

# **CERTIFICATION OF APPROVAL**

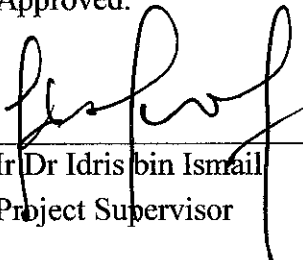
## **3D VIEW OF HAZARDOUS AREA CLASSIFICATION USING OPEN SOURCE**

by

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January 2011

## **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 the original work contained herein have not been undertaken or done by unspecified sources or persons.



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Nur Anis bte Ramle

## **ABSTRACT**

This paper presents a development of 3D view of hazardous area classification using the open source of 3D simulation software, Art of Illusion, for minimum cost implementation. The 3D simulation is meant to complement the existing 2D drawing for better hazardous area classification and visualization. The 3D simulation is developed based on the IEC 60079-10 hazardous area guideline. It is intended as user friendly tools that can be easily used for area hazard analysis such as identifying the hazard level and the presence of ignition sources to keep the level of safety at the highest level. The assessment for the process plant is focus on Crude and Distillation Unit which typical product are gasoline, diesel fuel, asphalt base, kerosene, and heating oil and liquefied petroleum gas. The area classification visualization used the zone classification as the color code i.e. for Zone 0 is red, Zone 1 is yellow and Zone 2 is green. The color code is developed based on the zone in present of flash point, ignition temperature, explosive limit, and vapor density. Finally the extent of the hazardous zones will be determined based on ideal spherical ball dispersion. Currently case study have shown different gases with different properties will give different value of release mass and extent of zone. Current works have shown that the layout of the process plant can be view from 360 degrees or from the 3D view. Thus user would be able to rotate the view to assess the overall area of the hazard zones including the extent of the zones.

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## **LIST OF ABBREVIATIONS AND NOMENCLATURES**

<b>IEC</b>	International Electrotechnical Commission
<b>OSHA</b>	Occupational Safety and Health Administration
<b>ATEX</b>	ATmosphères EXplosibles
<b>EN</b>	European standards
<b>DSEAR</b>	Dangerous Substances and Explosive Atmospheres Regulations
<b>LEL</b>	Lower Explosive Limit

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

The process plant has the highest possibility for the incident of fires and explosion which is the reason why the area classification is carried out. Regulatory bodies like Occupational Safety and Health Administration (OSHA) have established systems that classify locations which exhibit potentially dangerous conditions to the degree of hazard presented. [1]

OSHA Publication 3073 defines a hazardous location as follows:

*Hazardous locations are areas where flammable liquids, gases or vapours or combustible dusts exist in sufficient quantities to produce an explosion or fire. In hazardous locations, specially designed equipment and special installation techniques must be used to protect against the explosive and flammable potential of these substances.*

The first action need to be done is to identify the source of release of the flammable gas or vapour. These flammable gas or vapour may arise as result from the constant activities, from time to time in normal operation or due to the unplanned event. Even though there are no source of release, the process equipment may also be consider as hazardous area if the both component which are the gas/vapour and air are present.

A flammable mixture must be preventing from being released to the atmosphere and the possible ignition of flammable or explosive atmospheres must be preventing. The electrical equipment need to have special protection to prevent from releasing the flammable mixture to the air. The ignition will only occur when both the flammable atmosphere and the means for an ignition exist simultaneously. It is very important to safeguard both the installation of the plant and the human life [2].

The Fire Triangle must be avoided at all cost where it contains three ingredients which together will give rise to an explosion. It is consists of the combination of the flammable material, air and ignition source. The figure below shows the sign of Fire Triangle. [2]



**Figure 1: The Fire Triangle**

The most commonly used standard in the UK for determining area extent and classification is BS EN 60079-10. It is apparent that direct link between the amounts of flammable vapor that may be released, the ventilation at that location, and the zone number. It contains a simplistic calculation relating the size of zone to a rate of release of gas or vapor.

The 3D simulation process plant is developed through the process of developing a mathematical representation of any three-dimensional surface of object [3]. This can be done using the specialized software. Unfortunately, there is no software available at this moment for this kind of purpose. The only reference for the

hazardous area is the 2D drawing. The purpose of having the simulation is to allow very flexible control over the scene and animation. The user can rotate the process plant in any angle unlike the 2D drawing.

In extending the hazardous area classification procedure, many steps and thought need to be taken. First step is to identify the flammable atmosphere and the question should be asked to whether it can be reduced, both in extent and frequency. Then the assessment of all possible ignition sources should be carrying out. The electrical ignition source should not be the only one to be considering when others of potential ignition source are exists.

The table below shows a matrix approach in common with some other qualitative risk assessment methods. The matrix is designed to assist with judging the acceptability of a given situation. [4]

**Table 1: Hazardous Area Classification based risk assessment matrix**

<b>Grade of Release</b>	<b>Grade of Ignition</b>			
	<b>Continuous</b>	<b>Frequent</b>	<b>Infrequent</b>	<b>Very Infrequent</b>
<b>Continuous</b>	Explosion	Unacceptable	Unacceptable unless low consequences	Acceptable
<b>Primary</b>	Unacceptable	Unacceptable	Risk assessment required – look at consequences	Acceptable
<b>Secondary</b>	Risk assessment required – look at consequences but probably unacceptable	Risk assessment required – look at consequences	Acceptable	Acceptable
<b>Non-hazardous</b>	Acceptable but examine catastrophic releases	Acceptable but examine catastrophic releases	Acceptable	Acceptable

## **1.2 Problem Statement**

The areas are classified based from the source of release and the flammable materials. The electrical equipment will need to meet the requirement such as the type of protection and temperature class, in order to be installed in the specific zone. Take into consideration that the process equipment also gives contribution when at the design stage of the hazardous area since the process equipment could be the source of release.

After some time the process plant will experience the expansion process and thus new electrical equipment need to be install to give better performance for the productivity of the process plant. Installing the new electrical equipment is a not an easy task since the process plant is running and a lot of consideration must be taken since the safety of the employees is very important as well as the productivity of the process plant itself. It is impossible to shut down the process plant for the purpose to install the new electrical equipment because the process plant wills loss.

The only reference for the hazardous area classification is the 2D drawing that is made at the earlier stage when the process plant is designed. There is some probability that the drawing is not updated. Thus a lot of consideration and time will be taken to complete the job of installation. The personnel in charge for the installation job need to fully understand the 2D drawing which is not an easy task because of limited information provided.

## **1.3 Objectives and Scope of Study**

### *1.3.1 Objectives*

The main objectives of this project is to design a 3D simulation of hazardous area classification and in order to achieve that, the list below are sub-objective which are:

- i. To review hazardous area classification, specification and standard to relate to extending area of zone as the concept about the hazardous area classification is wide and different for each country. It is necessary to choose which standard to be followed.
- ii. To design 3D simulation that can communicate with the user to define the zones and differentiate the zones with different colour. The blank process plant will be classified by the user and the simulation will help the user to get better analysis about the hazardous area classification.
- iii. To develop 3D layout that provides the user with the data of the specific area as the calculation for extent of the area will be provided to the user and some other important information's.

### *1.3.2 Scope of Study*

This project is intended to design a 3D plant that simulates the real existing process plant. The user will define the area in the process plant as Zone 0, Zone 1, or Zone 2. Then the area of the zone will change into different colour which is red for Zone 0, yellow for Zone 1 and green for Zone 2. The target of this project is when an electrical equipment want to be install in the process plant, there will be an immediate indication stated the status of the equipment whether it is in the correct zone or not. Installing correct equipment in the correct place is very important as in the process plant safety comes first.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Area Classification**

A hazardous area is an area in that contains an explosive atmosphere is, or may be expected to be, where it presents in quantities such as to require special precautions for the construction, installation and use of electrical equipment [5].

There are two main purposes of performing the area classification which is to identify the possibility of an explosive atmosphere existing in the particular area and to give appropriate guideline in designing the plant in order to minimize such risks.

The areas can be classified as a hazardous location is based on the following criteria: [6]

- i. The possible presence of an explosive atmosphere such as flammable gases, vapours or liquids, combustible dusts or ignitable fibers and flying.
- ii. The likelihood with the present of explosive atmosphere when equipment is operating.
- iii. The ignition-related properties of the explosive atmosphere that is present.

New approach has been introduced by IEC 60079-10 known as “source of hazard method” to trade the conventional method of area classification. The evaluation for the plant by restricting the size of hazardous areas is achievable if each source of release and the characteristics of release at that point are identified.



## **2.2 Explosive Atmosphere**

The definitions of an explosive given by the Health and Safety Executive, is a mixture, under atmospheric conditions, of air and one or more dangerous substances in the form of gases, vapors, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture. [7]

The ATEX directive does not define atmospheric conditions, but normally a temperature range of -20 °C to +60 °C and a pressure range of between 0.8 and 1.1 bars is accepted. It should be noted that electrical products are usually designed and tested for use in an ambient temperature range of -20 °C to +40°C in conformity with EN 50014.

## **2.3 Source Ignition**

The ignition will only happen if the right amount of energy is present and the amount of energy required is dependent upon these factors:[1]

- i. The concentration of the hazardous substance within its specific flammability limits
- ii. The explosive characteristics of the particular hazardous substance
- iii. The volume of the location in which the hazardous substance is present

There could be several sources of ignition in hazardous areas. Some of the common sources of ignition are:

- i. Heat
- ii. Electrical sparking
- iii. Mechanical sparking
- iv. Flames
- v. Hot gases coming out of a junction box
- vi. Transient currents
- vii. Static charges

## 2.4 Zone Definition

DSEAR defined the hazardous areas as “any place in which an explosive atmosphere may occur in quantities such as to require special precautions to protect the safety of workers”. [1]

Area classification is a method of analyzing and classifying the environment where explosive gas atmospheres may occur. The main purpose is to facilitate the proper selection and installation of apparatus to be used safely in that environment, taking into account the properties of the flammable materials that will be present. DSEAR specifically extends the original scope of this analysis, considering non-electrical source of ignition and mobile equipment that creates an ignition risk.

Hazardous areas are classified into zones based on an assessment of the frequency of the occurrence and duration of an explosive gas atmosphere, as follows:

- i. Zone 0 : An area in which an explosive gas atmosphere is present continuously or for long periods
- ii. Zone 1 : An area in which an explosive gas atmosphere is likely to occur in normal operation
- iii. Zone 2 : An area in which an explosive gas atmosphere is not likely to occur in normal operation and, if occurs, will only exist for a short time

Various sources have tried to place time limits on to these zones, but none have been officially adopted. The most common values used are: [12]

- i. Zone 0 : Explosive atmosphere for more than 1000 hour/year
- ii. Zone 1 : Explosive atmosphere for more than 10, but less than 1000 hour/year
- iii. Zone 2 : Explosive atmosphere for less than 10 hour/year, but still sufficiently likely as to require controls over ignition sources

The remainder of the hazardous areas of the process plant that has not been classified will be defined as non-hazardous area or well known as safe areas. The figure below shows the classification used to describe the various grades of hazardous area.

## **2.5 Group Definition**

The explosive characteristics of the air mixture of gases, vapors, or dusts vary with the specific material involved. Materials have been placed in groups based on their ignition temperatures and explosion pressures. Electrical apparatus for potentially explosive atmospheres is divided into two groups per EN 50014: [1]

- i. Group I : Electrical apparatus for mines susceptible for firedamp (for use underground) where methane and coal dust are present
- ii. Group II : Electrical apparatus for places with a potentially explosive atmosphere, other than mines susceptible to firedamp which is the surface industries.

The Group II gases are sub-grouped according to their volatility. This enables electrical equipment to be designed to less onerous tolerance if it is to be used with the least volatile gases. The table of the IEC Gas Group with its typical gases can be referring at APPENDIX B.

## 2.6 Temperature Classes

A mixture of air and hazardous gases may ignite by coming in contact with a hot surface. An ignition depends on surface area, temperature and the concentration of the gas [2]. Refer to the temperature class table at APPENDIX C which it shows the maximum surface temperature of each classification. The list of the surface temperature is based on a surrounding ambient temperature of 40 degrees Centigrade. The suitability for the equipment to be used in the area can be reached by comparing the surface temperature and the ignition temperature of the gas/gases which may come into contact with the equipment.

If the hazardous area in which the installing equipment has gases or vapours with a low auto ignition temperature then the equipment must have bigger T number to ensure that any hot surfaces on the equipment will not ignite the hazard [8].

For example, if a hazard has an auto ignition temperature of 180°C, then it would be safe to use equipment which is marked T6 or T5 or T4. It would not be safe to use equipment marked T3 or T2 or T1 as this equipment could exhibit surface temperatures which are hot enough to ignite the hazardous atmosphere [8].

## 2.7 Source of Release

Each potential source of release of flammable including the process equipment should be considered. The grade of release is required to be determining if the equipment has established that it may release flammable material into the atmosphere. The grade is based on the probable frequency and duration of release. The sources of release are classified based on following basis: [9]

### 1) Continuous grade of release

An explosive atmosphere could be formed during the continuously or for long periods of release of the flammable gas, flammable vapour, flammable mist or combustible dust into the atmosphere.

### 2) Primary grade of release

An explosive atmosphere could be formed during the periodically or occasionally in normal operation of released of the flammable gas, flammable vapour, flammable mist or combustible dust into the atmosphere.

### 3) Secondary grade of release

This is a point or location from which flammable gases, flammable vapour, flammable mist or combustible dust is not expected to be released in normal operation, but at which release may be expected in frequently and for short periods or where dust layers form to an extent such that if disturbed an explosive atmosphere would be formed.

## 2.8 Degree of Ventilation

The effectiveness of the ventilation in controlling dispersion and persistence of the explosive atmosphere will depend upon the degree and availability of ventilation. There are three degrees of ventilation as shown on following: [10]

### 1) High Ventilation

Can reduce the concentration at the source of release virtually instantaneously, resulting in a concentration below the lower explosive limit (LEL)

### 2) Medium Ventilation

Can control the concentration, resulting in a stable situation in which the concentration beyond the zone boundary is below the LEL while release is in progress

### 3) Low Ventilation

Cannot control the concentration while release is in progress and cannot prevent undue persistence of a flammable atmosphere after release has stopped

The extent of the zone will be reduced with the increase of ventilation. Obstacles that impede the ventilation may increase the extent of the zone but some obstacles may also limit the extent of the zone such as walls or ceilings. There are two types of ventilation that has been practise which is the freely ventilated and not freely ventilated.

For freely ventilated situation, general method when classify an area is by calculating extent of the hazardous area. The source of hazard need to be identified and types of releases.

## 2.11 Calculation of release rates and extent of hazardous area

The orifices are designed to ensure the maximum flow for minimum effort. Thus these mathematical approaches are built around calculation of fluid flow from orifices. [6]

### 2.11.1 Release of gas and vapour

The mass release of gas from an orifice can be calculated using the Equation 4. This equation is only valid if upstream absolute exceed  $2 \times 10^5 \text{ N/m}^2$ , if not consideration should be taken about the diffusion effect since the effect of atmospheric is significant.

$$G = 0.006aP\left(\frac{M}{T}\right)^{0.5} \text{ kg/s} \quad (4)$$

Where,

- $G$  mass release, kg/s
- $a$  cross-sectional area of leak,  $\text{m}^2$
- $P$  upstream pressure,  $\text{N/m}^2$
- $M$  molecular weight
- $T$  absolute temperature of released gas, K

The volume of released gas  $V$  can be calculated using the equation shown,

$$V = \frac{V_0 GT}{T_0 M} \quad (5)$$

Where,

- $V_0$  molar volume,  $\text{m}^3/\text{kg}$
- $T_0$  melting point of ice, 273 K

Then substituting both values, the formula will be simplify as,

$$V = \frac{0.082GT}{M} \quad (6)$$

As the target is to find the extent of hazardous area, the distance 'X' of the gas and vapour traversing falls below LEL, which is already mixing with the air can be calculated equation the equation below provided that the jet velocity is sufficiently high as compared to air/wind speed.

$$X = 2.1 \times 10^3 \left[ \frac{G}{E^2 M^{1.5} T^{0.5}} \right]^{0.5} \quad (7)$$

Where,

$E$  lower explosive limit (LEL), %

If the difference between the jet velocity and the air/wind speed is reduces, the distance can be calculated using equation below as it is based form experimentation where,

$$X = 10.8 \left( \frac{GT}{ME} \right)^{0.55} \quad (8)$$



### 2.11.2 Obstruction to the gas and vapour release

There is a possibility that there is presence of a barrier or an object during the release of gas or vapour. The volume need to be calculated first using equation below in order to determine the distance  $X$ .

$$B = 100 - L \left[ \frac{(100 - LEL)}{X} \right] \dots \% \quad (9)$$

Where,

$B$       % gas/vapour in air

$L$       distance to obstruction

$X$       distance to LEL

Then the new effective molecular weight can be calculated since the volume ratio is known. After obtaining the result from the calculation below, the new dispersion distance can be finding using Equation 8.

$$M_{(mixture)} = \left[ \frac{M_{(gas)} \times \%_{(gas)}}{100} \right] + \left[ \frac{M_{(air)} \times \%_{(air)}}{100} \right] \quad (10)$$

$$V_{(gas)} = \frac{0.082GT}{M_{(gas)}} \quad (11)$$

$$V_{(mixture)} = V_{(gas)} \times \left[ \frac{100}{\% \text{ gas in mixture}} \right] \text{m}^3 \quad (12)$$

$$G_{(mixture)} = V_{(mixture)} \times \frac{12.19M_{(mixture)}}{T \text{ kg}} \quad (13)$$

$$LEL_{(mixture)} = LEL_{(gas)} \times \left[ \frac{100}{\% \text{ gas in mixture}} \right] \% \quad (14)$$

## **CHAPTER 3**

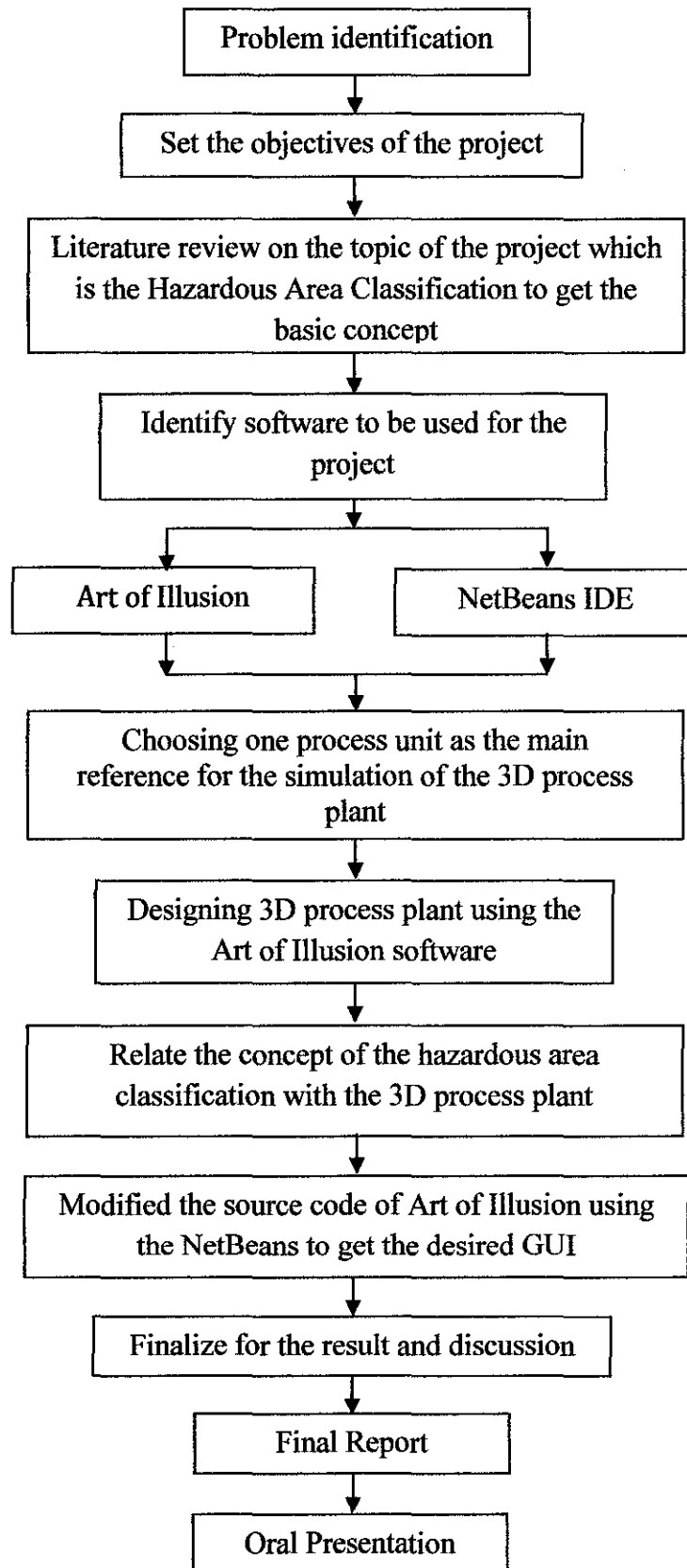
### **METHODOLOGY**

#### **3.1 Procedure Identification**

First step is to identify the problem that normally occurred and find a solution for a better performance. In this project, the problem occurs is the installation of the electrical equipment in the process plant. Electrical equipment can cause ignition by spark or hot surfaces. This ignition will then complete the Fire Triangle thus exposing the process plant into danger situation. In order to avoid this situation, the electrical equipment will have various type of protection and must meet certain requirement in order to be installing in the process plant.

The objective of this project has been stated earlier in this report and so does the literature review about this project. Basically this project is conduct to make a 3D simulation process plant that will make it easier for the process of installing the electrical equipment. The basic of the process plant will be divided into various zones that normally applied to the real plant which is Zone 0, Zone 1, Zone 2 and non-hazardous area.

There are many 3D software has been develop nowadays but there is no precise 3D software has been develop for this project. So a modification is needed for the 3D software has been used to get the desired result. The 3D software is used to make the simulation process plant and as for now the Art of Illusion has been chosen to be the main software for this project. As starting for this project, one process unit is built through the 3D software and will be used as reference. Later on, the process unit will be expanding to make it the same as the real process plant.



**Figure 2: The flow chart of project**

As the 3D software needs some modification, the programming software will be used. The NetBeans fits the objective of this project. It can create the dialogue boxes that are desired and change the colour of the area. This is crucial because it will give better view and understanding for the user to analyze the zone of the area.

The concept of the hazardous area will then be related with the 3D process plant. The idea is to have made a division area between each zone and it can be done by distance. The concept of classification is very important and will be implemented here. Not to mention the other factors that will contribute to area classification. Each zone can be recognised through the different colour when the cursor touches the zone. The final result is based from the capability of the software used as many modification need to be done to accomplish this project.

### **3.2 Methodology**

There are a number of discrete steps that need to be completed in order to arrive at the hazardous area classification for a process plant. The basis of the work procedures are as following:

- i. Identify the point sources of release
- ii. Determine the grade of release and fluid category
- iii. Establish zone classification
- iv. Determine hazard radius
- v. Preparation of hazardous area drawing
- vi. Hazardous area classification review

### *3.2.1 Identification of source of release*

The starting point for any area classification is to determine all the potential source of release. The source of release is determined by the following key document:

- i. Equipment list
- ii. Piping and instrument diagrams
- iii. Heat and material balance
- iv. Plot plan

The other potential source of release should be consider, for example oily water drain system, drain hubs and vent pipes, vents from balanced bellows relief valves and analyser vents.

It is significant that all continuous, primary sources and secondary sources which are likely to have an impact on the extent of Zone 2 outside the plant boundary are identified at an early stage. Small secondary releases within the process plant are less important, as they are unlikely to have an impact on the extent of hazardous zones.

### *3.2.2 Determine the grade of release and fluid category*

The grade of a source is dependent on the likely frequency of release. The grades are defined in IP15 as continuous, primary or secondary. [13]

Continuous release is considered, as a rule of thumb, for instances where it is likely to be present for a period in excess of 1000 hours per year, primary releases for between 10 and 1000 hours per year, and secondary for less than 10 hours.

Primary grades when releases are present for less than 10 hours but occur on a frequent basis during normal operation. The table below shows the fluid category defined in IP15:

**Table 2: Fluid category based on IP15**

<b>Fluid Category</b>	<b>Description</b>
A	A flammable liquid that on release would vaporise rapidly and substantially. This category includes: <ul style="list-style-type: none"> <li>a) Any liquefied petroleum gas or lighter flammable liquid</li> <li>b) Any flammable liquid at a temperature sufficient to produce on release more than about 40% vaporisation with no heat input other than from the surroundings</li> </ul>
B	A flammable liquid not in Category A, but at a temperature sufficient for boiling to occur on release
C	A flammable liquid not in categories A or B, but which can, on release, be at a temperature above its flash point, of form a flammable mist or spray
G (i)	A typical methane-rich natural gas
G (ii)	Refinery hydrogen
Unclassified	Heavy oils with flash point greater than 100 °C handled at a temperature below flash point, which will not form a mist or spray on release

### 3.2.3 Establish zone classification

The following zones depending on the grade of release apply to for an open and freely-ventilated area:

- i. Continuous : Zone 0
- ii. Primary : Zone 1
- iii. Secondary : Zone 2

### 3.2.4 Determine hazard radius

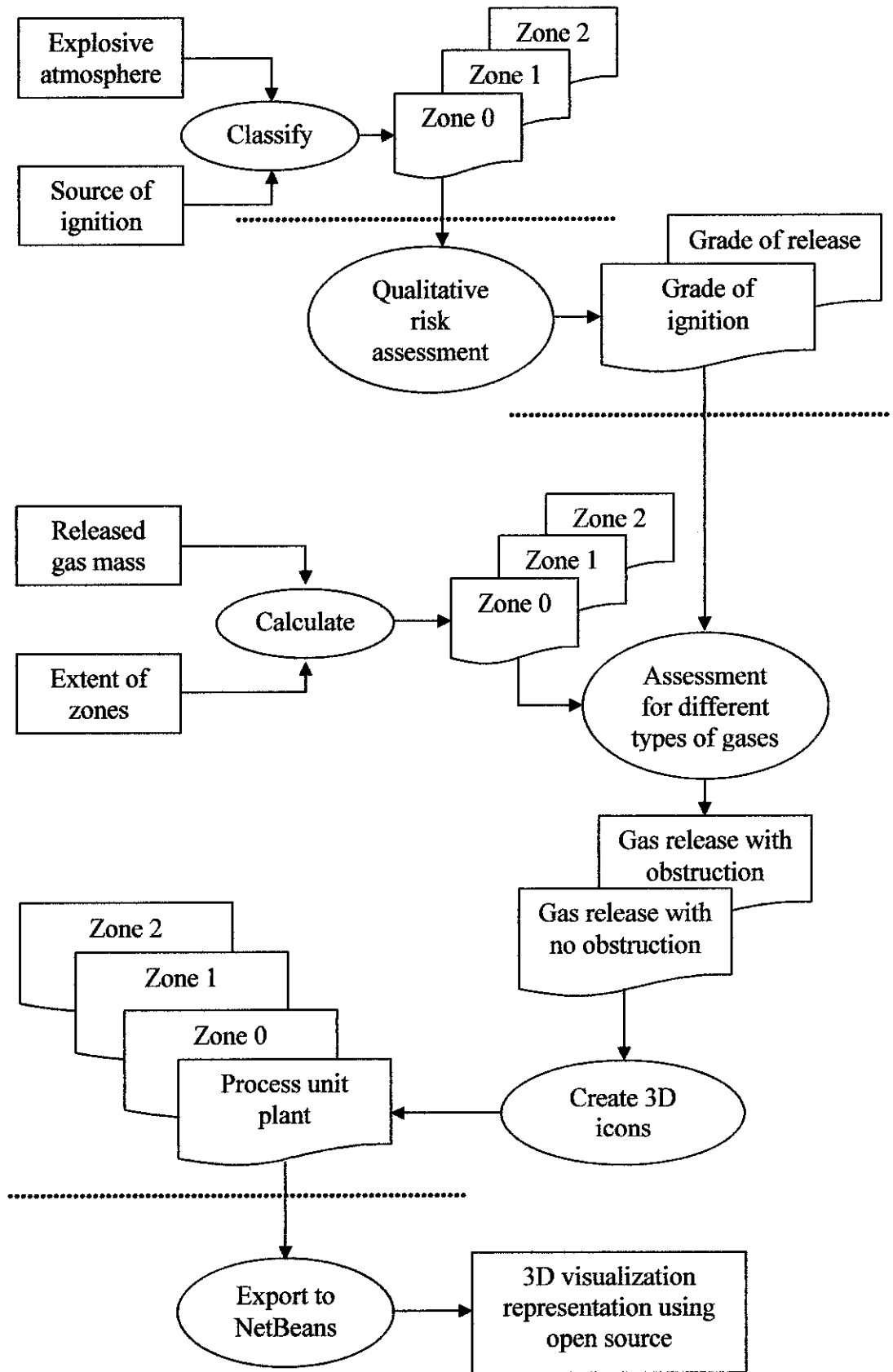
The method used to determine a hazardous radius is dependent on the grade of release.

The tables within IP15 section 5 is used as reference for primary and continuous releases where the potential leaks sizes and fluid categories are within the

limits. For cases outside the limits, it is necessary to undertake dispersion modelling to determine the extent of a flammable cloud.

For a secondary grade releases it is first necessary to determine the level of release, and then to determine the hazardous radius either directly from IP15 or from dispersion modelling.

The overall procedures for the hazardous area classification involve the understanding of the concept and calculation to determine the degree of hazardous. The classification starts from the basic concept, calculations until it will be converted into 3D using the NetBeans and Art of Illusion or any other open source. Figure 3 depicts this process graphically.



**Figure 3: Flowchart representing the process**



### 3.3 Tools and Equipment used

Based on the objective of the project, the software is used to develop the 3D simulation process plant. There is no exact software built yet for this kind of project. There is variety of software used in this project in order to get the desired output and by the end of discussion and trials; the Art of Illusion is chosen to be the main software to build the 3D simulation process plant. The NetBeans IDE is the programming software with the purpose of modifying the Art of Illusion to modify the main software to fit the objective of the project.

#### 3.3.1 *Art of Illusion*

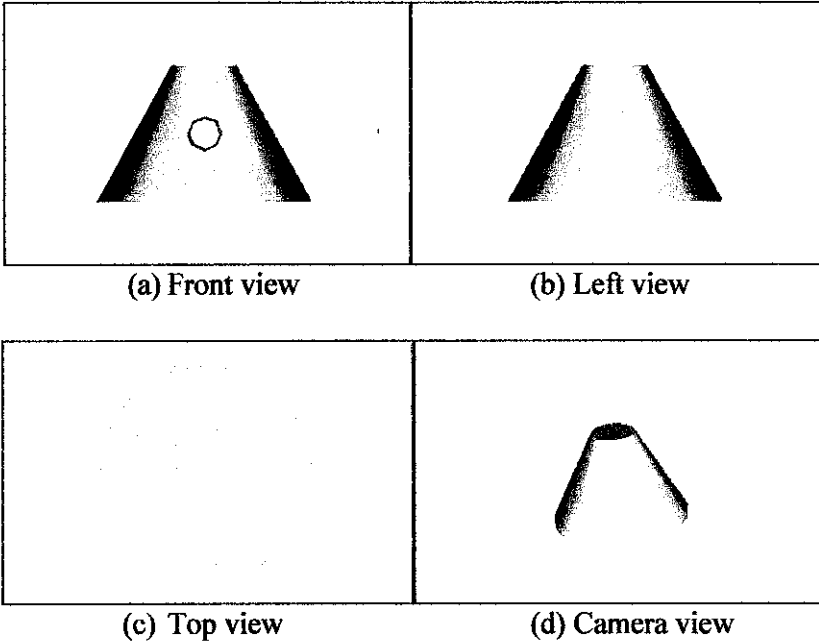
The Art of Illusion is a software package used for 3D modelling, texturing, ray tracing, and otherwise rendering computer generated imagery stills or animations [14].

The objective of the Art of Illusion is to provide powerful 3D modelling tools with a user interface that improves on those found in other 3D software packages. Though its interface is simple, this application contains many features found in high-end commercial graphics software [14].

This software enables the user to have view of the 3D simulation process plant from 360 degrees or from the 3D view since it has four different windows. Beside, the user can also rotate the view to assess the overall area of the process plant.

The software is preferred as compare with the other 3D software is due to its flexibility and ease of rendering. This software also easy to be understands and learns for the new beginner. The flexibility including the command to makes modification to the original software in order to fits the objective of the project.

The figure below shows the interface in the Art of Illusion where it provides four different windows that enables the users to experience different angle of view. The user can choose at which angle to view as Art of Illusion offer view from Front, Back, Top, Bottom, Left, Right and Camera view. The object can also be rotate with 360 degree and this should give advantages to get better observation.



**Figure 4: Example of variety object view in Art of Illusion**

### 3.3.2 *NetBeans IDE*

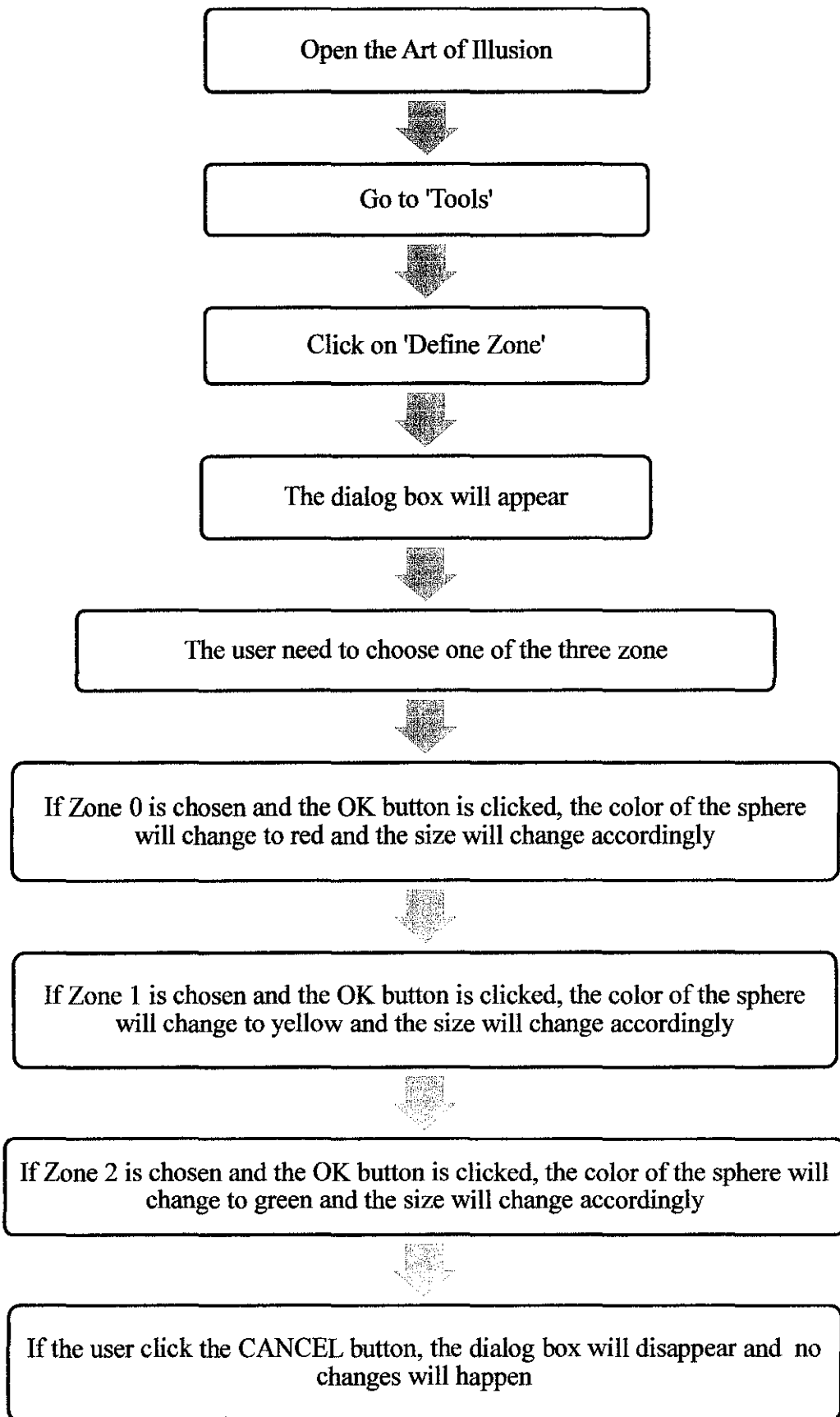
The NetBeans IDE is an open-source integrated development environment. It supports development of all Java application types out of the box. [15]

This software will be used to create the GUI for the 3D simulation process plant. The NetBeans IDE will create the dialog box for the user to enter the input which is the type of zone for the area. Then the colour of the area will be change based from type of zone. This is essential for the user because they can easily recognize the types of zones based on the colour.

All the hard work of programming will be done through this software. The target is to provide the user with all the data about the area that has been classified so that the user can learn the reason for every classification and not just accepting the fact.

So the NetBeans is used to make the GUI which is the dialog boxes and the user need to define the type of zone which later on will change the colour of the area based on the type of zone. The information of the area that will be covered is the types of gas, molar weight, ambient temperature, the pressure and etc.

The next flow chart shows the procedure taken to define the zone. This procedure is to be found at the Art of Illusion but it is being control by the programming that is been done through the NetBeans. The Art of Illusion used now is not the original software but has been modified through the NetBeans where all the desired features have been added. The source codes for this part can be referring at APPENDIX F and APPENDIX G.



**Figure 5: The flow chart to define the zone**

## **CHAPTER 4**

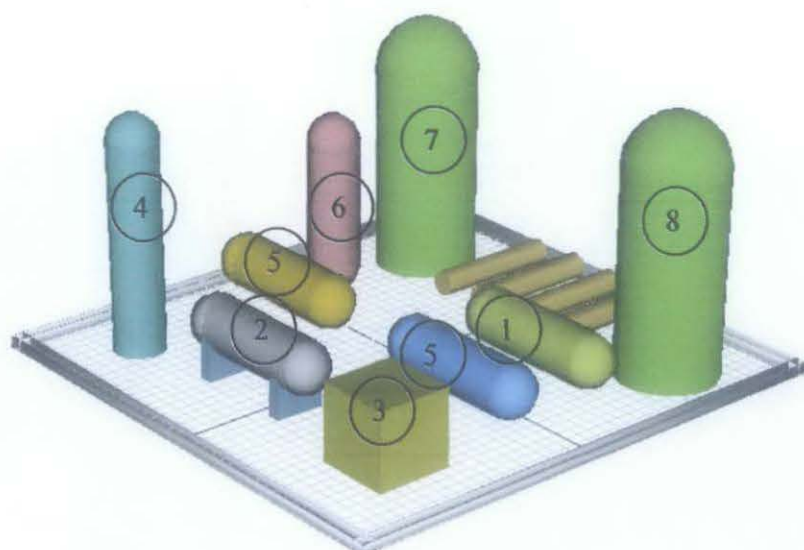
### **RESULTS AND DISCUSSION**

#### **4.1 Decision features**

The final features of the 3D process plant will have a complete process plant with all the process units inside it. Each unit will have its own parameter where it contains the data of the product, gases and key attributes to the unit. Each zone will be distinguished by different colour every time the cursor touches the area.

The initial stage of this project is by creating a 3D process plant. Since the real process plant including a lot of process unit so for this project, it will focus on the Crude and Vacuum Distillation Unit first. The figure shows the 3D plant simulation using the Art of Illusion software. The following are the process equipment in the unit is the summary of the sub-units within these two units which based on numbering:

- 1) Preheat train
- 2) Desalter
- 3) Furnace
- 4) Crude Charge Heater
- 5) Pumparounds
- 6) Stripper
- 7) Crude Distillation Column
- 8) Vacuum Distillation Column

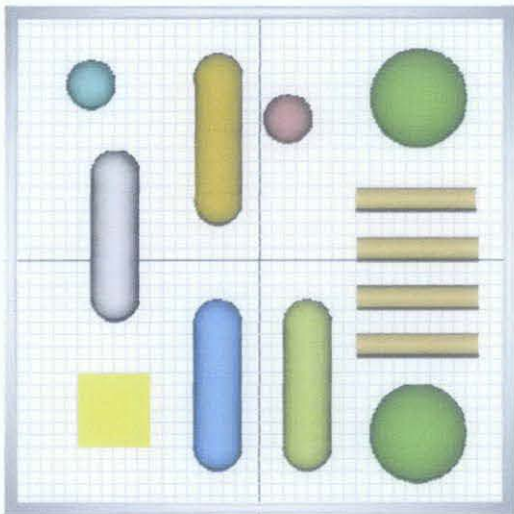


**Figure 6: Crude and Vacuum Distillation Unit**

The next step is to classify the 3D process plant into hazardous area classification. As mention earlier, a hazardous area is one in which a flammable mixture of gases or vapours may exist [16]. Identification of the flammable substances is the first step to starts the area classification for the process plant.

The Crude and Vacuum Distillation unit fractionates raw crude to produce components which are used as feed in downstream units. The products formed from the Crude Distillation Unit (CDU) are the unit's overhead gasses which consist of liquefied petroleum gas (LPG) and the full range of naphtha, kerosene, light gas oil and atmospheric residue. The Vacuum Distillation Unit (VDU) is designed to allow continuous processing of atmospheric residue. The products formed are sour water, light vacuum gas oil, medium vacuum gas oil, heavy vacuum gas oil and vacuum residue.

The figure below shows the top view of the 3D process plant of the Crude and Vacuum Distillation Unit.



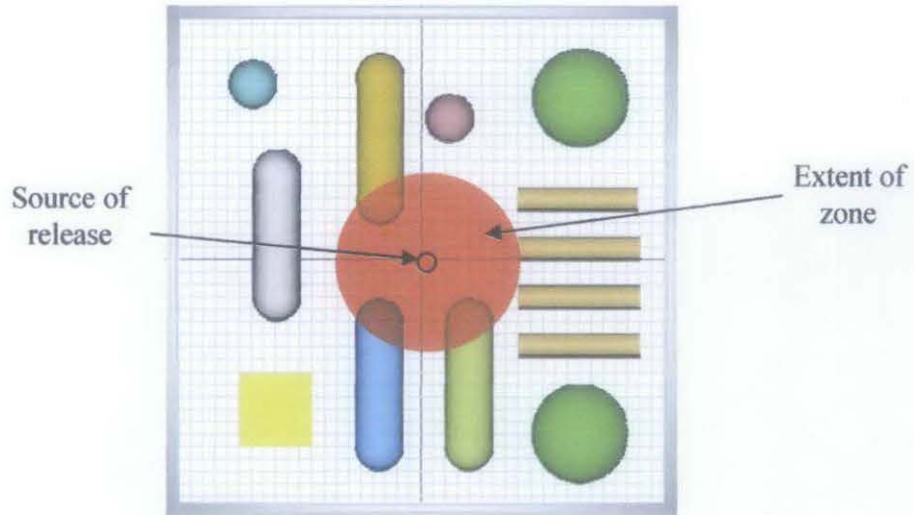
**Figure 7: Top view of the Crude and Vacuum Distillation Unit**

**4.2     Extent of hazardous area based on gas release with no obstruction**

Consider a situation where there is a gas released due to leakage from a pipe flange gasket. Thus a rapid expansion and fall in pressure will takes place. The probably way the envelope of explosive and flammable gases will develop during mixing stage. While the likelihood of area till which place the hazardous area will extent. So the aim is to find the distance which is extending of hazardous area.

**Table 3: Data information gathered**

Type of Gas	Ethylene
Molar weight	28
Ambient temperature	22 °C
Size of orifice	$4 \times 10^{-5} \text{ m}^2$
The pressure in pipe	$4 \times 10^5 \text{ N/m}^2$
LEL at the given ambient	2.7%



**Figure 8: Top view of geometry of gas release in sphere**

Based from the equation provided earlier, the released mass can be calculated as following using the Equation 4:

$$G = 0.006aP\left(\frac{M}{T}\right)^{0.5} \text{ kg/s}$$

$$G = 0.006 \times 4 \times 10^{-5} \times 4 \times 10^5 \left(\frac{28}{295}\right)^{0.5}$$

$$G = 0.03 \text{ kg/s}$$

After obtaining the value of the released mass, using Equation 7 to obtain the distance of the gas release spread to the surrounding or known as the extent of zone:

$$X = 2.1 \times 10^3 \left[ \frac{G}{E^2 M^{1.5} T^{0.5}} \right]^{0.5}$$

$$X = 2.1 \times 10^3 \left[ \frac{0.03}{(2.7^2)(28^{1.5})(295^{0.5})} \right]^{0.5}$$

$$X = 2.7 \text{ m}$$



As the final result, the hazardous area will be a sphere extending 2.7 m from the source of release in all directions.

#### 4.3 Extent of hazardous area based on gas release with obstruction

Now consider that there an obstruction present at a horizontal distance of 1 m from the source of release at Figure 8. The extent of hazardous area for this case has a different value than the previous case. The value of mass release  $G$  is remains the same which is at 0.03 kg/s and the amount of gas in the mixture at the obstruction is calculated using Equation 9 as follows:

$$B = 100 - L \left[ \frac{(100 - LEL)}{X} \right] \dots \%$$

$$B = 100 - 1 \left[ \frac{(100 - 2.7)}{27} \right]$$

$$B = 64\%$$

Next is to calculate the volume release rate of gas at the point of leakage using Equation 6 as following:

$$V = \frac{0.082GT}{M}$$

$$V = \frac{0.082 \times 0.03 \times 295}{28}$$

$$V = 0.026 \text{ m}^3/\text{s}$$

Since there is obstruction, so the volume of the gas/air mixture at the point of obstruction must be calculated using the Equation 12 which is as following:

$$V_{(mixture)} = V_{(gas)} \times \left[ \frac{100}{\% \text{ gas in mixture}} \right] \text{m}^3$$

$$V_{(mixture)} = 0.026 \times \left[ \frac{100}{57.7} \right]$$

$$V_{(mixture)} = 0.04 \text{ m}^3/\text{s}$$

The molecular weight of the mixture at the point of obstruction needs now be calculated using Equation 10 and is given by the following:

$$M_{(mixture)} = \left[ \frac{M_{(gas)} \times \%_{(gas)}}{100} \right] + \left[ \frac{M_{(air)} \times \%_{(air)}}{100} \right]$$

$$M_{(mixture)} = \left[ \frac{28 \times 64}{100} \right] + \left[ \frac{27 \times 36}{100} \right]$$

$$M_{(mixture)} = 27.6$$

Rearrange the value obtained earlier and then mass of mixture at the point of obstruction is calculated using Equation 13 as shown below:

$$G_{(mixture)} = V_{(mixture)} \times \frac{12.19 M_{(mixture)}}{T \text{ kg}}$$

$$G_{(mixture)} = 0.04 \times \frac{12.19 \times 27.6}{295}$$

$$G_{(mixture)} = 0.046 \text{ kg/s}$$

Next, the new lower explosion limit (LEL) with the obstruction is calculated using Equation 14 as follows:

$$LEL_{(mixture)} = LEL_{(gas)} \times \left[ \frac{100}{\% \text{ gas in mixture}} \right] \%$$

$$LEL_{(mixture)} = 2.7 \times \left[ \frac{100}{57.7} \right]$$

$$LEL_{(mixture)} = 4.68 \%$$

The previous values obtained can now be used to give the extent of the hazardous area beyond the obstruction using Equation 8 as follows:

$$X = 10.8 \left( \frac{GT}{ME} \right)^{0.55}$$

$$X = 10.8 \left( \frac{0.046 \times 295}{27.6 \times 4.68} \right)^{0.55}$$

$$X = 3.1 \text{ m}$$

The hazardous area in the direction of the obstruction therefore is extent to 4.1 m from the source of leakage and vertically upwards and downwards from the obstruction for 3.1 m.

#### 4.4 Simple cases study with different types of gas release

The different types of gases will have different molar weight and LEL at the given ambient. In the case of the Crude and Vacuum Distillation Unit, these are the several gases that probably will be release. The extent of the zone for these different types of gases will be calculated with using the same value of the ambient temperature, size of orifice and the pressure in pipe. The types of gases and their characteristics are shown in the next table.

**Table 4: Type of gases and the characteristics**

Type of Gas	Molar Weight	LEL at the given ambient
Methane	16.042	5.0 %
Propane	44.1	2.1 %
Ethane	30.07	3.0 %
Carbon Monoxide	28.01	12.0 %

The value of the ambient temperature, size of orifice and the pressure in pipe is as stated below:

- Ambient temperature : 22 °C
- Size of orifice :  $4 \times 10^{-5} \text{ m}^2$
- The pressure in pipe:  $4 \times 10^5 \text{ N/m}^2$

Next, the released mass and extent of the zone is calculated for each different gas release using Equation 4 and Equation 7.

1) *Methane*

- Released mass:

$$G = 0.006aP\left(\frac{M}{T}\right)^{0.5} \text{ kg/s}$$

$$G = 0.006 \times 4 \times 10^{-5} \times 4 \times 10^5 \left(\frac{16.042}{295}\right)^{0.5}$$

$$G = 0.022 \text{ kg/s}$$

- Extent of zone

$$X = 2.1 \times 10^3 \left[ \frac{G}{E^2 M^{1.5} T^{0.5}} \right]^{0.5}$$

$$X = 2.1 \times 10^3 \left[ \frac{0.022}{(5.0^2)(16.042^{1.5})(295^{0.5})} \right]^{0.5}$$

$$X = 1.875 \text{ m}$$

## 2) Propane

- Released mass:

$$G = 0.006aP\left(\frac{M}{T}\right)^{0.5} \text{ kg/s}$$

$$G = 0.006 \times 4 \times 10^{-5} \times 4 \times 10^5 \left(\frac{44.1}{295}\right)^{0.5}$$

$$G = 0.037 \text{ kg/s}$$

- Extent of zone

$$X = 2.1 \times 10^3 \left[ \frac{G}{E^2 M^{1.5} T^{0.5}} \right]^{0.5}$$

$$X = 2.1 \times 10^3 \left[ \frac{0.037}{(2.1^2)(44.1^{1.5})(295^{0.5})} \right]^{0.5}$$

$$X = 2.71 \text{ m}$$

## 3) Ethane

- Released mass:

$$G = 0.006aP\left(\frac{M}{T}\right)^{0.5} \text{ kg/s}$$

$$G = 0.006 \times 4 \times 10^{-5} \times 4 \times 10^5 \left(\frac{30.07}{295}\right)^{0.5}$$

$$G = 0.03 \text{ kg/s}$$

- Extent of zone

$$X = 2.1 \times 10^3 \left[ \frac{G}{E^2 M^{1.5} T^{0.5}} \right]^{0.5}$$

$$X = 2.1 \times 10^3 \left[ \frac{0.03}{(2.0^2)(30.07^{1.5})(295^{0.5})} \right]^{0.5}$$

$$X = 3.42 \text{ m}$$

#### 4) Carbon Monoxide

- Released mass:

$$G = 0.006aP\left(\frac{M}{T}\right)^{0.5} \text{ kg/s}$$

$$G = 0.006 \times 4 \times 10^{-5} \times 4 \times 10^5 \left(\frac{28.01}{295}\right)^{0.5}$$

$$G = 0.029 \text{ kg/s}$$

- Extent of zone

$$X = 2.1 \times 10^3 \left[ \frac{G}{E^2 M^{1.5} T^{0.5}} \right]^{0.5}$$

$$X = 2.1 \times 10^3 \left[ \frac{0.029}{(12.0^2)(28.01^{1.5})(295^{0.5})} \right]^{0.5}$$

$$X = 0.589 \text{ m}$$

The results of the release mass and extent of zones is recorded in the table below. It can be seen that each gas release will give different result when calculated.

**Table 5: Results for released mass and the extent of zone**

Type of Gas	Released Mass (kg/s)	Extent of Zone (m)
Methane	0.022	1.875
Propane	0.037	2.710
Ethane	0.030	3.420
Carbon Monoxide	0.029	0.589

The released mass and extent of zone for some common gases are indicated in the next table. This value is proper only for the condition same as the simple cases study as shown previously.

**Table 6: Common gases and the value of extent of the zone**

Type of Gas	Released Mass (kg/s)	Extent of Zone (m)
Acetaldehyde	0.037	1.425
Acetone	0.043	1.900
Acetylene	0.029	2.995
Ammonia	0.023	0.611
Arsine	0.049	0.838
Benzene	0.049	3.162
n-Butane	0.043	2.684
iso-Butane	0.043	2.773
Butylene	0.052	2.028
Carbon Disulfide	0.049	3.347
Cyclohexane	0.051	3.168
Cyclopropane	0.036	2.425
Diethyl Ether	0.048	2.313
Ethylene	0.030	2.618
Ethyl Alcohol	0.038	1.693
Ethyl Chloride	0.045	1.243
Hydrogen	0.008	6.698
Isobutane	0.043	2.773
Isopropyl Alcohol	0.043	2.434
Gasoline	0.060	2.541
Methyl Alcohol	0.032	1.004
Naphthalene	0.063	3.710
n-Heptane	0.056	3.786
n-Hexane	0.052	3.268
Neopentane	0.047	3.216
Neohexane	0.052	3.433
n-Octane	0.060	3.739
iso-Octane	0.060	4.498
n-Pentane	0.047	3.170
iso-Pentane	0.047	3.362
Propylene	0.036	2.910
Silane	0.032	4.479
Styrene	0.057	3.373
Toluene	0.054	3.118
Triptane	0.056	3.506
p-Xylene	0.058	3.690

## 4.5 Software modification

The modification is made to the Art of Illusion in order to add some features that are needed to complete the objective of this project. The modification can only be done through programming which using the software NetBeans IDE. The first modification is to have a dialog box that will enable the user to define the zone for that particular area.

The figure below shows the dialog box and the programming code can be view at APPENDIX F. The programming code for changing the size of the sphere for different zone can be view at APPENDIX G.

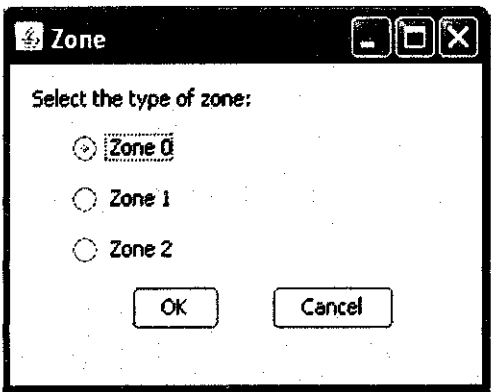


Figure 9: The dialog box

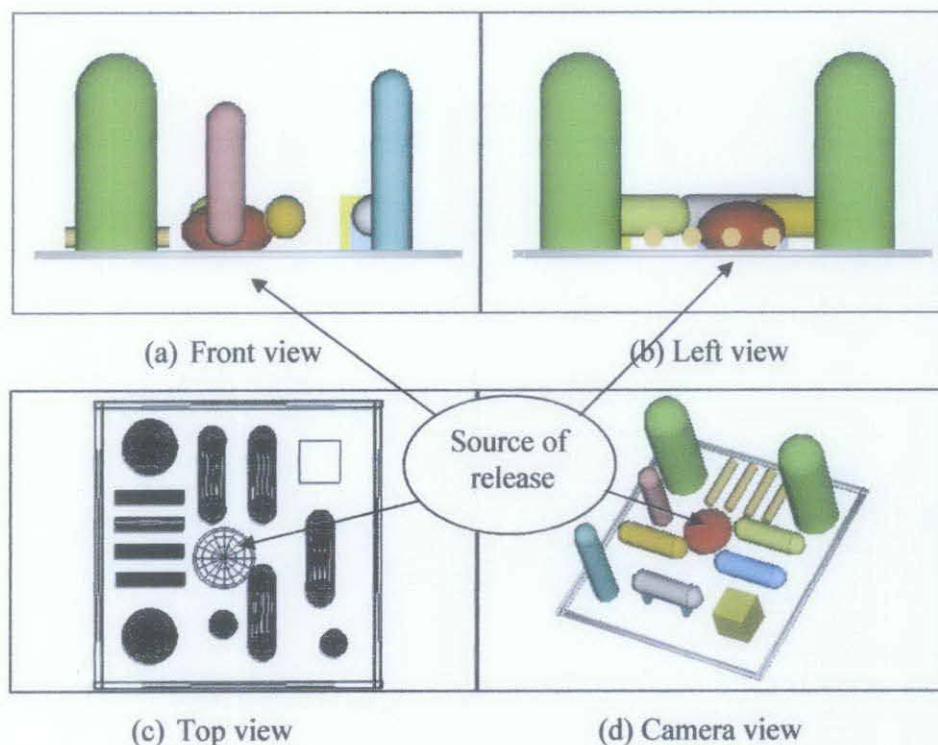
Once the user has opened the Art of Illusion, he needs to go to the Tools first and there will be list of commands. Click on the Define Zone command and only then the dialog box will appear. After he has defined the zone, for example Zone 0, the size and the colour of the area will change according as shown in the table below:

Table 7: Zone identification based on colour

Zone	Colour
0	Red
1	Yellow
2	Green



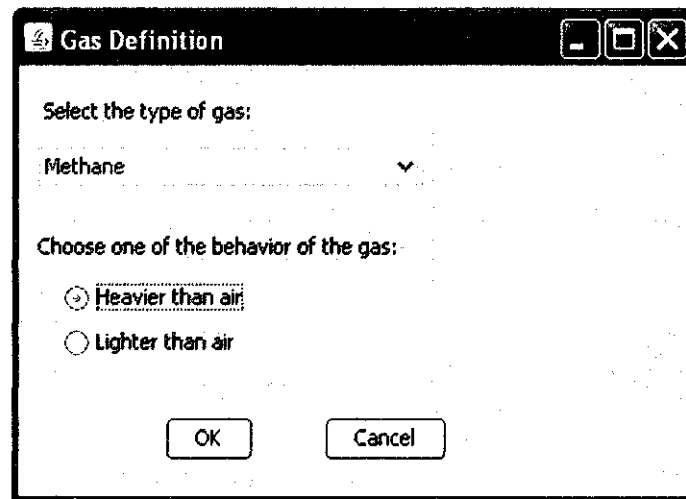
Figure 10 shows the results that will be obtained when the user has defined the zone. The result is view from the top, left, front and camera view.



**Figure 10: The different view for defining zone**

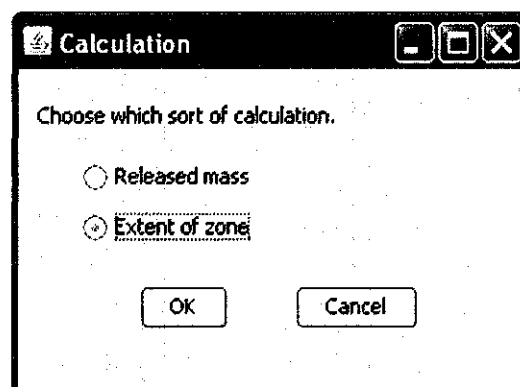
If the user clicks the Cancel button on the dialog box, nothing will change at the 3D process plant and the dialog box will disappear. The zone is determined based on the calculation of the flammable material and the source release. But further clarification need to be done to determine the extent of the zone.

Another feature that has been added to the Art of Illusion to make the software is worth and give value to the user is by having a pop up window to define type of gas and the characteristic of the gas to be compare to the air. Figure 11 shows the pop window for the Gas Definition and refer to APPENDIX H for the coding.



**Figure 11: The Gas Definition**

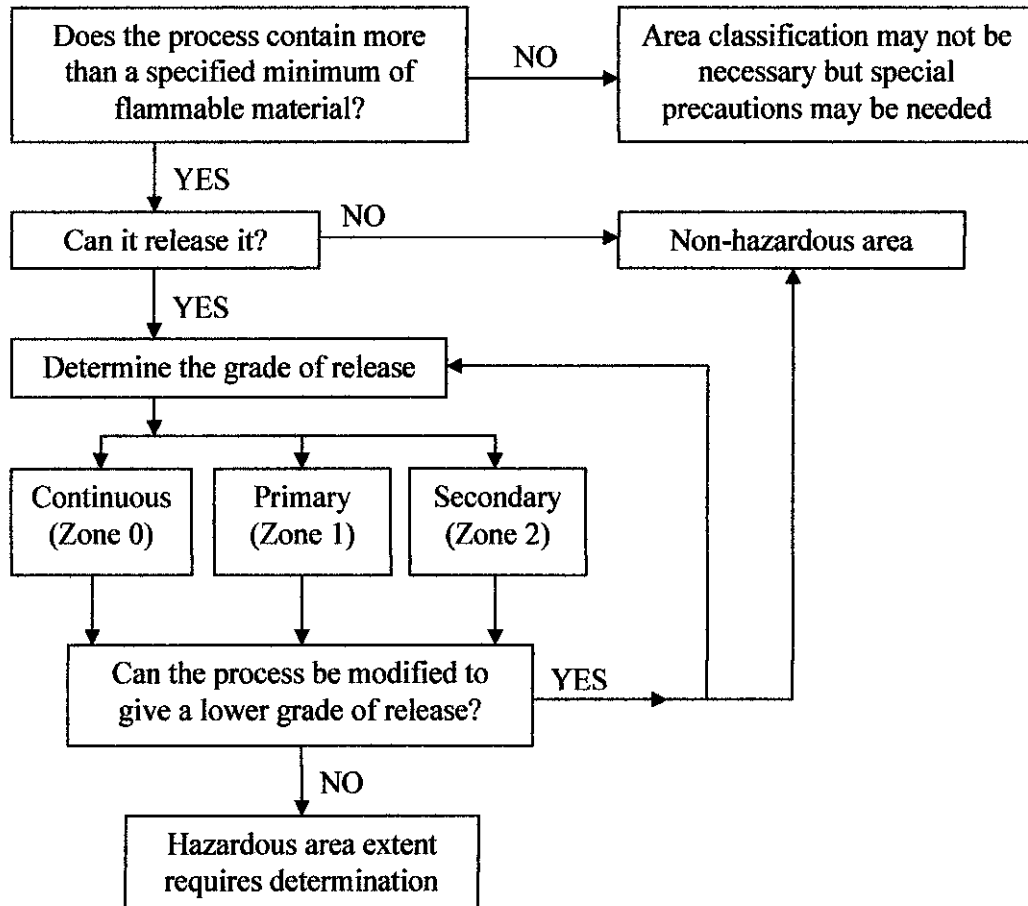
Next, the Art of Illusion will have the features to calculate the release mass and extent of the zone by itself through the programming which is powered by NetBeans. So far, there are only two calculations that we are interested to know so the user will asks to choose which calculation that they want to be calculated. Figure 12 shows the pop window for this purpose and refer to APPENDIX I for the coding.



**Figure 12: Choice of calculation**

#### 4.6 Procedures for area classification

There are many consideration has to be taken in order to make classification of the area in the process plant. The figure below shows the procedure of the area classification: [10]



**Figure 13: Area classification procedures for explosive atmospheres**

For Zone 2 area, the possibility is deemed to exist when a fault develops in the equipment. It is possible that a leakage may result from some mal-operation. For example, a heavy object is accidentally dropped onto equipment that contains a hazardous fluid such the pipe. [16]

Zone 1 area has a higher risk of hazard than that applicable to a Zone 2 area. Some parts of the plant are more prone to leakage than other, some types of seals

used in rotating shafts of pumps and compressors, discharges from safety valves, some methods of venting gases and vapours, some types of open drains for volatile liquids. The leakage may be considered likely to occur sometime during a long period. [16]

The highest risk of hazard is found in Zone 0 area. These areas are usually the gaseous volume immediately above a volatile liquid contained in a vessel or tank. The surroundings close to the atmospheric vent aperture would therefore be a Zone 0 area [16]. In this zone, no electrical motor can be installing as the fire triangle will be complete with the three factors combine together.

Each source of release must be identified but the will be problem if there is more than one source of release in the same location. There sources of release probably not release at the same time but some may. It is impossible to assume that all source of release released simultaneously and some guide is necessary. The table below shows the method of calculating total release from multiple sources of release. [9]

**Table 8: Simultaneously release from source of hazard**

<b>Number of sources of hazard</b>	<b>Number releasing simultaneously</b>
1	1
2	2
3-5	3
6-9	4
10-13	5
14-18	6
19-23	7
24-28	8
29-33	9
34-39	10
40-45	11
46-51	12

## **CHAPTER 5**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **5.1 Conclusions**

The first objective of this project has been achieved as the review about the hazardous area classification has been done and still ongoing for improvement purpose. The standard used in this project is the International Electrotechnical Commission (IEC) but it has no different from the other standard as the aim is still the same. A lot of consideration needs to be taken when it comes to defining the zone and it is including the extending area. Some situation need further clarification where the calculation to determine the extending zone is required.

The process of designing the 3D simulation is on the modification stage where the dialog box that is required to let the user to define the zone has completed. It is in the progression to be transfer to the Art of Illusion which is quite complex. The source code of Art of Illusion will be modified using the NetBeans for this purpose. The procedure of changing the size and the colour of the area based on the zone is completed.

The main objective of this project which is to develop a 3D layout that provides the user with the data of the specific area and to achieve this objective required a lot of time and research. All of this can only be done using the programming which is through the NetBeans and a lot of aspect should be consider as different area having different characteristic. All of this involves mathematical equation and detailed analysis.

## **5.2 Recommendations**

The recommendation made here is with the intention of improving the problems faced while working on this project. The recommendations to this project are:

- 1) Doing modification to the 3D software used so that it is compatible with the hazardous area classification.
- 2) Truly understand the relation between the factors that will contribute to the hazardous area classification with the equipment in the process plant.
- 3) Having a reference to the real process plant in order to simulate the 3D process plant.

## **5.3 Future Planning**

For the next step of modification in order to completing this project, here is the planning:

- 1) Relate the concept of the hazardous area classification with one of the equipment, for example a high voltage electric motor, as reference.
- 2) Get point of view of the hazardous area classification based on the mathematical aspect.
- 3) Relate the hazardous area classification concept with the software used, Art of the Illusion.
- 4) Doing the Java programming to make the 3D process plant more interactive and user friendly.
- 5) Doing a better figure for the equipment in the 3D process plant that will look the same as the real equipment. The Google SketchUp 3D is recommended to be used for better figure since it is easy to be used where there are 3D process plant available but the software is not an open source.

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**APPENDIX A**  
**GANTT CHART FOR FYP 2**

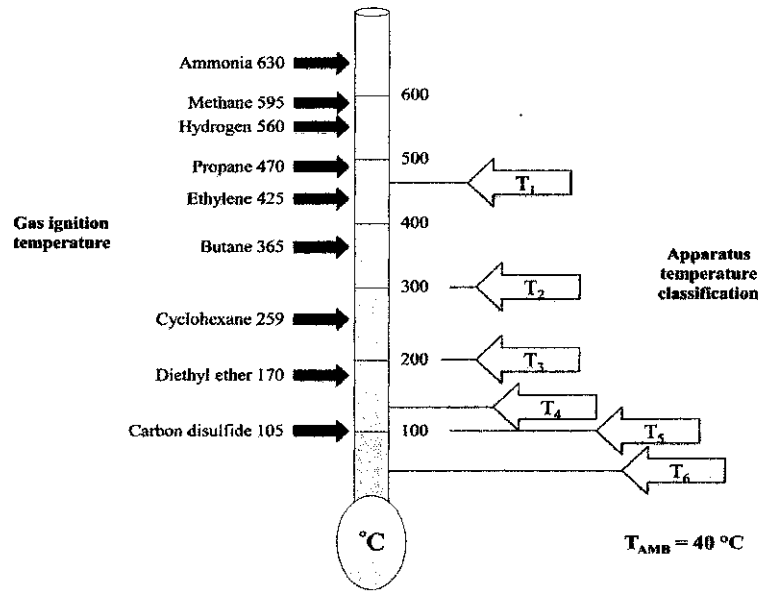
		Jan	February					March					April				May		
No	Task Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1	Project Work Continue																		
2	Submission of Progress Report																		
3	Project Work Continue																		
4	Poster Exhibition																		
5	Project Work Continue																		
6	Submission of Draft Report																		
7	Seminar																		
8	Submission of Dissertation (soft bound)																		
9	Submission of Technical Paper																		
10	Oral Presentation																		
11	Submission of Project Dissertation (Hard Bound)																		

# **APPENDIX B** **IEC GAS GROUP**

IEC Gas Group	Typical gas
I	Methane
IIC	Acetylene Hydrogen
IIB	Ethylene Ethyl ether Cyclopropane Butadene 1-3
IIA	Propane Butane Benzene Pentane Heptane Acetone Methyl ethyl Methyl alcohol Ethyl alcohol

**APPENDIX C**  
**TEMPERATURE CLASS AND TEMPERATURE RATING**  
**SYSTEM**

Classification	Maximum surface temperature, °C
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85



# **APPENDIX D** **TYPE OF PROTECTION BASED ON ZONE**

Hazardous area classification	Protection method
Zone 0	Intrinsically safe (2 fault) : "ia"
Zone 1	Encapsulation: "m" Flameproof: "d" Increased safety: "e" Intrinsically safe (1 fault): "ib" Oil immersion: "o" Powder filling: "q" Purged/pressurized: "p"
Zone 2	Hermetically sealed: "nC" Nonincendive: "nC" Non-sparking: "nA" Restricted breathing: "nR" Sealed device: "nC"

**APPENDIX E**

**EXTENT OF HAZARDOUS AREAS ABOVE AND BEYOND**

**POOL LIMITS**

Pool area m <sup>2</sup>	Extent of hazardous area above and beyond pools when liquid vapour pressure is the following percentage of atmospheric pressure in m				
	<10%	25%	50%	75%	>90%
0.1	0.04	0.1	0.2	0.3	0.4
0.3	0.07	0.2	0.4	0.5	0.7
1.0	0.1	0.3	0.6	1.0	1.0
3.0	0.2	0.5	1.0	1.5	2.0
10.0	0.4	0.8	2.0	2.5	3.0
30.0	0.6	1.5	3.0	4.5	5.5
100.0	1.0	2.5	5.0	7.5	9.0
300.0	2.0	5.0	10.0	15.0	18.0
1000.0	3.0	7.5	15.0	23.0	27.0
3000.0	4.5	12.0	23.0	34.0	41.0
10000.0	7.5	19.0	38.0	56.0	68.0

## APPENDIX F

### PROGRAMMING CODE FOR THE DIALOG BOX

```
package javaapplication3;
import javax.swing.*;
/**
 *
 * @author Anice
 */
public class NewJFrame extends javax.swing.JFrame {

    /** Creates new form NewJFrame */
    public NewJFrame() {
        initComponents();
        ButtonGroup buttonGroup = new ButtonGroup ();
        buttonGroup.add(this.jRadioButton1);
        buttonGroup.add(this.jRadioButton2);
        buttonGroup.add(this.jRadioButton3);

    }
    public NewJFrame(LayoutWindow win){

    }

    /** This method is called from within the constructor to
     * initialize the form.
     * WARNING: Do NOT modify this code. The content of this method is
     * always regenerated by the Form Editor.
     */
    @SuppressWarnings("unchecked")
    // <editor-fold defaultstate="collapsed" desc="Generated Code">
    private void initComponents() {

        jTextField1 = new javax.swing.JTextField();
        jRadioButton1 = new javax.swing.JRadioButton();
        jRadioButton2 = new javax.swing.JRadioButton();
        jRadioButton3 = new javax.swing.JRadioButton();
        jButton1 = new javax.swing.JButton();
        jButton2 = new javax.swing.JButton();
    }
```

```

setDefaultCloseOperation(javax.swing.WindowConstants.EXIT_ON_CLOSE);
setTitle("Zone");

jTextField1.setBackground(java.awt.SystemColor.control);
jTextField1.setText(" Select the type of zone:");
jTextField1.setBorder(null);
jTextField1.setSelectionColor(java.awt.SystemColor.inactiveCaptionBorder);
jTextField1.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jTextField1ActionPerformed(evt);
    }
});

jRadioButton1.setText(" Zone 0");
jRadioButton1.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jRadioButton1ActionPerformed(evt);
    }
});

jRadioButton2.setText(" Zone 1");

jRadioButton3.setText(" Zone 2");

jButton1.setText("OK");

jButton2.setText("Cancel");

javax.swing.GroupLayout layout = new javax.swing.GroupLayout(getContentPane());
getContentPane().setLayout(layout);
layout.setHorizontalGroup(
    layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(layout.createSequentialGroup()
            .add(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                .addGroup(layout.createSequentialGroup()
                    .add(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                        .add(layout.createSequentialGroup()
                            .add(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                                .add(layout.createSequentialGroup()
                                    .add(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                                        .add(layout.createSequentialGroup()
                                            .addComponent(jTextField1, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))
                                        .add(layout.createSequentialGroup()
                                            .addGap(29, 29, 29)
                                            .add(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                                                .addComponent(jRadioButton2)
                                                .addComponent(jRadioButton1)
                                                .addComponent(jRadioButton3)))
                                        .add(layout.createSequentialGroup()
                                            .addGap(64, 64, 64)
                                            .addComponent(jButton1)
                                            .addGap(27, 27, 27)

```

```

        .addComponent(jButton2)))
        .addContainerGap(46, Short.MAX_VALUE))
    );
    layout.setVerticalGroup(
        layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(layout.createSequentialGroup()
            .addContainerGap()
            .addComponent(jTextField1, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
            .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
            .addComponent(jRadioButton1)
            .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
            .addComponent(jRadioButton2)
            .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
            .addComponent(jRadioButton3)
            .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
            .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                .addComponent(jButton2)
                .addComponent(jButton1))
            .addContainerGap(28, Short.MAX_VALUE))
        );

    pack();
} // </editor-fold>

private void jRadioButton1ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
}

private void jTextField1ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
}

/**
 * @param args the command line arguments
 */
public static void main(String args[]) {
    java.awt.EventQueue.invokeLater(new Runnable() {
        public void run() {
            new NewJFrame().setVisible(true);
        }
    });
}

// Variables declaration - do not modify
private javax.swing.JButton jButton1;
private javax.swing.JButton jButton2;
private javax.swing.JRadioButton jRadioButton1;

```



```
private javax.swing.JRadioButton jRadioButton2;  
private javax.swing.JRadioButton jRadioButton3;  
private javax.swing.JTextField jTextField1;  
// End of variables declaration  
  
}
```

## APPENDIX G

### PROGRAMMING CODE FOR THE SIZE OF SPHERE

```
package artofillusion.ui;
import javax.swing.*;
import artofillusion.*;
import artofillusion.ObjectTextureDialog;
import artofillusion.material.Material;
import artofillusion.object.Object3D;
import artofillusion.object.ObjectInfo;
/**
 *
 * @author Anice
 */
public class NewJFrame extends javax.swing.JFrame {
    private LayoutWindow window;
    private int returnStatus;
    Object3D obj;
    ObjectInfo objinfo[];
    /** Creates new form NewJFrame */
    public NewJFrame(LayoutWindow window, Object3D obj2, ObjectInfo obj[]) {
        this.window = window;
        this.obj = obj2;
        this.objinfo = obj;
        initComponents();
        ButtonGroup buttonGroup = new ButtonGroup ();
        buttonGroup.add(this.jRadioButton1);
        buttonGroup.add(this.jRadioButton2);
        buttonGroup.add(this.jRadioButton3);

        //java.awt.EventQueue.invokeLater(new Runnable() {
        // public void run() {
        //JFrame frame1=new NewJFrame();
        // new NewJFrame().setVisible(true);

        this.setVisible(true);
        this.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
        // }
        // });
    }
```

```

    }

    public NewJFrame(LayoutWindow win){
        window=win;
    }

    /** This method is called from within the constructor to
     * initialize the form.
     * WARNING: Do NOT modify this code. The content of this method is
     * always regenerated by the Form Editor.
     */
    @SuppressWarnings("unchecked")
    // <editor-fold defaultstate="collapsed" desc="Generated Code">
    private void initComponents() {

        jTextField1 = new javax.swing.JTextField();
        jRadioButton1 = new javax.swing.JRadioButton();
        jRadioButton2 = new javax.swing.JRadioButton();
        jRadioButton3 = new javax.swing.JRadioButton();
        jButton1 = new javax.swing.JButton();
        jButton2 = new javax.swing.JButton();

        setDefaultCloseOperation(javax.swing.WindowConstants.EXIT_ON_CLOSE);
        setTitle("Zone");

        jTextField1.setBackground(java.awt.SystemColor.control);
        jTextField1.setText(" Select the type of zone:");
        jTextField1.setBorder(null);
        jTextField1.setSelectionColor(java.awt.SystemColor.inactiveCaptionBorder);
        jTextField1.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                jTextField1ActionPerformed(evt);
            }
        });

        jRadioButton1.setText(" Zone 0");
        jRadioButton1.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                jRadioButton1ActionPerformed(evt);
            }
        });

        jRadioButton2.setText(" Zone 1");
        jRadioButton2.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                jRadioButton2ActionPerformed(evt);
            }
        });
    }

```

```

jRadioButton3.setText(" Zone 2");
jRadioButton3.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jRadioButton3ActionPerformed(evt);
    }
});

jButton1.setText("OK");
jButton1.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jButton1ActionPerformed(evt);
    }
});

jButton2.setText("Cancel");
jButton2.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jButton2ActionPerformed(evt);
    }
});

javax.swing.GroupLayout layout = new javax.swing.GroupLayout(getContentPane());
getContentPane().setLayout(layout);
layout.setHorizontalGroup(
    layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(layout.createSequentialGroup()
            .addContainerGap()
            .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                .addComponent(jTextField1, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))
                .addGap(29, 29, 29)
                .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                    .addComponent(jRadioButton2)
                    .addComponent(jRadioButton1)
                    .addComponent(jRadioButton3)))
            .addGap(64, 64, 64)
            .addComponent(jButton1)
            .addGap(27, 27, 27)
            .addComponent(jButton2)))
        .addGap(46, Short.MAX_VALUE))
);
layout.setVerticalGroup(
    layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(layout.createSequentialGroup()
            .addContainerGap()
            .addComponent(jTextField1, javax.swing.GroupLayout.PREFERRED_SIZE,
Short.MAX_VALUE, Short.MAX_VALUE))
            .addGap(10, 10, 10)
            .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
                .addComponent(jRadioButton2)
                .addComponent(jRadioButton1)
                .addComponent(jRadioButton3))
            .addGap(10, 10, 10)
            .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
                .addComponent(jButton1)
                .addComponent(jButton2))
            .addGap(10, 10, 10))
);

```

```

        .addComponent(jTextField1, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
        .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
        .addComponent(jRadioButton1)
        .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
        .addComponent(jRadioButton2)
        .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
        .addComponent(jRadioButton3)
        .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
        .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
            .addComponent(jButton2)
            .addComponent(jButton1))
        .addContainerGap(28, Short.MAX_VALUE)
    );

```

```

    pack();
} // </editor-fold>

```

```

private void jRadioButton1ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
    window.setZone1();
    obj.setSize(.5, .5, .5);
}

```

Edit this part to  
change the size  
of the sphere for  
Zone 0

```

private void jTextField1ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
}

```

```

private void jButton2ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
    returnStatus = 0;
    this.setVisible(false);
    dispose();
}

```

```

private void jButton1ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
    System.out.println();
    // obj.setSize(100, 50, 50);
    this.setVisible(false);
    dispose();
}

```

```

private void jRadioButton2ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
    window.setZone2();
    obj.setSize(1, 1, 1);
}

```

Edit this part to  
change the size  
of the sphere for  
Zone 1

```

private void jButton3ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
    window.setZone3();
    obj.setSize(2, 2, 2);
}

/**
 * @param args the command line arguments
 */

// Variables declaration - do not modify
private javax.swing.JButton jButton1;
private javax.swing.JButton jButton2;
private javax.swing.JRadioButton jRadioButton1;
private javax.swing.JRadioButton jRadioButton2;
private javax.swing.JRadioButton jRadioButton3;
private javax.swing.JTextField jTextField1;
// End of variables declaration
}

```

Edit this part to  
 change the size  
 of the sphere for  
 Zone 0

## APPENDIX H

### PROGRAMMING CODE FOR GAS DEFINITION

```
package artofillusion.ui;

import artofillusion.LayoutWindow;
import javax.swing.ButtonGroup;
import javax.swing.JFrame;

/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */

/*
 * NewJFrame1.java
 *
 * Created on 27-Apr-2011, 03:36:54
 */

/**
 *
 * @author Anice
 */
public class NewJFrame1_1 extends javax.swing.JFrame {

    /** Creates new form NewJFrame1 */
    public NewJFrame1_1() {
        initComponents();
    }

    public NewJFrame1_1(LayoutWindow window) {
        initComponents();
        ButtonGroup buttonGroup = new ButtonGroup ();
        buttonGroup.add(this.jRadioButton1);
        buttonGroup.add(this.jRadioButton2);

        this.setVisible(true);
        this.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
    }
}
```

```

}

/** This method is called from within the constructor to
 * initialize the form.
 * WARNING: Do NOT modify this code. The content of this method is
 * always regenerated by the Form Editor.
 */
@SuppressWarnings("unchecked")
// <editor-fold defaultstate="collapsed" desc="Generated Code">
private void initComponents() {

    jTextField1 = new javax.swing.JTextField();
    jComboBox1 = new javax.swing.JComboBox();
    jButton1 = new javax.swing.JButton();
    jButton2 = new javax.swing.JButton();
    jTextField2 = new javax.swing.JTextField();
    jRadioButton1 = new javax.swing.JRadioButton();
    jRadioButton2 = new javax.swing.JRadioButton();

    setDefaultCloseOperation(javax.swing.WindowConstants.EXIT_ON_CLOSE);
    setTitle("Gas Definition");

    jTextField1.setBackground(java.awt.SystemColor.control);
    jTextField1.setText(" Select the type of gas:");
    jTextField1.setBorder(null);
    jTextField1.setSelectionColor(java.awt.SystemColor.inactiveCaptionBorder);
    jTextField1.addActionListener(new java.awt.event.ActionListener() {
        public void actionPerformed(java.awt.event.ActionEvent evt) {
            jTextField1ActionPerformed(evt);
        }
    });

    jComboBox1.setModel(new javax.swing.DefaultComboBoxModel(new String[] { "Methane", "Propane", "Ethane",
"Carbon Monoxide" }));
    jComboBox1.addActionListener(new java.awt.event.ActionListener() {
        public void actionPerformed(java.awt.event.ActionEvent evt) {
            jComboBox1ActionPerformed(evt);
        }
    });

    jButton1.setText("OK");
    jButton1.addActionListener(new java.awt.event.ActionListener() {
        public void actionPerformed(java.awt.event.ActionEvent evt) {
            jButton1ActionPerformed(evt);
        }
    });

    jButton2.setText("Cancel");

```



```

jButton2.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jButton2ActionPerformed(evt);
    }
});

jTextField2.setBackground(java.awt.SystemColor.control);
jTextField2.setText("Choose one of the behavior of the gas:");
jTextField2.setBorder(null);
jTextField2.setSelectionColor(java.awt.SystemColor.inactiveCaptionBorder);
jTextField2.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jTextField2ActionPerformed(evt);
    }
});

jRadioButton1.setText("Heavier than air");
jRadioButton1.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jRadioButton1ActionPerformed(evt);
    }
});

jRadioButton2.setText("Lighter than air");
jRadioButton2.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jRadioButton2ActionPerformed(evt);
    }
});

javax.swing.GroupLayout layout = new javax.swing.GroupLayout(getContentPane());
getContentPane().setLayout(layout);
layout.setHorizontalGroup(
    layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(layout.createSequentialGroup()
            .addGap(155, 155, 155)
            .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                .addComponent(jTextField1, javax.swing.GroupLayout.DEFAULT_SIZE, 189, Short.MAX_VALUE)
                .addComponent(jComboBox1, javax.swing.GroupLayout.PREFERRED_SIZE, 203, javax.swing.GroupLayout.PREFERRED_SIZE)
                .addGap(141, Short.MAX_VALUE))
            .addGap(155, 155, 155)
        )
        .addGroup(layout.createSequentialGroup()
            .addComponent(jButton1)
            .addContainerGap()
        )
);

```

```

        .addGap(37, 37, 37)
        .addComponent(jButton2))
    .addGroup(layout.createParallelGroup(GroupLayout.Alignment.LEADING)
        .addComponent(jTextField2, javax.swing.GroupLayout.PREFERRED_SIZE, 216,
javax.swing.GroupLayout.PREFERRED_SIZE)
        .addGroup(layout.createSequentialGroup()
            .addGap(10, 10, 10)
            .addGroup(layout.createParallelGroup(GroupLayout.Alignment.LEADING)
                .addComponent(jRadioButton2)
                .addComponent(jRadioButton1))))
        .addContainerGap(128, Short.MAX_VALUE))))
);
layout.setVerticalGroup(
    layout.createParallelGroup(GroupLayout.Alignment.LEADING)
        .addGroup(layout.createSequentialGroup()
            .addContainerGap()
            .addComponent(jTextField1, javax.swing.GroupLayout.PREFERRED_SIZE, 26,
javax.swing.GroupLayout.PREFERRED_SIZE)
            .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)
            .addComponent(jComboBox1, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
            .addGap(18, 18, 18)
            .addComponent(jTextField2, javax.swing.GroupLayout.PREFERRED_SIZE, 26,
javax.swing.GroupLayout.PREFERRED_SIZE)
            .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)
            .addComponent(jRadioButton1)
            .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)
            .addComponent(jRadioButton2)
            .addGap(26, 26, 26)
            .addGroup(layout.createParallelGroup(GroupLayout.Alignment.BASELINE)
                .addComponent(jButton1)
                .addComponent(jButton2))
            .addContainerGap(18, Short.MAX_VALUE))
        );

pack();
} // </editor-fold>

private void jTextField1ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
}

private void jComboBox1ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
}

private void jButton1ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
}

```

```

String gasName = (String)jComboBox1.getSelectedItem();
String behaviour;
if(jRadioButton1.isSelected()){
    behaviour = "Heavier than air";
}else
    behaviour = "Lighter than air";

new NewJFrame3(gasName, behaviour);
System.out.println("test");
    this.setVisible(false);
dispose();
}

private void jButton2ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
    this.setVisible(false);
    dispose();
}

private void jTextField2ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
}

private void jRadioButton1ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
    // window.setZone1();
    // obj.setSize(.5, .5, .5);
}

private void jRadioButton2ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
    // window.setZone2();
    // obj.setSize(1, 1, 1);
}

/**
 * @param args the command line arguments
 */
public static void main(String args[]) {
    java.awt.EventQueue.invokeLater(new Runnable() {
        public void run() {
            new NewJFrame1().setVisible(true);
        }
    });
}

```

```
// Variables declaration - do not modify
private javax.swing.JButton jButton1;
private javax.swing.JButton jButton2;
private javax.swing.JComboBox jComboBox1;
private javax.swing.JRadioButton jRadioButton1;
private javax.swing.JRadioButton jRadioButton2;
private javax.swing.JTextField jTextField1;
private javax.swing.JTextField jTextField2;
// End of variables declaration

}
```

## APPENDIX I

### PROGRAMMING CODE FOR CHOICE OF CALCULATION

```
package artofillusion.ui;

import javax.swing.ButtonGroup;
import javax.swing.JFrame;

/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */

/*
 * NewJFrame3.java
 *
 * Created on 27-Apr-2011, 03:47:38
 */

/**
 *
 * @author Anice
 */
public class NewJFrame3 extends javax.swing.JFrame {
    private String gasName;
    private final String behaviour;
    /** Creates new form NewJFrame3 */
    public NewJFrame3(String gasName, String behaviour) {

        this.gasName = gasName;
        this.behaviour = behaviour;
        initComponents();
        ButtonGroup buttonGroup = new ButtonGroup ();
        buttonGroup.add(this.jRadioButton1);
        buttonGroup.add(this.jRadioButton2);

        this.setVisible(true);
        this.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
    }
}
```

```

/** This method is called from within the constructor to
 * initialize the form.
 * WARNING: Do NOT modify this code. The content of this method is
 * always regenerated by the Form Editor.
 */
@SuppressWarnings("unchecked")
// <editor-fold defaultstate="collapsed" desc="Generated Code">
private void initComponents() {

    jTextField1 = new javax.swing.JTextField();
    jRadioButton1 = new javax.swing.JRadioButton();
    jRadioButton2 = new javax.swing.JRadioButton();
    jButton1 = new javax.swing.JButton();
    jButton2 = new javax.swing.JButton();

    setDefaultCloseOperation(javax.swing.WindowConstants.EXIT_ON_CLOSE);
    setTitle("Calculation");

    jTextField1.setBackground(java.awt.SystemColor.control);
    jTextField1.setText("Choose which sort of calculation. ");
    jTextField1.setBorder(null);
    jTextField1.setSelectionColor(java.awt.SystemColor.inactiveCaptionBorder);
    jTextField1.addActionListener(new java.awt.event.ActionListener() {
        public void actionPerformed(java.awt.event.ActionEvent evt) {
            jTextField1ActionPerformed(evt);
        }
    });

    jRadioButton1.setText("Released mass");
    jRadioButton1.addActionListener(new java.awt.event.ActionListener() {
        public void actionPerformed(java.awt.event.ActionEvent evt) {
            jRadioButton1ActionPerformed(evt);
        }
    });

    jRadioButton2.setText("Extent of zone");
    jRadioButton2.addActionListener(new java.awt.event.ActionListener() {
        public void actionPerformed(java.awt.event.ActionEvent evt) {
            jRadioButton2ActionPerformed(evt);
        }
    });

    jButton1.setText("OK");
    jButton1.addActionListener(new java.awt.event.ActionListener() {
        public void actionPerformed(java.awt.event.ActionEvent evt) {
            jButton1ActionPerformed(evt);
        }
    });
}

```

```

jButton2.setText("Cancel");
jButton2.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jButton2ActionPerformed(evt);
    }
});

javax.swing.GroupLayout layout = new javax.swing.GroupLayout(getContentPane());
getContentPane().setLayout(layout);
layout.setHorizontalGroup(
    layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(layout.createSequentialGroup()
            .addGap(10, 10, 10)
            .addComponent(jTextField1, javax.swing.GroupLayout.PREFERRED_SIZE, 176,
javax.swing.GroupLayout.PREFERRED_SIZE)
            .addGap(10, 10, 10)
            .addGroup(layout.createSequentialGroup()
                .addComponent(jButton1)
                .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED, 35, Short.MAX_VALUE)
                .addComponent(jButton2)
                .addGap(10, 10, 10)
                .addGroup(layout.createSequentialGroup()
                    .addComponent(jRadioButton2)
                    .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)
                    .addComponent(jRadioButton1)
                    .addGap(10, 10, 10)
                    .addGap(10, 10, 10)
                ))
            .addGap(10, 10, 10)
        )
);
layout.setVerticalGroup(
    layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(layout.createSequentialGroup()
            .addGap(10, 10, 10)
            .addComponent(jTextField1, javax.swing.GroupLayout.PREFERRED_SIZE, 26,
javax.swing.GroupLayout.PREFERRED_SIZE)
            .addGap(10, 10, 10)
            .addComponent(jRadioButton1)
            .addGap(10, 10, 10)
            .addComponent(jRadioButton2)
            .addGap(10, 10, 10)
            .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
                .addComponent(jButton2)
                .addComponent(jButton1)
            )
            .addGap(10, 10, 10)
        )
);

```

```
pack();  
} // </editor-fold>  
  
private void jTextField1ActionPerformed(java.awt.event.ActionEvent evt) {  
    // TODO add your handling code here:  
}  
  
private void jButton1ActionPerformed(java.awt.event.ActionEvent evt) {  
    // TODO add your handling code here:  
}  
  
private void jButton2ActionPerformed(java.awt.event.ActionEvent evt) {  
    // TODO add your handling code here:  
}  
  
private void jButton3ActionPerformed(java.awt.event.ActionEvent evt) {  
    // TODO add your handling code here:  
    int a;  
    if(this.gasName == "Methane"){  
        a = 1 + 2;  
        String behaviour = this.behaviour;  
        //formula  
  
        if(this.jRadioButton1.isSelected()){  
            double release = 0.022;  
            new JFrame4(this.gasName,behaviour, release);  
            this.setVisible(false);  
        }  
        dispose();  
    }  
  
    if(this.jRadioButton2.isSelected()){  
        double release = 1.875;  
        new JFrame5(this.gasName,behaviour, release);  
        this.setVisible(false);  
    }  
    dispose();  
}  
}  
else if(this.gasName == "Propane"){  
    a = 1 + 2;  
    String behaviour = this.behaviour;  
    //formula
```



```

        if(this.jRadioButton1.isSelected()){
            double release = 0.037;
            new JFrame4(this.gasName,behaviour, release);
            this.setVisible(false);
        }
        dispose();
    }

```

```

        if(this.jRadioButton2.isSelected()){
            double release = 2.710;
            new JFrame5(this.gasName,behaviour, release);
            this.setVisible(false);
        }
        dispose();
    }
}
else if(this.gasName == "Ethane"){
    a = 1 +2;
    String behaviour = this.behaviour;
    //formula
}

```

```

        if(this.jRadioButton1.isSelected()){
            double release = 0.030;
            new JFrame4(this.gasName,behaviour, release);
            this.setVisible(false);
        }
        dispose();
    }

```

```

        if(this.jRadioButton2.isSelected()){
            double release = 3.420;
            new JFrame5(this.gasName,behaviour, release);
            this.setVisible(false);
        }
        dispose();
    }
}
else if(this.gasName == "Carbon Monoxide"){
    a = 1 +2;
    String behaviour = this.behaviour;
    //formula
}

```

```

        if(this.jRadioButton1.isSelected()){
            double release = 0.029;
            new JFrame4(this.gasName,behaviour, release);
            this.setVisible(false);
        }
        dispose();
    }

```

```

        if(this.jRadioButton2.isSelected()){

```

```

        double release = 0.589;
        new JFrame5(this.gasName,behaviour, release);
        this.setVisible(false);
    dispose();
    }
}

// obj.setSize(100, 50, 50);
this.setVisible(false);
dispose();
}

private void jButton2ActionPerformed(java.awt.event.ActionEvent evt) {
    // TODO add your handling code here:
    this.setVisible(false);
    dispose();
}

/**
 * @param args the command line arguments
 */

// Variables declaration - do not modify
private javax.swing.JButton jButton1;
private javax.swing.JButton jButton2;
private javax.swing.JRadioButton jRadioButton1;
private javax.swing.JRadioButton jRadioButton2;
private javax.swing.JTextField jTextField1;
// End of variables declaration
}

```

**APPENDIX J**  
**PAPER SUBMITTED TO 3<sup>RD</sup> INTERNATIONAL CONGRESS ON**  
**ENGINEERING EDUCATION (ICEED2011)**

# 3D View of Hazardous Area Classification Using Open Source

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**Abstract**—This paper presents a development of 3D view of hazardous area classification using the open source of 3D simulation software, Art of Illusion, for minimum cost implementation. The 3D simulation is meant to complement the existing 2D drawing for better hazardous area classification and visualization. The 3D simulation is developed based on the IEC 60079-10 hazardous area guideline. It is intended as user friendly tools that can be easily used for area hazard analysis such as identifying the hazard level and the presence of ignition sources to keep the level of safety at the highest level. The assessment for the process plant is focus on Crude and Distillation Unit which typical product are gasoline, diesel fuel, asphalt base, kerosene, and heating oil and liquefied petroleum gas. The area classification visualization used the zone classification as the color code i.e. for Zone 0 is red, Zone 1 is yellow and Zone 2 is green. The color code is developed based on the zone in present of flash point, ignition temperature, explosive limit, and vapor density. Finally the extent of the hazardous zones will be determined based on ideal spherical ball dispersion. Currently case study have shown different gases with different properties will give different value of release mass and extent of zone. Current works have shown that the layout of the process plant can be view from 360 degrees or from the 3D view. Thus user would be able to rotate the view to assess the overall area of the hazard zones including the extent of the zones.

**Keywords**—Hazardous area classification; 3D simulation; open source; zone classification; installing electrical equipment; safety

## I. INTRODUCTION

The process plant has the highest possibility for the incident of fires and explosion which is the reason why the area classification is carried out. Regulatory bodies like Occupational Safety and Health Administration (OSHA) have established systems that classify locations which exhibit potentially dangerous conditions to the degree of hazard presented. [1]

OSHA Publication 3073 defines a hazardous location as follows:

*Hazardous locations are areas where flammable liquids, gases or vapors or combustible dusts exist in sufficient quantities to produce an explosion or fire. In hazardous locations, specially designed equipment and special installation techniques must be used to protect against the explosive and flammable potential of these substances.*

The first action need to be done is to identify the source of release of the flammable gas or vapor. These flammable gas or vapor may arise as result from the constant activities, from time to time in normal operation or due to the unplanned event. Even though there are no source of release, the process equipment may also be consider as hazardous area if the both component which are the gas/vapor and air are present.

A flammable mixture must be preventing form being released to the atmosphere and the possible ignition of flammable or explosive atmospheres must be preventing. The electrical equipment need to have special protection to prevent from releasing the flammable mixture to the air. The ignition will only occur when both the flammable atmosphere and the means for an ignition exist simultaneously. It is very important to safeguard both the installation of the plant and the human life [2].

In extending the hazardous area classification procedure, many steps and thought need to be taken. First step is to identify the flammable atmosphere and the question should be asked to whether it can be reduced, both in extent and frequency. Then the assessment of all possible ignition sources should be carrying out. The electrical ignition source should not be the only one to be considering when others of potential ignition source are exists.

## II. AREA CLASSIFICATION

A hazardous area is an area in that contains an explosive atmosphere is, or may be expected to be, where it presents in quantities such as to require special precautions for the construction, installation and use of electrical equipment [5].

There are two main purposes of performing the area classification which is to identify the possibility of an explosive atmosphere existing in the particular area and to give appropriate guideline in designing the plant in order to minimize such risks.

The areas can be classified as a hazardous location is based on the following criteria: [6]

- i. The possible presence of an explosive atmosphere such as flammable gases, vapours or liquids, combustible dusts or ignitable fibers and flying.
- ii. The likelihood with the present of explosive atmosphere when equipment is operating.
- iii. The ignition-related properties of the explosive atmosphere that is present.

New approach has been introduced by IEC 60079-10 known as “source of hazard method” to trade the conventional method of area classification. The evaluation for the plant by restricting the size of hazardous areas is achievable if each source of release and the characteristics of release at that point are identified.

### III. EXPLOSIVE ATMOSPHERE

The definitions of an explosive given by the Health and Safety Executive, is a mixture, under atmospheric conditions, of air and one or more dangerous substances in the form of gases, vapors, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture. [7]

The ATEX directive does not define atmospheric conditions, but normally a temperature range of -20 °C to +60 °C and a pressure range of between 0.8 and 1.1 bars is accepted. It should be noted that electrical products are usually designed and tested for use in an ambient temperature range of -20 °C to +40°C in conformity with EN 50014.

### IV. SOURCE OF IGNITION

The ignition will only happened is the right amount of energy is present and the amount of energy required is dependent upon these factors:[1]

- i. The concentration of the hazardous substance within its specific flammability limits
- ii. The explosive characteristics of the particular hazardous substance
- iii. The volume of the location in which the hazardous substance is present

### V. ZONE DEFINITION

DSEAR defined the hazardous areas as “any place in which an explosive atmosphere may occur in quantities such as to require special precautions to protect the safety of workers”. [1]

Area classification is a method of analyzing and classifying the environment where explosive gas atmospheres may occur. The main purpose is to facilitate the proper selection and installation of apparatus to be used safely in that environment, taking into account the properties of the flammable materials that will be present. DSEAR specifically extends the original scope of this analysis, considering non-electrical source of ignition and mobile equipment that creates an ignition risk.

Hazardous areas are classified into zones based on an assessment of the frequency of the occurrence and duration of an explosive gas atmosphere, as follows:

- i. Zone 0 : An area in which an explosive gas atmosphere is present continuously or for long periods
- ii. Zone 1 : An area in which an explosive gas atmosphere is likely to occur in normal operation
- iii. Zone 2 : An area in which an explosive gas atmosphere is not likely to occur in normal operation and, if occurs, will only exist for a short time

Various sources have tried to place time limits on to these zones, but none have been officially adopted. The most common values used are: [12]

- i. Zone 0 : Explosive atmosphere for more than 1000 hour/year
- ii. Zone 1 : Explosive atmosphere for more than 10, but less than 1000 hour/year
- iii. Zone 2 : Explosive atmosphere for less than 10 hour/year, but still sufficiently likely as to require controls over ignition sources

The remainder of the hazardous areas of the process plant that has not been classified will be defined as non-hazardous area or well known as safe areas. The figure below shows the classification used to describe the various grades of hazardous area.

### VI. GROUP DEFINITION

The explosive characteristics of the air mixture of gases, vapors, or dusts vary with the specific material involved. Materials have been placed in groups based on their ignition temperatures and explosion pressures. Electrical apparatus for potentially explosive atmospheres is divided into two groups per EN 50014: [1]

- i. Group I : Electrical apparatus for mines susceptible for firedamp (for use underground) where methane and coal dust are present
- ii. Group II : Electrical apparatus for places with a potentially explosive atmosphere, other than mines susceptible to firedamp which is the surface industries.

The Group II gases are sub-grouped according to their volatility. This enables electrical equipment to be designed to less onerous tolerance if it is to be used with the least volatile gases.

### VII. SOURCE OF RELEASE

Each potential source of release of flammable including the process equipment should be considered. The grade of release is required to be determining if the equipment has established that it may release flammable material into the atmosphere. The grade is based on the probable frequency and duration of release. The sources of release are classified based on following basis: [9]

#### i. Continuous grade of release

An explosive atmosphere could be formed during the continuously or for long periods of release of the flammable gas, flammable vapour, flammable mist or combustible dust into the atmosphere.

#### ii. Primary grade of release

An explosive atmosphere could be formed during the periodically or occasionally in normal operation of released of the flammable gas, flammable vapour, flammable mist or combustible dust into the atmosphere.

#### iii. Secondary grade of release

This is a point or location from which flammable gases, flammable vapour, flammable mist or combustible dust is not expected to be released in normal operation, but at which release may be expected in frequently and for short periods or where dust layers form to an extent such that if disturbed an explosive atmosphere would be formed.

### VIII. DEGREE OF VENTILATION

The effectiveness of the ventilation in controlling dispersion and persistence of the explosive atmosphere will depend upon the degree and availability of

ventilation. There are three degrees of ventilation as shown on following: [10]

i. *High Ventilation*

Can reduce the concentration at the source of release virtually instantaneously, resulting in a concentration below the lower explosive limit (LEL)

ii. *Medium Ventilation*

Can control the concentration, resulting in a stable situation in which the concentration beyond the zone boundary is below the LEL while release is in progress

iii. *Low Ventilation*

Cannot control the concentration while release is in progress and cannot prevent undue persistence of a flammable atmosphere after release has stopped

The extent of the zone will be reduced with the increase of ventilation. Obstacles that impede the ventilation may increase the extent of the zone but some obstacles may also limit the extent of the zone such as walls or ceilings. There are two types of ventilation that has been practice which is the freely ventilated and not freely ventilated.

For freely ventilated situation, general method when classify an area is by calculating extent of the hazardous area. The source of hazard need to be identified and types of releases.

The typical areas of restricted ventilated are the open areas surrounded by walls, covered areas, above-ground rooms and below ground rooms. In the process plant, most of the electrical equipment such as the switch gear that have the highest possibility to produce spark is location inside a well ventilated room known as substation.

#### IX. ASSESSMENT OF DEGREE OF VENTILATION

The knowledge of the maximum release rate of gas or vapor at the source of release, either by verified experience, reasonable calculation or sound assumptions is needed in order to perform the assessment. Equation 1 shows the theoretical minimum ventilation flow rate to dilute a given release of flammable material to the required concentration below the lower explosive limit: [10]

$$\left(\frac{dV}{dt}\right)_{\min} = \frac{\left(\frac{dG}{dt}\right)_{\max}}{k \times LEL} \frac{T}{293} \quad (1)$$

Where:

$\left(\frac{dV}{dt}\right)_{\min}$  minimum flow rate of fresh air [m<sup>3</sup>/s]

$\left(\frac{dG}{dt}\right)_{\max}$  maximum rate of release [kg/s]

$LEL$  lower explosive limit [kg/m<sup>3</sup>]

$k$  safety factor: 0.25 for continuous and primary grades of release; 0.5 for secondary grade of release

$T$  ambient temperature [K]

Equation 2 estimates the hypothetical volume  $V_z$  [m<sup>3</sup>] of potentially explosive atmosphere around the source of release:

$$V_z = \frac{f \times \left(\frac{dV}{dt}\right)}{C} \quad (2)$$

Where:

$f$  efficiency of ventilation, ranging from 1 (ideal situation) to 5 (impeded air flow)

$C$  number of air changes [s<sup>-1</sup>]

The time required for the average concentration to fall from an initial value  $X_0$  to the  $LEL$  times  $k$  after the release has stopped (persistence time) can be estimated from:

$$t = \frac{-f}{C} \ln \frac{LEL \times k}{X_0} \quad (3)$$

Where:

$X_0$  initial concentration flammable substance [kg/m<sup>3</sup>]

$\ln$  natural logarithm: 2.303 log<sub>10</sub>

The ventilation can be rating as high, medium or low from the volume  $V_z$  while the persistence time can be used to decide what degree of ventilation is required for one area to comply with the definitions of Zones 0, 1 or 2.

It is significant to note that the higher the amount of ventilation in respect of the possible release rates, the smaller will be the extent of the zones, in some cases reducing them to a negligible extent.

#### X. EXTENT OF ZONES

The boundary of a particular zone is mainly determined by both chemical and physical parameters which are the release rate of gas and vapor; volatility of the flammable liquid; ventilation; relative density of the gas or vapor when it is released, and the region topography. [11]

It always takes into consideration the possibility that if the gas is heavier than air, it will fall and spread at ground level and if the gas is lighter than air, and it rises on release and can become trapped in the roof space. [6]

The extent of the zone depends on the estimated or calculated distance over which an explosive atmosphere exists before it disperses to a concentration in air below its lower explosive limit (LEL). In the gas and vapours cases, it is said that the greater the release rate, the larger the extent of the zone. The release rate itself depends on other parameter which is: [12]

- Geometry of the source of release
- Release velocity
- Concentration
- Volatility of a flammable liquid
- Liquid temperature

#### XI. CALCULATION OF RELEASE RATES AND EXTENT OF HAZARDOUS AREA

The orifices are designed to ensure the maximum flow for minimum effort. Thus these mathematical approaches are built around calculation of fluid flow from orifices. [6]

### A. Release of gas and vapour

The Equation 4 calculates the mass release of gas from an orifice. This equation is only valid if upstream absolute exceed  $2 \times 10^5 \text{ N/m}^2$ , if not consideration should be taken about the diffusion effect since the effect of atmospheric is significant.

$$G = 0.006 a P \left( \frac{M}{T} \right)^{0.5} \text{ kg/s} \quad (4)$$

Where,

- $G$  mass release, kg/s
- $a$  cross-sectional area of leak,  $\text{m}^2$
- $P$  upstream pressure,  $\text{N/m}^2$
- $M$  molecular weight
- $T$  absolute temperature of released gas, K

The equation 5 calculates the volume of released gas.

$$V = \frac{V_0 GT}{T_0 M} \quad (5)$$

Where,

- $V_0$  molar volume,  $\text{m}^3/\text{kg}$
- $T_0$  melting point of ice, 273 K

Then substituting both values, the formula will be simplify as,

$$V = \frac{0.082 GT}{M} \quad (6)$$

As the target is to find the extent of hazardous area, the distance 'X' of the gas and vapour traversing falls below LEL, which is already mixing with the air can be calculated equation the equation below provided that the jet velocity is sufficiently high as compared to air/wind speed.

$$X = 2.1 \times 10^3 \left[ \frac{G}{E^2 M^{1.5} T^{0.5}} \right]^{0.5} \quad (7)$$

Where,

- $E$  lower explosive limit (LEL), %

If the difference between the jet velocity and the air/wind speed is reduces, the distance can be calculated using equation below as it is based form experimentation where,

$$X = 10.8 \left( \frac{GT}{ME} \right)^{0.55} \quad (8)$$

### B. Obstruction to the gas and vapour release

There is a possibility that there is presence of a barrier or an object during the release of gas or vapour. The volume need to be calculated first using equation below in order to determine the distance.

$$B = 100 - L \left[ \frac{(100 - \text{LEL})}{X} \right] \dots \% \quad (9)$$

Where,

- $B$  gas/vapour in air
- $L$  distance to obstruction
- $X$  distance to LEL

Then the new effective molecular weight can be calculated since the volume ratio is known. After

obtaining the result from the calculation below, the new dispersion distance can be finding using Equation 8.

$$M_{(mixture)} = \left[ \frac{M_{(gas)} \times \%_{(gas)}}{100} \right] + \left[ \frac{M_{(air)} \times \%_{(air)}}{100} \right] \quad (10)$$

$$V_{(gas)} = \frac{0.082 GT}{M_{(gas)}} \quad (11)$$

$$V_{(mixture)} = V_{(gas)} \times \left[ \frac{100}{\% \text{ gas in mixture}} \right] \text{m}^3 \quad (12)$$

$$G_{(mixture)} = V_{(mixture)} \times \frac{12.19 M_{(mixture)}}{T \text{ kg}} \quad (13)$$

$$\text{LEL}_{(mixture)} = \text{LEL}_{(gas)} \times \left[ \frac{100}{\% \text{ gas in mixture}} \right] \% \quad (14)$$

## XII. ART OF ILLUSION

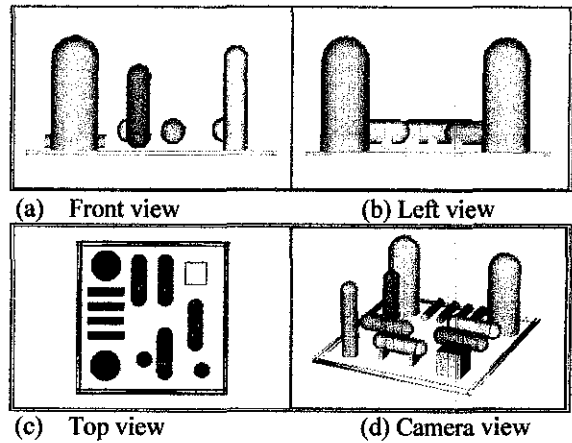


FIGURE 1: EXAMPLE OF VARIETY OBJECT VIEW IN ART OF ILLUSION

The figure above shows the interface in the Art of Illusion where it provides four different windows that enables the users to experience different angle of view. The user can choose at which angle to view as Art of Illusion offer view from Front, Back, Top, Bottom, Left, Right and Camera view. The object can also be rotate with 360 degree and this should give advantages to get better observation.

The Art of Illusion is a software package used for 3D modeling, texturing, ray tracing, and otherwise rendering computer generated imagery stills or animations [14].

The objective of the Art of Illusion is to provide powerful 3D modeling tools with a user interface that improves on those found in other 3D software packages. Though its interface is simple, this application contains many features found in high-end commercial graphics software [14].

This software enables the user to have view of the 3D simulation process plant from 360 degrees or from the 3D view sine it has four different windows. Beside, the user can also rotate the view to assess the overall area of the process plant.

The software is preferred as compare with the other 3D software is due to its flexibility and ease of rendering. This software also easy to be understands and learns for the new beginner. The flexibility including the command

to makes modification to the original software in order to fits the objective of the project.

### XIII. NETBEANS

The NetBeans IDE is an open-source integrated development environment. It supports development of all Java application types out of the box. [15]

This software will be used to create the GUI for the 3D simulation process plant. The NetBeans IDE will create the dialog box for the user to enter the input which is the type of zone for the area. Then the colour of the area will be change based from type of zone. This is essential for the user because they can easily recognize the types of zones based on the colour.

All the hard work of programming will be done through this software. The target is to provide the user with all the data about the area that has been classified so that the user can learn the reason for every classification and not just accepting the fact.

So the NetBeans is used to make the GUI which is the dialog boxes and the user need to define the type of zone which later on will change the colour of the area based on the type of zone. The information of the area that will be covered is the types of gas, molar weight, ambient temperature, the pressure and etc.

### XIV. CASE STUDY ON EXTENT OF ZONES

Consider a situation where there is a gas released due to leakage from a pipe flange gasket. Thus a rapid expansion and fall in pressure will takes place. The probably way the envelope of explosive and flammable gases will develop during mixing stage. While the likelihood of area till which place the hazardous area will extent. So the aim is to find the distance which is extending of hazardous area.

The different types of gases will have different molar weight and LEL at the given ambient. In the case of the Crude and Vacuum Distillation Unit, these are the several gases that probably will be release. The extent of the zone for these different types of gases will be calculated with using the same value of the ambient temperature, size of orifice and the pressure in pipe. The types of gases and their characteristics are shown in the next table.

TABLE I  
TYPE OF GASES AND THE CHARACTERISTICS

Type of Gas	Molar Weight	LEL at the given ambient
Methane	16.042	5.0%
Propane	44.1	2.1%
Ethane	30.07	3.0%
Carbon Monoxide	28.01	12.0%

The value of the ambient temperature, size of orifice and the pressure in pipe is as stated below:

- Ambient temperature : 22 °C
- Size of orifice :  $4 \times 10^{-5} \text{ m}^2$
- The pressure in pipe:  $4 \times 10^5 \text{ N/m}^2$

Next, the released mass and extent of the zone is calculated for each different gas release using Equation 4 and Equation 7. The results of the release mass and extent of zones is recorded in the table below. It can be seen that each gas release will give different result when calculated.

TABLE II  
RESULTS FOR RELEASED MASS AND THE EXTENT OF ZONE

Type of Gas	Released Mass (kg/s)	Extent of Zone (m)
Methane	0.022	1.875
Propane	0.037	2.710
Ethane	0.030	3.420
Carbon Monoxide	0.029	0.589

### XV. SOFTWARE MODIFICATION

The modification is made to the Art of Illusion in order to add some features that are needed to complete the objective of this project. The modification can only be done through programming which using the software NetBeans IDE. The first modification is to have a dialog box that will enable the user to define the zone for that particular area. Figure 3 shows the dialog box.

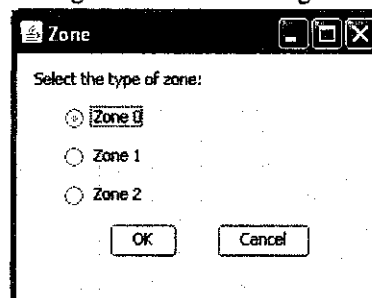


FIGURE3: THE DIALOG BOX

Once the user has opened the Art of Illusion, he needs to go to the Tools first and there will be list of commands. Click on the Define Zone command and only then the dialog box will appear. After he has defined the zone, for example Zone 0, the size and the colour of the area will change according as shown in the table below:

TABLE III  
ZONE IDENTIFICATION BASED ON COLOUR

Zone	Colour
0	Red
1	Yellow
2	Green

Another feature that will be added to the Art of Illusion to make the software is worth and give value to the user is by having a pop up window to define type of gas and the characteristic of the gas to be compare to the air. Figure 4 shows the pop window for the Gas Definition.

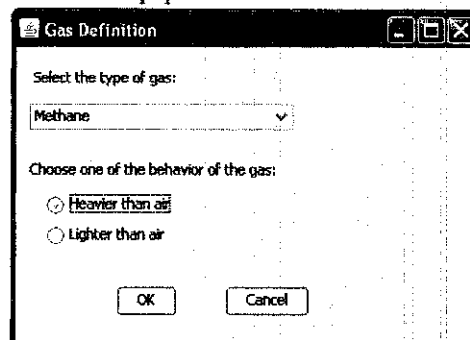


FIGURE 4: THE GAS DEFINITION



Next, the Art of Illusion will have the features to calculate the release mass and extent of the zone by itself through the programming which is powered by NetBeans. So far, there are only two calculations that we are interested to know so the user will asks to choose which calculation that they want to be calculated. Figure 5 shows the pop window for this purpose.

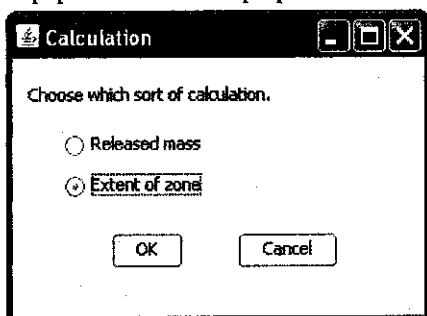


FIGURE 5: CHOICE OF CALCULATION

The result for both calculations will then appear in separate window as once the user click the button OK, a pop window will appear and display the result. If the user click on the Released Mass and then OK button, a window as shown in Figure 6 will appear and if the users choose to calculate the Extent of Zone, a pop window as shown in Figure 7 will appear.

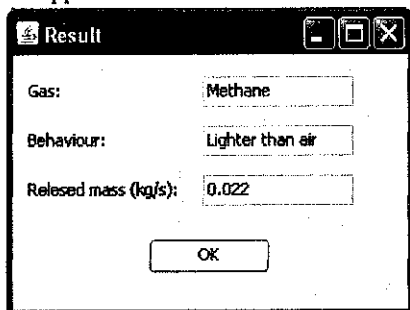


FIGURE 6: RESULT FOR RELEASED MASS

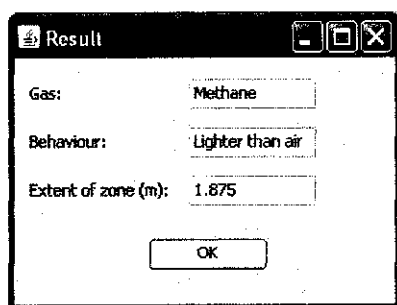


FIGURE 7: RESULT FOR EXTENT OF ZONE

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