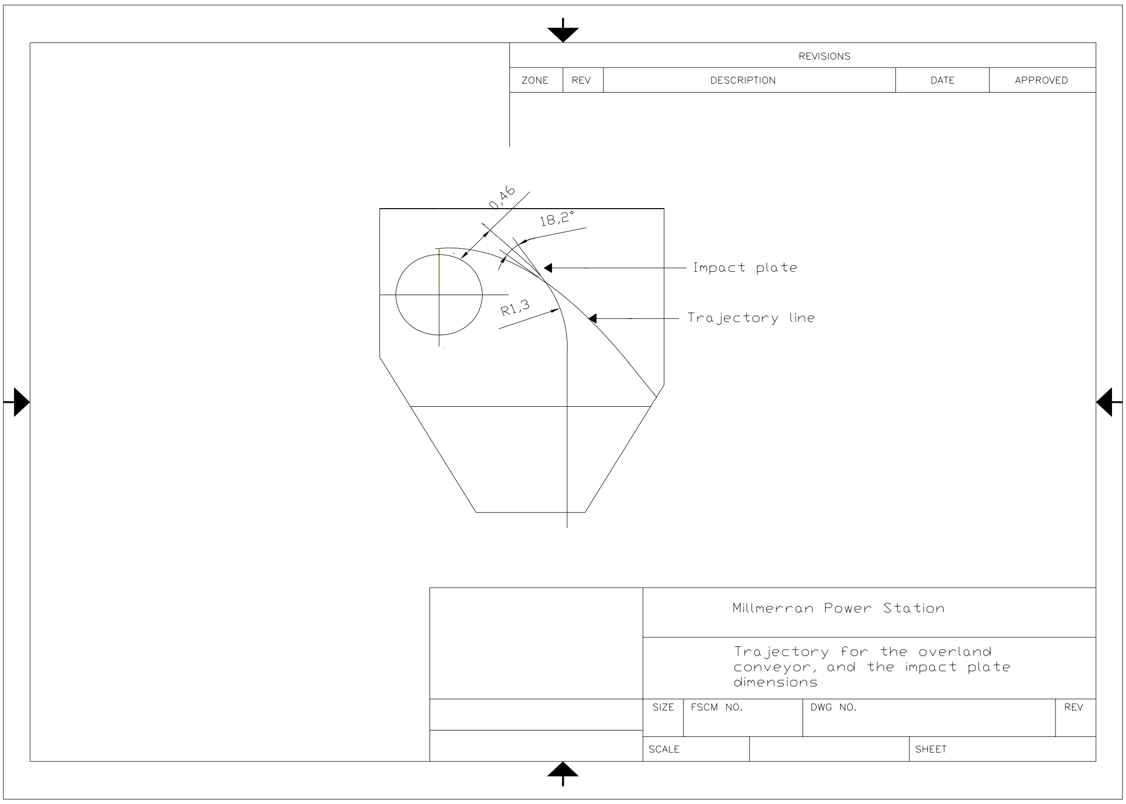
Design Cross Section - dotted red line; CEMA max allow. - solid bla

*C.O.G. = center of gravity of material, shown as △ and △

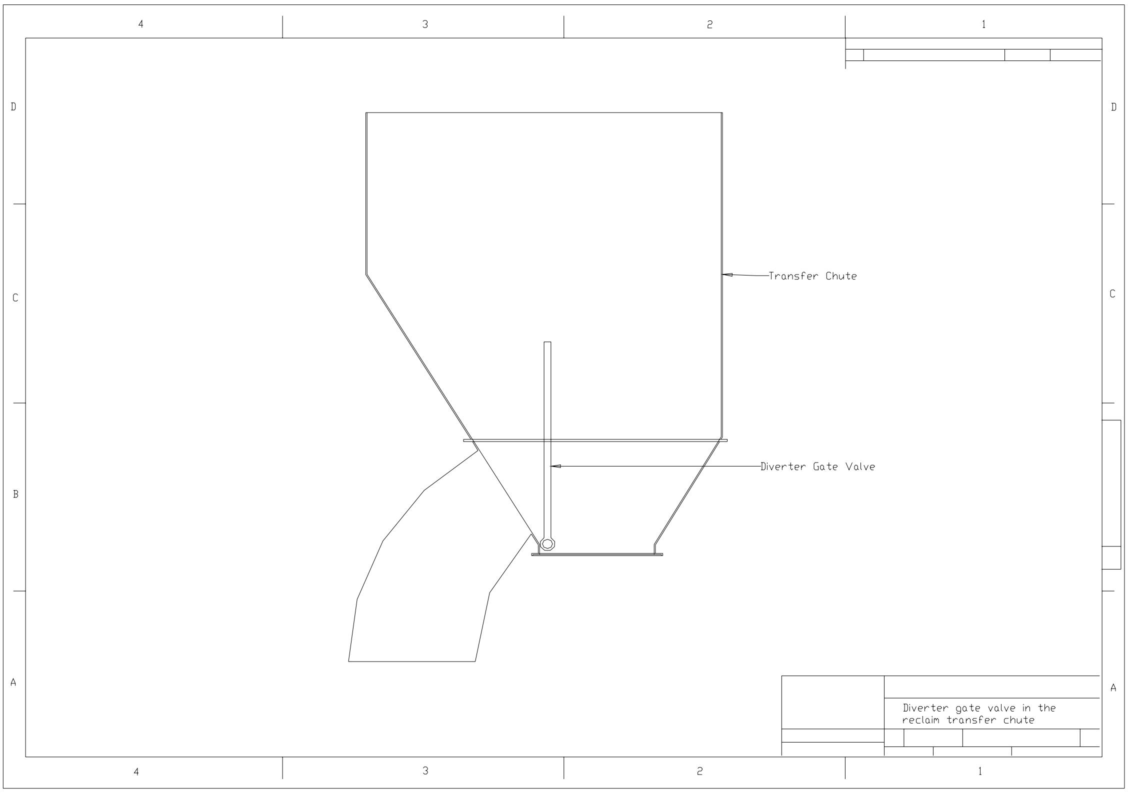
APPENDIX D – Impact Plate Design, Diverter Gate Valve



Drawing D.1- Reclaim Chute



Drawing D.2 – Overland Chute



Drawing D.3 – Diverter Gate Valve

APPENDIX E – Conversion Factor to SI-units

To convert from:	To:	Multiply by:
inches (in)	millimeters (mm)	25.40
feet (ft)	meters (m)	.3048
mass (lbs)	kilograms (kg)	.4536
pound-force (lbf)	newton (N)	4.4482
velocity (fpm)	meters per sec (m/s)	.0051
mass per length (lbs/ft)	kilograms per meter (kg/m)	1.4882
pounds per cubic foot (lbs/ft^3)	kilograms per cubic meter (kg/m^3)	16.0185

APPENDIX F – Idler selection

Selection procedure for idler;

- Steps 1, 2 and 3: Calculate idler load with the load ratings from Tables E3 - Table E7. Select idler class.
- Steps 4, 5 and 6: Bearing L_{10} life correction
- Step 7: Determine idler life

Step 1 - Calculate idler load

CIL = ((WB + (WM x K1)) x SI) + IML

Where WB = belt weight, estimate from table E.1

WM = material weight = (Q x 2000)/ (60 x V)

Q = quantity of material conveyed

V = design belt velocity

SI = spacing of idlers

K1 = lump factor from table E.2.

IML = idler misalignment load due to higher difference and belt tension = (D x T) / (6 x SI)

where D = misalignment

T = belt tension

SI = idler spacing

Belt Width (inches (b))	Material Carried, lbs./cu. ft.		
	30-74	75-129	130-200
18	3.5	4	4.5
24	4.5	5.5	6
30	6	7	8
36	9	10	12
42	11	12	14
48	14	15	17
54	16	17	19
60	18	20	22
72	21	24	26
84	25	30	33
96	30	35	38

Table E.1

Maximum Lump Size (inches)	Material Weight, lbs./cu. ft.						
	50	75	100	125	150	175	200
4	1.0	1.0	1.0	1.0	1.1	1.1	1.1
6	1.0	1.0	1.0	1.1	1.1	1.1	1.1
8	1.0	1.0	1.1	1.1	1.2	1.2	1.2
10	1.0	1.1	1.1	1.1	1.2	1.2	1.2
12	1.0	1.1	1.1	1.2	1.2	1.2	1.3
14	1.1	1.1	1.1	1.2	1.2	1.3	1.3
16	1.1	1.1	1.2	1.2	1.3	1.3	1.3
18	1.1	1.1	1.2	1.2	1.3	1.3	1.4

Table E.2

When the idler is higher than the next idler, belt tension will add load to that idler displayed in figure E.3. The sum of height variation can vary with installation and idler type.

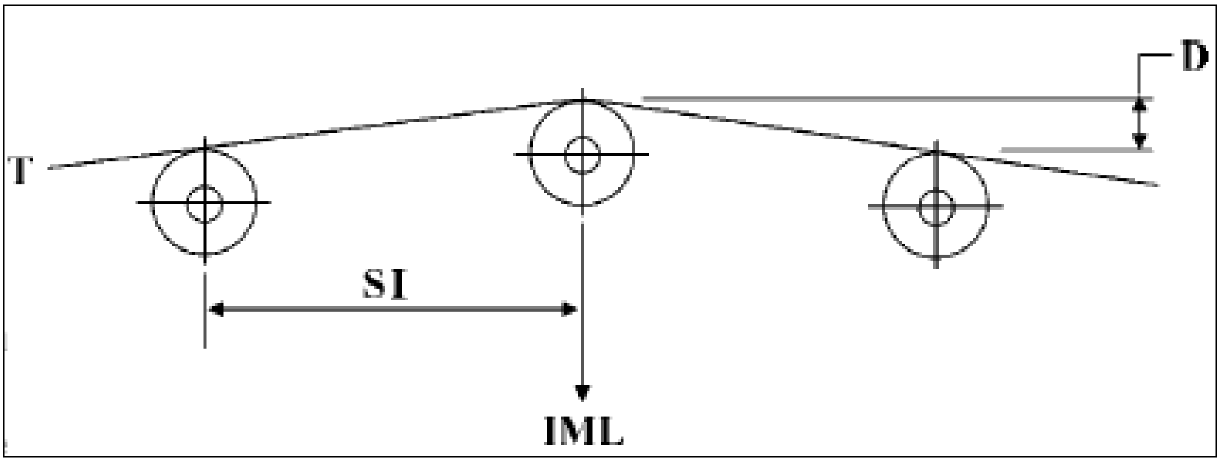


Figure E.3

Use CIL and choose the appropriate series of idler from Table E.3.

Load Ratings for CEMA Idlers - Rigid Frame							
Idler Class	Belt Width (inches)	Trough Angle			Single Roll Return	Two Roll Vee	
		20	35	45			
CEMA B Idlers	18	410	410	410	220		Table E.3
	24	410	410	410	190		
	30	410	410	410	165		
	36	410	410	396	155		
	42	390	363	351	140		
	48	390	353	342	125		
	Ratings based on Minimun of L10 of 30 000 hours @ 500rpm						
CEMA C Idlers	18	900	900	900	475		Table E.4
	24	900	900	900	325		
	30	900	900	900	250	500	
	36	900	837	810	200	500	
	42	850	791	765	150	500	
	48	800	744	720	125	500	
	54	750	698	675	*	500	
	60	700	650	630	*	500	
	66				*	500	
	Ratings based on Minimun of L10 of 30 000 hours @ 500rpm *Use CEMA "D" Return Idler						
CEMA D Idlers	24	1200	1200	1200	600		Table E.5
	30	1200	1200	1200	600		
	36	1200	1200	1200	600	850	
	42	1200	1200	1200	500	850	
	48	1200	1200	1200	425	850	
	54	1200	1116	1080	375	850	
	60	1150	1070	1035	280	850	
	66				215	850	
	72	1150	977	945	155	850	
	78				125	850	
	Ratings based on Minimun of L10 of 60 000 hours @ 500rpm						
CEMA F Idlers	36	1800	1800	1800	1000	1300	Table E.6
	42	1800	1800	1800	1000	1300	
	48	1800	1800	1800	1000	1300	
	54	1800	1800	1800	925	1300	
	60	1800	1800	1800	850	1300	
	66				775	1300	
	72	1800	1800	1800	700	1300	
	78				625	1300	
	84	1674	1674	1620	550	1300	
	90				475	1300	
	96	1750	1628	1575	400	1300	
	102				250	1300	
	Ratings based on Minimun of L10 of 60 000 hours @ 500rpm						
CEMA F Idlers	60		3000	3000	1500	**	Table E.7
	72		3000	3000	1200	**	
	84		3000	3000	900	**	
	96		3000	2800	600	**	
	Ratings based on Minimun of L10 of 60 000 hours @ 500rpm ** Vee returns consider using CEMA "E" Idler						

Table E.3

Step 2 – Return idler selection

Calculate idler load = CIL_R = (WB x SI) + IML

Use the CIL_R value to select the idler series from the following table E.4. The CIL_R value should be equal or less than the return idler rating.

Load Ratings for CEMA Idlers - Rigid Frame							
Idler Class	Belt Width (inches)	Trough Angle			Single Roll Return	Two Roll Vee	
		20	35	45			
CEMA B Idlers	18	410	410	410	220		Table E.3
	24	410	410	410	190		
	30	410	410	410	165		
	36	410	410	396	155		
	42	390	363	351	140		
	48	390	353	342	125		
	Ratings based on Minimun of L10 of 30 000 hours @ 500rpm						
CEMA C Idlers	18	900	900	900	475		Table E.4
	24	900	900	900	325		
	30	900	900	900	250	500	
	36	900	837	810	200	500	
	42	850	791	765	150	500	
	48	800	744	720	125	500	
	54	750	698	675	*	500	
	60	700	650	630	*	500	
	66				*	500	
	Ratings based on Minimun of L10 of 30 000 hours @ 500rpm *Use CEMA "D" Return Idler						
CEMA D Idlers	24	1200	1200	1200	600		Table E.5
	30	1200	1200	1200	600		
	36	1200	1200	1200	600	850	
	42	1200	1200	1200	500	850	
	48	1200	1200	1200	425	850	
	54	1200	1116	1080	375	850	
	60	1150	1070	1035	280	850	
	66				215	850	
	72	1150	977	945	155	850	
	78				125	850	
	Ratings based on Minimun of L10 of 60 000 hours @ 500rpm						
CEMA F Idlers	36	1800	1800	1800	1000	1300	Table E.6
	42	1800	1800	1800	1000	1300	
	48	1800	1800	1800	1000	1300	
	54	1800	1800	1800	925	1300	
	60	1800	1800	1800	850	1300	
	66				775	1300	
	72	1800	1800	1800	700	1300	
	78				625	1300	
	84	1674	1674	1620	550	1300	
	90				475	1300	
	96	1750	1628	1575	400	1300	
	102				250	1300	
	Ratings based on Minimun of L10 of 60 000 hours @ 500rpm						

Table E.4

Step 3 – Impact idler selection

The following is used for homogeneous material without lumps displayed in figure E.7.

Inpact force = F = (0.1389) $Q\sqrt{H}$

where;

Q = rate of flow

H = height of fall

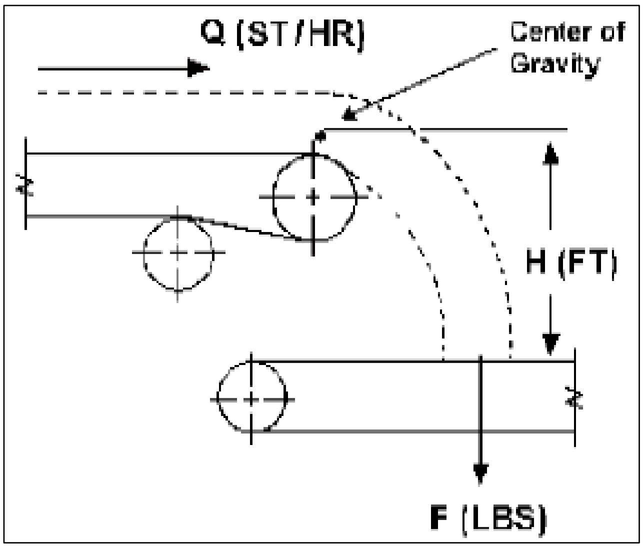


Figure E.7

The calculated impact force is then multiplied by an impact idler spacing factor, from table E8, to establish the impact force on one

Unit impact force = F_U = F(f)

Select the appropriate impact idler from the table E.8 below, F_U should be equal or less than the idler rating.

Impact Idler Spacing, SI	Impact Idler Spacing Factor, f
1' - 0"	0.5
1' - 6"	0.7
2' - 0"	0.9
> 2' - 0"	1

Table E.8 – Impact Idler Spacing Factor

Step 4 - K2, Effect of load on preloaded bearing L_{10} life

The bearing life will increase when the calculated idler load (CIL) is less than the CEMA load rating of idler series selected, which is shown below in table E.9.

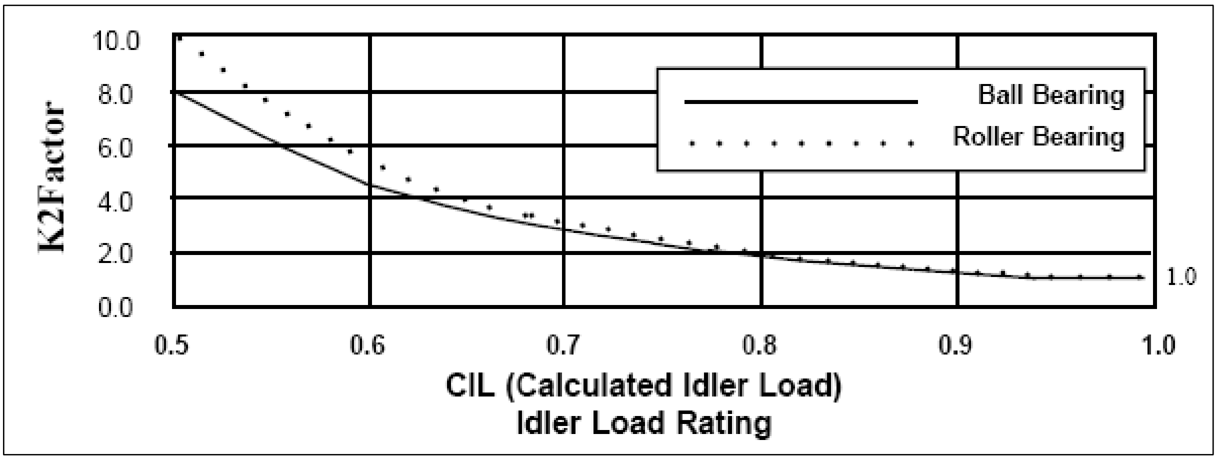


Table E.9 – K2, Effect of load on preloaded bearing L_{10} life

Step 5 – K3A, Effect of belt speed on preload bearing L_{10} life.

CEMA L_{10} bearing life ratings are rated on 500 revolutions per minute (rpm). The table E.10 below show the relationship between slow and fast velocities and the effect on the bearing L_{10} life.

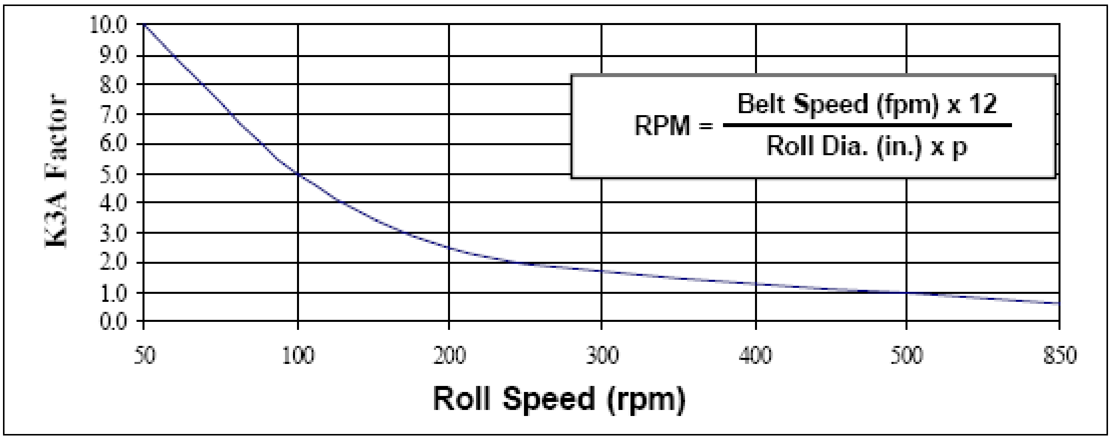


Table E.10 – K3A, Effect of belt speed on preload bearing L_{10} life.

Step 6 – K3B, Effect of roll diameter on preloaded bearing L_{10} life.

By using larger idler rolls for a certain velocity, L_{10} life increase. Figure E.3 illustrates L_{10} life for various roll diameters using 4 inch diameter as a value of 1.0.

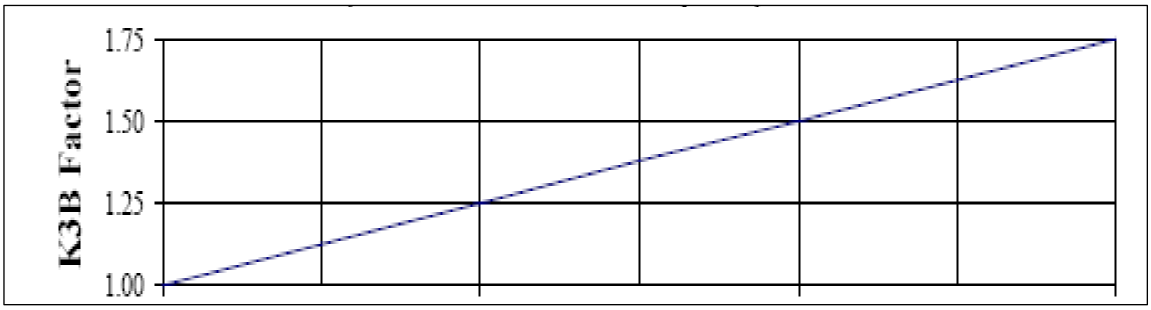


Figure E.3 – K3B, Effect of roll diameter on preloaded bearing L_{10} life

Step 7 – K4, Environmental, maintenance and other conditions

K4A, is the effect of the maintenance on idler life show in figure E.4.

K4B, is the effect of the environment on idler life shown in figure E.5.

K4C, is the effect of operating temperature on idler life show in figure E.6.

Figure E.4 – K4A, effect of the maintenance on idler life

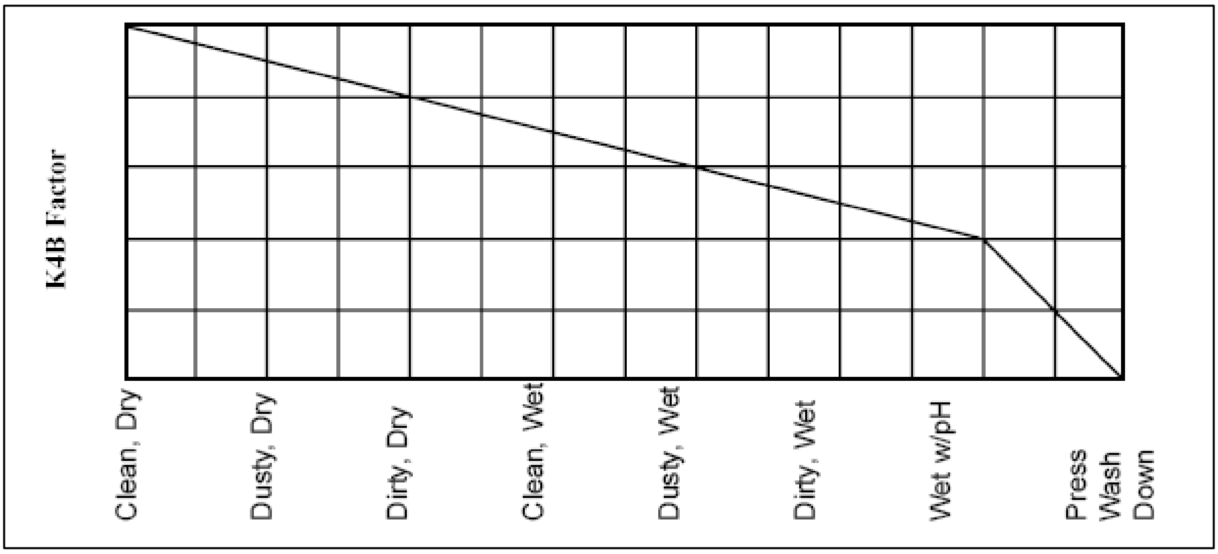


Figure E.5 – K4B, effect of the environment on idler life

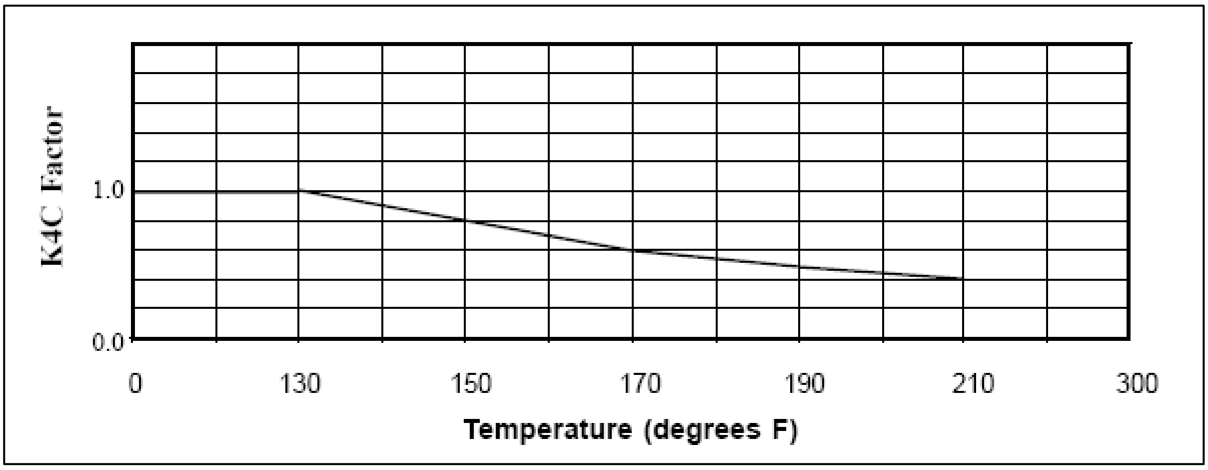
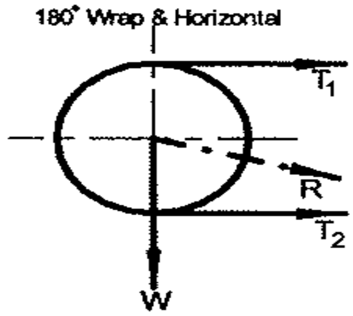
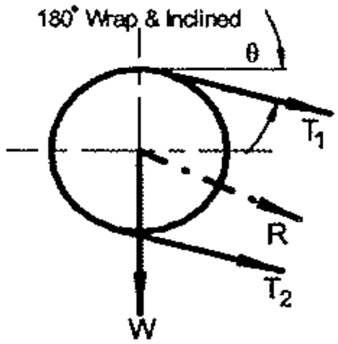
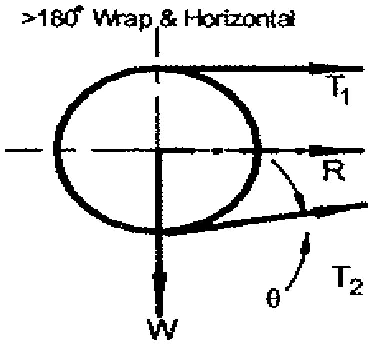
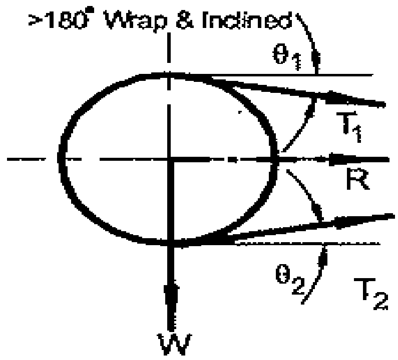
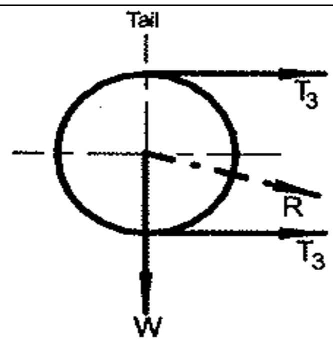
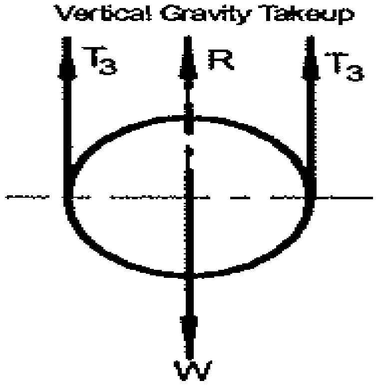
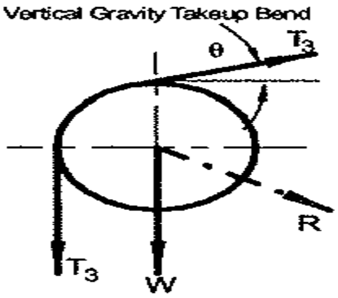
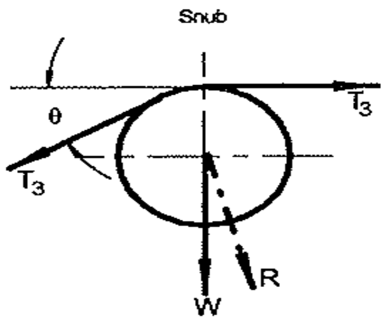
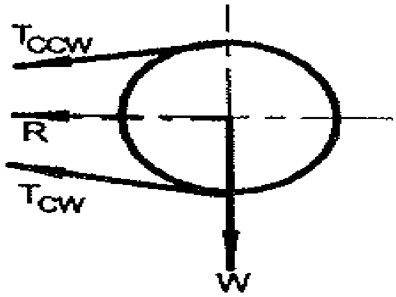
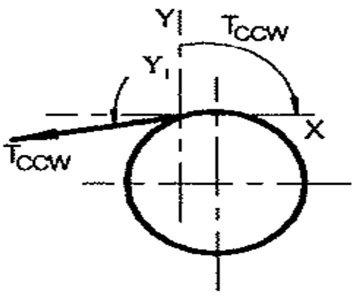
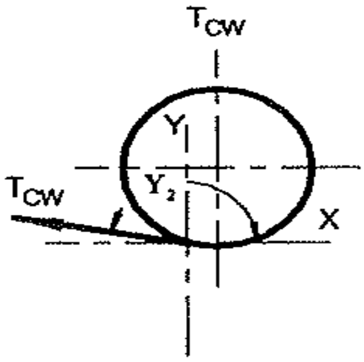
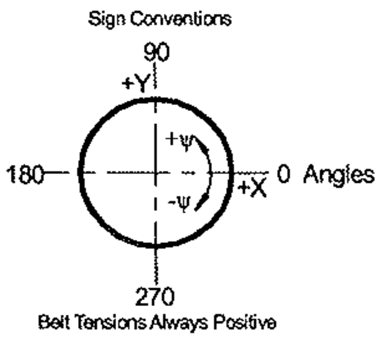


Figure E.6 – K4C, effect of operating temperature on idler life

APPENDIX G – Conveyor wrap around angle

Calculation formula for typical drive pulley arrangement	Resultant load diagram
$R = \sqrt{(T_1 + T_2)^2 + W^2}$	
$R = \sqrt{((T_1 + T_2)\ x\ \cos(\theta))^2 + ((T_1 + T_2)\ x\ \sin(\theta) + W)^2}$	
$R = \sqrt{(T_1 + (T_2\ x\ \cos(\theta)))^2 + ((T_2\ x\ \sin(\theta)) - W)^2}$	
$R = \sqrt{((T_1\ x\ \cos(\theta_1) + (T_2\ x\ \cos(\theta_2)))^2 + (-(T_1\ x\ \sin(\theta_1)) + (T_2\ x\ \sin(\theta_2)) - W)^2}$	

Calculation formula for typical non-drive pulley arrangements	**Resultant load diagram**
$R = \sqrt{(2\ x\ T_3)^2 + W^2}$	
$R = (2\ x\ T_3) - W$	
$R = \sqrt{(T_3\ \cos(\theta))^2 + ((1-\sin(\theta))\ x\ T_3 + W)^2}$	
$R = \sqrt{(T_3\ x\ (1-\cos(\theta)))^2 + (T_3\ x\ \sin(\theta) + W)^2}$	

Calculation formula for general case	**Resultant load diagram**
$R = \sqrt{((T_{ccw}\ x\ \cos(\psi_1)) + (T_{cw}\ x\ \cos(\psi_2)))^2 + ((T_{ccw}\ x\ \sin(\psi_1)) + (T_{cw}\ x\ \sin(\psi_2)) - W)^2}$	

APPENDIX H – Risk Assessment

A risk assessment is essential for this project to avoid hazards that might be encountered while conducting this research project.

At Millmerran Power Station all activities and work was conducted under the procedure of the Workplace Health and Safety program. All the necessary Personal Protective Equipment was supplied and includes; hard hat, steel capped boots, safety glasses and ear muffs. Long sleeve shirt and long pants was also expected to be worn at the power station.

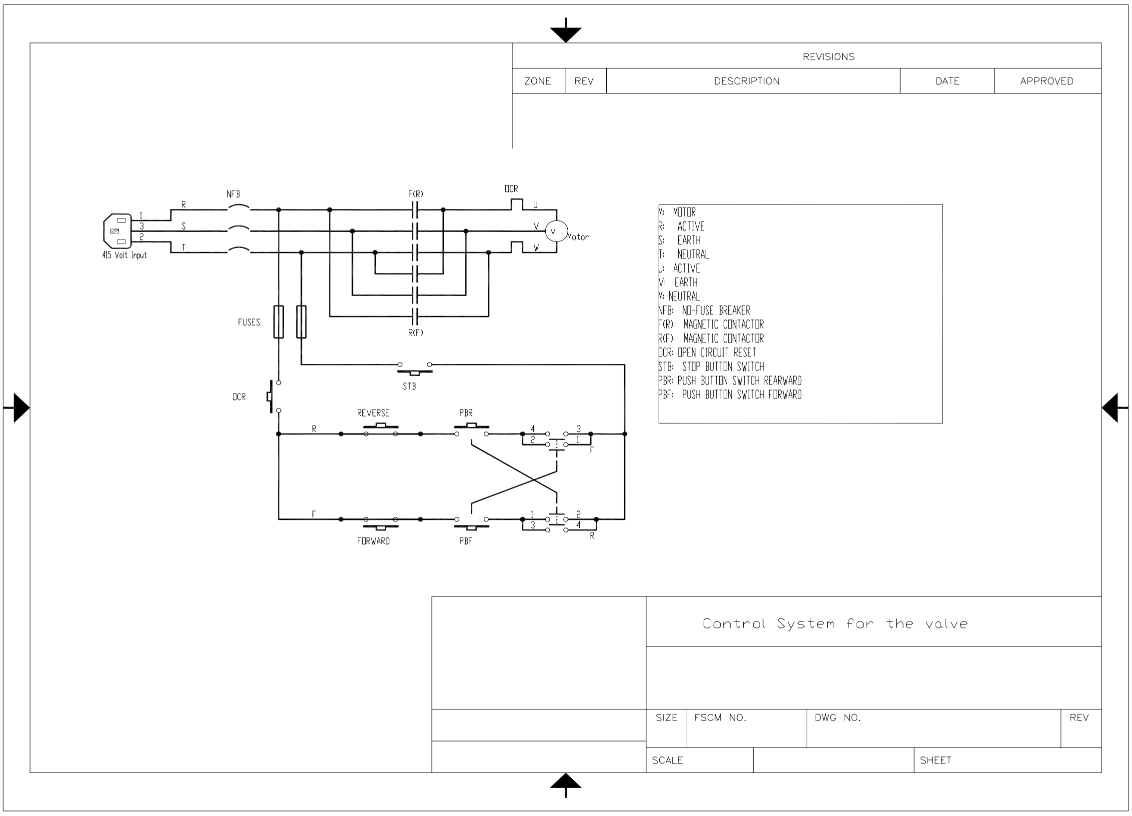
All work activities was conducted in a safe manner. The following is possible risks while working at the power station;

- hearing damage
- clothes getting caught in rotating machines
- foreign objects in the eyes
- falling objects
- falling from heights
- burns from high steam temperature.

APPENDIX I – Timelines

Month	March					April				May				June					July				August					September				October			
Task	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26
Submit Project Specification					■																														
Literature Search					■	■	■	■	■	■	■	■																							
Literature Review													■	■	■	■	■																		
Conveyors																		■	■	■	■														
Conveyor Calculatios																						■	■	■	■	■									
Chute design																						■	■	■	■	■	■	■	■	■					
Submit Extended Abstract																												■							
Write Disertation of Findings																	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Submit Dissertation																																			■

APPENDIX J – Control System for the Diverter Gate Valve



Drawing I.2