Internship Report

BHP Billiton Worsley Alumina Pty Ltd

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November 2009

A report submitted to the School of Engineering and Energy, Murdoch University in partial fulfilment of the requirements for the degree of Bachelor of Engineering

Abstract

BHP Billiton Worsley Alumina has had a long standing relationship with Murdoch University of over 8 years. During this time, BHP Billiton Worsley Alumina has offered Murdoch University engineering students the opportunity to gain industrial experience through six month final year internships.

Interns work at the Refinery in Facility 141, along side Process Control Engineers in the Central Control Room area. While on site the Intern is exposed to a large variety of engineering work, including on site control system upgrades and drop of the hat emergency problem solving.

During the four months on site at the Worsley Refinery the intern worked under the direct supervision of Process Control Superintendent Arnold Oliver and Senior Process Control Engineer Angelo D'Agostino.

This report will discuss in detail the major pieces of work undertaken by the intern during 2009 internship.

Disclaimer

Work detailed in this report is the work of the author unless otherwise referenced.

All work was carried out under the supervision of employees or contractors at Worsley Alumina Pty Ltd, in particular Process Control Superintendent Arnold Oliver and Senior Process Control Engineer Angelo D'Agostino.

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

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Acknowledgements

From the first day I worked on site until the last day of the internship the friendliness, help and support offered was beyond expectation.

I'd like to thank the entire Process Control group, along with all the Process Control Applications Engineers and Systems Engineers for the patience and support offered while I probed them for information and data. Even though the team on site was very busy, they still found the time to sit with me and explain the process.

I'd also like to thank my university supervisor Parisa Bahri, Senior Process Control Engineer Angelo D'Agostino and Process Control Superintendent Arnold Oliver for giving me the opportunity to carry out the internship.

Special thanks should be given Carlos Elliott, Alex Mercader, Vishwesh Soni, Ben Marler and Sol Sadek, all of whom are Murdoch graduates now working for Worsley, for their friendly guidance and support throughout the internship.

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Introduction

BHP Billiton Worsley Alumina is a joint venture operation between BHP Billiton (86 per cent), Japan Alumina Associates (Australia) Pty Ltd (10 per cent) and Sojitz Alumina Pty Ltd (four per cent). Located in Western Australia, operations include a bauxite mine and an alumina refinery. Worsley Alumina is the manager of the joint venture [14]

The Worsley Alumina Refinery is located near the West Australian town of Collie, in Australia's south west. The mine itself is located approximately 50 kilometers away from the refinery near a town called Boddington. Construction of the mine site and refinery began in 1980 and the first alumina was produced in April 1984.

A $109 million expansion project in 1992 increased production of alumina to 1.5 million tonnes per annum. In 1994 Shell sold its 37.5 per cent interest to Billiton Aluminium Australia Pty Ltd (30 per cent), Reynolds (6 per cent) and Sojitz Alumina (1.5 per cent). In May 2000, Worsley completed a $1 billion expansion and annual production was increased to 3.1 million tonnes.

Currently the AU$3 billion Efficiency and Growth (E&G) expansion is one of the single largest industrial investments in Western Australia's South-West region. It will lift Worsley's annual alumina production from 3.55 to 4.6 million tonnes per annum and provide opportunities to improve the energy and water
efficiency of the operation.

This report is broken into four sections with the first section detailing the Bayer process used to extract alumina from bauxite. The remaining sections of this report detail the major pieces of work undertaken by the intern during the 16 week assessable period of the four month internship.

1. The Worsley Bayer Process

The Bayer Process was named after the German chemist Karl Bayer after he discovered a commercially viable method in 1888 to extract Alumina from bauxite using hot caustic soda. Alumina is used to make aluminium, a light weight, high strength and low cost metal used in many applications across the world.

The Bayer Process is the process of extracting hydrated alumina from bauxite. Worsley Alumina sources its bauxite from the Boddington Bauxite Mine via a 51 km cable belt conveyor. The bauxite mined is of a reddish colour and contains approximately 30 per cent alumina in the form of gibbsite [$AL(OH)_3$].

The process relies on a property of bauxite that allows the alumina hydrate to separate from unwanted substances in the bauxite. The use of hot caustic soda is fundamental to the process because it dissolves alumina, allowing the dissolved solution to be separated from undissolved waste for further processing.

The Worsley Alumina Bayer Process is a relatively simple process of extraction, made complex by considerable efforts to maximise plant efficiency and output. The refinery consists of four areas of processing that turns the bauxite into refined alumina hydrate. This chapter will summarize the Worsley Bayer Process from grinding of bauxite (Area 1) to Calcination and storage of alumina hydrate (Area 4).

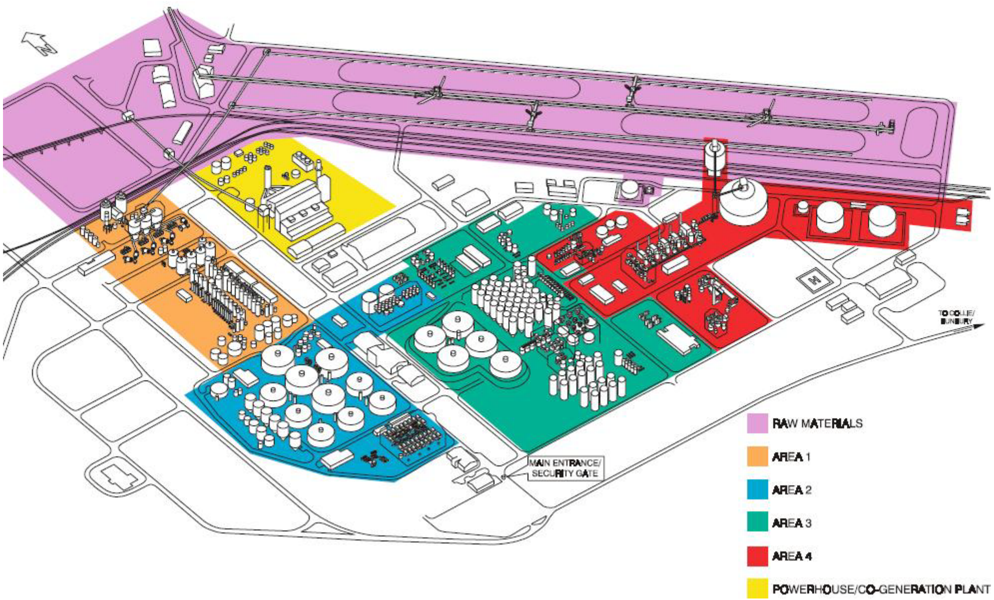

Figure 1-1 BHP Billiton Worsley Alumina Refinery Area Overview [14]

The following is an adaptation of the Worsley Alumina Pty Ltd Introductory Bayer Process Training Manual, 2003. [14]

1.1 Area 1

Area 1 focuses on carrying out the first stages of the Bayer process. Bauxite is supplied to Area 1 from Raw Materials. Area 1 consists of six facilities as presented in the table below. Each facility will be discussed in the paragraphs to come.

Table 1-1: Area 1 Facility Summary

Facility Number	Facility Title
024	Bauxite Grinding
026	Desilication
030	Digestion
025	Lime Slaking
106	Lime Unloading and Storage
107	Acid Unloading and Storage

1.1.1 Facility 024 Bauxite Grinding

The first stage in area one is to crush the incoming bauxite ore from approximately 22mm diameter down to less than 1.2mm diameter. This is accomplished in facility 024 – Bauxite Grinding. Facility 024 crushes approximately 450 to 500 tonnes of bauxite ore per hour. The ore is first fed into the rod mill, which reduces particle size from <22mm to <4mm in diameter. During crushing, caustic spent liquor is poured into the crusher to produce slurry. The slurry is pumped through a set of DSM (Dutch State Mines) screens. If the material is larger than 1.2mm in diameter it will not pass through the screens and will be directed to the ball mill for finer crushing. If the material is smaller than 1.2mm diameter, it is passed on to the Desilicator tank in Facility 026. Any discharge from the ball mill is returned through the DSM screens to ensure only particles smaller than 1.2mm in diameter pass through to Facility 026.

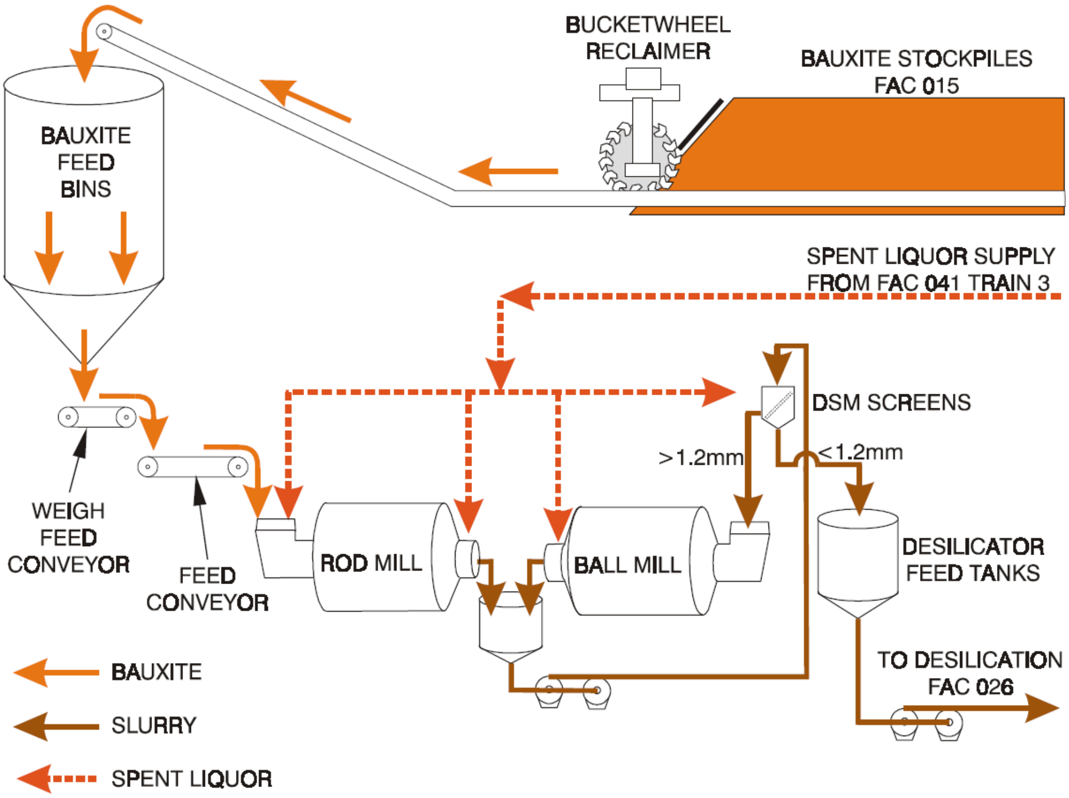

Figure 1-2 Area 1 Process Flow Diagram [14]

1.1.2 Facility 026 Desilication

The bauxite contains approximately 1.5 – 2.2 % reactive silica content. To neutralize this content, a process known as Desilication is used. This is an important step in the Bayer process because failure to neutralize reactive silica can lead to a hard coating forming on the tubes of the heaters and can restrict flow through the circuit. If not removed, the final product can be contaminated by silica.

Reactive silica is converted into non-reactive silica by heating it to 98° C for seven to nine hours. This process produces Desilicated product (DSP).

Heat is injected into the Desilication process using steam at 175° C and 450 kPa (gauge). A residence time of approximately nine hours is achieved by passing the slurry through a series of five tanks, and recycling a percentage of the discharge back into the tank from which it originated.

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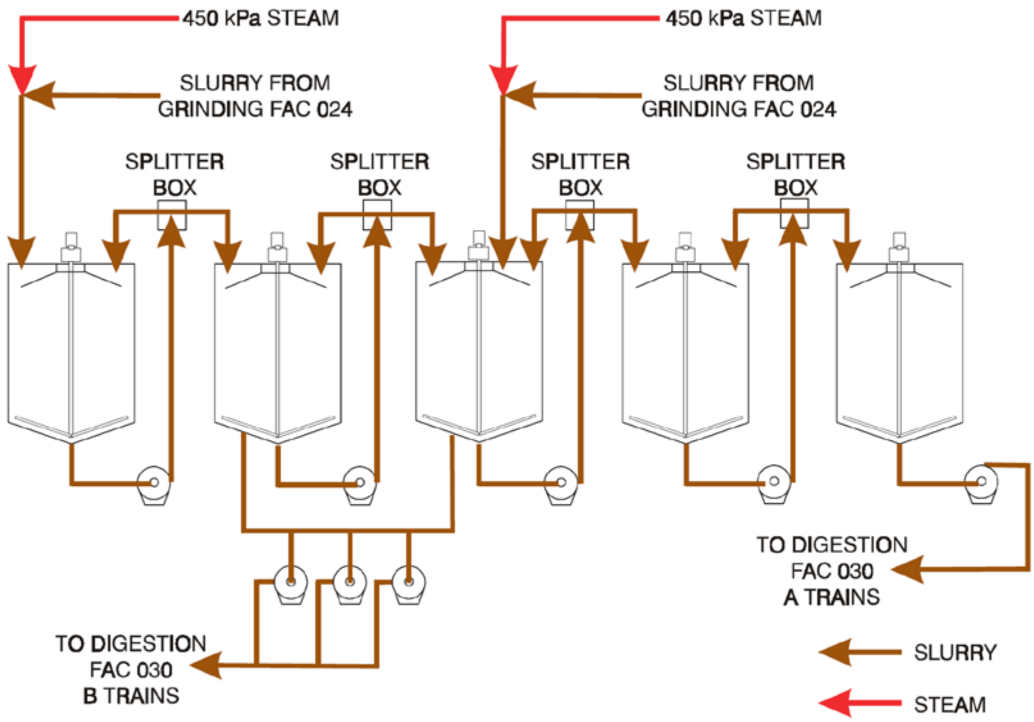

Figure 1-3 Desilication Circuit [14]

1.1.3 Facility 030 Digestion

In order to dissolve alumina from the slurry, a process known as digestion is used.

Desilicated slurry, also known as DSP, is mixed with spent liquor in mixing tanks (known as digestor feed tanks) to achieve an alumina to caustic ratio (A/C ratio) at the end of the process. This ratio indicates how much dissolved alumina there is in the slurry stream compared to caustic.

Underflow from the digestor feed tanks is pumped through slurry heaters which gradually raise the temperature of the slurry to 175° C at a pressure of 700 kPa. Slurry heating occurs in five stages, the first four of which increase the temperature by approximately 16° C each stage. The slurry heaters utilize steam from associated flash vessels. Indirect Steam Heaters (ISHs) are used to heat the slurry in the final stage of heating. ISHs use 1300 kPa steam supplied from the Powerhouse. In this stage the slurry is heated a further 30° C before flowing into the digestor vessel.

Most of the alumina is dissolved out of the slurry following a residence time of approximately twenty minutes inside the digestor vessel. The slurry leaves the digestor vessels through the aforementioned flash vessels. Flash vessels lower the pressure of the slurry, allowing water to boil off the slurry in the form of steam, which then passes its heat energy to the associated heaters by condensing. This method returns heat energy to the digestion circuit.

The chemical composition of the slurry is now;

$$NaOH + Al(OH)_3 \rightarrow NaAl(OH)_4$$

or

Caustic Liquor + Aluminum Hydrate (in Bauxite) → Sodium Aluminate (in solution)

The slurry exits the last flash vessel in the train at approximately 107° C and is known as Digestor Blow-Off (DBO).

1.1.4 Facilities 025/106 Overview

Slaked lime has two main uses in the Bayer process, these are:

1) Causticising,
2) Lime aging.

Causticising means restoring the plant liquor back to a good caustic strength so that it can be re-used to dissolve alumina. Causticising uses approximately 60 m^3/hr of lime slurry.

Lime ageing is the process of creating Tri-Calcium – Aluminate (TCA), which is an aid to Polishing Filtration. TCA is a compound of coarse particles that act as a pre-filter to help prevent the filtration cloth from blocking-up. This increases the life of the filtration cloth and reduces maintenance costs and down time. This process uses approximately 35 m^3/hr of slaked lime.

1.1.5 Facility 106 Lime Unloading

Lime is brought to the refinery by train usually twelve railway wagons at a time. The lime is blown out of the railway wagons by pressurizing the wagon and allowing the air to displace the lime through an exiting air stream. Lime is stored in either of two lime storage silos.

1.1.6 Facility 025 Lime Slaking (The Dorr-Oliver System)

Drag chains are used to reclaim powdered lime from the lime storage silos and discharge it onto a conveyor belt. The conveyor deposits the lime into an agitator tank called a Slaker.

Lime is mixed with process water and dirty condensate in the Slaker. This mixing process is temperature controlled to 40°C. The mix ratio is four parts water to one part lime, with approximately 18 to 20 metric tons of lime being consumed every hour.

The lime Slaker uses a reciprocating rake to remove coarse grits from the slurry mixture. Coarse grit represents undissolved lime. The coarse grits are removed and dumped at the Bauxite Residue Disposal Area (BRDA).

The reaction between lime and water gives off heat, resulting in a temperature rise of approximately 48 – 50°C. The final product from facility 025 can be as hot as 94°C. When the slurry has been sieved for fine grit and raked for coarse grit, it awaits transfer to various locations around the refinery in an agitated transfer tank.

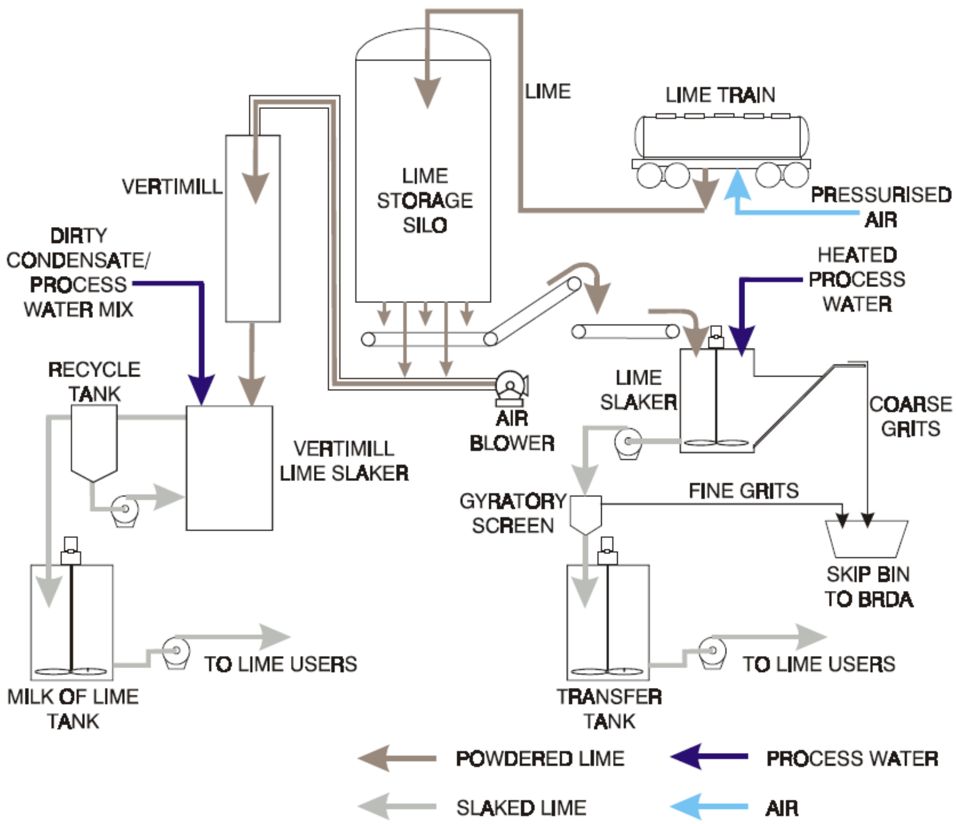

Figure 1-4 Facility 025 Lime Slaking Process [14]

1.1.7 Facility 107 Acid Handling

Facility 107 receives, blends and distributes hydrochloric and sulphuric acid deliveries. The hydrochloric acid is used for cleaning calcium deposits from pipes, heaters and vessels while the sulphuric acid is used to clean heaters and the treat water at the powerhouse.

1.2 Area 2

Area 2 houses the facilities for separating the green liquor from slurry, cleaning the waste mud of caustic soda and disposing of the waste mud. In area 2, all the un-dissolved solids are settled out of the slurry, leaving behind caustic soda rich in alumina called settler overflow. The settler overflow becomes green liquor after filtration, and is passed onto area 3 for precipitation. A substantial effort is made to remove caustic from the waste mud before disposing the mud in the Bauxite Residue Disposal Areas. The following facilities are included in area 2, and will be discussed in the paragraphs to come.

Table 1-2: Area 2 Facility Summary

Facility Number	Facility Title
032	Flocculant Mixing and Storage
033	Clarification and Causticisation
034	Bauxite Residue Filtration and Sand Washing
035	Green Liquor (Polishing) Filtration

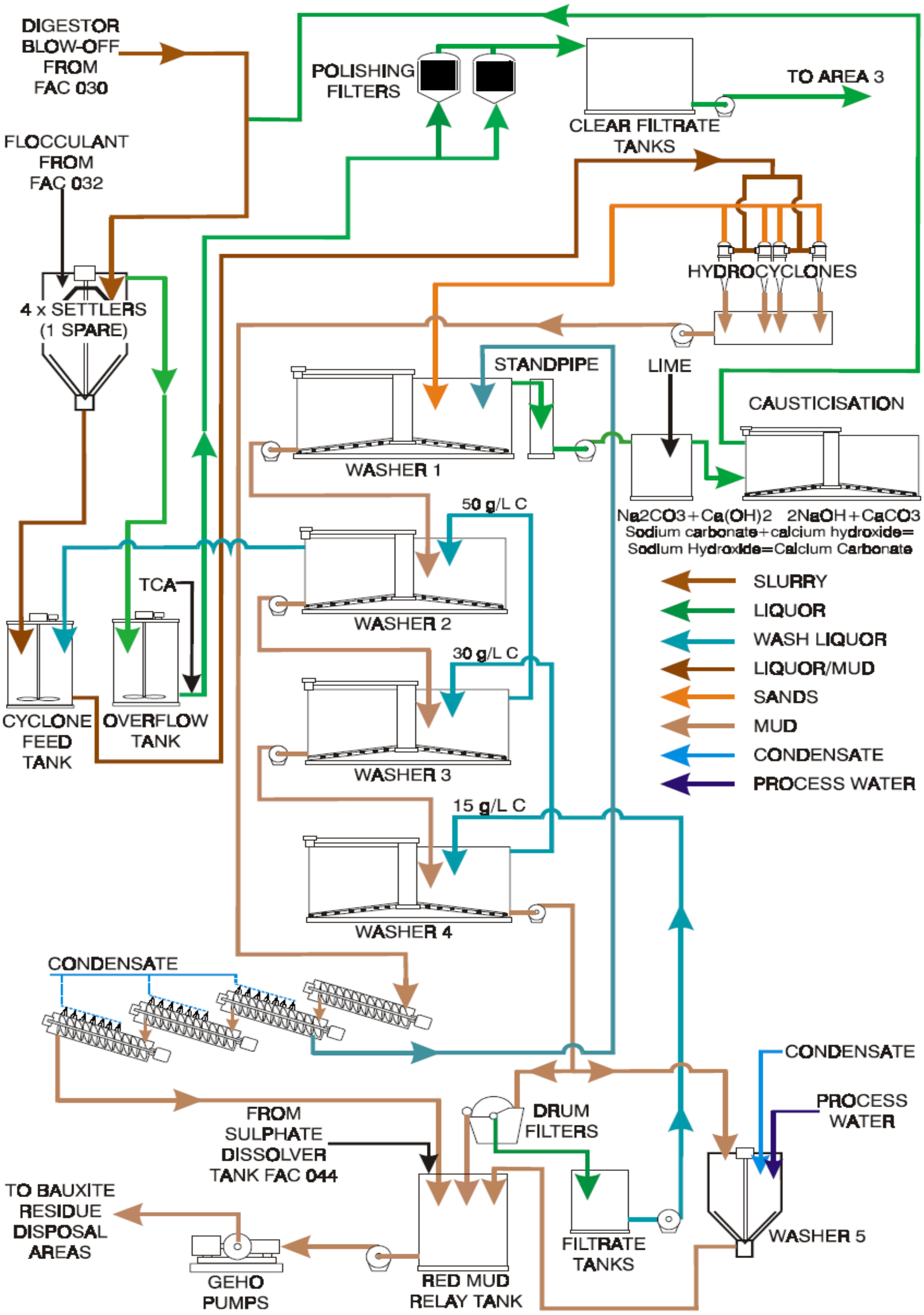

Figure 1-5 Area 2 Flow Diagram [14]

1.2.1 Facility 032 - Flocculant Mixing and Storage

Facility 032 is responsible for receiving, handling, storing and mixing flocculant powders. There are two types of flocculant used in the refinery, they are as follows;

1) Liquid and Powdered Synthetic Flocculant

Liquid and synthetic flocculant is used to aid in settling bauxite residue from the slurry in area 2. The synthetic mixtures are pumped into the settler and washer tanks in in facility 033 - Clarification and Causticisation.

2) Natural Flocculant – Starch Flour

The starch is mixed with potable water and caustic and the solution is pumped to the final washers to assist mud filtration and control tank clarity.

1.2.2 Facility 033 - Clarification and Causticisation

Clarification

In facility 033, bauxite residue is settled out of the slurry. The Clarification process removes any alumina rich liquor from this residue, which is then washed and disposed of in the Bauxite Residue Disposal Areas. The alumina rich liquor is pumped to facility 035 - Green Liquor (Polishing) Filtration.

Facility 033 receives Digestor Blow-Off (DBO) slurry from facility 030 in area 1. The slurry is received at a temperature of 105°C at the settling tanks, where flocculant is automatically added according to settler throughput. The bauxite residue is then allowed to settle at the bottom of the settling tanks, while the alumina rich liquor leaves the settling tanks as overflow. There are five settlers in the circuit, with one off line to be used as a redundancy.

Alumina rich liquor leaves the settling tanks as overflow. This liquor is free of all but the finest of solids. The alumina rich liquor is pumped to the Polishing Filters in facility 035 where these fine solids are removed.

Because the particles in the liquor are so fine, they tend to block up the filter cloth in facility 035. In order to extend the life of these filter cloths, coarse particles called Tri-Calcium Aluminate (TCA) are introduced. TCA acts as a pre-filter, holding the fine particles from the surface of the filter cloth.

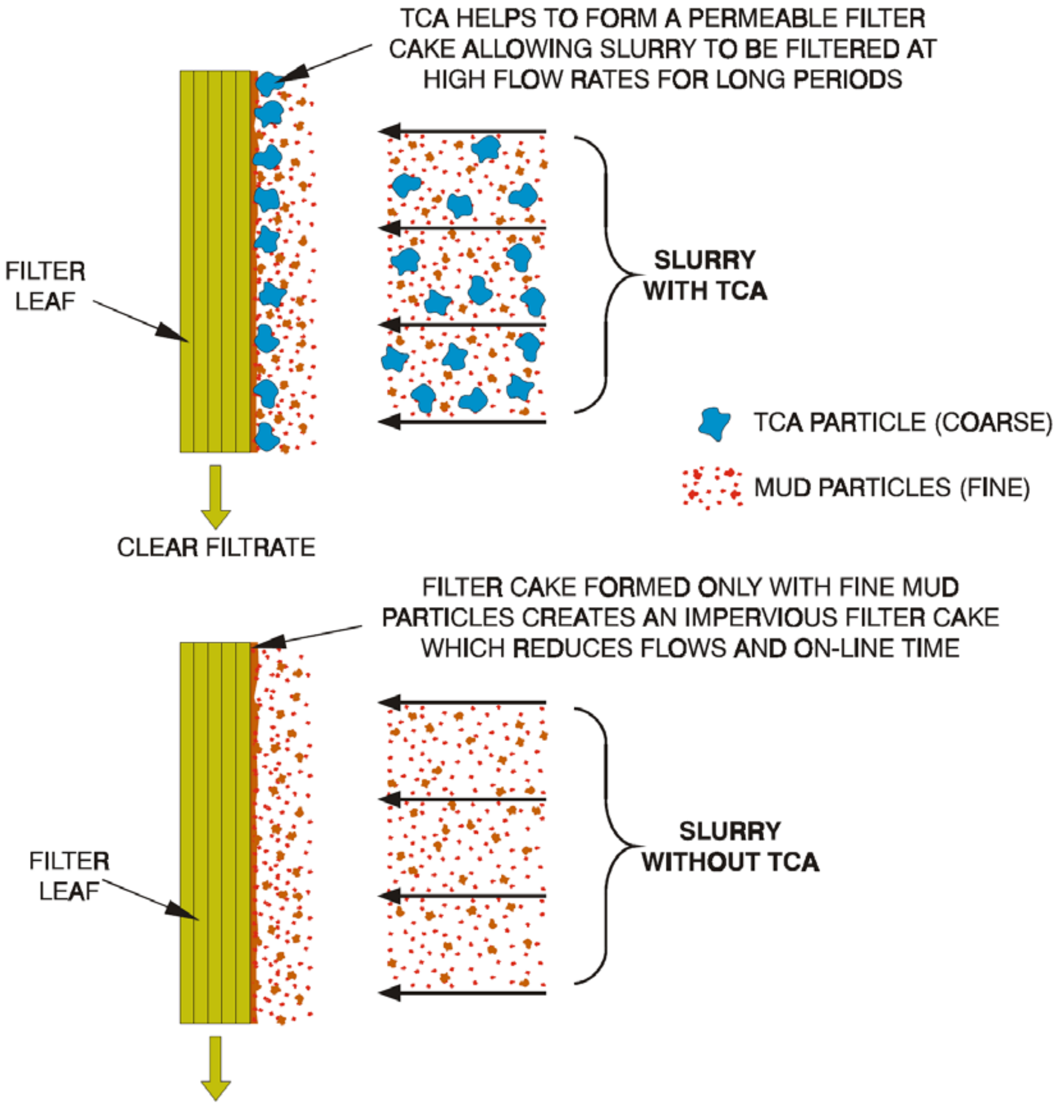

Figure 1-6 Filtration With and Without Tri-Calcium Aluminate (TCA) [14]

Underflow flow from the settling tanks, or mud, is pumped to the continuously agitated cyclone feed tanks. Overflow from the second stage washers is also pumped into these tanks. This creates slurry, which is pumped in hydrocyclones. These hydrocyclones use centrifugal force to separate coarse sand from the slurry. The hydrocyclone underflow (the slurry with coarse sand particles) is pumped to the sand classifiers in facility 034. The hydrocyclone overflow (liquor and fine sand particles) is pumped to a series of four washers in two series washer trains (i.e. two washers per train).

The mud from each washer is pumped to the inlet of the next downstream tank. Each washer has a rake inside that rakes the mud towards the outlet, while a dilute stream of filtrate washes over the mud in a process called Counter Current Decantation (CCD). A CCD circuit moves mud in one direction down train towards the filters, while wash liquor moves counter current up the train towards the settler tanks. As the mud reaches each tank it settles and moves out as underflow with less caustic concentration. The liquor washing the mud leaves with a higher caustic concentration. There are two CCD circuits in area 2, of which both normally operate. A small amount of flocculant is used during this process, and is added according to tank process conditions.

Causticisation

The CCD wash liquor gains caustic concentration as it moves up the circuit. Some of the caustic is in a free or available form, meaning it is capable of dissolving alumina. This is known as caustic soda (NaOH) and is measured by the 'C' concentration. Some of the caustic also exists in another form known as sodium carbonate (Na_2CO_3) which is formed when caustic soda reacts with the carbon dioxide in the air. Sodium carbonate is un-reactive and forms part of the 'S' concentration. Causticisation occurs in area 2 to convert sodium carbonate back into caustic soda using slaked lime mixed with the wash liquor overflows from the first washer. The chemical equation for this process is as follows:

$$Na_2CO_3+Ca(OH)_2 \rightarrow 2NaOH+CaCO_3$$

or

Sodium carbonate+Calcium hydroxide = Sodium hydroxide+Calcium carbonate

This reaction takes place at approximately 102°C. Heating takes place in heaters on the overflow line from the first washers in each train. The heat is sourced from the Area 1 flash vapour.

The 'C' concentration of the liquor on its way to precipitation is very important as it measures the amount of free caustic. 'S' measures the total soda in the liquor, thus the 'C' / 'S' ratio provides an indication of how much alumina is being delivered to area 3 for precipitation.

1.2.3 Facility 034 – Bauxite Residue Filtration

Special screw conveyors installed on an incline perform the sand classifier duties in facility 034. The sand classifiers are arranged in three trains, with four screw conveyors per train. Three of the four screw conveyors in each train operate at any one time with the fourth providing a redundancy feature for backup and maintenance tasks.

The sand slurry enters the lower part of the first screw conveyor (being the highest in the train). The sand is conveyed up the incline, while water is sprayed into the screw conveyor at intervals up the slope. The water acts to wash out liquor from the sand. The liquor washes down the incline, and is collected in a liquor launder at the base of the incline.

Sand from the first stage screw conveyor enters the second stage screw conveyor at the bottom of the incline. The washing process is repeated and further removes liquor from the sand. Again, the liquor runs down the incline and is collected while the sand is conveyed up the incline, which is deposited into the third stage screw conveyor. The process is repeated again in the third conveyor. At the end of the process the liquor concentration in the sand has been substantially reduced, and the sand is deposited in the red mud relay tank. Mud from this tank is discharged to the Bauxite Residue Disposal Area in facility 070 via Geho pumps.

Although the facility is named Bauxite Residue Filtration, the facility serves only to wash the sand slurry. In past times large drum filters were used to further remove caustic soda from the sand, however in recent years the drum filters were decommissioned due to poor efficiency and high maintenance costs.

1.2.4 Facility 035 – Green Liquor (Polishing) Filtration

Green liquor constitutes the final product of the Bayer process thus far. The liquor is a caustic solution with a high concentration of alumina hydrate dissolved into it. Facility 035 performs the final part of the process in area 2. The facility removes fine bauxite residue from the green liquor in preparation of precipitation in area 3.

Facility 035 removes fine bauxite residue from the green liquor via twenty pressure filters known as polishing filters. At any one time fourteen to fifteen of these filters are on line to maintain the clear filtrate tank at 85% full. Clear filtrate is the final product of area 2.

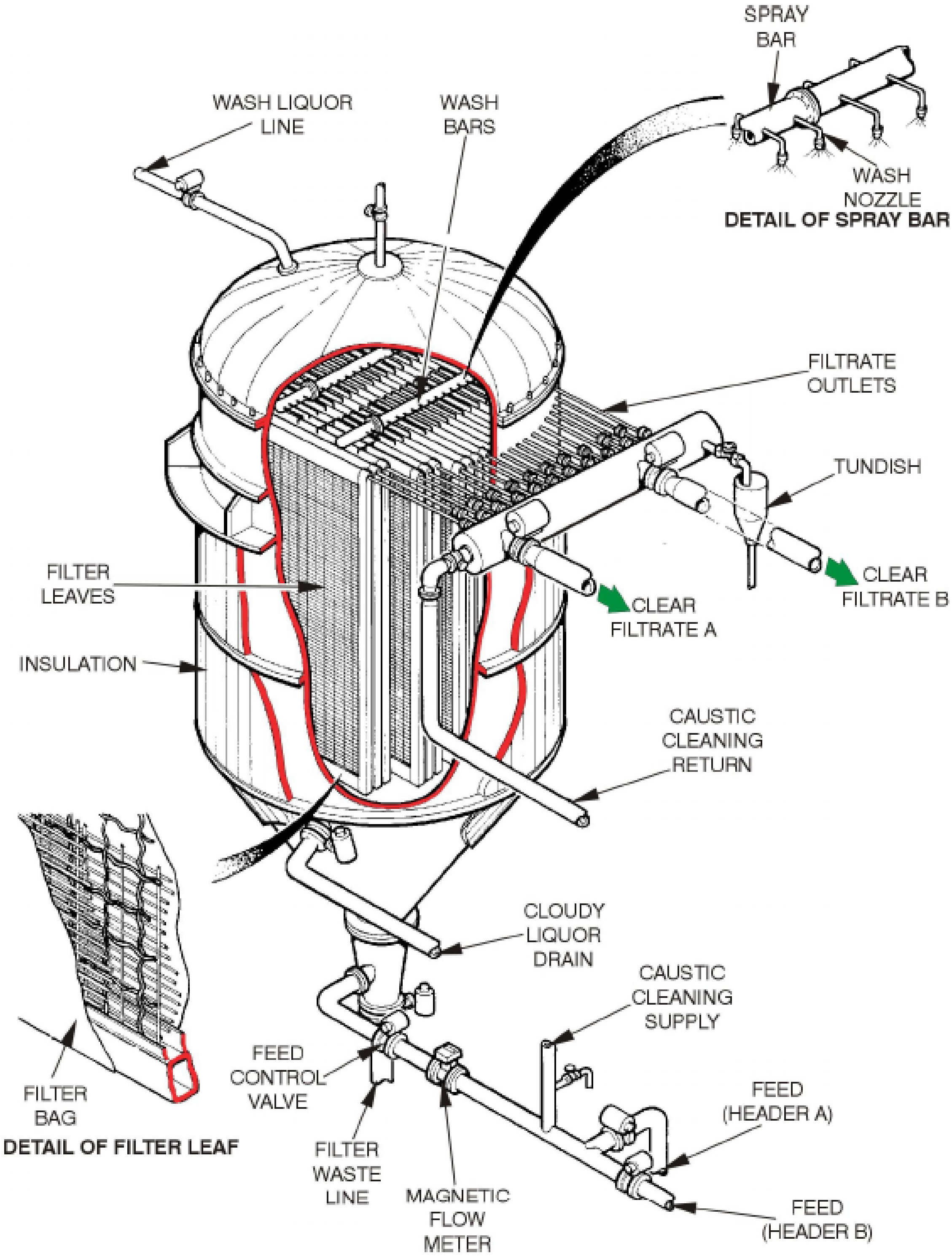

Figure 1-7 Facility 035 Polishing Filter [14]

TCA is added to the settler overflow liquor being pumped into the polishing filters. As described and illustrated in section 1.2.2 - Facility 033 - Clarification and Causticisation, this prolongs the life of the filter cloth by helping prevent cloth blockage.

Controlled constant pressure is supplied to the polishing filters via the high-rate settler tank overflow pumps which are connected in parallel to the polishing filters. Green liquor is forced through the filter cloth and is collected in the clear filtrate tanks. Clear filtrate is then pumped to area 3 for further processing.

1.3 Area 3

Area 3 performs the task of producing alumina hydrate crystals through a process known as precipitation. Precipitation crystals should normally be larger than 44 micron and be free of oxalates. Precipitation occurs when a concentrated alumina rich caustic soda solution is seeded with small, clean hydrate crystals and allowed to cool. Collecting, storing and cleaning hydrate crystals is also a function of area 3.

Table 1-3: Area 3 Facility Summary

Facility Number	Facility Title
040	Spent Liquor Evaporation
041	Green Liquor Heat Interchange
042	Process Trim Evaporation
045	Precipitation and Heat Interchange (Flash Cooling)
046	Seed Separation, Filtration and Hydrate Classification
180	180 Water Treatment and Storage Plant

1.3.1 Facility 041 Heat Interchange

Facility 041 represents the first stage of the precipitation process in area 3. Clear filtrate arrives at facility 041 at 103°C. Three headers split the flow into three Heat Interchange trains. Each flow is pumped through one side of the heat exchangers and is cooled to approximately 85°C by transferring its heat energy to the other side of the plate heat exchangers. Spent liquor is pumped through the other side of the heat exchangers. The spent liquor enters the heat exchanger at 60°C and leaves at 80°C.

The cooled clear filtrate is pumped to the respective precipitation trains in facility 045 to begin the precipitation process while the spent liquor is pumped back to area one facilities 024 - Grinding and 030 – Digestion.

The train 3 heat exchanger has an extra set of plates where internal cooling water from facility 50 transfers its heat to the spent liquor. The internal cooling water from facility 050 in area 4 is a closed loop system.

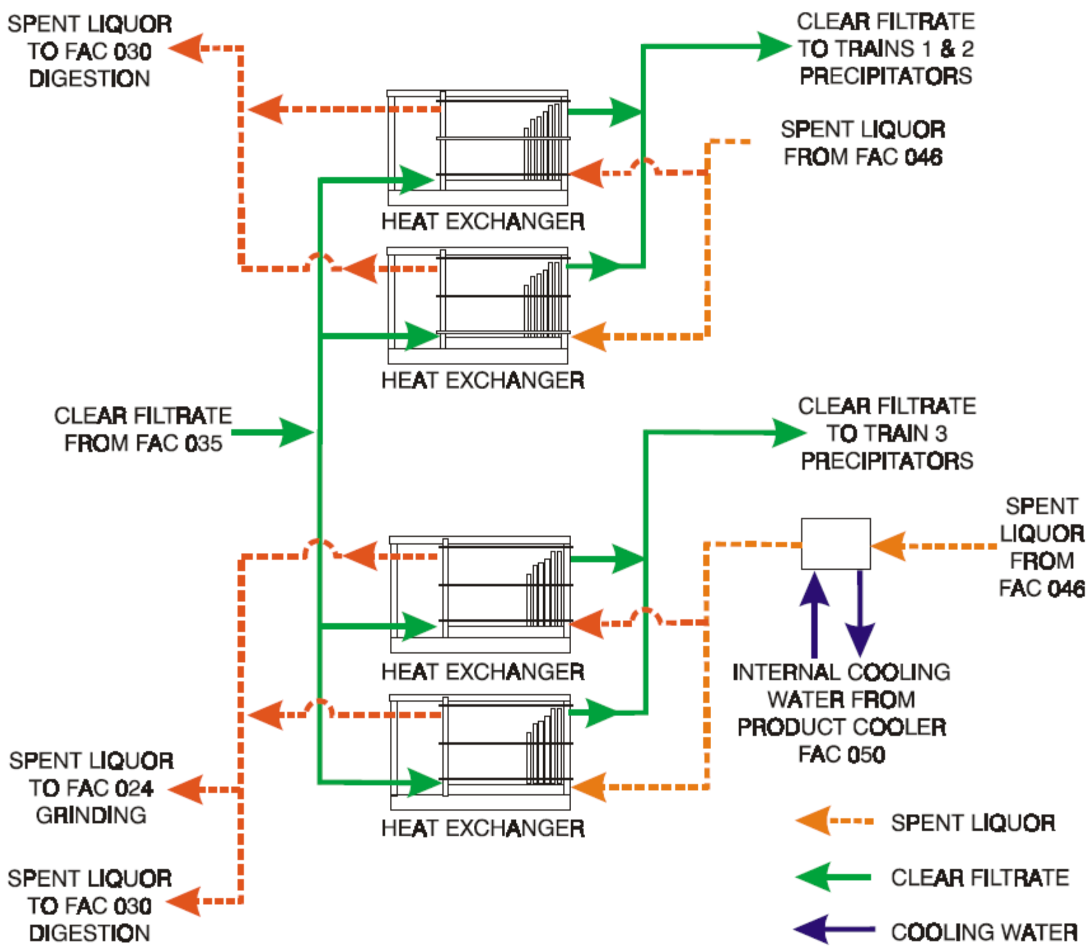

Figure 1-8 Heat Interchange Process at Facility 041 [14]

1.3.2 Facility 045 Precipitation and Heat Interchange (Flash Cooling)

Precipitation is the chemical process of forming alumina hydrate crystals from a high alumina concentration caustic soda solution. In precipitation, sodium aluminate drops out of liquor solution producing aluminum hydrate. The chemical notation of the reaction is as follows:

$$NaAl(OH)_4 \rightarrow NaOH + Al(OH)_3$$

or

Sodium Aluminate (in solution) → Caustic Liquor + Aluminum Hydrate (in Bauxite)

The first step in the process in facility 045 is Agglomeration. Agglomeration involves mixing clean seed from facility 046 with alumina saturated green liquor from facility 041 and allowing sufficient residence time for individual particles to cement together. Alumina hydrate crystals (clean seeds) act as catalysts to the process, drawing dissolved hydrate out of the green liquor solution and depositing on the seed crystal, essentially "growing" the size of the seed.

There are three trains in the precipitation process. Trains one and two have three mechanically agitated Agglomeration Precipitators and two air agitated Agglomeration Precipitators. Train three has three mechanically agitated Agglomeration Precipitators only.

The next two stages of precipitation take place in the Intermediate and Final precipitators. In these precipitators the hydrate crystallises and settles to the bottom of the precipitator tanks, while the liquor overflows from one tank to the next. Train one and two liquor overflow ultimately flows to the seed thickeners in facility 046. There is no final overflow from train three. For all trains, the slurry from the bottom of the intermediate precipitators is pumped to the inlet of their corresponding first row final precipitator. The slurry from the first row final precipitator is then pumped to the inlet of their corresponding second row final precipitators, and the slurry from the second row final precipitators is forwarded to the product cyclones. The cyclones separate the coarse hydrate crystals from the fine hydrate crystals. Coarse hydrate crystals are directed to area 4 for Calcification while the fine hydrate crystals and liquor are sent to facility 046 to form seed slurry.

Each stage of Agglomeration is preceded by a Flash Cooling (HID) operation where heat is transferred out of the trains via flash vapour. Flash Cooling is the operation of introducing a high temperature and high pressure solution to a lower pressure environment, thus allowing water to boil off and vaporize. In this operation the liquor is introduced to the low pressure environment and water and heat is removed from the liquor via vaporization.

The first of the Flash Cooling operation takes place in facility 041 Heat Interchange. The second and third Flash Cooling operations occur in facility 045.

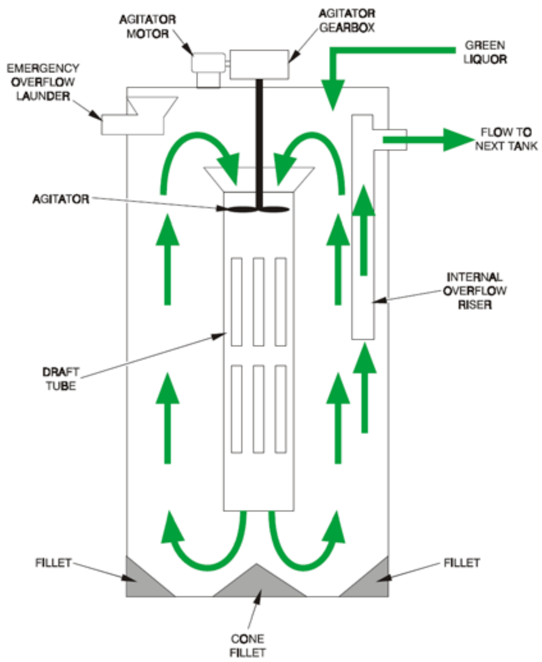

Figure 1-9 Mechanically Agitated Agglomeration Precipitator [14]

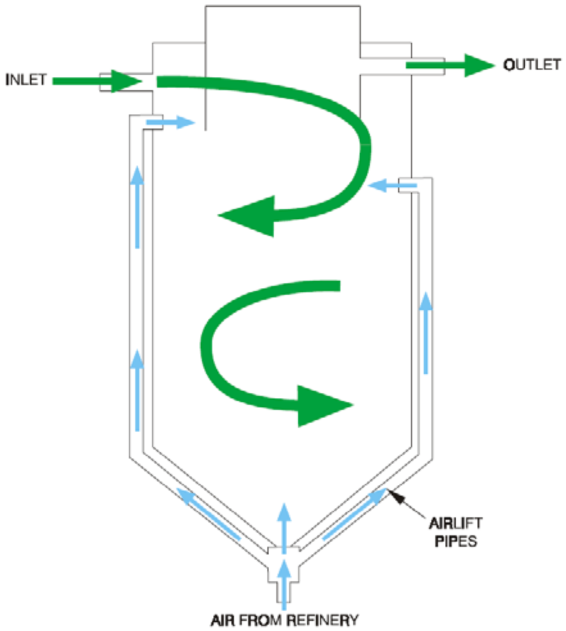

Figure 1-10 Air Lifted Agglomeration Precipitator [14]

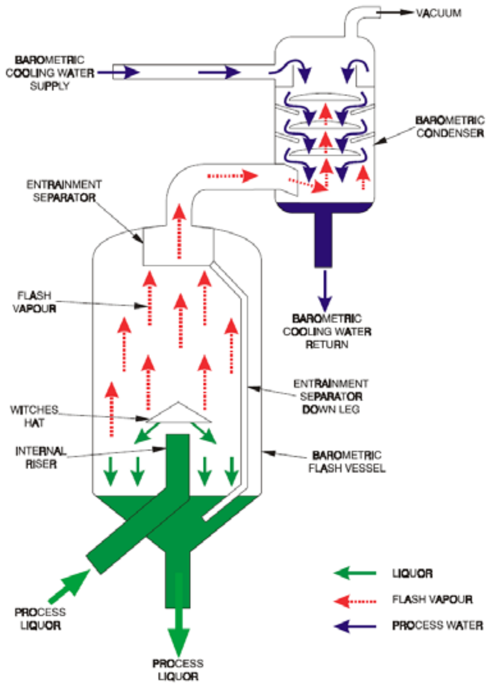

Figure 1-11 Barometric Flash Vessel [14]

1.3.3 Facility 046 Seed Separation, Filtration and Hydrate Classification

Facility 046 performs three important tasks for area 3, they are:

- Seed Thickening,
- Filtration and
- Hydrate Classification.

Seed Thickeners

Seed thickeners provide spent liquor to area 1, provide surge capacity for plant volume and settle fine and coarse seed. There are five seed thickeners used in facility 046. Two thickeners are used for fine seed and two thickeners are used for coarse seed with the fifth thickener offline to be used as a redundancy. The thickeners are fed by two streams of liquor feed;

- Overflow from the seed cyclones feeds the two online fine seed thickeners
- Final overflow from trains 1 and 2 precipitators feeds the two online coarse seed thickeners

Overflow liquor from the trains one and two precipitators is fed into the two online coarse seed thickeners. Any remaining hydrate in the liquor is settled in these tanks. Underflow from the coarse seed thickener tanks is pumped to the seed cyclone feed tank for hydrate classification.

The seed cyclones separate the fine seed from the coarse seed. Fine seed exits the cyclone as overflow, and is directed to the two online fine seed thickeners. Fine seed is then collected as underflow from the thickeners and sent to fine seed storage, where it is then used to supply the Fine Seed Filtration building. Overflow from the fine seed thickeners is returned to area 1 through facility 041- Heat Interchange, for use in grinding and digestion.

Filtration

The Filtration building is separated into coarse seed and fine seed sections.

Fine Seed Section:

The fine seed section consists of two stages.

Stage one:

Stage one consists of six rotary drum vacuum filters. The stage one filters separates the fine seed from the liquor. Stage one filters are supplied from the fine seed storage tanks. The vacuum drum filters work by revolving on a horizontal axis while partially submerged in a fine seed / liquor slurry. The drum is wrapped in filter cloth and a vacuum is applied to the inside of the drum, forcing liquor to be sucked through the cloth while fine seed is “caked” onto the cloth. As the drum revolves, the cake builds up and is discharged to a dissolver tank by a burst of air. The seed cake is called dirty cake, due to the presence of oxalates in the fine seed. Oxalates are considered a contaminant in the final alumina product. To remove the oxalates from the fine seed, the dirty cake is mixed with hot condensate, which dissolves the oxalates from the fine seed.

Stage two consists of four rotary drum vacuum filters. The dirty cake / hot condensate solution is pumped into the stage two filters where the fine seed is removed from the solution, free of oxalates. The fine seed is then conveyed to the fine seed re-slurry tank, where it is mixed with green liquor and discharged to the lead agglomeration tanks on all three precipitation trains. This is called the Fine Seed Charge.

The condensate / oxalate solution is called Wash Filtrate and is pumped to facility 043 in area 4 for further processing.

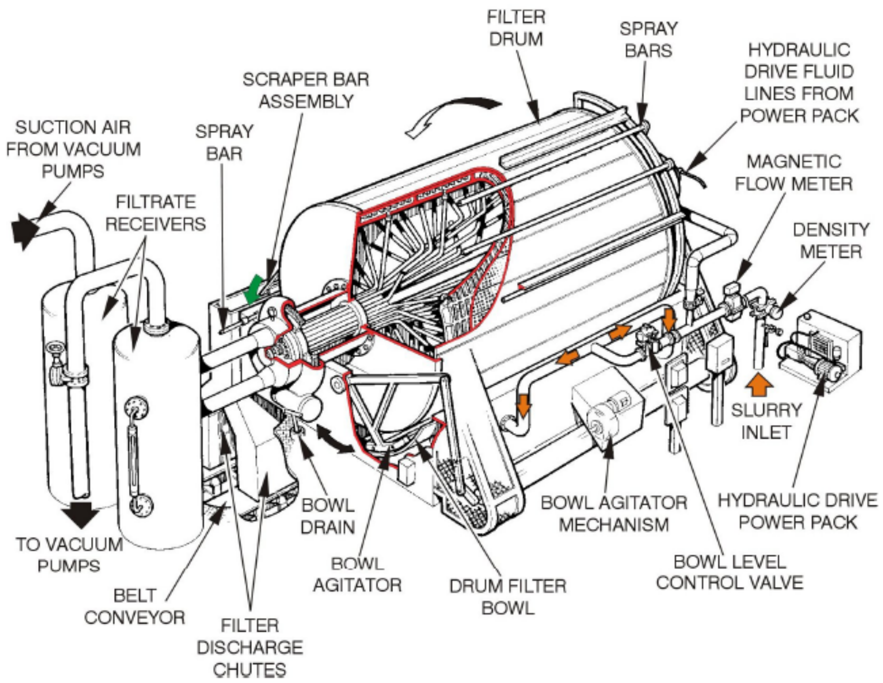

Figure 1-12 Facility 046 Stage 2 Fine Seed Rotary Drum Vacuum Filter [14]

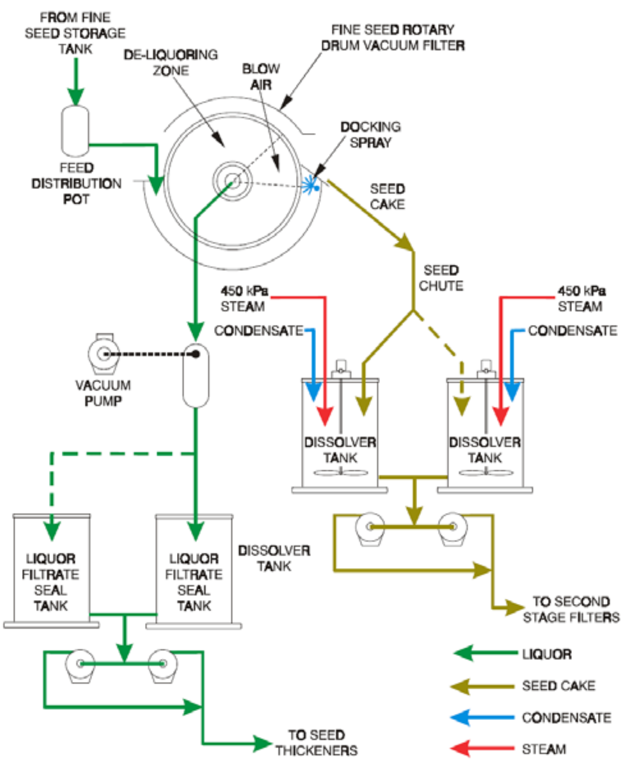

Figure 1-13 Facility 046 Stage 1 Fine Seed Filter System [14]

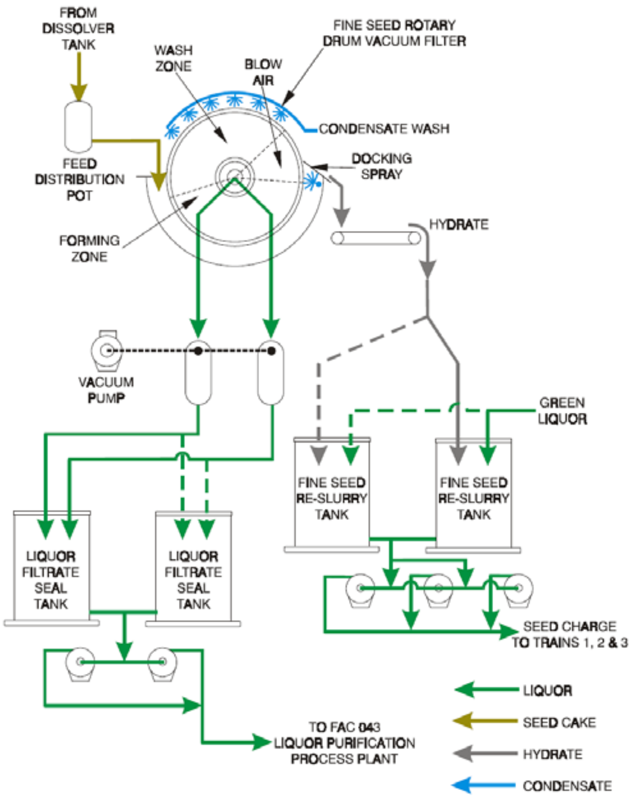

Figure 1-14 Facility 046 Stage 2 Fine Seed Filter System [14]

Coarse Seed Section:

Coarse seed is removed from the liquor via three disc filters as illustrated in figure 1-15. The liquor is returned to facility 046 while the coarse seed is discharged to the coarse seed re-slurry tank, where it is mixed with green liquor and pumped to the intermediate precipitation tanks in all three precipitation trains.

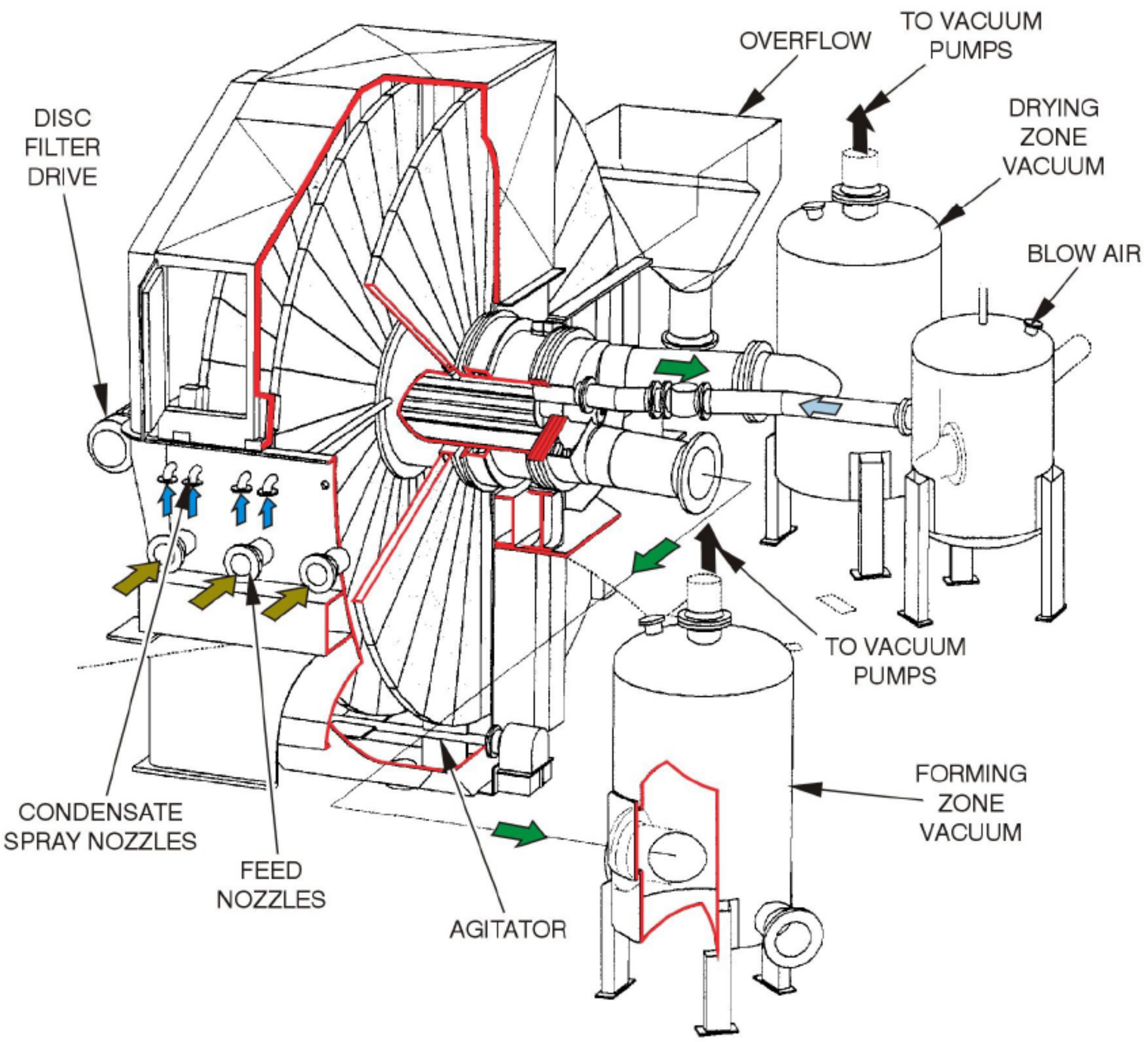

Figure 1-15 Facility 046 Coarse Seed Disc Filter [14]

Hydrate Classification

The hydrate classification process comprises two systems; the Product System and the Seed System.

The Product System:

The Product System contains the product storage tank and six clusters of product cyclones. The continuous cyclone pumps in trains 1, 2 and 3 pump hydrate slurry to the product cyclones. These cyclones separate the heavier product from the lighter product. Heavier product is discharged from the bottom of the cyclone into a product storage tank where it is pumped to area 4 for Calcination. The lighter product is discharged from the top of the cyclone into the Seed Cyclone Feed tank.

The Seed System:

The Seed System contains the Fine Seed tank, the Coarse Seed tank, the Seed Cyclone Feed tank, five clusters of Seed Cyclones and five Needle tanks.

The Fine Seed tank

The Fine Seed tank stores the fine seed underflow from the fine seed thickeners.

The Seed Cyclone Feed tank

The Seed Cyclone Feed tank is fed by the product cyclone overflow and the coarse seed thickeners underflows.

Seed Cyclones

The Seed Cyclones are fed by the Seed Cyclone Feed tank. The cyclones separate the heavier material from the lighter material. Heavier material is discharged at the bottom of the cyclones into the coarse seed tank, where it is pumped to the coarse seed disc filters. Lighter materials are discharged at the top of the cyclones into the Needle tanks, which is then discharged to the fine seed thickeners.

1.3.4 Facility 042 & 040 Evaporation

Facility 042

Facility 042 carries out the task of evaporation. The process is known as a “once-through” system and is performed by five flash vessels with associated spent liquor heat exchangers and two flash vessels with associated surface condensers.

Evaporators use pressure reduction and temperature to boil spent liquor. This increases liquor concentration by giving off water vapour. The vapour is condensed to water in the heat exchangers, giving off heat energy which is used to preheat the spent liquor. After the liquor is heated, the pressure is once again reduced and the liquor boils again. The process is repeated, each time giving off more water vapour. Each pressure reduction and subsequent boiling process is known as a flash stage.

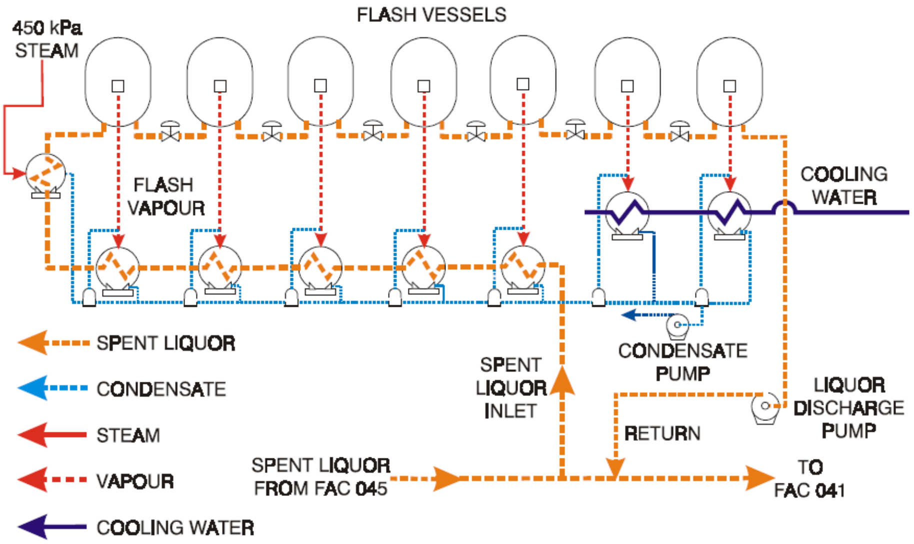

Figure 1-16 Facility 042 Evaporation System [14]

Evaporators maintain a pre-determined caustic concentration in the liquor by balancing the water entering the process liquor, e.g., dilution water, bauxite moisture, steam injection, etc., with the total quantity being evaporated. In the first five stages, heated spent liquor cascades through flash vessels, while cooler spent liquor flows in the opposite direction through the heat exchangers. The spent liquor is fed into the first heat exchanger and flows in sequence through the remaining four heat exchangers, absorbing heat from the condensing vapour as it passes through them. The spent liquor then passes through a live steam heater which raises the temperature to approximately 140°C, which provides the temperature differential between the liquor flowing through the flash vessels and the liquor flowing through heat exchangers, allowing flashing to take place.

The concentrated liquor is returned to the main spent liquor stream.

Facility 040

Facility 040 performs essentially the same task as facility 042. Facility 040 operates in parallel with facility 042, providing a redundancy to one another.

There are two identical trains in facility 040, both consisting of six flash vessels with associated heat exchangers and two flash vessels fitted with barometric condensers. Each train operated in essentially the same way as described in facility 042, with each successive flash vessel boiling off more water, and further condensing the slurry. The slurry flows through the six heat exchanger flash vessels in series, then through the barometric flash vessels. The barometric flash vessels collect condensate and return it to the Refinery Catchment Lake (RCL), while the heat from the heat exchangers is used to heat up spent liquor.

1.3.5 Facility 180 – water treatment and Storage Plant

Fresh water from the Fresh Water Lake is pumped to facility 180, where it is stored in a storage tank. This storage tank supplies the Microfiltration system, which removes bacteria and impurities from the water. Filtered water is then pumped to the treated water storage tank, where chlorine is added. The treated water is then pumped around the refinery as potable water and fire water.

1.4 Area 4

Area 4 carries out the final stages of the Bayer process. The following facilities perform these final stages, and are discussed in detail in this section.

Table 1-4: Area 4 Facility Summary

Facility Number	Facility Title
043	Liquor Purification and Oxalate Degradation
050	Alumina Hydrate Filtration, Washing and Calcination
044	Liquor Burning Plant
051	Alumina Storage and Shipping

1.4.1 Facility 043 Liquor Purification and Oxalate Degradation

While area 2 is responsible for removing solid residue and impurities, it does not remove dissolved impurities. The precipitation process in area 3 allows these impurities to solidify if the concentration of these impurities is high enough. These substances are known as sodium oxalates, and often precipitate in the cooler parts of the plant as long needle like crystals. Sodium oxalates tend to concentrate in the seed slurry and are dissolved with warm clean concentrate. The solution is sucked through the filter cake on the facility 046 filters. This results in a wash filtrate with an oxalate concentration of approximately 15g/L. The wash filtrate is pumped to facility 043 in area 4 where it is treated to remove the oxalates.

Three operations are undertaken in facility 043. These are;

- Concentration Operation,
  This operation uses flash vessels and Indirect Steam Heaters (ISH) to remove water vapour from the wash filtrate.
- Flash Evaporation,
  This operation removes water from the refinery process loop. Water can enter the process through many avenues (bauxite, liquid caustic, seed washing, liquid flocculant, lime slurry and steam hydroheaters) and the facility 043 evaporator accounts for the excess water from these avenues. The facility 043 evaporator processes 570 m^3 /hr of spent liquor while the facility 042 evaporator processes 850 m^3 / hr of spent liquor.
- Crystallisation Operation
  This operation is fed by the oxalate rich concentrator discharge. Secondary feeds include cleaning caustic from the precipitation tanks in facility 045, facility 043 evaporator discharge, wash filtrate from the seed filters in facility 046 and facility 046 recycled seed oxalate filter cake.

The final product of these three operations is oxalate crystals, which are transported by truck to the Oxalate Degradation Plant (ODP).

The ODP is a batch process, utilizing two reaction tanks. Urea and air are added to the reaction tanks, causing the micro-organisms to degrade the solid sodium oxalate to sodium carbonate.

1.4.2 Facility 050 Hydrate Filtration, Washing and Calcination

Filtration

Underflow from the product feed tanks in facility 046 is pumped to the two stage filtration operation in facility 050. There are seven pan filters in the two stage operation. Three pans operate in each stage with one pan reserved for use in either stage.

The first stage filters remove liquor from the slurry. The liquor is pumped to facility 046 seed thickeners. The hydrate cake is removed from the filter and discharged into a re-slurry tank where it is re-mixed. The re-slurry is then pumped to the second stage filters where clean condensate flows onto the hydrate cake and is sucked through the hydrate to wash the remaining caustic soda and any other impurities.

The wash filtrate is pumped back to the re-slurry tank while the hydrate with a moisture content of approximately 8% is scrolled off the top of the second stage filter onto a conveyor belt for transport to the operating calciners hydrate feed bin.

Calcination

Washed alumina hydrate is conveyed to the calciner first stage venturi drier at a metered flow rate. The venturi drier drives away physical moisture using hot gas. The hydrate is heated to approximately 170°C during this process. Approximately 80% of the hydrate leaves the venturi drier via a chute, while an Electrostatic Precipitator (ESP) collects and discharges any remaining airborne hydrate to the main hydrate stream.

Hydrate now remains fluidised throughout the rest of the calcination process via large air blowers.

The hydrate is then blown to the second stage venturi drier for the next stage of drying. In the second stage venturi drier, the hydrate mixes with waste gas from the hottest part of the calciner, via the re-cycle cyclone, at approximately 900°C and most of the crystalline water is driven off. A heat loss of approximately 100°C occurs as a result of the energy being used to break the chemical bonds between the alumina and water molecules. The de-hydrated alumina is then discharged to the second stage cyclone, where the alumina is separated from the hot gases. The hot gases are re-cycled to the first stage venturi drier.

The alumina now enters the calciner furnace section of the Fluid Bed Calciner (FBC) through flap valves which maintain a high pressure inside the furnace. Primary air is supplied to the FBC from the bottom of the furnace via two primary air blowers. The primary air is pre-heated to 600°C from prior in-direct contact with the first three product cooler compartments. A secondary air supply is supplied by three secondary air blowers. Secondary air is pre heated by direct contact with all six product cooling compartments.

At the bottom of the calciner the hot gas suspends a large volume of alumina, however there is significantly less alumina in suspension by the time the gases reach the top of the furnace and enters the recycle cyclone. In the recycle cyclone, the calcined alumina solids are separated out to be recycled into the furnace. The hot gases flow back to the second stage venturi drier.

Approximately 620 metric tons per hour of washed hydrate is fed to the five on-line furnaces, but only 390 tonnes per hour leaves the calcination process. This is due to the large amounts of crystalline water being removed from the product.

The chemical reaction of the calcination process is as follows:

$$2Al(OH)_3 + Heat\ (900°C) = Al_2O_3 + 3H_2O$$

or

Hydrate Gibbsite + Heat = Alumina + Water

The final product of the calcination process represents the final product of the Bayer process. White alumina powder is cooled via two air stream and a water stream then stored in facility 051 for shipping.

1.4.3 Facility 051 Alumina Storage and Shipping

After leaving facility 050, alumina is conveyed to facility 051 where it is stored in either the storage or shipping silos. The storage silo has a capacity of 100,000 tonnes of alumina, while the shipping silo has 10,000 tonnes of alumina storage capacity. Alumina is blown around facility 051 via air ducts and air blowers.

Westrail trains transport the alumina to the port facility in Bunbury where the final product – Alumina – is shipped around the world.

1.4.4 Facility 044 Liquor Burning Plant

Throughout areas 1, 2 and 3 spent liquor is recycled via the spent liquor circuit. While spent liquor is in the circuit, it becomes concentrated with oxalates and other impurities which must be removed to make the spent liquor circuit clean and efficient. The liquor burning plant conducts this function. There are three operations carried out in the liquor burning plant that perform the cleaning function, they are;

- Evaporation
  Where the main feedstock of spent liquor is concentrated by boiling of the entrained water,
- Drying
  Where the reaction between the alumina and soda to form sodium aluminate is completed and the carbon is burnt off,
- Filtration
  Where the leach slurry produced at the end of the burning stage is separated into cleaned liquor and solids.

The evaporation operation is the first of three operations in liquor burning. In this operation spent liquor and oxalate slurry from facility 043 are concentrated by boiling off approximately 60% of the entrained water.

The drier circuit performs the second operation in liquor burning. Its purpose is to remove the water content from the feed slurry, reduce the slurry to dry granule form, provide suitable feed for the rotary liquor burning kiln and to clean the stack exhaust to meet statutory requirements with regard to particle content. The rotary liquor burning kiln is a 58 meter long cylinder which rotates at approximately 1 RPM. The rotary liquor burning kiln completes the reaction between alumina and soda to form sodium aluminate. The kiln is supplied by the drying circuit with highly concentrated slurry. The slurry is prepared in the drier circuit by mixing slurry with a high concentration of soda with alumina dust collected from the ESPs in the exhaust stack. The ESPs perform the task of cleaning the stack exhaust of particles. The final product of the drier circuit exits the kiln and is sent to the filtration circuit.

The filtration circuit completes the liquor burning plant operation by removing solids from the leach liquor. The final product is the filtered clean “liquor burned” product which is returned to the process via the liquor relay tank. Solids and impurities are either burnt off, or filtered out and disposed of in the Bauxite Residue Disposal Area.

2. The Automation Research Corporation Benchmarking Consortium Quarterly Data Collection – 2nd Quarter 2009

2.1 Background

The Automation Research Corporation (ARC) Benchmarking Consortium allows plants and refineries the opportunity to submit and compare process control performance data against similar operations around the world.

Established in 1986, the ARC is a consultancy in manufacturing, logistics, and supply chain solutions. Worsley Alumina became involved with the ARC in 2006 as an initiative to improve process control throughout the plant.

Worsley Alumina participates by submitting plant process control metrics every quarter to the ARC Benchmarking Consortium

The intern was tasked with carrying out the data collection for the 2nd quarter of 2009. As the task is often complicated and daunting to new data collectors, the intern was also tasked with updating existing guidelines for future data collectors to base their collections on.

2.2 Investigation and Method

A number of methods and practices were applied throughout the course of the project in order to accurately collect process control data metrics.

Data base searches, query tools and extensive communication with Process Engineers, Process Control Engineers, Systems Engineers and Human Resources staff was essential to accurately collect and verify existing data.

The primary method used during this data collection was to view previous quarterly metrics and verify the data was still accurate. Substantial changes were noted due to recent upgrades around the process control environment and many existing metrics (as collected in prior ARC collections) had to be investigated and verified.

The recent migration of many tags from the Honeywell TPS (Total Plant Solution) 2000 system to the new Honeywell Experion system is a key example of these changes.

2.2.1 Time Frame

The time frame for data collection considered in this report is the 2nd quarter, 2009. This quarter begins on the 1st April 2009 and ends the 30th June 2009.

When discussing quarterly periods in this report the following dates correspond to quarters of the year.

- Quarter 1: 1st of January to 31st of March.
- Quarter 2: 1st of April to 30th of June
- Quarter 3: 1st of July to 30th of September
- Quarter 4: 1st of October to 31st of December

2.2.2 Data Metrics Collection Methods

The ARC Benchmarking Consortium requires a substantial amount of data to be collected from all process areas at the Worsley Alumina Refinery. The following data metrics were collected for this quarter:

- Plant I/O Data
- Personnel Data
- Control Loops Data
- Security Patch Management
- Analysers in Control
- Advanced Process Controllers (APC) Data
- Plant Energy / Production Data
- Alarm Data

2.2.2.1 Plant I/O

The ARC Benchmarking Consortium requires a total count of plant wide process control inputs and outputs. Collection of these metrics provides the ARC Benchmarking Consortium with base information with which to compare plant size and performance against all other metrics. This includes all analogue and digital inputs and outputs throughout the plant, including the powerhouse. Also required was the percentage of these I/O's that were considered Safety Integration Level (SIL) I/O's.

Non SIL I/O:

I/O data spreadsheets from previous ARC Benchmarking data collections were found on the BHP Billiton Worsley Alumina Refinery engineering public drive. These data sheets originated from a data collection in the 3rd quarter of 2008. Due to the recent upgrades however it was considered necessary to verify the data.

The initial approach used to verify the old data was to interrogate Doc4000 using a variety of queries. Doc4000 is a plant control system documentation tool based on a SQL 2005 database, which records all process control related data. This approach was un-yielding. Despite the Process Control System Name Tagging convention implemented [6], many input and output tags had been doubled up by the recent addition of the Experion system and the ensuing migration of tags from the TPS 2000 databases to the newer Experion system. As a result, the query returned inaccurate results.

The next approach was to contact Ben Marler (Worsley Alumina Applications Engineer) who was able to obtain a revised spreadsheet containing some inputs and outputs. This spreadsheet was not considered useful as it was realized it did not contain data on the whole plant.

The end approach was to consult the area engineers and discuss if any new inputs or outputs had been added in the past year. The aim of this approach was to determine whether using the old metrics again was an accurate solution, or whether taking an estimate as to the number of existing I/O was acceptable. The outcome of this approach was that it was considered acceptable to use the previous years metrics as the area engineers agreed the number of new inputs and outputs added over the past year would not be significant.

SIL I/O:

The Safety Integrity Level (SIL) of a system specifies the level of risk reduction provided by that system. The Safety Integrity Level of a system is defined by the potential impact (financial, health and safety, environment) to a process the failure of that system poses.

Four SILs are defined, with SIL4 being the most dependable and SIL1 being the least. A SIL is determined based on a number of quantitative factors in combination with qualitative factors such as development process and safety life cycle management.

Area engineers were consulted for SIL I/O information. Doc4000 was not helpful because typical plant I/O are not labelled, named, tagged or described as SIL I/O. The following documents were also located on the BHP Billiton Worsley Alumina Refinery engineering public drive and were considered useful in determining plant SIL I/O.

- BHP Billiton Worsley Alumina Refinery Facility 044 Liquor Burning Review – SIL Verification Study [1],
- BHP Billiton Worsley Alumina Refinery High Digestor Blow-Off Temperature Interlock – SIL Study [2],
- BHP Billiton Worsley Alumina Refinery Liquor Burning Odour Control – 25% LEL RTO Interlock SIL Study [3],
- BHP Billiton Worsley Alumina Refinery Powerhouse Coal Fired Boilers Protection Upgrade (045015) – SIL Determination and Allocation Study [4].

2.2.2.2 Personnel Data

In order for the ARC Benchmarking Consortium to accurately determine the efficiency of the plants process control and automation system maintenance it requires information on the following employees.

- Process Control Personnel
- Field Instrumentation Personnel (or Electrical Instrument Technicians)
- Hardware/ Software Personnel
- Maintenance Personnel
- Contractors (Process Control Group contractors)

Information gathered includes how many employees fall into the categories above, and the number of hours worked by each employee group during that quarter.

The approach to the data collection of this metric was to contact Human Resources specialists and request the information.

An Excel spreadsheet was provided by Human Resources detailing the relevant members swipe card entry and exit from the refinery over the 3 month period. This information also included hours on site, employee names and organization units to which the employees belonged. The BHP Billiton Worsley Alumina Enterprise Resource Planning System (SAP) was consulted to confirm what disciplines (i.e. process control, instrumentation technicians, hardware/ software personnel, maintenance personnel, contractors) the unit organizations were associated with. The information provided was extensive and required an excel macro to filter out the required information. The macro can be viewed in Appendix A.

2.2.2.3 Control Loops

The ARC Benchmarking Consortium required specific information on control loops throughout the refinery. These metrics are collected to measure the plants control loop performance. This information includes the total number of loops, the number of key loops and the amount of time these loops spent operating in normal mode.

A key loop is defined as loops that *"represent the 10% or so of all control loops that are critical to safety, environment, quality, inventory and performance." [5]*

Doc4000 and PlantState Suite plant database programs were used to collect these metrics. Both programs are plant control system documentation tools based on a SQL 2005 database. The SQL 2005 database records refinery wide process control information. Specific queries and procedures can be seen in Appendix A – *ARC Guidelines June 2009.*

For this metric only Proportional Integral Derivative (PID) (both feed forward and feedback), Ratio Controllers (RATIOCTL) and Cascaded controllers were considered, as was outlined in the metric collection template.

The first step in collecting the data was to count the total number of control loops operating in the plant. To do this, Doc4000 was queried. Due to the recent addition of Experion, Doc4000 splits the tags up into different data owners depending on the area. For example, old TPS 2000 tags were located in the "Refinery Local Control Network (LCN)" and "Powerhouse LCN" data owners, while Experion tags had been separated into area specific data owners. The solution was to perform queries in each data owner, then sum the results to create a final solution.

The next phase of data collection was to discover and confirm key loops. A Previous ARC data collection had yielded a list of key loops, which was referred to again for this quarters data collection. The list was last updated in September 2008. The list had to be verified as there have been a number of small changes around the plant since 2008. The approach was to first use Doc4000 to confirm the loops in the list still existed in the areas indicated. The next step was to arrange meetings with both Process Engineers and Process Control Engineers from all the areas of the refinery. This allowed the opportunity to discuss the list with the engineers and explain the definition of a key loop.

The final step in collecting data for this metric is to use PlantState Suite to interrogate the database and determine how many hours the loops have spent operating in normal mode. Only PlantState Suite was suitable for this type of query because it was designed specifically for handling alarm data. Doc4000 did not provide sufficient alarm data to carry out this query.

While collecting data for the Control Loop metrics, bugs were found in the PlantState Suite database query tool that prevented the successful collection of information regarding the amount of time these loops spent operating in normal mode.

Query results for the number of hours the key loops were in normal mode determined that all loops had operated outside normal mode for the entire duration of the quarter. Following consultation with Process Control Engineers, the Experion training package [7] and PlantState Suite user manual [8] it was determined that the cause of the problem was the addition of the Honeywell Experion control system. The database (SQL 2005) uses what are known as TPS Points to map from the older Honeywell TPS 2000 to the newer Experion control network [7]. Unfortunately the TPS Points do not convey all parameters. PlantState Suite queries the SQL 2005 database and uses the TPS Points directly to collect information [9]. In this case the loss of the parameter recording the time a loop spends in normal mode is responsible for the problem.

It was determined that the best course of action was to inform the PlantState Suite vendor PAS and allow them to rectify the problem. As a result, information on the number of hours the control loops spent in normal mode was not collected and the project was submitted without this information.

2.2.2.4 Security Patches

As stated by the ARC Benchmarking Consortium metric template, "*This metric is designed to capture information about a company's policy and effectiveness in managing Microsoft OS-related security patches (MS-Patch) in their manufacturing operations."[5]*

This metric focused on process control PCs with Microsoft Windows operating systems. Information such as who was responsible for patch management, who performed operating systems upgrades and how often were patch upgrades installed was collected as metric data.

The data was collected by arranging a meeting with Worsley Alumina Systems Engineers to discuss the collectable information.

2.2.2.5 Analysers in Control

The ARC Benchmarking Consortium requires information on the number of Analysers used in process control, and the number of devices reading these analysers. This data is collected to measure the plants effectiveness of maintenance efforts for analysers used in process control. Only analysers used in process control are counted, emissions monitoring analysers were not considered for this metric.

The *"BHP Billiton Worsley Alumina Process Control System Name Tagging Convention"* [6] was referred to for this metric. The convention sets out guide lines for how tags in the process control systems are named. In this case, an analyser would have a tag beginning with AI (Analysis Indicator). Using Doc4000 to query the refinery database, any device or instrument with a tag beginning with AI was called up and saved to an excel spreadsheet.

This method yields all tags labelled as analysers used in process control. Many of the results were not of the category required by the ARC Benchmarking Consortium while most results were points of reference and did not represent the actual device (I/O). For this reason the list was considerably larger than expected. Attempts to refine the search were made but these attempts were made difficult because it was realized the tag naming convention has been ignored in a number of cases in the past.

To overcome this problem the area Process Control Engineers were consulted to help verify the list and sort the analysers from the results.

2.2.2.6 Advanced Process Controllers

This metric focuses on Advanced Process Controllers (APCs) data. Currently the plant has a number of Multi Variable Controllers (MVCs) which are classed as APCs. The ARC Benchmarking Consortium requires this data to measure the use of Advanced Process Controllers throughout the plant. Advanced Process Controllers are sophisticated controllers capable of executing process models and performing predictive control.

Although the Worsley Alumina Refinery utilizes a large number of APCs in the process control network, the ARC Benchmarking Consortium data collection template provided space for information on only nine controllers. The controllers listed in table 2-1 were selected because they were used in previous data collections and an effort was made to remain consistent throughout the data collection process.

The collection required information such as; the average number of controlled variables that are at active constraint, the number of manipulated variables that are at an engineering constraint and the number of extra manipulated variables. Data on the number of hours these controllers spent in a normal mode of operation was also collected.

Information on the Multi-Variable Controllers was obtained using a tool called the Uniformance Excel Companion, a software tool that plugs in to Microsoft Excel (MS Excel). This allows the user the option of pulling process information directly from the Honeywell Process History Database (PHD). PHD, a plant historian, keeps records on nearly all tagged process control devices on site, which is why it was useful for interrogation of MVC data.

Several MS Excel spreadsheets were created in previous years data collection procedures and were adapted for use with this quarter's data collection. This required changing dates to match the new quarter. The spreadsheet was designed to acquire MVC data and has been created in a manner that allows easy adaptation to future collections.

Table 2-1 outlines the MVCs used for this quarter's data collection.

Table 2-1: Multi-Variable Controllers used for ARC data collection

Controller	Master_ Tag
Digestor Blow Off Alumina/Caustic Ratio	UCACMSTR
Digestion Balancing MVC	UCDBMSTR
Counter Current Decanter 1	UCC1MSTR
Counter Current Decanter 2	UCC2MSTR
Mill Circuit	UCMCMSTR
Fine Seed MVC	UCSFMSTR
Course Seed MVC	UCCSMSTR
Calciner MVC	UCCBMSTR
Train 3 Clear Flow	UCCFMSTR

2.2.2.7 Plant Energy / Production Metrics

The ARC Benchmarking Consortium collects information about the refineries production and energy efficiency. This section requires three pieces of information to be collected, these are:

Overall Equipment Effectiveness (OEE) Metric:

This metric measures the effectiveness of production through three components; production equipment availability, quality, and production rate. These three measurements are combined to produce the Overall Equipment Effectiveness metric.

Actual production data was collected by contacting Worsley Alumina Technical Support Specialist who were able to use Uniformance ModTag (a tool used to query the Experion PHD) to pull monthly averages on production. These values were entered in an MS Excel spreadsheet and averaged over the 90 day quarter. Planned values were obtained using the Daily Energy Summary Report which was available on the BHP Billiton Worsley Alumina engineering public drive. This report provided daily energy and production summary information, as well as end of week averages. The end of week averages were used, collecting 12 weeks in total of averaged information and then creating an overall average across the 91 day quarter using MS Excel.

Total Energy Effectiveness (TEE) Metric:

This is a Performance Metric designed to measure the effectiveness of Energy Utilization in production. It compares actual production rate and energy consumed to planned production rate and energy consumed. This "Ratio" approach makes the Total Energy Effectiveness comparable across all production plants in a company as well as providing a cross company benchmark.

The Daily Energy Summary Report was referred to for this metric to collect data for both the actual and planned figures. These reports are created daily, and provide daily averages of both production of alumina and energy consumption. After some MS Excel working to create monthly averages, the quarterly figures were compiled by summing the monthly averages.

Energy Management Metric:

Energy Management is an increasingly important topic among manufacturers. This metric is intended to focus attention on a plant's ability to actively manage the use of energy. It is not designed to measure capital projects for energy management, but many of the driving forces that create the need for capital projects are also driving forces for having energy considerations as part of the operations.

Data collected includes information about energy management policies on site, energy management and automation and energy complexity (the number and types of energy sources on site). This data was collected by arranging meetings with PowerHouse Process Control Engineers.

2.2.2.8 Alarms Data

Alarm data is collected to determine the effectiveness of alarming throughout the Bayer process. Alarms are used to inform control room operators of undesirable process situations. Such events may include temperatures, pressures or flow rates exceeding optimized process limits or exceeding safety limits.

Alarm data is collected for the 90 day quarter using data base queries performed in both Doc4000 and PlantState Suite. Standing alarms, peak alarm rates and total configured alarms information is collected according to area and compared against the number of operators working at the respective area consoles. This provides ratios of alarms to operators and gives an overall indication of how effective the process control alarming is. See appendix A – *ARC Guidelines June 2009* for the method used in acquiring the data.

2.3 Project Conclusions

The ARC Benchmarking Consortium data collection project represented the largest project undertaken by the intern during the internship. The project required five weeks of work and has created a number of opportunities to learn about the engineering environment at the BHP Billiton Worley Alumina refinery. Various tasks were undertaken and valuable plant knowledge has been learnt. These have been summarized below.

- The nature of the project required the use of databases to acquire information. This, as a result, has led to the development of database query skills. Doc4000 and PlantState Suite are plant control system documentation tools based on a SQL 2005 database. These tools were used extensively to search for information on control loops, alarms, analysers and input/outputs.
- Communications skills have been improved following numerous discussions and meetings with engineering staff, human resources staff and technical support staff. Good workplace communication etiquette skills are required in any work environment. These skills have been introduced and honed over the course of the project and the intern has become confident in communicating and working alongside Worsley employees.
- The ARC Benchmarking Consortium Data Collection Guidelines were updated to provide assistance to future ARC data collectors.

- Many process control engineering terms and theories have been learnt during the course of the project. SIL ratings were studied and alarm management theory has been learnt. The intern has also developed an appreciation for the size, scope and architecture of a process control system that incorporates two generations of control technology.
- In addition to the aforementioned skills, an understanding on the size and scope of the BHP Billiton Worsley Alumina refinery has been realized. The extent to which the refinery is automated and the size of the process is obvious when discussing process control device inputs and outputs in the order of tens of thousands.

As a result of the interns involvement in this project the process control engineering team was able to submit and compare their performance against similar operations around the world. This enables the team the opportunity to identify areas which require improvement, which is often a difficult task in large scale process control projects.

The interns' involvement in this project has offered many opportunities for learning, but the main benefit of partaking in this task is the project's excellent ability to introduce the intern to the process control environment. Prior to participating in this project, the intern had little knowledge of the databases, the control systems and the sheer size of the refinery. Having collected data on nearly all aspects of the process control environment the intern now has a detailed knowledge on the size and scope of the control systems on site, as well as introductory database skills. In addition to this, the project has provided the intern with numerous opportunities to meet and discuss process control with the various engineers, technicians and other staff on site, offering excellent learning opportunities.

3. BHP Billiton Worsley Alumina Refinery PlantState Suite Real-Time Server Loading Study

3.1 Introduction

The current upgrade and expansion project at the BHP Billiton Worsley Alumina Refinery will result in a number of new instruments, devices and equipment being added to the plant. Consequently new tags and alarms will also be added to provide automation functionality of the new equipment.

The PlantState Suite system is responsible for recording and processing alarms and events throughout the refinery. Currently one PlantState Suite server processes alarms and events for the whole refinery. It has been proposed that this service be expanded to accommodate additional and upgraded facilities. The following are proposals for the expansion of the PlantState Suite services:

1. Provide independent servers for Redside (Area 1 and Area 2), Whiteside (Areas 3 and 4) and PowerHouse (including Raw Materials). Only facilities from these areas will be assigned to the respective servers. This requires the addition of two new servers.

2. Provide independent servers that will distribute alarms from facilities evenly across each server, regardless of area assignment.

The following details the methods and results of a study into the current and future PlantState Suite server loading.

3.2 Alarm Definitions

Alarm priorities are defined by the severity of impact to the refinery the initiating event will cause against the maximum allowable time required for response to the situation. During the alarm rationalizing procedure engineers are required to assess these factors in order to determine the priority of the alarm. Engineers use the following matrices:

		Severity Rating				
		0	1	2	3	4
Financial Impact		No loss	Less than $5,000	$5,000-$20,000	$20,000-$100,000	Above $100,000
HSEC	Reputation	Workforce concerns	Local community	Local media attention	State media and community attention	
	Personnel Safety	No injury	First aid treatment	Medical treatment	Multiple injuries	LTI
	Environment	Localised impact inside pad	Impact outside process pad		Breach of license conditions	Impact outside Refinery

Figure 3-1 Potential Consequences and Severity Rating [15]

		Severity Rating				
		<2	3-4	5-6	7-8	9+
Reaction Time	> 30 Minutes	No Alarm	Journal	Low	Low	High
	10-30 minutes	Journal	Low	High	High	**Emergency**
	3-10 minutes	Low	Low	High	**Emergency**	**Emergency**
	<3 minutes	Low	High	**Emergency**	**Emergency**	**Emergency**

Figure 3-2 Severity vs. Operator Reaction Time [15]

There are five alarm priorities used in the BHP Billiton Worsley Alumina Refinery process control system, They are defined as follows [13]:

- No Action priority means there is no alarm or event defined.
- Journal alarms are events that require historical capture only. These alarms are not annunciated to the Senior Control Room Operators (SCROs).
- Low alarms are alarms that require operator action to prevent a plant up-set and escalation to a higher priority.
- High alarms are alarms that require RAPID Operator action to:
  - prevent a situation escalating to an EMERGENCY priority, or
  - prevent equipment damage and production losses
- Emergency or Urgent alarms are alarms that require IMMEDIATE Operator action to:
  - prevent an adverse health, safety, environment or community (HSEC) event, or
  - react to major equipment shutdown

3.3 Method

3.3.1 Assumptions

During this study the following assumptions were made:

1. Configured alarms do not necessarily indicate the number of instruments or equipment in the field. “Configured Alarms” indicate how many alarms have been configured to annunciate or journalled, in that respective area or facility.
2. Only configured alarms will generate alarms.
3. This study includes low, high, urgent/emergency and journal alarms. NoAction alarms were not considered for this study because they impose no load on the alarm system.
4. As a worst case scenario, the additional tags from the E&G project are assumed to all be configured with fourteen alarms. This figure represents the result of an independent study into the highest number of alarms currently configured to an existing tag. This ensures that no underestimate is made.
5. New facilities with no existing alarm information will use the highest “alarms per hour to configured alarms” ratio calculated (0.151).
6. The ratio of alarms per hour to configured alarms will provide an accurate method of estimating the extra alarms per hour generated by the additional E&G tags.
7. Assume that Redside consists of Area 1 and Area 2.
8. Assume that Whiteside consist of Area 3 and Area 4.
9. Assume that PowerHouse consists of PowerHouse and Raw Materials.
10. The alarms per hour data has been averaged over a six month period from February 1st 2009 to August 1st 2009.
11. The port has not been included. Raw Materials Process Control Engineers have confirmed that port data is not recorded on the refinery PSS server due to the large distance between sites. As such, it has been concluded that the port does not contribute to the refinery PSS loading.

3.3.2 Process

The aim of the study is to accurately predict the increase in alarms as a result of additional and upgraded facilities in order to determine the increase to PlantState Suite server loading.

In order to do this, Doc4000 and PlantState Suite were used to query for information on alarms per facility.

The following data was found using PlantState Suite:

- "Alarms per hour" averaged over a six month interval from February 2009 to August 2009. This query is performed per facility.

The following data was found using Doc4000:

- The number of configured alarms per facility. The acquisition of this data required the intern to run a number of queries as well as use excel to compile the query results.

The "Alarms per hour" query provides information on the number of alarms being generated per hour per facility. This provides a measure of the processing power required by each facility. Facilities generating a higher number of alarms per hour require more processing power and thus contribute to a higher server loading.

Configured alarms data provides information on how many tags are responsible for creating the above "alarms per hour" data.

3.3.2.1 Data Collection - Alarms per Hour

The number of alarms per hour generated by each facility has been queried using PlantState Suite. PlantState Suite has been used because it offers the built in "Alarms per time Period" query and thus is the appropriate tool for this query type. The intern must enter a time frame to be able to create an averaged result. In this case the query has been set to "per hour" over a six month period from February 1st 2009 to August 1st 2009. The query has been performed in each area Experion Process Knowledge System (EPKS) data owner. Only the area EPKS data owners need be queried, as these data owners collect all TPS 2000, SCADA and EPKS alarm system performance data. The queries were filtered by facility, and the results recorded in an excel spreadsheet for later reference.

3.3.2.2 Data Collection – Configured Alarms

The refinery utilizes both the older TPS 2000 (LCN based) control system and the newer Experion control system for process control. Both systems are independent of each other, but the Experion system is setup to be able to access the TPS 2000 control system. This is because the refinery is in the process of upgrading the entire control network to Experion and require Experion to access some of the older modules around the plant. As a result, discovering the number of configured alarms can become complicated. Alarms can be configured to the following tags:

- Control Modules (CM) – These represent tags assigned to points in the Experion network (ACE nodes, C300 / C200 controllers) of an analogue nature.
- Sequential Control Modules (SCM) – These represent tags assigned to points in the Experion network (ACE nodes, C300 / C200 controllers) processing control sequences.
- Status Points (SP) – These represent tags assigned to digital points in the SCADA, within the Experion network (all other non ACE, C300 or C200 controllers)
- Analogue Points (AP) – These represent tags assigned to analogue points in the SCADA, within the Experion network (all other non ACE, C300 or C200 controllers)
- LCN – These points represent all configured alarms for both digital and analogue devices on the TPS 2000 network.

The number of configured alarms per facility required a substantial number of queries to be written and applied to data owners across area EPKS, Refinery LCN and PowerHouse LCN. PlantState Suite was not used to collect this data because it fails to indicate how many "Urgent/Emergency" alarms are configured per facility, meaning the results will be inaccurate.

Configured alarms per facility can be found in Doc4000. Each facility will have alarms in SCADA, Experion and the LCN. This means the user must query the following object types:

- SCADA – Status Points, Analogue Points
- Experion - Control Modules (CM), Sequential Control Modules (SCM)
- LCN – Alarms

SCADA query

Doc4000 can be queried for SCADA tagged alarms however the query will not yield which facilities these alarms are assigned to. To query Doc4000 for SCADA alarms per facility, four individual queries per data owner must be created. The first two queries will define the number of SCADA points (Status and Analogue) per data owner with the relevant facility or unit assignment, the third query will define all alarms configured for that data owner and the fourth query will combine the first two to determine SCADA points that have alarms. Tables 3-1, 3-2, 3-3, 3-4, 3-5 and 3-6 outline the queries used.

Table 3-1: Status Points Query Procedure Doc4000

Status Points:

Type of Query	Property Data
Asset	EPKS (data owner, i.e. Area, Raw Materials or PowerHouse)
Object Type	Status Point
Property names*	AreaCode, AlarmEnableState0 -> 7, AlarmPriorityState0 -> 7, Tag
Search Criteria	(AlarmEnableState0 = 'True') or (AlarmEnableState1 = 'True') or (AlarmEnableState2 = 'True') or (AlarmEnableState3 = 'True') or (AlarmEnableState4 = 'True') or (AlarmEnableState5 = 'True') or (AlarmEnableState6 = 'True') or (AlarmEnableState7 = 'True')

This query yields the number of status points configured in a data owner along with which facility it belongs to. AlarmEnableState and AlarmPriorityState were required to indicate the results were accurate and were used for debugging the results. The "Tag" property was essential in matching up the results against the Alarms query.

Table 3-2: Analogue Points Query Procedure Doc4000

Analogue Points:

Type of Query	Property Data
Asset	EPKS (data owner, i.e. Area, Raw Materials or PowerHouse)
Object Type	Analogue Point
Property names*	AreaCode, AlarmPriority 1 -> 8, AlarmDisable, Tag
Search Criteria	AlarmDisable = 'False'

This query yields the number of analogue points configured in a data owner along with which facility it belongs to. The "AlarmPriority1 ->8" property was used to debug the search and confirm the results were accurate. The "Tag" property was essential in matching up the results against the Alarms query.

*NOTE: AlarmEnableState0 -> 7, AlarmPriorityState0 -> 7 or AlarmPriority1 -> 8; 1 -> 8 or 0 -> 7 denotes X0,X1,X2,X3,X4,X5,X6,X7 or X1,X2,X3,X4,X5,X6,X7,X8.

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Table 3-3: SCADA Alarms Query Procedure Doc4000 (Status Point Generated)

Alarms:

Type of Query	Property Data
Asset	EPKS (data owner, i.e. Area, Raw Materials or PowerHouse)
Object Type	Alarms
Property names	Tag, AlarmType, TagType, Priority, TagAlarmsEnabled, AlmEnbState
Search Criteria	((Priority = 'low') OR (Priority = 'high') OR (Priority = 'urgent') OR (Priority = 'journal')) AND (TagAlarmsEnabled = 'TRUE') and (AlmEnbState = 'TRUE') and (Alarmtype <> 'None')

This query yields the number of alarms configured for a data owner. The search criteria must be slightly modified for the analogue points as follows:

Table 3-4: SCADA Alarms Query Procedure Doc4000 (Analogue Point Generated

Search Criteria	((Priority = 'low') OR (Priority = 'high') OR (Priority = 'urgent') OR (Priority = 'journal')) AND (TagAlarmsEnabled = 'TRUE') and (Alarmtype <> 'None')

)

The final query is an advanced query using SQL. Its purpose is to combine the Status/Analogue Point queries with the Alarm query. The combination compares the tags of each set of results and displays the Status/Analogue Point alarms with AreaCode, which translates into facility number.

The query is split into two parts, the Status Point Alarms and the Analogue Point Alarms. They can be seen in tables 3-5 and 3-6 below.

Table 3-5: SCADA SQL Alarm Query – Status Points

Type of Query	SQL
Asset	EPKS (data owner, i.e. Area, Raw Materials or PowerHouse)
SQL code	select [AlarmsQuery].*, [StatusPointQuery].* from [AlarmsQuery] join [StatusPointQuery] on [AlarmsQuery].[Tags] = [StatusPointQuery].[Object Name]

Table 3-6: SCADA SQL Alarm Query – Analogue Points

Type of Query	SQL
Asset	EPKS (data owner, i.e. Area, Raw Materials or PowerHouse)
SQL code	select [AlarmsQuery].*, [AnaloguePointQuery].* from [AlarmsQuery] join [AnaloguePointQuery] on [AlarmsQuery].[Tags] = [AnaloguePointQuery].[Object Name]

Experion Query

Doc4000 has a range of built in queries that are perfect for Experion queries. In this case, the user is interested in Control Modules (CM) and Sequential Control Modules (SCM). Only two SQL queries are required to collect this information. These can be seen in tables 3-7 and 3-8 below.

Table 3-7: Control Module Query

Type of Query	SQL
Asset	EPKS (data owner, i.e. Area, Raw Materials or PowerHouse)
SQL code	select [Alarms - All].*, [ControlModule List].* from [Alarms - All] join [ControlModule List] on [Alarms - All].[Tags] = [ControlModule List].[Object Name]

Table 3-8: Sequential Control Module Query

Type of Query	SQL
Asset	EPKS (data owner, i.e. Area, Raw Materials or PowerHouse)
SQL code	select [Alarms - All].*, [SequentialControlModule List].* from [Alarms - All] join [SequentialControlModule List] on [Alarms - All].[Tags] = [SequentialControlModule List].[Object Name]

Refinery and PowerHouse LCN

The following query was applied to both Refinery LCN and PowerHouse LCN. The query returned the number of alarms configured per facility. The results were saved into an excel spreadsheet and the alarms contributing to individual facilities were tallied. The results can be viewed in Appendix B. Table 3-9 illustrates the query used.

Table 3-9: Local Control Network Query

Type of Query	Property Data
Asset	Refinery LCN / PowerHouse LCN
Object Type	Alarms
Property names	Unit, Priority, Tag, Alarm, Type
Search Criteria	(Priority Not Like 'NOACTION')

y

The results from these queries were saved in an excel spreadsheet referenced in Appendix B. The results from these queries indicate the number of alarms configured in each area throughout the refinery from SCADA tags.

3.3.3 Calculations

A definitive estimate of the E&G project tags were provided by the Process Control Engineering group. These tags have been used to provide an estimate of extra alarms generated in each facility. See 'Assumptions' for more information.

"Alarms per hour to Configured alarms" ratios have been calculated for each facility by dividing the alarms per hour generated by a facility by the number of configured alarms in that facility. These ratios were then used to extrapolate the number of additional alarms generated by each facility following the addition of the E&G tags.

The E&G tags were multiplied by fourteen, then by the "Alarms per hour to Configured alarms" ratios to estimate the extra alarms per hour generated by the E&G tags, per facility. Where no existing "alarms per hour" data is available to calculate an alarms ratio, the highest alarms ratio was used. The results have been added to the current alarm rate and a percentage increase in alarm generation, per facility, has been created.

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3.4 Discussion of Results

The first step in completing this study was to have the relevant area Process Control Engineers confirm that the results were reasonably accurate. Following this peer review stage, the study was formally written up and submitted to Senior Process Control Engineer Angelo D'Agostino.

Actual study results can be viewed in Appendix B. The following discussion references appendix B.

The "Shared" Unit

Query results showed many units and facilities that were contributing to areas they did not belong. For example, Area 1 queries showed a contribution being made by a unit labelled RM (Raw Materials). While this unit was not a part of Area 1, it showed up in the Doc4000 query under the Area 1 data owner, thus some tags from unit RM were contributing to server loading on an Area scale. It was rationalised that even though the shared units or facilities did not belong to the areas, some alarms belonging to the units were showing up in the query results as belonging to the area data owner, thus it was contributing to the area server. As such, the decision was made to accept the results and reason that the shared unit alarms were contributing to that areas portion of the server loading. Table 3-10 (snap shot of excel results) demonstrates this effect.

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Table 3-10: The "Shared" Unit

Area 1						
Facility	**SP**	**AP**	**CM**	**SCM**	**LCN**	**Total**
24	1950	282	34	0	250	**2516**
25	686	102	14	0	123	**925**
26	175	64	0	0	130	**369**
30	731	285	31	0	677	**1724**
A1	79	44	9	0	28	**160**
A3	9	0	0	0	20	**29**
LU	0	32	0	0	0	**32**
RM	0	0	12	0	5	**17**
P1	0	0	0	0	40	**40**

RM						
Facility	**SP**	**AP**	**CM**	**SCM**	**LCN**	**Total**
16	82	0	0	0	0	**82**
C1	278	304	0	0	0	**582**
C2	188	134	0	0	0	**322**
RC	137	244	6	9	0	**396**
RM	377	366	666	0	5	**1414**
ST	83	24	470	0	0	**577**
CB	0	36	0	0	0	**36**
UT	0	12	13	0	18	**43**
44		0	8	0	807	**815**
A1	0	0	16	0	28	**44**
ED	0	0	136	0	61	**197**

Facility Alarm Loading Summary

Appendix B - table 9-1 shows loading contribution by facility. Note that only facilities are included in this table. These figures have been calculated as indicated in 'Methods', with the calculations based on facility contributions from the data source. Shared units have not been included.

Area Alarm Loading Summary

The Area Alarm Loading Summary table shows the alarm loading contribution made by an area. The figures shown in appendix B - table 9-2 are not related to the facility summary in appendix B table 9-1. This is because of the "shared" unit effect. The figures have been calculated in the same fashion indicated in 'Methods', however the data source includes shared units as these units are considered to contribute to area server loading.

Proposed Server Loadings

Appendix B -table 9-3 summarizes the results from Area Alarm Loading Summary for ease of results interpretation. This table shows the alarm loadings of the proposed servers before and after the addition of E&G alarms. This table includes all units contributing from each area as well as facilities from those areas. RedSide consists of areas one and two, WhitSide consists of areas three and four and PowerHouse consists of the PowerHouse and Raw Materials.

3.5 Summary

Appendix B - table 9-3 "Proposed Server Loadings" indicates the difference in server loading between the proposed RedSide, WhiteSide, and PowerHouse server allocation method. The percentage increase in alarm loading for each proposed server is relatively large, with the largest increase being 66.6% for Redside.

The table indicates that the RedSide Server will process an estimated 695 alarms per hour, while WhiteSide will process 2871 alarms per hour and PowerHouse will process 758 alarms per hour.

The study concludes that under the proposed architecture for servers for RedSide, WhiteSide and PowerHouse the system will demonstrate an uneven loading. It was recommended that two additional servers be added to the current hardware architecture. These additional servers will carry out the same role as the current PlantState Suite Real Time server. In addition to this, it is recommended that all real time servers be allocated facilities regardless of area to balance out the server loading.

3.6 Project Conclusion

The project has provided the intern with the opportunity to apply problem solving skills, data analysis and reasonable judgment to determine the loading of a real-time server. The project presented the intern with the challenge of applying the data collection methods obtained in the ARC Benchmarking Consortium data collection project to a task higher in complexity.

The study has never before been performed, and many engineers were never required to determine the number of alarms configured to each facility. As such, this project presented the intern with the opportunity to create precedence for discovering the alarm rates from alarms configured in a facility or unit. It is anticipated that future investigations will endorse and use the methods created by the intern.

4. PCC Pending Closure Closeouts

4.1 Background

Process Control Change (PCC) requests act as work orders for Process Control Engineers. They are distributed to engineers through the electronic PCC system. When a change to a process control system has been identified as necessary, a request is lodged and the respective area Process Control Engineer is notified of the request. Once action has been taken and the change made, PCC's must be closed out. This task is an engineering related administrative task where a considerable backlog had developed.

4.2 Process

The project requires the intern to act as the PCC Co-ordinator for the duration of the internship period. PCC's are managed via a program called Service Desk. Service Desk resides on a network server and is accessed via remote desktop.

PCC's originate from customers. These PCC's are registered in the system by the PCC co-ordinator, who determines the category. PCC's are categorized by level of impact to the process and refinery.

Category 0 changes are normal or scheduled repair/maintenance/operations activities associated with the Process Control group. No change management procedures are required [6].

Category I changes are normal or scheduled repair/maintenance/operations activities associated with the Process Control group that carry a high risk. These changes are subject to internal review [6].

Category II changes are activities that require approval from parties outside the Process Control group without internal review [6].

Category III changes are activities that require approval from parties outside the Process Control group and are subject to internal review [6].

The procedures in place to handle the different categories of PCC are best explained using the Process Control Change Flow Chart (figure 3.2.1).

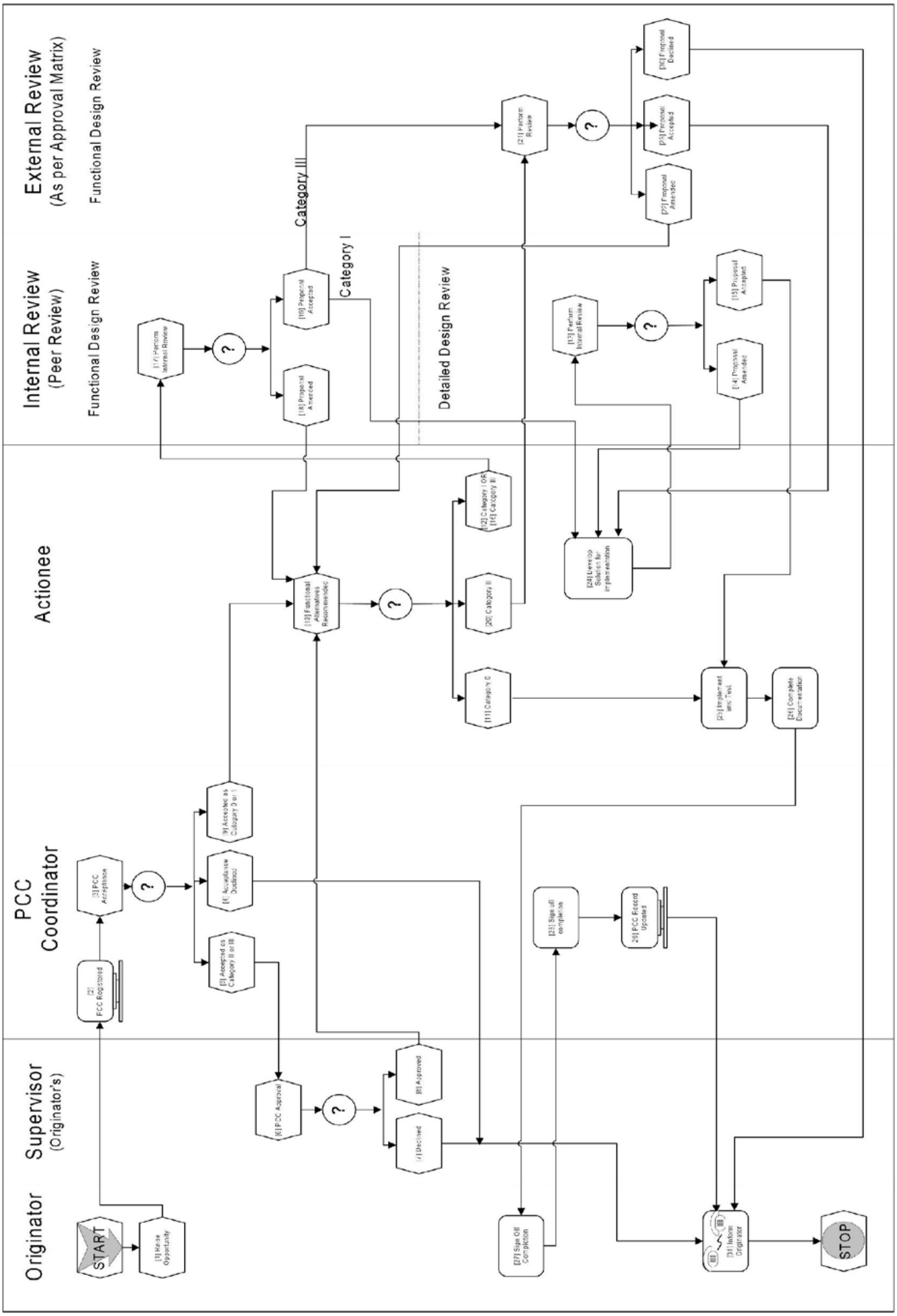

Figure 4-1 Process Control Change Request Flow Chart [11]

PCCs are closed out by firstly confirming that the job status is "Pending closure". Following this, both customer and engineering forms must be filled in as demonstrated in figure 4-2. The forms are saved and closed, Service Desk will re-assign the PCC as closed and the relative parties are informed of the closed status [5].

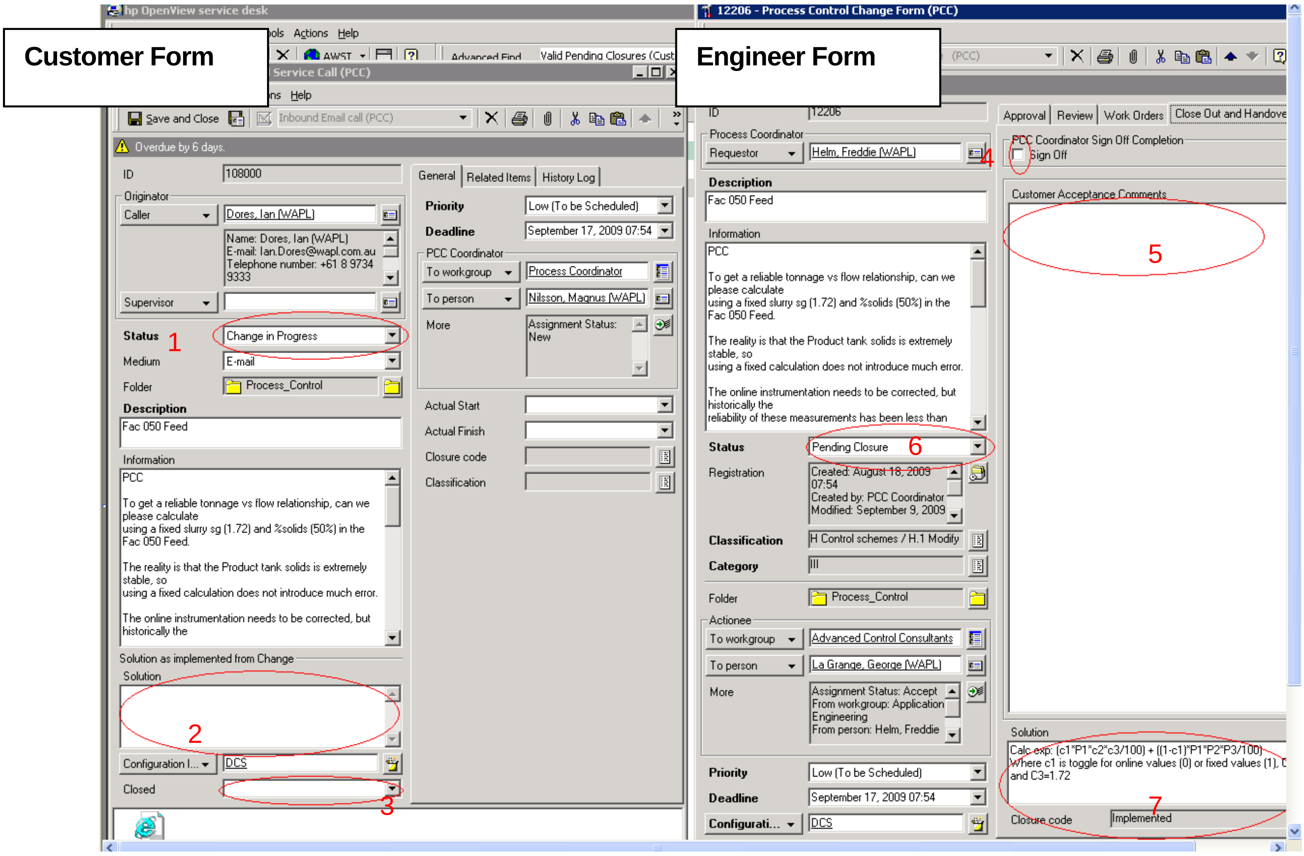

Figure 4-2 PCC Closeout Windows

1. The status window must be changed to "closed".
2. The solution from (7) must be copied into this field.
3. The date of closure must be entered; this date is found in the "history" tab of the Engineer form.
4. The "Sign Off" box must be ticked.
5. The "Customer Acceptance Comments" field must have display a useful response from the customer, this field is used to indicate the customer is satisfied with the product.
6. The status window must be changed to "closed".
7. The solution field should briefly indicate the solution the engineer has implemented.

4.3 Project Conclusion

Throughout the semester the intern was exposed to the BHP Billiton Worsley Alumina engineering process control change system. By assuming the role of Process Control Coordinator, the intern was exposed to a variety of tasks including closing out PCCs, interacting with Process Control Engineers and presenting data to the control group.

While the project presented the intern with little technical application, it outlined the importance of record keeping and the necessity of administrative tasks in large scale operations as is demonstrated at the BHP Billiton Worsley Alumina Refinery. The PCC system provides a level of control over changes made to the refinery, it is essential in ensuring that process changes are made by people who are sufficiently qualified and that the solutions adopted are recorded for future reference.

The project also provided the intern with a level of responsibility in that if the PCCs are not managed properly, process changes cannot be tracked in the future and solutions adopted cannot be assessed or re-used in future applications. In taking on the role as PCC coordinator the intern has developed an appreciation for proper engineering administration and record keeping.

5. Internship Review

Throughout the course of the internship I have participated in a number of projects and activities designed to develop my engineering skills and help apply the lessons learnt at university.

The Worsley Alumina Bayer process represents one of the world's most automated industrial scale Bayer processes. A well organized team of twenty engineers is responsible for monitoring, maintaining and upgrading an automation system that incorporates thousands of devices and instruments built on top of two generations of control system architecture.

My participation in the internship ensured that the skills and lessons learnt throughout the Industrial Computer Systems Engineering course were re-enforced through real work in the engineering workplace. With the Process Control Engineering team available and willing to provide help, I felt the internship really helped me apply theory to practice.

I have applied the many communications and data management skills learnt at university to successfully gather large quantities of data utilizing the many information resources available in the engineering workplace.

I have witnessed both the benefits and limitations of complete industrial process automation. A high level of automation has the great benefit of providing ease of process optimisation through comprehensive monitoring and recording of process variables, but the size and scale of such a control system requires a great deal of maintenance. The smallest of details cannot be ignored when managing such a large scale control environment. In addition to this, the requirement to regularly update and upgrade the control network and its associated devices, instruments, controllers, physical layers and human interface machines can be a massive task for any team.

Documentation control and record keeping is essential in any workplace, but in an industrial operation the size and scale of the Worsley Alumina refinery it is absolutely paramount. The Process Control Change request project has taught me the importance of change control and administrative tasks in such a work place.

In conclusion, the BHP Billiton Worsley Alumina internship has enabled me to finish my engineering degree with an increased understanding of how engineering is practiced in industry. It has provided me with opportunities to apply theory to practice and network with people in the industry as well as enable me to broaden my understanding of industrial computer systems and their applications.

6. Definitions, Terms and Abbreviations

A/C	Alumina to Caustic Ratio
AP	Analogue Point
APC	Advanced Process Controller
ARC	Automation Research Corporation
BRDA	Bauxite Residue Disposal Area
C/S	Usable Caustic Soda to Unusable Caustic Soda Ratio
CCD	Counter Current Decantation
CM	Control Module
CRO	Control Room Operator
DBO	Digestor Blow Off
DSM	Dutch State Mines
DSP	Desilication Product
E&G	Efficiency and Growth
EPKS	Experion Process Knowledge System
ESP	Electrostatic Precipitator
FBC	Fluid Bed Calciner
HID	Heat Interchange Department
HSEC	Health, Safety, Environment and Community
I/O	Input / Output
ISH	Indirect Steam Heaters
LCN	Local Control Network
MS	Microsoft
MVC	Multi-Variable Controller
ODP	Oxalate Degradation Plant
OEE	Overall Equipment Effectiveness

PH	PowerHouse
PHD	Process History Database
PID	Proportional Integral Derivative
PLC	Programmable Logic Controller
PSS	PlantState Suite
RATIOCTL	Ratio Controller
RCL	Refinery Catchment Lake
RM	Raw Materials
SCADA	Supervised Control And Data Acquisition
SCM	Sequence Control Module
SCRO	Senior Control Room Operator
SIL	Safety Integrity Level
SP	Status Point
SQL	Structured Query Language
TCA	Tri-Calcium – Aluminate
TEE	Total Energy Effectiveness
TPS 2000	Total Plant Solution 2000

7. References

[1] D.Howarth. *BHP Billiton Worsley Alumina Refinery Facility 044 Liquor Burning Review – SIL Verification Study.* Perth Western Australia: WorleyParsons Pty Ltd, 2005. [PDF] Available: Worsley Alumina Refinery Process Control Engineering.

[2] M.Karyinga. *BHP Billiton Worsley Alumina Refinery High Digestor Blow-Off Temperature Interlock – SIL Study.* Perth Western Australia: WorleyParsons Pty Ltd, 2004. [PDF] Available: Worsley Alumina Refinery Process Control Engineering.

[3] M.Karyinga. *BHP Billiton Worsley Alumina Refinery Liquor Burning Odour Control – 25% LEL RTO Interlock SIL Study.* Perth Western Australia: WorleyParsons Pty Ltd, 2004. [PDF] Available: Worsley Alumina Refinery Process Control Engineering.

[4] D.Calcan. *BHP Billiton Worsley Alumina Refinery Powerhouse Coal Fired Boilers Protection Upgrade (045015) – SIL Determination and Allocation Study.* Perth Western Australia: WorleyParsons Pty Ltd, 2004. [PDF] Available: Worsley Alumina Refinery Process Control Engineering.

[5] *ARC Benchmarking Consortium April - June 2009 Metric Collection Template.* U.S.A: ARC Pty Ltd, 2009. [Spread Sheet] Available: Worsley Alumina Refinery Process Control Engineering

[6] L. Skelly. *BHP Billiton Worsley Alumina Process Control System Name Tagging Convention.* Collie, Western Australia: Worsley Alumina Pty Ltd, 2009. [PDF] Available: Worsley Alumina Refinery Process Control Engineering

[7] C.Elliott, R.Duggan, F.Helm, B.Marler, T.Shah. "*Module 1 – System Architecture, Module 3 – Experion Tools,"* in *Experion Training for Electrical / Instrumentation Technicians.* [Hardcopy]. BHP Billiton Worsley Alumina Refinery Process Control Engineering 2009.

[8] *PlantState Suite: User Guide*, Version 5.2. U.S.A: PAS, 2006

[9] *Honeywell Knowledge Builder*. [Software]. U.S.A: Honeywell International copyright 1996 – 2007.

[10] *ARC Benchmarking Consortium Quarterly Data Collection Template: 2nd Quarter 2009.* [Microsoft Excel Spreadsheet]. U.S.A: Automation Research Corporation, 2009.

[11] A.D'Agostino. "Process Control Change" Procedural Information. [PDF Online]. BHP Billiton Worsley Alumina Refinery Process Control Engineering 2009.

[12] A.D'Agostino. "PC Change Classification Code" Procedural Information. [PDF Online]. BHP Billiton Worsley Alumina Refinery Process Control Engineering 2008.

[13] A.D'Agostino. "Alarm Management Philosophy" Procedural Information. [PDF Online]. BHP Billiton Worsley Alumina Refinery Process Control Engineering 2006.

[14] "Introductory Bayer Process Training Manual". Perth, Western Australia: Technical Illustrators Group, 2003. [PDF] Available: Worsley Alumina Refinery Process Control Engineering.

[15] A.D'Agostino. "Process Alarm Priority". [PDF Online]. BHP Billiton Worsley Alumina Refinery Process Control Engineering 2008.

8. Appendix A - ARC Benchmarking Consortium Project

8.1 ARC Guidelines June 2009

General Considerations

The following are guidelines based strongly on the ARC Benchmarking collection for the quarter ending June 2009. Included here are the queries used to obtain specific data. This information is a simplified version of the ARC Guidelines June 2009 document and has been doctored to suit this internship report. Specific names, email addresses and phone numbers have been removed.

Control Loops

Requirements:
This metric requires the count of control loops in the refinery. Control loops in the PID, RATIOCTL and CASCADE are counted only. Advanced Process Controllers such as MVCs should not be included as indicated in the metric template.

Method:
Using DOC4000:

Method for LCN Total Loops:

Using DOC4000, the following query was used:

Refinery
Query type: Property data
Object type: Tag
Asset: Refinery
Sub Types: REGAM, REGCLNIM
Search Criteria: (CTLALGID Like PID%) OR (CTLALGID Like RATIOCTL%)

Powerhouse
Query type: Property Data
Object type: Tag
Asset: Powerhouse
Sub Types: REGAM, REGCLNIM
Search Criteria: (CTLALGID Like PID%) OR (CTLALGID Like RATIOCTL%)

Method for Experion and SCADA Total Loops:

Using doc4000, use the following queries:

Area 1
Type of query: Property Data
Asset: EPKS Area1
Object type: PID block group
Results located in

This process was repeated again for areas 2, 3, 4 and powerhouse. Raw Materials had no results for any Experion based PID or ratio control loops. Results were compiled into an excel spreadsheet then summed to create a final result.

Loops in Normal Mode

Requirements:
This metric requires the total number of hours the control loops were not in their normal mode over a 90 day period.

Method Information for this section was not able to be acquired.

Reason:
PlantState Suite issue.

Explanation:
Query results for the number of hours the key loops were in normal mode determined that all loops had operated outside normal mode for the entire duration of the quarter. Following consultation with process control engineers, the Experion training package and PlantState Suite user manual it was determined that the cause of the problem was the addition of the Honeywell Experion control system. The database (SQL 2005) uses what are known as TPS Points to pass information from the older Honeywell TPS 2000 (Total Plant Solution) to the newer Experion control system. Unfortunately the TPS Points do not convey all parameters. PlantState Suite queries the SQL 2005 database and uses the TPS Points directly to collect information. In this case the loss of the parameter recording the time a loop spends in normal time is responsible for the problem.

Actions:

Applications Engineers Jodie Wilson and Alex Mercader have been informed. They have contacted PAS about the issue, and are awaiting a solution to be developed.

Key Loops

Requirements:

This metric requires information on how many key control loops there are in the refinery as well as the total number of hours these loops were not in their normal mode over a 90 day period.

Method:

The January 2008 collection yielded a list of the key loops. This list was then circulated amongst the respective area process and process control engineers to confirm the loops were still active and considered key loops. This process will take a couple of weeks as there are quite a large number of people involved in the confirmation of these loops.

The list of Area Engineers is as follows:

Area 1: Phil Sandford	(Engineer Process)
Area 2: Phil Sandford	(Engineer Process)
Area 3: Jessica Bingham	(Engineer Process)
Area 4: Sophia Yiannakis	(Engineer Process)
Liquor Burner: Erin Simons	(Engineer Process)

Area 1: Carlos Elliott	(Engineer Process Control)
Area 2: Tejas Shah	(Engineer Process Control)
Area 3: Manoj Tupkari	(Engineer Process Control)
Area 4: Fred Helm	(Engineer Process Control)
Liquor Burner: Vishwesh Soni	(Engineer Process Control)

PowerHouse: Gerhard Oosthuizen (Engineer Process Control)

It is recommended that separate meetings with each Area engineer should be arranged in order to:

- Explain the reason behind this part of the collection,
- Explain what a key loop is, and
- Discuss what other control loops should be added to the list (if needed).

This provides a better understanding of what control loops the area engineers find most important that would otherwise be neglected from a process control point of view.

Furthermore, the key loops within each area should be grouped into their specific application or purpose. This allows the Area Engineers to be able quickly identify the control loop.

Alarms

Requirements:

This metric requires the following information.

- The number of alarms that have occurred in the last 91 days.
- The number of these alarms that are critical.
- The number of operators there are per shift and the number of hour's these operators would work over that 91 day period.

Method:

For this analysis only consider low, high and emergency/urgent alarms. The survey is interested in alarms that the operators are confronted with. Journals are not presented to the operators and thus should not be considered.

The queries were conducted using DOC4000.

Configured alarms:

Area tags are split into two sections, EPKS and Refinery. Refinery results must be filtered for specific area tags then added to the EPKS results, as demonstrated in the results spreadsheet.

Area EPKS:

Type of query: Property Data

Asset: EPKS Area1

Object type: Alarm

Property Names:

Friendlyname, tag, alarmtype, tagdescription, tagtype, priority, tagalarmsenabled, almenbstate

Search Criteria:

((Priority = 'low') OR (Priority = 'high') OR (Priority = 'urgent')) AND (TagAlarmsEnabled = 'TRUE') AND (AlmEnbState = 'TRUE')

Area specific for rest of refinery

Asset: Refinery

Object type: Alarm

Property names:

Priority, unit

Search criteria:

((Unit = '32') OR (Unit = '33') OR (Unit = '34') OR (Unit = '35')) AND ((Priority = 'low') OR (Priority = 'high') OR (Priority = 'urgent'))

Alarm occurrences:

Using plant state suite, create query in the "alarm analysis" tab and run query for "priority distribution". Make the query parameters a time period from the 1st April until the 30th June. This will need to be repeated in each area (both EPKS and refinery, PowerHouse and Raw Materials)

Standing Alarms:

Use PlantState Suite to perform area queries for standing alarms over the 91 day interval. The query type is an in-built type so the query is very basic.

Peak Alarms:

For this metric only query EPKS data owners, as the LCN tags are included in the EPKS data.

Using PlantState Suite, perform area specific queries. Set the time parameters to the 91 day period and execute the "alarms per time period" in-built query. LCN based queries must be filtered for area specific facilities.

Analysers in control

Requirements:

This metric requires the following pieces of information:

- The number of analysers used in process control.
- The total number of measurement points connected to a controller.

Method:

Analysers have tags beginning with AI (see Process Control System Tag Naming Convention). Thus using DOC4000, perform the following queries.

LCN based analysers:

Type of query: Property data

Asset: ****** (Refinery/Powerhouse)

Object type: Tag
Property type: FriendlyName, UNIT, PTDESC, KEYWORD,
Search criteria: (Name Like 'AI%')

EPKS tags:

Asset: EPKS ****** (Area 1, 2, 3, 4 etc)
Object type: TPSpoint
Property names: EntityName, ItemID
Search criteria: (entityname like 'AI*')

This query method yields the number of analysers used in process control. This list will be quite large, and not all results are analysers. At this point the data collector must discuss the specific areas with the area process control engineers in order to refine the results further.

APC Service Factor
Requirements:
This metric requires the total time the advanced controllers are online (hours) during the quarter.

Method:
The APC service factor is calculated, for each controller, by averaging 1 minute snapshots of the controller status for the 91 day period.

The following table lists the controllers and their master points:

Controller	Master_ Tag
A/C Ratio	30UCACMSTR
Digestion MVC	30UCDBMSTR
CCD2	33UCC2MSTR
Spent Liquor MVC	46UCSLMSTR
Fine Seed MVC	46UCSFMSTR
Evaporator MVC	40UCEVMSTR
Calciner MVC	50UCCBMSTR
Paddle Mixer	44UCPMMSTR
Clear Filtrate MVC	45UCCFMSTR

To get to the data, use the excel spreadsheets provided on the engineering public drive. Simply open the spreadsheet named after the MVC tag you are investigating and change the dates in the top left corner to your specific time period. Following this, select the cell J3 (light blue located above the label “timestamp”), go to the uniformance tab and click “PHD data” -> “get data”. Excel will fetch the data in about a minute. The results are located at the top of the spreadsheet, and represent the values for the total period of time. Simply enter this data into the ARC metrics spreadsheet.

8.2 Personnel Metrics Excel Spread Sheet Data Sorting Macro

The following code represents the Microsoft Excel VBA Macro that was executed to sort the vast quantity of information provided by human resources into usable data.

```
Sub datafinder()


Dim Maint
Dim Contract
Dim Eltech
Dim Process

Dim M
Dim C
Dim E
Dim P

'hours count
Dim checkrow As Integer    'orgunit
Dim checkcol As Integer    'orgunit
Dim hrsrow As Integer      'hours worked
Dim hrscol As Integer      'hours worked

'personnel count
Dim checkrow2 As Integer    'orgunit
Dim checkcol2 As Integer    'orgunit
Dim namerow As Integer      'hours worked
Dim namecol As Integer      'hours worked

checkrow2 = 2
checkcol2 = 27

hrsrow2 = 2
hrscol2 = 10
```

```
checkrow = 2
checkcol = 14

hrsrow = 2  'hours onsite
hrscol = 10  'hours onsite

M = 0
C = 0
E = 0
P = 0

Contract = 0
Maint = 0
Eltech = 0
Process = 0

Do While Cells(checkrow, checkcol).Value <> "69"  'while the orgunit col has data, continue loop
  Select Case Cells(checkrow, checkcol).Value
  Case "RPAC2-B"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "RSCMP-B"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "RSACP -B"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "REMB"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "RSCMS -B"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "RSEM"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "RSACP -A"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "RSCMP -A"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "RSCMF -A"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "RPTMV"
  Maint = Maint + Cells(hrsrow, hrscol).Value
  Case "RPTM"
```

```
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCMS -C"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPTMV -Day"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSAC4 -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCMS -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPTMS -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPAC1 -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCMS -D"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCMF"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPAC"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPTMS -C"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSIP"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCMF -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPAC2 -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "Rem"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "REMU"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSAC4 -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCMG -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSAC"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "REMA"
Maint = Maint + Cells(hrsrow, hrscol).Value
```

```
Case "RSEMS -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSEMC -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCM"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPTMS -D"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSEMS -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPTMS -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPAC3 -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCMG"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPHC -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPH"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSEMB -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPAC1 -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCMG -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPAC3 -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSMS"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSEMA"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPACM -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPHS -C"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPHS -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPHS -D"
```

```
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPHC -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPHS -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSEMB -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPACM -A"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSEMC -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RSCMA"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPTMV -C"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPTMV -D"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPTMV -B"
Maint = Maint + Cells(hrsrow, hrscol).Value
Case "RPTMV -A"
Maint = Maint + Cells(hrsrow, hrscol).Value


Case "HONEY"
Contract = Contract + Cells(hrsrow, hrscol).Value
Case "I&E Systems"
Contract = Contract + Cells(hrsrow, hrscol).Value
Case "APEGC"
Contract = Contract + Cells(hrsrow, hrscol).Value
Case "RPTMC"
Contract = Contract + Cells(hrsrow, hrscol).Value


Case "REWT"
Eltech = Eltech + Cells(hrsrow, hrscol).Value
Case "RS6S"
Eltech = Eltech + Cells(hrsrow, hrscol).Value

Case "REDP"
```

```
        Process = Process + Cells(hrsrow, hrscol).Value
        Case "RERT"
        Process = Process + Cells(hrsrow, hrscol).Value

        End Select

        checkrow = checkrow + 1
        hrsrow = hrsrow + 1

    Loop

    Do While Cells(checkrow2, checkcol2).Value <> "69"  'while the orgunit col has data, continue loop
        Select Case Cells(checkrow2, checkcol2).Value
        Case "RPAC2-B"
        M = M + 1
        Case "RSCMP-B"
        M = M + 1
        Case "RSACP -B"
        M = M + 1
        Case "REMB"
        M = M + 1
        Case "RSCMS -B"
        M = M + 1
        Case "RSEM"
        M = M + 1
        Case "RSACP -A"
        M = M + 1
        Case "RSCMP -A"
        M = M + 1
        Case "RSCMF -A"
        M = M + 1
        Case "RPTMV"
        M = M + 1
        Case "RPTM"
        M = M + 1
        Case "RSCMS -C"
        M = M + 1
        Case "RPTMV -Day"
        M = M + 1
```

```
Case "RSAC4 -A"
M = M + 1
Case "RSCMS -A"
M = M + 1
Case "RPTMS -B"
M = M + 1
Case "RPAC1 -B"
M = M + 1
Case "RSCMS -D"
M = M + 1
Case "RSCMF"
M = M + 1
Case "RPAC"
M = M + 1
Case "RPTMS -C"
M = M + 1
Case "RSIP"
M = M + 1
Case "RSCMF -B"
M = M + 1
Case "RPAC2 -A"
M = M + 1
Case "Rem"
M = M + 1
Case "REMU"
M = M + 1
Case "RSAC4 -B"
M = M + 1
Case "RSCMG -B"
M = M + 1
Case "RSAC"
M = M + 1
Case "REMA"
M = M + 1
Case "RSEMS -B"
M = M + 1
Case "RSEMC -A"
M = M + 1
Case "RSCM"
```

```
M = M + 1
Case "RPTMS -D"
M = M + 1
Case "RSEMS -A"
M = M + 1
Case "RPTMS -A"
M = M + 1
Case "RPAC3 -A"
M = M + 1
Case "RSCMG"
M = M + 1
Case "RPHC -A"
M = M + 1
Case "RPH"
M = M + 1
Case "RSEMB -A"
M = M + 1
Case "RPAC1 -A"
M = M + 1
Case "RSCMG -A"
M = M + 1
Case "RPAC3 -B"
M = M + 1
Case "RSMS"
M = M + 1
Case "RSEMA"
M = M + 1
Case "RPACM -B"
M = M + 1
Case "RPHS -C"
M = M + 1
Case "RPHS -B"
M = M + 1
Case "RPHS -D"
M = M + 1
Case "RPHC -B"
M = M + 1
Case "RPHS -A"
M = M + 1
```

```
Case "RSEMB -B"
M = M + 1
Case "RPACM -A"
M = M + 1
Case "RSEMC -B"
M = M + 1
Case "RSCMA"
M = M + 1
Case "RPTMV -C"
M = M + 1
Case "RPTMV -D"
M = M + 1
Case "RPTMV -B"
M = M + 1
Case "RPTMV -A"
M = M + 1


Case "HONEY"
C = C + 1
Case "I&E Systems"
C = C + 1
Case "APEGC"
C = C + 1
Case "RPTMC"
C = C + 1


Case "REWT"
E = E + 1
Case "RS6S"
E = E + 1

Case "REDP"
P = P + 1
Case "RERT"
P = P + 1

End Select
```

```
    checkrow2 = checkrow2 + 1
Loop



Cells(11, 22) = M
Cells(12, 22) = C
Cells(13, 22) = E
Cells(14, 22) = P

Cells(14, 21) = Process
Cells(13, 21) = Eltech
Cells(11, 21) = Maint
Cells(12, 21) = Contract
End Sub
```

9. Appendix B – PlantState Suite Realtime Server Loading Study

9.1 Facility Alarm Loading Summary

Raw Materials	Facility	Current Alarms/Hr	Configured Alarms	Ratio (Alarm/Hr / Configured Alarms)	Additional E&G Tags	Additional Alarms	Total Config. Alarms (Existing + E&G)	Estimated Alarms/Hr	% Increase
Coal Storage	11/CB	0.380	36	0.011	0	0	36	0.380	0.000
Bauxite Sampling	14/RM	32.800	1025	0.032	0	0	1025	32.800	0.000
Bauxite Blending & Storage	15/ RC,ST	19.180	662	0.029	1	14	676	19.586	2.115
Coal Handling	16	1.370	82	0.017	9	126	208	3.475	153.659
E&G Facility	17	0.000	0	0.151	0	0	0	0.000	New Fac
Conveyor 1	C1	47.120	582	0.081	0	0	582	47.120	0.000
Conveyor 2	C2	8.160	322	0.025	0	0	322	8.160	0.000
Area 1									
Mill circuits	24	59.530	2491	0.024	40	560	3051	72.913	22.481
Lime slaking	25	20.510	925	0.022	14	196	1121	24.856	21.189
Desilication	26	8.410	369	0.023	110	1540	1909	43.509	417.344
Digestion	30	64.770	2403	0.027	50	700	3103	83.638	29.130
Area 2									
E&G Facility	31	0.000	0	0.151	248	3472	3472	524.272	New Fac
Flocculant mixing	32	5.900	882	0.007	9	126	1008	6.743	14.286
Clarification	33	8.650	4598	0.002	65	910	5508	10.362	19.791
Mud Filtration	34	8.850	1883	0.005	4	56	1939	9.113	2.974
Polishing Filtration	35	27.450	1397	0.020	75	1050	2447	48.082	75.161
Area 3									
Heat Interchange	40	1.560	1202	0.001	18	252	1454	1.887	20.965
Green Liquor Heat Inter.	41	2.250	125	0.018	112	1568	1693	30.474	1254.400
Evaporation	42	0.950	267	0.004	7	98	365	1.299	36.704
Precipitation	45	19.470	12779	0.002	223	3122	15901	24.227	24.431
Seed handling	46	29.150	10195	0.003	150	2100	12295	35.154	20.598
E&G Facility	47	0.000	0	0.151	317	4438	4438	671.401	New Fac
E&G Facility	48	0.000	0	0.151	51	714	714	108.017	New Fac
Area 4									
Calcination	50	69.080	6113	0.011	186	2604	8717	98.507	42.598
Alumina Loading	51	3.830	977	0.004	0	0	977	3.830	0.000
Concentrator/ Evaporator	43	109.530	724	0.151	18	252	976	147.654	34.807
Liquor Burning	44	25.500	2978	0.009	70	980	3958	33.892	32.908
PowerHouse	110	504.000	28920	0.017	6	84	29004	505.464	0.290

Table 9-1: Facility Alarm Loading Summary

9.2 Area Alarm Loading Summary

	Current Alarms per Hour Handling	Predicted Alarms per Hour Handling	% Increase
Raw Materials	179.2	186.2	3.9
Area 1	138.6	210.4	51.8
Area 2	279.0	485.5	74.0
Area 3	1427.7	2006.8	40.6
Area 4	696.6	864.5	24.1
PowerHouse	504.0	572.3	13.6

Table 9-2: Area Alarm Loading Summary

9.3 Proposed Server Loadings

	Current Alarms per Hour Handling	Predicted Alarms per Hour Handling	% Increase	Comment
Redside	417.7	695.9	66.6	Area 1 & 2
Whiteside	2124.3	2871.4	35.2	Area 3 & 4
PowerHouse	683.2	758.5	11.0	PowerHouse & Raw Mat.

Table 9-3: Proposed Server Loadings