

University of Southern Queensland
Faculty of Engineering & Surveying

**Profiling Coal on a Conveyor Belt for the Automation of
a Train Loadout Facility**

A dissertation submitted by

Mitch Cunningham

in fulfilment of the requirements of

ENG4112 Research Project

towards the degree of

Bachelor of Electrical & Electronic Engineering

Submitted: October, 2009

Abstract

Throughout the coal industry within the Bowen Basin there are very few mines that have an automated control system on their train loadout facilities. The existing systems use dozers to regulate how much coal is in the bin and is not an exact science. Weighers are also used but are generally unreliable and not designed for the specific purpose of conveyor speed control to maintain levels within the loadout bins.

The project aim is to investigate the practicality and possibility of using control techniques based on instrumentation to automate a train loadout facility.

- Determine the requirements for automating a train loadout
- Determine what coal is made of
- Research appropriate head unit for conveyor control
- Conceptual Design

A number of units were tested and looked at for various locations around the train loadout facility.

A minor setback for the development of a working model is that the weight of coal depends on the amount of moisture that the coal retains. This can be overcome if an inline moisture analyzer is installed. Sampling of the coal will need to continue to determine the ash content of the coal being loaded.

This project has shown that the LMS-111 laser is the stand out device as it is simple, inexpensive and can be used in a range of locations for various applications. Due to the

LMS-111's unique features the device can be utilized in a number of various locations around the train loadout facility.

A project package for the installation of the LMS-111 has been developed and plans are currently underway to test and commission the device on an inloading conveyor at Dalrymple Bay Coal Terminal, located 30km south of Mackay.

University of Southern Queensland
Faculty of Engineering and Surveying

ENG4111/2 <i>Research Project</i>
--

Limitations of Use

The Council of the University of Southern Queensland, its Faculty of Engineering and Surveying, and the staff of the University of Southern Queensland, do not accept any responsibility for the truth, accuracy or completeness of material contained within or associated with this dissertation.

Persons using all or any part of this material do so at their own risk, and not at the risk of the Council of the University of Southern Queensland, its Faculty of Engineering and Surveying or the staff of the University of Southern Queensland.

This dissertation reports an educational exercise and has no purpose or validity beyond this exercise. The sole purpose of the course pair entitled “Research Project” is to contribute to the overall education within the student’s chosen degree program. This document, the associated hardware, software, drawings, and other material set out in the associated appendices should not be used for any other purpose: if they are so used, it is entirely at the risk of the user.

Prof F Bullen

Dean

Faculty of Engineering and Surveying

Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

MITCH CUNNINGHAM

Q9722400

Signature

Date

Acknowledgments

I would like to acknowledge and thank my Research Project Supervisor, John Leis, for his guidance. John's advice was invaluable and contributed extensively to the learning experience.

I would also like to thank my wife Michelle. Her patience, understanding, and flexibility throughout this undertaking has allowed us to balance this project, work and family commitments.

MITCH CUNNINGHAM

University of Southern Queensland

October 2009

Contents

Abstract	i
Acknowledgments	v
List of Figures	xii
List of Tables	xv
Glossary	xvi
Chapter 1 Introduction	1
1.1 Statement of Problem	1
1.2 Research Objectives	4
1.3 Conclusion	5
Chapter 2 Project Management	6
2.1 Introduction	6
2.2 Project Selection	7

CONTENTS	vii
2.3 Project Schedule	7
2.4 Project Budget	8
2.5 Assessment of Consequential Effects	9
2.5.1 Overview	9
2.5.2 Design reliability	9
2.5.3 Design Integrity	9
2.5.4 Design Installation	9
2.5.5 Ethics	10
Chapter 3 Introduction to Coal Mining and Product Review	11
3.1 Chapter Overview	11
3.2 Coal Mining	12
3.2.1 What is Coal?	12
3.2.2 Types of Coal	12
3.2.3 Use of Coal In The Modern World	15
3.2.4 Coking Coal	17
3.2.5 Ethanol Production	17
3.2.6 Gasification	18
3.2.7 Liquefaction	19
3.2.8 Refined Coal	20
3.2.9 Coal as a Trade Commodity	21

CONTENTS	viii
3.2.10 Environmental Effects	21
3.2.11 Energy Density And Carbon Intensity	22
3.2.12 World Coal Reserves	23
3.3 Chemical Analysis of Coal	24
3.3.1 Test One - Moisture	25
3.3.2 Test Two - Ash	25
3.3.3 Test Three - Volatile Matter	26
3.4 Coal Handling Preparation Plants	26
3.4.1 Conveyor Belt Systems	27
3.5 Belt Weighers	27
3.6 Laser Scanning Techniques	29
3.7 Ultrasonic Sensors	32
3.7.1 Overview	32
3.7.2 Detectors	33
3.7.3 Distance Calculation	34
3.7.4 The Limitations of Ultrasonic Sensors	34
3.7.5 Conclusion	34
Chapter 4 Belt Weighers	36
4.1 Overview	36
4.2 Costings	42

CONTENTS	ix
4.3 Typical Flow Rates	43
4.4 Advantages	51
4.5 Disadvantages	52
Chapter 5 Design Approaches	58
5.1 Overview	58
5.2 Photovoltaics	58
5.2.1 Overview	58
5.2.2 Testing of the Photovoltaic Cell	60
5.2.3 Advantages	60
5.2.4 Disadvantages	61
5.2.5 Conclusion	62
5.3 Video & Web Cameras	62
5.3.1 Overview	62
5.3.2 Testing of the Video / Web Camera	64
5.3.3 Conclusion	66
Chapter 6 Laser Head Units	68
6.1 Overview	68
6.2 LMS-111 Laser Unit	71
6.2.1 Overview	71

CONTENTS	x
6.2.2 Testing of the LMS-111	74
6.2.3 Advantages	79
6.2.4 Disadvantages	80
6.2.5 Conclusion	81
6.3 LM2D Laser Unit	82
6.3.1 Overview	82
6.3.2 Advantages	84
6.3.3 Disadvantages	85
6.3.4 Conclusion	85
Chapter 7 Implementation and Testing	87
7.1 Implementation and Testing	87
Chapter 8 Conclusions and Future Work	94
8.1 Conclusions and Future Work	94
References	96
Appendix A Project Specification	100
Appendix B Job Safety Analysis	103
Appendix C Consignment Notes	106
Appendix D Conveyor Mechanical Drawings	108

CONTENTS	xi
Appendix E Electrical Schematics	110
Appendix F Layout Drawings	113

List of Figures

3.1	Bowen Basin, Central Queensland, Australia.	
	Picture Courtesy: (<i>Bowen Basin Central Queensland</i> 2008)	14
3.2	Typical Speed Sensor.	
	Picture Courtesy: (<i>Belt Weigher Overview</i> 2009)	28
4.1	HPFS4 Belt Weigher.	
	Picture Courtesy: (<i>Belt Weigher Overview</i> 2009)	38
4.2	PFS4 Belt Weigher.	
	Picture Courtesy: (<i>Belt Weigher Overview</i> 2009)	39
4.3	PCS2 Belt Weigher.	
	Picture Courtesy: (<i>Belt Weigher Overview</i> 2009)	40
4.4	PCX2 Belt Weigher.	
	Picture Courtesy: (<i>Belt Weigher Overview</i> 2009)	41
4.5	PCX2 Belt Weigher.	
	Picture Courtesy: (<i>Belt Weigher Overview</i> 2009)	42
4.6	Aerial Representation of Riverside Train Loadout	45
4.7	CC3 Conveyor Coal Valve Open 235mm	46
4.8	CC3 Conveyor Coal Valve Open 280mm	47

4.9	CC3 Conveyor Coal Valve Open 305mm	48
4.10	CC3 Conveyor Coal Valve Open 350mm	49
4.11	CC3 Conveyor Coal Valve Open 395mm	50
4.12	CC3 Conveyor Feeder Set at 1700tph	51
4.13	CC3 Conveyor Feeder Set At 600tph	52
4.14	CC3 Conveyor Vibrating Feeder Set At 50tph,2600tph,1500tph	53
4.15	CC3 Conveyor Coal Valve Fully Open & Vibrating Feeder Set To 50% .	54
4.16	CC3 Conveyor Coal Valve Fully Open & Vibrating Feeder Set To 100%	55
4.17	CC3 Conveyor Feeder A & Coal Valve B Open	56
4.18	CC3 Conveyor Feeder A & Coal Valve B Open	57
5.1	Basic Photovoltaic Cell	
	Picture Courtesy: (Luque & Hegedus n.d.)	59
5.2	Installation of Photovoltaic Cell	61
5.3	Photovoltaic Cells Profiling Product On a Conveyor Belt	63
5.4	Testing Laser Effectiveness on a Conveyor Belt (Shade)	65
5.5	Testing Laser Effectiveness on a Conveyor Belt (Sunlight)	66
6.1	Scanning Empty Belt	
	Picture Courtesy: (<i>The New LMS100 Laser Measurement System</i> 2009)	69
6.2	Scanning Product On Belt	
	Picture Courtesy: (<i>The New LMS100 Laser Measurement System</i> 2009)	70

6.3	Determining Product Area	
	Picture Courtesy: (<i>The New LMS100 Laser Measurement System</i> 2009)	71
6.4	Determining Product Area	
	Picture Courtesy: (<i>The New LMS100 Laser Measurement System</i> 2009)	72
6.5	LMS-111 Laser Scanner	73
6.6	Test Conveyor	75
6.7	Installation of the LMS-111	76
6.8	Calibration on Empty Belt	77
6.9	Scanning of Large Object	78
6.10	Shadow Cast from Large Object	79
6.11	Scanning of a Small Object	80
6.12	Scanning of Scattered Timber	81
6.13	Scanning of Scattered Timber With Gaps	82
6.14	LM2D Laser	
	Picture Courtesy: (<i>Laser Scanners Promise Volumetric Accuracy</i> 2008)	83
6.15	LM2D Error Vs Crossectional Area	
	Picture Courtesy: (<i>Laser Scanners Promise Volumetric Accuracy</i> 2008)	86
7.1	LMS-111 Locations	89
7.2	LMS-111 Located Within TLO Bin	90
7.3	LMS-111 Located On Main Conveyor	91
7.4	LMS-111 Location on Feed Conveyor	92

7.5	LMS-111 Locations Underneath TLO Bin	93
-----	--	----

List of Tables

3.1	Typical Content of Elements Within Coal	15
4.1	Approximate Cost of Belt Weighers	43
4.2	Conservative Total Cost of Belt Weighers	44
5.1	Voltages From Photovoltaic Cells	60
5.2	Video / Web Camera Associated Costs	67
6.1	LM2D Specifications	84
7.1	Comparison of Units	88

Glossary

Coal Handling Prep Plant (CHPP)-	Is a facility which washes / separates the soil and rock from the coal.
Controller Area Network (CAN)-	Is a vehicle bus standard designed to allow PLC's and microcontrollers to communicate with each other without a host computer.
DeviceNet -	Is a communications protocol used in industry to interconnect field devices for data exchange. DeviceNet was developed by Allen Bradley.
Human Machine Interface (HMI) -	Is how the users interact with particular equipment
Profibus (Process Field Bus) -	Very similar to DeviceNet. Profibus is a standard for field bus communications which is used to operate field devices via a centralized controller. Siemens products support the Profibus standard
Programmable Logic Controller (PLC) -	Is a digital computer used for the automation of electromechanical processes
Run of Mine (ROM) -	Is the location where raw coal is dumped after collecting it from the seam. The Run of Mine feeds directly into the CHPP.
Supervisory Control and Data Acquisition (SCADA) -	A computer system capable of controlling and monitoring a process
Variable Frequency Drives (VFD) / Variable Speed Drives (VSD) -	Is a system used for controlling the rotational speed of an alternating current electric motor

Chapter 1

Introduction

This chapter gives an overview of the problem including the problems associated with measuring instruments. The chapter also includes the research objectives, the project methodology and the requirements for automating a train loadout.

1.1 Statement of Problem

Throughout the coal industry within the Bowen Basin there are very few mines that have an automated control system on their train loadout facilities. The existing systems use dozers to regulate how much coal is in the bin, and it is not an exact science. Weighers are also used but are generally unreliable and not designed for the specific purpose of conveyor speed control to maintain levels within the loadout bins.

Various weighing devices are used for applications which really test their accuracy. If these weighing devices were just flow rate indicators, the accuracy issue would be simpler; however, since most of the weighing devices looked at have included a totalizer upon which all the errors are accumulated, the errors can seem larger than they really are.

Stockpile management is the ideal example of the need for an accurate weighing device for product reconciliation. Firstly, there is a need for an understanding of real weighing

device accuracies, and then an informed use of the information when used to value assets such as stockpiles. There are many horror stories about "the coal that disappeared from the stockpile" or "how the train or ship could be not loaded because the coal that was supposed to be there did not turn out to be there". Some peoples' careers have been unfairly affected by this basic misunderstanding of how weighing device errors work.

As with all measuring instruments, there are two types of error

- systematic error ie. the error that's always there; and
- random error ie. the inability of the equipment to give exactly the same answer when measuring the same thing a second time.

A typical stockpile problem is one which has an incoming weighing device such as a belt weigher with a 0.25% accurate belt weigher, and one reclaim belt weigher also 0.25% accurate. For this example we will consider that the two belt weighers each have a systematic error of 0.25% each, and that one is reading 0.25% high, and the other 0.25% low. Over large amounts of material, the random errors will in theory have averaged to zero. The problem with stockpiles is that belt weighing errors add and also accumulate. The errors from the input and output weighers will combine, even though the difference (or subtraction) of the two results is used as the stockpile figure. Worse still, this same error accumulates after the weighed material has left the stockpile.

The error in the stockpile figure is the sum of the errors of the belt weighers used to calculate the figure. If two belt weighers are involved, each with real errors of 0.25%, then the error in the stockpile figure will be 0.5%. In terms of statistics, the random components of error (known as the variances) of the two weighers would add, but here we are speaking about a hypothetically known systemic error, and the random error component really should integrate to zero.

As material passes through the stockpile, the error we are considering remains 0.5% of the total amount of material which has passed through, it is not just 0.5% of the amount in the stockpile now. After, three million tonnes have been through a stockpile there may be theoretically 30,000 tonnes remaining. The problem is that 0.5% of three million tonnes is 15,000 tonnes. The truth is that the stockpile figure is the difference between

the 'ins' and the 'out' plus or minus the sum of the errors. So the real stockpile could be anywhere between 15,000 and 45,000 tonnes. If systematic errors can be determined, they can be adjusted to zero. The problem is that it is difficult to accurately determine the amount of coal that is being moved because a reasonable proportion of it is water, and the amount of water changes over time.

Another factor in the equation is that the random errors in weighing don't enter results at a high frequency, so that errors might average to zero over one day. Random errors in weighing are more properly called Influence Factors. Some of these have a period of one day, a week, or a year, as temperatures and seasons change.

The other major purpose of a weighing device is process control. In this role, the focus is on the indicated flow rate than in the accumulated tonnage figure.

The common belief is that a weighing device with much lower accuracy is adequate for this role. However, systematic and random errors are still at work. The combined effect of these can lead to an apparent need for heavy maintenance, and errors much larger than expected.

The process control weighing device is at the other end of the application spectrum when compared to the 'product reconciliation' use. In the case of product reconciliation, final results consist of the accumulation of many measurements taken over days, weeks or even months. The result is accumulated in the totalizer. It includes all the systematic error of the weighing device and in a sense, none of the random error. The process control application however, uses the instantaneous flow rate from the device. This output has all the random error and all the systematic error in it. As a result, and especially given the common choice of a single idler belt weigher for this role, the user has built into their process a $\pm 1\%$ variability from day to day. This can hardly be helpful in controlling a process.

Therefore the project aim is to investigate the practicality and possibility of using control techniques based on instrumentation to fully automate a train loadout facility and in doing so improve the reliability and productivity of the existing systems.

1.2 Research Objectives

The specific objectives of the project are listed below:

- Determine the requirements for automating a train loadout
- Determine what coal is made of
- Research possible methods for volumetric measurement of coal on a conveyor belt including methods such as:
 - o Ultrasonics
 - o Photovoltaic cells
 - o Video and web camera imaging
 - o Belt weighers
 - o Various laser techniques

When researching these methods a number of factors will be considered including:

- o Reliability of head unit in harsh environments
 - o Power supply
 - o PLC requirements
 - o Mounting
 - o Installation
 - o Cost
- Conceptual Design

The project was undertaken in five main phases:

- Research & Planning
- Literature Review
- Conceptual Design
- Recording & Testing of Results

1.3 Conclusion

To automate a train loadout facility a number of requirements will need to be fulfilled:

- Evaluate the weight of coal on the feed conveyor belts
- Evaluate the weight of coal on the main conveyor belt
- Evaluate the weight of coal within the train loadout bin
- Evaluate the weight of coal within each wagon
- Maintain a consistent distribution of coal on the feed conveyor belts
- Maintain the level of the train loadout bin
- Consistently fill the train wagons with a set level of product

It is proposed to use a device or a number of devices to fulfil these requirements.

Chapter 2

Project Management

2.1 Introduction

There are four standard project phases encompassed by Project Management:

- Concept
- Development
- Implementation
- Finalization.

Management is achieved via the Project Plan. The purpose of the Project Plan is to disclose to the Sponsor and other key stakeholders the planning and control methodology to be applied to the project to produce the desired outcomes.

2.2 Project Selection

The project is being undertaken to satisfy the USQ Bachelor of Engineering Research Project (ENG4111/4112) requirements. The option to undertake an 'Own Project' was elected. The proposed project topic was selected to:

- Research and optimize an appropriate controller
- Develop an automated control system that can be utilized in the coal mining sector

2.3 Project Schedule

As part of the project a specific timeline has been developed. The methodology is listed in order and justification of each item is also included. The first task will be to research and acquire an appropriate device. The device will be a critical piece of equipment and the design of the installation will be based on the specific type of device utilized. Research of the various devices will include:

- How the device is to operate
- Whether it is suitable in a rugged environment
- The power supply requirements,
- The PLC connection type,
- The weight and size of the laser,
- How the device is to be installed
- The cost of the device

The next task will be to develop a project package. This is a necessity as it will incorporate a preliminary design and a detailed design. A project package will highlight

many of the design issues and it will also contribute to determining the cost of the installation. The project package will include the below items:

- I/O Listing
- Schematic Drawings
- Termination Drawings
- Layout Drawings
- Cable Schedule
- Bill of Material
- Scope of Work

The final step will be to design a prototype system. This means setting up, testing and commissioning a complete system to determine how it will function and also to iron out any of the bugs associated with the design and code. The system does not necessarily have to be set up at a mine site but this is the intended application for the design and it will be beneficial in debugging the software if the system is installed at its designed location.

2.4 Project Budget

The project budget was capped at \$200.

A large portion of the equipment was on loan, the project required a small amount of equipment to be bought.

2.5 Assessment of Consequential Effects

2.5.1 Overview

As with any engineering project there are always implications and consequential effects that come with any of the project activities. A number of these issues are discussed below.

2.5.2 Design reliability

The design of the system must be simple, robust, fault free, inexpensive and effective. For a prototype design to be successful and outperform many similar systems the above characteristics will be required. The system must be easy to use, fault find and repair if necessary. The system will require being less expensive than other means otherwise no one will buy if another system is cheaper and does the same job.

2.5.3 Design Integrity

The design must be able to withstand the test of time. The most important aspect when designing an electrical system is to design it so it is foolproof and no one can be injured or no equipment damaged as a result of poor design. As a designer it would not be very comforting to know that someone was injured while using your system and therefore systems should be designed to incorporate safety features that will protect someone that has very limited knowledge of a system. Majority of these safety features can be incorporated within the code and can be as simple as the equipment shutting down if a guard or control panel cover is removed or opened.

2.5.4 Design Installation

The safety of the people that will be installing the equipment will be extremely important. Workplace Health and Safety and the Coal Mining Act now have very specific

rules and regulations when working within the coal industry. The majority of contractors will have their own system of Job Safety Analysis forms and all mine sites will have a Workplace Health and Safety Management Plan that all workers must abide by. Specific scopes of work as well as a detailed design which includes drawings, bills of materials etc will also ensure that the work is completed safely.

2.5.5 Ethics

The Engineers Australia Code of Ethics was reviewed. There were no issues identified relating to the Code throughout the project.

Chapter 3

Introduction to Coal Mining and Product Review

3.1 Chapter Overview

An introduction into coal, the coal mining industry and the effects that coal mining has on the global economy is covered in this chapter. This overview skims the surface of the coal industry but is helpful in the understanding that coal is a major commodity and heavily relied upon worldwide.

Other topics covered in the literature review include:

- The Chemical Analysis of Coal
- Coal Handling Prep Plants
- Belt Weighers
- Laser Scanning Techniques
- Ultrasonics

3.2 Coal Mining

3.2.1 What is Coal?

Coal is a combustible brownish-black or black rock occurring in rock strata layers or veins called coal beds. Coal primarily consists of carbon but other elements such as sulfur, hydrogen, nitrogen and oxygen can be found in its makeup. Coal was formed millions of years ago, during the Carboniferous Period, in widespread shallow seas and large swamp areas when layer upon layer of plant remains accumulated on top of each other. The plant matter was protected from degrading by a covering of acidic water which prevented bacteria and microorganisms from breaking down the plant material. After some time mud covered the plant material, this also aided in the prevention of oxidization and also trapped atmospheric carbon under the ground. Over time these bogs were gradually covered with sediment and with the increasing pressure and heat the plant material was gradually turned from peat to lignite. Lignite is generally considered to be 'immature' coal at this point in time due to its lighter colour and its softer composition. Coal, classed as a fossil fuel due to the process of how it was formed, is the largest source of energy for electricity generation in the world. Due to its composition it is also one of the world's largest sources of carbon dioxide emissions, exceeding the emissions produced from petroleum and almost double the emissions of natural gas. Coal is extracted from the ground usually by two methods. If the coal seam is close to the top of the ground generally 0-50 m deep, the top soil is removed and stockpiled, the rock is then blasted and carted away and the coal seam is left exposed. If the coal seam is deeper than 50m underground mining techniques are then utilized.

3.2.2 Types of Coal

There are a number of different coal types that are found worldwide. These form as geological processes apply pressure to dead biotic matter over time:

- Peat - considered to be a precursor of coal, has industrial importance as a fuel in some regions, for example, Ireland and Finland.

- Lignite - increases in maturity by becoming darker and harder and is then classified as sub-bituminous coal. Lignite also referred to as brown coal, is the lowest rank of coal and used almost exclusively as fuel for electric power generation. Jet is a compact form of lignite that is sometimes polished and has been used as an ornamental stone since the Iron Age.
- Sub-bituminous coal - whose properties range from those of lignite to those of bituminous coal are used primarily as fuel for steam-electric power generation. Additionally, it is an important source of light aromatic hydrocarbons for the chemical synthesis industry.
- Bituminous coal - dense mineral, black but sometimes dark brown, often with well-defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications in manufacturing and to make coke. Bituminous coal ignites easily and burns long with a relatively long flame. If improperly fired bituminous coal is characterized with excess smoke and soot.
- Anthracite - is the last classification, the ultimate maturation of a harder, glossy, black coal used primarily for residential and commercial space heating. It may be divided further into metamorphically altered bituminous coal and petrified oil.
- Graphite - technically the highest rank, but difficult to ignite and is not so commonly used as fuel: it is mostly used in pencils and, when powdered, as a lubricant.

In Australia, bituminous coal is the most common of coal types which is commonly located in Queensland and New South Wales. Bituminous coal can then be divided into three different types of black coal which determines its value as a commodity. Coking coal as its name indicates is used to make coke in coke ovens which is the fuel that is used to mix with iron ore to make raw steel in blast furnaces. Coke is actually produced from a mixture of mainly coking coals and some other coals. A lot of Bowen Basin (Central Queensland) coal is hard coking coal. This coal is the best for steel manufacturing as it has specific chemical properties which enables the coke to be more efficient in steel making when it converts iron ore to raw steel. There are several types of coking coal and the most valuable of those is hard coking coal. This

coking coal is found and mined in the Bowen Basin in places like Goonyella / Riverside and in the Wollongong area in New South Wales. These deposits are the largest known deposits of hard coking coal in the world. Thermal coal commonly found in New South Wales reserves is used to generate heat which is used in power stations to generate steam to drive turbines which in turn produces electricity. PCI Coal or Pulverized Coal Injection Coal is mined in central Queensland around the Nebo area. This type of coal is crushed into a fine powder and injected into blast furnaces as a replacement for coke in the production of pig iron. It is also used in the steel-making process to reduce the need for the much higher priced hard coking coal.

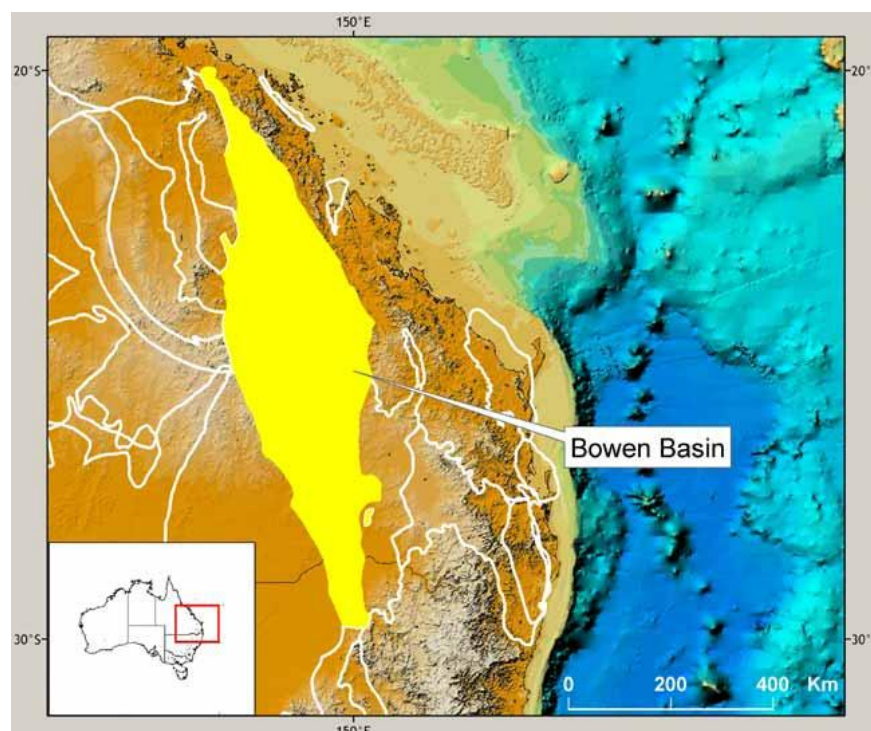


Figure 3.1: Bowen Basin, Central Queensland, Australia.

Picture Courtesy: (*Bowen Basin Central Queensland* 2008)

Typical element content of the three most commonly used types of coal are listed below:

	<i>Anthracite Coal</i>	<i>Bituminous Coal</i>	<i>Lignite Coal</i>
Sulfur Content (% of Weight)	0.6 - 0.77 %	0.7 - 4 %	0.4 %
Moisture Content (% of Weight)	2.8 - 16.3 %	2.2 - 15.9 %	39 %
Fixed Carbon Content (% of Weight)	80.5 - 85.7 %	44.9 - 78.2 %	31.4 %
Ash Content (% of Weight)	9.7 - 20.2 %	3.3 - 11.7 %	4.2 %
Bulk Density (kg/m ³)	800 - 929	673 - 913	641 - 865
Weight (kg/m ³)	Solid - 1506 Broken - 1105	Solid - 1346 Broken - 833	

Table 3.1: Typical Content of Elements Within Coal

3.2.3 Use of Coal In The Modern World

World coal consumption was about 6,743,786,000 short tons in 2006 (*World Coal Consumption 1980-2006* 2008) and is expected to increase 48% to 9.98 billion short tons by 2030. (*World Energy Projections Plus* 2009) China produced 2.38 billion tons in 2006. India produced about 447.3 million tons in 2006. 68.7% of China's electricity comes from coal. The USA consumes about 14% of the world total, using 90% of it for generation of electricity. (*World Energy Usage* 2009a)

Electricity generation using coal generally consists of the coal being pulverized and then burnt in a furnace. The heat from the furnace is used to boil water into steam and this steam is then used to turn turbines connected to generators which in turn produces electricity. "Standard" steam turbines have topped out with some of the most advanced reaching about 35% thermodynamic efficiency for the entire process,

although newer combined cycle plants can reach efficiencies as high as 58%. Increasing the combustion temperature can boost this efficiency even further. (*Fossil Power Generation* 2009) Old coal power plants, especially the older style plants, are significantly less efficient and produce higher levels of waste heat. About 40% of the world's electricity comes from coal, (*Coal Produced Electricity* 2009) and approximately 49% of the United States electricity comes from coal. (*World Energy Usage* 2009b)

The emergence of the supercritical turbine concept envisions running a boiler at extremely high temperatures and pressures with projected efficiencies of 46%, with further theorized increases in temperature and pressure perhaps resulting in even higher efficiencies. (*Balancing Economics and Environmental Friendliness* 2006)

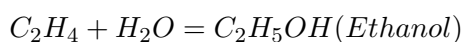
Approximately 40% of the world's electricity production uses coal. The total known deposits recoverable by current technologies, including highly polluting, low energy content types of coal (i.e., lignite, bituminous), is sufficient for many years. However, consumption is increasing and maximal production could be reached within decades. A more energy-efficient way of using coal for electricity production would be via solid-oxide fuel cells or molten-carbonate fuel cells (or any oxygen ion transport based fuel cells that do not discriminate between fuels, as long as they consume oxygen), which would be able to get 60%-85% combined efficiency (direct electricity + waste heat steam turbine). Currently these fuel cell technologies can only process gaseous fuels, and they are also sensitive to sulfur poisoning, issues which would first have to be worked out before large scale commercial success is possible with coal. As far as gaseous fuels go, one idea is pulverized coal in a gas carrier, such as nitrogen. Another option is coal gasification with water, which may lower fuel cell voltage by introducing oxygen to the fuel side of the electrolyte, but may also greatly simplify carbon sequestration. However, this technology has been criticized as being inefficient, slow, risky and costly, while doing nothing about total emissions from mining, processing and combustion. (*Clean Coal Facts and Figures* 2006) Another efficient and clean way of coal combustion in a form of coal-water slurry fuel (CWS) was well developed in Russia (since the Soviet Union time). CWS significantly reduces emissions saving the heating value of coal.

3.2.4 Coking Coal

Coke is a solid carbonaceous residue derived from low-ash, low-sulfur bituminous coal from which the volatile constituents are driven off by baking in an oven without oxygen at temperatures as high as 1,000 C so that the fixed carbon and residual ash are fused together. Metallurgical coke is used as a fuel and as a reducing agent in smelting iron ore in a blast furnace. The product is too rich in dissolved carbon, and must be treated further to make steel. The coke must be strong enough to resist the weight of overburden in the blast furnace, which is why coking coal is so important in making steel by the conventional route. However, the alternative route is direct reduced iron, where any carbonaceous fuel can be used to make sponge or pelletized iron. Coke from coal is grey, hard, and porous and has a heating value of 24.8 million Btu/ton (29.6 MJ/kg). Some coke making processes produce valuable by-products that include coal tar, ammonia, light oils, and "coal gas". Petroleum coke is the solid residue obtained in oil refining, which resembles coke but contains too many impurities to be useful in metallurgical applications.

3.2.5 Ethanol Production

Coal and natural gas are both abundant in nature and available at a very low cost compared to other resources.



Coke which represents about 80% of coal reacts with natural gas producing ethylene gas. Ethylene Hydration provides ethanol. Product ethanol outweighs other liquid fuels for its availability and low cost. The reaction itself is obvious, a simple addition reaction where one mole of carbon reacts with one mole of methane gas producing one mole of ethylene gas.

The reaction of coal and natural gas was used by a German manufacturer for Buna rubber: Chemische Werke Huls, at Marl, Germany, and AVCO Corp in the US.

Consequently several references had described both Huls Arc Process and AVCO rotating arc reactor. (*Ullmann's Encyclopedia of Industrial Chemistry* 1987) (Kirk & Othmer 2004a) Both reactors are of cylindrical shape and have a rotating electric arc. The cathode is at the cylinder axis, while the anode is on the circumference. As methane gas provided the highest yield, then it is forced with coal powder into a vortex passing through the electric arc for few milliseconds.

Huls Arc Process (Weissermel 2003) produced a mixture of acetylene and ethylene gases. The reaction conditions can be varied to determine the needed product. Increasing the Specific Energy Requirement (SER) favor acetylene production, and lower SER is for ethylene:

Enthalpy Change for Ethylene: (Perry & Green 1984) = 127.34 kJ/mol, while for acetylene: = 301.4 kJ/mol. As a consequence, recent production processes are using conventional heating instead of electric arc.

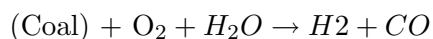
Hydration of ethylene gas producing ethanol is the most important process for ethanol production. Vapor phase process is the preferred one (Kirk & Othmer 2004b) in which ethylene and steam pass over a catalyst. One of the most accepted catalyst is diatomite impregnated with phosphoric acid.

3.2.6 Gasification

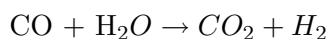
Coal gasification can be used to produce syngas, a mixture of carbon monoxide (CO) and hydrogen (H₂) gas. This syngas can then be converted into transportation fuels like gasoline and diesel through the Fischer-Tropsch process. Currently, this technology is being used by the Sasol chemical company of South Africa to make gasoline from coal and natural gas. Alternatively, the hydrogen obtained from gasification can be used for various purposes such as powering a hydrogen economy, making ammonia, or upgrading fossil fuels.

During gasification, the coal is mixed with oxygen and steam (water vapor) while also being heated and pressurized. During the reaction, oxygen and water molecules oxidize the coal into carbon monoxide (CO) while also releasing hydrogen (H₂) gas.

This process has been conducted in both underground coal mines and in coal refineries.



If the refiner wants to produce gasoline, the syngas is collected at this state and routed into a Fischer-Tropsch reaction. If hydrogen is the desired end-product, however, the syngas is fed into the water gas shift reaction where more hydrogen is liberated.



High prices of oil and natural gas are leading to increased interest in "BTU Conversion" technologies such as gasification, methanation and liquefaction. The Synthetic Fuels Corporation was a U.S. government-funded corporation established in 1980 to create a market for alternatives to imported fossil fuels (such as coal gasification). The corporation was discontinued in 1985.

In the past, coal was converted to make coal gas, which was piped to customers to burn for illumination, heating, and cooking. At present, the safer natural gas is used instead.

3.2.7 Liquefaction

Coal can also be converted into liquid fuels like gasoline or diesel by several different processes. In the direct liquefaction processes, the coal is either hydrogenated or carbonized. Hydrogenation processes are the Bergius process, (Haul 1985) the SRC-I and SRC-II (Solvent Refined Coal) processes and the NUS Corporation hydrogenation process. (Speight n.d.) (Lowe & Schroeder 2009) In the process of low temperature carbonization coal is coked at temperatures between 680 F (360 C) and 1,380 F (750 C). These temperatures optimize the production of coal tars richer in lighter hydrocarbons than normal coal tar. The coal tar is then further processed into fuels. Alternatively, coal can be converted into a gas first, and then into a liquid, by using the Fischer-Tropsch process.

Coal liquefaction methods involve carbon dioxide (CO₂) emissions in the conversion process. If coal liquefaction is done without employing either carbon capture and storage technologies or biomass blending, the result is lifecycle greenhouse gas footprints that are generally greater than those released in the extraction and refinement of liquid fuel production from crude oil. If CCS technologies are employed, reductions of 5-12% can be achieved in CTL plants and up to a 75% reduction is achievable when co-gasifying coal with commercially demonstrated levels of biomass (30% biomass by weight) in CBTL plants. (Tarka & Wimer 2004) For most future synthetic fuel projects, Carbon dioxide sequestration is proposed to avoid releasing it into the atmosphere. Sequestration will, however, add to the cost of production. Currently all US and at least one Chinese synthetic fuel projects, (*Shenhua Group Starts China's First Coal-to-Fuel Plant* 2009) are including sequestration in their process designs.

Coal liquefaction is one of the backstop technologies that could potentially limit escalation of oil prices and mitigate the effects of transportation energy shortage that will occur under peak oil. This is contingent on liquefaction production capacity becoming large enough to satiate the very large and growing demand for petroleum. Estimates of the cost of producing liquid fuels from coal suggest that domestic U.S. production of fuel from coal becomes cost-competitive with oil priced at around 35 USD per barrel, (n.d.) (break-even cost). With oil prices back at around USD 40 per barrel in the U.S. as of December 15, 2008, liquid coal has currently lost much of its economic allure in that country.

Among commercially mature technologies, advantage for indirect coal liquefaction over direct coal liquefaction are reported by Williams and Larson (2003).

3.2.8 Refined Coal

Refined coal is the product of a coal upgrading technology that removes moisture and certain pollutants from lower-rank coals such as sub-bituminous and lignite (brown) coals. It is one form of several pre-combustion treatments and processes for coal that alter coal's characteristics before it is burned. The goals of pre-combustion coal

technologies are to increase efficiency and reduce emissions when the coal is burned. Depending on the situation, pre-combustion technology can be used in place of or as a supplement to post-combustion technologies to control emissions from coal-fueled boilers.

3.2.9 Coal as a Trade Commodity

The price of coal has gone up from around \$30 per short ton in 2000 to around \$150.00 per short ton as of September 26, 2008. As of July 31st, 2009, the price per short ton has declined to \$78.62. (*Coal Market Prices* 2009)

3.2.10 Environmental Effects

There are a number of adverse environmental effects of coal mining and burning, specially in power stations. These effects include:

- Release of carbon dioxide, a greenhouse gas, which causes climate change and global warming according to the IPCC. Coal is the largest contributor to the human-made increase of CO₂ in the air. (*Coal And The Environment* 2008)
- Generation of hundred of millions of tons of waste products, including fly ash, bottom ash, flue gas desulphurization sludge, that contain mercury, uranium, thorium, arsenic, and other heavy metals
- Acid rain from high sulfur coal
- Interference with groundwater and water table levels
- Contamination of land and waterways and destruction of homes from fly ash spills such as Kingston Fossil Plant coal fly ash slurry spill
- Impact of water use on flows of rivers and consequential impact on other land-uses
- Dust nuisance

- Subsidence above tunnels, sometimes damaging infrastructure[citation needed]
- Coal-fired power plants without effective fly ash capture are one of the largest sources of human-caused background radiation exposure
- Coal-fired power plants shorten nearly 24,000 lives a year in the United States, including 2,800 from lung cancer. (MSNBC Staff and Service 2008)
- Coal-fired power plant releases emissions including mercury, selenium, and arsenic which are harmful to human health and the environment. (World Coal Institute 2009)

3.2.11 Energy Density And Carbon Intensity

The energy density of coal, i.e. its heating value, is roughly 24 megajoules per kilogram. (Fisher 2005) The energy density of coal can also be expressed in kilowatt-hours for some unit of mass, the units that electricity is most commonly sold in, to estimate how much coal is required to power electrical appliances. One kilowatt-hour is 3.6 MJ, so the energy density of coal is 6.67 kWh/kg. The typical thermodynamic efficiency of coal power plants is about 30%, so of the 6.67 kWh of energy per kilogram of coal, 30% of that-2.0 kWh/kg-can successfully be turned into electricity; the rest is waste heat. So coal power plants obtain approximately 2.0 kWh per kilogram of burned coal. As an example, running one 100 watt computer for one year requires 876 kWh ($100 \text{ W} \cdot 24 \text{ h/day} \cdot 365 \text{ days in a year} = 876000 \text{ Wh} = 876 \text{ kWh}$). Converting this power usage into physical coal consumption:

$$\frac{876 \text{ kWh}}{2 \text{ kWh/kg}} = 438 \text{ kg} \quad (3.1)$$

It takes 438 kg of coal to power a computer for one full year. (*How much coal is required to run a 100-watt light bulb 24 hours a day for a year?* 2006) One should also take into account transmission and distribution losses caused by resistance and heating in the power lines, which is in the order of 5-10%, depending on distance from the power station and other factors.

Commercial coal has a carbon content of at least 70%. Coal with a heating value of 6.67 kWh per kilogram as quoted above has a carbon content of roughly 80%, which is:

$$\frac{0.8 \text{ kg}}{12 \text{ kg/kmol}} = 2/30 \text{ kmol} \quad (3.2)$$

where 1 mol equals to N_A (*AvogadroNumber*) *atoms*.

Carbon combines with oxygen in the atmosphere during combustion, producing carbon dioxide, with an atomic weight of $(12 + 16 \cdot 2 = 44 \text{ kg/kmol})$. The CO₂ released to air for each kilogram of incinerated coal is therefore

$$\frac{2}{30 \text{ kmol}} \cdot \frac{44 \text{ kg}}{\text{kmol}} = \frac{88}{30} \text{ kg} \approx 2.93 \text{ kg} \quad (3.3)$$

This can be used to calculate an emission factor for CO₂ from the use of coal power. Since the useful energy output of coal is about 30% of the 6.67 kWh/kg(coal), the burning of 1 kg of coal produces about 2 kWh of electrical energy. Since 1 kg coal emits 2.93 kg CO₂, the direct CO₂ emissions from coal power are 1.47 kg/kWh, or about 0.407 kg/MJ. The U.S. Energy Information Agency's 1999 report on CO₂ emissions for energy generation, (Department of Energy 1999) quotes a lower emission factor of 0.963 kg CO₂/kWh for coal power. The same source gives factor for oil power in the U.S. of 0.881 kg CO₂/kWh, while natural gas has 0.569 kg CO₂/kWh. Estimates for specific emission from nuclear power, hydro, and wind energy vary, but are about 100 times lower.

3.2.12 World Coal Reserves

At the end of 2006 the recoverable coal reserves amounted around 800 or 900 gigatons. The United States Energy Information Administration gives world reserves as 930 billion short tons[48] (equal to 843 gigatons) as of 2006. At the current extraction rate, this would last 132 years. (*World Energy Usage 2009a*) However, the rate of coal consumption is annually increasing at 2-3% per year and, setting the

growth rate to 2.5% yields an exponential depletion time of 56 years (in 2065). At the current global total energy consumption of 15.7 terawatts,[51] there is enough coal to provide the entire planet with all of its energy for 37 years (assuming 0% growth in demand and ignoring transportation's need for liquid fuels).

The 930 billion short tons of recoverable coal reserves estimated by the Energy Information Administration are equal to about 4,116 BBOE (billion barrels of oil equivalent). The amount of coal burned during 2007 was estimated at 7.075 billion short tons, or 133.179 quadrillion BTU's. (*World Energy Usage 2009a*) In terms of heat content, this is about 57 million barrels of oil equivalent per day. By comparison in 2007, natural gas provided 51 million barrels of oil equivalent per day, while oil provided 85.8 million barrels per day.

British Petroleum, in its annual report 2007, estimated at 2006 end, there were 909,064 million tons of proven coal reserves worldwide, or 147 years reserves-to-production ratio. This figure only includes reserves classified as "proven"; exploration drilling programs by mining companies, particularly in under-explored areas, are continually providing new reserves. In many cases, companies are aware of coal deposits that have not been sufficiently drilled to qualify as "proven". However, some nations haven't updated their information and assume reserves remain at the same levels even with withdrawals.

Of the three fossil fuels coal has the most widely distributed reserves; coal is mined in over 100 countries, and on all continents except Antarctica. The largest reserves are found in the USA, Russia, Australia, China, India and South Africa.

3.3 Chemical Analysis of Coal

There are a large number of coal properties, such as ash and sulfur content, that are frequently measured to help determine if a particular coal is suitable for use in a particular process. The most frequently used analysis is a simple type of chemical analysis called a proximate analysis. This consists of a determination of the moisture and ash content of the coal as well as an estimate of the amount of gas that can be

driven from the coal by heating. The final component of a proximate analysis is an estimate of the nonvolatile carbon called fixed carbon.

At most of the mine sites within the Bowen Basin strict testing of coal samples are undertaken. At Goonyella Riverside Mine, I had the opportunity to spend some time in the coal sampling lab and observe the methods which are used to test the moisture, ash and volatile matter found in the coal.

The main objective is to determine how much of the coal is usable. The moisture and ash are undesirable as they are not significant to the heating process. For example, if one hundred train wagons were loaded with coal that has 10 percent ash and 5 percent moisture are shipped to a power plant, the equivalent of ten of those wagons carrying rock and five wagons are simply carrying water. At the power plant, where the coal is burned, only the volatile matter and the carbon in the coal are burned. Therefore, the most valuable coal has the lowest content of ash and moisture. The value of these for each train is recorded on a form referred to as a consignment note. An example of theses consignment notes can be found in Appendix D.

3.3.1 Test One - Moisture

In this test the moisture is evaporated during the heating so that the difference between the starting weight and the final weight represents the moisture. One gram of coal is heated to 105 degrees C. When the weight stops changing, the sample weight remaining is 0.892 grams. Therefore the amount of moisture within the coal sample is calculated by:

$$1.0 \text{ grams} - 0.892 \text{ grams} = 0.108 \text{ grams or } 10.8 \% \text{ moisture.}$$

3.3.2 Test Two - Ash

In this test everything except the ash is burned so that the final weight is the ash. The same sample from test one is burned in air to a final weight of 0.094 grams
 $0.094\text{grams of ash} = 9.4 \% \text{ ash.}$

3.3.3 Test Three - Volatile Matter

In this test the volatile matter is evaporated during the heating so that the difference between the starting weight and the final weight represents the volatile matter. An additional one-gram sample of the same coal is heated for seven minutes in the absence of air to 750 degrees C. The weight at the end of the test is 0.72 grams.

$1.00 \text{ gram} - 0.72 \text{ grams} = 0.28 \text{ grams}$ or 28 % volatile matter

Therefore to determine the amount of fixed coal in this sample the following formula is used:

$\text{Fixed Carbon} = 100 \% - 10.8 \% (\text{moisture}) - 9.4 \% (\text{ash}) - 28 \% (\text{volatile matter}) = 51.8 \% \text{ fixed carbon}$

3.4 Coal Handling Preparation Plants

Once the coal has been removed from the ground, the coal requires washing to remove dirt and any impurities within the coal. A basic Coal Handling Preparation Plant (CHPP) will separate the raw coal from the clean coal and the CHPP also has a number of circuits which collect and wash the fines and deposits them into the clean coal.

A control room performs the centralized functions of monitoring, operating and controlling the CHPP and all other associated equipment. This involves recording, controlling the complex belt conveyor-system, train loading, truck unloading systems and other required functions and needed systems. Several thousand inputs and outputs are analyzed by the Programmable Logic Controller (PLC) usually located adjacent to the control room. There will also be remote PLC racks located around various areas of the plant including the Train Loadout, Run of Mine (ROM), Raw Coal and Clean Coal. These remote racks are typically connected by a fibre optic network due to the heavy demand associated with the control of the plant. The fibre network also takes care of the HMI/SCADA applications and the communication systems, such as phone and data, around site. The benefits of using fibre is that data

sent to the HMI/SCADA software is in real time and aids in effective decision-making based on real time status/event listings.

3.4.1 Conveyor Belt Systems

In a complex conveyor belt system, the starting sequence, flow separations, ascent and descent angles, bulk weights and distribution, changing operating conditions (particularly difficult to define are belt tensions and longitudinal oscillations) as well as emergency and repair modes and other critical factors must be taken into consideration. The latest drive and motor technology, such as the Variable Frequency Drives (VFD) drive, are now utilizing the fibre optic cabling systems. A specially written SCADA program is embedded in the speed and synchronizing controller to synchronize the VFD drives located at the ends of the conveyor systems. This separation of the synchronizing, load balancing and protection functions into a dedicated speed and synchronizing controller ensures that the core functions required for the long conveyor operation are always solved at the highest priority. An adaptive load balancing/sharing algorithm ensures minimum power consumption (a very important criterion considering the large drive ratings and varying load patterns).

This is very important, as the slightest mismatch while starting, stopping or running can cause belt fatigue and premature failure of the conveyor. The conveyor system is the lifeline of the plant; the system cannot afford to have failures, and/or long downtime due to maintenance procedures or repairs.

3.5 Belt Weighers

Conveyor belt weighers are integrating weighing devices that use a simple integral calculus summation process to measure the quantity of material along a belt. Two variables are involved: weight and speed.

A weight function measures the weight of a small section of a conveyor. The gross weight on the scale is the weight of the belt, the belt conveyor idler and the material

on the belt. The net weight of material is the gross weight less the weight of the supported section of the belt and the scale idler. The total weight sensed at any particular position of the conveyor is the sum of all particles in the weighing area with respect to their individual triangular waveforms and their position in the scale weighing area. This weight function is a representation of the weight per unit distance at any one point on the conveyor belt. This is usually represented in kg/m.

The speed function is the second variable to be measured. Most modern speed sensors are rotary digital pulse generators or encoders typically located on the tail pulley of the conveyor. A rotary digital pulse generator consists of an inductive proximity sensor which picks up the arms of a metallic spider connected to the conveyors tail pulley.

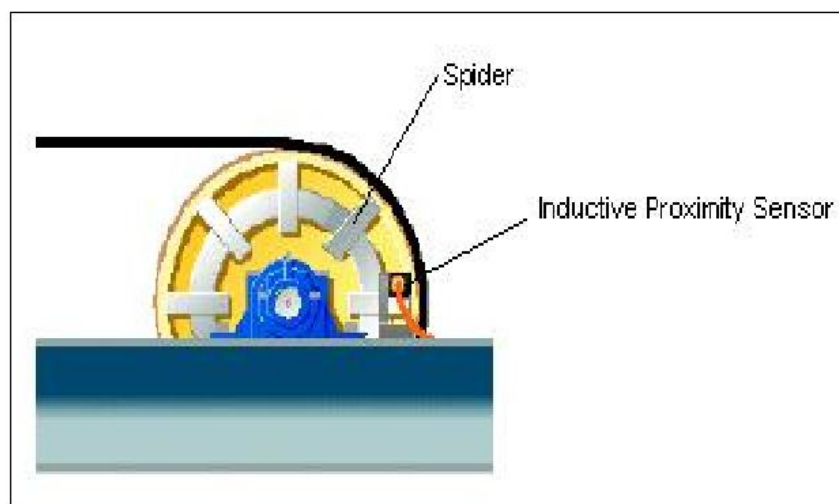


Figure 3.2: Typical Speed Sensor.

Picture Courtesy: (*Belt Weigher Overview* 2009)

As the conveyor moves a small discrete distance as measured by the speed sensor a portion of the weight is totalled. If the belt loading is 50 kg/m and the belt moves 1/10 of a metre then the totalizer adds 5 kg to the total. This happens at a relatively high speed. A conveyor travelling at 300 m/min will generate approximately 3000 additions per minute or 50 readings per second.

Multiple readings per pulse are used to attain higher resolutions. This equates to 50 analog weight readings per second in the above example.

3.6 Laser Scanning Techniques

The second technique that will be discussed is the use of a laser to scan material flowing along a conveyor belt. After numerous hours of searching through books, patent websites, online journals and various web pages it was found that there are not many companies that have developed a laser designed to scan bulk materials, such as coal, travelling along a conveyor. A number of the patent websites, online journals and various web pages are listed below:

- Google Patents - <http://www.google.com/patents>
- Wiki Patents - <http://www.wikipatents.com/>
- Patent Storm - <http://www.patentstorm.us/>
- Fresh Patents - <http://www.freshpatents.com/>
- Free Patents Online - <http://www.freepatentsonline.com/>
- Google Scholar - <http://scholar.google.com.au/>
- IEEE Explore - <http://ieeexplore.ieee.org/xpl/periodicals.jsp>

After a little more research, it was determined that there are even fewer companies that have a laser designed specifically for use as a product profiling device. There are a number of existing patents that can be found that incorporate the design of a laser scanning head, although majority of these designs cannot be utilized within the

mining industry due to the nature of the environment. The dust, vibration and temperature extremes of a coal mine environment require that any equipment that is to be utilized must be specifically designed for such a purpose. Designs that incorporate the specific alignment of mirrors and prisms will simply not last in such an environment. K-Tek has a very informative website (www.ktekcorp.com) and the following information is a brief overview of the products that they provide specifically for conveyor scanning of bulk solids. K-Tek's primary product for bulk scanning of solid material is the LM2D Laser. This laser "is a real-time noncontact volume scanner for conveyor based materials that provides an accurate, easy to use and maintenance free alternative to belt scales.

(<http://www.engineeringtalk.com/index.html>) The LM2D uses a rotational laser head that that uses a number of points to determine the profile of the material that is being scanned. A 3D map is created of the surface of the material and the head unit of the laser uses algorithms to calculate the scanned material's volume and weight. These measurements can then be sent via a RS232 or 4-20mA interface to any associated PLC equipment. The advantages of using the LM2D Laser include:

- Simple and inexpensive installation as there are only two cables (power and control) that are required.
- Mounting of the device is relatively simple and the LM2D Laser can be mounted virtually anywhere with a minimum of fuss.
- It is a non-contact measuring device
- It can also be used to monitor belt speed using a second measuring head and utilizing Doppler Radar to determine the speed of the belt
- No calibration and minimum maintenance
- No special software required

The disadvantages of using the LM2D Laser include:

- The LM2D Laser is quite expensive - \$29,000 as quoted on the 30th March 2009

- The unit does not take into account the moisture content of the coal Although there are a number of advantages of using the laser system, the cost of the unit is a major setback as companies will also have to factor in design costs, install costs and the procurement of materials required to complete the installation.

3.7 Ultrasonic Sensors

3.7.1 Overview

Ultrasonic sensors are relatively simple and easy to interface with and thus are a good sensor to use in robotics. Ultrasonic sensors (also known as transceivers when they both send and receive) work on a principle similar to radar or sonar which evaluate attributes of a target by interpreting the echoes from radio or sound waves respectively. Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object.

This technology can be used for measuring: wind speed and direction (anemometer), fullness of a tank, and speed through air or water. For measuring speed or direction a device uses multiple detectors and calculates the speed from the relative distances to particulates in the air or water. To measure the amount of liquid in a tank, the sensor measures the distance to the surface of the fluid. Further applications include: humidifiers, sonar, medical ultrasonography, burglar alarms, and non-destructive testing. (Ohya 1996)

Systems typically use a transducer which generates sound waves in the ultrasonic range, above 20,000 hertz, by turning electrical energy into sound, then upon receiving the echo turn the sound waves into electrical energy which can be measured and displayed. The technology is limited by the shapes of surfaces and the density or consistency of the material. For example foam on the surface of a fluid in a tank could distort a reading.

An ultrasonic transducer is a device that converts energy into ultrasound, or sound waves above the normal range of human hearing. While technically a dog whistle is an ultrasonic transducer that converts mechanical energy in the form of air pressure into ultrasonic sound waves, the term is more apt to be used to refer to piezoelectric transducers that convert electrical energy into sound. Piezoelectric crystals have the property of changing size when a voltage is applied, thus applying an alternating

current (AC) across them causes them to oscillate at very high frequencies, thus producing very high frequency sound waves. (*Ultrasonic Ranger* 2002)

The location at which a transducer focuses the sound, can be determined by the active transducer area and shape, the ultrasound frequency and the sound velocity of the propagation medium.

3.7.2 Detectors

Transducer The piece of hardware that sends the original pulse and senses the returned echo is called a transducer. There are two types of transducers: electrostatic and piezo.

Piezo Transducers Piezo electric transducers use the piezo effect to create and measure ultrasonic pulses. The sensors use a crystal or ceramic material bonded to a metal case or cone. To emit the pulse, the crystal is excited by a signal (usually 40 khz), which expands or contracts the piezo material. The connected metal cone also expands or contracts which generates the ultrasonic burst. The return echo causes the piezo material to vibrate, which generates a signal. Piezo transducers are generally less expensive than electrostatic transducers, but their construction makes them better suited for harsh environments. Since piezo electric crystals generate a voltage when force is applied to them, the same crystal can be used as an ultrasonic detector. Some systems use separate transmitter and receiver components while others combine both in a single piezoelectric transceiver. (*Ultrasonic Ranger* 2002)

Electrostatic transducers are similar to a capacitor. They consist of a fixed plate and a moveable plate. The fixed plate is usually aluminum and the moveable one is Kapton coated with a thin gold layer. The Kapton acts as an insulator. When a signal is applied to the two plates (typically at 50hz), the gold foil is attracted to the backplate which displaces air and creates an ultrasonic burst.

3.7.3 Distance Calculation

The distance calculation is quite simple. Once the pulse is sent and the echo is sensed, one only needs to use the following equation to find the distance (Ohya 1996):

$$\frac{\textit{Elapsed Time} \cdot \textit{Speed of Sound}}{2} = \textit{Distance} \quad (3.4)$$

The maximum distance that can be sensed varies with the power and sensitivity of the transducer.

3.7.4 The Limitations of Ultrasonic Sensors

The majority of the limitations of ultrasonic sensors are directly related to the cone shape of the emitted pulse. One of the major problems is that anything in the sensors path will return a pulse. There is no way to discern between a 1 inch pipe and a wall, because both will return an echo. This problem can be fixed by using multiple sensors or by rotating a single sensor. (Ohya 1996) Another problem with ultrasonic sensors is that it can be hard to sense openings in a wall such as a door or corner. If one side of the opening falls into the sonic cone, it will return an echo. Therefore, to sense openings it is best for the sensor to be close to the opening or to have a narrowed sonic cone. A narrowed cone can be accomplished by using a horn. A horn attaches to the end of the transducer and directs the ultrasonic pulse into a narrower cone. There are limitations to using horns. Since the sonic cone is narrower, less objects are sensed at a close proximity. Using a combination of sensors is usually a good idea.

3.7.5 Conclusion

Ultrasonic scanning of a bulk material is very rare throughout the coal mining industry. The majority of applications for ultrasonic scanning are within the robotic industry and also process plants where the ultrasonic head detects when an object such as a box is on the conveyor belt. Ultrasonic head units operate on the principle

that the head unit emits a sound or radio wave and then evaluates attributes of an object or material from echoes or sound waves that have been bounced back to the head unit.

Taking this into consideration the speed of a conveyor belt is approximately 4.3 m/s, for the ultrasonic unit to take accurate measurements of a coal conveyor belt profile it would be necessary to obtain a high end¹ ultrasonic device. Also ultrasonics depends on sound waves being bounced off an object, it is very difficult to determine a depth of the coal on a conveyor belt as the coal bounces back the signal to the receiving unit. Majority of the ultrasonic devices have not been designed for the specific purpose of profile mapping coal and therefore there are limited options when designing installations that include ultrasonic measuring devices.

¹High end device is a device that is capable of handling the input data. Due to the increase in components required an increase in cost is also incurred

Chapter 4

Belt Weighers

4.1 Overview

Belt weighers are the most common method of determining the weight of coal on a belt within the Bowen Basin coal mines. Depending on the accuracy required there are a number of belt weighers that can be utilized. In short, the greater the number of load cells used to weigh the sample the greater the accuracy is. Below is a list showing what kind of belt weighers are commonly available:

1. HPFS4 Model - is a high precision fully suspended 4 point conveyor weighing system which incorporates the following features:

- High precision fully suspended weigh frame
- Direct force measurement (no lever arms, pivots or bearings)
- 4 load cells
- 4 12 idler weigh length
- High accuracy up to 0.1%
- Fully non-intrusive design option (no conveyor modifications required)
- Individually engineered/custom designed
- Designed for minimal material build up
- Extended idler pitch (if required for high tension belts)
- Solid mild steel construction or stainless steel for extreme environments
- Australian made



Figure 4.1: HPFS4 Belt Weigher.

Picture Courtesy: (*Belt Weigher Overview* 2009)

2. PFS4 Model - is a precision fully suspended 4 point conveyor weighing system which incorporates the following features:

- 4 load cells (with stainless pod covers)
- 2 - 8 idler weigh length
- NMI trade approved class 0.5
- High accuracy application up to 0.25%

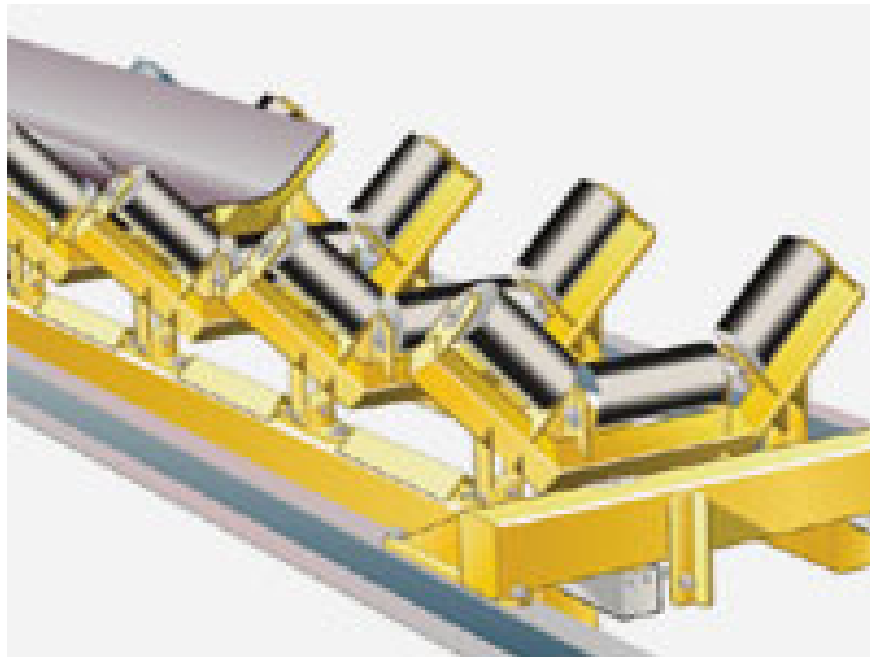


Figure 4.2: PFS4 Belt Weigher.

Picture Courtesy: (*Belt Weigher Overview 2009*)

3. PCS2 Model - is a precision centrally suspended 2 point conveyor weighing system which incorporates the following features:

- 2 load cells (with stainless pod covers)
- 2 - 4 idler weigh length
- NMI trade approved class 1
- Accuracy application up to 0.5%

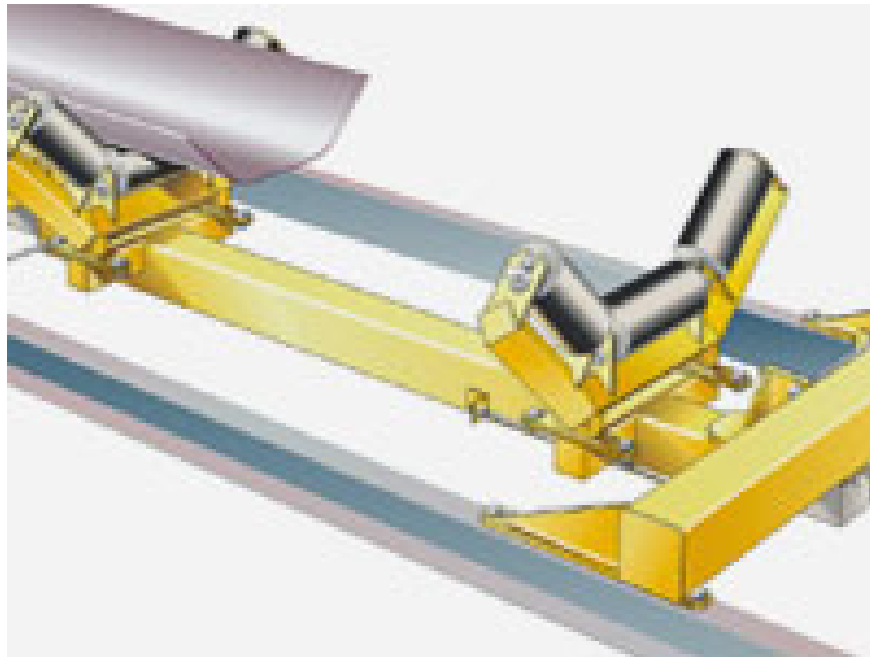


Figure 4.3: PCS2 Belt Weigher.

Picture Courtesy: (*Belt Weigher Overview 2009*)

4. PCX2 Model - is a precision centrally cross supported 2 point conveyor weighing system which incorporates the following features:

- 2 load cells (with stainless pod covers)
- 1 - 2 idler weigh length
- NMI trade approved class 1
- Accuracy application up to 0.5%
- Suited for tight and complex applications

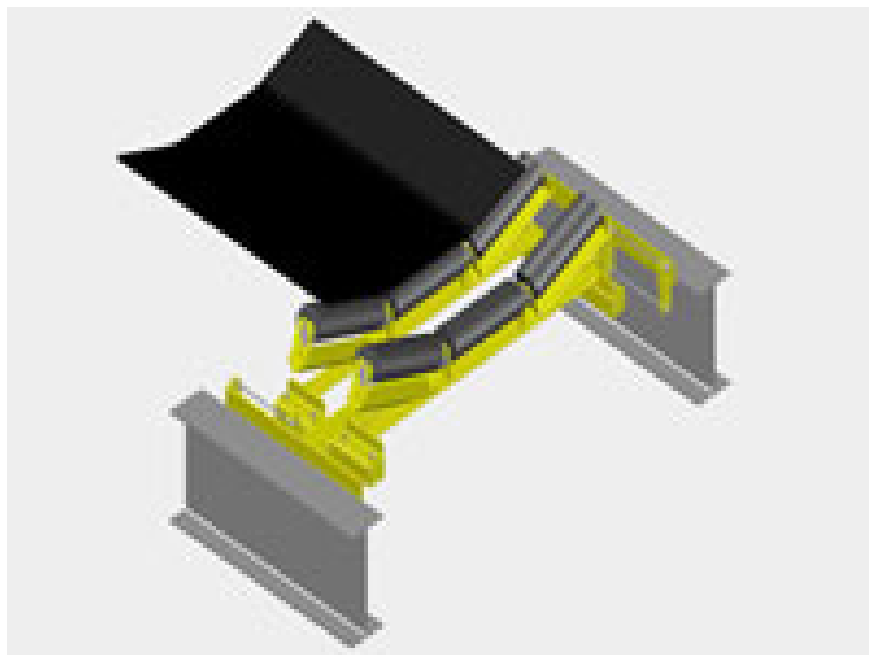


Figure 4.4: PCX2 Belt Weigher.

Picture Courtesy: (*Belt Weigher Overview 2009*)

5. PCS1 Model - is a precision centrally suspended single point conveyor weighing system which incorporates the following features:

- 1 load cell (with stainless pod cover)
- 1 idler weigh length
- NMI trade approved class 2
- Accuracy application up to 1.0%

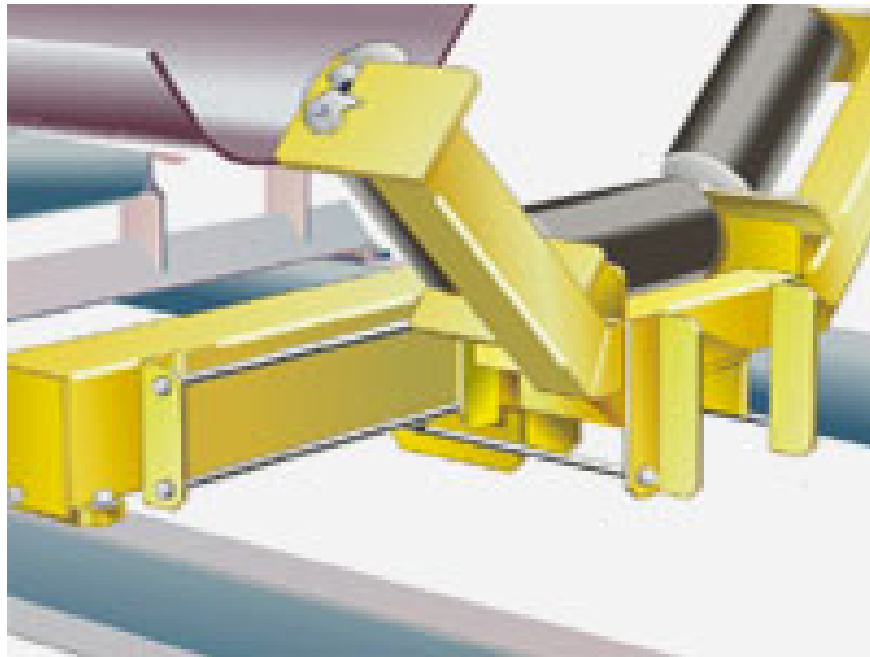


Figure 4.5: PCX2 Belt Weigher.

Picture Courtesy: (*Belt Weigher Overview 2009*)

The above belt weighers all require the use of a Intelligent Production Controller (IPC14). This device provides the interface required between the belt weigher and the PLC. A number of different connections may be utilized for connection to the PLC, but the most common of these connections is the Allen Bradley Device Net connections or the Siemens Profibus connection. Over 90 % of the mines within the PLC Basin have either Allen Bradley or Siemens PLC's.

4.2 Costings

For the costing of a complete design, procurement and installation of a belt weigher there are a number of variables that need to be taken into consideration. The below costs include the design and a mechanical install fee. Electrical installation and cost of materials have not been included in these prices. These prices are indicative of the approximate costs to supply and install the below belt weighers.

<i>Model of Belt Weigher</i>	<i>Approximate Cost</i>
HPFS4 Belt Weigher	\$51230
PFS4 Belt Weigher	\$41760
PCS2 Belt Weigher	\$32680
PCX2 Belt Weigher	\$24500
PCS1 Belt weigher	\$20000

Table 4.1: Approximate Cost of Belt Weighers

In addition to the above costs the base model of belt weigher has an accuracy of 1%. A mean average of five mines yearly production figures is approximately five million tonnes per year per mine output. Yearly, this equates to 50,000 tonnes of coal per mine that have been unaccounted for. The price of coal at the moment is hovering around the \$120 per tonne and this equates to \$6M worth of coal being 'lost'.

Therefore if the weigher is running at a - 1% accuracy level the mine is undercutting itself by giving more coal to its client for the same cost and on the other hand, if the weigher is running at a + 1% accuracy level the mine is supplying less coal to the client and basically making money. In the case of the later the client will certainly not like to be paying for something it is not receiving.

Ongoing maintenance costs must also be factored into the equation when purchasing a new belt weigher. Generally a work order is produced monthly to maintain the belt weighers. The work order is for 1 tradesman for 4 hours to complete the general maintenance of the Belt Weigher. For example, DRE Electrical can charge out a tradesperson at \$65 per hour and not incur any cost to the company. For a month these belt weighers will cost approximately \$260 (4 hours x \$65 per hour) to

maintain. Hence for a year the cost is approximately \$3380 to maintain. The above figures are very conservative and the average tradesman's charge out is \$90 per hour. Therefore increasing the total maintenance cost per year to approximately \$4680.

Therefore a conservative estimate of belt weigher costings to install and maintain for the first year would be as stated in Table 4.2. For each year after the installation only the maintenance costs would be relevant:

<i>Model of Belt Weigher</i>	<i>Basic Cost</i>	<i>Maintenance Costs</i>	<i>Total Costs</i>
HPFS4 Belt Weigher	\$51230	\$4680	\$55810
PFS4 Belt Weigher	\$41760	\$4680	\$46440
PCS2 Belt Weigher	\$32680	\$4680	\$37360
PCX2 Belt Weigher	\$24500	\$4680	\$29180
PCS1 Belt weigher	\$20000	\$4680	\$24680

Table 4.2: Conservative Total Cost of Belt Weighers

4.3 Typical Flow Rates

With belt weighers being the most common weighing device in the mining industry they must be interfaced with the PLC to provide feedback to the operators.

The most common of the older techniques is to provide feedback to the PLC via a 4-20mA analog input module. The mA input is then converted to a weight within the PLC. i.e $4\text{mA} = 0$ tonnes and $20\text{mA} = \text{maximum tonnes}$.

With weighers installed over the last five years the most common way to interface the belt weigher to the PLC is via communications bus. There are many types of communication buses but the majority of these buses in the Bowen Basin are Allen Bradley's DeviceNet and Siemen's Profibus systems. A common layout drawing of the Siemen's Profibus system can be found in Appendix B.

At Riverside Mine the Train Loadout consists of a total of six belts. Figure 4.6 shows

CC1 and CC2 conveyors (coloured purple) feed the clean coal from the Coal Handling Preparation Plant (CHPP) to the product stockpile area where it is stacked via a stacker. The coal from the stockpiles falls into a vibrating feeder and a coal valve on located at the tail end of CC3, CC4, CC5 conveyor. The Coal Valves on each conveyor consist of two vibrators, a control gate which opens in small increments and a cut off gate which opens in larger increments. The vibrating feeder is a vibrating motor attached to a large pan. The coal valve and the vibrating feeder both regulate the flow of coal onto these conveyors. CC3, CC4 and CC5 Conveyors (coloured green) run from under the stockpiles and feed onto the main conveyor belt CC6. CC6 conveyor then feeds directly into the Train Loadout bin. The train travels directly underneath the bin and is loaded by an operator who controls the rate at which the coal is loaded into the bin.

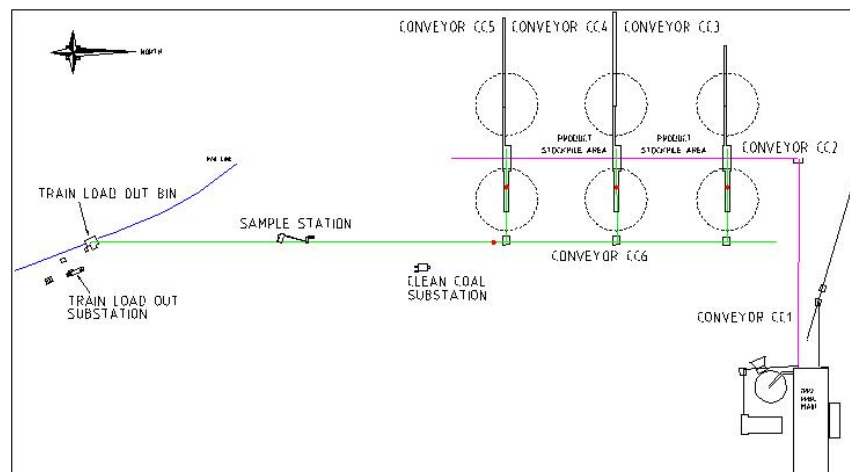


Figure 4.6: Aerial Representation of Riverside Train Loadout

There are four belt weighers used in this particular system. The belt weighers (highlighted red in the above figure) are located on CC3, CC4, CC5 and CC6 Conveyors. The belt weighers are located as close as possible to the coal valves and feeders on CC3, CC4 and CC5 Conveyors. The belt weigher on CC6 is located after the Transfer Head of CC5 and CC6. Typical flow rates in various situations using the belt weighers can be found below:

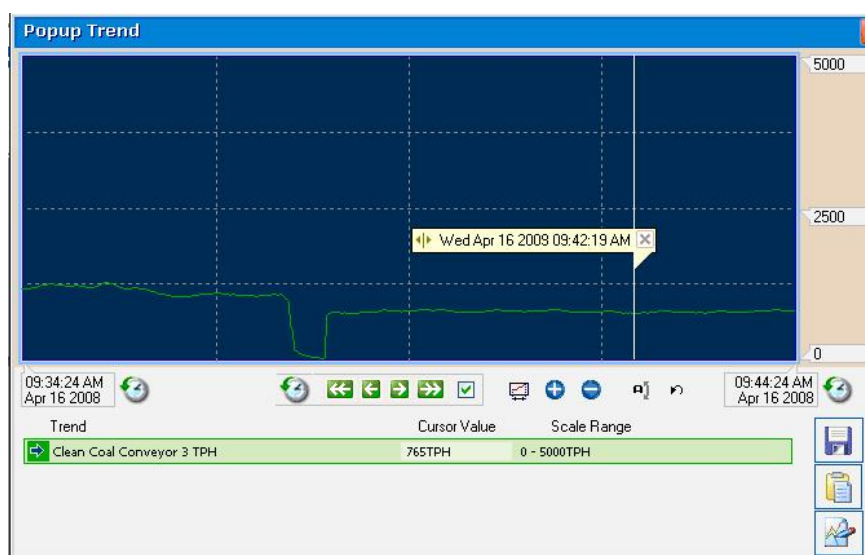


Figure 4.7: CC3 Conveyor Coal Valve Open 235mm

Figure 4.7 shows weight of coal on CC3 Conveyor. On the Coal Valve the cut off gate has been opened to its minimum distance of 235mm while the control gate remains closed. The rate of flow over CC3 Belt Weigher remains fairly constant at 760 - 800 tonnes per hour.

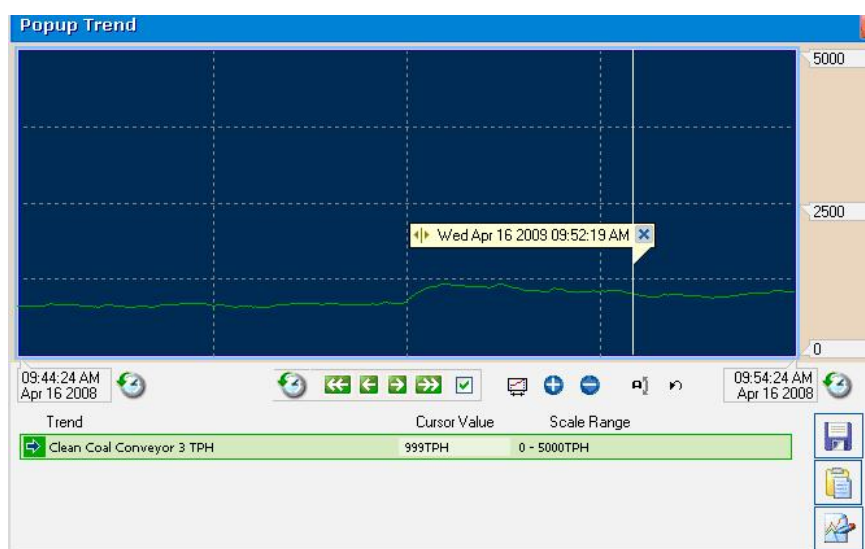


Figure 4.8: CC3 Conveyor Coal Valve Open 280mm

Figure 4.8 shows weight of coal on CC3 Conveyor with the the cut off gate opened to a distance of 280mm while the control gate remains closed. The rate of flow over CC3 Belt Weigher remains reasonably constant at 950 - 1000 tonnes per hour.

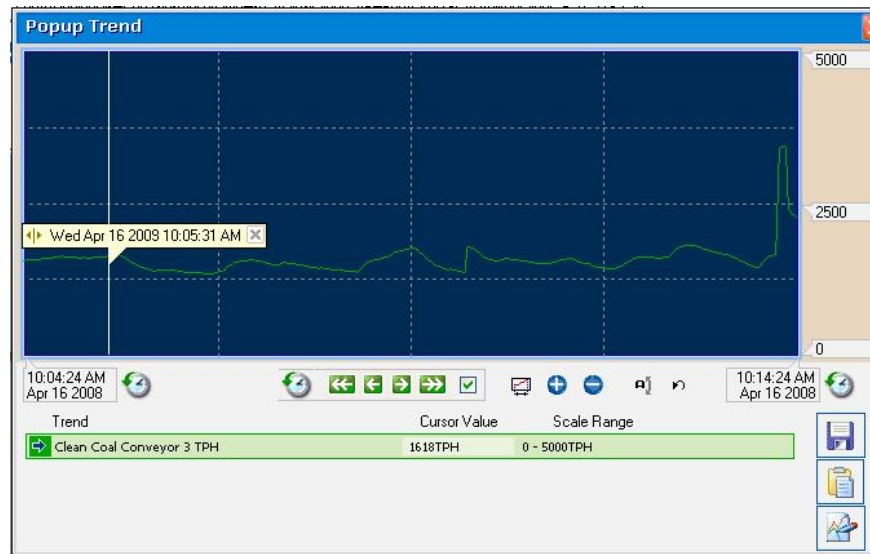


Figure 4.9: CC3 Conveyor Coal Valve Open 305mm

Figure 4.9 shows weight of coal on CC3 Conveyor with the the cut off gate opened to a distance of 305mm while the control gate remains closed. The rate of flow over CC3 Belt Weigher remains reasonably constant at 1600 - 1650 tonnes per hour.

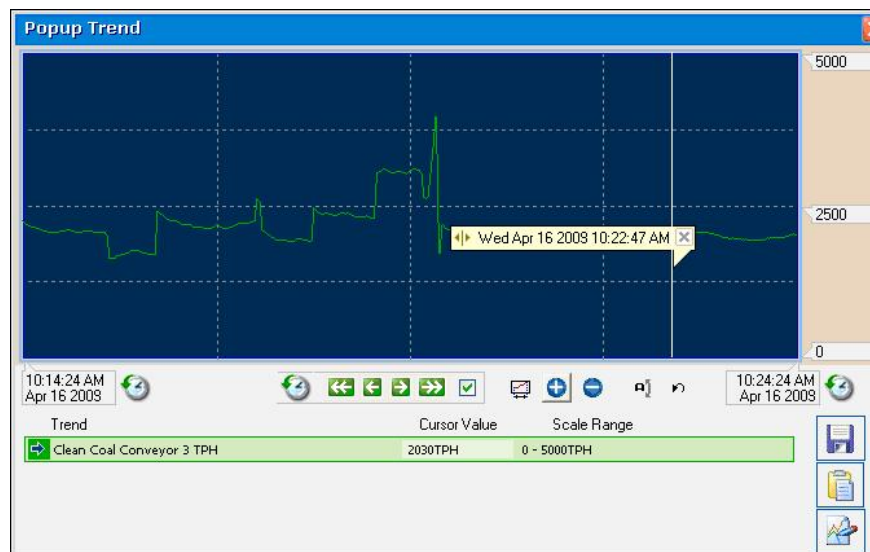


Figure 4.10: CC3 Conveyor Coal Valve Open 350mm

Figure 4.10 shows weight of coal on CC3 Conveyor with the the cut off gate opened to a distance of 350mm while the control gate remains closed. The rate of flow over CC3 Belt Weigher averages 2000 tonnes per hour. The surging weight of coal is caused by coal surging into the coal valve due to the lack of coal on the stockpile.

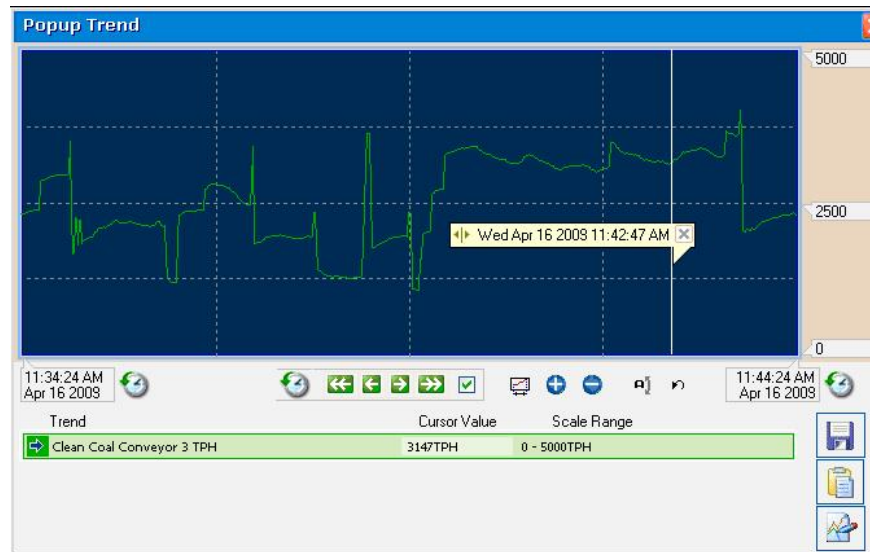


Figure 4.11: CC3 Conveyor Coal Valve Open 395mm

Figure 4.11 shows weight of coal on CC3 Conveyor with the the cut off gate opened to a distance of 395mm while the control gate remains closed. The rate of flow over CC3 Belt Weigher averages 2200 tonnes per hour. The surging weight of coal is caused by coal surging into the coal valve due to the lack of coal on the stockpile. A blocked coal valve alarm has activated and the system is shutdown. The dozers will push more coal onto the stockpile to prevent this from occurring again.

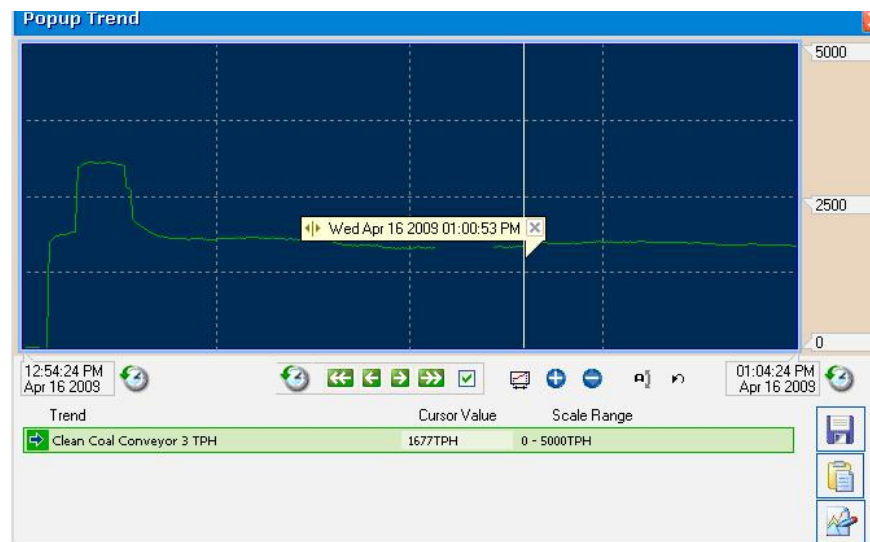


Figure 4.12: CC3 Conveyor Feeder Set at 1700tph

Figure 4.12 shows weight of coal on CC3 Conveyor with only the Vibrating Feeder in operation. The set point on the Citect operator's page has been set to 1700tph. The

rate of flow over CC3 Belt Weigher remains reasonably constant at 1650 - 1700 tonnes per hour.

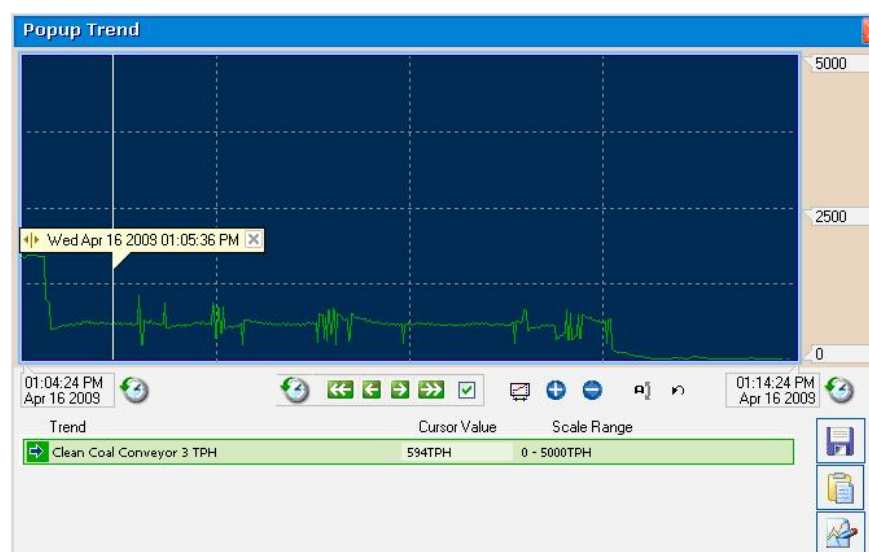


Figure 4.13: CC3 Conveyor Feeder Set At 600tph

Figure 4.13 shows weight of coal on CC3 Conveyor with only the Vibrating Feeder in operation. The set point on the Citect operator's page has been set to 600tph. The rate of flow over CC3 Belt Weigher remains reasonably constant at 550 - 600 tonnes per hour. The lower the tonnes per hour set point the harder it is for the vibrating feeder to regulate itself due to the decrease in frequency required to vibrate the pan.

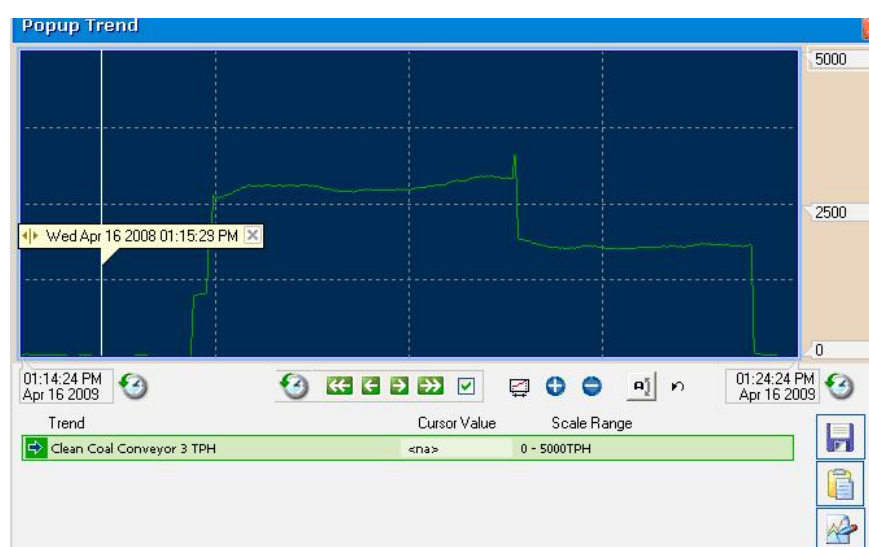


Figure 4.14: CC3 Conveyor Vibrating Feeder Set At 50tph,2600tph,1500tph

Figure 4.14 shows weight of coal on CC3 Conveyor with only the Vibrating Feeder in

operation. The set point on the Citect operator's page has been set to three separate rates, 50tph, 2600tph and 1500tph. The rate of flow over CC3 Belt Weigher remains reasonably constant at these three rates.

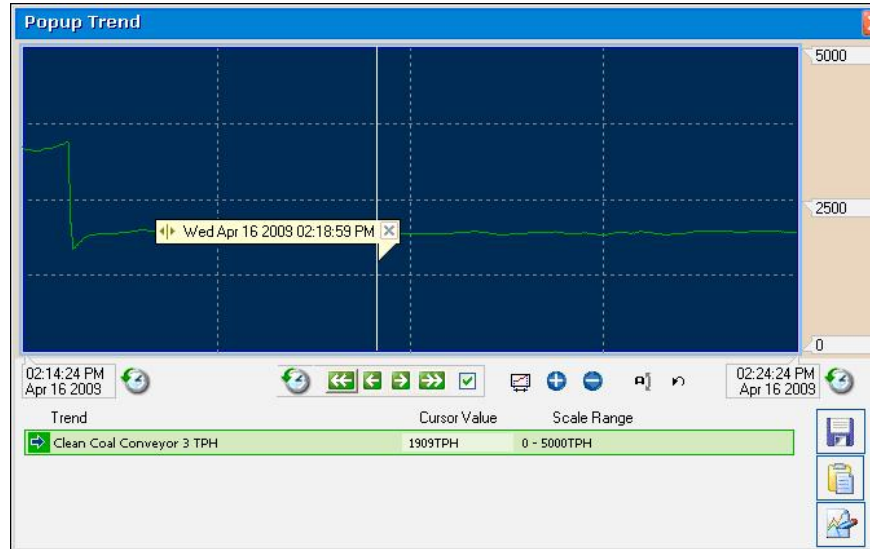


Figure 4.15: CC3 Conveyor Coal Valve Fully Open & Vibrating Feeder Set To 50%

Figure 4.15 shows weight of coal on CC3 Conveyor with the Coal Valve fully open and the Vibrating Feeder operating at 50% stroke (1900tph). The rate of flow over CC3 Belt Weigher remains reasonably constant at 1900tph.

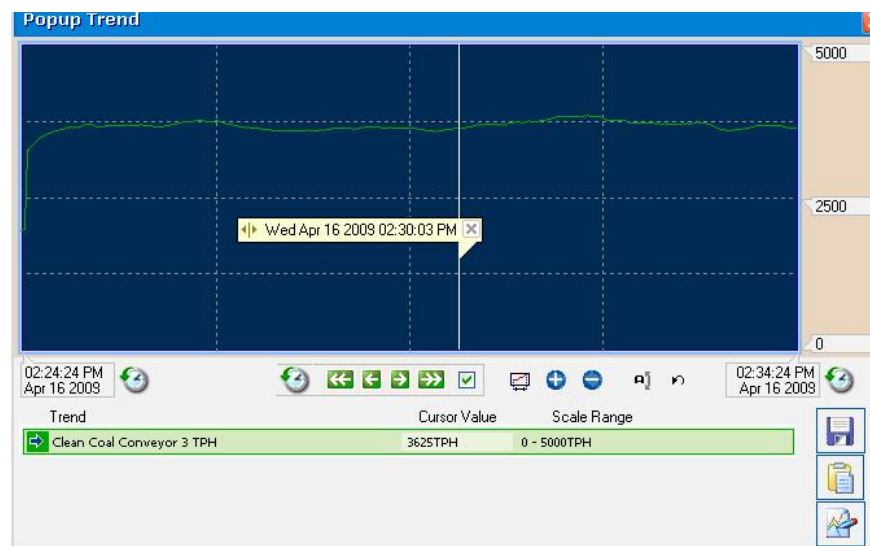


Figure 4.16: CC3 Conveyor Coal Valve Fully Open & Vibrating Feeder Set To 100%

Figure 4.16 shows weight of coal on CC3 Conveyor with the Coal Valve fully open and the Vibrating Feeder operating at 100% stroke (3600tph). The rate of flow over CC3

Belt Weigher remains steady at 3600tph.

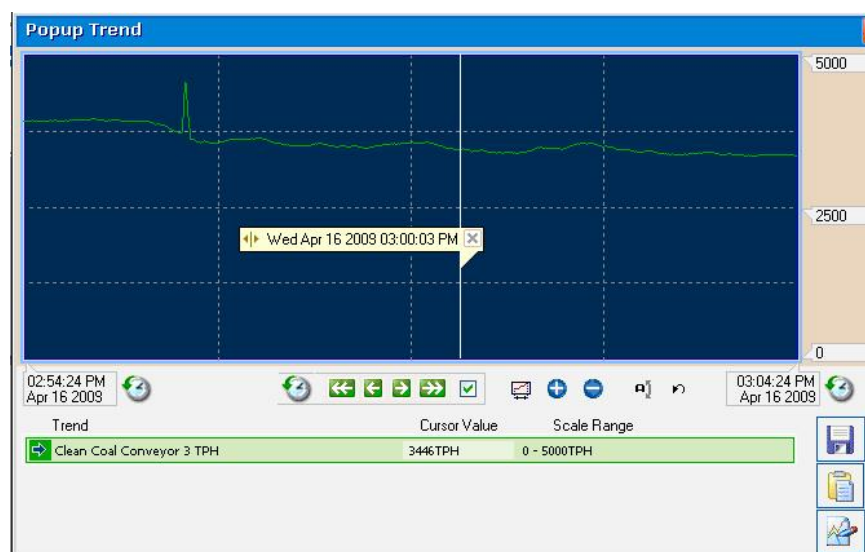


Figure 4.17: CC3 Conveyor Feeder A & Coal Valve B Open

Figure 4.17 shows weight of coal on CC3 Conveyor with the Coal Valve fully open and the Vibrating Feeder operating at 100% stroke (3600tph). The ratio to CC3 Conveyor is then reduced to 3450tph. The rate of flow over CC3 Belt Weigher remains steady at 3600tph and peaks before dropping to approximately 3450tph.

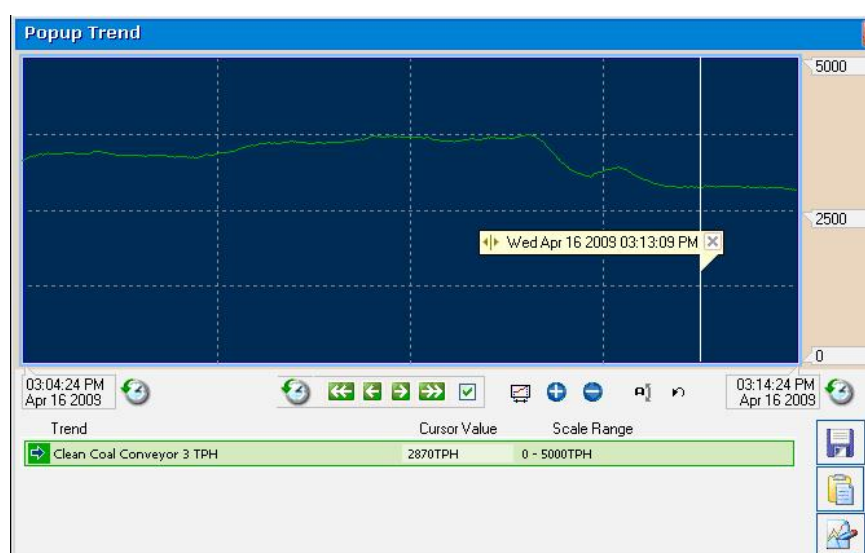


Figure 4.18: CC3 Conveyor Feeder A & Coal Valve B Open

Figure 4.18 shows weight of coal on CC3 Conveyor with the Coal Valve fully open and the Vibrating Feeder operating at 3450tph. The ratio to CC3 Conveyor is then reduced to 2900tph. The rate of flow over CC3 Belt Weigher remains steady at these

rates.

As we can see from the above figures the Belt Weighers have to have a highly sensitive range from as little as 50tph up to as high as 6000tph. The calibration on these machines must be completed on a regular basis i.e every month to maintain the accuracy of each one of these weighers.

4.4 Advantages

The advantages of using a Belt Weigher include:

- Inexpensive (The single load cell model price starts at from \$20000 for a complete unit uninstalled and becomes greater the more load cells added)
- Easily interfaced to majority of PLC's
- Simple design great from maintenance viewpoint The above figures are based on an average of five separate weigher installations by Control Systems Technology. The price is inclusive of design costs.

4.5 Disadvantages

The disadvantages of using a Belt Weigher include:

- Inaccurate
- Timely to install
- Conveyor must be shutdown to install
- Requires ongoing maintenance and calibration
- Maintenance required on the mechanical rollers

Although that the belt weigher is relatively inexpensive to install the regular maintenance costs associated with the up keep of the belt weighers drives the overall cost of the belt weighers upwards.

Chapter 5

Design Approaches

5.1 Overview

There are three other techniques that have been taken into consideration when finding a belt profiling device. These three techniques are:

- Photovoltaic cells
- Video Camera / Web Camera
- Ultrasonics

For reasons discussed below these techniques are inferior to the techniques discussed previously and therefore do not include the detail of the previous sections.

5.2 Photovoltaics

5.2.1 Overview

Photovoltaics is the process known to directly convert light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that

causes them to absorb photons of light and release electrons. These free electrons form a flowing current which can then be harnessed. (Luque & Hegedus n.d.)

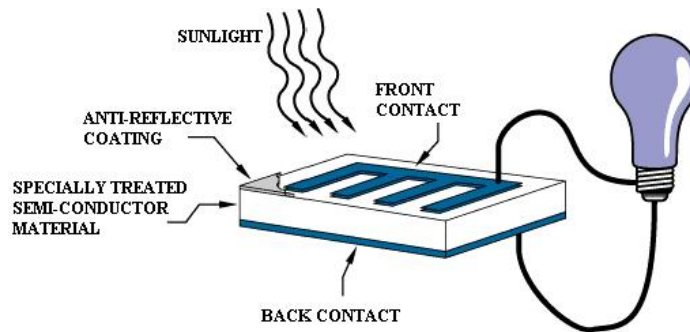


Figure 5.1: Basic Photovoltaic Cell

Picture Courtesy: (Luque & Hegedus n.d.)

Figure ?? above illustrates the operation of a basic photovoltaic cell, also called a solar cell. Solar cells are made of the same kinds of semiconductor materials, such as silicon, used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current. This electricity can then be used to power a load, such as a light or a tool.

A number of solar cells electrically connected to each other and mounted in a support structure or frame is called a photovoltaic module. Modules are designed to supply electricity at a certain voltage, such as a common 12 volts system. The current produced is directly dependent on how much light strikes the module. In general, the larger the area of a module or array, the more electricity that will be produced. Photovoltaic modules and arrays produce direct-current (DC) electricity. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination. (Blakers 2009)

5.2.2 Testing of the Photovoltaic Cell

The testing of the photovoltaic cells incorporated the use three small solar cells connected within a small junction box. Three small pen lasers were also used to provide the source of light.

Step 1 - Installing the Solar Cells Adjacent to the Conveyor

Referring to Figure 5.2 the solar cells were set up on one side of the conveyor, while the three laser pointers were installed to shine directly into the solar cells. A multimeter was incorporated to determine the amount of voltage created when the lasers were directed at the solar cells .



Figure 5.2: Installation of Photovoltaic Cell

The solar cells were installed in the shade of the structure to limit the amount of sun shining into the cells. The below table shows the voltage reading taken when the lasers were directed at the solar cells.

5.2.3 Advantages

The advantages of using the a photovoltaic array include:

No. of Lasers	Voltage (VDC)
1	0.034
2	0.055
3	0.092

Table 5.1: Voltages From Photovoltaic Cells

- Non contact conveyor profiling
- Minimal maintenance

5.2.4 Disadvantages

The disadvantages of using the a photovoltaic array include:

- A large vertical array of lasers and cells would be required to produce an accurate profile
- The unit does not take into account the moisture content of the coal
- Medium to high capital cost
- The system must be installed out of the sun
- The system would only work effectively on a flat belt system

5.2.5 Conclusion

Although the experiment was very basic, it showed that it is possible for a photovoltaic system to be installed on a conveyor to profile the product. A large array would be required to adequately show the correct resolution. For this specific application in the coal industry the photovoltaic cells were deemed not suitable for the profiling of a belt due to the medium to high capital coat incurred when installing the device. It would be possible to establish this kind of system within process plants, although a number of factors may have to be taken into account when installing the device such as:

- The belt is flat
- The installation would require adequate protection from sunlight

A system which incorporated the above features would likely to be very similar to Figure 5.3 below.

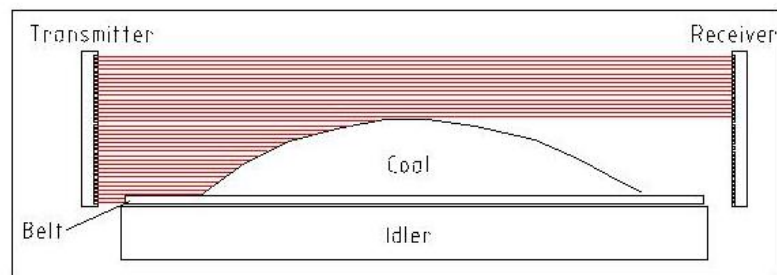


Figure 5.3: Photovoltaic Cells Profiling Product On a Conveyor Belt

5.3 Video & Web Cameras

5.3.1 Overview

Security/Surveillance video cameras are positioned at all transfer points and along the belt lines, load-outs, silos, bins, stockpiles inside of plant. Security cameras are at the gates for incoming and outgoing and on the scales for incoming trucks and outgoing trucks. An interconnected fibre network provides the backbone for these devices to operate adequately for mine usage.

At all underground mines within the Bowen Basin, coal is transported to the surface on a conveyer belt and when this belt breaks the conveyor has to be stopped for maintenance and coal production comes to a halt until the belt is repaired and started again.

Depending on the mine and the location of the break, this can cost tens of thousands of dollars in lost revenues in a very short period of time. Conveyor belt video inspection systems, or an automated inspection system monitoring the belt where it is most likely to fail, namely the belt splices, provide images of the belt splices to the mine personnel for evaluation resulting in proactive action prior to belt splice failure. Therefore detecting and correcting potential failures before they happen and minimizing potential downtime.

This is due to the repair of a splice before it fails can be accomplished in a significantly shorter amount of time than it takes to repair a broken belt. The belt video inspection system hardware consists of cameras for imaging the belt, lighting for illuminating the belt, a computer for digitizing and analyzing the camera image, a flat panel touch screen display for a local user interface and power distribution components. Depending on the level of control room integration, the computer, screen and power distribution components would be used in multiple roles for multiple sub-systems. Mine personnel can review splices several times a day with minimal effort.

There are many monitoring systems for conveyor belt systems. The above system has its advantages and a possible solution to belt profiling would be to incorporate a unit that also profiles coal on a belt.

To integrate the two systems together it is anticipated that the video camera would be utilized to profile the belt. Also incorporated into the system would be a software used in a similar fashion to facial recognition software.

5.3.2 Testing of the Video / Web Camera

To determine if a video camera profiling system would work adequately within the mining environment it was decided to test how well a laser could be seen on a conveyor belt.

Using the conveyor test rig set up in the previous examples the pen lasers were installed to point directly at the belt.



Figure 5.4: Testing Laser Effectiveness on a Conveyor Belt (Shade)

The above images (Refer Figure 5.3) are of the lasers pointed directly at the belt whilst in the shade. As you can see the laser dots are visible although the further away from the belt the harder the dots of light are to pick up. The figure (Refer Figure 5.4) below shows the lasers pointing directly at the belt, this time in full sun.

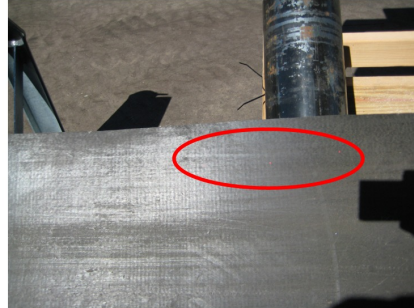


Figure 5.5: Testing Laser Effectiveness on a Conveyor Belt (Sunlight)

As you can see from Figure 5.4 the laser dots of light are very hard to see when the laser pointers are positioned in the direct sun.

5.3.3 Conclusion

The above tests showed that there were major inconsistencies with the laser light becoming visible as it moved from the sunlight and into the shade. Major development would be required to refine the above system to a point where the coal recognition software can accurately determine the profile of moving coal. In addition to the above, the capital cost of such a system would be very high. Listed below are some of the costs associated with installing such a system.

Equipment / Labour	Cost
Fibre Optic Cable	\$145/m (As quoted by Group Engineering 06-08-09)
Fibre Terminations	\$120/ termination (As quoted by Group Engineering 06-08-09)
Video Camera and Associated Software ¹	\$45276 (As quoted by Group Engineering 06-08-09)

Table 5.2: Video / Web Camera Associated Costs

Majority of the mines do not have the fibre network available within the local proximity to all of their conveyors. The additional cost of installing a fibre optic backbone is a major disadvantage. Additionally the high capital cost when compared to a laser profiling device such as the LMS-111 proves that the video camera belt profiling system is not viable for this particular application.

Chapter 6

Laser Head Units

6.1 Overview

The second technique that will be discussed is the use of a laser to scan material flowing along a conveyor belt. There are a number of laser scanning techniques that may be utilized to profile coal travelling along a conveyor belt. Typically the lasers operate in basically the same manner. Although there are a number of lasers that maybe adapted to this type of application, two separate units were chosen to discuss below. The laser units both use a similar technique to determine firstly the cross dimensional area of product and secondly the volume of the product on the belt. As per the diagram below (Figure 6.1) the lasers scan the belt while it is empty, stores the belt profile and then calculates the empty belt area A_1 .

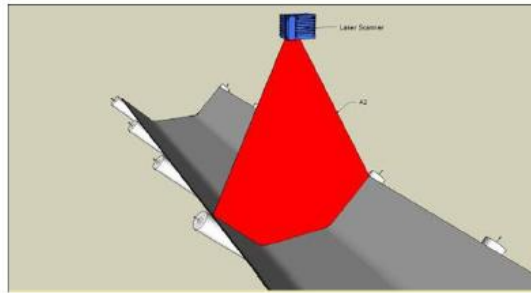


Figure 6.1: Scanning Empty Belt

Picture Courtesy: (*The New LMS100 Laser Measurement System* 2009)

As material passes underneath the laser the system then calculates the reduced area A2. Refer Figure 6.2 and Figure 6.3

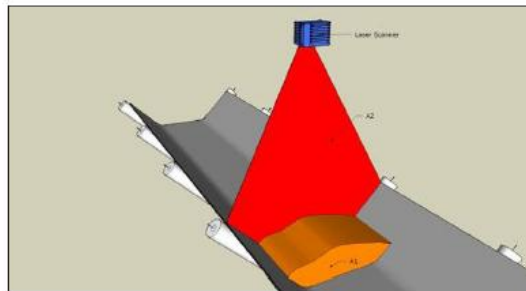


Figure 6.2: Scanning Product On Belt

Picture Courtesy: (*The New LMS100 Laser Measurement System* 2009)

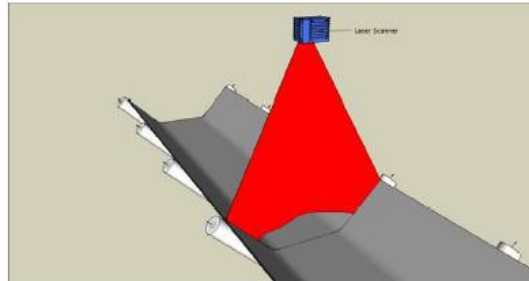


Figure 6.3: Determining Product Area

Picture Courtesy: (*The New LMS100 Laser Measurement System 2009*)

The calculated material area is calculated via Simpson's rule as $A_1 - A_2$ as demonstrated in Figure 6.4. The volume of material can then be determined only once the belt speed is known. All these values are sent to the Main PLC where through a number of algorithms the volume and the weight of the material can be determined.

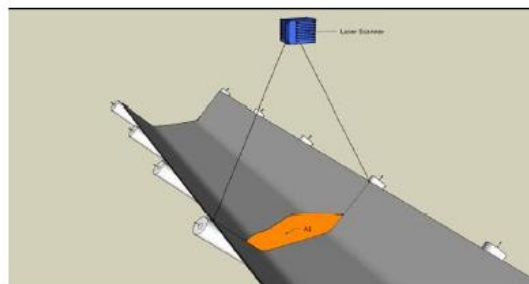


Figure 6.4: Determining Product Area

Picture Courtesy: (*The New LMS100 Laser Measurement System 2009*)

6.2 LMS-111 Laser Unit

6.2.1 Overview



Figure 6.5: LMS-111 Laser Scanner

The LMS100 Laser Measurement System from SICK is typically utilized for collision prevention and navigational support on vehicles in container ports, in intralogistics and on service robots; traffic-related applications on signalling systems and toll stations; positioning and path guidance on automated agricultural vehicles; monitoring shelf fronts; checking pallets are empty; or as a control system for picking processes.

It was decided to test run this particular device firstly due to its low cost and secondly it also provides a simple and inexpensive solution to the problem of profiling material on a moving conveyor belt. The sensor offers a scanning angle of 270°, angular resolution of 0.25°, scanning frequencies of up to 50 Hz, and ranges of 20 m or 18 m on jet-black objects (with a typical reflectivity of only 10%). The device is small, requires little electricity, and offers a voltage input of 9 - 30 V. As per the specifications the LMS-111 can provide effective detection through heavy airborne particles, such as sawdust sprays from woodcutting machinery, improving its usability. It is IP67 environmentally protected, and is designed for outdoor use in harsh environments including highways, docks and harbours and the coal mining industry.

Connection to the device is via either Ethernet or RS-232. There are four inputs, two of which can be used as encoder inputs, as well as three digital switching outputs, while further switching outputs can be formed via external CAN modules. The 4 - 20mA analog output settings are listed below:

- Channel 1 - Area / Volume: The cross-sectional area of the material on the belt in square engineering units. Cross sectional area resolution 5 cm (Volume accuracy dependant of belt speed)
- Channel 2 & 3 - Left Hand and Right Hand Side Belt Edge Distance: The laser unit can determine the edge of the conveyor and where the material is positioned in relation to the edge. If the conveyor is under loaded, a control loop may be utilized to control the amount of product on the belt. This would ensure that the belt is being used to its full capacity.
- Channel 4 - Health Status: Indicates if the device is healthy or not

6.2.2 Testing of the LMS-111

Step 1 - Erecting the Conveyor To test the laser unit a conveyor was needed.

Due to the safety requirements and the time constraints required on site to shut down and install the device on a conveyor a make shift conveyor was erected. Refer Figure 6.6. The conveyor consisted of four idler frames and idlers and an old piece of conveyor belt. The conveyor belt could be pulled over the idlers to simulate movement of the conveyor.

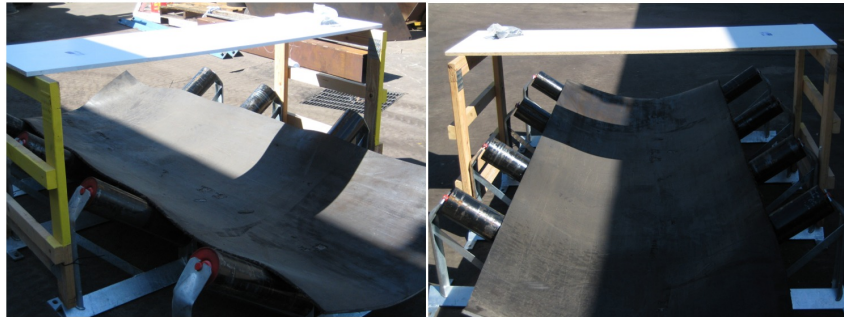


Figure 6.6: Test Conveyor

Step 2 - Mounting & Programming the Laser

The next step was to adequately mount the laser unit as per the figures below. (Refer Figure 6.7)

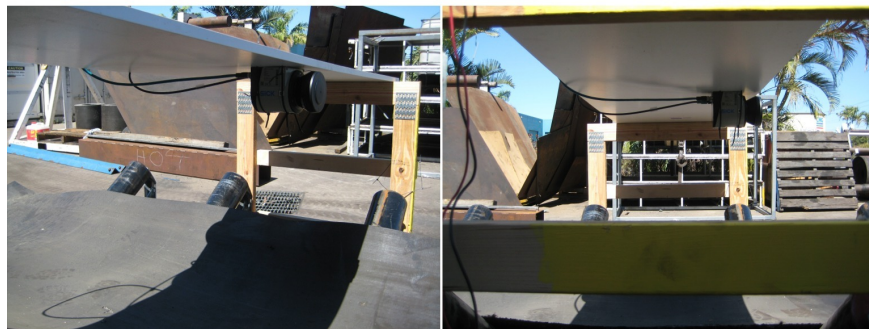


Figure 6.7: Installation of the LMS-111

Once the laser was secured it was just a matter of setting up the laptop with the required software and running the simulation program which comes with the laser. The following screen dumps were taken during the testing process. As discussed above the laser requires an empty belt to calibrate. Figure 6.8 shows what the laser scanner sees when mounted above an empty belt. From the scan you can determine where the edge of the belt finishes and the idlers start.

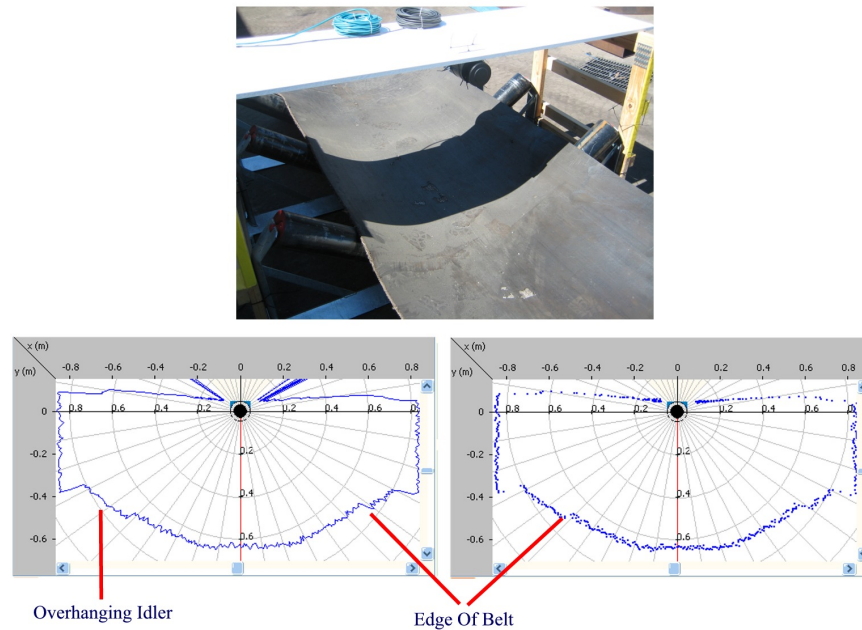


Figure 6.8: Calibration on Empty Belt

Step 3 - Scanning of a Large Object

The next test was to see if the laser could detect the image from a large object. Figure 6.9 shows a 20 litre container being placed on the conveyor and pulled underneath the scanning device. From the scan you can see the raised lid of the container. There is a little shadow on the sides of the container where the laser cannot 'see'. If the laser were meant to scan large objects there may be discrepancies in the actual area and the scanned area resulting in a larger totalized weight.

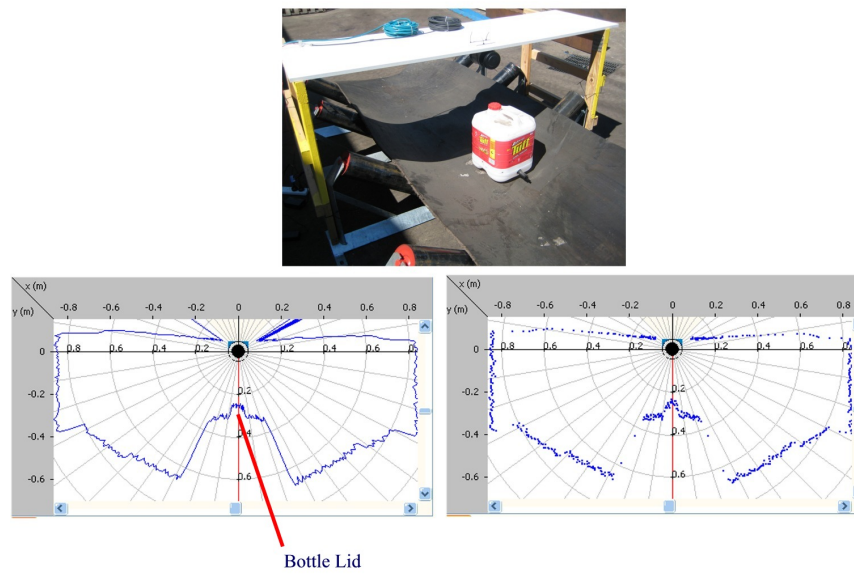


Figure 6.9: Scanning of Large Object

The container was then placed to one side of the conveyor to determine if the laser would still cast a 'shadow' over a particular area. Figure 6.10 shows there is little difference between shadows cast when the object is directly under the scanner or to the side.

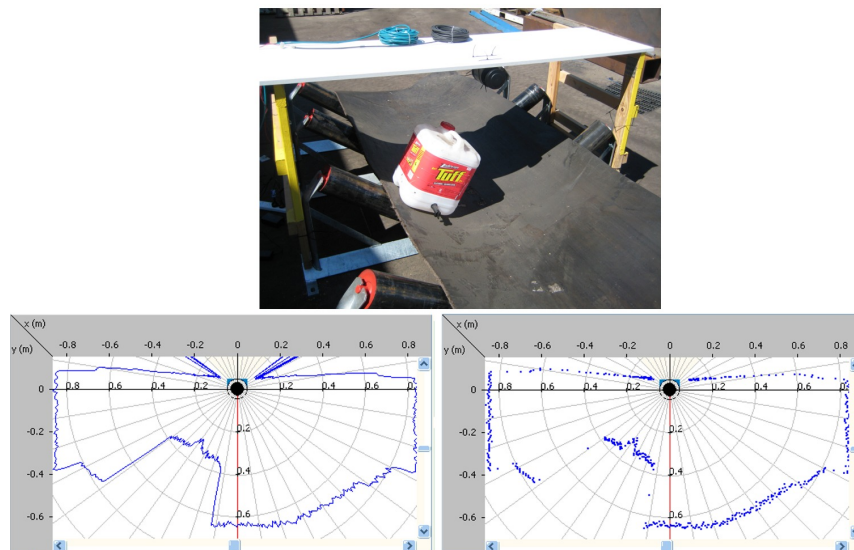


Figure 6.10: Shadow Cast from Large Object

Step 4 - Scanning of a Small Object

The next step involved the scanning of a smaller object to determine the resolution of the device. This is required because a small amount of matter that has been disregarded over a long period of time amounts to quite a substantial amount of lost product. Coal being the predominant product scanned is also small in size and therefore the test will show the accuracy of the laser scanner. Figure 6.11 shows the smaller container adequately.

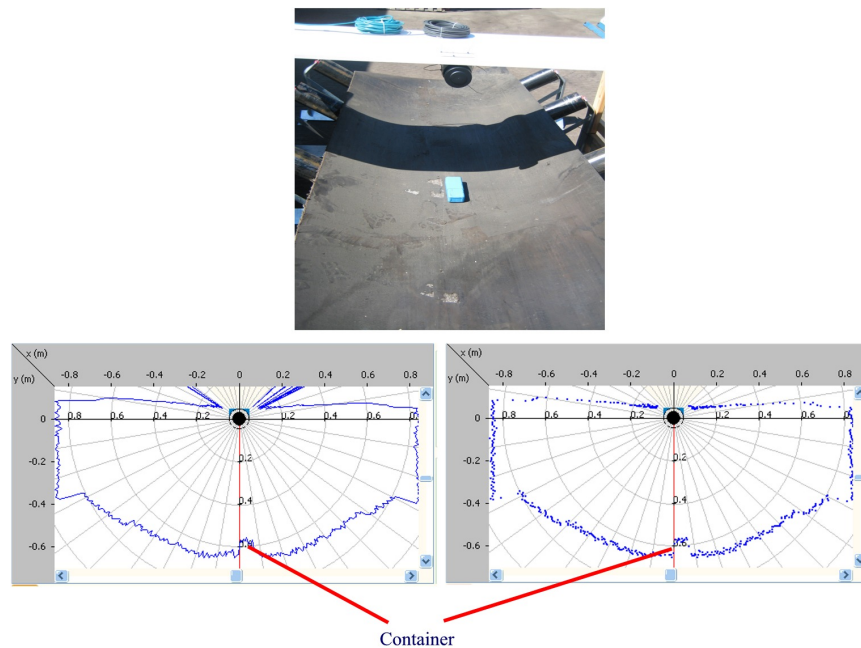


Figure 6.11: Scanning of a Small Object

Step 5 - Scanning of an Irregular shaped object

To determine if the laser could adequately scan the irregular shape of coal, these lengths of timber were placed on the conveyor. The laser scan shows the profile of the timber and even when moved apart the gaps are shown on the scan.

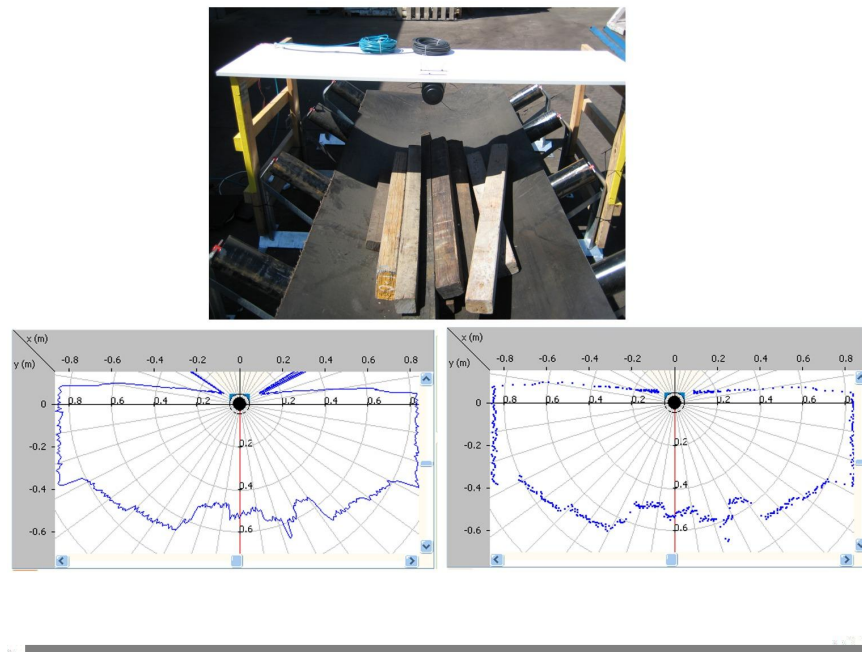


Figure 6.12: Scanning of Scattered Timber

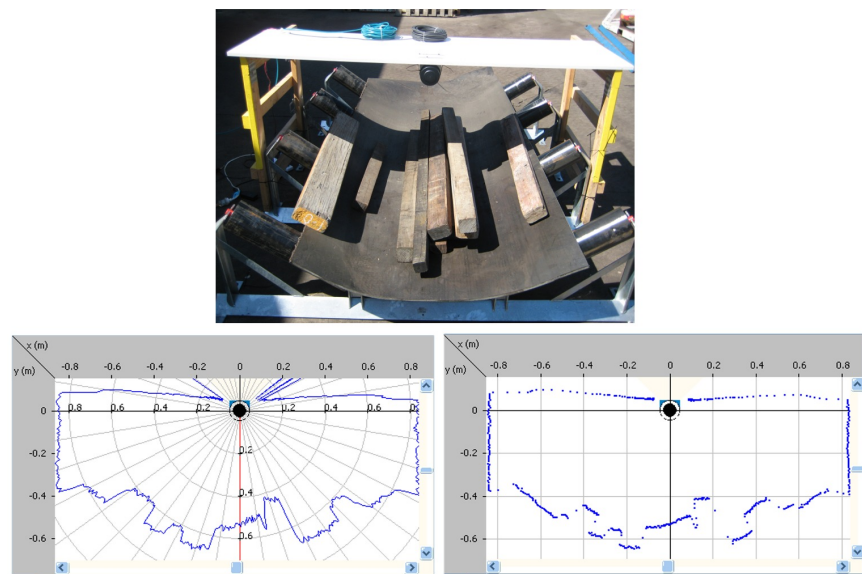


Figure 6.13: Scanning of Scattered Timber With Gaps

6.2.3 Advantages

There are a number of advantages for the LMS-111. These advantages are listed below:

- Non contact conveyor volume/weight measurement
- Low capital cost
- Minimal maintenance
- Simple quick calibration process
- Can be setup to provide a number of options which may include:
 - Belt drift monitoring
 - Belt Tear Alarming
 - Increased productivity by determining where the product is positioned on the belt and hence controlling the maximum allowable amount of product on the belt
 - Increasing productivity by reducing the amount of spillage along a belt

6.2.4 Disadvantages

There are a few disadvantages for the LMS-111. These disadvantages are listed below:

- The stability of the electronics within Devices
- Requires the use of a moisture meter to determine the weight of the coal

6.2.5 Conclusion

The LMS-111 laser scanner is a cheap and effective solution for providing a profile of coal along a conveyor belt. An accurate profile is required to determine the weight of coal on a conveyor belt. As can be seen from the scans the image produced is

accurate and with the correct algorithms will be able to produce an accurate weight. The laser seems to cope well with preliminary scanning and the next step is to mount the device above an operational conveyor to determine if the device can operate as effectively in the harsh environment of a coal mine.

6.3 LM2D Laser Unit

6.3.1 Overview

K-Tek's primary product for bulk scanning of solid material is the LM2D Laser. This laser "is a real-time noncontact volume scanner for conveyor based materials that provides an accurate, easy to use and maintenance free alternative to belt scales." (*Laser Scanners Promise Volumetric Accuracy* 2008)

The LM2D uses a rotational laser head that uses a number of points to determine the profile of the material that is being scanned. A 3D map is created of the surface of the material and the head unit of the laser uses algorithms to calculate the scanned material's volume and weight. These measurements can then be sent via a RS232 or 4-20mA interface to any associated PLC equipment. Figure 6.14 shows an overview of the LM2D Laser unit and its features.

The 4 - 20mA analog output settings are listed below:

- Channel 1 - Flow: The flow of material on the conveyor belt in engineering units per minute. The 4mA value will typically remain at 0.00 whilst the 20mA value will be the highest expected flow rate.
- Channel 2 - Speed: The speed of the conveyor belt in engineering units per second. The 4mA value will typically remain at 0.00 whilst the 20mA value will be the highest expected speed.
- Channel 3 - Area: The cross-sectional area of the material on the belt in square engineering units. This output can be used on instruments without a radar

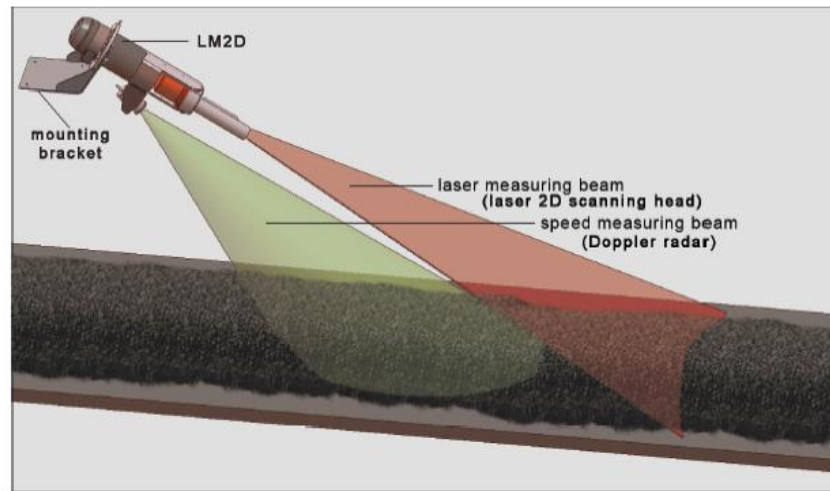


Figure 6.14: LM2D Laser

Picture Courtesy: (*Laser Scanners Promise Volumetric Accuracy* 2008)

speed sensor. The material flow can be calculated from this area multiplied by the speed of the conveyor belt as measured externally.

- Channel 4- Totalizer: The Totalizer shows accumulated (or total) volume or mass over an elapsed time period.

The LM2D Laser Unit uses the following resources: Infrared laser: Class 1M infrared beam (905nm) used to measure distance

Wavelength	905nm
Peak power	24W
Pulse duration	0.48uJ
Pulse rep frequency	25khz
Pulse energy	50nJ
Beam diameter	20mm
Divergence	6mrad

Table 6.1: LM2D Specifications

Laser pointer: Class 3R visible beam (wavelength 635nm) for aiming purpose:

- Wavelength 635nm
- Power less than 2mw CW
- Beam Diameter 5mm
- Divergence less than 1.5mrad

According to IEC60825-1, Ed 1.2, 2001-08, this product is designated as Class 3R during all procedures of operation.

6.3.2 Advantages

The advantages of using the LM2D Laser include:

- Simple and inexpensive installation as there are only two cables (power and control) that are required.
- Mounting of the device is relatively simple and the LM2D Laser can be mounted virtually anywhere with a minimum of fuss.
- It is a non-contact measuring device
- It can also be used to monitor belt speed using a second measuring head and utilizing Doppler Radar to determine the speed of the belt
- No calibration and minimum maintenance
- No special software required

6.3.3 Disadvantages

The disadvantages of using the LM2D Laser include:

- The LM2D Laser is quite expensive - \$29,000 as quoted on the 30th March 2009
- The unit does not take into account the moisture content of the coal

- The smaller the amount of material on the belt the greater the error produced (Refer Figure 6.15)

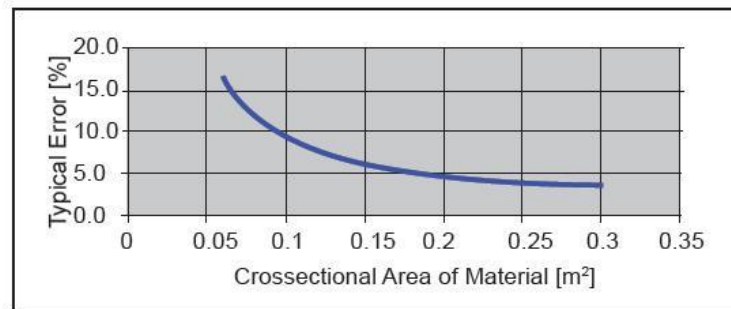


Figure 6.15: LM2D Error Vs Crossectional Area

Picture Courtesy: (*Laser Scanners Promise Volumetric Accuracy* 2008)

6.3.4 Conclusion

Although there are a number of advantages of using the laser system, the cost of the unit is a major setback as companies will also have to factor in design costs, installation costs and the procurement of materials required to complete the installation.

Chapter 7

Implementation and Testing

7.1 Implementation and Testing

As noted above, there are many methods and devices to profile product on a belt. Armed with the above information a decision on the best particular device for the intended application is necessary. Below is a table (Table 7.1) which shows the advantages and disadvantages of each device.

	Belt Weighers	PV Cells	Camera Systems	LMS- 111 Laser	LM2D Laser
Cost	Medium	Low	Very High	Medium	High
Accuracy	5/10	5/10	3/10	9/10	9/10
Installation	Involved	Involved	Involved	Simple	Simple
Maintenance	Ongoing	Minimal	Minimal	Minimal	Minimal
Non Contact Measurement	No	Yes	Yes	Yes	Yes
Calibration	Simple	Involved	Involved	Simple	Simple
Stability	7/10	7/10	6/10	8/10	8/10

Table 7.1: Comparison of Units

After the testing of multiple units it has been found that the most cost effective device is the LMS-111 laser scanner. This is an excellent device that is capable of being utilized in various areas around the train loadout to fulfil the requirements of automation. This device is relatively inexpensive when compared to other weight measuring devices available. Although it does not provide all the features of its competitors the LMS-111 laser scanner provides more than adequate information for various applications. Basically with other models you are paying for features that are not required for this particular application i.e train loadout automation.

Using Goonyella Riverside Mine as an example, Figure 7.1 shows where the LMS-111 laser scanner may be utilized in the design of an automated train loadout for a Coal Handling Prep Plant.

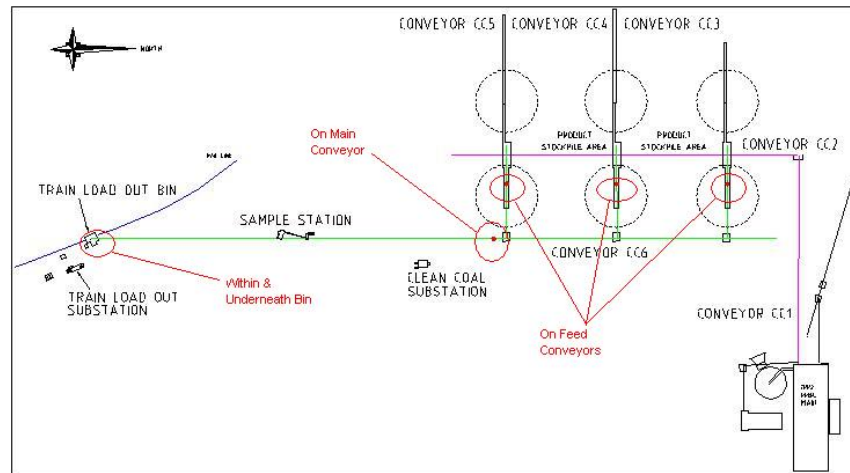


Figure 7.1: LMS-111 Locations

The LMS-111 laser can be used in a number of locations. Firstly, within the train loadout bin for the purpose of bin level measurement. The laser will provide a low and high level alarm and will also be used in a PID loop. Once the bin reached a certain predefined level, the laser in conjunction with the PLC uses a PID loop to control the speed of the belts (assuming the belts are Variable Speed Drives). This loop would maintain the bin level and reduce the number of stop / starts the conveyor belt requires if the bin level becomes too high normally. The device and code in conjunction with existing hardware infrastructure will be used to consistently control the bin level on a train load out facility. As a result an increase in productivity occurs.

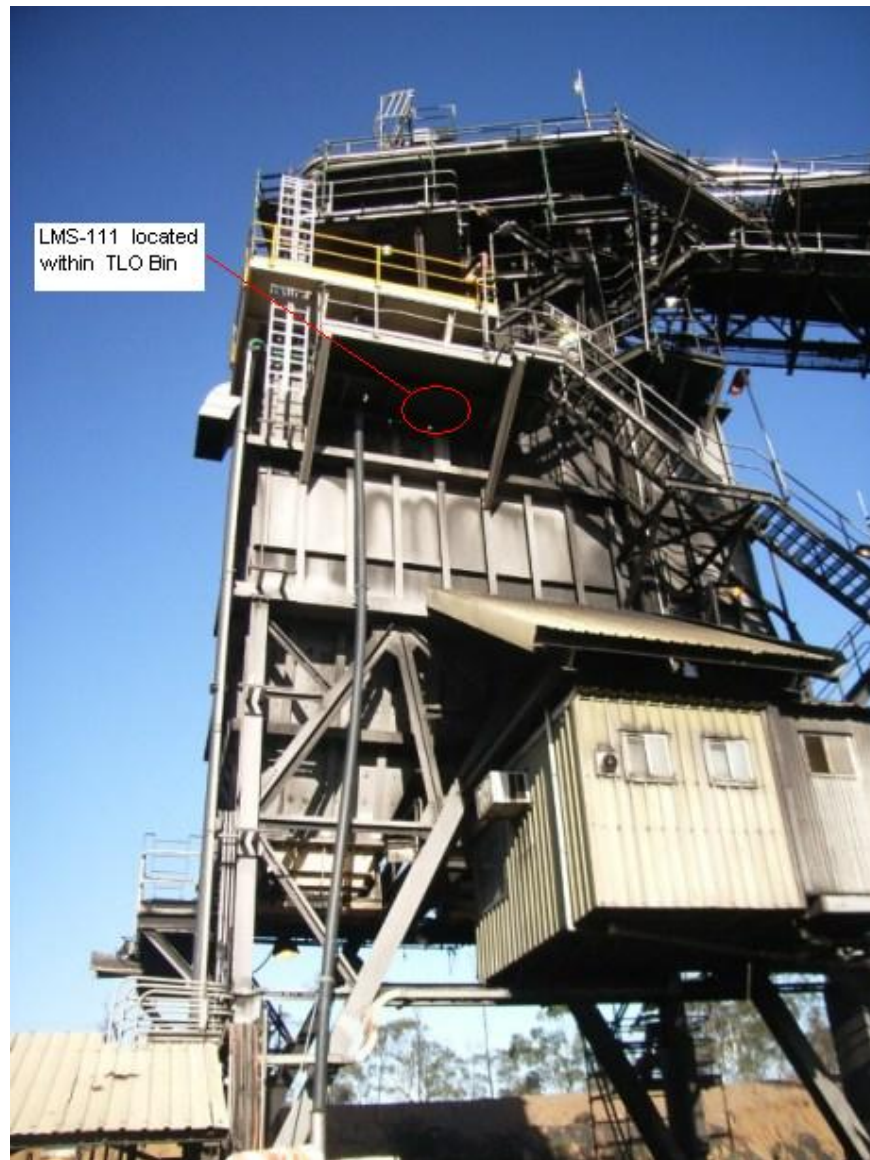


Figure 7.2: LMS-111 Located Within TLO Bin

To profile coal on a moving conveyor belt the LMS-111 Laser scanner is also the device most capable for determining the profile and converting the information to usable data within the PLC.

A minor setback for the development of a working model is that the weight of coal depends on the amount of moisture that the coal retains. This can be overcome if an inline moisture analyzer is installed. Sampling of the coal will need to continue to determine the ash content of the coal being loaded.

Therefore secondly, a LMS-111 which incorporates a moisture meter in the design

would be more than adequate to profile the coal on the main conveyor belt. This device would be located on the main conveyor just after the last transfer tower chute. Once the profile is determined this data can be integrated with the data from the moisture meter to determine the weight of coal on the belt. From here it will be possible to determine the amount of coal heading into the bin from the main conveyor. Using the PLC to integrate the profile and determine the weight, the LMS-111 would replace the existing belt weighers. The LMS-111 may also replace belt drift and belt tear switches if used to its full potential. A margin of error can be set up within the software of the LMS-111 to state if the belt is drifting too far in one direction. If the belt drifts too far an alarm can be sent to the operators via the PLC and the SCADA system. Similar profiling can also be used to determine if the belt has been split or even if the edges are damaged.



Figure 7.3: LMS-111 Located On Main Conveyor

A third position for the laser unit is within the tunnels coming from underneath the coal stockpiles. The device would be installed directly after the coal valves. The purpose of this laser would be to include it within a PID loop which controls the opening and closing of the coal valves. For example, if there was not enough coal on the belt the LMS-111 would signal the coal valve to open hence more coal on the belt. Once again escalating productivity by using the belt to its full potential and therefore increasing train loading speeds. The device may also be used instead of a belt weigher to weigh the coal and also as a replacement for belt drift and belt tear switches in this position on the feed conveyors.



Figure 7.4: LMS-111 Location on Feed Conveyor

The forth position, is to use multiple laser scanners underneath the train loadout bin to determine the amount of coal within each train wagon. The laser scanners would be installed before each one of the hopper doors and therefore by scanning the amount of coal within each wagon a number of PID loops may be utilized which would be used to control each of the hopper doors below the train loadout bin. Normally an operator would control the opening and closing of these doors, but with the LMS-111 the operator would no longer be required. Once set correctly an exact weight of coal would be able to be placed into each carriage. The PID loop must also take into consideration how fast the train is travelling.



Figure 7.5: LMS-111 Locations Underneath TLO Bin

Chapter 8

Conclusions and Future Work

8.1 Conclusions and Future Work

In summary the objectives stated in Chapter 1 have been achieved throughout the project. These objectives and the discussion relating to these points are listed below:

- Determine the requirements for automating a train loadout (Chapter 1.4)
- Determine what coal is made of (Chapter 3.3)
- Research possible methods for volumetric measurement of coal on a conveyor belt including methods such as:
 - o Ultrasonics (Chapter 3.7)
 - o Photovoltaic cells (Chapter 5.2)
 - o Video and web camera imaging (Chapter 5.3)
 - o Belt weighers (Chapter 4)
 - o Various laser techniques (Chapter 6)

When researching these methods a number of factors will be considered including:

- o Reliability of head unit in harsh environments

- o Power supply
 - o PLC requirements
 - o Mounting
 - o Installation
 - o Cost
- Conceptual Design (Chapter 8)

From the workshop testing of the LMS-111 an automated Train Loadout facility based on this device is a reality. Further testing of the devices within the field will determine if the LMS-111 is a suitable product for use in this application.

As a result of the above decision, a project package for the installation of the LMS-111 has been developed and plans are currently underway to test and commission the device on an inloading conveyor at Dalrymple Bay Coal Terminal, located 30km south of Mackay.

Unfortunately the work conducted after the conceptual design of the LMS-111 is out of the scope for this particular project, but I do foresee the continuation and development of an automated control system consisting of a number of LMS-111 laser scanners.

References

(n.d.).

Balancing Economics and Environmental Friendliness (2006).

http://www.powergeneration.siemens.com/download/pool/PGE2005_BalancingEconomics.

Belt Weigher Overview (2009).

<http://www.controlsyste.ms.com.au/products/belt-weighers>.

Blakers, A. . (2009), *Solar and Wind Electricity in Australia*, Vol. 7, Australian Journal of Environmental Management.

<http://solar.anu.edu.au/pubs/papers/SolarWind.pdf>.

Bowen Basin Central Queensland (2008).

http://www.bowenbasin.cqu.edu.au/basin_data/map.html.

Britannica (2004), *Coal mining: ancient use of outcropping coal*.

Clean Coal Facts and Figures (2006).

Coal (2009). http://www.nymex.com/coa_fut_descri.aspx.

Coal And The Environment (2008).

http://www.columbia.edu/~jeh1/2007/IowaCoal_20071105.pdf.

Coal Market Prices (2009).

<http://www.eia.doe.gov/cneaf/coal/page/coalnews/coalmar.html>.

Coal Produced Electricity (2009).

<http://www.worldcoal.org/pages/content/index.asp?PageID=188>.

Committee on Resources-Inde (2005a).

<http://resourcescommittee.house.gov/archives/108/testimony/johnmasterson.htm>.

Committee on Resources-Inde (2005b).

<http://www.fire.blm.gov/textdocuments/6-27-03.pdf>.

Cunliffe, B. W. (1984), *Roman Bath Discovered*, London: Routledge, chapter 1.

Department of Energy (1999), 'CO₂ Carbon Dioxide Emissions from the Generation of Electric Power in the United States'.

EHP 110-5, 2002: Forum (2005).

<http://ehp.niehs.nih.gov/docs/2002/110-5/forum.html>.

Fisher, J. (2005), 'Energy Density of Coal'.

<http://hypertextbook.com/facts/2003/JuliyaFisher.shtml>.

Forbes, R. J. (1966), *Studies in Ancient Technology*, Brill Academic Publishers, Boston.

Fossil Power Generation (2009).

<http://w1.siemens.com/responsibility/en/environment/portfolio>.

Golas, P. J. & Needham, J. (1999), *Science and Civilisation in China*, Vol. 1, Cambridge University Press, Cambridge, UK, pp. 186–191.

Haul, R. (1985), *Chemie in unserer Zeit*, Vol. 1, Cambridge, UK, p. 62.

Hook, M. & Aleklett, K. . (n.d.), *A Review on Coal to Liquid Fuels and its Coal Consumption*.

How much coal is required to run a 100-watt light bulb 24 hours a day for a year?

(2006). <http://science.howstuffworks.com/question481.html>.

ICE: Coal Futures (2009). <https://www.theice.com/coal.jhtml>.

Kirk & Othmer (2004a), *Encyclopedia of Chemical Technology*, Wiley-Interscience, chapter Acetylene.

Kirk & Othmer (2004b), *Encyclopedia of Chemical Technology*, Wiley-Interscience, chapter Ethanol.

Laser Scanners Promise Volumetric Accuracy (2008).

<http://www.engineeringtalk.com/index.html>.

Lowe, P. & Schroeder, W. (2009), *Technical Economies, Synfuels and Coal Energy Symposium, Solid-Phase Catalytic Coal Liquefaction Process*, American Society of Mechanical Engineers.

Luque, A. & Hegedus, S. . (n.d.), *Handbook of Photovoltaic Science and Engineering*.

MSNBC Staff and Service (2008), ‘Deadly power plants? study fuels debate: Thousands of early deaths tied to emissions.’.

Ohya, A. (1996), ‘Obstacle detectability of ultrasonic ranging system’.

Overview about ITC’s activities in China (2005).

<http://www.itc.nl/personal/coalfire/activities/overview.html>.

Perry, R. & Green, D. (1984), *Perry’s Chemical Engineers’ Handbook*, McGraw Hill.

Salway, P. (2001), *A History of Roman Britain*, Oxford University Press.

Shenhua Group Starts China’s First Coal-to-Fuel Plant (2009).

<http://www.bloomberg.com/apps/news?pid=20601072sid=a3SIXbVZ8JiErefer=energy>.

Sino German Coal fire project (2005).

http://www.coalfire.caf.dlr.de/projectareas/world_wide_distribution_en.html.

Smith, A. (1997), *Provenance of Coals from Roman Sites in England and Wales*, Vol. 28, second edn, Britannica, London, UK. Pages 297-324.

Speight, J. G. (n.d.), *Synthetic Fuels Handbook: Properties, Process, and Performance*.

Tarka, T. & Wimer, J. (2004), *Affordable Low Carbon Diesel from Domestic Coal and Biomass*, United States Department of Energy, National Energy Technology Laboratory, chapter Page 21.

The New LMS100 Laser Measurement System (2009).

[http://www.sick.com/group/EN/home/products/product_{news}/laser_{measurement}_{systems}/P](http://www.sick.com/group/EN/home/products/product_news/laser_measurement_systems/P)

Ullmann’s Encyclopedia of Industrial Chemistry (1987), Vch Pub, chapter Acetylene.

Ultrasonic Ranger (2002). <http://www.lynxmotion.com/usr.htm>.

Weissermel, K. (2003), *Industrial Organic Chemistry*, Science.

World Coal Institute (2009), 'Environmental impact of coal use'.

World Coal Consumption 1980-2006 (2008).

<http://www.eia.doe.gov/pub/international/iealf/table14.xls>.

World Energy Projections Plus (2009).

<http://www.eia.doe.gov/pub/international/iealf>.

World Energy Usage (2009a).

<http://www.eia.doe.gov/cneaf/coal/page/special/feature.html>.

World Energy Usage (2009b).

<http://www.eia.doe.gov/cneaf/electricity/epa/figes1.html>.

Appendix A

Project Specification

University of Southern Queensland
FACULTY OF ENGINEERING AND SURVEYING
ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: Mitch Cunningham

TOPIC: Bin Level Control

SUPERVISOR: John Leis / Chris Snook

SPONSORSHIP: Group Engineering

PROJECT AIM: Throughout the coal industry within the Bowen Basin there are very few mines that have an automated control system on their Train Loadout facilities. The existing systems use dozers to regulate how much coal is in the bin and is not an exact science. Weighers are also used but are generally unreliable and not designed for the specific purpose of conveyor speed control to maintain levels within the Loadout bins. Therefore the project aim is to investigate the practicality and possibility of using analytical techniques to control the bin level of a Train Loadout Facility. To control the bin level it is proposed to use a laser to determine the profile (height and distribution) of coal on a conveyor belt. Once the profile is determined this data can be integrated to determine the weight of coal on the belt. From here it will be possible to determine the amount of coal heading into the bin (Input) from the main conveyor. Once the weight of coal is determined an algorithm to control the speed of the main conveyor and therefore the level of the bin can be determined. The laser and code in conjunction with existing hardware infrastructure will be used to consistently control the bin level on a train load out facility.

PROGRAMME:

- Research and acquire appropriate laser i.e: reliability of laser in harsh environments, power supply, PLC requirements, how it will be mounted and installed etc
- Develop and test code for coal profile detection
- Develop and test code for the processing of data into a live weight
- Develop and test code for the control of the bin level
- Develop a small project package (Cable Schedule, Bill of Materials, Scope of Work, Schematic and Termination Drawings) to install device
 - o Development of a MATLAB with Simulink model with full model of the system including:
 - o Bin Out loading with Train wagon simulation (Determine live train weights)
 - o Bin Level simulation
 - o Main Conveyor Simulation (weight estimation)
 - o Feed conveyor (with vibrating / coal valve feeders)
 - o Dozer loading simulation and stockpile simulation
 - o Statistical variation of loading

AGREED _____ (student) Date: ___/ ___/ 2009

AGREED _____ (supervisor) Date: ___/ ___/ 2009

Co-examiner: _____

Appendix B

Job Safety Analysis

As with all electrical installations there are risks involved when completing the work. Majority of these risks and hazards can be limited by pre planning the job and considering all factors that may be associated with the work. Majority of the JSA's are for the installation portion of the project as this is where majority of the risks and hazards are. Appendix A includes a number of Job Safety Analysis (JSA) Sheets that incorporate risk identification, risk evaluation and risk management. The JSA's are listed below:

- JSA-001 - Working in the Workshop
Applies to any work within the workshop environment and incorporates the use of various power tools, hand tools and fabrication equipment.
- JSA-002 - Glanding and Terminating Cables
Applies to the glanding off and terminating of the power and control cables associated with the laser installation
- JSA-003 - Commissioning
Applies to the statutory tests such as Point to Point Tests and Insulation Resistance required before turning power onto an electrical installation
- JSA-004 - Removing and Drilling Gland Plates
Applies to the removing, drilling and installing of the gland plates

- JSA-005 - Housekeeping

Refers to the general housekeeping that may be required if entering a mine site

- JSA-006 - Manual Handling

Refers to any manual handling task that will be required within the workshop and or mine site

- JSA-007 - Cables Near Conveyor

Applies to the installation of cables adjacent to or in the approximate vicinity of any conveyors. As the laser will be required to be installed above a conveyor, a suitable route for the power and control cables must be considered.

- JSA-008 - Cleaning

Refers to any cleaning task that will be required within the workshop or the mine site

- JSA-009 - During and Post Project Work

Applies to the risks which may occur throughout the duration of the project and also to the risk which may remain beyond the completion of the project

RISK ASSESSMENT MATRIX

RISK = Probability x Consequences

<u>Probability Factor</u>	
A	Happens often
B	Could easily happen
C	Could happen & has occurred here or elsewhere
D	Hasn't happened yet but could
E	Conceivable, but only in extreme circumstances

		CONSEQUENCE SEVERITY				
		1	2	3	4	5
PROBABILITY FACTOR	A	High	High	Extreme	Extreme	Extreme
	B	Moderate	High	High	Extreme	Extreme
	C	Low	Moderate	High	Extreme	Extreme
	D	Low	Low	Moderate	High	Extreme
	E	Low	Low	Moderate	High	High

INTOLERABLE
ALARP
ALARP
TOLERABLE

Hierarchy of Control

1	ELIMINATION - Complete removal of the hazard
2	SUBSTITUTION - Replacing the material or process with a less hazardous one
3	RE-DESIGN - Redesign the equip. or the process
3	SEPARATION - Isolation of the hazard by guarding
4	ADMINISTRATION - Providing controls such as training or procedures
5	PERSONAL PROTECTIVE EQUIPMENT - Use of PPE where other controls are not practical

Consequences

1	No medical treatment (<\$20,000)
2	Reversible disability or impairment e.g. Disabling & short lost time injury (\$20,000-\$200,000)
3	Moderate irreversible disability or impairment >30% (\$200,000-\$2M)
4	Single Fatality and/or severe irreversible disability >30% (\$2M-\$20M)
5	Multiple Fatality and/or significant irreversible effects to >50 People(> \$20M)

A.	AS
L.	LOW
A.	AS
R.	REASONABLY
P.	POSSIBLE

JOB SAFETY ANALYSIS

JOB DESCRIPTION: Work in Workshop	WORKER CLASSIFICATION: All Personnel	SUPERVISOR: M.CUNNINGHAM	ANALYSIS BY: M.CUNNINGHAM			
LOCATION: TBA	PROJECT: BIN LEVEL CONTROL	DEPARTMENT: Electrical	REVIEWED / APPROVED BY:			
JSA NUMBER: JSA- 001	IMPORTANT: AS A MINIMUM REQUIREMENT FOR ALL JOBS. ISOLATE, TEST AND PROVE DEAD, APPLY PERSONAL DANGER TAGS AND LOCKS AT THE RELEVANT ISOLATION POINT FOR ALL WORK THAT COULD BECOME LIVE. ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT AS REQUIRED. ALL PERSONS HAVE AN OBLIGATION TO ENSURE THEIR WORK AREA IS FREE FROM HAZARDS - LEAVE IT CLEAN AND TIDY					
JOB ACTIVITY	P	C	Risk Score	P	C	Control Risk Score
POTENTIAL HAZARDS	RECOMMENDED JOB PROCEDURE					
1. Use of various power tools, fabrication equipment and hand tools -	C	5	Ext	D	3	Mod
- Bench grinder	B	2	High	D	2	Low
- Drop saw	B	2	High			
- Pedestal drill	B	2	High			
- Oxy cutting equipment	B	2	High			
- Welding equipment	B	2	High			
- Hand grinders	C	2	Mod	D	3	Mod
- Power drills						
- Various hand tools	B	2	High	D	2	Low
				E	2	Low
				D	2	Low
				D	2	Low

A SIGNATURE BELOW CERTIFIES THAT THIS JSA HAS BEEN READ AND UNDERSTOOD.

NAME	DATE	NAME	DATE
Mitch Cunningham	15-04-09		

IMPORTANT: IF ANY MISTAKES ARE FOUND OR CHANGES REQUIRED IN THIS JSA, CONTACT YOUR SUPERVISOR IMMEDIATELY.

SUPERVISORS SIGNATURE: _____

JOB SAFETY ANALYSIS

JOB DESCRIPTION: Gland and / or Terminate Cables		WORKER CLASSIFICATION: All Personnel		SUPERVISOR: M.CUNNINGHAM		ANALYSIS BY: M.CUNNINGHAM				
LOCATION: TBA	PROJECT: BIN LEVEL CONTROL	JOB No		DEPARTMENT: Electrical		REVIEWED / APPROVED BY:				
JSA NUMBER: JSA- 002	IMPORTANT: AS A <i>MINIMUM REQUIREMENT</i> FOR ALL JOBS. ISOLATE, TEST AND PROVE DEAD, APPLY PERSONAL DANGER TAGS AND LOCKS AT THE RELEVANT ISOLATION POINT FOR ALL WORK THAT COULD BECOME LIVE. ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT AS REQUIRED.									
ALL PERSONS HAVE AN OBLIGATION TO ENSURE THEIR WORK AREA IS FREE FROM HAZARDS - LEAVE IT CLEAN AND TIDY										
JOB ACTIVITY	POTENTIAL HAZARDS		P	C	Risk Score	RECOMMENDED JOB PROCEDURE		P	C	Control Risk Score
1. Preparing cable into position	1. Electrocution		B	4	Ext.	1. Isolate and apply "personal danger" tags and locks to isolators. Ensure cable being terminated is not energised. Test for dead before proceeding		C	2	Med
2.Strip outer sheathing 0-25mm using Swivel Blade Stripper	1. Cuts / lacerations / gashes to hands 2. Strain / sprains / bruising		A	2	High	1. Kevlar gloves to be worn when using knife. 2. Competent personnel 3. Correct positioning of person & job 4. Cutting techniques & cut away from yourself		C	2	Med
3.Strip outer sheathing 0-25mm using Heavy Duty Blade stripper	1. Cuts / lacerations / gashes to hands 2. Strain / sprains / bruising		C	2	Med	1. Kevlar gloves to be worn when using knife. 2. Competent personnel 3. Correct positioning of person & job 4. Cutting techniques & cut away from yourself 5. Cover knife when not in use		C	1	Low
4.Strip outer sheathing 0-25mm using Retractable Blade stripper	1. Cuts / lacerations / gashes to hands 2. Strain / sprains / bruising		C	3	High	1. Kevlar gloves to be worn when using knife. 2. Competent personnel 3. Correct positioning of person & job 4. Cutting techniques & cut away from yourself 5. Cover knife when not in use		C	2	Med
5.Strip inner sheathing 0-25mm using Retractable Blade stripper	1. Cuts / lacerations / gashes to hands 2. Strain / sprains / bruising		C	3	High	1. Kevlar gloves to be worn when using knife. 2. Competent personnel 3. Correct positioning of person & job 4. Cutting techniques & cut away from yourself 5. Cover knife when not in use		C	2	Med
6.Strip inner cores 0-25mm using Retractable Blade stripper	1. Cuts / lacerations / gashes to hands 2. Strain / sprains / bruising		C	3	High	1. Kevlar gloves to be worn when using knife. 2. Competent personnel 3. Correct positioning of person & job 4. Cutting techniques & cut away from yourself 5. Cover knife when not in use		C	2	Med

7. Strip outer cores >25mm using Retractable Blade stripper	1. Cuts / lacerations / gashes to hands 2. Strain / sprains / bruising	C	3	High	1. Kevlar gloves to be worn when using knife. 2. Competent personnel 3. Correct positioning of person & job 4. Cutting techniques & cut away from yourself 5. Cover knife when not in use	C	2	Med
8. Install cable into gland plate	1. Sprains and strains 2. Crush injuries to hands 3. Manual lifting injury	C	3	High	1. Use mechanical lifting equipment or machinery if load too heavy or awkward. If lifting by hand, ensure enough people share the load 2. Ensure that all personnel are aware of the dangers of limbs being dragged into areas that could cause injury. Wear gloves 3. Use of mechanical devices and / or team effort. Adhere to correct "manual lifting procedure"	C	2	Med
9. Removing insulation and wadding	1. Trips and falls 2. Cuts / lacerations / gashes to hands	C	3	High	1. Regular clean up of work area should be performed to remove trip hazards. Dispose of insulation, armouring and wadding as soon as possible in appropriate manner 2. Gloves to be worn when using knife. Cut away from body when using knife	C	2	Med
10. Housekeeping	1. Trips and falls 2. Injuries as a result from an untidy workplace (housekeeping)	C	3	High	1. Replace floor plates at end of shift if required to prevent personnel from tripping and falling 2. Regular clean up of work area before, during and after work activity	C	2	Med

A SIGNATURE BELOW CERTIFIES THAT THIS JSA HAS BEEN READ AND UNDERSTOOD.

NAME	DATE	NAME	DATE	DATE
M.CUNNINGHAM	15-04-09			

IMPORTANT: IF ANY MISTAKES ARE FOUND OR CHANGES REQUIRED IN THIS JSA, CONTACT YOUR SUPERVISOR IMMEDIATELY.

SUPERVISORS SIGNATURE: _____

JOB SAFETY ANALYSIS

JOB DESCRIPTION: Commissioning / Testing 110V - 415V	WORKER CLASSIFICATION: All Personnel	SUPERVISOR: M.CUNNINGHAM	ANALYSIS BY: M.CUNNINGHAM
LOCATION: TBA	PROJECT: BIN LEVEL CONTROL	DEPARTMENT: Electrical	REVIEWED / APPROVED BY:
JSA NUMBER: JSA - 003	IMPORTANT: AS A MINIMUM REQUIREMENT FOR ALL JOBS. ISOLATE, TEST AND PROVE DEAD, APPLY PERSONAL DANGER TAGS AND LOCKS AT THE RELEVANT ISOLATION POINT FOR ALL WORK THAT COULD BECOME LIVE. ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT AS REQUIRED.		
ALL PERSONS HAVE AN OBLIGATION TO ENSURE THEIR WORK AREA IS FREE FROM HAZARDS - LEAVE IT CLEAN AND TIDY			
JOB ACTIVITY	P	C	Risk Score
POTENTIAL HAZARDS	P	C	Risk Score
Meggar/Injection testing	B	5	Ext
1. Electric shock	B	3	High
2. Stored energy	B	4	Ext
3. Communication breakdown	B	4	Ext
4. Danger to personnel	B	4	Ext
RECOMMENDED JOB PROCEDURE			
1. Isolate test circuit. Confirm documentation before proceeding with tests			
2. Discharge windings to earth			
3. Use two ways for positive communication. Use of spotter at non testing end of cable			
4. Restrict area with barricade and signage			
P			
C			
Risk Score			
E 3 Mod			
D 2 Low			
D 2 Low			
D 2 Low			

A SIGNATURE BELOW CERTIFIES THAT THIS JSA HAS BEEN READ AND UNDERSTOOD.

NAME	DATE	NAME	DATE
M.CUNNINGHAM	15-04-09		
IMPORTANT: IF ANY MISTAKES ARE FOUND OR CHANGES REQUIRED IN THIS JSA, CONTACT YOUR SUPERVISOR IMMEDIATELY.			

SUPERVISORS SIGNATURE: _____

JOB SAFETY ANALYSIS

JOB DESCRIPTION: Remove / Install Gland Plates Drill Glands / Install Plates	WORKER CLASSIFICATION: All Personnel	SUPERVISOR: M.CUNNINGHAM	ANALYSIS BY: M.CUNNINGHAM
LOCATION: TBA	PROJECT: BIN LEVEL CONTROL	DEPARTMENT: Electrical	REVIEWED / APPROVED BY:
JSA NUMBER: JSA - 004	IMPORTANT: AS A MINIMUM REQUIREMENT FOR ALL JOBS. ISOLATE, TEST AND PROVE DEAD, APPLY PERSONAL DANGER TAGS AND LOCKS AT THE RELEVANT ISOLATION POINT FOR ALL WORK THAT COULD BECOME LIVE. ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT AS REQUIRED. ALL PERSONS HAVE AN OBLIGATION TO ENSURE THEIR WORK AREA IS FREE FROM HAZARDS - LEAVE IT CLEAN AND TIDY		

JOB ACTIVITY	POTENTIAL HAZARDS			RECOMMENDED JOB PROCEDURE			Control Risk Score
	P	C	Risk Score	P	C		
Access work area	B A A	3 4 4	High Ext Ext	D D E	2 2 2	1. Check for sharp edges on switchboard or adjacent area. Use padding if needed. Wear correct PPE 2. Barricade below work area. Communicate with workers in area 3. Eyes on path and good housekeeping	Low Low Low
Remove / install gland plate	B B	3 3	High High	D D	2 2	1. Wear correct PPE 2. Use correct tool for job. Correct lifting techniques or team lift	Low Low
Drill gland plate	B B B B	3 3 4 4	High High Ext Ext	D D D E	2 2 3 2	1. File sharp edges after drilling. Wear PPE 2. Clamp job to work area. Position body correctly 3. Check in date test tag and visually inspect for damage 4. Wear correct PPE	Low Low Mod Low
Install glands	B B A	3 3 4	High High Ext	D D	2 2	1. Wear correct PPE 2. Use correct tool for job. Avoid crushing fingers	Low Low

A SIGNATURE BELOW CERTIFIES THAT THIS JSA HAS BEEN READ AND UNDERSTOOD.

NAME	DATE	NAME	DATE
M.CUNNINGHAM	15-04-09		

IMPORTANT: IF ANY MISTAKES ARE FOUND OR CHANGES REQUIRED IN THIS JSA, CONTACT YOUR SUPERVISOR IMMEDIATELY.

SUPERVISORS SIGNATURE: _____

JOB SAFETY ANALYSIS

JOB DESCRIPTION: Housekeeping	WORKER CLASSIFICATION: All Personnel	SUPERVISOR: M.CUNNINGHAM	ANALYSIS BY: M.CUNNINGHAM					
LOCATION: TBA	PROJECT: BIN LEVEL CONTROL	DEPARTMENT: Electrical	REVIEWED / APPROVED BY:					
JSA NUMBER: JSA - 005	IMPORTANT: AS A MINIMUM REQUIREMENT FOR ALL JOBS, ISOLATE, TEST AND PROVE DEAD, APPLY PERSONAL DANGER TAGS AND LOCKS AT THE RELEVANT ISOLATION POINT FOR ALL WORK THAT COULD BECOME LIVE. ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT AS REQUIRED. ALL PERSONS HAVE AN OBLIGATION TO ENSURE THEIR WORK AREA IS FREE FROM HAZARDS - LEAVE IT CLEAN AND TIDY							
JOB ACTIVITY	POTENTIAL HAZARDS	P	C	Risk Score	RECOMMENDED JOB PROCEDURE	P	C	Control Risk Score
Storage and stacking	1. Falling objects 2. Protruding objects 3. Trip hazards	A 4 B 4 A 4	4 4 4	Ext Ext Ext	1. Marked and barricaded storage / stacking areas 2. Keep designated walkways clear as practicable with regard for the specific work areas	D 2 D 2		Low Low
Cables, leads and hoses	1. Trip hazards	A 4	4	Ext	1. Secure all above head height 2. Avoid crossing walkways 3. Ramps may be used to cover 4. Keep stairway and ladder access clear at all times	E 1 D 2 D 2 D 1		Low Low Low Low
Liquid spills	1. Slip hazards	A 4	4	Ext	1. Barricade area when spill occurs 2. Advise supervisor of spill, environmental officer to be notified 3. Clean area immediately after the spill 4. Thoroughly dry area when finished cleaning	D 1 D 1 D 1 D 1		Low Low Low Low
Waste removal	1. Fire / slips / trips	B 4	4	Ext	1. Place rubbish in appropriate bins 2. Check smaller house bins each shift 3. Keep work areas clear of waste 4. Do not throw rubbish from heights	D 1 D 2 D 2 D 2		Low Low Low Low
Use of chemicals	1. Exposure	B 4	4	Ext	1. Read the substances material safety data sheet and follow manufacturers guidelines 2. Wear the prescribed PPE 3. Data sheets are available in the site office	D 2 D 2 D 2		Low Low Low

A SIGNATURE BELOW CERTIFIES THAT THIS JSA HAS BEEN READ AND UNDERSTOOD.

NAME	DATE	NAME	DATE
M.CUNNINGHAM	15-04-09		

IMPORTANT: IF ANY MISTAKES ARE FOUND OR CHANGES REQUIRED IN THIS JSA, CONTACT YOUR SUPERVISOR IMMEDIATELY.

SUPERVISORS SIGNATURE: _____

JOB SAFETY ANALYSIS

JOB DESCRIPTION: Manual Handling	WORKER CLASSIFICATION: All Personnel	SUPERVISOR: M.CUNNINGHAM	ANALYSIS BY: M.CUNNINGHAM
LOCATION: TBA	PROJECT: BIN LEVEL CONTROL	JOB No	REVIEWED / APPROVED BY:
JSA NUMBER: JSA - 006	IMPORTANT: AS A MINIMUM REQUIREMENT FOR ALL JOBS. ISOLATE, TEST AND PROVE DEAD, APPLY PERSONAL DANGER TAGS AND LOCKS AT THE RELEVANT ISOLATION POINT FOR ALL WORK THAT COULD BECOME LIVE. ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT AS REQUIRED. ALL PERSONS HAVE AN OBLIGATION TO ENSURE THEIR WORK AREA IS FREE FROM HAZARDS - LEAVE IT CLEAN AND TIDY		

JOB ACTIVITY	POTENTIAL HAZARDS		Risk Score		RECOMMENDED JOB PROCEDURE		Control Risk Score	
	P	C	P	C	P	C	P	C
Manual single lifts	1. Muscle sprains and strains	A	3	Ext	1. Size up load	D	1	Low
	2. Pinch points	B	3	High	2. Plan lift	D	2	Low
	3. Oversized load	A	3	Ext	3. Plan and clear route of travel	D	1	Low
	4. Falling load	B	4	Ext	4. Use team lifting	D	1	Low
	5. Equipment damage	B	3	High	5. Utilise team lifting	D	1	Low
Manual team lifts	1. Muscle sprains and strains	A	3	Ext	1. Size up load	D	1	Low
	2. Pinch points	B	3	High	2. Plan lift	D	2	Low
	3. Oversized loads	A	3	Ext	3. Plan and clear route of travel	D	1	Low
	4. Falling load	B	4	Ext	4. Utilise lifting aids	D	1	Low
	5. Equipment damage	B	3	High		D	1	Low
	6. Improper lift coordination							

A SIGNATURE BELOW CERTIFIES THAT THIS JSA HAS BEEN READ AND UNDERSTOOD.

NAME	DATE	NAME	DATE
M.CUNNINGHAM	15-04-09		

IMPORTANT: IF ANY MISTAKES ARE FOUND OR CHANGES REQUIRED IN THIS JSA, CONTACT YOUR SUPERVISOR IMMEDIATELY.

SUPERVISORS SIGNATURE: _____

JOB SAFETY ANALYSIS

JOB DESCRIPTION: Pulling / Terminating Cables adjacent to Conveyor	WORKER CLASSIFICATION: All Personnel	SUPERVISOR: M.CUNNINGHAM	ANALYSIS BY: M.CUNNINGHAM
LOCATION: TBA	PROJECT: BIN LEVEL CONTROL	DEPARTMENT: Electrical	REVIEWED / APPROVED BY:
JSA NUMBER: JSA - 007	IMPORTANT: AS A MINIMUM REQUIREMENT FOR ALL JOBS. ISOLATE, TEST AND PROVE DEAD, APPLY PERSONAL DANGER TAGS AND LOCKS AT THE RELEVANT ISOLATION POINT FOR ALL WORK THAT COULD BECOME LIVE. ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT AS REQUIRED. ALL PERSONS HAVE AN OBLIGATION TO ENSURE THEIR WORK AREA IS FREE FROM HAZARDS - LEAVE IT CLEAN AND TIDY		

JOB ACTIVITY	Risk Score			RECOMMENDED JOB PROCEDURE	Control Risk Score
	P	C	P		
Assess work area	POTENTIAL HAZARDS				
	A	4	Ext	1. Good housekeeping. Remove coal from walkway 2. No cable pulling along walkway when conveyor is running 3. Refer to train schedule. Audible siren is prewarning start	2
	B	4	Ext		2
Pulling cables along tray	B	3	High	1. Wear gloves 2. Use correct pulling procedure or team pull	2
	B	3	High		2
Terminating cables	B	3	High	1. Wear correct PPE, cut away from hands and body 2. Use isolation procedure (tags and locks) 3. Competent person to use crimpers	2
	B	4	Ext		2
	B	4	Ext		2

A SIGNATURE BELOW CERTIFIES THAT THIS JSA HAS BEEN READ AND UNDERSTOOD.

NAME	DATE	NAME	DATE
M.CUNNINGHAM	15-04-09		

IMPORTANT: IF ANY MISTAKES ARE FOUND OR CHANGES REQUIRED IN THIS JSA, CONTACT YOUR SUPERVISOR IMMEDIATELY.

SUPERVISORS SIGNATURE: _____

JOB SAFETY ANALYSIS

JOB DESCRIPTION: Cleaning	WORKER CLASSIFICATION: All Personnel	SUPERVISOR: M.CUNNINGHAM	ANALYSIS BY: M.CUNNINGHAM
LOCATION: TBA	PROJECT: BIN LEVEL CONTROL	DEPARTMENT: Electrical	REVIEWED / APPROVED BY:
JSA NUMBER: JSA - 008	IMPORTANT: AS A MINIMUM REQUIREMENT FOR ALL JOBS. ISOLATE, TEST AND PROVE DEAD, APPLY PERSONAL DANGER TAGS AND LOCKS AT THE RELEVANT ISOLATION POINT FOR ALL WORK THAT COULD BECOME LIVE. ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT AS REQUIRED. ALL PERSONS HAVE AN OBLIGATION TO ENSURE THEIR WORK AREA IS FREE FROM HAZARDS - LEAVE IT CLEAN AND TIDY		

JOB ACTIVITY	Risk Score			RECOMMENDED JOB PROCEDURE	Control Risk Score
	P	C	E		
Isolation	B	4	Ext	1. Isolate as per the mine site procedure	2 Low
Prepare work area	B	3	High	1. Observe the precautions in the solvent manufacturers MSDS. Protect hands with gloves or suitable barrier cream 2. Use single person for high pressure water blasting 3. Area below work to be barricaded off 4. Persons working at height to wear safety harnesses 5. Occupants of dogbox / EWP to wear safety harnesses	2 Low 2 Low 1 Low 2 Low 2 Low
Remove bulky dirt and grease	B	3	High	1. Use care as floor area, rungs, handholds may be slippery 2. All persons to be aware of others in their work area 3. Use team lifting or slide containers. Be aware of workers in the vicinity 4. Use safety harnesses for dogbox 5. Barricade area below work area	1 Low 2 Low 1 Low 2 Low 2 Low
Remove cleaning material				1. Use team lifting or slide containers	

A SIGNATURE BELOW CERTIFIES THAT THIS JSA HAS BEEN READ AND UNDERSTOOD.

NAME	DATE	NAME	DATE
M.CUNNINGHAM	15-04-09		

IMPORTANT: IF ANY MISTAKES ARE FOUND OR CHANGES REQUIRED IN THIS JSA, CONTACT YOUR SUPERVISOR IMMEDIATELY.

SUPERVISORS SIGNATURE: _____

JOB SAFETY ANALYSIS

JOB DESCRIPTION: During and Post Project	WORKER CLASSIFICATION: All Personnel	SUPERVISOR: M.CUNNINGHAM	ANALYSIS BY: M.CUNNINGHAM
LOCATION: TBA	PROJECT: BIN LEVEL CONTROL	DEPARTMENT: Electrical	REVIEWED / APPROVED BY:
JSA NUMBER: JSA - 009	IMPORTANT: AS A MINIMUM REQUIREMENT FOR ALL JOBS. ISOLATE, TEST AND PROVE DEAD, APPLY PERSONAL DANGER TAGS AND LOCKS AT THE RELEVANT ISOLATION POINT FOR ALL WORK THAT COULD BECOME LIVE. ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT AS REQUIRED. ALL PERSONS HAVE AN OBLIGATION TO ENSURE THEIR WORK AREA IS FREE FROM HAZARDS - LEAVE IT CLEAN AND TIDY		

JOB ACTIVITY	POTENTIAL HAZARDS			RECOMMENDED JOB PROCEDURE			Control Risk Score	
	P	C	Risk Score	P	C			
Code Programming	B	3	High	E	2	Low		
Design	B	4	Ext	D	2	Low		
	B	4		D	2	Low		
	B	3		E	1	Low		
Prototype	B	3	High	D	1	Low		
Matlab Simulation	B	3	High	D	1	Low		
	B	3		E	2	Low		
	B	3		D	2	Low		

A SIGNATURE BELOW CERTIFIES THAT THIS JSA HAS BEEN READ AND UNDERSTOOD.

NAME	DATE	NAME	DATE
M.CUNNINGHAM	15-04-09		

IMPORTANT: IF ANY MISTAKES ARE FOUND OR CHANGES REQUIRED IN THIS JSA, CONTACT YOUR SUPERVISOR IMMEDIATELY.

SUPERVISORS SIGNATURE: _____

Appendix C

Consignment Notes

The consignment notes are forms utilized by the coal sampling operators at Goonyella Riverside Mine. These forms define train details, loading details, weighbridge weights and the quality of coal including the moisture and ash content of each sample

CONSIGNMENT NOTE



QRNational
Telephone 61 7 3235 3002
Facsimile 61 7 3235 2589
Email qr.coal@qr.com.au
Queensland Rail/ABN 47 564 947 264

Date: 30/6/2009

Consignment number **HF 90964**

Signed on behalf of the consignor:
BHP Billiton

Mine: **Goonyella (Riverside)**By: *Ben Williams*Traffic: **Goonyella (Riverside) to Hay Point**Signature: *B. Williams*

Freight payable by:
BHP Billiton

Product Type: **CYLS**

train details		No. locos (1-6)		loading time details		
Train No.	in out	Wagon class	Number	TIME (using 2400 hour clock)		date
First wagon no.	<i>E664 / E665</i>	<i>VNSQB</i>	<i>10</i>	TST (as defined)	<i>10.10</i> Hrs	<i>30/6/09</i>
- 1st consist	<i>46926</i>	<i>VHLQB</i>	<i>10</i>			
Last wagon no.	<i>VCAS</i>	<i>VLAS</i>	<i>19</i>	TLT (as defined)	<i>12.20</i> Hrs	<i>30/6/09</i>
- 1st consist	<i>53484</i>	<i>VCAL</i>	<i>19</i>			
First wagon no.	<i>VHQB</i>	<i>VSAS</i>	<i>25</i>	reason for delay	responsibility QR mine	time lost
- 2nd consist	<i>47504</i>	<i>VSAL</i>	<i>25</i>			
Last wagon no.	<i>VNLQ</i>	<i>VNRB</i>	<i>7</i>	Out of coal		
- 2nd consist	<i>45493</i>	<i>VNSQB</i>	<i>1</i>	Loading equip failure		
No fully loaded		<i>VNLQB</i>	<i>1</i>	Remove overload		
No light loaded		<i>VNRQ</i>	<i>2</i>	Change shift		
No not loaded		<i>VNLQ</i>	<i>2</i>	Unmanned or unsafe loadout		
No over loaded				Faulty wagon doors		
Tot train inc ELRC			<i>121</i>	Train failure		
weighbridge weights		head office use		Meal break		
Gross mass	<i>12268.65</i>		As'd	(Others)		
Tare mass	<i>2505.30</i>			ALLOW./DELAY		
Net mass	<i>9763.35</i>		Cl'd	LIABLE TIME		

explanations and/or remarks :

coal quality	1st consist	2nd consist	special unloading instructions
moisture	<i>ND</i>	<i>10-8</i>	
ash	<i>SAMPLE</i>	<i>9-10</i>	
volatiles			

TLT: The time when loading of the train is completed and wagon loads are removed excluding delays caused by QR.

TST: The time the train stops before entering Loading Facility when requested by Customer, or resulting from QR driver placing train in low speed, or The time the first wagon is positioned under the chute on the overhead bin that loads coal into wagons at the Loading Facility, as applicable.

ORIGINAL (white): QRNational

DUPLICATE (blue): Consignor

TRIPLICATE (pink): To Destination

CONSIGNMENT NOTE

Form 22960



QRNational
Telephone 61 7 3235 3002
Facsimile 61 7 3235 2589
Email qr.coal@qr.com.au
Queensland Rail/ABN 47 564 947 264

Date: 31712009

Consignment number HF 90965

Signed on behalf of the consignor:
BHP Billiton

Mine: Goonyella (Riverside)

By: *Wayne M. Hilly*
Signature: *[Signature]*

Traffic: Goonyella (Riverside) to Hay Point

Freight payable by:
BHP Billiton

Product Type: GYLS

train details		No. locos (1-6)		loading time details		
Train No.	in out	Wagon class	Number	TIME (using 2400 hour clock)		date
First wagon no.	<i>E854 16655</i>	<i>VHSQB</i>	<i>11</i>	TST (as defined)	<i>0440</i> Hrs	<i>317109</i>
- 1st consist	<i>46898</i>	<i>VHLQB</i>	<i>11</i>			
Last wagon no.	<i>VSAH</i>	<i>VSAH</i>	<i>22</i>	TLT (as defined)	<i>0702</i> Hrs	<i>317109</i>
- 1st consist	<i>50553</i>	<i>VSAH</i>	<i>22</i>			
First wagon no.	<i>VHSQB</i>	<i>VCHS</i>	<i>12</i>	reason for delay	responsibility	time lost
- 2nd consist	<i>47430</i>	<i>VCHS</i>	<i>12</i>			
Last wagon no.	<i>VNLQ</i>	<i>KLRC</i>	<i>1</i>	Out of coal		
- 2nd consist	<i>46615</i>	<i>VNLQ</i>	<i>13</i>	Loading equip failure		
No fully loaded		<i>VNSQ</i>	<i>9</i>	Remove overload		
No light loaded		<i>VNLQ</i>	<i>9</i>	Change shift		
No not loaded				Unmanned or unsafe loadout		
No over loaded				Faulty wagon doors		
Tot train inc ELRC			<i>122</i>	Train failure		
weighbridge weights		head office use		Meal break		
Gross mass	<i>12016.60</i>		As'd	(Others)		
Tare mass	<i>2536.70</i>			ALLOW./DELAY		
Net mass	<i>9479.90</i>		Ck'd	LIABLE TIME		

explanations and/or remarks :

coal quality	1st consist	2nd consist	special unloading instructions
moisture	<i>9.6</i>	<i>9.4</i>	
ash	<i>10.60</i>	<i>10.85</i>	
volatiles	<i>—</i>	<i>—</i>	

TLT: The time when loading of the train is completed and wagon loads are removed excluding delays caused by QR.

TST: The time the train stops before entering Loading Facility when requested by Customer, or resulting from QR driver placing train in low speed, or The time the first wagon is positioned under the chute on the overhead bin that loads coal into wagons at the Loading Facility, as applicable.

ORIGINAL (white): QRNational

DUPLICATE (blue): Consignor

TRIPPLICATE (pink): To Destination

CORRECTIVE ACTION RANGE

CONSIGNMENT NOTE

Form 22960



QRNational
Telephone 61 7 3235 3002
Facsimile 61 7 3235 2589
Email qr.coal@qr.com.au
Queensland Rail/ABN 47 564 947 264

Date: 5/07/2009

Consignment number HF 90966

Signed on behalf of the consignor:
BHP Billiton

Mine: Goonyella (Riverside)

By: JASON VAN VLIET

Traffic: Goonyella (Riverside) to Hay Point

Signature: [Signature]

Freight payable by:
BHP Billiton

Product Type: GYLS

train details		No. locos (1-6)		loading time details		
Train No.	in out	Wagon class	Number	TIME (using 2400 hour clock)		date
First wagon no.	VHSQB	VHSQB	8	TST (as defined)		18.41 Hrs 5/17/09
- 1st consist	47216	VALQB	8	TLT (as defined)		2130 Hrs 5/17/09
Last wagon no.	VSAL	VSAS	20	reason for delay		responsibility QR mine time lost
- 1st consist	50689	VSAL	20	Out of coal		
First wagon no.	VHSQB	VLAS	17	Loading equip failure		40 mins 19.20 - 2000
- 2nd consist	46870	VLAL	17	Remove overload		
Last wagon no.	VNQB	ELRC	1	Change shift		
- 2nd consist	45391	VNSQ	12	Unmanned or unsafe loadout		
No fully loaded		VNLQ	12	Faulty wagon doors		
No light loaded		VNQB	7	Train failure		
No not loaded				Meal break		
No over loaded				(Others)		
Tot train inc ELRC	122		122	ALLOW/DELAY		
weighbridge weights		head office use		LIABLE TIME		
Gross mass	12249.75		As'd			
Tare mass	2521.30					
Net mass	9728.45		Ck'd			

explanations and/or remarks : WEIGHT BRIDGE OK TAPE ATTACHED

coal quality	1st consist	2nd consist	special unloading instructions
moisture	11.7	10.9	
ash	9.41	10.14	
volatiles			

CORRECTIVE
ON RANGE

TLT: The time when loading of the train is completed and wagon loads are removed excluding delays caused by QR.

TST: The time the train stops before entering Loading Facility when requested by Customer, or resulting from QR driver placing train in low speed, or The time the first wagon is positioned under the chute on the overhead bin that loads coal into wagons at the Loading Facility, as applicable.

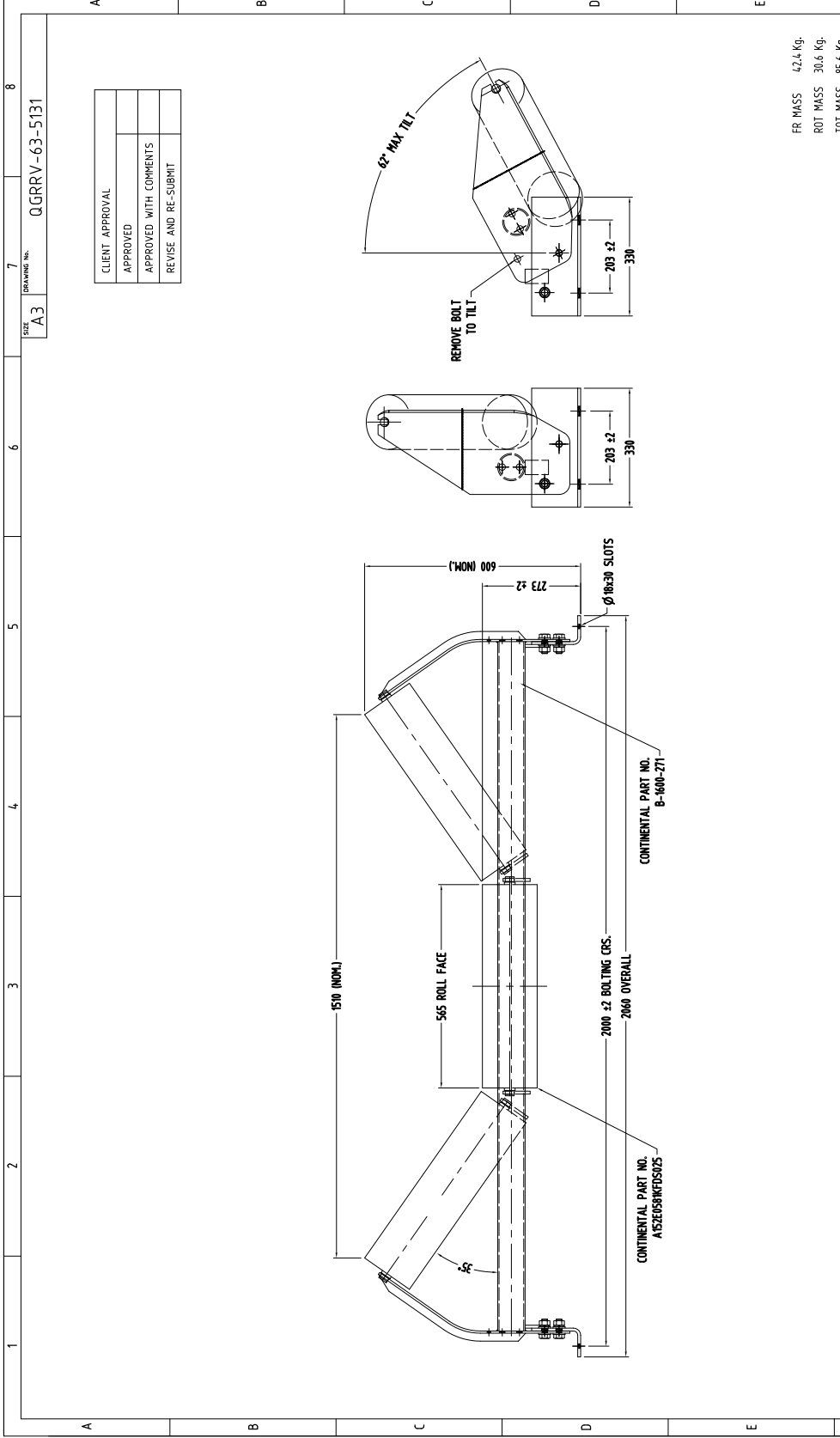
ORIGINAL (white): QRNational

DUPLICATE (blue): Consignor

TRIPLICATE (pink): To Destination

Appendix D

Conveyor Mechanical Drawings



REV.		1	2	3	4	5	6	7	8
B		REVISED AS PER CLIENT COMMENTS	RH	DMR	25.11.05				
A		ISSUE FOR APPROVAL	RH	DMR	9.8.05				
F		ISSUE FOR CONSTRUCTION							

CONTINENTAL CONVEYOR & EQUIPMENT PTY. LTD.		BHP BILLITON		DIMENSIONS IN MILLIMETRES. DO NOT SCALE.		CLIENT		CONTRACT No.		COST CODE	
10 SOMERSET FALLS RD, SOMERSET, NSW 2259 AUSTRALIA		PROJECT		DRAWN		BHPC - GOONYELLA RIVERSIDE		DATE		9.8.05	
INTERNATIONAL 602 4349 2011		CHECKED		DATE		TRAIN LOADOUT CC3, CC4, CC5 & CC6.		DATE		9.8.05	
FAX: 602 4342 2011		APPROVED		DATE		3 ROLL 35° TILT OVER CARRY IDLER		DATE		9.8.05	
		THIS IS A CAD DRAWING AND MUST NOT BE REVISED MANUALLY		SCALE		SERIES : 152/6306		1:10		BELT : 1600	
		DRAWING No.		3		DRAWING No.		4		DRAWING No.	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2		3		4		5	
		1		2							

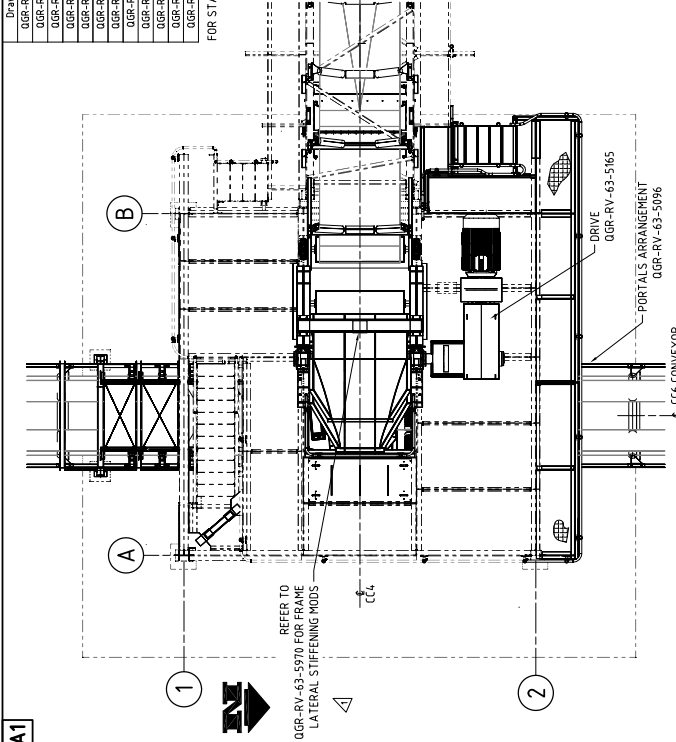
A1

Drawings No.		Reference Drawings
QGR-RV-63-5806	CC4 CONVEYOR C4 ARRANGEMENTS & DETAILS SH1 OF 2	
QGR-RV-63-5806	CONVEYOR C4 ARRANGEMENT HEAD CHUTE	
QGR-RV-63-5806	GENERAL ARRGT OF HEAD END MODIFICATIONS C4-1 OF 22	
QGR-RV-63-5806	CONVEYOR C4 HEAD END GUARDING	
QGR-RV-63-5806	WASH BOX ASSEMBLY	
QGR-RV-63-5806	ARRANGEMENT OF MODIFICATIONS SH2 OF 2	
QGR-RV-63-5806	TRANSFER HOUSE TH3 ARRANGEMENT SH1 OF 2	
QGR-RV-63-5806	DEMOLITION PLAN FOR HEAD END OF CC4	
QGR-RV-63-5806	DRIVE PULLEY ASSEMBLY	
QGR-RV-63-5806	TRANSFER ARRGT OF SUPPORTS	
QGR-RV-63-5806	DRIVE MOTOR ASSEMBLY	
QGR-RV-63-5806	HEAD CHUTE LINER & TILING DETAILS	

FOR STANDARD STRUCTURAL & CIVIL NOTES SEE DRG QGR-RV-63-5116

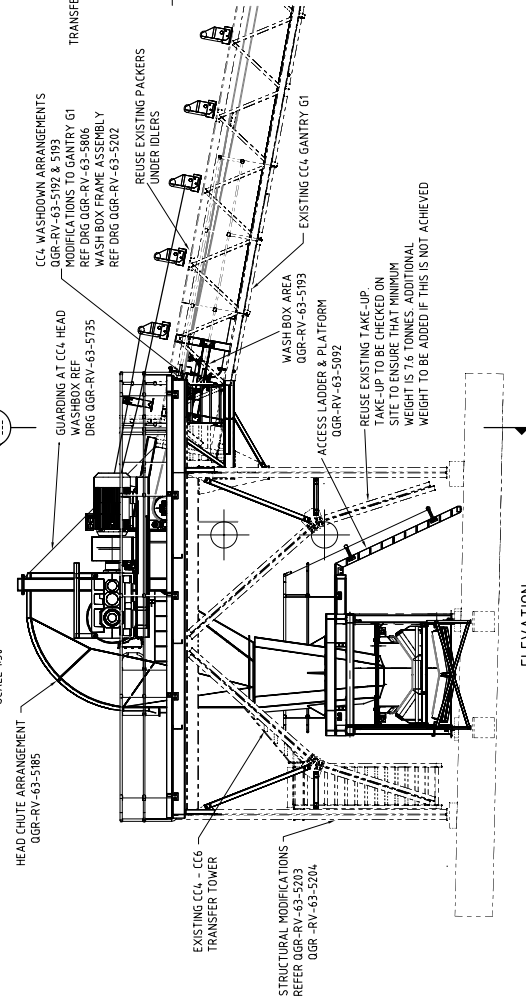
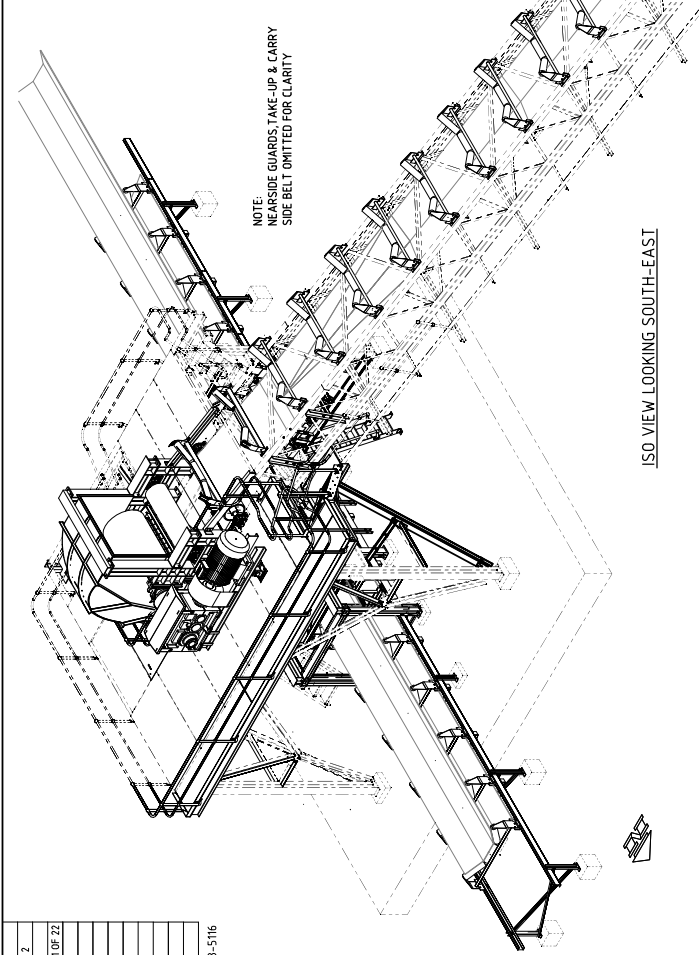
TBM CC4 (SURVEY MARKER)
RAMSET IN CONCRETE
E 597604.944
N 7593494.019
RL 276.997

FOR DEMOLITION OF HEAD END CC4
REF DRG QGR-RV-63-5181



PLAN
SCALE 1:50

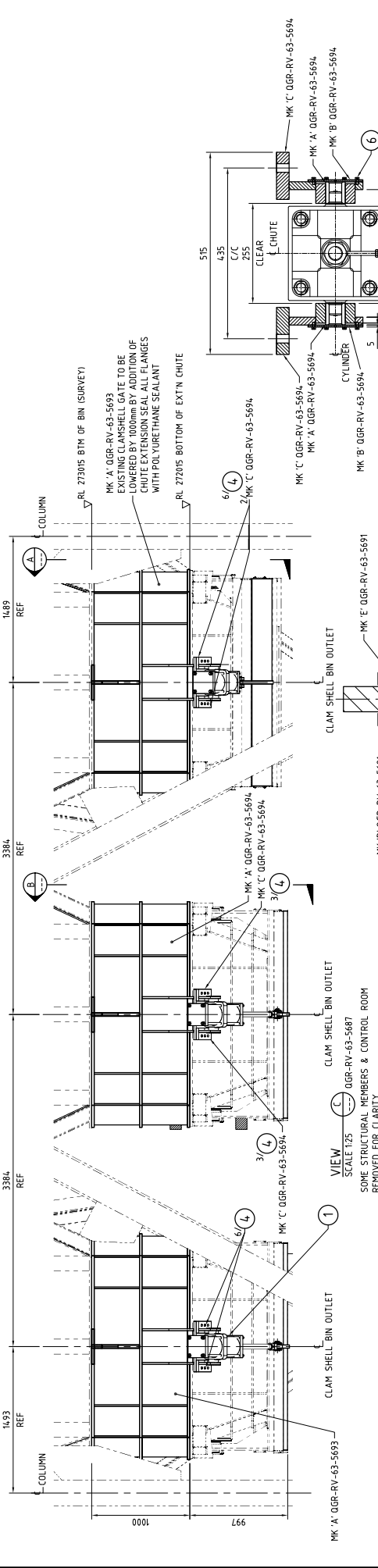
ISO VIEW LOOKING SOUTH-EAST



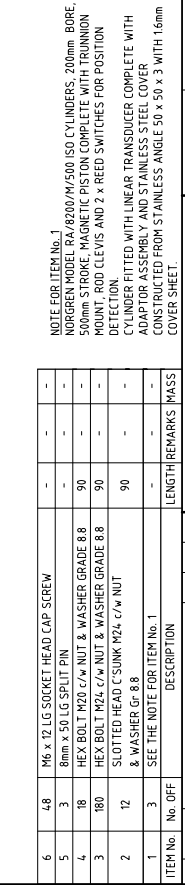
ELEVATION
SCALE 1:50

SECTION
SCALE 1:50

Rev.		Date	By	App.	Ver.	App.	Revision Details
1	12/12/06						MODIFICATION NOTE ADDED
0	2/23/06						ISSUED FOR CONSTRUCTION
A	9/1/06						ISSUED FOR DESIGN REVIEW
							Client
							BHP BILLITON MITSUBISHI ALLIANCE GOONYELLA / RIVERSIDE MINE
							Client
							BMA GOONYELLA RIVERSIDE CPP2 TRAIN LOAD OUT UPGRADE CC4 - CC6 & TRANSFER HOUSE TH4 GENERAL ARRANGEMENT SHEET 2 OF 2
							Client
							HE57 RV
							Scale 1:50
							Rev 1
							Drawing No. QGR-RV-63-5184



ITEM NO.	DESCRIPTION	LENGTH	REMARKS	MASS
1	SEE THE NOTE FOR ITEM No. 1	-	-	-
2	1	3	-	-
3	2	1	90	-
4	180	4	90	-
5	4	180	90	-
6	4	180	90	-
7	4	180	90	-
8	4	180	90	-
9	4	180	90	-
10	4	180	90	-
11	4	180	90	-
12	4	180	90	-
13	4	180	90	-
14	4	180	90	-
15	4	180	90	-
16	4	180	90	-
17	4	180	90	-
18	4	180	90	-
19	4	180	90	-
20	4	180	90	-
21	4	180	90	-
22	4	180	90	-
23	4	180	90	-
24	4	180	90	-
25	4	180	90	-
26	4	180	90	-
27	4	180	90	-
28	4	180	90	-
29	4	180	90	-
30	4	180	90	-
31	4	180	90	-
32	4	180	90	-
33	4	180	90	-
34	4	180	90	-
35	4	180	90	-
36	4	180	90	-
37	4	180	90	-
38	4	180	90	-
39	4	180	90	-
40	4	180	90	-
41	4	180	90	-
42	4	180	90	-
43	4	180	90	-
44	4	180	90	-
45	4	180	90	-
46	4	180	90	-
47	4	180	90	-
48	4	180	90	-
49	4	180	90	-
50	4	180	90	-
51	4	180	90	-
52	4	180	90	-
53	4	180	90	-
54	4	180	90	-
55	4	180	90	-
56	4	180	90	-
57	4	180	90	-
58	4	180	90	-
59	4	180	90	-
60	4	180	90	-
61	4	180	90	-
62	4	180	90	-
63	4	180	90	-
64	4	180	90	-
65	4	180	90	-
66	4	180	90	-
67	4	180	90	-
68	4	180	90	-
69	4	180	90	-
70	4	180	90	-
71	4	180	90	-
72	4	180	90	-
73	4	180	90	-
74	4	180	90	-
75	4	180	90	-
76	4	180	90	-
77	4	180	90	-
78	4	180	90	-
79	4	180	90	-
80	4	180	90	-
81	4	180	90	-
82	4	180	90	-
83	4	180	90	-
84	4	180	90	-
85	4	180	90	-
86	4	180	90	-
87	4	180	90	-
88	4	180	90	-
89	4	180	90	-
90	4	180	90	-

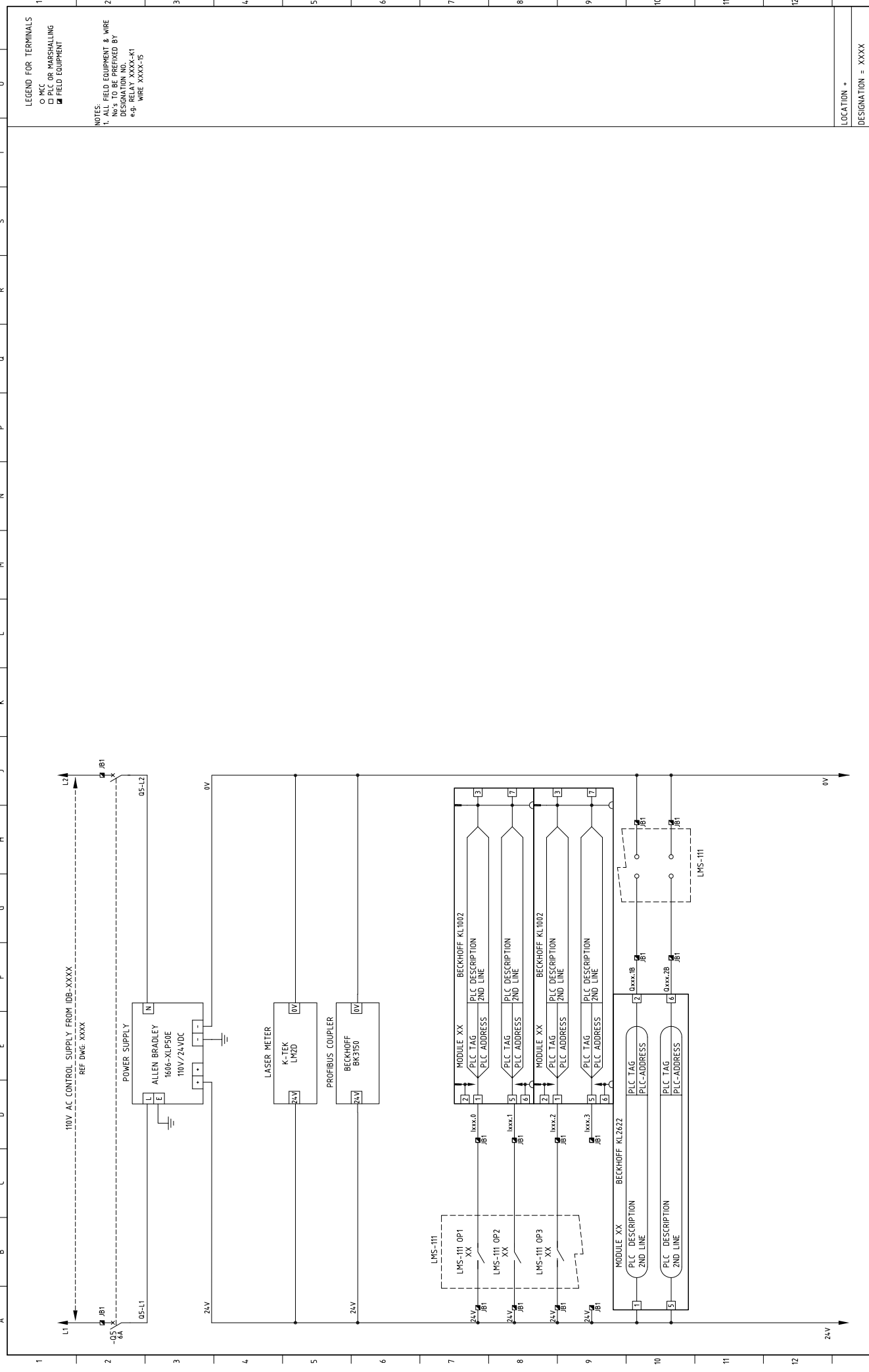


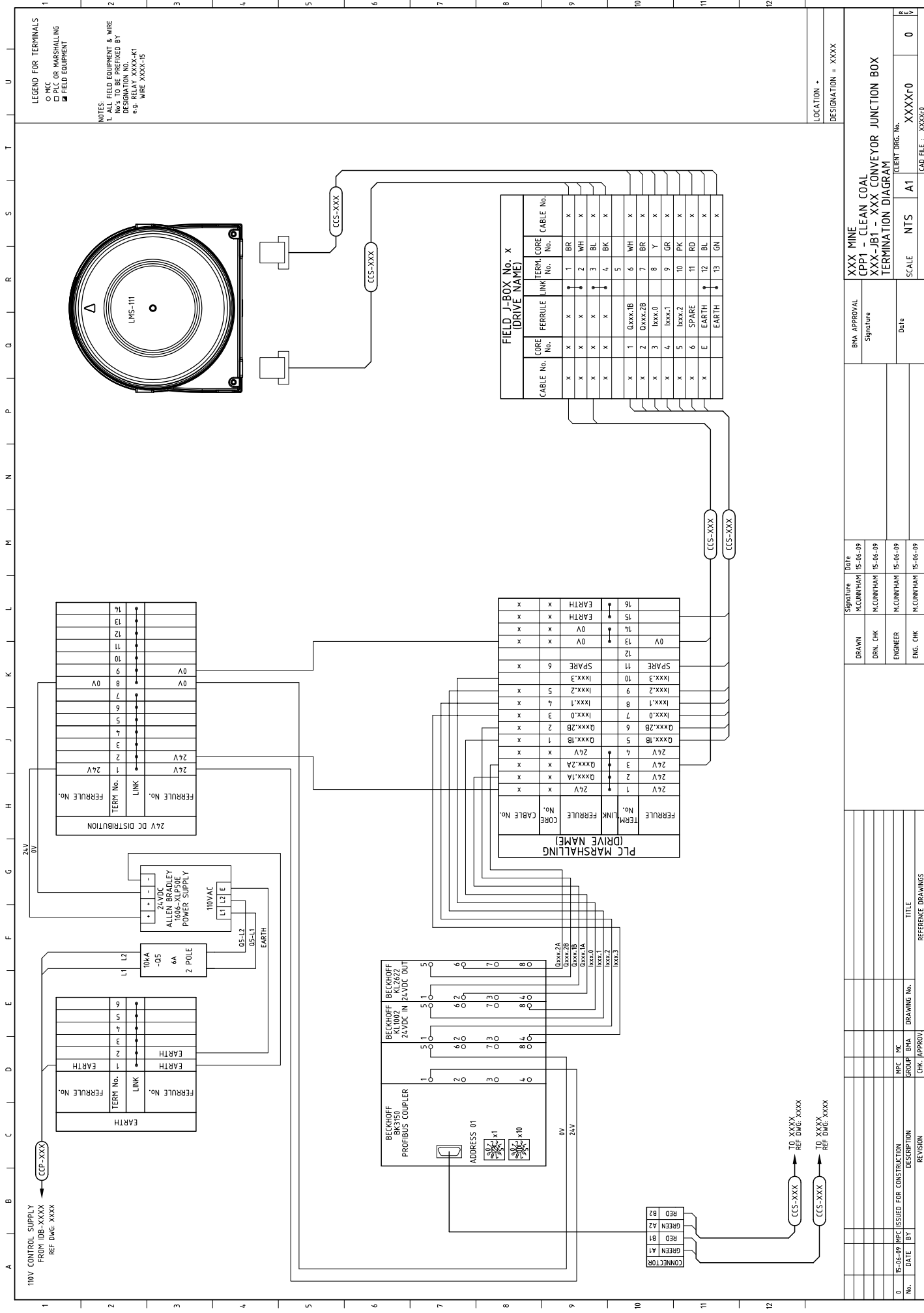
1	3	SEE THE NOTE FOR ITEM No. 1	-	-
ITEM No.	No. OFF	DESCRIPTION	LENGTH	REMARKS
				MASS

[illegible]

Appendix E

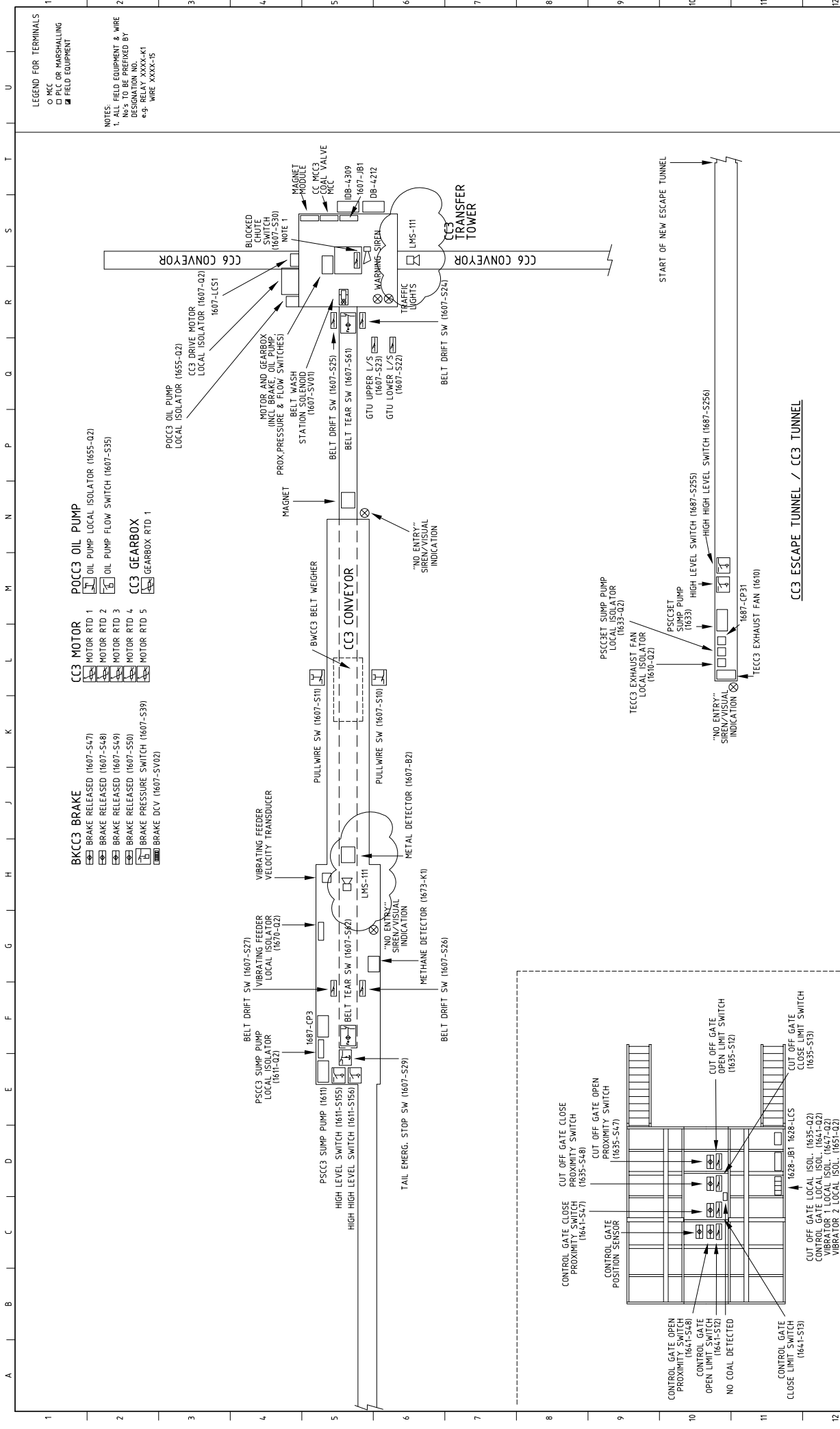
Electrical Schematics

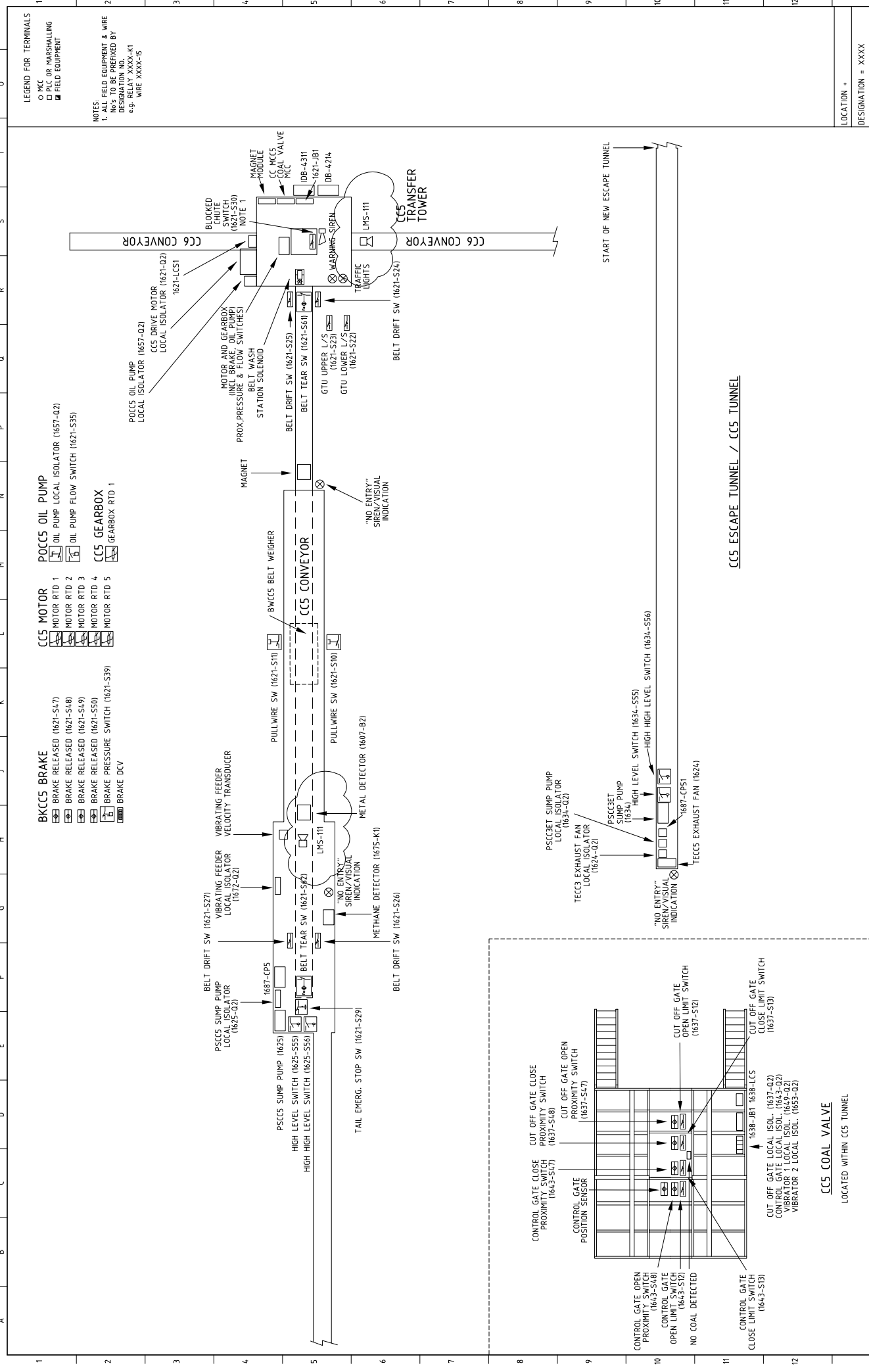
[illegible]



Appendix F

Layout Drawings

[illegible]

[illegible]

