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Murdoch Campus

ENG450 – Engineering Internship
Final Report

Kalgoorlie Nickel Smelter Furnace Rebuild (KNS) Project and Kalgoorlie Nickel Smelter Expansion (KNE) Project

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Author:
Rebecca Suzanne French
Student Number: 30320053

Unit Coordinator:
Parisa A. Bahri

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Abstract

The Kalgoorlie Nickel Smelter (KNS) Furnace Rebuild Project and the Kalgoorlie Nickel Smelter Expansion (KSE) Project are both conducted by the contractor Fluor Australia Pty Ltd for the client BHP Billiton Nickel West. The Nickel Smelter is located on a brown-fields site situated 12 km from Kalgoorlie, Western Australia [1].

The engineering internship is a minimum 16 week full-time work placement with an industrial partner conducted as an alternative pathway to an engineering thesis for final year engineering students at Murdoch University, Perth, Western Australia. The purpose of the internship is to provide the engineering student with experience to the world of engineering practice through a period of workplace employment. This internship fits in closely with the Industrial Computer Systems major of Murdoch University's Bachelor of Engineering degree.

This report details the work performed during a 19 week internship placement with the engineering, procurement, construction and management (EPCM) contractor Fluor Australia Pty Ltd. The report features the Kalgoorlie Nickel Smelter process description, including the primary plant sections and interrelated processes employed to smelt and convert the main input of nickel in concentrate to produce the final product of nickel in matte. In particular, the matte granulation process and the differences between the original and proposed upgraded process are discussed. The design, instrumentation and control systems work completed for the addition of new equipment and instrumentation for the matte granulation system upgrade of the Kalgoorlie Nickel Smelter (KNS) Expansion (KSE) project is addressed. The future work

required to be completed as a continuation of the work performed during the internship placement is presented.

Disclaimer

I declare the following to be my own work, unless otherwise referenced, as defined by the University's policy on plagiarism.

Rebecca French

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1. Introduction

The Kalgoorlie Nickel Smelter is situated 12km from Kalgoorlie in Western Australia [1]. BHP Billiton acquired 100% ownership of the Nickel West operation facilities, in August 2005 by a takeover of the Western Mining Corporation (WMC) Resources [2]. The facilities included the Kalgoorlie Nickel Smelter, Mount Keith Operation, Leinster Operation, Ravensthorpe Operation, Kambalda Concentrator and Kwinana Nickel Refinery [1] and [3]. The Kalgoorlie Nickel Smelter facility became operational in 1972 [3]. The nickel concentrate is supplied to the Kalgoorlie Nickel Smelter from the Mount Keith, Leinster and Kambalda Concentrator operations [1] and [3]. The dry nickel concentrate is converted to nickel matte. The matte is transported to the Kwinana Nickel Refinery to be processed into nickel or shipped to the Fremantle port for exportation [1].

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Figure 1: BHP Billiton Nickel West Facilities and Locations [3]

Originally the KNS Furnace Rebuild project and the Kalgoorlie Nickel Smelter Expansion project were both set to begin in FY2009 however, both of the projects began an emergency start almost a year ahead of schedule in FY2008.

The Kalgoorlie Nickel Smelter Furnace Rebuild project and the Kalgoorlie Nickel Smelter Expansion project are run in parallel and are interrelated. The purpose of the Kalgoorlie Nickel Smelter (KNS) Furnace Rebuild project is to conduct an emergency rebuild of the Kalgoorlie Nickel Smelter flash furnace to replace the old Outokumpu flash furnace with a new ELT (Enhanced Low Temperature) furnace because it has come to the end of its service life [4] and [5]. The aim of the Kalgoorlie Nickel Smelter Expansion project is to conduct a definition study on the Kalgoorlie Nickel Smelter facilities. The expansions to be studied consist of modifications and improvements to expand the current production throughput capacity of the facility from 771 kilo tonne per annum (ktpa) to 900 kilo tonne per annum (ktpa) of dry concentrate [6], [8] and [9].

The engineering internship will focus on one main section of the Kalgoorlie Smelter Expansion project being the matte granulation system upgrade. The purpose of the matt granulation upgrade is to increase the pumping rate of the water in the matte granulation process [10]. This requires the installation of three larger pumps with motor starters and any resultant works to increase the capacity of the water flow [10], [11] and [12]. All instrumentation and control work associated with the new equipment was required to be addressed with new instruments and modification of the current Allen Bradley PLC system [11].

Each project undertaken by Fluor Australia Pty Ltd. can be classified as any combination of engineering, procurement, construction or management (EPCM). The Kalgoorlie Nickel Smelter Furnace Rebuild Project required having all the engineering, procurement, construction and management work carried out by Fluor Australia Pty Ltd. For the Kalgoorlie Nickel Smelter Expansion project the engineering and procurement work was to be carried out by Fluor Australia Pty Ltd. All project work for both projects was to be conducted from the Perth office. Project team members were often required to visit the Kalgoorlie Nickel Smelter site throughout the duration of the project. The Fluor Australia Pty Ltd. project phases are detailed engineering, procurement and fabrication, construction and pre-commissioning, commissioning and handover [7]. For the Kalgoorlie Nickel Smelter Furnace Rebuild project all work necessary in terms of design, procurement, construction and pre-commissioning to replace the furnace was required [6]. All of the design and procurement work to complete the definition study on the upgrade of the smelter facilities at the Kalgoorlie Nickel Smelter are required. The work carried out during the internship placement focused on the detailed engineering phase of the project.

At this current stage the Kalgoorlie Nickel Smelter Furnace Rebuild project has been completed and fully commissioned. The Kalgoorlie Nickel Smelter was restarted after being in shutdown to replace the furnace on 9 September 2008 [13]. The Kalgoorlie Nickel Smelter Expansion project is currently continuing with the matte granulation section of the project in progress and the effluent treatment section of the project beginning.

The following chapters of the internship report will detail relevant background information and a description of the work carried out for the matte granulation upgrade. Chapter 2 will detail a description of the industrial partner Fluor Australia Pty Ltd. The Kalgoorlie Nickel Smelter plant sections and process descriptions, most importantly the matte granulation section, are presented in chapter 3. An overview of the control system at the Kalgoorlie Nickel Smelter is described in chapter 4. The matte granulation control system and the control system work carried out for the matte granulation upgrade are explained in chapter 5. The instrumentation work carried out for the matte granulation upgrade is illustrated in chapter 6. The design work carried out for the matte granulation upgrade is shown in chapter 7. The additional small projects not related to the matte granulation upgrade that were completed are explained in chapter 8. The tools and methodologies used throughout the internship placement and the future work to be completed on the mate granulation upgrade are also described in chapters 9 and 10, respectively. A summary of the work completed and the major findings from the internship placement are presented in chapter 11.

2. Fluor Australia Pty Ltd.

Fluor Australia Pty Ltd. is a branch of the Fluor Corporation [14]. The Fluor Corporation is an engineering, procurement, construction and maintenance company [14]. They have offices around the world in more than 25 countries and employ more than 41,000 people [14]. In 1969 Fluor began its operations in Australia [14]. Today, in Australia Fluor Pty Ltd. have offices in Melbourne, Brisbane and Perth [15].

As a contracting company Fluor as a business aims to serve clients across a wide range of industries. Globally Fluor operates in the

> mining; chemicals and petrochemicals; oil and gas; power; life sciences; manufacturing; microelectronics; telecommunications; transportation infrastructure; commercial and institutional; telecommunications and government services [14].

The main services carried out within these industries are engineering, procurement, construction, and maintenance and project management [16]. Within Australia the main sectors Fluor Australia Pty. Ltd. caters for are mining and mineral processing, oil and gas and operations and maintenance, power generation, steel manufacture and iron ore processing [14]. The main business units of the company are mining and metals, energy and chemicals and operations and maintenance [17]. The mining and metals group serves clients in the mining and metals industries that deal with minerals such as nickel, copper, gold, diamonds, alumina, copper and iron ore [18]. The Kalgoorlie Nickel Smelter Furnace Rebuild Project and the Kalgoorlie Nickel Smelter Expansion Project are two of many projects undertaken by the mining and minerals group. Other projects within Australia include the Oxiana Prominent Hill Copper/Gold Project and the BHP Billiton Iron Ore Asset Development Projects [18].

As a part of a business it is important to adhere to and adopt the values held by the company. The values upheld by Fluor Australia Pty Ltd. as a business throughout daily operation are:

- Safety
- Integrity
- Teamwork, and
- Excellence

[14]

On every project at Fluor Australia Pty Ltd. awareness of the Health, Safety and Environmental (HSE) philosophy plays a key role and is an important part of Fluor as a business. The HSE philosophy of Fluor Australia Pty Ltd. is apart of all projects undertaken by the company and states that it is necessary to:

- ‘ Protect People
- Protect the Environment
- Protect Property
- Avoid loss ‘

[19]

The Murdoch University engineering internship on the Kalgoorlie Nickel Smelter Furnace Rebuild project and Kalgoorlie Nickel Smelter Expansion project will focus on the engineering services provided by Fluor Australia Pty Ltd. The engineering services provided as a part of the internship project will be instrumentation, control systems and design engineering work.

3. Kalgoorlie Nickel Smelter Plant Process

During the Kalgoorlie Nickel Smelter Furnace Rebuild project there was to be no alteration to the smelting process that was previously being used at the Kalgoorlie Nickel Smelter [4]. The furnace was to be rebuilt with expansions to the smelters facilities.

Numerous interconnected sections and processes are used at Kalgoorlie Nickel Smelter to smelt and convert the main input of nickel in concentrate to produce the final product of nickel in matte. The primary sections of the Kalgoorlie Nickel Smelter include the flash furnace, converters, matte granulation, matte packing and dispatching and the flux, oxygen, sulphuric acid and effluent treatment plants [3]. A smelter process representation is shown in Figure 2. Each of the primary sections at the Kalgoorlie Nickel Smelter will be described. The matte granulation section of the Kalgoorlie Nickel Smelter will be described in greater detail as the internship project was based on this section.

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Figure 2: Smelter Process Representation [3]

Nickel in concentrate is transported to the site from Mount Keith, Leinster and Kambalda Nickel West operations [3]. This is stored in the concentrate storage silos to be later supplied to the flash furnace.

The Kalgoorlie Nickel Smelter furnace is an Outokumpu integrated flash furnace [3]. The flash furnace functions to smelt the nickel concentrate into a nickel matte product [3]. The nickel matte product is then fed to the converters for further processing. Iron as an iron silica slag, dust and waste gasses are removed in the process [3]. The products of the flash furnace then undergo further processing, are reused or disposed of [3]. The iron silica slag exits the furnace and is disposed of [3]. The units used for processing are a waste heat boiler and electrostatic precipitators [3]. The remaining waste products are fed into the waste heat boiler and steam and off gasses are produced [3]. Dust is collected and reinjected into the flash furnace from the cooled off gases by being processed in electrostatic precipitators [3]. The remaining off gases are fed to the acid plant for processing [3].

Three Pierce-Smith converters are installed at Kalgoorlie Nickel Smelter facility [3]. Each converter is a 28 tuyere reaction vessel [3]. Tuyeres facilitate input of oxygen and air for the process reaction to take place. The nickel matte processing cycle is called a blow. For each blow cycle nickel matte is moved into a converter by overhead cranes [3]. The converter is then rolled so that the tuyere contacts the matte and lump quartz flux is input into the process vessel. The air or oxygen blown from the tuyere contacts the nickel matte and a silica slag layer is formed on the surface within the converter [3]. Due to the difference in density the slag and the matte separate and the slag is skimmed off the top of the converter [3]. The process continues until a higher purity nickel matte product is achieved [3]. The higher purity nickel matte product is then transported to the matte granulation section of the plant for further processing.

Figure removed for confidentiality and/or copyright reasons.

Figure 3: Matte Granulation Process Representation

Matte granulation processes the nickel matte into finer particles. Two matte granulating processes run simultaneously designated matte granulation sequence 1 and 2. The matte granulation process uses a top and bottom nozzle set of water blowers for each granulating process to separate the matte poured from two matte ladles into finer particles as it falls into the associated matte granulation tanks 1 and 2.

For each granulation sequence matte is poured into the tilting ladle from the high grade transfer ladle by crane [3]. The hydraulic system functions to tilt the ladle and pour the matte from the ladle down the matte launder. As pouring occurs a granulator robot manipulates the molten crust on the top of the rim of the high grade tilting ladle to prevent the crust formation on the ladle rim. The robots scrape the build up that forms on the rim back into the high grade tilter ladle to be remelted by the molten matte. If a large build up of crust is allowed to fall through the granulation water jets into the granulation pond dangerous steam explosions can occur. The large ball of granulated matte would have a cooled exterior and a hot molten centre. As the ball fractures the cool water and hot molten centre produce a dangerous steam explosion. Due to the occurrence of steam explosions in the matte granulation process the matte granulation section of the plant is a red zone and no personnel are allowed access to the area when the process is in operation. As the nickel matte is poured water from a top and bottom nozzle sprays jets of low pressure high volume water onto the matte resulting in granulation, producing granules of 1-4 mm in diameter [3]. Water is supplied to the nozzles by a set of matte granulation jet pumps from the hot well, a large water storage tank. The granulated matte then falls into the granulation tank where the matte is agitated by an agitation nozzle.

The resulting granulated product is moved onto conveyor #2 into a feed chute. The granulated product is then separated into the Kwinana Nickel Refinery (KNR) matte surge bin or the export matte surge bin using a feed diversion/ flop gate. A stream from each bin is fed into a truck for export. Another stream from each bin is transferred to conveyor 3 where it is sprayed with water and the feed is fed into a matte rotary drier for drying. Waste dust from the rotary drier is extracted into matte bags by being passed through two matte drier dust cyclones. The product is then transferred to the matte handling bin feed conveyor into the matte packing shed for packing. The simplified matte granulation process is shown in Figure 3.

There is one main difference in the general operation of the matte granulation process between the original and the upgraded matte granulation system. The upgraded matte granulation process will run in almost an identical way to the current matte granulation process. In the original matte granulation process the water was supplied to the granulation nozzles by four matte granulation jet pumps. Two matte granulation jet pumps (1 and 3) supply water to the bottom granulation nozzles and two matte granulation jet pumps (2 and 4) to supply water to the top granulation nozzles. In the upgraded matte granulation process the four matte granulation water jet pumps are to be upgraded and replaced with three larger more powerful jet pumps. Matte granulation jet pump 1 will supply the blower box/nozzle top water jets while jet pump 2 will supply the blower box/nozzle bottom water jets with jet pump 3 acting as a standby pump. Jet pump 2 also operates the agitation nozzle in each of the granulation tanks. The rest of the matte granulation process remains the same.

The acid plant functions to process the waste gas produced by the furnace [3]. Sulphur dioxide is converted to sulphuric acid [3]. The gas is processed by moving through the three main sections of the acid plant. The first section is the gas cleaning section. This section functions to cool and clean the gas by removing dust and heavy metals [3]. The second section, the oxidation section, converts the sulphur dioxide into sulphur trioxide which combines with weak sulphuric acid to produce a stronger sulphuric acid solution of approximately 98.5% [3]. The last step is transportation to storage tanks [3].

In addition to these main sections of the Kalgoorlie Nickel Smelter facility other areas which act to support the main areas of the facility are the effluent treatment plant, the flux plant, the oxygen plant and the power generation section of the facility [3].

The flash furnace smelting process and its associated facilities at Kalgoorlie Nickel Smelter produces effluent, raw untreated waste water resulting mainly from the acid plant gas cleaning area [3]. The weak acid effluent stream is composed of approximately 10% of sulphuric acid and 1.5% of hydrochloric acid [3]. The waste water stream also contains up to 2000 ppm (parts per million) of arsenic [20]. The purpose of the effluent treatment process is to treat the water to remove any harmful substances and produce a reusable recycled water product. Sulphuric acid and arsenic are then required to be removed from the water. Sulphuric acid is removed through the process of neutralisation using lime slurry in neutralisation reactors [21]. Arsenic is removed as ferric arsenate using reagents through precipitation in the arsenic fixation reactor/s. The reagents are calcium hydroxide (lime slurry/$Ca(OH)_2$), sodium hypochlorite ($NaOCl$) and ferric sulphate ($Fe_2(SO_4)_3$) [21].

The crusher and flux plant functions to process flux and revert [3]. The crusher processes revert into correct sized particles [3]. Flux is passed through a dryer and ball mill for drying and grinding and is pneumatically transported to the flux silos [3]. The flux and revert product is used in the flash furnace and converters [3].

The function of the oxygen plant is to provide oxygen to the flash furnace. Air is compressed, cooled and then passed through a scrubber, two molecular sieve units and then cooled and passed through a series of columns [3]. The scrubber removes water soluble impurities, the molecular sieves remove all moisture, carbon dioxide and hydrocarbons and the columns separate oxygen and nitrogen [3]. The oxygen is fed to the flash furnace [3]. The nitrogen is recycled into the molecular sieve units [3].

4. Kalgoorlie Nickel Smelter Control System

There are many process sections throughout the Kalgoorlie Nickel Smelter facility and each of these sections are controlled by a number of programmable logic controller's and a Yokogawa Distributed Control System, all of which are interconnected by numerous different communication interface mediums. The main PLC type used throughout the plant is Allen Bradley however, other vendor packages are also used.

The Kalgoorlie Nickel Smelter control system consists of a microXL Yokogawa Distributed Control System (DCS) connected to many units in the field within the oxygen plant, waste heat boiler and furnace areas through a Yokogawa RL bus. MOPL and/or MOPS Yokogawa operator stations in the computer room and the powerhouse are connected to the DCS [22]. The Yokogawa MOPS operator stations in the computer room and MOPL operator stations in the powerhouse are both connected to a Kalgoorlie Nickel Smelter Citect server by RS-232/RS-485 communications [22]. A Yokogawa Centum CS 3000 Integrated Production DCS is connected to the Yokogawa microXL DCS through a bus connector. Yokogawa PFCD duplexed field control stations and KFCS field control stations are connected to the DCS from the flash furnace, power house and fume capture areas by VL net [22] and [23]. Human interface stations (HIS) are also connected to the DCS in the computer room [24]. VL net connects the Centum CS 3000 to the Citect servers. The main control room on site houses operator interface terminals (OIT). The computer room contains the PC's, laser and inkjet printers, a firewall, exaquantum server and associated network equipment, terminal server, many Citect servers, a SQL server, backup server connected to a tape drive and a file server. The exaquantum server is a Yokogawa Plant Information Management System (PIMS), which ties into the Yokogawa DCS systems and functions to gather, process and clarify data from all sections of the plant [25]. Ethernet 172 connects all nodes in the computer room excluding the ink jet printer and the main control room, the operator interface terminals in the field (OIT) in each plant section. Ethernet 11 connects all nodes in the computer room excluding the laser printer, Yokogawa PFCD duplexed field control stations in the flash furnace area and a KFCS field control stations in the fume capture area, and the majority of PLC's out in the field. Control Net, DH+ 1 and DH+2 are used to connect between many PLC's out in the field. The Ethernet 11 and 172, DH +1, DH+2 and ControlNet communication interfaces are all connected by a gateway chassis. [26]

The main communication interface mediums employed in the Kalgoorlie Nickel Smelter are VL Net, RL Bus, Ethernet 11 and 172, DH +1, DH+2, Radio Link, ControlNet, RIO and Serial RS-232/485 [26].

The internship project focused on the matte granulation control system which is a sub division of the overall control system of the Kalgoorlie Nickel Smelter facility. The main communication methods used in the matte granulation section of the Kalgoorlie Nickel Smelter facility are Ethernet and DeviceNet.

5. The Matte Granulation Control System

5.1. Operator Interface Terminal and CitectSCADA Software

CitectSCADA is a human machine interface supervisory control and data acquisition form of software developed by Citect [27]. The human machine interface software supplied by Citect enables the development of a graphical interface to control software such as programmable logic controllers to enable easy and efficient control of industrial processes [27].

A control cabin was installed in the matte granulation area during a previous upgrade to protect the system operator from the process. The control cabin for the matte granulation control system contains an operator interface terminal. The operator interface terminal is equipped with CitectSCADA software and provides the graphical interface between the control system and the operator for the matte granulation section of the Kalgoorlie Nickel Smelter [28]. The matte granulation CitectSCADA interface connects to the CitectSCADA server of the Kalgoorlie Nickel Smelter in the computer room and acts as a client on the system [28]. The matte granulation Citect screen display is made up of two displays. The first display is the primary screen showing the matte granulation process flow and layout, the major equipment and instrumentation and their status [29]. The second screen is the interlock page which shows all of the interlocks for the granulation and tilter sequences [29].

The existing matte granulation control system is primarily an Allen Bradley PLC control system. The matte granulation control system controls and monitors the matte granulation equipment and instrumentation to ensure safe and efficient operation of the matte granulation process.

Within the matte granulation control system there are 6 main programmable logic controllers which all monitor and/or control different regions of the process [28]. These include the Matte Granulation (MGRAN) PLC, Converter (CONV) PLC, Robot PLC, Safety PLC, Fume Capture PLC1 and the Fume Capture PLC2.

5.2. Matte Granulation (MGRAN) PLC

The matte granulation PLC is an Allen Bradley 17-L63 ControlLogix 5563 Programmable Logic Controller. The structure of the matte granulation PLC consists of a 1756-A10 10 slot ControlLogix chassis. The original 10 slot chassis contained the 1753-L63 ControlLogix PLC processor, the 1756-ENET/B Ethernet module, two 1756-IB32/B digital input modules, two 1756-OW16I digital output modules, two 1756-IF16 analog input modules and one 1756-OF8 analog output module.

The matte granulation PLC controls the tilting process by operating ladle tilters 1 and 2 by adjusting the raising or lowering speed based on the tilter position [28]. The tilter position is adjusted by monitoring and control of the hydraulic system [28]. The matte granulation PLC implements start, pause and stop interlocks and permissives for the matte granulation tilting process [28]. It also controls the two scraper robots. The matte granulation PLC also monitors the instrument air dryer and receiver vendor package instrument air supply to granulators 1 and 2 and the pressurising air system vendor package pressurizing air fan 1 and 2 connected to the SO_2 Scrubber.

The matte granulation PLC interfaces with the Robot PLC, Converter PLC and a CCTV system [28]. The communication interface methods used by the matte granulation PLC to connect to the other PLC's are Ethernet and hardwiring [28].

5.3. The Converter (CONV) PLC

The converter PLC is an Allen Bradley PLC5, which contains a PLC5/80E processor. The structure consists of two 16 slot chassis which each contain two 8 slot racks. Analog and digital input and output modules are contained within the racks. Many of the primary equipment signals of the matte granulation process are hardwired into the Converter PLC. These include the inputs and outputs for the bottom granulation pump 1 and top granulation pump 2 (for the original process), scrapers 1 and 2, conveyor 2, the flop gate, water pressure switches and the tilter interlock outputs [28]. Information and interlocks for the granulation jet pumps, vibrating screens, matte conveyor, scraper conveyor and ladle tilter hydraulic pumps are sent to the matte granulation PLC [28]. The converter PLC controls the matte granulation jet pumps 1 and 2 (for the original process) and the hydraulic pumps for the tilting process [28].

The converter PLC exchanges data to and from the matte granulation PLC, Fume Capture PLC1, Fume Capture PLC2, the north crane PLC and the south crane PLC through Ethernet communications. Data is also able to be sent through DH+ communications between PLC's, however, Ethernet has priority over DH+ communication methods. If Ethernet communications fail the DH+ is used as a redundant method of data transfer between PLC's.

5.4. The Robot System (PLC), Safety PLC and Control Console Vendor Package

The safety PLC is a PILZ Safety PLC, which functions to ensure the safety of the personnel on site. The matte granulation area is a red zone where no personnel are allowed to enter during its operation as the process is dangerous. If any gate is opened, the tilting process will stop and the matte granulation robots will return home [28]. Information is sent to the matte granulation PLC for interlocking purposes [28].

The Robot PLC is an Allen Bradley ControlLogix Programmable Logic Controller, and its function is to monitor and control all of the interlocking sequences of the two robots [28]. The control choices made about the robots occur through a chair interface [28]. The robot PLC also functions to connect the chair interface to the matte granulation PLC for robot monitoring and control [28]. The robot PLC is connected to the matte granulation PLC over Ethernet communications [28]. The chair is connected to the Robot PLC through a Device Net network [28].

5.5. Fume Capture PLC1

The Fume Capture PLC1 is an Allen Bradley PLC5 Programmable Logic Controller and contains a PLC5/80E processor. The structure consists of one 16 slot chassis that contains two 8 slot racks. Analog and digital input and output modules are contained within the racks.

Many of the primary equipment signals of the matte granulation process are hardwired into the Fume Capture PLC1. This equipment includes the matte granulation valves, instrument air pressure switch and the matte granulation pump 3 and matte granulation pump 4 [28]. The I/O for the bottom granulation pump 1 and top granulation pump 2 (for the original process), scrapers 1 and 2, conveyor 2, the flop gate, water pressure switches and the tilter interlock outputs that are connected to the Converter PLC are transferred to the Fume Capture PLC1 [28]. The Fume Capture PLC1 contains all of the control logic to control the equipment hardwired into both the converter PLC and the matte granulation PLC and to operate the matte granulation process.

The Fume Capture PLC1 exchanges data to and from the Fume Capture PLC2, Converter PLC and the Oxidation PLC through Ethernet communications. Data can be sent through DH+ communications between PLC's, however, Ethernet has priority over DH+ communication methods. DH+ is used for redundant data transfer.

5.6. Fume Capture PLC 2

The Fume Capture PLC2 is an Allen Bradley PLC5 Programmable Logic Controller. It contains a PLC5/80E processor. The structure consists of one 16 slot chassis that contains two 8 slot racks. Analog and digital input and output modules are contained within the racks.

The Fume Capture PLC2 monitors and controls part of the operation of the three converters for the purification of the nickel matte product before it enters the matte granulation system. For the matte granulation process the Fume Capture PLC2 contains the control logic to operate the north and south matte tilters and calculates the speed of the tilter movement.

The Fume Capture PLC2 exchanges data to and from the Fume Capture PLC1, Converter PLC, Air-Conditioning PLC and the Oxidation PLC through Ethernet communications. Data is also able to be sent through DH+ communications between PLC's, however, Ethernet has priority over DH+ communication methods. The DH+ communication method is used as a redundant method of data transfer between PLC's.

5.7. PLC Analog and Digital Module I/O Configurations

Four Allen Bradley PLC programs were supplied to Fluor Australia Pty Ltd. by BHP Billiton Kalgoorlie Nickel Smelter site personnel. The four PLC programs supplied were studied intensively to understand the function of each PLC in relation to the matte granulation system to determine the interrelation between the PLC's. Once the PLC programs had been studied, it was noticed that the available a master tag list for each PLC within the Kalgoorlie Nickel Smelter Expansion project was incomplete. Many of the PLC I/O points were not present within the master tag list. A substantial amount of time was spent on determining the I/O configurations of each of the four PLC's from the programs provided. A new Microsoft Excel spreadsheet was created externally from the master tag list that detailed the I/O configuration of each of the four PLC's. The I/O configuration for each PLC specifies firstly, the PLC chassis structure detailing the analog and digital input and output module arrangement. The structure of each chassis contains information about the rack number, slot number, module type, I/O point number and a general description. A sample of the chassis layout for the matte granulation PLC is shown in Table 1. Secondly, for each analog or digital I/O module the details of each I/O point were determined. The module layout contains the location and a description of each tag/address within the PLC in relation to both the PLC program and the master tag list and whether the I/O point or instrument was present within the master tag list. A sample module layout for the digital output module in the matte granulation PLC is shown in Table 2.

The I/O configuration spreadsheets were created to help understand the purpose, operation and the equipment attached to each PLC unit. To determine which PLC program required alteration and conduct PLC programming it was necessary to determine which PLC's the four original matte granulation jet pumps were connected to. The I/O configuration layout in the future will also be the basis for determining the additional hardware required to accommodate the additional equipment and instrumentation of the matte granulation upgrade.

For the upgrade the new matte granulation jet pumps are not to be connected to the original I/O addresses of the fume capture PLC1 or the converter PLC. The new matte granulation jet pumps and associated instrumentation are to be connected to the matte granulation PLC. Each analog and digital I/O signal for the new matte granulation jet pumps and instrumentation are to be wired to terminal strips within a new digital or analog junction box in the field. From each junction box the signals are to be fed back to a new remote I/O rack and then to the matte granulation PLC within the substation.

Table 1: Matte Granulation (MGRAN) PLC Chassis and I/O Module Arrangement

Table removed for confidentiality and/or copyright reasons.

Table 2: Matte Granulation (MGRAN) PLC Rack 0 Slot 4 Module Arrangement

Table removed for confidentiality and/or copyright reasons.

6. The Matte Granulation Process Instrumentation

The expansion to the matte granulation system requires the addition of 35 new instruments. As a part of the detailed engineering phase of the project instrumentation work was required. A large section of the internship was dedicated to instrumentation work for the matte granulation section of the project creating, reviewing and maintaining the instrument index, cable schedule, I/O list and the instrument data sheets. The documents were created in an instrumentation database software package, PiSYS. Throughout the internship a large amount of time was spent updating and altering the PiSYS database to reflect the changes in the project and maintain instrumentation documentation.

6.1. Matte Granulation Instruments

The expansion to the matte granulation system requires the addition of 35 new instruments. The new instruments were 6 Butterfly Control Valves, 9 Knife Gate On/Off Valves, 2 Ultrasonic Level Transmitters, 6 Magnetic Flow Meters, 3 Pressure Gauges, 6 Pressure Transmitters and 3 Temperature Transmitters. A general simplified representation of the instrument locations within the process is shown in Figure 6. There are two sections to the matte granulation process the matte granulation pumping section which consists of the matte granulation jet pumps and piping inclusive of the knife gate valves and pressure gauges. This section is located behind a large newly constructed wall that functions remove the equipment from the red zone to enable it to be easily accessible and to increase safely. In addition to this, previously, due to the matte granulation jet pumps being located in the red zone if maintenance was required on any pump the matte granulation process would be required to be stopped. The design of the upgrade is such that any one of the granulation jet pumps is able to be put into maintenance and worked on by being isolated and the matte granulation process can continue to run. The second section is the matte granulation spraying section which is classified as a red zone. As no employees are able to enter the red zone while the matte granulation process is in operation due to the dangerous nature of the process all instrument readings are to be sent back to the PLC to be viewed the operator if required.

6.1.1. Butterfly Control Valves

There are three types of butterfly valves swing through, lined and high performance [30]. The butterfly valves used in the matte granulation upgrade are lined butterfly control valves. Butterfly control valves contain a body, a seat, a butterfly disk, a stem, packing, a notched positioning plate, an actuator and a positioner [31]. The butterfly disk is a flat circular plate positioned within the valve body, which is rotated about a internally positioned stem by an actuator mounted externally to the valve [31]. The actuator is currently specified to be rack and pinion type with a pneumatic positioner. The positioner is present to improve the control of the butterfly valve in response to a control signal from the PLC [30]. It does this using a feedback loop comparing data about the valve stem position and controller signal and adjusting the stem position accordingly [30]. A 90 clockwise or anticlockwise degree turn of the valve fully opens or closes the flow through the pipeline [31]. The seat provides a seal around the inside of the valve body and between the valve body and the stem [31]. Packing is used as a seal around the stem [31]. The general structure and placement of a butterfly valve in a closed position within a pipeline is shown in Figure 4.

Figure removed for confidentiality and/or copyright reasons.

Figure 4: General Butterfly Valve Placement in Pipeline [32]

The main criteria generally required to be considered when selecting butterfly valves are:

Quotation removed for confidentiality and/or copyright reasons.

The water supplied to the granulation spray nozzles and the agitation nozzles is corrosive. Therefore, a lined butterfly valve type has been selected. The butterfly vales are required to be lined with elastomeric materials to prevent contact between the metallic valve body and the liquid [30].

The butterfly control valves are present as the actuator to control the flow of water through the four spraying lines, the top spraying line #1 and #2, the bottom spraying line # 1 and #2 and the two agitation lines #1 and #2 to the granulation tanks within each granulation process as shown in Figure 6. The butterfly control valves are the manipulated variable within the flow control loops and are controlled based on the flow reading from the signal sent back to the PLC from the magnetic flow meter within the same spray or agitation line.

6.1.2. Magnetic Flow Meters

Magnetic flow meters require to be used on applications with a conductive fluid. The general structure of a magnetic flow meter consists of a meter tube, electrode coils, a laminated iron core, a cover and the instrumentation end connections [30]. Magnetic flow meters operate on the principle of Faraday's law of electromagnetic induction [30].

Quotation removed for confidentiality and/or copyright reasons.

The magnetic flow meter functions to produce a voltage proportional to the average velocity or flow rate of the fluid at the instruments electrodes [30]. The magnetic flow meter outputs a 4-20 mA signal proportional to this voltage. This signal is fed back to the PLC.

The magnetic flow meter is used in the process due to the corrosiveness of the fluid. The magnetic flow meters are located in each of the four spraying lines, the top spraying lines #1 and #2, the bottom spraying lines # 1 and #2 and the two agitation lines #1 and #2 to the granulation tanks within each granulation process as shown in Figure 6. The flow of each spray line is the process variable signal sent to the PLC to control the flow of water through each spray or agitation line. A high volume jet of spraying water is required to be supplied through each spray line.

6.1.3. Knife Gate On/Off Valves

On/off knife gate valves control the flow of fluids through the pipeline in either an open or closed position through the movement of a flat cylindrical plate. The plate is situated within the valve body and is moved up and down by the stem that is situated externally to the valve body. The seat provides a seal around the inside of the valve body and between the valve body and the stem [31]. Packing is used as an additional seal [31].

Figure removed for confidentiality and/or copyright reasons.

Figure 5: General Knife Gate Valve Operation and Placement in Pipeline [33]

The knife gate on/off valves are used for shut off isolation purposes of lines due to either an emergency or the requirement to conduct maintenance on the jet pumps, pipelines or instrumentation and/or equipment within the system. The knife gate on/off valves are located within the pumping end of the matte granulation system before proceeding to the spray and agitation nozzles. More specifically, one in each line on the suction side of the jet pumps, the discharge side of the jet pumps, between jet pump 2 and jet pump 3 and one in each return line to the hot well. The knife gate on and off valves are desired to be operated by hand switches from a solenoid/hand switch panel external to the red zone of the matte granulation area and on an electrical and instrumentation equipment plinth.

6.1.4. Ultrasonic Level Transmitters

Ultra sonic level transmitters use sound waves to determine the level within a vessel such as a tank. In the matte granulation system the ultrasonic level transmitters are to be mounted externally from the hot well and the granulation sump well. The ultrasonic level transmitter will transmit an electronically pulsed sound wave converted by a piezoelectric crystal within a transducer to the surface of the liquid [34]. The sound wave signal will then be reflected back and received by the transducer [34]. The instrument will then calculate the level dependent on the time interval for the sound wave to return as the time and distance are proportional [34]. The ultra sonic level transmitters function to provide a 4-20mA signal back to the PLC displaying the level within both the hot well water storage tank and the granulation sump well.

6.1.5. Pressure Gauges

The pressure gauges are Bourdon pressure gauges. The gauge is constructed of a coiled tube connected to a needle point within the indication gauge [35]. As the pressure increases the coil expands [35]. The expansion of the coil moves the pointer [35].

The pressure gauges are located on the pipeline on the discharge side of the matte granulation jet pumps. These gauges indicate the pressure in the pipeline on the discharge side of each jet pump.

6.1.6. Pressure Transmitters

The pressure transducer or transmitter functions to convert pressure into a 4-20 mA analog signal [36]. There are numerous methods and types of devices which are able to be used to measure pressure. The pressure sensing element is a gauge pressure sensor. It measures pressure relative to the specific atmospheric pressure at a particular location such as at the Kalgoorlie Nickel Smelter facility [37]. Numerous types of technologies can be used to measure pressure some of these include the use of a strain gauge, piezoresistive material, piezoelectric material, optical pressure elements and many more.

The Pressure transmitters measure the pressure of water within each of the spray and agitation lines of the both matte granulation process #1 and #2. A low pressure jet of water is required to be supplied through each spray line.

6.1.7. Temperature Transmitters

The temperature is measured by a platinum resistance temperature detector (RTD) enclosed in a thermowell which is inserted into the pipeline. A thermowell is a stainless steel fitting and enclosure which isolates the temperature transmitter/RTD from the measured material and connects the temperature transmitter onto the pipeline [38]. The transmitter is located above the thermowell. Electrical resistance changes as the temperature of the fluid being measured increases or decreases [30]. The temperature change is proportional to the electrical resistance of the metallic element. The transmitter produces a proportional 4-20 mA output signal proportional to the induced electrical resistance [30].

Temperature transmitters are located in the hot well, the bottom jets spray line and the top jets spray line. The temperature in these three locations is required to be known because if the temperature being supplied to spray the molten matte is too high effective granulation of the matte will not occur. An interlock on the matte granulation control system is also in place which will prevent the tilting ladle from being operated when the temperature in the hot well exceeds a temperature high limit [28].

Figure removed for confidentiality and/or copyright reasons.

Figure 6: Matte Granulation Instrumentation Representation [39] [40] [41] [42] [43] [44]

6.2. Master Instrument Index

The master instrument index lists all of the instruments to be used on a project and is developed from the P&ID documentation of the process. Its purpose is to list all of the instruments on the P&ID drawings in a concise and easily readable manner. These instruments can include valves, level transmitters, flow transmitters, pressure gauges, pressure transmitters, temperature transmitters and limit switches. It was originally decided that the instrument index would only list all the instruments on the P&ID. However, it was later decided that the PLC software control settings for each of the matte granulation jet pumps being the remote start, remote selected, drive ready, drive running, and drive tripped settings were to be included in the instrument index. The instrument index was created by the Electrical, Instrumentation and Control Team.

Each instrument within the instrument index is identified by a tag number. The tag number is a unique tag differentiating each individual instrument element. It is made up of three main components, the plant area (i.e. 07 for the matte granulation section of the Kalgoorlie Nickel Smelter), the instrument type (i.e. FIT for a flow instrument transmitter) and a unique three digit number identifier. Control loops are present in the process. In the control loops the instruments are labelled so that they are still unique, however, the loop number is present to make all elements in that control loop common and easily distinguishable e.g. the hand switch that operates the hand valve or the open/closed limit switches associated with a butterfly valve. In the tag numbering convention for control loops the instrument type changes but the plant area and the unique number identifier remain the same (i.e. 07FIT209 for the flow indicator transmitter and 07FI209 for the flow indication in the PLC software).

Each instrument is designated to a single record in the PiSYS database and row within the instrument index. All of the descriptive and reference information corresponding to that instrument is in the row.

Specific data is required to be stored in regards to each instrument. The data is stored in columns in the PiSYS database. When the instrument index is generated by the PiSYS software, it extracts the required columns from the database and creates the instrument index.

The information required for the instrument index is separated into five main categories. The categories are instrument identification, instrument specification, connection details, contract and remarks. The instrument specification section requires the tag number, description of the instrument, service description and the functional description. The instrument specification needs the manufacturer, model, spec number (instrument data sheet number), loop drawing number, range, set point, units and the scale of the instrument. The connection details should contain the P&ID drawing number, equipment number, location, Loop ID, Junction Box/MCC number, PLC address and card address. The contracts section contains purchase and installation information and a remarks section is available for any additional comments required in relation to the instrument. A sample of the instrument index is shown in

Figure removed for confidentiality and/or copyright reasons.

Figure 7. In the sample only a selection of instruments are shown and the remarks column of the index has been removed for clarity. The complete instrument index is shown in Appendix A.

The original instrument index was created with the instrument labelling on the original P&ID's and then all of the P&ID instrument labels were changed. Due to these changes the instrument index was required to be updated with instrument names and control loops were required to be changed within PYSIS. Different sections of the instrument index were completed as time progressed and more information became available, such as equipment types and drawing numbers. Once the instrument index was developed an I/O list and cable schedule were developed using the same PYSIS database. The instrument index will continue to evolve and change throughout the detailed engineering phase of the project.

Figure removed for confidentiality and/or copyright reasons.

Figure 7: Matte Granulation Instrument Index Sample

6.3. Instrument Data Sheets

The instrument data sheets detail the instrument specification which must meet process conditions and associated standards relevant to the project requirements. A data sheet is required to be created for each of the 35 instruments displayed on the matte granulation P&ID's.

The data sheets were created within Microsoft Excel using an already existing standardised spreadsheet. The spreadsheet contains a large selection of instrument types, which are listed in an index. Each row of the index corresponds to one type of instrument. There are five columns in the index. The columns are the type that contains a 2 digit identifier, the instrument lists that contains the instrument name and is hyperlinked to the instrument list sheet in the excel file of each instrument type, the instrument data sheets that contains the instrument name and is hyperlinked to the instrument data sheet template sheet in the excel file for the instrument type that shows what each of the datasheets created are going to be displayed as, the number of instruments and the cost. A section of the index is shown in Figure 8. The instrument list and the data sheet corresponding to each instrument display the generic specifications necessary to be defined for that instrument. The information required for the spreadsheet was gathered by correspondence with the Piping Engineering Team and by consultation of the BHP Billiton Standard Engineering Specifications. The specifications used in the selection of instrument characteristics required to meet process requirements for the new instrumentation for the matte granulation process upgrade are the following BHP standard engineering specifications:

- SES 731 Standard Engineering specification For Control Valves, Actuators and Accessories

- SES 730 Standard Engineering Specification For Flow, Level, Pressure and Temperature Instrumentation
- SES 700 Standard Engineering Specification For Instrument Installations
- SES 203 Standard Engineering Specification For Piping
- SES 266 Standard Engineering Specification For Valves

These specifications are used as outlined in the instrument scope of work for the matte granulation upgrade.

The data gathered from the Piping Engineering Team and the BHP Billiton Standard Engineering Specifications was entered into the instrument list. Common to each instrument list is the instrument title, the project number, client name and date. For the datasheet that is displayed in the excel spreadsheet the datasheet directory location and the row number of the datasheet to be viewed as the template is also common. The macro action buttons act to create the datasheets, print the list, format the list, delete the revision history, delete all revisions, to export the list, to import the list and to insert or delete rows in the list. The highlighted yellow section of the instrument list spreadsheet contained the main classification sections of data to be contained in the instrument datasheet when created. Each row of the instrument list contains all the information relevant to that instrument. Each column is a single data item required to be specified for the instrument type. Different information was required depending on the instrument type. A sample of the beginning section of the instrument list for the butterfly control valves is shown in Figure 9 and an example of the sizing data section of the instrument list spreadsheet is shown in Figure 10.

The butterfly control valves as shown in Figure 11 require the 8 main sections and corresponding information as follows:

Text describing datasheet information requirements removed for confidentiality and/or copyright reasons.

The data entered into the instrument list was linked to the datasheet template. Once the instrument list is completed the data sheets are generated as individual excel spreadsheets from using the create spreadsheet button in the instrument list for the instrument. It is required to specify the first and last row number for the single instrument or the range of instruments that are to be created. The instruments are then generated into a data sheet directory that is defined on the cover page of the standardised Microsoft Excel spreadsheet. A sample of one of the 35 data sheets created is shown in Figure 11. A selection of one of each of the datasheet types created is shown in Appendix B.

Figure removed for confidentiality and/or copyright reasons.

Figure 8: Microsoft Excel Standardised Instrument Spreadsheet Index

Figure removed for confidentiality and/or copyright reasons.

Figure 9: Microsoft Excel Instrument List

Figure removed for confidentiality and/or copyright reasons.

Figure 10: Specification Sizing Data Section for Butterfly Control Valves

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Figure 11: Microsoft Excel Instrument Datasheet

The data sheets that were created for the matte granulation process instrumentation are as follows:

- 6 On/Off Butterfly Valves (later deleted)
- 6 Butterfly Control Valves
- 9 Knife Gate On/Off Valves (Pneumatically Actuated)
- 2 Ultrasonic Level Transmitters
- 6 Magnetic Flow Meters
- 3 Pressure Gauges
- 6 Pressure Transmitters, and
- 3 Temperature Transmitters

The datasheet instrument numbers and reference drawing numbers changed many times as the instrument tag numbers on the P&ID's changed. Originally, it was thought that the butterfly valves would be of the on/off type but it was later decided that they would be modulating butterfly control valves and therefore the original datasheets created were deleted and new data sheets were created. In addition to this the magnetic flow meters were originally to have power supplied to the instrument by an 110V AC power supply according to the SES 730 Standard Engineering Specification For Flow, Level, Pressure and Temperature Instrumentation. In consultation with the client it was decided that the power supply to the magnetic flow meters was to be changed to a 24V DC power supply.

Towards the end of the internship two new jet recirculation pumps were added into the scope of work for the matte granulation upgrade. Instrument datasheets for four additional pneumatically actuated on/off knife gate valves were required to be created. This is to be completed as future work.

The next step will be for the data sheets to be reviewed and sent to the procurement department to be sent to vendors who submit bids on products that meet the specifications. The bids received from vendors are then to be reviewed and a technical evaluation report prepared which compares the bids of each of the vendors and accesses if the products suggested by vendors meet the specifications.

6.4. I/O List

The I/O list details all of the input and outputs, digital and analog, for both the new instruments and the associated equipment such as the motor connections that needs to be connected to the PLC control system.

By adjusting the PiSYS database and using the instrument index, an I/O list was created which displayed the analog and digital inputs and outputs required for the instruments and associated equipment. All instruments excluding the pressure gauges in the field were contained on the I/O list as analog inputs. The analog outputs present in the list were the current to pressure (I/P) converters required for the supply from the analog junction box to the pneumatically actuated valve to convert the current supplied from the junction box to the pneumatic supply to the valve. The jet pump settings of remote selected, drive ready, drive tripped and drive running and each of the jet pump discharge proximity switches are digital inputs. The digital outputs are the remote start for each jet pump. There is a total of 56 I/O points for the matte granulation upgrade at the end of the internship placement being 17 analog inputs, 6 analog outputs, 30 digital inputs and 3 digital outputs. The I/O list changed several times as the instrument labelling of the P&ID's changed.

The I/O list requires the main title details of the module type, location and a general description of the module to be specified. The body of the I/O list requires the channel number of the digital or analog input/output card, the tag number of the instrument or piece of equipment connected to that channel/address of the analog input/output card, the address the instrument is connected to in the PLC, a description of the instrument or piece of equipment the failure state and the revision number. At this point in time the revision number was not needed.

The PLC to which the new instrumentation and equipment was to be connected was only defined at the end of the internship placement. The PLC address location of each instrument has not yet been completed and will be required in the future. Therefore, in conjunction with the control systems work still to be completed on the matte granulation upgrade the I/O list will continue to be expanded upon and updated as the project progresses. A sample of the I/O list is shown in Figure 12. The complete I/O list is shown in Appendix C.

Figure removed for confidentiality and/or copyright reasons.

Figure 12: I/O List Selection of Analog Inputs

6.5. Cable Schedule

The purpose of the cable schedule is to provide a list of all of the cables in the matte granulation project listing the cable source, destination and length.

Each cable in the cable schedule is designated with a cable number. The cable number is represented by the piece of equipment the cable is sourced from such as a junction box or instrument, the plant area code (i.e. 07 for the matte granulation area), and the cable type whereby, A is for analog and C is for digital and a cable unique number identifier beginning at 01 identifying the number of cables associated with that piece of equipment. It is required to be taken into account that the cable numbering convention differs depending on the equipment type. For a junction box it is plant area code, equipment tag, cable type and cable number (i.e. 07JB001-A01). For an instrument the cable number is represented by the instrument type (i.e. FIT for a flow indicator transmitter), plant area code, instrument unique identifier, cable type and cable unique number identifier (i.e. FIT07209-A01).

Each individual cable is designated to a row of the cable schedule. The data items associated with each cable are in each column. The data items required are the cable number, cable type, source, destination, drum, description, signals, estimated length, actual length on installation, operating voltage, cable route, outer diameter (mm2) and any notes or revisions.

The cable schedule was created by addition of information to the PiSYS database. The source and destination for each cable was determined from instrument index and the cable block diagram of the matte granulation upgrade. The instrument location drawings of the matte granulation area were used to determine the cable length from the instrument and junction box locations. A sample of the cable schedule is shown in Figure 13 and the complete cable schedule is shown in Appendix D.

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Figure 13: Cable Schedule Example

7. Matte Granulation Design

7.1. Design Management Block Diagram (Cable Block Diagram)

The purpose of a Design Management Block Diagram (Cable Block Diagram) is to provide a graphical representation of the cabling layout of the matte granulation section of the plant between all equipment to enable the placement of cables to be easily visualised and seen for design and construction staff during the design phases of the project.

The cable block diagram was created in Microsoft Visio. It was drawn with reference from the matte granulation schematic, termination and P&ID diagrams. The design management and cable block diagram is current as at the end of the internship placement, however, the drawing may be updated to reflect changes to the design of the matte granulation upgrade throughout the duration of the detailed engineering phase of the project.

Each of the jet pumps are to be wired to the motor control centre (MCC) within a substation and then from the motor control centre to the remote I/O rack in the substation. The design management and cable block diagram displays each of the three matte granulation pumps (matte granulation jet pump 1/top jets, matte granulation jet pump 2/bottom jets and matte granulation jet pump 3/standby) each with a field isolator and local control station. A matte granulation sump pump with the low level and high level cut out floats, two junction boxes and a local control station. Towards the end of the internship placement two recirculation jet pumps added into the scope of work for the matte granulation upgrade were needed to be included on the cable block drawing. Each of the recirculation jet pumps were displayed with a field isolator and local control station. This is shown on the matte granulation design and management block diagram in Appendix E.

Each analog and digital I/O signal for the matte granulation jet pumps and the new instrumentation are to be wired to terminal strips within a new digital or analog junction box in the field. From each junction box the signals are to be fed back to a new remote I/O rack and then to the matte granulation PLC within the pulpit. The analog junction box displays the connection to each analog instrument. The magnetic flow meter instruments required a 24V power supply from a distribution board in the field. The butterfly control valves required a current to pressure (I/P) converter in between the current signal supplied from the analog junction box to convert it to the pneumatic signal required to actuate the valve. The pneumatic signal then passes through an air intake manifold to supply air to the instruments. This is shown on the matte granulation design and management block diagram in Appendix E.

A digital junction box with connections to the digital settings of the pneumatic knife gate valves was also required. This is shown on the matte granulation design and management block diagram in Appendix E.

A panel displaying the hand switches for the operation of the knife gate valves to be used during maintenance purposes, as requested by the client, and the connection from the box to the valves is shown on the matte granulation design and management block diagram in Appendix E.

The cabling connections between all equipment that are defined are displayed are also displayed in Appendix E.

The design and management cable block diagram for the matte granulation area was created, maintained and continually updated throughout the duration of the internship as the matte granulation upgrade evolved.

7.2. Instrument Location Drawings

Instrument location drawings function to provide a graphical representation of the exact location of the instrumentation in the mate granulation section of the facility. Piping and Mechanical General Arrangement drawings were altered to include the exact instrument locations. There were two main instrument location drawings. The first drawing details the three new matte granulation jet pump and two recirculation pump locations and the associated instrument locations in this area. The second drawing shows the instrument locations throughout the granulation section of the plant. The instrument location drawings were current as at the completion of the internship placement. A sample of the matte granulation instrument locations is shown in Figure 14. Additional instrument location drawings samples are displayed in Appendix F.

Figure removed for confidentiality and/or copyright reasons.

Figure 14: Instrument Locations Sample

7.3. Plinth for Electrical and Instrumentation Equipment Layout

The Plinth for Electrical and Instrumentation Equipment Layout drawing displayed the layout for the plinth required to be installed in the project to accommodate the five electrical cabinets and the analog junction box, digital junction box, solenoid panel and the 24V distribution board which are all to be located in the matte granulation area in the field. Three views plan, elevation and section were shown on the drawing. The analog, digital and solenoid/knife gate valve hand switch panels are drawn based on the standard junction box specifications required by BHP Billiton. The 24V field distribution panel and the electrical panels are drawn based on the design decided to be placed in the procurement package from the selected vendor to be used. A sample of the elevation view of the drawing is shown in Figure 15. The complete drawing is shown in Appendix G.

Figure removed for confidentiality and/or copyright reasons.

Figure 15: Elevation on Plinth for Electrical and Instrumentation Equipment

8. Small Project Work

Tasks throughout the internship placement that were not related to the matte granulation upgrade have been completed. The majority of the tasks are apart of the Kalgoorlie Nickel Smelter Furnace Rebuild Project and the Kalgoorlie Nickel Smelter Expansion Project. Additional tasks which were aimed to provide useful experience to aspects of different sections of a project were also carried out.

8.1. Furnace Rebuild Tasks

Several tasks were completed on the furnace rebuild in preparation for carrying out tasks for the matte granulation section of the internship project.

8.1.1. Furnace Rebuild Drawing Extension and Checking

Each junction box or large piece of equipment in the furnace rebuild project had a set of drawings associated with it. They consisted of general arrangement, layout, termination and schematic drawings. The drawings were checked one set at a time in conjunction with checking the two design and management cable block diagrams for the furnace rebuild in order of equipment type to ensure all the drawings for each piece of equipment, instrumentation and cabling were correct and all references to the drawings were correct and included. Errors which were found were red pen amended.

The P&ID and the instrument index were also checked to make sure that all instruments that were on the P&ID's were in the instrument index and on the design and management diagrams. Many of the drawings for junction boxes on the design and management diagrams were unavailable and were required to be obtained before checking could be completed. As information that was not included on the block diagram was discovered such as missing cables, sunshades and lighting, incorrect cable sizes and types, incorrect drawing reference numbers etc. it was added in. The alteration of the furnace rebuild design and management cable black diagrams were completed to provide experience and preparation for the development of the matte granulation upgrade design and management cable block drawing.

8.1.2. Furnace Rebuild Instrument Index

The furnace rebuild instrument index was checked against the design and management block diagrams. Any changes required were red pen amended on the block diagram and the instrument index was corrected. Additional information such as the cabinet destinations, junction box numbers and design and management drawing numbers were added into the index. The P&ID and design and management block diagram drawing numbers were entered into the instrument index. The furnace rebuild instrument index was maintained throughout the beginning of the internship placement to provide knowledge and experience for when the matte granulation upgrade instrument index was required to be maintained and adjusted.

8.1.3. Furnace Rebuild Instrument Drawing Register and Electrical Drawing Register

The instrument drawing register and electrical drawing register are separate lists that contain each instrument or electrical drawing that have been produced for the project. The instrument register was checked for correctness against the drawing sets. Several drawings that existed but were not placed on the drawing register were required to be included. All drawings which were not included in the instrument or electrical folders were recorded so that they could be obtained to be put in the folders. In addition to this all of the drawing names were changed and red pen amended on the actual drawings to comply with the KNS drawing numbering and labelling system.

8.2. Kalgoorlie Nickel Smelter Expansion (KSE) Instrumentation

8.2.1. Oxygen Plant Data sheets

The data sheets detail the instrument specification which must meet process conditions and associated standards relevant to the project requirements. Data sheets were created for the oxygen plant section of the Kalgoorlie nickel smelter expansion project. The data sheets were created for a new oxygen line to supply each of the three converters that provide the high concentrate matte slag to the matte granulation process.

The instrument data sheets created consisted of:

- 3 Butterfly control valves
- 3 Enrichment oxygen analyser transmitters
- 3 Orifice flow meters
- 3 Pressure transmitters
- 3 Temperature transmitters

The pressure transmitters, temperature transmitters and butterfly control valves require the same information to be gathered as the matte granulation instrumentation. There were no standardised datasheet spreadsheets for the orifice flow meter or the enrichment oxygen analyser. New datasheet categories were required to be created. The required data for each data sheet was compiled and a new category of data sheet was included into the standard list of data sheets. The data required for and an example of the data sheet for each instrument type is discussed in Appendix G.

8.3. Aries Bore Field Motors, PLC Program and Citect Configuration Pre-Commissioning and Testing

8.3.1. Plummer's Visit – Testing of Control Panels and Citect/PLC Program

A visit was conducted to Plummer's, a company which constructs control switchboards. Two switchboard panels designed for the Aries Bore Fields project were tested. Each switchboard panel had 5 motors which required testing. Assistance as apart of the internship placement in the form of testing each of the motor control panels through the Citect screen configuration developed for the project was provided. The critical interlocks were tested first by others. The four modes of operation (auto, manual, maintenance and out of service) and the duty and standby settings were then tested for correct operation for each panel from Citect. Some design errors in the Citect screen configuration were detected while testing was taking place. The purpose of this exercise was to be exposed to a small section of the pre-commissioning and testing phase of a project.

9. Tools/Methodologies

9.1. The Master Tag List

The master tag list was an excel spreadsheet that contained all of the PLC I/O points and their associated addresses/tags and a description for each PLC in the Kalgoorlie Nickel Smelter Expansion Project. The master tag list for the matte granulation section of the plant was found to be incomplete with many I/O points within each of the four PLC programs not included in the list. Therefore, the I/O configuration spreadsheets were created for the matte granulation upgrade to be used in the place of the master tag list. The master tag list was used in the creation of the I/O configuration spreadsheets as the spreadsheets contained the designation of each tag/address within the PLC in relation to the PLC program and the master tag list so it was known which I/O points were not included in the master tag list.

9.2. Master P&ID's

A P&ID is a Piping and Instrumentation Diagram. A piping and instrumentation diagram displays 'the interconnection of process equipment and the instrumentation used to control the process' [45].

The master P&ID's for the matte granulation system are physical paper based documents. The P&ID documentation is developed and maintained by the Process Engineering Team of Fluor Australia Pty Ltd. There were originally two P&ID drawings developed by the Process Engineering Team for the matte granulation system. However towards the end of the internship placement a third P&ID drawing was developed and included into the matte granulation drawing sets. The P&ID's for the matte granulation system display all the new instrumentation and process equipment to control the expanded matte granulation process. Each P&ID details the water treatment and pumps section of the matte granulation process. The first P&ID drawing shows the matte pouring and spraying section of the matte granulation process. The second P&ID drawing shows the matte granulation jet pumps and control section of the matte granulation process. The third P&ID displays the matte granulation pond services, gland water and spray water recirculation pumps.

The P&ID documentation played an integral part in the instrumentation and control work carried out on the matte granulation expansion. It was the point of reference and was consulted on a regular basis for the development of the instrument index, I/O list, instrumentation data sheets, cable schedule and design and management (cable) block diagram that were all created throughout the duration of the internship.

The P&ID's were the building blocks for the instrumentation work which was to be carried out on the matte granulation expansion project. The P&ID's created underwent red per amended mark ups and several changes were made at different stages through out the project as the P&ID's supplied did not meet standard labelling conventions. The time spent on all of the instrumentation work was increased as changes were made to the work interrelated with the P&ID drawings of the matte granulation process.

9.3. PiSYS

The instrumentation documents of the instrument index, cable schedule and the I/O list were created in an instrumentation database software package, PiSYS which stands for Plant Instrumentation System.

Each instrument is designated to a single record or row in the PiSYS database. All of the descriptive and reference information corresponding to that instrument is in the row. Specific data is required to be stored in regards to each instrument. The data is stored in columns in the PiSYS database. As the different documents are required to be created at different stages in the project the PiSYS database is continually expanded and the data required for each document is added into the corresponding predefined columns in the PiSYS database. The instrument index is generally the first instrumentation document created followed by the cable schedule and the I/O list. An example of a section of the PiSYS database is shown in Figure 16.

Figure removed for confidentiality and/or copyright reasons.

Figure 16: PiSYS Plant Instrumentation System Database

Throughout the internship a large amount of time was spent updating and altering the PiSYS database to reflect the changes in the project and maintain instrumentation documentation.

10. Matte Granulation Upgrade Future Work

The Kalgoorlie Nickel Smelter Expansion Project is in the detailed engineering phase and procurement packages are being prepared within the definition study. In the future construction, pre-commissioning, commissioning and handover if requested for by the client are able to be implemented and completed. At this stage however, the project is a study.

After the completion of the internship placement there is a requirement for additional instrumentation work. The additional digital and analog I/O and hardware for the additional recirculation jet pumps added into the scope of work needs to be added onto the cable schedule, and I/O list. Additional datasheets for the four new knife gate valves are also required to be created. The additional instrumentation has been added into the instrument index.

A selection of control systems work is still required to be carried out for the detailed engineering section of the matte granulation expansion. It is required to determine whether all of the existing instrumentation and equipment can be accommodated into the matte granulation PLC and acquire any necessary existing hardware for the matte granulation PLC. Modification of the Allen Bradley PLC programs in accordance with the existing program standards and specifications are required. This is required to control the process associated with the three new matte granulation jet pumps using new matte granulation PLC I/O addresses and the new recirculation jet pumps using the original Converter PLC or Fume Capture PLC1 I/O addresses and programs. The I/O addresses of the four original matte granulation jet pumps that will be used for the recirculation pumps have not currently been decided. This will also need to be determined. The instrumentation and associated program logic will need to be included in the control software. Adaptation of the Citect screen configuration to comply with the changes made to the control software and the new equipment locations and layout will also be necessary. The interlocks will need to be adjusted and changed.

The work completed during the internship placement was a small part of a much larger project and therefore future work is still required to be conducted as the project continues from detailed engineering to procurement and to the completion of the definition study.

11. Conclusion

The internship project provided a valuable industry based experience. The project was a small part of a much larger Kalgoorlie Nickel Smelter Expansion project and the Kalgoorlie Nickel Smelter Furnace Rebuild project. However, the work completed during the internship project was important to the matte granulation upgrade. Instrumentation control systems and design work was carried out. A large contribution was made to the instrument index, cable schedule and the I/O list, the control system I/O configurations, the design and management block diagrams, instrument locations and the electrical and instrumentation plinth layout. The work completed would enable the future PLC programming to be carried out and the detailed engineering package to be completed. It will facilitate the future work required to be conducted as the project continues from detailed engineering to procurement and to the completion of the definition study.

The industry based experience provided a valuable resource of workplace based experience. The knowledge gained from both the Industrial Computer Systems Engineering Major and the Instrumentation and Control Systems Engineering major assisted in the instrumentation and control work completed throughout the internship project.

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Appendix A – Master Instrument Index

The instrument index contained in this report is current at the end of the internship placement; however future changes to the instrument index may occur.

Instrument Index removed for confidentiality and/or copyright reasons.

Appendix B – Data Sheet Information

Datasheet requirement description and examples removed for confidentiality and/or copyright reasons.

Appendix C – I/O List and I/O Loading

I/O List and I/O Loading removed for confidentiality and/or copyright reasons.

Appendix D – Cable Schedule

Cable Schedule removed for confidentiality and/or copyright reasons.

The current cable schedule shown does not display the cable lengths. These were determined from the instrument location drawings and recorded on a printed copy of the cable schedule. They have not yet at this point in time been included on the electronic copy of the cable schedule by updating the data contained within the PiSYS database.

Appendix E – Design and Management (Cable) Block Diagram

Design and Management (Cable) Block Diagram removed for confidentiality and/or copyright reasons.

Appendix F – Sections of Instrument Location Drawings

The following displays a selection of instruments from the instrument location drawings.

Instrument Location drawings removed for confidentiality and/or copyright reasons.

Appendix G – Plinth for Electrical and Instrumentation Equipment Layout

Plinth for Electrical and Instrumentation Equipment Layout removed for confidentiality and/or copyright reasons.