

## Exploring 3D Chemical Plant Using VRML

By

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Dissertation submitted in partial fulfillment of  
the requirements for the  
Bachelor of Technology (Hons)  
(Information System)

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- 1) Hypertext systems
- 2) VRML (computer program language)
- 3) virtual reality
- 4) IT/IS -- theory

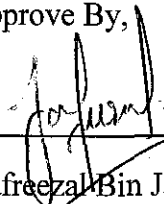
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Approve By,



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(Jafreezal Bin Jaafar)

UNIVERSITI TEKNOLOGI PETRONAS  
TRONOH, PERAK  
DECEMBER 2004

## **CERTIFICATION OF ORIGINALITY**

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that original work contained herein have not been undertaken or done by unspecified.

A handwritten signature in black ink, appearing to be 'Kasmawati', written above a horizontal line.

(Tuan Kasmawati Bt Tuan Abdullah)

## ABSTRACT

The research project focused on how virtual reality could create an immersive environment and improve in designing a chemical plant. The main problem is the difficulties in designing chemical plant since 2D plant layout cannot provide the real walking-through. The aim of this project is to develop and design 3D Chemical Plant which allows users to explore the virtual plant environment freely. The objectives of this project are to design and develop 3D Chemical Plant in the virtual environment; to enable user to walkthrough the chemical plant; and at the same time evaluate the effectiveness of the implementation of 3D Chemical Plant. In completion the project, the framework used is based on the waterfall modeling theory. This study also examines the structure and existing use of VRML (International standard for 3D modelling on the internet) in construction and architectural practice as a means of investigating its role and potential for extensible construction information visualization in chemical plant. The phases involved in the framework used for project development is the initiation phase, design specification, project development, integration and testing and lastly project implementation. Developments tools have been used in the project are VRML and 3D Max 6. As a result from the evaluation conducted, the mean of 3.5 from level of satisfaction ranking shows that mostly the evaluators are satisfied with the project and feel that the realism of 3D chemical plant and suitability of color and textures will improve the designing of chemical plant in virtual environment. As conclusion, the research project show that VR/VE are very useful and give a good impact for the chemical Engineer in designing a chemical plant.

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## **ABBREVIATIONS AND NOMENCLATURES**

**2D = 2 dimension**

**3D = 3 dimension**

**6DOF = Six-degree-of-freedom**

**CAVE = Cave Automatic Virtual Environment**

**CAD = Computer Aided Design**

**HMD = Head Mounted Display**

**IVEs = Immersive Virtual Environments**

**LCD = Liquid Crystal Display**

**P53 = Gene/protein that plays the pivotal role present in the nucleus**

**VE = Virtual Environment**

**VIVED = Virtual Visual Environment Display**

**VIEW = Virtual Interactive Environment Workstation**

**VR = Virtual reality**

**VRML = Virtual Reality Modeling/Mark-up Language**

**WBS = Work breakdown structure**

# **CHAPTER 1**

## **INTRODUCTION**

Virtual reality, VR, is a rapidly developing computer interface that strives to immerse the user completely within an experiential simulation, thereby greatly enhancing the overall impact and providing a much more intuitive link between the computer and the human participants. VR has been applied successfully to hundreds if not thousands of scenarios in diverse areas of art, architecture, medicine, military training, archeology, rapid prototyping, manufacturing, entertainment, chemistry, business, scientific visualization, engineering, and education. Although the project are focused of a single research group working specifically on the application of VR to chemical engineering development plant, there are an increasing number of projects in closely related fields, and there are many reasons to forecast a positive future for VR in chemical engineering. The project highlights the usefulness of VRML in viewing immersive virtual reality in chemical industry that related to the Acid Acrylic Chemical Plant.

### **1.1 BACKGROUND OF STUDY**

The overall aim of this report is to outline current research into Virtual Reality (VR) in Chemical Plant. Projects involving VR in construction are presented and in some cases the hardware and software in use are described. Most information has been gathered from the Internet, papers, articles, books and personal contacts. There are four area focused in this project as describe below:

#### **1.1.1 Virtual Environment Overview**

A “virtual environment” is defined by Stuart as:

*“Systems capable of producing an interactive immersive multisensory 3-D synthetic environment; it uses position-tracking and real-time update of visual, auditory, and other displays (e.g., tactile) in response to the user’s motions to give the users a sense being ‘in’ the environment, and it could be either a single or multi-user system.”*

Stuart uses the term “virtual environment” in this definition to avoid misconceptions related to the more common term “virtual reality”. In this text, the above definition will be applied to a “VR system” since it describes a system capable of displaying a synthetic environment. Virtual Reality could be classified into two main types according to the degree of immersion and interface in the synthetic environment. The two types include immersive and non-immersive Virtual Reality systems and for this project, it is under an Immersive Virtual Environment.

### **1.1.2 Immersive Devices in Virtual Reality**

There are a lot of devices used in rendering the virtual environment. VR hardware systems can vary greatly depending on available resources and specific needs. At the low end, desktop VR systems, also called “fish-tank VR”, provide simple, small-scale VR capabilities using a workstation monitor with stereoscopic graphics capabilities and a six-degree-of-freedom (6DOF) tracking unit. At the high end, multi-screen immersive projection systems combine several projection screens positioned adjacently, a 6DOF tracking system, and a computer capable of rendering high-speed, high-resolution stereo graphics. In the middle are traditional head-mounted display (HMD) systems and single-wall projection systems both with 6DOF tracking systems. The devices used in the project are details described in Chapter 3 under point 3.2 Design Specification Phase.

### **1.1.3 Immersive Visualization**

An immersive visualization environment can be used for everything from science to art, and from industrial simulations to education. There are numerous examples and fields that can benefit from a 3D visualization environment such as to test future products or to investigate otherwise unreachable environments. In this project the immersive environment should be study to ensure the best practices will achieve to render the project.

### **1.1.4 3D Chemical Plant Virtual Environment**

The chemical engineering industry often requires people to work in hazardous environments and to operate complicated equipment which often limits the type of training that is carried out on site. The daily job of chemical plant operators is becoming more demanding due to the increasing plant complexity together with increasing requirements on plant safety, production capacity, product quality and cost effectiveness. The importance of designing systems and environments that are as safe as possible to educate and train personnel is vital for the chemical process industries. Virtual reality offers the potential to expose personnel to hazardous situations in a safe, highly visual and interactive manner.

Virtual reality has been proposed as a technological breakthrough that holds the power to facilitate learning. The ability to visualize complex and dynamic systems involving personnel, equipment and layouts during any real operation is a potential advantage of such an approach. Virtual reality and multimedia training is commonly used in many industries, aiding understanding and memory retention and creating a more interactive learning experience.

## **1.2 PROBLEM STATEMENT**

As general, the problems that causes of developing 3D Chemical Plant are;

- i. A real walking-through in the plant could not be achieved using 2D plant layout. By developing the virtual reality approach would enhance the experience of walking-through the site.
- ii. Real chemical plants are too dangerous to explore without having any information or guidance of the location. Having 3D Chemical Plant will provide the feeling inside the virtual world, so this will help user aware with the surrounding and know the exact location to assembly when the explosion or any problems/accidents occur.
- iii. To construct the real chemical plant take a long time because reviews were carried out by circulating multiple sets of paper drawings to all the parties involved. Many of the people involved in the process, such as operations and maintenance, had difficulty understanding the 2D drawings with the result that extra time had to be spent in meetings explaining the design intent, and multiple iterations were often required. The use of 3D Chemical Plant as an intelligent object that improves graphical representation of the model will reduce the design cycle time.

## **1.3 AIMS AND OBJECTIVES**

The aim of this project is to develop and design 3D Chemical Plant Tour which allows users to explore the virtual plant environment freely. The objectives of this project are:

1. To design and develop 3D Chemical Plant in the virtual environment.
2. To enable user to walkthrough in the chemical plant.
3. To evaluate the effectiveness of the implementation of 3D Chemical Plant.

## 1.4 SCOPE

Basically this project is concern on developing and giving the immersive environment to Chemical Plant of Acid Acrylic. The modeling should includes all section of chemical plant such as loading area, process area, tankage area, flare stack area and also all the building and laboratory such as in figure 1.4. (*Refer Appendix B*)

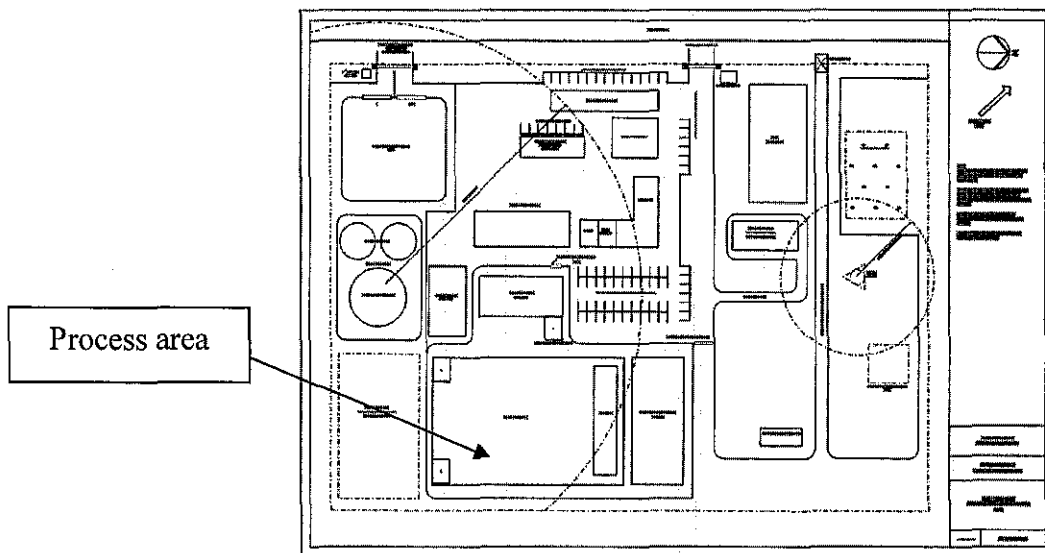


Figure 1.0 Scope of plant modeling area

The location for model of chemical plant should be located as in the plant layout. The project concentrates on modeling process area part because in this part, it should follow the flow of schematic drawing such as P&ID and PFD (*Refer Appendix B*). There are various devices used in presenting the virtual reality, but the scope of this project is developing immersive environment so the hardware used are HMD and also the power wall with stereoscopic glasses. There are a wide variety of possible input devices such as keyboard, mouse, trackball, joystick, and glove. Using keyboard or mouse is suitable for walkthrough application in this project since the project is based on walkthrough application. At the end of the development, a prototype that fulfills the purpose of the project that is providing the real virtual exploration of the chemical plant in various views is created.

## **CHAPTER 2**

### **LITERATURE REVIEW**

Numerous literatures have been found regarding related research that supports the objectives of this project. Therefore, the following subsections review published works that are related to each objective of the study.

#### **2.1. Introduction to Virtual Environments**

In the field of computer science a Virtual Environment (VE) is an artificial computer generated representation of an environment. The heart of a VE consists of the data describing it and the way in which it is interpreted. Of course, what makes a VE an *environment* though is the experience of it. To create this experience a system is required to interpret and present the data, and typically it will accept input(s) from a person in order for them to explore the environment. More often than not, these basic requirements are exceeded to provide additional application specific functions that might be necessary. Virtual environments come in many forms. Some regard VEs in a particular light and here some particular type should be considered, but it should be noted that a *virtual environment* is often used as a general term [1].

##### **2.1.1 Immersive Virtual Environments**

Immersion may be defined as the extent to which a person is enveloped by the VE. This is a fairly generic definition, and there are differing views of what immersion more specifically is. Witmer & Singer define immersion as: “a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences” [2]. Slater & Wilbur however relate immersion directly to the enabling technology. For them, a more immersive

system is one in which the technology provides a more compelling environment: “Immersion is a description of a technology, and describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant.” [3] For instance, by noticeably improving the resolution of a display the level of immersion would be said to have increased. Again, a system that does not provide force-feedback would not be as immersive as the same system with a force-feedback capability. This objective view of immersion is certainly of value, as there must be a way in which to rate the technology’s impact upon the user’s feeling of envelopment. Smith, Marsh, Duke & Wright also look at immersion to determine its part in building a mental model of the immediate environment [4]. They propose a person’s senses should be the basis for the definition of immersion. This therefore could be seen as the other side of the coin to the Slater (et al.) argument, which they appear to uphold. They present this relationship as being the way forward to measuring levels of immersion. The objective, technological definition of immersion allows it to be used as a referential point from which arguments can be made. Opponents of this idea may defend other definitions of immersion, but would surely accept that the specifics of the immersing technology to be of great value, and more than that, of great pertinence in the determination of the level of subjective presence [5].

VEs appear in many forms, one of the most well known being the Goggles ‘n’ Glove system. This type and a number of others such as the CAVE are often described as Immersive Virtual Environments (IVEs) due to the high levels of immersion they create. Their display emphasis is largely upon the visual sense of the user, which is deemed to be the one that most easily influences the sense of presence in the virtual environment. The intention of the IVE is to engage the user with the virtual environment directly, just as they would in the real world. This ideally means stimulating as many of the user’s senses as



possible, exactly as they would be in the real world. The user's senses and perceptual systems are presented with information from an artificial source (i.e. the computer) and are at least in part fooled into believing that they are [6], physically elsewhere, and that there is no mediating device between them and the virtual environment [7]. This is described as the illusion of non-mediation [8], and is important in the sense that the user should not be reminded that they are within an artificial environment, but rather have only natural cues. This can be described as the disregard of the knowledge that the apparent environment does not originate directly from the real world and that it is rather the display of stimuli information from a database. So then, that information which would normally cause disbelief in the existence of the presented environment is suspended. This then is the immersive virtual environment (IVE.)

## **2.2. Virtual Reality**

Virtual Reality (VR) has received an enormous amount of publicity over the past few years. Potentials of VR applications have been realized in many disciplines. VR with its increasing dynamic, interactive and experiential characteristics becomes able to simulate real environments with various degrees of realism. Jaron Lanier coined the name Virtual Reality (VR) to use in his business that was founded in 1989. It has since had numerous interpretations, and its meaning was quite thoroughly investigated by Steuer [9]. The term Virtual Reality has been used in a much more general sense [10] to describe almost any virtual environment.

### **2.2.1 Definitions of Virtual Reality**

There is almost no standard definition to the term Virtual Reality. It has been defined it as the illusion of participation in a synthetic environment rather than external observation of such an environment. VR relies on three

dimensional (3D), stereoscopic, head-tracked displays, and hand/body tracking. Based on Morgan & Zampi definition, VR is “...an immersive multi-sensory experience...” [11]. Ervin (1997) has defined Virtual Reality as “...the simulated reality...”[12] while Pimental & Teixeira (1995: xvii) explained Virtual Reality as “...a breakthrough technology that allows the person to step through the computer screen into a 3-D simulated world...”[13] and Regenbrecht & Donath (1997) have defined it as “...the component of communication which takes place in a computer generated synthetic space and embeds human as an integral part of the system...”[14]

### **2.2.2 History of Virtual Reality**

Roots of virtual reality began at 1962 with the “Sensorama” of Morton Heilig. At 1968 Ivan Sutherland described the head-mounted display which tracked the viewer and updated a graphic display. Military investigation during the cold war added numerous contributions to the field of Virtual Reality by development of flight simulators by the “US Air Force”. In 1984 “NASA” presented “VIVED” (Virtual Visual Environmental Display), and later the “VIEW” (Virtual Interactive Environment Workstation) [15]. During the last 15 years, Virtual Reality was perceived as the 6th generation of computer evolution in which no barrier exists between the user and the machine. Further applications of Virtual Reality for public research began by the attempted by “Brookes” group of researchers in the mid 1980’s who created a computer simulation of their research building’s architectural proposal in both interiors and exteriors in order to explore it before construction [13]. During the last decade there have been large-scale expansions in Virtual Reality applications in many disciplines. One of the reasons that VR has attracted so much interest is that it offers many benefits to many different areas of applications. Examples include operations in hazardous or remote environments, scientific visualization, architectural

visualization, design, education and training, computer supported co-operative work, space exploration, and entertainment [15]. In the last few years, there has been a practical need in many fields of creation to visualize ideas before establishment.

### **2.2.3 Types of Virtual Reality**

Virtual Reality could be classified into two main types according to the degree of immersion and interface in the synthetic environment. The two types include Immersive and non-immersive Virtual Reality systems. Morgan and Zampi (1995) have explained Immersive VR as “...*an application in terms of quasi-physical experiences...*” [11] In such experiences, fuller contact between users and the virtual space is maintained. Examples of these VR interactive experiences could be achieved by using data gloves and multi-media head mounted display devices (HMD). Non-immersive VR, e.g. screen based VR or Desktop VR, enables users through screen interface using special tools, e.g. eye glasses, to feel the simulated spatial environment. Current screen based VR systems include “Division”, and “Superscape” software. A recent emerging type of Virtual reality is the network VR. It is a result of the massive progress in the Internet and the World Wide Web in particular. Campbell (1996) indicated that the technology of Virtual Reality and the Internet continue to integrate, as the online culture is now the fastest growing demographic on the planet [16]. The standard virtual reality format on the web is VRML (Virtual Reality Modelling Language) or (Virtual Reality Mark up Language) created by “Silicon Graphics Inc.”. VRML, as a phenomenon that is universally accessible, hyper-linked, is becoming common place on the World Wide Web. It is a file format for describing 3D interactive 3 dimensional virtual environments. It is capable of representing static and animated objects and it can have hyperlinks to other media such as sound, movies and images. [17]

## 2.3 VRML

Virtual Reality Modeling Language (VRML) is a standard language for the animation and 3D modeling of geometric shapes. It allows for 3D scenes to be viewed and manipulated over the Internet in an interactive environment. Using a special *VRML browser*, the user can connect to an online VRML site, choose a 3D environment to explore and move around the '3D world'. It is possible to zoom in and out, move around and interact with the virtual environment.

### 2.3.1 Introduction of VRML

Virtual Reality Modeling Language, called VRML and pronounced "vermal", is a language that specifies the parameters to create virtual worlds networked together via the Internet and accessed via the Web's hyperlinks. It was conceived in the spring of 1994 at the first annual WWW conference in Geneva, Switzerland [32]. Most of the uses of VRML today are VRML-based business, entertainment, and scientific applications [33]. Architects have been identified as the most prolific users of desktop VR applications [33] (**Thierauf, 1995**). However to date the use of VR has been mainly concentrated on visualization as a tool for design, rapid prototyping and realism visualization (marketing of a design) through the use of fly-through animations. There is a range of VR software and hardware currently available such as, VRML, QTVR, Viscap etc. VRML is but one of them, yet it is distinctive in that, similar to HTML, it has been developed and adopted as an international standard for 3D modelling on the internet. The current standard is **VRML 2.0 (97) 97 – ISO/IEC 14772**.

### 2.3.2 VRML Attributes.

There are a number of essential attributes of VR that distinguish it from other forms of representation of information and environments [34]. These include:

- Three dimensional representation of environment
- Interaction of user with the VR environment
- Interaction through navigation and multiple senses
- Real time representation and interaction

“VR can be defined as a computer-generated, simulated, and real time 3D environment in which the user views and manipulates the environment interactively” [33]

### 2.3.3 VRML as a type of VR System

Bodum, [35] establishes a distinction between Reality and Virtuality and intermediate stages in between including:

- i Reality
- ii Enhanced Reality
- iii Enhanced Virtuality
- iv Virtuality

VRML is a total virtual environment, in that it is a digital representation of reality, and in some cases a reality not yet created. However the VRML can create Enhanced Virtuality by the inclusion of real contextual information.

Thierauf [33] defines VR in four basic types including:

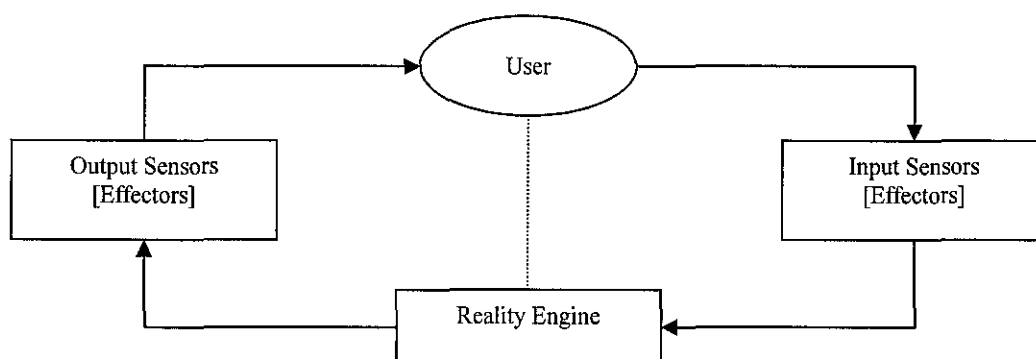
- i **Desktop VR System** - user navigates in 3D on a workstation
- ii **Partial Immersion System**– user navigates in 3D on a workstation with enhancements, such as gloves and goggles
- iii **Full Immersion System**- user wears headgear, gloves and body suits
- iv **3D Environment System** - externally generated with little or no body equipment

VRML fits into the first category of VR, the Desktop VR System. Desktop VR is a low level VR representation of information compared to Immersion

Environments and each has advantages and disadvantages with regard to VR application.

### 2.3.4 Benefits of VRML

The major benefit of VRML is that information is visualised and communicated in 3 dimensional interactive images. Thierauf, [33] identifies that people comprehend images more rapidly than they understand other forms of information. He also notes that VR is the most natural way in which to interpret information due to the fact that half of the brain is dedicated to visual processing.



*Figure 2.0 - Sensory feedback system - Closed Loop System*

Diagrams show a VR system that provides an understanding of the interactivity of a VR system and user [33]. Architectural practice and the communication of construction information traditionally requires an understanding of 2D information in three dimensions. The integration of VRML offers the ability to provide interactive 3D representations to integrate with the existing 2D representations of drawings and information.

VRML as a desktop system is of interest to this study. Desktop VR is currently the most accessible and extensible form of VR. The essential

difference is that immersive VR aims to insert the user into the virtual environment. Desktop VR contains both real-time visualization and user interaction yet is removed to a screen or monitor.

Desktop VR and in particular VRML is currently more integrative into existing systems and processes, especially architectural practice and construction. CAD and animation packages in architectural practice are common and integration of VRML into these systems is already possible with software packages exporting to the VRML format.

Another benefit is that the architectural practice and construction industry already deal with predominately visual information in order to communicate the construction of a design.

“At this time, it is expected that desktop VR systems may well have the greatest impact on the business community in the next several years. Using the broadest definition, it includes early products like Microsoft’s Flight Simulator but typically it refers to navigating through a truly 3D-rendered landscape. Architectural walkthrough packages, a leading application for this type of VR program, allow designers a sense of their creations by walking through simulated models. As such, users are drawn into the simulated reality as if it were a real thing.” [33]

Unlike some immersive VR, Desktop VR does lack tactility. It is important here to look at how desktop VR is applied, and what its role is.

It goes without saying that VRML applications should be suitable for their proposed use. Thierauf [33] identifies two important considerations for the application of VR, including; that VR systems should be installed to provide for its users, and that the way the user interacts with the system is fundamental to its success.

This highlights the importance of the interface, as this is the point of interaction between the user and the VR environment, and raises issues

concerning the visualization and communication aspects of VR that need to be understood and addressed in terms of the user. This has implications with regard to the application of VRML in architectural practice and construction, in respect of, a specific collection of information is required to be visualized and communicated and the number and type of users is varied. What VRML offers is a way of interfacing, visualizing and communicating this information to a variety of users using an integrative and extensible VR application.

### **2.3.5 Issues concerning VRML and application to construction**

There are a number of issues that arise due to both external and internal considerations. Some of these issues are addressed in this study, such as extensibility and integration.

When VRML was in its formative years the large central processing power and related costs required to run VRML effectively meant that VRML was not widely used. These barriers are now not as much of an issue. Due to VRML being an international web standard, it is easily accessible and programmed. The main issue that seems apparent currently is how to use VRML effectively, the size of the VRML environment and extensibility (understanding the scope of the application).

Other issues include the lack of standards and uniform concepts for the display and structuring of information [36] . This is certainly the case for the application of VRML to architectural practice and construction. This study concentrates on the structural aspects of VRML from individual model structure to the interface and navigation of the display of information. Standards for the presentation of construction information in terms of drawing standards converted to a VRML environment have only been explored in order to include content in the example case study.



The resolution and visual quality of information is also addressed. The visualization and communication of construction information does not attempt to provide realistic simulations (such as Lighting simulations) of representations. Essentially construction information is a simplified representation or diagram showing location, elements, assemblies and schedules of information.

#### **2.4 Virtual Reality used in Industry**

Efforts to apply Virtual Reality (VR) technology to advance the fields of medicine, engineering, education, design, training, and entertainment are currently underway. The medical profession has expressed its desire to use VR systems as training tools [20]; human factors specialists are using VR for user-system analysis and design. Scientists are utilizing VR to visualize complex data [21]. Stock market analysts want to use VR to predict market trends and achieve financial gains [22] and, the military currently uses VR to carry out virtual war scenarios and training exercises [23]. Interest in this technology is so widespread that the United States government asked the National Research Council, Washington, DC, to identify and determine U.S. VR research priorities [24]. Here are just a few another examples of activity involving VR, education, and engineering:

- a) The Virtual Reality in Education Laboratory at East Carolina University has put together an online bibliographic listing of over 300 references to journal articles on the topic of VR in education. [31] Although most of these citations relate to K-12 education, there is increasing interest in applying VR to higher education.

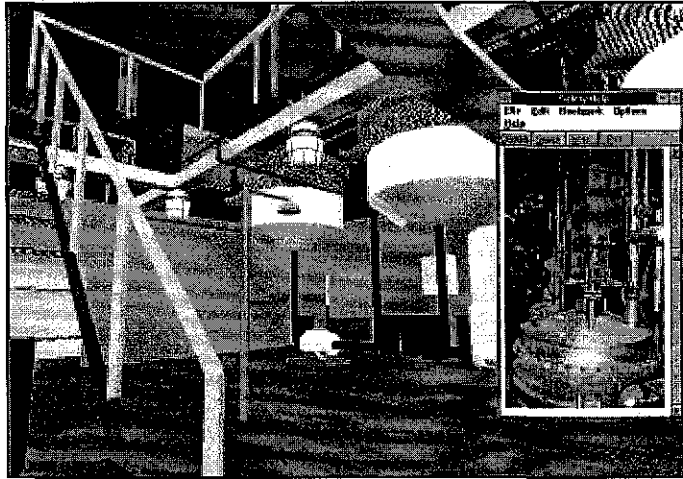


Figure 2.1: The application of Virtual Reality in chemical engineering education. The safety and hazards analysis module includes a help document containing photographs of the industrial site being modeled.

b) Construction engineering firms, longtime users of high-end CAD systems, have begun modeling their projects (including chemical plants and refineries) in VR to check for design flaws, hazards, and operability prior to construction [30].

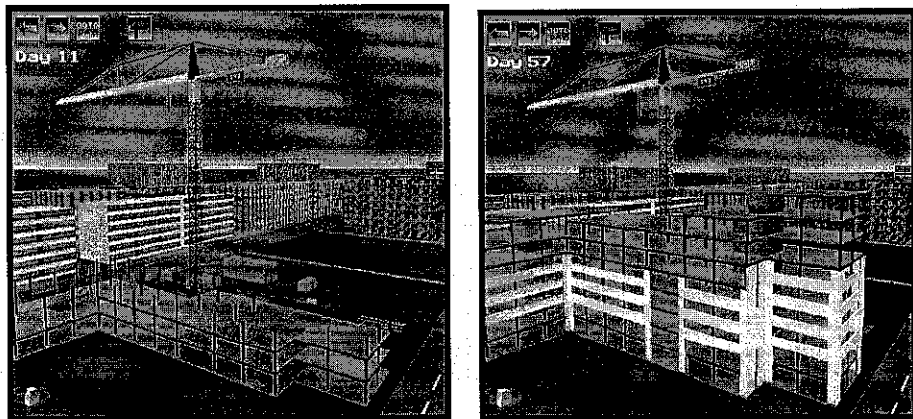


Figure 2.2: Visualization of stages in a construction process

c) The Boeing 777 airplane was completely designed, developed, debugged, and tested in VR, with no physical prototypes being made. The first 777 manufactured was sold to a customer [30].

d) Motorola has used VR to train factory workers, and found the method to be more effective than using actual factory equipment for training [30].

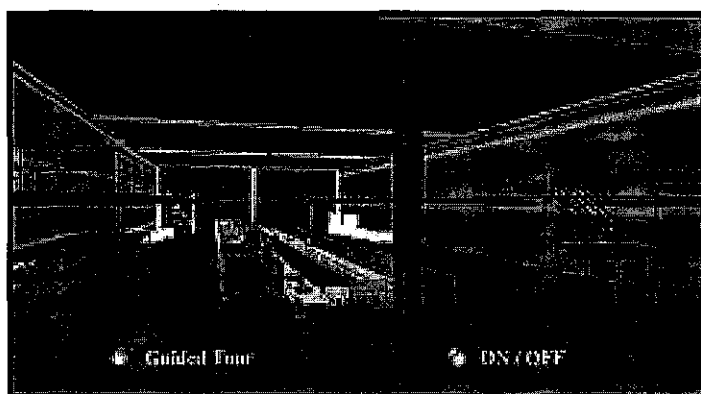


Figure 2.3: The application of Virtual Reality in manufacturing.

e) NASA has developed a virtual wind tunnel that allows scientists and engineers to move about the airfoil under study without affecting air flow patterns [30].

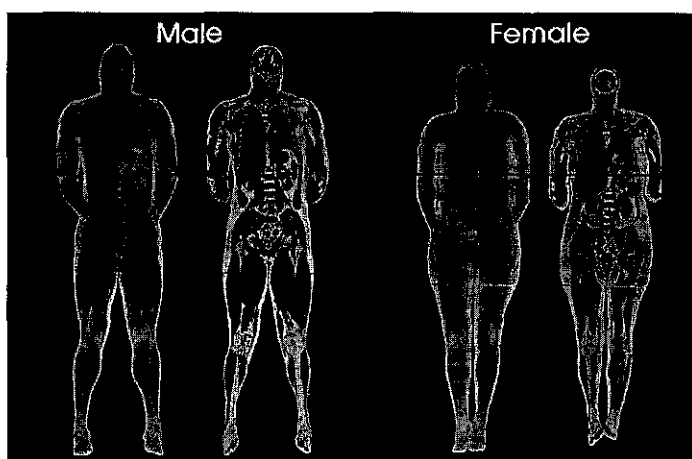


Figure 2.4: The application of Virtual Reality in medical. Full body images of Visible Human Male and Visible Human Female computed from color cryosections.

### 2.4.1 Virtual Reality in Chemical Engineering

Although VR has been used in a wide variety of fields, it has been applied to chemical engineering in only a few applications. A virtual simulation of a modern chemical plant has been created by the Department of Chemical Engineering at the University of Michigan, USA. Called 'Virtual Reality in Chemical Engineering Laboratory (VRiChEL)', this project has developed a prototype VR based educational module named Vicher (Virtual Chemical Reaction module), designed to aid in the instruction of undergraduate chemical reaction engineering. The module has been based on WorldToolKit from Sense8. The focus is on the modelling of reactions inside the chemical reactors which enable the conceptualization of mathematical formulae in chemical engineering [25].

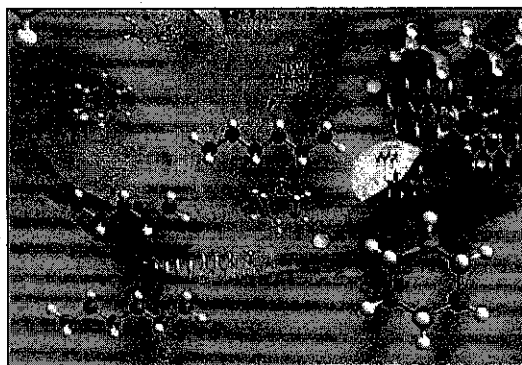


Figure 2.5: The interior of a microscopic catalyst pore, illustrating reaction mechanisms in Vicher 1

In Cancer Research, the 3D structure of the p53 tumor suppressor protein has been created by the Department of Physical Chemistry at the Darmstadt University of Technology, Germany. VRML is used for this biochemical application. In the VRML scenario, all the structures and information are cross linked via "space buttons", allowing the user to interactively explore the structure and properties of the p53-DNA complex as well as effects of mutations on the p53 structure and the binding region properties [26]. At Lawrence Berkley Laboratory, a VR model has been created which allows petroleum engineers to move oil recovery and flooding wells by hand and view

the resulting changes in the subterranean flow fields [27]. The Department of Chemistry at Imperial College of Science, Technology and Medicine, London, UK, has developed 3D Molecular Hyperglossary, a result of a 3D search of the Cambridge Structural Database for intermolecular interactions between chlorinated aryl hydrogen atoms and oxygen centre. VRML has been used to represent a scatter diagram of points about a well defined molecular centre to enable the user to inspect specific features interactively [28].

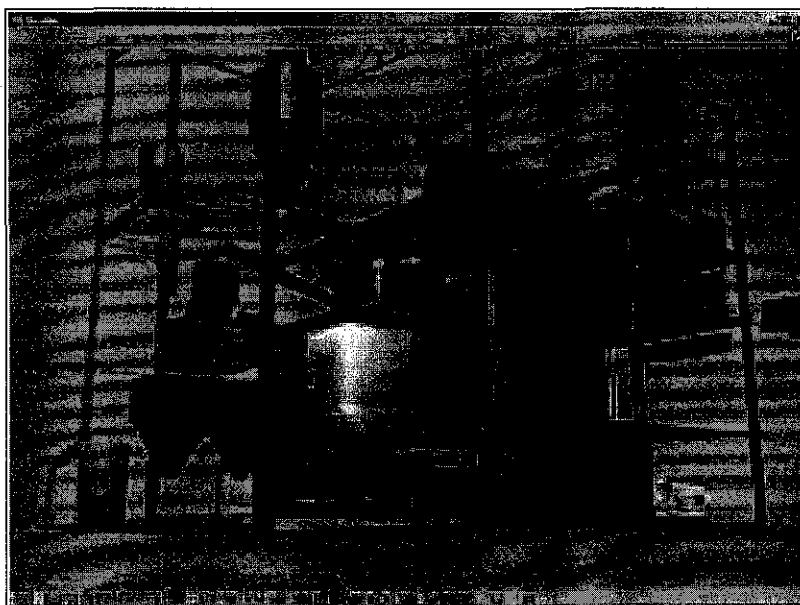
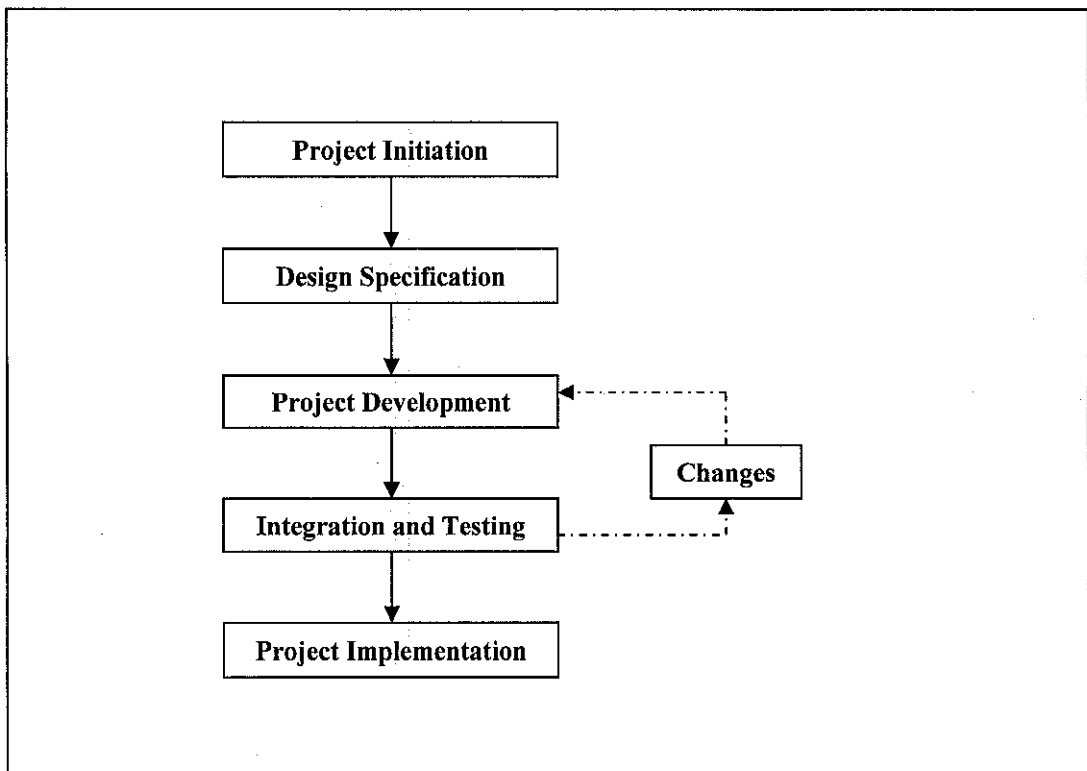


Figure 2.6 Paste Fill Plant VR Model (Courtesy of Falconbridge Ltd. – Kidd Mining Division)

## CHAPTER 3

### METHODOLOGY

A methodology exists generally to ensure that standard set of steps or tasks are carried out predictably, reliably, and with a focus towards continuous improvement. A "methodology" just means having a relatively standard set of steps or tasks. This is also the basis behind a lifecycle model, which describes how a development process is carried out. Methodology that is used during the development of this system is referring with the Waterfall Model. Every phase is cascading from one another and it is widely used for practical systems development. The five phases of system model are followed closely to ensure a systematic approach to system development. The core main phases are project planning and initiation, design specification, project development, integration and testing, and system implementation.



### **3.1 Project Initiation Phase**

The Initiation phase is the beginning of a system or project when a business need or opportunity is identified. During this phase, the approaches for accomplishing the concept for feasibility and appropriateness of the project are identified. The data are gathered thru various resources and after obtaining enough data, analysis are done to keep the information that are related to the project. Meeting with the client are conducted to ensure the product provide the required capability on-time and fulfills the client needs.

The system concept was developed to describe how the system will operate once it is implemented. Furthermore, is to assess how the system will give an impact to end users while performing their daily activities. Before moving on to the next phase, the problems, opportunities, and directives towards the development of the proposed system are identified. The outcome of this task are problem statements, objectives as well as significant of the system being developed.

Detailed project Work Breakdown Structure (WBS) was also being developed to provide the basis for deciding how to do the work. It also supplies an elementary platform for creating the project schedule. From WBS, the Gantt chart are developed which provides a standard format for displaying project schedule information and list of project activities and their corresponding start and finish dates in a calendar format. The tasks, duration estimates, and dependencies were identified. All activities on the Gantt chart are coinciding with the activities in WBS.

### **3.2 Design Specification Phase**

During this phase, the design layout is produced and studied. The purpose of system design phase is to transform the requirement statements from the requirement analysis and definition phase into design specifications for construction. It involves identifying and describing the basic software system abstractions to ensure completeness, usability, reliability, performance, and quality. This phase will defines

*how* the product will be built, and *how* to designs the physical characteristics of the system and establishes the operating environment. The full project description such as model specification and system working flow (walkthrough) are identified by meeting and discussing with the client. Since the project deals with virtual reality, 3D model are visualized or constructed from images or miniature model referring with the architecture drawing of chemical plant.

Hardware or software requirements are determined in this phase. From the data gathered from previous phase, decisions on *what* types of tools and equipments those are best to use are list down. The use of tools and equipments is to assist processes and constructed the system. Tools and equipments used will divide into two categories which is hardware and software.

### **3.2.1 Hardware**

Hardware is the physical part of a computer system and equipment. Among the hardware used are:

- i. Personal Computer

Personal computer is used to build and develop the 3D model of Chemical Plant. The pc is powered by Intel Pentium 4, 2.40GHz processor with 256MB of RAM running on Microsoft Windows XP operating system.

### **3.2.2 Software**

Software is the computer program that tells a computer's hardware what to do. Among the software used are:

- i. 3D Studio Max 6.0

3D Studio Max is a 3D modeling software that is used to author 3D models easily. All 3D virtual models for the project are built using this software. Once all parts of the model is finished, they need to be put together in a single



environment and exported to VRML (.wrl) format to be modified for visualization enhancements.

ii. VRML

Virtual Reality Modeling Language is a programming language for the creation of virtual worlds. VRML viewer allows users to take a virtual tour of a 3D model building, or manipulate animations of 3D objects. Hyperlinks to other sites and files can be embedded in the world that user visit.

### **3.3 System Development**

The objective of the development phase is to convert the deliverables of the system design into a complete system. The development phase contains activities for building the system and testing the system to ensure the system functional processes satisfy the user requirements. In this phase, the modeling are divided into two parts; Part A and Part B before both of it merge together to provide one complete design model. Below is the division of the 3D Chemical Plant location;

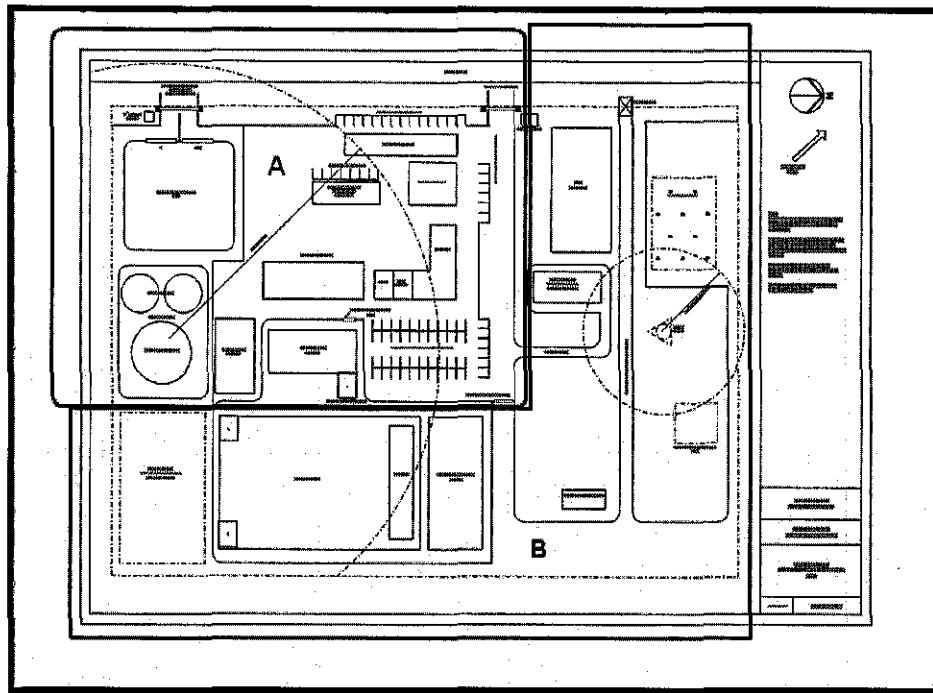


Figure 3.0 Chemical Plant Layout. (Bird's view)

### 3.4 Integration and Testing Phase

In integration and testing phase, individual program units or programs are integrated and tested as a complete system to ensure that the software requirements have been met. There are two levels of testing to be performed namely unit testing, and system testing. Unit testing is a test whereby all events and modules that have been coded and a program are tested as an integrated unit. Whereas system testing ensures that application programs written and tested in isolation will work properly when they are integrated into the total system. The integrated set of programs should be run through a system test to make sure one program properly accepts, as input and output of other programs. The evaluation also conducted to ensure the usefulness and realism of the project. There are two types of evaluation conducted in this phase which is asking VR expertise to evaluate the performance and realism of the system. This evaluation also known as heuristic

evaluation which required evaluator to look and test the system developed and judges it on the smoothness of movement. Below is the process of heuristic evaluation:

- i. The evaluator explores the 3D Chemical Plant using HMD.
- ii. The evaluators defines the problem arise during implementing the system and evaluate the system performance.
- iii. The evaluator comments and suggests some solution to enhance the system.

The questionnaire also conducted to users to get the feedback of the usefulness and realism of the project. All the feedback and suggestion are going to be used in developing hypothesis for future enhancement. Once the system test is complete and determined to be successful, implementation of the system shall take place.

### **3.5 Project Implementation**

Implementation phase consists of a fully functioning operational hardware-software system, including such objectives as program and data conversion, installation, and training. The system or system modifications are installed and made operational in a production environment. During this stage, the client will approve the validation of the system and satisfied with it.

## CHAPTER 4

### RESULTS AND DISCUSSION

#### 4.1 FINDING AND DISCUSSION

The research has been conducted from virtual reality and narrow down to the research element itself which is more realistic. From the research, it can be defined that virtual reality as the simulation of real or imagined environment that can be experienced visually in three dimensions of width, height, and depth. It also can provide an interactive experience visually in full real-time motion. Below is the result of converting Chemical Plant layout from 2D view to 3D view. Refer *Appendix B* for clear plant layout.

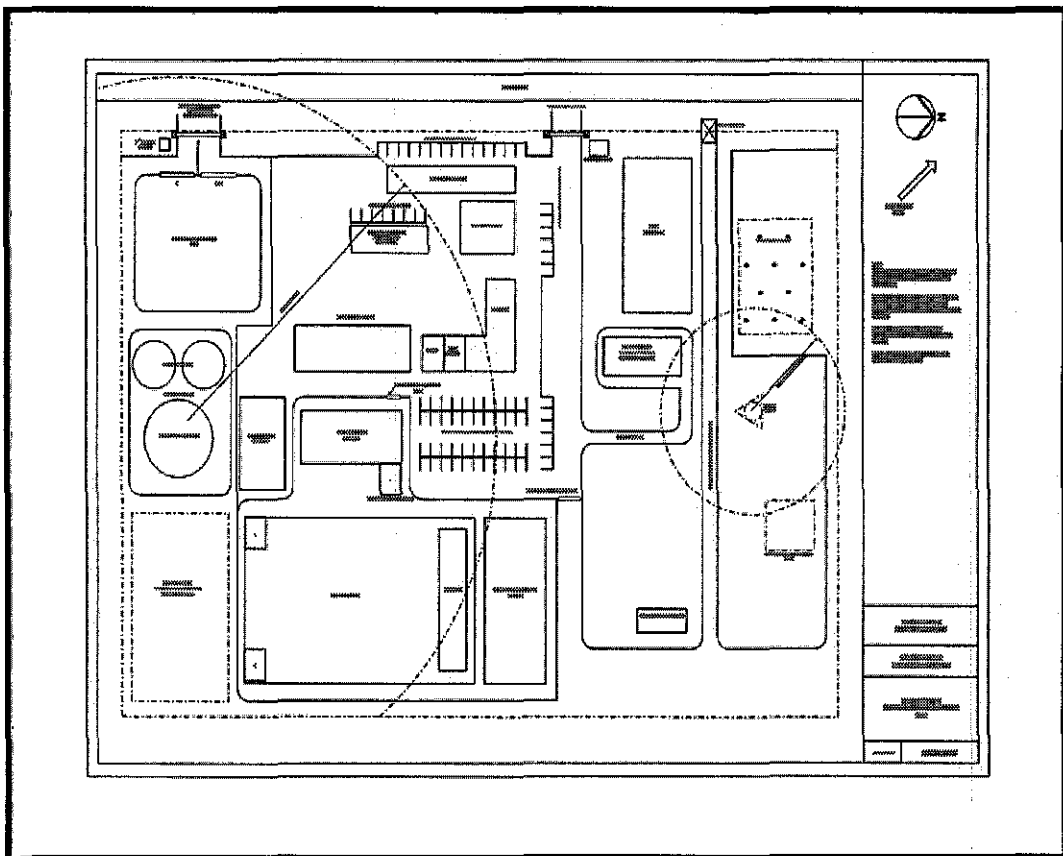


Figure 4.0 Chemical Plant Layout. (Bird's view)

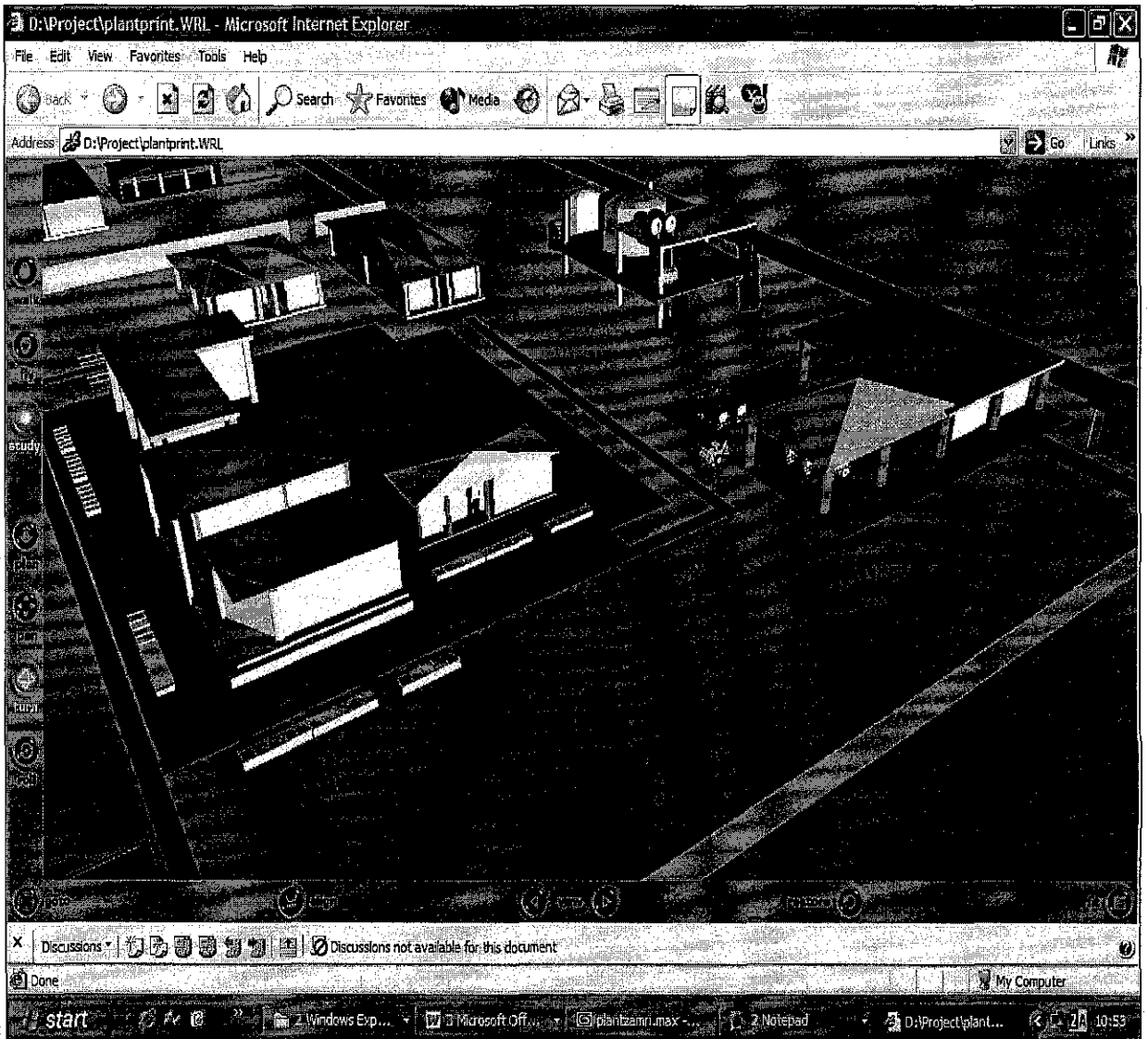
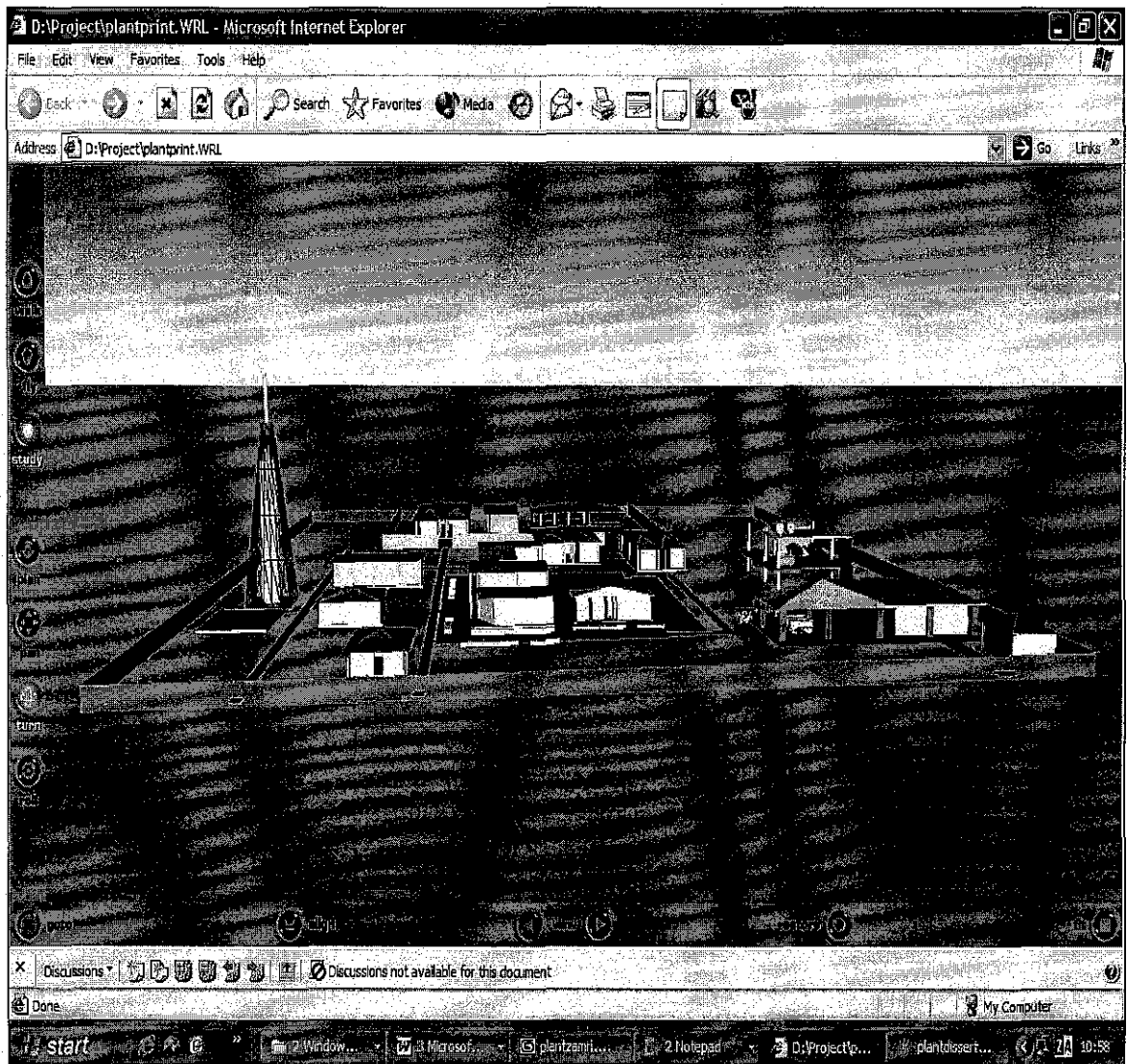
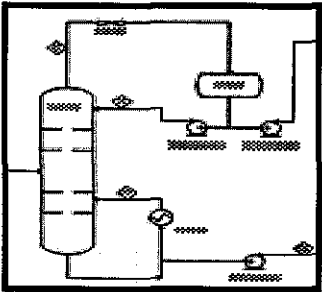
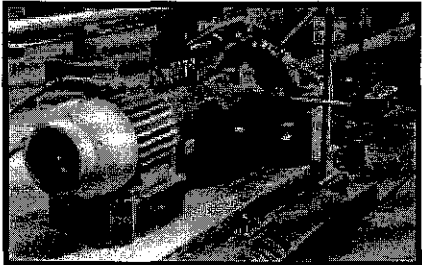
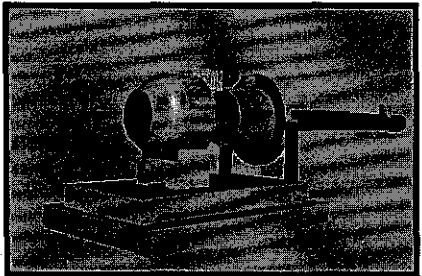


Figure 4.1 Chemical Plant in perspective view



Since the development is focused on the process area, the designing of its parts should be as real as the original picture. Figure 4.1 shows the perspective view of 3D chemical plant in 75% of its modeling parts. Below is the result of modeling pump; one of the process area equipment. Figure 4.3 shows the parts of distillation column symbol in the process flow diagram (PFD) such as pump, distillation column, condenser, reflux drum and boiler in schematic drawing. The part looks like figure 4.5 when modeled in 3D.

Drawing / Picture	Description
	<p><u>Figure 4.2</u></p> <p>This is a part of Process Flow Diagram (PFD) schematic drawing in the process area. The drawing shows the pipe connection of distillation column.</p>
	<p><u>Figure 4.3</u></p> <p>This is the photo of real pump taking from the oil and gas industry. (Vinyl Chloride (M) Sdn.Bhd)</p>
	<p><u>Figure 4.4</u></p> <p>This is the pump in 3D view. The model is create based on the photo of real pump in figure 4.3</p> <p>A pump is a machine that expends energy to increase the pressure of a fluid and move it from one point to another.</p>

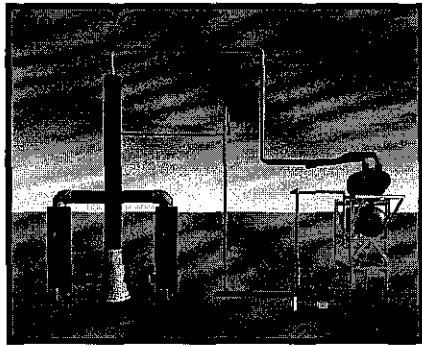


Figure 4.5

This model's appearance is close to the original. The model is design based on PFD (figure 4.2) consist of connection between pump, distillation column, condenser, reflux drum, and boiler in 3D.

Some supports such as ladders and stairs are not included yet.

## 4.2 RESULTS OF THE EVALUATION

During the evaluation phase, valuable data are collected from evaluators. The data then are being converted to statistical and charts for ease of interpretation and evaluation. In this evaluation, the evaluators are asked to experience the prototype and evaluate it based on the checklist given. The checklist is divided into two part; part A and part B. In part A, evaluators are test the understanding of the Chemical Plant location based on the drawing and layout and compare the realism between 2D and 3D chemical Plant prototype. In section B, the focus is more on the use of VR in exploring the chemical plant using immersive devices. The questionnaire for each part can be seen at the appendix. Below is the analysis for every part:



### 4.3.1 Prototype Evaluation

#### Part A – Level of understanding and realistic of the object.

This is the first part of evaluation in analyzing the user's requirements and understanding of the product based on 2D and 3D Chemical Plant model. The evaluation is done by 10 students. Below is the data gathered from the evaluation;

No	Attributes	2D Model	3D Model
1	Easy to visualize	3	7
2	Reflect better	1	9
3	More interactive and attractive	0	10
4	Provide more information	4	6
5	Preferred ways in detecting the location	3	7
<b>Total</b>		11	39

Figure 4.6 Result of prototype for 2D and 3D evaluation

From the evaluation, it show that 3D model of chemical plant is more easy to visualize, have a better reflect of its objects, more interactive and easy to detect location. 3D model also will provide more information.

### Part B – Prototype Evaluation.

This is the second part of the evaluation where the same evaluators will evaluate and comment the projects. Below is the cognitive walkthrough result from the prototype evaluation.

Attributes	Number of students	Level of rank				Sum (rank)	Mean
		2	3	4	5		
1. Realism of 3D Chemical Plant	10	-	2	7	1	39	3.9
2. Smoothness of movement in plant	10	1	7	3	-	35	3.5
3. Placement and location of the plant	10	-	2	7	1	39	3.9
4. Lighting affect in the environment	10	3	5	2	-	29	2.9
5. The suitability of color and textures	10	-	-	8	2	42	4.2
6. Other environment elements	10	4	5	1	-	27	2.7
<b>Mean Overall</b>							<b>3.5</b>
<b>Range</b>							<b>0.8</b>

Figure 4.7 Cognitive walkthrough result from the prototype evaluation.

Based on figure 4.7, the overall mean is 3.5 with the range of 0.8. The lowest mean is 2.7 and the highest mean is 4.2. From the analysis, the cause of the lowest mean is because there are not many virtual environment elements used in the project. The project just presenting the lighting and to increase the level of realism, adding other environment such as the animations and characters to the environment like winds blowing on the flair or workers movements can formulate a better feel to the environment. The sounds or audio parts also can be inserting in the project to improve the reality environment. Even though the element used in this project not much, attributes no five with mean 4.2 represents

the better surrounding of the application that will help users feel present at the workplace.

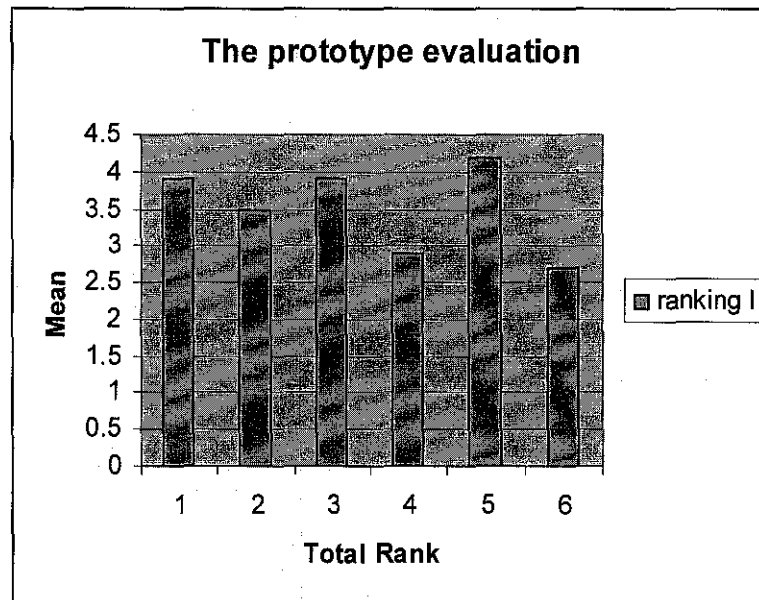


Figure 4.8 Histogram of result for prototype evaluation for Group A

#### 4.3.2 Interview

The approach used to gather data is conducting an interview with the potential and current users such as student and lecturer. In this project, among interviewees involve are author's friends and Mr. Zamri Abdullah, Chemical Engineering lecturer as a client. The interviews are conducted to get information learned from the interview and apply various aspects of it to the prototype model. The three approaches are distinguished by the extent to which the questions are standardized and predetermined, each approach having strengths and weaknesses dependant to some extent upon the purpose of the interview. Mostly the interview session are conducting in the informal

situation which includes an informal conversation, general interview guide approach and also the standardized open-ended interview.

Before the interview session start, interviewee will be given a brief explanation of the project and they will give with some hand-out regarding the prototype. From their understanding, the suggestion and problems arise will be ask.

The data gathered from the interview combine together and analyze as described below:

No	Element	Comment	Solution
1	Interface	-No formal interface	-Provide more interactive interface
2	Interactivity	- Have a simple interaction. - Using key board to command the walk through.	- For the future enhancement try to create VR with the ability to create new objects and alter existing ones.
3	Color and textures	-Inappropriate texturing for some parts of model. Eg: pipe	-Apply proper texture and specific color for the pipe to differentiate it types.
4	Lighting and Camera	-Some part of the plant did not locate proper light.	-Add lighting in the right position.
5	Sound	-No sound elements	-Future enhancement
6	Movement	-Average	-Apply suitable algorithm.

#### 4.9 Data analysis of VE elements.

From the discussion and evaluation, the main characteristics of a 3D environment are as follows:

- The environment is modeled using 3D vector geometry, meaning that objects are represented using x, y and z coordinates describing their shape and position in 3D space.
- The user's view of the environment is rendered dynamically according to their current position in 3D space, that is, the user has the ability to move freely through the environment and their view is updated as they move.
- At least some of the objects within the environment respond to user action, for example, doors might open when approached and information may be displayed when an object is selected with a mouse.

## **CHAPTER 5**

### **RECOMMENDATION AND CONCLUSION**

#### **5.1 Summary of project**

The overall aim of this project is to improve industrial performance by developing systems, based on virtual reality, which will enable and enhance the design, monitoring, safe control and operation of industrial processes, as well as providing high quality training of staff in the operation and maintenance of industrial plants. The technology that VR brings to the project enables operators to be interactive and to be immersed into the "virtual and real" workplace.

The research framework used is based on the waterfall modeling as a guideline to develop project. The framework used in the project development is the initiation phase, design specification, project development, integration and testing and lastly project implementation. Upon the completion of the prototype, many testing and evaluation have been done to ensure the project meets its objectives.


#### **5.2 Recommendation and future research.**

The following are some recommendations, which arise from the research work:

- ✓ Virtual reality training environments should be introduced to the chemical engineering industry to enhance current training programs. Virtual environments can alternatively be used for extension planning and configuration changes of existing chemical process industries.
- ✓ The current project is using VRML to display the 3D chemical plant. For the future project, it is suggested that the project will be presented using more advanced

technology such as CAFÉ or trackers to enhance the realism of virtual environment.

- ✓ In terms of GIS (Geographical Information System), searching and query could also be done in a VE. In an environment that has a large scope, such as an admin building or the whole process area, searching and query could be very useful for new users to find their way to a desired spot. Using searching methods, user could find a desired location just by keying in the specific name for it such as find the location of maintenance building and the specific area will be highlighted. With searching, it will not only take the user to the desired location, but also show them the exact route for them to get there.
- ✓ In virtual reality, the user will be represented by the camera view from which the user uses to explore the virtual environment. Therefore, with virtual reality technology, a user will be guided through the route in a first person's view from starting point to the desired location.
- ✓ The virtual environment is constraint to only for the exterior part of the chemical plant. With the proper interior plan drawing, implementing the interior of the chemical plant would be more real in exploring the plant.
- ✓ Adding the animations and characters to the environment like winds blowing on the flair or workers movements can formulate a better feel to the environment. To increase the level of realism, the sounds or audio parts can be inserting in the project.
- ✓ With more technological advances, the user can immerse in the virtual environment by allowing a character to be generated within the virtual environment representing the user. For example, users can use trackers to coordinate the user's movement to the virtual environment and reflect the real time action. This is one way to improve navigation and feeling of immersiveness. Users can also use a haptic glove which allows user to touch and feel the objects within the virtual environment. Haptic gloves could also do modifications or



initiate functions to objects inside the environment if the object programmed to have functions to it.

It is recommended that this project will be enhanced and proposed as a title for the final year project.



### **5.3 Conclusion**

The project is developed to provide the immersive virtual reality in chemical plant that will help user feels a real walking through in the plant. From this project, the comparison between 2D and 3D shape of the plant are studied and resulted that working in 2D increases the cognitive load and reconstruct the 3D shape from 2D sections is a good solutions for this problem. The use of 3D Chemical Plant as an intelligent object that improves graphical representation of the model will reduce the design cycle time. The project had highlighted on the importance of an immersive environment which the correctness of applying texture in achieving lifelike scene. The unique features and flexibility of VR give it extraordinary potential for use in work-related applications. It permits users to experience and interact with a life-like model or environment, in safety and at convenient times, while providing a degree of control over the simulation that is usually not possible in the real-life situation.

Devices used to view 3D Chemical Plant also important to present the immersive virtual reality. In this project, VRML used to visualize the immersive environment and suggested for the future enhancement, the chemical plant will be display using CAVE to increase the level of immersiveness of the plant. By extending VR into the management, visualization and communication of construction information, an integrative VRML environment could be used to manage all aspects of construction information in the chemical plant. This study provides an initial investigation of VRML construction visualization and through an established framework and example application that addresses a range of issues and provides further direction for future development.

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# **APPENDICES**

**APPENDIX A:**  
EVALUATION CHECKLIST

**APPENDIX B:**  
GANTT CHART

**APPENDIX C:**  
CHEMICAL PLANT LAYOUT

## EVALUATION FORM

UNIVERSITI  
TEKNOLOGI  
PETRONAS

*Note: This is an evaluation form for project prototyping of 3D Chemical Plant.  
Please rank an appropriate level to assist developer in improving the performance  
and realism of the system application. Your cooperation is highly appreciated.*

**Part A:**

After you have look at the Figure attached and experienced with the system displayed, please tick the model having the most of interactivity and connectivity level of the system.

No	Attributes	2D Model	3D Model
1	Easy to visualize		
2	Reflect better		
3	More interactive and attractive		
4	Provide more information		
5	Preferred ways in detecting the location		
<b>Total</b>			

Comments:

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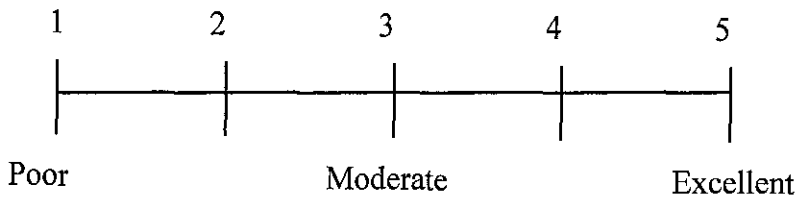
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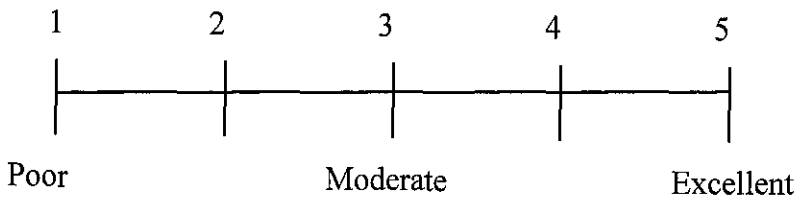




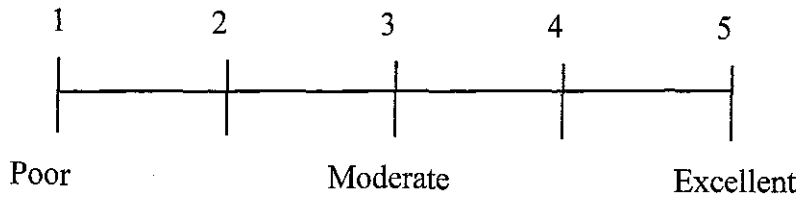
4) Finding the selected location



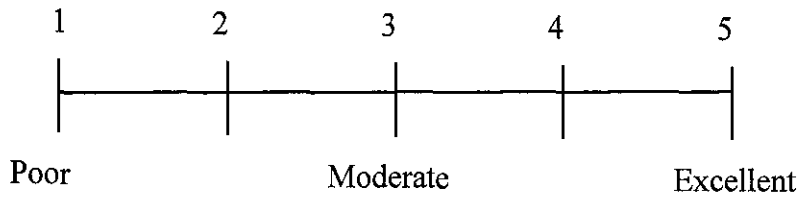
5) The lighting affect in the environment



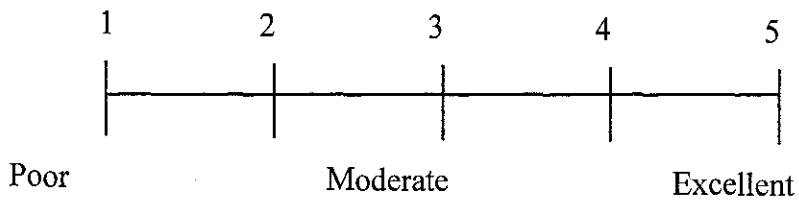
6) The suitability of color and textures



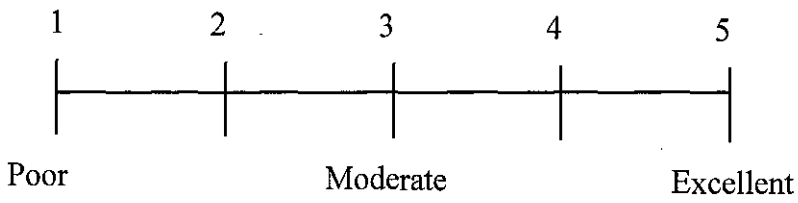
7) The level of reality for virtual environment - other environment elements such as *wind, fire, etc.*



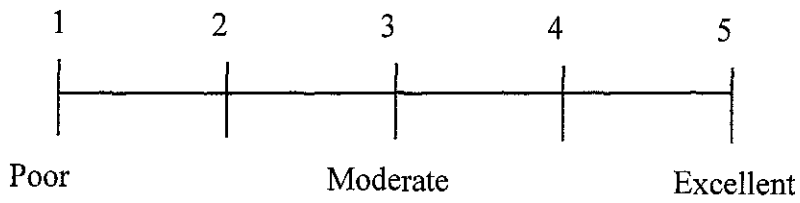
8) Be able to work with the product from start until end



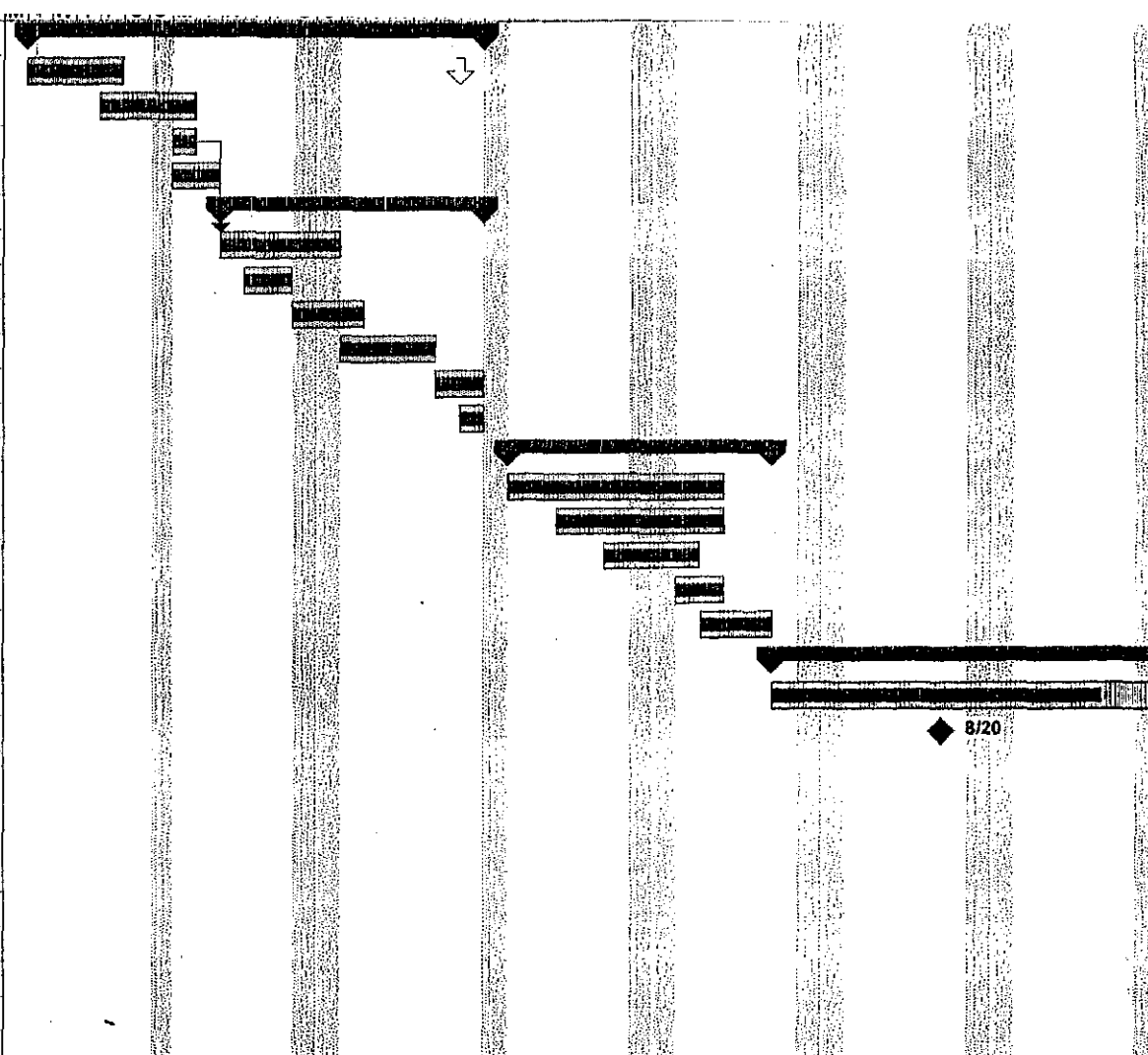
9) Enable to define the system



10) Overall performance of the system



1	✓	<b>1. Initiation Phase</b>	<b>18 days?</b>
2	✓	1.1 Define Problems, Opportunities, Directives	4 days?
3	✓	1.2 Establish Scope	3 days?
4	✓	1.3 Prepare Scope Statement	1 day
5	✓	1.4 Prepare Work Breakdown Structure	2 days?
6	✓	<b>1.5 Data Gathering and Task Analysis</b>	<b>8 days?</b>
7	✓	1.5.1 Determine Task Resources and task duration	3 days?
8	✓	1.5.2 Create Gantt Chart Draft	2 days?
9	✓	1.5.3 Review and finalize Gantt Chart	1 day?
10	✓	1.5.4 Consultation with Client	4 days?
11	✓	1.5.5 Develop detailed user requirements	2 days?
12	✓	1.6 Prepare Mitigation Plan	1 day?
13	✓	<b>2. Design Specification</b>	<b>9 days?</b>
14	✓	2.1 Study the Chemical Plant drawing	7 days
15	✓	2.2 Analysis P&ID and PFD Scheme	5 days
16	✓	2.3 Facilitate Detailed Design	2 days
17	✓	2.4 Identify Hardware and Software	2 days?
18	✓	2.5 Sketch Chemical Plant Layout for perspective view	3 days
19	✖	<b>3. Project Development</b>	<b>56 days</b>
20	✖	3.1 Modelling 3D Chemical Plant	56 days
21	✓	3.2 Submission of Progress Report	0 days
22		<b>4. Integration and Testing</b>	<b>26 days?</b>
23	✖	4.1 Integrate 3D Max model with VRML	14 days
24		4.2 Integrate VRML with Amira Inventor	7 days
25	✖	4.3 Integration Test	25 days
26	✖	4.3 Submission of Final Draft	1 day?
27		<b>5. Implementation Phase</b>	<b>4 days</b>
28	✖	5.2 Oral Presentation	2 days
29	✖	5.3 Submission of project Dissertation	1 day
30	✖	5.7 Project hand over	1 day



Final Year Project Mon 10/18/04	Task		Milestone		External Tasks	
	Split		Summary		External Milestone	
	Progress		Project Summary		Deadline	

TUAN KASMAWATI BT TUAN ABDULLAH

1	▼	1.1 Define Problems, Opportunities, Directives
2	✓	1.2 Establish Scope
3	✓	1.3 Prepare Scope Statement
4	✓	1.4 Prepare Work Breakdown Structure
5	✓	1.5 Data Gathering and Task Analysis
6	✓	1.5.1 Determine Task Resources and task duration
7	✓	1.5.2 Create Gantt Chart Draft
8	✓	1.5.3 Review and finalize Gantt Chart
9	✓	1.5.4 Consultation with Client
10	✓	1.5.5 Develop detailed user requirements
11	✓	1.6 Prepare Mitigation Plan
12	✓	2. Design Specification
13	✓	2.1 Study the Chemical Plant drawing
14	✓	2.2 Analysis P&ID and PFD Scheme
15	✓	2.3 Facilitate Detailed Design
16	✓	2.4 Identify Hardware and Software
17	✓	2.5 Sketch Chemical Plant Layout for perspective view
18	✓	3. Project Development
19	▼	3.1 Modelling 3D Chemical Plant
20	☒	3.2 Submission of Progress Report
21	✓	4. Integration and Testing
22	☒	4.1 Integrate 3D Max model with VRML
23	☒	4.2 Integrate VRML with Amira Inventor
24	☒	4.3 Integration Test
25	☒	4.3 Submission of Final Draft
26	☒	5. Implementation Phase
27	☒	5.2 Oral Presentation
28	☒	5.3 Submission of project Dissertation
29	☒	5.7 Project hand over
30	☒	



Final Year Project Mon 10/18/04	Task		Milestone		External Tasks	
	Split		Summary		External Milestone	
	Progress		Project Summary		Deadline	

TUAN KASMAWATI BT TUAN ABDULLAH

FINAL YEAR PROJECT TIMELINE

ID	Task Name	Oct 24, '04			Oct 31, '04			Nov 7, '04			Nov 14, '04			Nov 21, '04			Nov 28, '04			Dec 5, '04										
		F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F
1	1. Initiation Phase																													
2	1.1 Define Problems, Opportunities, Directives																													
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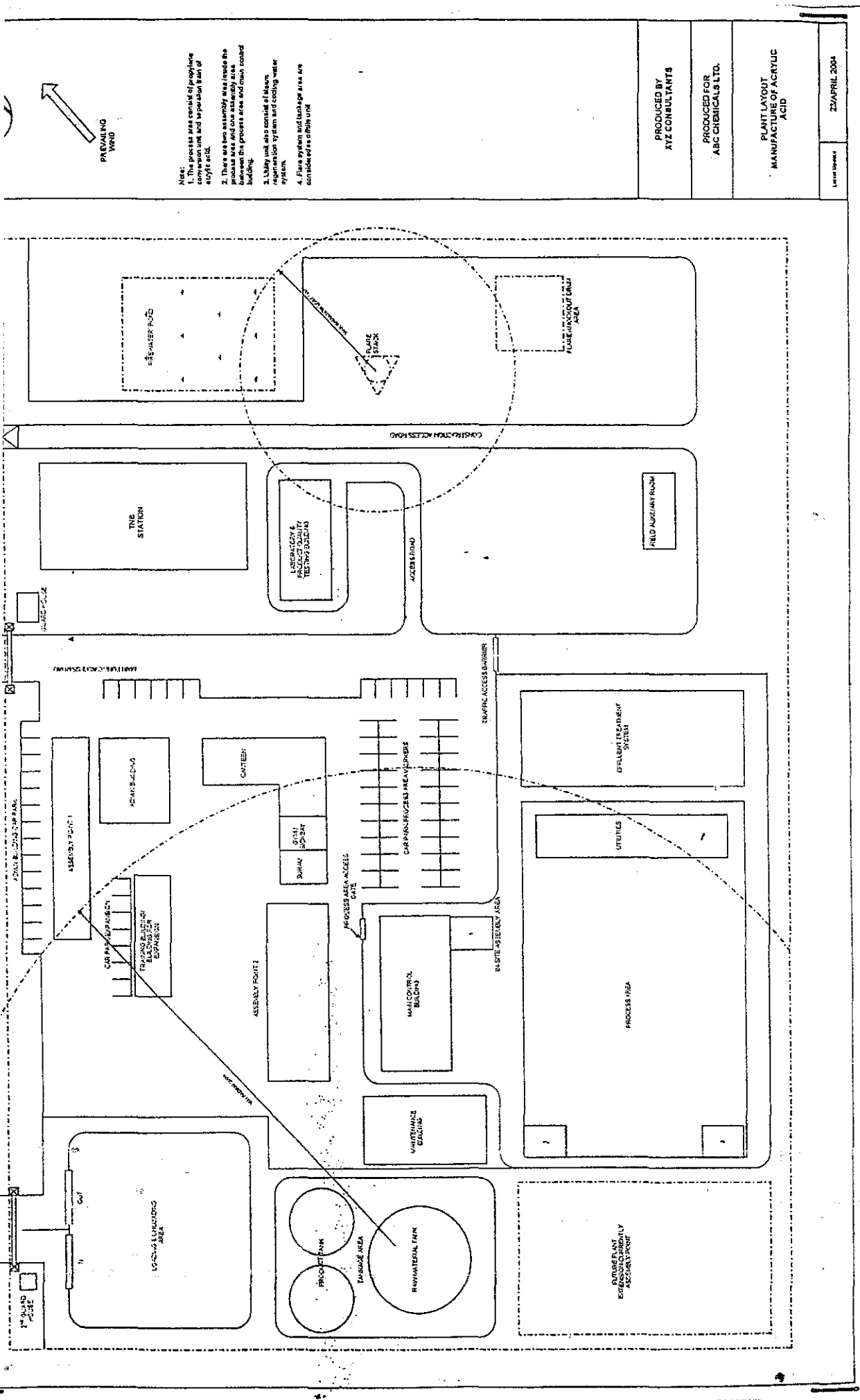
Final Year Project  
Mon 10/18/04

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

TUAN KASMAWATI BT TUAN ABDULLAH

PREVAILING WIND

- Notes:**
1. The process area consists of propylene conversion unit and polymerization of acrylic acid.
  2. There are two assembly areas inside the process area and one assembly area between the process area and main control building.
  3. Utility unit also consists of steam regeneration system and cooling water system.
  4. Flare system and tankage area are considered as a utility unit.



PRODUCED BY  
XYZ CONSULTANTS

PRODUCED FOR  
ABC CHEMICALS LTD.

PLANT LAYOUT  
MANUFACTURE OF ACRYLIC  
ACID

Issue Number: 22/APRIL 2004

# UNIVERSITI TEKNOLOGI PETRONAS

## Bandar Seri Iskandar, Perak

Final Year Design Project – Semester January 2004

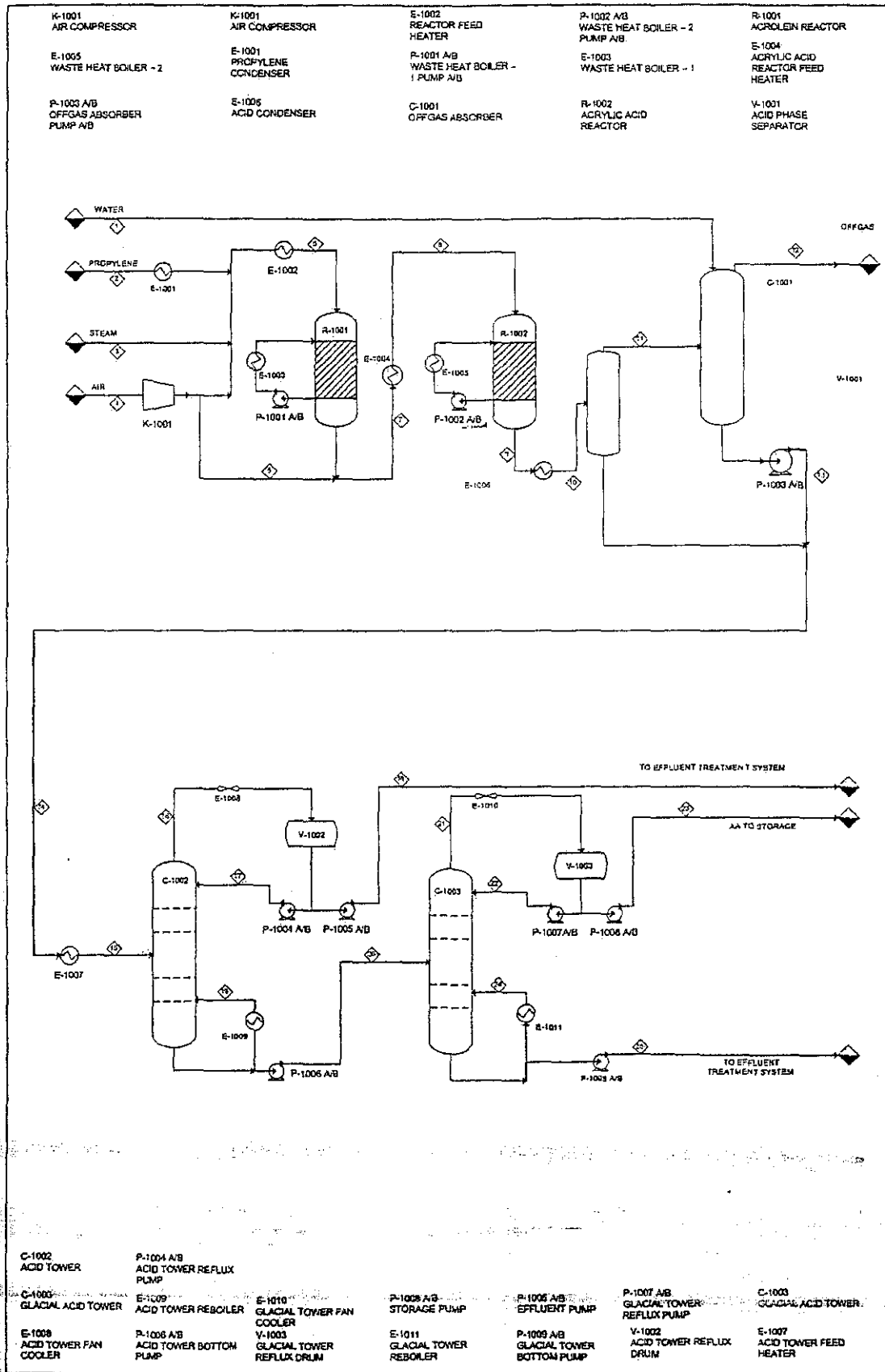
Group 11 :

Vimal Gopinadhan, Nur Anirah Abd Rahman, Azlan Shah Hussain, Nor Sharihan Md Saad

Supervisors :

A.P Dr Isa, Risza Rusli, Suriati Sufian, Ng Tze Ling

TI  
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AS



PROCESS FLOW DIAGRAM (PFD)





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PETRONAS

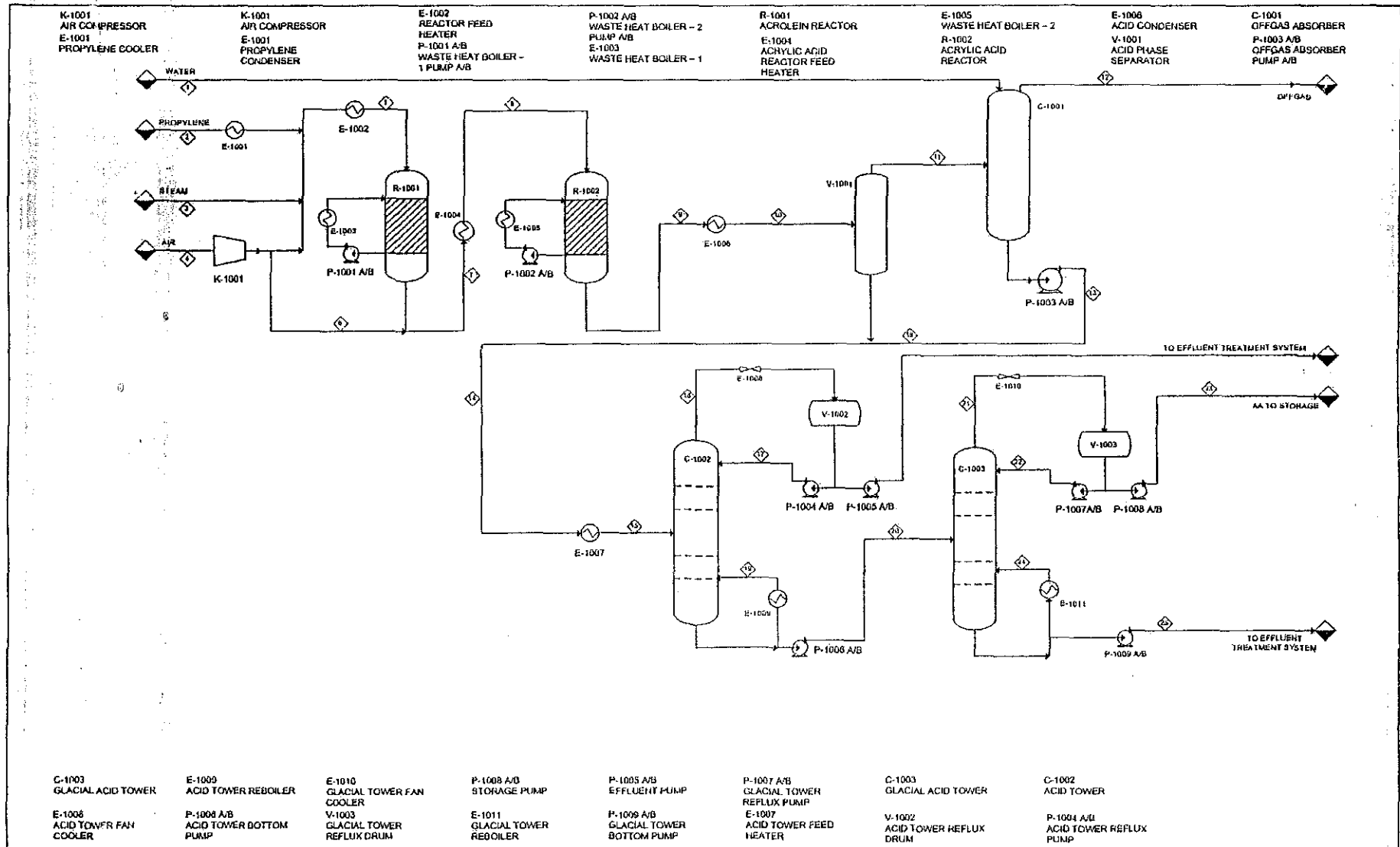
### Final Year Design Project – Semester January 2004

Group 11 :

Vimal Gopinadhan, Nur Anirah Abd Rahman, Azlan Shah Hussain, Nor Sharihan Md Saad

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PROCESS FLOW DIAGRAM (PFD)



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TEKNOLOGI  
PETRONAS

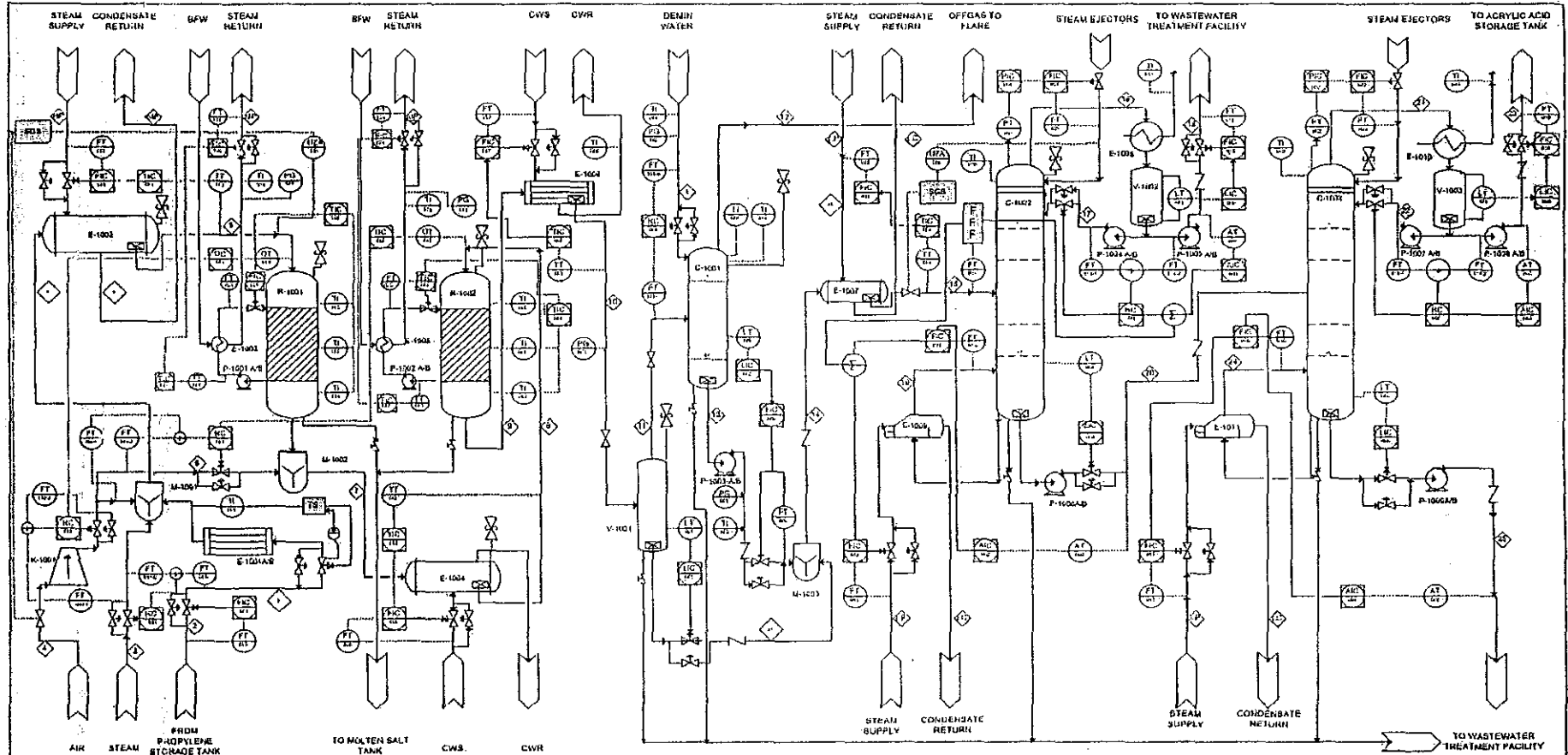
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Supervisors :

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NOMENCLATURE

	Temperature Indicator		Pressure Gauge		
	Temperature Transmitter		Pressure Transmitter		
	Temperature Controller		Pressure Controller		
	Flow Transmitter		Mass Controller		

PIPING AND INSTRUMENTATION DIAGRAM (P&ID)