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

The Murdoch University Internship program represents the final semester of study in the four year, eight semester, extensive double major engineering degree. Since 2001 Worsley Alumina Pty Ltd (WAPL) has engaged in Murdoch’s internship program, assisting students to fulfil their 500 hours of work experience required by both the Institute of Engineers Australia (IEAust) and the University. This program allows the students to meet this requirement in order to attain their engineering degree whilst developing their thinking and skills in an industrial environment.

The work experience program allows the Murdoch University Engineering students a chance to demonstrate their abilities gained from their study to potential employers, showcasing Murdoch’s standard of education in the process. The student is also able to gain invaluable exposure to industry which can be used as a gateway to their own professional engineering career.

Murdoch University’s Engineering program has had a strong relationship with Worsley for the past seven years with Worsley’s intake of internship students was raised from one to two in 2006 is indicative to the success of the program and internship program students. During these years the individual relationship between Worsley and Murdoch has grown to a point where 90% of the students who undertake the internship program stay on at Worsley for the graduate program. This year, 2008, the two internship students are Alex Mercader and the document author Paul Regan.

This report covers 15 of the total 20 week internship program, and includes the projects and major duties which the student was confronted with during this time. During the time at WAPL the student spent the time with of the Process Control group located in Facility 141, under the guidance Senior Process Control Engineer Angelo D’Agostino and Process Control Superintendent Arnold Oliver.

The duration of employment spans from August 2008 until December 2008, covering the University’s semester 2, 2008.
Disclaimer

All work detailed in this report is the sole 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 Senior Process Control Engineer Angelo D'Agostino, Process Control Superintendent Arnold Oliver and Process Control Engineer's Vishwesh Soni, Ben Marler and Carlos Elliott.

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

Paul Regan
November 2008
Acknowledgements

From the moment I stepped onto the site at Worsley Alumina, I felt at home. The team in the process control group were quick to dispense with awkwardness with many jokes and invitations to outings given.

Particular mention must be given to process control engineers Carlos Elliott, Soni Vishwesh and Ben Marler, all of whom are Murdoch Alumni who ensured that I settled in at lightning pace. These members of Worsley made sure I knew I was welcome at any and all outside work events as well as including me in the lunch games and conversations.

The corporate setup at Worsley was also a large factor which allowed me to make the move from Perth to living in Bunbury and working at Worsley. In terms of the corporate hierarchy at Worsley I quickly learnt the ‘big bosses’ were not the typical bosses and were approachable, easy to talk to and always keen to join in on the ‘regular’ employees, discussions, jokes and general tom-foolery. Specifically my direct bosses Angelo D’Agostino and Arnold Oliver fit this description very well.

A large recognition must be given to my academic supervisor, Graeme Cole, who also was essential in my understanding through the university course and my sanity. He had a huge effect on my time at university and without such a lecturer I would suggest insanity would be possible. His comedic attitude ensured jokes were a constant occurrence, the focus being myself on many occasions. Thankfully he can take a joke just as well as he can dish them out.

Recognition must also be given to all the lecturers throughout my Engineering Degree at Murdoch University, from the boring to exciting every lecturer played their part in getting me through this course.
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1. INTRODUCTION

Worsley Alumina is a joint venture operation between BHP Billiton, Japan Alumina Associates Pty Ltd and Sojitz Alumina Pty Ltd, with BHP as the major stakeholder at 86 per cent and Worsley Alumina the manager of the venture. Located in Western Australia, operations include a bauxite mine in Boddington and an alumina refinery in the Collie region.

There are three Worsley sites; the port, mine and refinery. They were built and commissioned between 1980 and 1984, with the first alumina production in April of 1984. Since 1984 the Worsley site has come under constant improvements. Major expansions include the May 2000 $1 billion expansion which boosted production to 3.1 million tonnes, and Worsley’s current (2008) $2.5 billion ‘Efficiency and Growth’ expansion expected to boost production to 4.6 million tonnes.

More than 1200 persons are employed at the mine site and refinery with the majority of these individuals being permanent employees. Each year Worsley allows one to two Murdoch Internship students to join the refinery team for three to six months; this year the internship students chosen were Alex Mercader and the author Paul Regan.

The students are chosen through a rigorous selection process including safety analysis, behavioural phone interview screening and then formal technical and behavioural interview. If the students are successful in gaining a contract position at WAPL they are tasked with several pre-defined projects which allow the student to meet all University and Engineers Australia set competencies, including the 500 hour work experience that is mandatory for all engineering degrees. The internship employment process is closely monitored by Murdoch in a typical unit form with a supervising lecturer who must have constant and thorough contact with the student to ensure the process runs smoothly and that work is relevant and beneficial.
1.1. Worsley Alumina Bayer Process

The Bayer Process is the process employed by WAPL to extract alumina from bauxite in a commercially efficient manner using hot caustic slurry. Worsley mines the bauxite at the Boddington mine, in the form of a reddish pebbly ore which contains about 30 percent alumina, with the 70 percent impurities are mainly made up of quartz, sulphates and reactive silica.

The Bayer Process is named after the German chemist Karl Bayer who in 1888 developed the process of using hot caustic soda to digest alumina from bauxite. The extraction process relies on a property of the bauxite that enables separation from the unwanted portion of the ore. With alumina, this property is its ability to dissolve in caustic soda solutions. The unwanted portion of the bauxite, mostly iron oxide, does not readily dissolve in caustic soda.

Worsley’s principal type of alumina contained in the bauxite has mainly three molecules of water combined with the aluminium oxide, so it is called tri-hydrated bauxite, also known as Gibbsite. Almost pure alumina, low in iron and silica, is required for the manufacture of aluminium.

Worsley’s Bayer process is broken down into four definitive areas, Areas 1 and 2 are dubbed the ‘Red-side’ and Areas 3 and 4, which are the ‘White-side’. These names come from the nature of the product in each current part of the process (colouring), as well as from the equipment and surroundings of these areas. They have, over time, turned these colours due to the product.

The following section of the reports information was obtained from the Worsley Alumina Pty Ltd Introductory Bayer Process Training Manual, 2003, which has been tailored and summarized for this report.
1.1.1. Process Overview

The Bayer Process involves the following five basic steps:

1. Dissolving alumina from crushed and ground bauxite ore using caustic liquor at high temperature and pressure to make an alumina-rich solution. When the crude bauxite is digested, sodium aluminate and silicates are formed.

2. Settling and filtering to remove the sodium aluminate, silicates, iron oxide and solid residue or red mud, leaving alumina-rich liquor, also called green liquor.

3. Seeding the sodium aluminate in caustic solution with crystalline hydrated alumina and cooling. Most of the alumina precipitates out as hydrate crystals which are washed and dried to produce almost pure alumina.

4. The Worsley refinery process extends the original Bayer Process to include the additional step of calcination, where the three molecules of water bound into the tri-hydrated alumina crystals are driven off to make the alumina product.

5. Concentrating the caustic liquor and recycling back into the basic Bayer Process.

Figure 1: The Worsley Alumina Refinery Process Flows [1]
1.1.2. Area 1

Area 1, contained in the red-side of the Worsley refinery is the first part of the Bauxite refining process. The principal function of the area is dissolving alumina out of the bauxite into a hot caustic soda solution, a process called Digestion.

Inclusive of Area 1 are eight facilities, ranging from process facilities to administration as shown in table 1.

Table 1: Area 1 Facilities

<table>
<thead>
<tr>
<th>Facility Number</th>
<th>Facility Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>024</td>
<td>Bauxite Grinding</td>
</tr>
<tr>
<td>026</td>
<td>Desilication</td>
</tr>
<tr>
<td>030</td>
<td>Digestion</td>
</tr>
<tr>
<td>106</td>
<td>Lime Unloading and Storage</td>
</tr>
<tr>
<td>107</td>
<td>Acid Unloading and Storage</td>
</tr>
<tr>
<td>025</td>
<td>Lime Slaking</td>
</tr>
<tr>
<td>311</td>
<td>Area 1 Control Room</td>
</tr>
<tr>
<td>321</td>
<td>Area 1 Office and Workshop</td>
</tr>
</tbody>
</table>

Initially Bauxite is mined at the Boddington mine, transported via a 52km conveyor belt and placed in a ‘Raw Materials’ stockpile. From this stockpile the Bauxite is reclaimed and is transported to the bauxite feed bin by further conveyor, from where it is fed into the grinding mills.

This conveyor is capable of reclaiming up to 550 tonnes per hour (tph) of bauxite ore from the feed bins and usually operates between 450 to 500 tph under typical conditions. In the rod (grinding) mill, spent liquor is mixed with the bauxite to form a slurry which is made up of approximately 46% solids. Spent liquor is the name given to the caustic solution which has been re-circulated back from the refinery process.

The rod mills grind the bauxite from ~22 mm down to ~4 mm, this slurry is then pumped to a set of Dutch State Mine screens (DSM). These screens allow material which are 1.2mm or lower to pass through the screens onto the descilicator. If the material is over 1.2mm it is re-directed to the ball mill where further spent liquor is ‘flushed over’ the material and further grinding occurs. The ball mill discharges to the DSM screens to ensure it is less than 1.2mm at the completion of the process.
The process of Desilication is utilized to neutralize the reactive silica content of the ground bauxite and caustic soda ore slurry. The silica is an unwanted contaminant in the slurry and if not treated it can cause a very hard coating which restricts the flow rate of the slurry through the tubes and heaters. The treatment is achieved by direct injection of 450 kPa steam which heats the slurry to approximately 98°C for seven to nine hours; this converts the reactive silica to an un-reactive form. The slurry is now transported to the digestion facility (030) for further processing.

Digestion is the final part of the Bayer process in Area 1, the aim of which is to heat the slurry and dissolve the contained alumina. The heating is done via flash vessels and slurry heaters. During this heating the contained alumina changes from a solid to a liquid state. A constant alumina to caustic (A/C) ratio is maintained during the dissolving process. This is done in tanks via correct proportions of slurry and spent liquor being mixed. The ratio is determined by the laboratory to achieve the highest output whilst maintaining adequate quality levels.

The new slurry is heated in the slurry heaters to 175°C and a pressure of 700 kPa. At this stage the heat and pressure assist in dissolving the alumina into the caustic soda and the chemical composition of the slurry is now given by eq. [1].

\[
\text{Equation 1: Slurry Chemical Reaction Equation [1]}
\]

\[
\begin{align*}
\text{NaOH} & + \text{Al(OH)₃} \quad \rightarrow \quad \text{Na Al (OH)₄} \\
\text{or Caustic Liquor} & + \text{Aluminum Hydrate} \quad \rightarrow \quad \text{Sodium Aluminate} \\
& \text{(in Bauxite)} \quad \text{(in solution)}
\end{align*}
\]

The slurry spends approximately twenty minutes in the digester, almost all of the alumina is dissolved and the slurry is sent to the flash vessels. The slurry is cooled in the flash vessels and exits the last vessel in the train at 107°C and is known as Digester Blow-off (DBO).

Lime slaking, which occurs in Area 1 (Facility 025), is a process which deviates from the original Bayer process. The modified process employed by Worsley is used to assist in reclaiming plant liquor back to useable caustic soda, creating Tri-calcium aluminate (TCA) and removing un-dissolved solids. The caustic soda is recollected to minimize waste and allow for re-use in dissolving the alumina. The TCA is used to assist in filtration later in the Bayer process. Finally, the undissolved solids are removed and disposed of in the Bauxite Residue Disposal Areas (BRDA’s).
1.1.3. Area 2

Area 2 is the second part of the ‘red-side’ at Worsley Alumina and is responsible for the Clarification and Filtration of the digester blow-off slurry produced in Area 1, as well as washing the residue to recover caustic.

Table 2: Area 2 Facilities [1]

<table>
<thead>
<tr>
<th>Facility Number</th>
<th>Facility Title</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Processing Facilities</strong></td>
<td></td>
</tr>
<tr>
<td>032</td>
<td>Flocculant Mixing and Storage</td>
</tr>
<tr>
<td>033</td>
<td>Clarification and Causticisation</td>
</tr>
<tr>
<td>034</td>
<td>Bauxite Residue Filtration and Sand Washing</td>
</tr>
<tr>
<td><strong>Control and Administration</strong></td>
<td></td>
</tr>
<tr>
<td>312</td>
<td>Area 2 Control Room</td>
</tr>
<tr>
<td>322</td>
<td>Area 2 Offices and Workshops</td>
</tr>
</tbody>
</table>

The first facility in Area 2 is concerned with Flocculant mixing and storage. Flocculant is a substance used as a settling agent to remove the bauxite residue from the slurry. Facility 032 is responsible for receiving, mixing and storing the flocculant powders. Two types of flocculant are used in the refinery; Liquid & Powder Synthetic Flocculant, which are mixed with the Refinery Catchment Lake (RCL) water to dilute the flocculant; the second is Natural Flocculant – Starch (Flour), which is mixed with potable water.

The second facility in Area 2 is concerned with Clarification and Causticisation. Clarification is concerned with separation of the mud and other coarse particles from the liquor, whereas Causticisation converts the sodium carbonate back to caustic soda, using slaked lime mixed with the wash liquor which overflows from the first washer.

In Facility 033, Clarification and Causticisation, Digester blow-off slurry is pumped to the settlers at approximately 105°C. Flocculant is added to the settlers to separate the bauxite residue from the alumina-enriched liquor and settle the residue to the bottom of the settlers. This residue, which is removed from the slurry, is then washed and discharged to the bauxite residue disposal areas (BRDA’s) commonly known as the ‘mud lakes’.
The overflow from the settling tanks is alumina-enriched liquor, which has been clarified of all but the very fine solids. It is discharged into the continuously-agitated overflow tanks, before being pumped to the Polishing Filters in Facility 035, where the fine solids are removed. As the solids to be filtered-out are very fine, they can blind or block-off the filter cloths quickly.

The underflow from the settling tanks, called mud, is pumped to the continuously-agitated cyclone feed tank. The slurry from the cyclone feed tanks is pumped to the inlets of the hydrocyclones.

The hydrocyclones separate the coarse sand particles from the slurry by centrifugal force. The underflow, or slurry, containing coarse sand particles is pumped to the sand classifiers in Facility 034. The hydrocyclones overflow, containing liquor and fine mud particles, discharges to the first in a series of four washers, in each of two washer trains. The mud is washed by a dilute stream of filtrate from the downstream tank overflow, in a process known as a Counter-current Decantation circuit, or CCD circuit. A CCD circuit moves the mud in one direction down the train towards the filters, while the wash liquor moves counter-current up the train towards the settlers.

The third facility in area two is Facility 034, Classification. This facility is used to retrieve caustic soda using multi-stage sand spiral classifiers. The sand is washed two or three times, depending on the number of classifiers in the set. The resultant then falls through a discharge chute to the red mud relay tank. The mud from this tank is discharged to the Bauxite Residue Disposal Areas (BRDA’s).

Facility 035 provides the final part of the Bayer Process in area 2, Filtration. Filtration occurs through the separation of the fine bauxite residue from the alumina hydrate, which is dissolved in the caustic liquor. The filters polish, or remove, the minute particles of mud from the liquor before it is discharged to Area 3, for further processing into alumina.

Tri-Calcium Aluminate (TCA) is added to the settler overflow liquor being pumped to the polishing filters. TCA acts as a prefilter by holding the very fine solids off the face of the cloths, thereby allowing improved filtration by preventing the solids from blinding or clogging the filter cloths.
1.1.4. Area 3

The main objective of Area 3 is to produce aluminium hydrate crystals. This is achieved via the precipitation process. Precipitation occurs when the alumina-rich caustic soda solution is cooled, concentrated and seeded with small, clean hydrate crystals. Collecting and cleaning the seed crystals is also a function of Area 3.

The facilities which are included in area 3 are listed below in Table 3.

Table 3: Area 3 Facilities [1]

<table>
<thead>
<tr>
<th>Facility Number</th>
<th>Facility Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>035</td>
<td>Clear Filtrate Pumps</td>
</tr>
<tr>
<td>040</td>
<td>Spent Liquor Evaporation</td>
</tr>
<tr>
<td>041</td>
<td>Green Liquor Heat Interchange</td>
</tr>
<tr>
<td>042</td>
<td>Process Trim Evaporation</td>
</tr>
<tr>
<td>045</td>
<td>Precipitation and Heat Interchange (Flash Cooling)</td>
</tr>
<tr>
<td>046</td>
<td>Seed Separation, Filtration and Hydrate Classification</td>
</tr>
<tr>
<td>180</td>
<td>Water Treatment and Storage Plant</td>
</tr>
<tr>
<td>313</td>
<td>Area 3 Control Room</td>
</tr>
<tr>
<td>323</td>
<td>Area 3 Office and Workshop</td>
</tr>
</tbody>
</table>

Agglomeration is the first process step in Facility 045. Agglomeration involves mixing Clean Seed, from Facility 046, with the saturated ‘green liquor’ from Facility 041 and allowing sufficient residence time for individual particles to group or ‘cement’ together. The presence of aluminium hydrate crystals acts as a catalyst, drawing dissolved hydrate out of the solution to deposit onto the seed and cement together groups of small crystals. This is the start of the Precipitation process.

The next two stages in the precipitation process take place in the Intermediate and Final precipitators. The alumina hydrate crystallises and settles to the bottom of the precipitator tanks. The liquor overflows from one tank to the next in continuous rows and eventually flows into the thickeners in Facility 046.

Agglomeration, Intermediate and Final stages of precipitation, in all trains, is preceded by a Flash Cooling (HID) operation in which heat is transferred by the flash vapour to another stream.
Facility 041 – Heat Interchange contains the first of these HID operations. Facility 045 is the location where the second and third HID operations occur, where water vapour is flashed from the slurry and condensed by process cooling water.

During the process of precipitation sodium aluminate drops out of the liquor solution, producing aluminum hydrate. The chemical formula for this reaction is given below in Equation 2.

\[
\text{Equation 2: Precipitation Chemical Reaction [1]} \\
\text{Na}_2\text{Al(OH)}_4 \rightarrow \text{NaOH} + \text{Al(OH)}_3 \\
\text{or \quad Sodium Aluminate \rightarrow Caustic Liquor + Aluminum Hydrate (in solution)}
\]

The main use of Facility 046 is to handle seed filtration, thickening and hydrate classification. Seed thickening is the first operation that is provided, and takes place in five large tanks. The first two thickeners are fed by the overflow from the seed cyclones and are known as the ‘fine’ seed thickeners. The second two thickeners are fed from the final overflow from the train 1 and 2 precipitators. The final tank is kept out of use, in reserve, for when maintenance and cleaning is needed on the other tanks. Inside the thickeners, the seed settles and the coarse seed underflow is pumped to hydrate classification.

The last process in area 3, hydrate classification, which occurs inside facility 046, makes use of a number of product cyclones that separate the hydrate slurry supplied to it from trains 1, 2 and 3. The underflow from these product cyclones is then sent to be filtered before entering the Calciners in Area 4.
1.1.5. Area 4

Area 4 is the final area and the second part of the ‘white side’ at the Worsley refinery. The main purpose of Area 4 is to put the ‘final touches’ on the hydrate before shipping it around the world. This occurs by first drying the hydrate and then calcining the product to remove the remaining chemically bound water. The facilities where all area 4 activities occur are listed below in Table 4.

Table 4: Area 4 Facilities [1]

<table>
<thead>
<tr>
<th>Facility Number</th>
<th>Facility Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>043</td>
<td>Liquor Purification and Oxalate Degradation</td>
</tr>
<tr>
<td>044</td>
<td>Liquor Burning Plant</td>
</tr>
<tr>
<td>050</td>
<td>Hydrate Filtration and Classification</td>
</tr>
<tr>
<td>051</td>
<td>Alumina Storage and Shipping</td>
</tr>
</tbody>
</table>

Before the drying and calcining process can take place the hydrate must be filtered out of the remaining liquor. This filtration occurs in Facility 050, in the pan filter system. The filtering system is tasked at lowering the moisture levels in the hydrate to approximately 8%. This is achieved by first using suction to remove the liquor and then passing the resultant through two stages of filtration. At the end of this process the hydrate is sent by conveyor to the calciners feed bin.

Calcining is where the hydrate is heated to approximately 900°C. This process removes the chemically bound water. This heating ‘frees’ the chemically bound water leaving behind the desired product of the Bayer process, alumina (Al₂O₃) as shown below in Equation 3.

Equation 3: Hydrate Chemical Reaction [1]

\[
2\text{Al(OH)}_3 + \text{Heat (900°C)} = \text{Al}_2\text{O}_3 + 3\text{H}_2\text{O}
\]

Before calcining occurs the hydrate is first dried in a three stage drying process via two venturi driers and a cyclone. The first of the drying stages is accomplished by varying both the pressure and temperature by adding hot waste gas. At the end of this first stage the hydrate leaves the venturi drier at approximately 170°C.
The second stage of hydrate drying is completed via a second venturi drier which makes use of hot waste gas collected from the hottest part of the Calciner. This helps to crystallise the hydrate, which occurs at 900°C, and in turn drives the water off. The reaction is endothermic in nature and loses approximately 100°C during this crystallisation process.

The final stage of the drying process is the removal of the left over waste gases via a cyclone. The product leaves the stage two venturi heater and enters this cyclone then passes the gas into the Fluid Bed Calciner (FBC).

The FBC works by burning natural gas to fluidise the alumina. This is the final stage in the process and upon completion the alumina has approximately 1% organic material by content whilst having also been cooled to a suitably transportable level.

The alumina is then sent to either the short term shipping silo or long term storage silo. The former of the two silos is used as a pre-transport stop-over for alumina. This alumina is then loaded onto a train which takes the alumina to the Bunbury port, ready for export.
2. **Alarm Rationalisation Project**

2.1. **Introduction to Project**

Alarm documentation and rationalisation is a regular occurrence for the Process Control (PC) group in Facility 141. A senior control room operator (SCRO) is an essential position in the refinery, being the first line of defence during a problem as well as dealing with day-to-day process changes required to keep the refinery at maximum possible efficiency. The PC group can be seen to have a client-contractor relationship with the CROs; work required is requested by the CROs which is then completed and maintained by the Process Control group.

Whilst Process Control at Worsley assists the operators in any way they can in terms of troubleshooting and issues, continuous improvement is also a high priority. The more efficient the operators are, the more time they have to deal with the real issues at hand, and in a crisis, the less that distracts them. Alarm documentation and rationalisation is a key element in this efficiency.

Alarm rationalisation from the perspective of a CROs aims to:

- Minimize the alarms they see by removing un-necessary annunciations,
- Have all relevant alarms available on the relevant human-machine interface (HMI) screen to allow them to pinpoint the source of the problem promptly
- Suitably set the priorities of alarms such that the most important issue can be located immediately and dealt with swiftly
- Keep the HMI screens functional and logical to allow the operators to find their way to the issue with ease and speed.

The internship alarm documentation and rationalisation project was supervised by Process Control Engineers Carlos Elliott and Vishwesh Soni. The project addresses all of the above four aims relative to the alarm groups reviewed.

Over time, when changes to the process occur, includes changes to instrumentation, technology or control. After these changes occur, the alarm rationalisation may require revision. One of many reasons for this revision is that the alarms which made sense five years ago may need to be completely changed to meet the current process. This section of the document will detail the project work which dealt with various alarm groups recommended by operators for re-rationalisation.
2.2. The History and Nature of the Alarm Problem

As is the case with all technology it is constantly evolving, constant improvements and upgrades occur as the generations pass. In the case of alarm management, control rooms were originally filled with immense numbers of lights, buzzers and moving-pen charts. This design was well thought out, the process status could be determined at a glance, the trends provided as long a history as a reel of printer paper, and the buzzers alerted operators to every alarm which became active. There lies the first part of the alarm problem: the operators were alerted to “every alarm”, which could be hundreds or thousands of alarms a day. If it took a minute to acknowledge or deal with each alarm, operators were already busy workers. The hardware based panel alarms also came at a large cost and were hence limited in number.

With the digital age came the era of Personal Computers (PCs) and the introduction of the Distributed Control System (DCS). Thus, slowly but surely, the control walls filled with alarm ‘light-boxes’ and trend printers have slowly been converted to this new technology. The conversion occurred as DCS systems are simply more powerful, more beneficial in both a business and a process control sense and allow for ‘free’ implementation and configuration of new alarms. This software is configurable at little or no hardware cost which also then leads to another problem; the over configuration of alarms.

With the new technology came the ability to show more alarms to the operator. The business saw alarms as free, so in many cases the ‘why not’ approach was taken, allowing the operators to see hundreds to thousands of alarms at once! The second part of the alarm problem had arisen. Operators could now see all the alarms, but would most likely see too many activating simultaneously, with not enough time to acknowledge or deal with them all.

During the digital age, PCs were not the only thing making headway in the technology stakes, as instrumentation had also undergone many upgrades. With the introduction of smart instrumentation many more alarms and alarming capabilities arose.
The original ‘the switch has tripped’ alarm became ‘the switch has reached its low point, its low low point...’ and so on; the number of configurable alarms had substantially increased. This increase in alarms amplified the effect of the first alarm problem, as thousands of alarms a day became tens of thousands, and the operator’s day was now a hectic, if not impossible activity.

Incidents occurred frequently before the 1990’s and during the early 1990s but during this time the alarm problem was not identified nor written about. During this period there were also some major industrial accidents that occurred. Many of these major accidents listed the alarm systems as key contributing factors in these incidents. At this stage, in the mid to late 1990’s, companies collaborated together to begin to research the “Alarm Management Problem”.

Now that the problem had been acknowledged by management and sufficiently documented by experts, the industry came to realize that the accidents were only a part of the issue. When the alarm problems were investigated further the companies discovered that nearly all process upsets were made worse or not dealt with in the proper manner due to the ineffectiveness of the alarm system.

With the clear requirement to revamp the alarm system, proper alarm management was put into motion. Spreadsheets and overhead projections quickly evolved into dedicated software specifically designed for the task and so the dynamic alarm management software revolution had begun.

During the analysis of the alarm management systems, it was quickly discovered that although DCS systems brought with them increased useability they allowed for easier modification. Early DCS systems allowed for on-the-fly alarm configurations by everyone from engineers to maintenance. This resulted in a huge problem; people were changing trip-points, alarm priorities or even disabling alarms without documenting or informing anyone.

This was the final alarm problem that contributed to making alarm systems extremely ineffective, overloaded and more of a hindrance to operators than an effective tool.
2.3. Alarm Rationalisation and Management Theory

Alarm management is the process of improving the ergonomics of the system, not only through the user interface, system performance and operator competency but through useful alarm mitigation. Alarm management is no longer about being able to have every instrument alarmed, and displaying all alarms, but rather to alarm only abnormal process situations and effectively communicate the situation to the operator.

Entire books, or even series of books, have been written on alarm rationalisation and management. The purpose of this section of the document is to touch on the key points and theories surrounding alarm documentation and rationalisation that is relevant to Worsley Alumina. As such, the 'control wall' alarm systems will not be discussed and the document will focus on DCS alarm management systems.

As discussed in section 2.2, The History and Nature of the Alarm Problem, there are three main problems which are common to alarm systems they are:

1. Alarm Flooding – Excessive numbers of alarms occurring at one time.
3. Alarm Configuration – Wrongly set trip points and access levels.

It should be noted that since the points all intertwine in some way many organisations group them into the single ‘alarm problem’. This document however has chosen to separate them to aid readability.

Worsley Alumina has implemented its alarm management through the Human Factors Engineering (HFE) past project, as well as continuous improvement via the Advanced Process Management (APM) project, which has been ongoing for many years. These projects began with a world leading operator control room, new control/indicator/alarm graphics and an initial alarm management process. Since then, it has involved constant alarm rationalisation activities which are used to further improve the alarm system. As such, much of Worsley’s alarm management is already in place and performs at a high standard. These in place high standards at Worsley, will be detailed throughout this document.
In dealing with the three alarm problem categories there are five items which need to be addressed:

- What should be alarmed?
- DCS Alarm Display Capabilities
- Rationalisation Grids
- Alarm Handling
- Alarm Reporting

During the alarm rationalisation process, not only was the alarm system optimised to allow for easier operator useability, but this also helped to lower process upsets. The rationalisation process helps to limit the upsets and deviations from normal operation conditions. This can be directly linked to increases in profit. Thus the reasoning for alarm rationalisation can be easily made from a safety or business perspective.

2.3.1. What should be alarmed?

This section is based around alarm mitigation and the key question ‘Does the event require operator action?’ At this stage the definition of a process alarm can be stated as:

“A process alarm is a mechanism for informing an operator of an abnormal process condition for which an operator action is required. The operator is alerted in order to prevent or mitigate process upsets and disturbances”

These two basic statements are the essence of a good alarm system. Only configured alarms are ones which require operator action. Other information that needs to be conveyed to the operator should be done through various other systems.

Another critical entity in this part of the rationalization process is the question ‘is the alarm the best indicator for the situations root cause?’ This refers to the doubling up of alarms instead of a single occurrence.
The last significant question which needs to be asked when rationalizing alarms is ‘is this alarm truly resulting from an abnormal situation?’ This is the final question that should be asked when diagnosing what to alarm: The basic theory is that no routine process changes should activate alarms.

If this system is employed it should eliminate many of the configured alarms that are not useful. This is the first step in dealing with alarm problems.

2.3.2. DCS Alarm Display Capabilities

Every modern DCS comes equipped with an alarm display page, usually a simple graphic menu filled with every alarm on a scroll down page setup. Different DCS manufacturers release their software with various capabilities. There are a few main elements that a DCS alarm display should included in order to be effective:

- Priority systems that allow independent priorities per alarm
- Alarm summaries that update the alarm list or measurement values
- Ability to temporarily suppress the low priority alarm horn
- Navigation ability to go, in one click, from an alarm on the display to the proper graphic for diagnosing the relevant situation
- Temporary alarm scroll freeze to aid readability during alarm floods

All these points are centered on optimizing the operator’s response to a process disturbance by sorting the alarms in order of criticality, making it obvious which alarms need to be dealt with first and allowing the operator to make the required change in the shortest possible time.

Worsley, as previously mentioned, has recently upgraded its central control room with a multi-million dollar development project which addressed all of the above points. Worsley developed custom graphics for all the alarm display screens to a world leading level allowing for a user friendly display. The process of this upgrade is outside of the scope of this document and thus will not be discussed.
2.3.3. **Rationalisation Grids**

In order to maintain a standard across alarm rationalisation, three rationalisation grids should be prepared before commencing the process. The first and arguably most important of the three, as defined by the PAS handbook, [1] is the ‘Areas of Impact and Severity of Consequences Grid’ as seen in Appendix B.

The grid is simple to use by considering the question ‘if the operator takes no action how severe are the consequences?’ All answers to this question should also be the worst case scenario. This question should be posed to each and every alarm-able DCS point as well as any other system which provides alarms or notifications to the operator.

The second grid which should be developed when dealing with an alarm rationalisation process is the ‘Maximum Time Available for Response and Correction’. This grid also adopts a simple configuration based around the question ‘what is the maximum time within which the operators can take actions(s) to prevent or mitigate the undesired consequences(s) caused by an abnormal condition [1]. This time must take into account the response time and action of outside personnel following direction from the console operator. This grid can be seen in Appendix B.

The third, and final, grid utilizes the results of the first two grids and determines the correct priority for the alarm. This grid can be found and viewed in Appendix B. Many computerized alarm rationalisation software packages exist that will automatically create the three grids and with minimal input determine the required alarm priority level.

[1]
2.3.4. **Alarm Handling**

Alarm handling is the topic which defines how the operators should be dealing with certain alarms, best practises and prioritization. This topic has books dedicated to it and as such this document will choose to focus only on alarm issues which relate to alarm rationalisation such as: alarm based suppression/shelving, state-based alarming, flood suppression, enforcement of alarm settings and operator alert systems.

2.3.4.1. **Alarm suppression / shelving**

Alarm suppression is the setting on an alarm which disables the alarm signal. The setting, although dangerous if not monitored, is extremely helpful in large process upsets or in the event of known equipment outages, if dynamic suppression is not employed.

The setting is used to stop the alarm annunciating in order to remove nuisance alarms such as chattering or broken sensors. This setting is very useful for the operators but if not correctly controlled and monitored, it can mask upsets when alarms are forgotten about. As such, alarm suppression should always establish a reminder feature to alert the operator to suppressed alarms, or if not acknowledged re-enable the alarms automatically. This temporary suppression setting is known as alarm shelving.

In the process of alarm rationalization all alarms which are being suppressed regularly should be reviewed and where possible dynamic suppression should be implemented. Dynamic suppression represents the automated process of suppression where the system looks for certain process occurrences, such as a sensor sending constant ‘bad/error values’, and shelves the alarm without the need of an operator action. Dynamic suppression is a very complex process and should not be implemented lightly; improper suppression can cause major upsets if the operator is not aware it is occurring.

[1]
2.3.4.2. **State-based alarming**

State-based alarming is the alarm principle which takes into account the alarm state before alerting the operator. Alarm-able equipment usually has multiple states such as: ‘ON’, ‘OFF’, ‘STARTUP’, etc. The alarm configuration when the equipment has been set to one state as opposed to another can be different. As previously discussed, an alarm should only occur during an abnormal situation. If the operator has chosen to switch the equipment off it should not be alarming ‘equipment off’ as this is a normal operating condition in this state.

As was the case with dynamic alarm suppression, state-based alarming should be implemented with caution, and complex state detection logic (SDT) should be employed to avoid process upsets.

2.3.4.3. **Flood Suppression**

Alarm floods, as previously discussed, are major problems in alarm systems. They can cause a process upset to become much more of a nuisance then it has to be for the operators. In the event of a major process disturbance the handling of flood suppressions can be the difference between the operator being able to deal with it effectively or not.

Flood suppression is best designed using robust equipment state detector logic as well as triggering events. This, if well designed, will allow the system to suitably suppress the non-critical alarms whilst enabling the logic to group alarms and only display the root cause of the upset.

2.3.4.4. **Enforcement of Alarm Settings**

The enforcement of alarm settings is an integral part of any alarming system. It is the part of the system which houses all records of alarm configurations and ensures that they are imposed upon the system. This is a way of ensuring that any changes which are not properly documented and passed through change management processes will not cause unwanted upsets.

This is a fairly simple fix to the third alarm problem, so long as the database is kept up-to-date and used to update all alarm configurations at a chosen refresh rate (daily / weekly / monthly). It is also a very easy process to track with the ability to compare spreadsheets / databases and determine how many alarms have been changed, when and by whom, thereby allowing management to chase up why it was changed before over-writing.
2.3.4.5. **Operator Alert Systems**

This last part of alarm handling is used to take some pressure off alarm notifications. Operator alert systems should be setup in a completely different manner to the alarm system, so that the operator could never confuse the two.

An operator alert system is an alert system which is used to notify the operator of certain occurrences. It should never require the operator’s input in less than 30 minutes and is reserved for reminders of shelved alarms or to do certain actions. This system allows the operator to use their own reminders without having to deal with the alarm system as well as be reminded that certain actions are occurring without distracting them from the alarms at hand.

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2.3.5. **Alarm Reporting**

Alarm reporting is a key component in alarm rationalisation. If the alarms are not monitored then reported performance cannot be accurately determined or improved. Most modern DCS alarm systems come with reporting functionalities. These functionalities should be constantly monitored by a suitable delegate who must monitor:

- **Average Process Alarm Rates**
  1. Percentage of time the alarm rate exceeds the Target rate
  2. Number of suppressed alarms
  3. Percentage of alarm priority activation
     (Low, High, Emergency, Critical)
  4. Chattering Alarms (constantly activating and de-activating)
  5. Stale Alarms (more than 24 hours old)
  6. Alarm Flood rates
  7. Changes to alarm configurations

With these key performance indicators (KPI) monitored, the delegate can determine certain system targets such as goal alarm rates.
2.4. Alarm Rationalisation Process

The process of alarm rationalisation is a slow and tedious one requiring at a minimum the co-ordination of both the area operator and area engineer. The process has three phases, beginning with operator discussions. The next step of this process is rebuilding of the HMI page as required and finally changing the alarm priorities and checking for correct implementation.

2.4.1. Operator Discussions

Operator discussion is the first part of the alarm rationalisation process and is where the decisions about possible alarm changes as well as alarm prioritisation are scoped. Worsley’s standard states that included in the operator discussions should be the process control engineer and process engineer. These people must be present in all following meetings.

This activity begins with the area engineer scheduling a meeting between them and the area operator to discuss the page/s to be re-rationalised. If there is an exceedingly complex process or control scheme active on the page then another engineer with knowledge of this process may also be invited to be present. In the case of the HMI pages rationalised during this project, the internship student was also present in these meetings.

The meetings take the list which is to be re-rationalised and individually discuss each alarm on the page as well as any alarms that may be relevant to the page that may need to be included or excluded. An average alarm page can have 100+ associated alarms, as shown in Appendix B for the rod and ball mill circuits 4 interlock alarm HMI page. Each one of the white squares on this page is an alarm with a possible four priority levels; Journal, Low, High and Urgent, from relatively lowest to highest. Thus each one of these alarms must be looked at and a priority chosen through discussions between the engineer and the CRO.

The process for each alarm is first to point out its location on the page to the CRO to see if he instantly recognises what it is or what priority it should be. If instant recognition of priority fails, the next step is to determine what alarm it is and what is its importance.
The CRO and the engineer will then discuss its current priority. This discussion involves deciding if the alarm priority requires change or to be left as is. The result is normally then marked on a printout of the HMI page for use during the priority change section of the process.

The last component of operator discussions involves considerations over other relevant alarms that should be included on the HMI page. This is a fairly simple process involving a list of alarms relative to the page that are not currently included. The main reasons why some alarms are not included is they are to be no-action alarms and thus have no bearing on the operators work or they are represented better by another alarm. There is no need for a general alarm which shows there is an alarm active for a piece of equipment, when displaying all the higher level alarms detailing what the alarm is specifically for. The general alarm is redundant in this case.

2.4.2. Re-building the HMI page

In general, when a HMI screen is reviewed and this alarm annunciation re-rationalised, there is normally a few alarms that could be added/removed or the page may be re-designed to be more aesthetically pleasing and easier to follow. This is often the case at Worsley due to the fact that the Experion based HMI graphics have only been in place for a few years and thus are only being reviewed for the first time in most cases.

For the rationalisation pages reviewed by the internship student, the re-building was minimal with only a few functional changes possible. During the rationalisation process there was however a varying number of alarm points which could be added, with a top of 30 alarms added to one of the HMI pages.

In order to add / change these HMI pages, the page must be edited using HMIWeb Display Builder [6] which is the Honeywell Experion [6] building tool. Before the building tool could be understood, a basic understanding of Experion itself was necessary.
2.4.2.1. **Honeywell Experion**

Experion, also known as Experion® Process Knowledge System (PKS) [6] is a Distributed Control System (DCS) which goes well beyond any other conventional DCS setup.

In a simplistic view Experion acts as the control system for the whole refinery. The HMI pages contain alarm notifications, process / instrument indicators and controls in a functionality based format. The Worsley Experion HMI pages have four levels of complexity, the higher the level the more detail and specific the alarms and controls / indicators. The operators are able to navigate through the levels in a web browser type format with a simple one click to follow through to the higher level page.

Worsley uses custom graphics and displays for the HMI pages to get the most functionally suitable objects for each control / indicator / alarm. The graphics were also developed with operator ergonomics in mind.

Worsley, during the development of these pages, created many standards that were adhered to during the development and that will be used in the future. With these standards, all are thoroughly documented and were reviewed by the intern student, after this review, the rebuilding process could begin using the Experion page builder, HMIWeb Display Builder [6]. An example of a page recently re-built in the Experion system can be seen at Appendix B for the rod and ball mill circuit’s 3 interlock alarm HMI page.
2.4.2.2. **Experion HMIWeb Display Builder [6]**

The Experion HMIWeb Display Builder is an easy to use, website builder style program with a comprehensive interface which allows fast and trouble-free page building. A view of this builder can be seen in Appendix E.

The adding and removing of controls / indicators is a fairly straightforward process. Worsley's custom graphics play a big role in the ease of this inclusion or deletion as they have been incorporated in such a way that it's a matter of choosing what type of control or indicator you wish and clicking add. Once the graphic has been added it is a simple matter of linking it to the tag-point by adjusting the properties appropriately.

When a page has been built to the desired specifications it is checked by the area engineer relative to the original page and then loaded into the live system's cache to allow for quick loading and accessing.

2.4.3. **Altering Alarm Priorities**

The last process of the alarm rationalisation process is altering the alarm priorities through the use of the DCS utility program Alarm Configuration Studio. This program is able to edit almost all of the DCS configuration parameters from tag-point building to system configuration.

The priority changing process is a simple one. Once the ‘build points’ option is selected in configuration studio, a list of the tags can be seen. The alarm tag can then be selected from the list of all tags at Worsley. Inside the tag options there is a drop-down style menu which allows for changing priority. Once complete, the change can be downloaded into the system.

2.5. **Conclusions & Future Work**

The rationalisation process was completed in a timely fashion and to a high standard of work. Currently the pages are being monitored on a weekly basis for alarms per day as well as control changes per day as to gauge the effect of the rationalisation.

The operators have verbally expressed their approval of the newly built pages and have specifically mentioned that the alarm additions which occurred have been useful in recent outages in diagnosing the problems.
3. **DEV System Simulation**

3.1. **Worsley Local Control Network**

Worsley Alumina employs various different networks throughout its refinery in order to securely enable all employees from human resources to engineering to complete their computing needs. The general IT network is dubbed the ‘APAC’ network which stands for Asia Pacific.

Process control operates on a separate more secure network named the ‘PCN’, which stands for Process Control Network. The process control network is connected via firewall to the control operations which operate on a Fault Tolerant Ethernet (FTE) network.

The FTE network is the network which handles all process control operations from pump status to advanced control techniques. The network is a cat-5 Ethernet network which employs the latest redundant fault tolerant Ethernet setup to ensure that if any part of the network goes down the network is able to continue in normal operation. Connected to the FTE network are the HPM, ACE, C200 and PLC controllers. All of these controllers are setup in a redundant-pair configuration, so that if a primary controller was to fail at any time then a back-up controller takes its place to ensure normal operation is continued.

There is a second FTE network called the FTE-DEV, which stands for Fault Tolerant Ethernet Development network. This is a separate newer network to the APAC, PCN and FTE networks and has been developed to allow testing and development of control or process techniques without using the live FTE network. The FTE-DEV has its own HPM, ACE, C200 and PLC controllers connected to it. It is also connected via firewall to the APAC and PCN networks to allow remote use of the DEV network.
3.2. Worsley Controllers

As mentioned the various networks in the Worsley system make use of numerous controllers. Of particular interest to the DEV project and to the intern during his placement were the HPM, C200, ACE and PLC controllers.

3.2.1. C200 Controller

The C200 controllers are the preferred controller for Worsley’s Experion system and handle the latest I/O, inputs and outputs, scaling points, advanced logic and control schemes. The C200 controller is set to replace the HPM and PLC controllers at Worsley.

3.2.2. HPM Controller

The HPM controller is an older style controller used for the same objectives as the C200 controller and is slowly being phased out in favour of the new system. Thus the HPM is capable of reading and outputting to I/O, scaling of logic and also in developing and maintaining control schemes.

3.2.3. ACE Controller

The Application Control Environment (ACE), controller is similar in operation to the C200 except it has no physical I/O. It is capable of handling control schemes, scaling of points and advanced logic.

3.2.4. PLC Controller

Programmable logic controllers (PLCs) are another controller that can handle I/O; it is currently being phased out at Worsley in preference for the C200 controller. These controllers can handle advanced logic and currently incorporate operations from scaling to advanced control at Worsley.
3.3. Proposed Project

The DEV System Simulation project was developed to satisfy the need for a simulator for applications testing. The applications that this project focuses on are mainly the PLC logic, ACE control schemes and other HPM utilized applications. The project’s timeline can be split into three definitive components; the initial proposal, the final project proposal and the project development and implementation. The initial proposed project scoped the design of a hardware I/O setup that would be connected to the DEV server and allows users to simulate certain inputs and outputs for their application, and allows users to do initial testing before moving the application to the live system.

The project specification at this stage was very open with the proposal allowing for the size, complexity and duration of the project to be established by the intern student. As such the intern defined two options: hardware based and software based systems. Each of these options has three possible levels of complexity that the project could follow. The levels of complexity were intended to give management a choice of how far to take the project, with the lowest level being achievable in a short time to the highest level being hard to achieve and most likely time-consuming. These three options and complexity levels were then presented to management and the project’s supervising engineer.

Initial discussions with the systems engineer, Magnus Nilsson, who originally proposed the project, yielded ideas of a hardware-based I/O ‘mimic panel’. This idea resulted in the first project option, the ‘Hardware concept’.
3.4. Hardware Concept

The 'mimic panel' design, as shown in Figure 2, is one that has been tried and tested through years of process control simulation. It is simple, easy to use and effective.

![Figure 2: DEV I/O Hardware Mimic Panel](image)

Three levels of complexity were designed in order to satisfy the supervising engineers original design ideas. Along with a simple graphical representation of each complexity level, a list of pros and cons was also drawn up in order to give management the most information possible.

3.4.1. Level 1- Lowest Level of Hardware Complexity

The first and lowest level of complexity showcases the tried and tested mimic panel that has existed for years in process control simulation. This complexity level is graphically shown in Figure 2 and includes a set number of inputs and outputs, both digital and analogue. An application status light configuration is also a key entity for simulations testing as it enables the tester to view if the application has crashed or is stuck in an endless logic loop.

Implementation of this level of complexity is simplistic as the setup would consist of readily available instrumentation such as input switches, potentiometers, digital lights and analogue meters. This setup would sufficiently allow the application tester to simulate digital and analogue inputs whilst viewing the relative outputs on a conveniently located panel.

This level of simplicity has numerous pros and cons as listed in the table located in Appendix C.
As is expected of the lowest level of complexity, this mimic panel will achieve the objective of simulations testing but falls down in many areas. One critical problem with this design is it is very outdated. With this style of hardware I/O simulators is being widely replaced by software simulators in the control industry.

There are still a few applications which exist; such as a fail safe control (FSC) system which requires this type of hardware based simulator. But in most cases they are an obsolete technology when compared to software simulators.

With these points in mind and the freedom to attempt to revamp a dying technology the choice was to finish the three levels of complexity as proposed. The complexity levels would take the old technology as a base and revitalise it with fresh injections of modern innovation.
3.4.2. Level 2 - Medium Level of Hardware Complexity

The first injection of modern technology to the mimic panel comes from the implementation of LCD screens. The constantly increasing level of application feedback allows both PLC logic and other control applications to output everything from error numbers and fault descriptions to descriptive labels.

At this level of complexity the project would take inputs, outputs and statuses from the PLC and replace the permanent numbering labels with LCD screens. This alteration would allow for dynamically changing labels relative to the particular application. An LCD screen would also be installed allowing for the applications tester to view if the application/logic has failed and more importantly where / how it failed.

This hardware increase would require various improvements to the communications from server to panel before it could be utilized. A protocol converter that allows correct output of error codes / label indicators is just one element that would have to be investigated if this was the chosen complexity level.

Brief research into the C200 / HPM and Modicon PLC’s has yielded that all do have the ability to output these errors / indicators as long as they are mated with the correct scaling software and protocol converters. Two design options and table of pros and cons for this level of hardware complexity can be found in Appendix C.

3.4.3. Level 3 - Highest Level of Hardware Complexity

As the last step up in terms of hardware based I/O ‘mimic panels’ the final level of complexity aims to move as far away from the traditional hardware based I/O simulation panels as possible.

Advancements in PLCs over the last decade have come in leaps and bounds; from a simple logic controller to a physically small, advanced controller capable of controlling almost any instrument or other I/O.

Figure 4: OCS “X” Series PLC [8]
Figure 4 represents the latest instalment of Horner operator control stations or OCS’s, which are PLCs that maintain the usual I/O and networking capabilities associated with other PLCs but combine them with touch screen functions. This results in a PLC which can be used in the field as a local instrument control whilst having a aesthetically pleasing HMI for quick control modifications. These PLCs are the basis for the highest level of complexity.

With the simple to configure HMI screens and advanced I/O abilities, the compact and relatively cheap PLCs represent the best choice for a technologically advanced ‘mimic panel’.

The use of these complex PLCs would not only fulfil all requirements of the ‘mimic panel’ but it would also allow for advanced logic to be implemented in the PLC itself. I.e. Rather than straight inputs activate output, logic such as time-delays, ramping and randomising could easily be implemented for testing purposes.

Figure 5: OCS "X" Series PLC [8]

Figure 4 and Figure 5 above are two examples of these PLCs, Table 10 is a list developed in order to give management an idea of the Pros and Cons of such an implementation.

3.5. Software Concept

Research into the final level of hardware and the OCS’s HMI development generated the theory behind software based I/O simulation; ‘why when the programming is done at a desktop can’t the simulation be based there, why not save the technician having to move from his desk.’

As described in the hardware concept section there are still safety and other systems that require hardware based testing in order to confirm the software is not unduly changing the outcome. In the case of Worsley’s HPM, ACE, C200 and PLC systems, this is not the case and after very brief discussions with Magnus the software concept was given the ok to be scoped for the management proposal.
3.5.1. Level 1 – Lowest level of Software Complexity

The first level of software complexity could easily be renamed the ‘combination’ level. Its simplified specifications entail a software package or set of logic which allows the chosen hardware specification to work as designed.

As such this level of software, technically, has three sub-categories of its own and is intertwined with the level 1 hardware complexity. This level of software complexity cannot exist without a minimum level 1 hardware complexity. On the flip-side all the hardware levels require a basic level of software with various requirements as listed below;

*Hardware Level 1:*
1. Pass values
   - Simple logic to pass inputs / outputs from and to the ‘mimic panel’.

*Hardware Level 2:*
2. Pass data labels
   - Labelling specific to each I/O point as well as the application naming, status and error codes

*Hardware Level 3:*
3. Full application communication
   - Constant and full communication with the application to allow dynamic changes of all variables.

It should be noted that each higher level will also share the lower level requirements. I.e. Hardware level 2 requires level 1 requirements and level 3 requires both level 2 and 1 requirements. As this software level is interlinked with the relative hardware level it will share any pros and cons of the respective level. These attributes can be referred to in Table 8, Table 9 and Table 10 respectively in Appendix C.
3.5.2. **Level 2 – Medium Level of Software Complexity**

The medium level of software complexity represents the first project choice which incorporates no hardware option and is solely based within a virtual environment. This complexity level is based on the use of a simulator for each system which all would be able to work together with any applications.

This level would require a specific piece of software for each of the HPM, C200 and CLM (PLC) networks. The software applications would be required to work in harmony simultaneously as well as in stand-alone.

3.5.3. **Level 3 – Highest Level of Software Complexity**

Level 3, the highest level of software complexity is the last stage of the project scope, and, if chosen, would require the design and creation of a custom software solution. The custom software solution would be required to fulfill all systems needs in a single application setup defined in level 2 – medium level of software complexity.

3.6. **Possible Software Options**

All of the levels of hardware and software were then placed in a presentation which was given to management and affected engineering staff for a choice of which direction to take the project. After the proposal had finished, a discussion ensued with the intern suggesting the level 2 software only package as the best option, which management accepted.

Initial discussions and research were then undertaken into possible software solutions to be used. The Honeywell packages “HPM I/O Simulator package” and “SIM-C200” were identified as possible HPM and C200 solutions and FasTrack’s “Modicon Simulator” package being a possible PLC simulation program.

This research has been included in Appendix C.
3.7. Future Work

The software solutions proposed by the intern are currently being reviewed by an Engineering technician and a phone conference with Honeywell to be organised in the near future.

Once the software options are chosen and approved by management for licensing and use, the project will be passed over to the systems engineers temporarily for software installations and configurations, and then passed back to the internship student for testing and completion.
4. Other Projects

4.1. Launder Level Interlock Logic Optimisation – Train 1 & 2

4.1.1. Facility 45 Process

Precipitation is the third step in the Bayer process at Worsley. Precipitation is the development of a solid in a chemical solution. In the case of the Bayer process it is the manner by which solids collect together in ‘lumps’ of suitable size and quality for further processing.

There are three main process ‘trains’ in Facility 45, named as they follow a certain track/path along the process. Trains 1 and 2 are identical in setup with train 3 having a similar setup but with the inclusion of a barometric condensing process. The trains also output to different locations. Trains 1 and 2 output their final tank overflow to the coarse seed thickeners as well as to the Facility 46’s product cyclone, while train 3 only outputs its product to the Facility 46’s product cyclone and does not yield any product for the seed thickeners.

This section of the document is intended to detail the PLC logic investigation into trains 1 and 2; train 3 logic was not investigated during this project.

Trains 1 and 2 are made up of various equipment including: air-lifted precipitators, pumps, flash vessels, heat exchangers and settling tanks. This project specifically focused on the PLC logic and interlocks related to the flash discharge pumps. In each of the two trains there are five tanks. Each of these sets of 5 tanks has a discharge pump. During normal operation only one of the five tanks will be in use at any time. Prior to this project, the operator chose which tank to use via the use of two hand-switches: one for tank on and one for tank off. The interlocks setups in the PLC logic are configured such that which ever tank is currently in use, it had to be selected via the set of hand-switches. The discharge pump interlocks were set to trip the pump on one of two events:

1. The hand-switches weren’t in the correct positions within a timed limit (One enabled, one disabled)
2. The tank currently or No tank was selected and the relative / any tank had reached the LSLL or LSHH limits.(Level Switch Low Low and High High, which activate when the tank reaches a certain pre-defined level)
4.1.2. **Purpose of the Project**

This optimisation process was undertaken as part of Worsley’s continuous improvement program but was raised with priority due to the recent change in operator HMI in the area. The change over to the Experion HMI resulted in some of the PLC logic becoming redundant due to the updated control. During the change over the logic was to be moved ‘as built’ and thus no optimisation/changes were allowed. During this change over the engineer in charge, Vishwesh Soni, examined the logic and noted many possible improvements.

The intern was then tasked with the formal optimisation and implementation process, including full documentation and work-pack creation to confirm optimisation had been achieved to the highest possible degree and all changes were correct before implementation occurred.

4.1.3. **Logic Optimisation Process**

This part of the documentation is dedicated to the initial processes of the interlock logic project, including the process of, understanding and grouping of the logic and removal of un-necessary coils and rungs, and logic review.

4.1.3.1. **Understanding and Grouping of PLC Logic**

During the process of attempting to understand the essentials of the launder level interlock logic it was observed that the logic could be grouped into its preformed action or which I/O it dealt with. This grouping resulted in six ‘levels’ of logic;

- Level 1: Physical Hand-switch inputs and hand-switch fault interlocks
- Level 2: LSHH audible alarm and No tank selected fault
- Level 3: Individual tank interlocks; LS faults, LSHH trips and Train discharge first stage output.
  (Occurs when tank-relative LSLL is active and no pump is running)
- Level 4: LSHH trip coils (Tank-relative LSHH has been tripped)
- Level 5: Output to physically trip flash discharge pump
- Level 6: Coil tracing; coils which are also used in other places’ logic.

During the logic analysis all the coils which linked the levels were clearly marked. This analysis ensured the flow between levels was well documented. An example of the logic complexity can be seen in Appendix E, Level Five Ladder Logic. The level analysis and flow can be seen graphically below in, Figure 6.
4.1.3.2. **Removal of Un-necessary Coils and Rungs**

During the project duration, a process control change (PCC) was raised by the operators of the area. The PCC defined the redundancy of the switch pairing system in the new Experion HMI's, proposing removal and the logic updated accordingly.

Optimisation at this stage aimed to remove as many coils and rungs as possible, to speed up the code execution, whilst keeping the code in an organised and easy to debug arrangement.

The most significant outcome of this removal of any un-necessary coils and rungs biggest outcome was the deletion of the level one logic (120 coils and 60 rungs removed in total): The physical hand-switch inputs were migrated to the level two logic. This removal was possible due to the removal of all hand-switch tank ‘Off’ hand-switch coils.
The number of Level two logic networks could be cut in half. Through discussion with the operators, the logic was edited so it is only possible to select one tank at a time or ‘No selection’. This second setting varies from the original ‘operator fault no selection’ as it enables the operator to physically select no tank to be in use, whilst allowing any of the tanks LSLL or LSHH trips to de-activate the discharge pump.

There were no removed coils or rungs from the level four and five logic. An example of the recommended logic changes is shown in Appendix D.

4.1.4. Logic Review

Logic review is the last element in the logic optimization and involves personal and peer review of the suggested optimization code. During this phase the logic was reviewed by the supervising engineer Vishwesh Soni as well as the intern.

4.2. Implementation Process

4.2.1. Work-pack Creation

A work-pack is defined as all the work to be completed, marked up on the previous work, in this case logic. The work-pack in this case was a printout of all the code inclusive of the Launder Level Interlock’s train 1 & 2, with red-line style markup for any changes that were to occur. A simple cross through a removed coil or rung was used: In the case of coil number changes the old coil number was crossed through with a red-line as well as highlighted, and the new number was then marked close to the coil and highlighted in an identical colour.

The main cause of coil re-numbering was the removal of all Tank # ‘Off’ hand-switch coils, 10 in total. This left the coil numbering of the hand-switches with gaps in the increment as opposed to the previously grouped numbers. This issue had to be resolved as a matter of logic coding etiquette as well as full project completion: The new coil numbers were thus marked up in the previously described fashion on the work-pack.

After this point the work-pack was reviewed once again by both the intern and the supervising engineer, and once approval was given, implementation of the changes could proceed.
4.2.2. Implementation and Testing of Changes

At the current stage of the project the implementation and testing is currently underway. The implementation is being done on the Modicon Quantum PLC builder program which is a ‘ladder’ logic style builder.

The implementation and testing of these changes will be completed by the intern and checked before downloading by Soni Vishwesh.

4.3. Documentation Process

Documentation detailing why the logic was to be optimised, including what was to be done has been created. The documentation details each network including the relevant changes and reasons for the change. This documentation has the work-pack of changes as attached as an Appendix.

As the implementation of changes has currently not been achieved the documentation for the ladder logic has not been updated but will be done once the changes have been completed. The other document that must be edited is the ladder logic description PDF document, this document contains the numbers and descriptions of each coil and network, and it must be updated accordingly. All these documents, once changed, will be saved and backed up on the ‘controlled documents’ hard-drive on the Worsley intranet network.
4.4. HMI Graphics Migration

4.4.1. Experion HMI Development

Worsley is currently in the process of moving from the Honeywell Global User Station (GUS) display screens onto the new Experion Human Machine Interface (HMI) setup screens. This move brings with it added functionality. The area which is currently being moved over is the Powerhouse.

The move is primarily based around replication of GUS screens functionality on the Experion system. The new features made available by the Experion control system however allow the designers to merge multiple GUS pages into a single Experion page whilst re-designing can also occur to improve the pages useability.

All graphics used by Worsley’s Experion system have been customised to allow for maximum functionality whilst still maintaining an aesthetically pleasing design.

4.4.2. Design of Pages

This project required the intern to first familiarise himself with the Experion builder previously mentioned, Experion HMIWeb Builder, and then set about copying all functionality incorporated in the GUS pages to the Experion system. The builder view can be seen in Appendix E, whilst building all alarms appears with the relative alarm border.

This process required the study of the GUS page which was to be re-built as well as understanding how to implement each part of the functionality using the Experion system. The system is simple in nature and adding advanced functionality to each graphic is made easy through the ability to link Visual Basic (VB) script to them.

An example of a page before (GUS) and after (Experion HMI) is included in Appendix E.
4.4.3. Results and Future Work

During the HMI graphics migration project the intern was able to assist in building from scratch approximately five pages, with many other pages beginning from a almost-finished state which required only a few hours of design to finish.

The possible future work for this project would include continuing to move other GUS pages to the Experion system until there are no pages left. There are approximately 100 pages remaining to be moved / built.
5. CONCLUSION

At this stage of the internship immense amounts of new knowledge has been gained regarding the workings of Worsley, as well as the type of work which would be encountered if the intern was to continue as a future professional engineer with the company. With the knowledge gained as well as the social network offered by the Process Control group at Worsley, the intern is well positioned to continue with success on all of his projects, with all expected to be completed on time and to an appropriate standard of work.

Through the completion of these projects all objectives and guidelines agreed upon by Murdoch and Worsley will be met, including the furthering of learning and experience to a degree that will allow for a smooth transition from an engineering student to life as a professional engineer.
6. NOMENCLATURE

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O</td>
<td>Input / Output; Commonly used in reference to controller hardwire read input and output capabilities.</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable logic controller, a digital computer used for automation of industrial processes, such as control of machinery on factory assembly lines.</td>
</tr>
<tr>
<td>PH</td>
<td>Power-House, The main function of the Powerhouse is to generate electricity and steam for general refinery use. This is achieved using coal-fired boilers and steam-driven turbines. It is also known as Worsley’s Co-generation plant.</td>
</tr>
<tr>
<td>PC</td>
<td>Process Control, the control group at Worsley responsible for development and maintenance of control strategies.</td>
</tr>
<tr>
<td>LCN</td>
<td>Local Control Network, The network of which all critical control related information is passed</td>
</tr>
<tr>
<td>HMI</td>
<td>Human Machine Interface, the interface used to interact with a computer or machine. Usually graphical based. In the case of Worsley this refers to the old GUS pages as well as the new Experion based station displays.</td>
</tr>
<tr>
<td>GUS</td>
<td>Global User Station, An interface into the process via a terminal. Can be physically accessed or accessed via remote desktop facility.</td>
</tr>
<tr>
<td>ICE</td>
<td>Instrumentation and Control Engineering, A major in the Murdoch University Engineering degree.</td>
</tr>
<tr>
<td>ICSE</td>
<td>Industrial Computer Systems Engineering, A major in the Murdoch University Engineering degree.</td>
</tr>
<tr>
<td>Experion</td>
<td>A Honeywell Platform product, Allows for integration of all process control and safety systems—including non-Honeywell systems—and automation software under a single, unified architecture.</td>
</tr>
<tr>
<td>FSC</td>
<td>Fail Safe Controller</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid Crystal Display (display technology)</td>
</tr>
<tr>
<td>OCS</td>
<td>Operator control stations</td>
</tr>
<tr>
<td>WAPL</td>
<td>Worsley Alumina Pty Ltd</td>
</tr>
<tr>
<td>DSM</td>
<td>Dutch State Mine screens</td>
</tr>
<tr>
<td>FBC</td>
<td>Fluid Bed Calciner</td>
</tr>
<tr>
<td>S/CRO</td>
<td>Senior / Control Room Operator</td>
</tr>
</tbody>
</table>
7. BIBLIOGRAPHY


8. Appendices

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<th>Appendix</th>
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<td>B</td>
<td>Alarm Rationalisation Project</td>
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<td>C</td>
<td>DEV Simulation Project</td>
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<td>D</td>
<td>Launder Level Interlock Logic Project</td>
</tr>
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8.1. Appendix A

Internship Housekeeping

A.1 Industry and Academic Supervisor endorsement............ 57
A.1 ENG450 Engineering Internship

Industry and Academic Supervisor endorsement pro forma

We are satisfied with the progress of this internship project and that the attached report is an accurate reflection of the work undertaken.

Signed:
Industry Supervisor

Signed:
Academic Supervisor
8.2. Appendix B
Alarm Rationalisation Project

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B.2 Rationalised HMI Page Examples.................................. 61
### B.1 Rationalisation Grids

#### Table 5: Rationalisation Grid - Consequences [1]

<table>
<thead>
<tr>
<th>Impact Category</th>
<th>Severity: NONE</th>
<th>Severity: MINOR</th>
<th>Severity: MAJOR</th>
<th>Severity: SEVERE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel Safety</td>
<td>No injury or health effect</td>
<td>Slight injury or health effect</td>
<td>Injury affects work performance maximum one week</td>
<td>Lost time injury &gt; 1 week, or worker disabling, or severe injuries, or Life Threatening</td>
</tr>
<tr>
<td>Safety</td>
<td>No disability</td>
<td>No disability</td>
<td>Reversible health effects</td>
<td></td>
</tr>
<tr>
<td>Public or Environment</td>
<td>No effect</td>
<td>Local environmental effect</td>
<td>Contamination causes some non-permanent damage</td>
<td>Limited or extensive toxic release</td>
</tr>
<tr>
<td>Safety</td>
<td>Does not cross fence line</td>
<td>Single complaint</td>
<td>Crosses fence line.</td>
<td></td>
</tr>
<tr>
<td>Public or Environment</td>
<td>Contained release</td>
<td>Single exceedance of statutory or prescribed limit</td>
<td>Impact involving the community</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Little, if any, clean up</td>
<td>Reporting required at the local or state agency level</td>
<td>Repeated exceedances</td>
<td></td>
</tr>
<tr>
<td>Public or Environment</td>
<td>Negligible financial consequence</td>
<td>Reporting required at the local or state agency level</td>
<td>Uncontained release of hazardous materials with major environmental impact and 3rd party impact</td>
<td></td>
</tr>
<tr>
<td>Costs / Production Loss / Downtime / Quality</td>
<td>Internal or routine reporting requirements only</td>
<td>Reporting required at the local or state agency level</td>
<td>Extensive cleanup measures and financial consequences</td>
<td></td>
</tr>
<tr>
<td>Costs / Production Loss / Downtime / Quality</td>
<td>Event costing &lt;$10,000.</td>
<td>Event costing $10,000 to $100,000</td>
<td>Reporting required at the site level</td>
<td></td>
</tr>
<tr>
<td>Costs / Production Loss / Downtime / Quality</td>
<td>Reporting required only at a the department level</td>
<td>Reporting required at the site level</td>
<td>Event costing &gt;$100,000</td>
<td></td>
</tr>
<tr>
<td>Costs / Production Loss / Downtime / Quality</td>
<td>No loss</td>
<td>Event costing &gt;$100,000</td>
<td>Reporting required above the site level.</td>
<td></td>
</tr>
</tbody>
</table>

#### Table 6: Rationalisation Grid - Corrective Actions [1]

<table>
<thead>
<tr>
<th>“Text Version”</th>
<th>Classes for maximum Time to Respond</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;No Alarm&gt;</td>
<td>&gt; 30 Minutes</td>
</tr>
<tr>
<td>Promptly</td>
<td>10 to 30 minutes</td>
</tr>
<tr>
<td>Rapidly</td>
<td>3 to 10 minutes</td>
</tr>
<tr>
<td>Immediately</td>
<td>&lt; 3 minutes</td>
</tr>
<tr>
<td>Maximum Time To Respond</td>
<td>Consequence Severity: MINOR</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>&gt; 30 Minutes</td>
<td>No Alarm</td>
</tr>
<tr>
<td>10 to 30 minutes</td>
<td>Low Priority</td>
</tr>
<tr>
<td>3 to 10 minutes</td>
<td>Low</td>
</tr>
<tr>
<td>&lt; 3 minutes</td>
<td>High</td>
</tr>
</tbody>
</table>
B.2 Rationalised HMI Page Examples

Figure 7: Mill Circuit 4 Interlock Alarms HMI Page
Figure 8: Mill Circuit 3 Interlock Alarms HMI Page
8.3.  Appendix C

DEV Simulation Project

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C.1 Hardware Specifications Level Designs

Figure 9: Hardware I/O mimic panel - 2nd level of complexity - Design #1

Figure 10: Hardware I/O mimic panel - 2nd level of complexity - Design #2
### C.2 Hardware Specifications Level Pros and Cons Tables

#### Table 8: Hardware Lowest Level Setup Pros/Cons

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Easy installation</td>
<td>• Not many indicators</td>
</tr>
<tr>
<td>• Small installations are relatively cheap</td>
<td>• Limited by physical size</td>
</tr>
<tr>
<td>• Simple to use</td>
<td>• Expandability low and costly</td>
</tr>
<tr>
<td></td>
<td>• Minimal Feedback from process</td>
</tr>
<tr>
<td></td>
<td>• Cannot see full application processes</td>
</tr>
<tr>
<td></td>
<td>• Hard to follow with I/O numbers as labels</td>
</tr>
</tbody>
</table>

#### Table 9: Hardware Medium Level Setup Pros/Cons

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Installation still relatively easy</td>
<td>• Not many indicators</td>
</tr>
<tr>
<td>• Small installations are relatively Cheap</td>
<td>• Limited by physical size</td>
</tr>
<tr>
<td>• Increased useability</td>
<td>• Expandability low and costly</td>
</tr>
<tr>
<td>• Debugging easier</td>
<td>• Medium level of Feedback from application</td>
</tr>
<tr>
<td>• Clear where code failed</td>
<td>• Cannot see full application processes</td>
</tr>
<tr>
<td>• Easy to follow with I/O numbers</td>
<td>• Larger installations are expensive</td>
</tr>
<tr>
<td>• Aesthetically pleasing</td>
<td>• Large number of outputs for labels etc.</td>
</tr>
</tbody>
</table>
## Table 10: Hardware Highest Level Setup Pros/Cons

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Aesthetically pleasing</td>
<td>• Still must link I/O to server</td>
</tr>
<tr>
<td>• Increased useability</td>
<td>• Must be mounted close to server to minimize costs</td>
</tr>
<tr>
<td>• Debugging very easy</td>
<td>• Limited by physical screen size</td>
</tr>
<tr>
<td>• Clear when code failed</td>
<td>• Expandability low and costly</td>
</tr>
<tr>
<td>• High level of Feedback from application</td>
<td>• Cannot see full application processes</td>
</tr>
<tr>
<td>• Development cheap due to ‘Ladder Logic’ programming.</td>
<td></td>
</tr>
<tr>
<td>• Dynamically changeable HMI screens</td>
<td></td>
</tr>
<tr>
<td>• Physically small</td>
<td></td>
</tr>
</tbody>
</table>
C.3 Possible Software Level 2 Options Research

C.3.1 HPM Software Solution – Honeywell HPM I/O Simulator package

The optional HPM I/O Simulator package simulates the functions of the HPM’s Input/Output Processors (IOPs). It is a low cost, high fidelity tool for database building, control strategy checkout, and operator training support without the need for IOPs to be present. A unique feature of this optional package is complete database transportability between the Simulation personality and the HPM On-Process (normal operating) personality. This is especially useful for configuring the system before the physical I/O is available or connected.

Features of the package include:

- “Bumpless” pause/resume interruption/restart
- Physical IOPs, FTAs and field wiring not required
- Simulation status indicated and journaled
- Data base (checkpoint) transportable to target system
- Simulation rerun from saved data base using PV data
- Full peer-to-peer capability
- I/O functions simulated by Communications processor
- Any I/O configuration can be simulated
- Simulation load and status supported on system network
- Fault response testing and I/O redundancy simulation

The benefits of this package include:

- The ability to perform high fidelity simulations
- Control strategy checkout
- Operator training
- Project cost savings
C.3.2 PLC Software Solution – FasTrack Modicon Simulator

Modicon Simulator™ allows you to program, run, and test Modicon™ ladder logic and simulated I/O without using a PLC.

Modicon Simulator seamlessly integrates with PLC WorkShop™ for Modicon – 32 Bit, making it convenient to use. Testing and debugging Modicon programs without such a tool would typically take days. With the simulator, these tests can be accomplished in minutes—without the need for expensive hardware.

The simulator may be used in conjunction with data acquisition software such as ControlShop™. For example, connect FTTrender to the simulator for a graphical display of expected trends.

When a program is online with Modicon Simulator, the simulator responds in a similar manner to the type of PLC that is being simulated. Programs may be loaded, saved, edited, and executed while online with the simulator. In addition, Modicon Simulator allows the specific simulator state that has been created to be saved.

Modicon Simulator allows you to perform the following tasks, which are not possible when testing on a PLC:

- **Step Debugging** – Step through a program network-by-network or instruction-by-instruction.
- **Controlled I/O Simulation** – Set up I/O exactly the way you want with predictable results every time.
- **Regression Testing** – Ensure that changes to your program do not cause previously working functions to fail.

**Additional Features:**

- The Simulator’s compact interface provides an easy-to-use, convenient view.
- Modicon Simulator supports its own file format, allowing simulator settings that have been created—such as PLC type, I/O recipes, and breakpoints—to be saved.
- The Startup Restore feature automatically saves the simulator file when the application is closed and loads it upon subsequent startup.
- Modicon Simulator offers controls to easily display the specific code where a break has occurred.
C.3.3 C200 Software Solution – Honeywell SIM-C200

The Experion® Process Knowledge System (PKS) fully supports the following two levels of system simulation which do not require actual controller hardware:

- Control strategy checkout.
- High fidelity process simulation for operator training.

Each Experion PKS controller has a matching simulation environment, which executes a full system on a PC platform or a combination of several PC platforms. Simulation environments support full peer-to-peer communication between each other just like real controllers.

The SIM-C200 is the corresponding simulation environment of the Level 1 embedded C200 process controller. The SIM-ACE is the simulation environment of the Application Control Environment. The simulation environments are identical to the real controllers from a control execution, supported IO and control capacity point of view. This guarantees that a configuration developed on a simulation system will fit the actual controller platform or vice versa.

In the case of control strategy checkout, a simulation environment is added to an existing Experion system. The simulation environment is isolated from on-process control so that the simulation cannot influence the actual process. The simulation environment can read, but not write to, any real controller; the real controller can write, but not read from, the simulation environment.

To achieve high fidelity process simulation, a special system license is used which includes a certain number of simulation environments at a fraction of the cost of an actual system. In addition a process simulator such as Honeywell’s Shadow Plant® is required to simulate the full process and control system. The real system and simulation system use the same control configuration, custom graphics, trends, reports, etc.
8.4. Appendix D
Launder Level Interlock Logic Project

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D.2 Level Five Ladder Logic Tracing.............................. 72
D.1 Level 3 Recommended Logic

<table>
<thead>
<tr>
<th>Tank</th>
<th>Coil Name</th>
<th>Reference No.</th>
<th>Descript.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INPUT 1</td>
<td>002612</td>
<td>T151 SEL HS3447A</td>
</tr>
<tr>
<td></td>
<td>LS 1</td>
<td>102417</td>
<td>LSHH-3447 PPT151</td>
</tr>
<tr>
<td></td>
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D.2  Level Five Ladder Logic Tracing

Figure 11: Level 5 Ladder Logic (12)
8.5. Appendix E
HMI Experion Page Building Project

E.1 Experion HMI Page under-construction....................... 74
E.2 GUS to Experion HMI Migration: Before and After Pages... 75
E.1 Experion HMI Page under-construction

Figure 12: Experion HMI Web Display Builder
E.2 GUS to Experion HMI Migration: Before and After Pages

Figure 13: GUS HMI Page (Before)
Figure 14: Experion HMI (After)