Investigation on Effect of Distance between Tanks on Fire Spread in Oil Refinery

by

Fatin Nabilah Binti Riswan
14764

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Universiti Teknologi Petronas
Bandar Seri Iskandar
Tronoh 32610
Perak Darul Ridzuan

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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FATIN NABILAH BINTI RISWAN

CERTIFICATION OF APPROVAL

by

Fatin Nabilah Binti Riswan

14764

A project dissertation submitted to the Mechanical Engineering Programme Universiti Teknologi PETRONAS in partial fulfilment of the requirement for the BACHELOR OF ENGINEERING (Hons) MECHANICAL ENGINEERING

Approved by,

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(Dr. Mohammad Shakir Nasif)

Abstract

Safety has become the priority for oil and gas industry in order to protect workforce, property and country’s economy. In spite of the oil industry's excellent efforts in the field of fire prevention, it is still necessary to provide fire protection. Oil refinery deals with large amount of hydrocarbons which are highly flammable. Therefore, a reliable and functional fire fighting system is important to ensure safety of the refinery. This research investigates the effect of distance between tanks on fire spread. Hydrocarbon fire of burning tanks will radiate heat to adjacent tank even when fire fighting operation is in progress. In general, some may think that as long as the fire fighting operation is in progress, the fire will be under control. However, in real situation when fire fighting is in progress, the heat release rate of the fuel will decreases but it will continue radiating heat to adjacent tanks which may cause fire spread. Defining the behaviour and heat release rate of hydrocarbon fire when there is fire fighting operation is in progress relating in distance of tanks. This study also adapt fire safety on performance based design where Fire Dynamic Simulator CFD software will be used to study the safe boundary distance of tanks containing hydrocarbon. It has been found from the simulation that when fire fighting operation in progress, fire spread between tanks at distance of 3 meter and 5 meter. However, fire did not spread when distance is 7 meter.

Acknowledgment

First of all, Praise is to ALLAH the Almighty for His endless blessings in my life and the happiness and success He granted me during my life and undergraduate studies program. My deepest heart gratitude to my parents who always give me support and provide me with every necessity through my entire life.

I would like to express my gratitude to my supervisor, Dr. Mohammad Shakir Nasif, whose expertise, understanding, and patience, added considerably to my graduate experience. I appreciate his vast knowledge and skill in many areas in which I was very encouraged to improve my presentation skills. Very special thanks goes out to Mr. Ali Hasnain, who truly helped me to have a better understanding by dedicating his valuable time to explain on the fundamentals of fire engineering and enlightening me the first glance of project.

I wish to sincerely thank my course mates and colleagues who are a source of great emotional support and, of course, thanks for their constant support through the ups and downs of my academic years. My gratitude is also extends to all, who supported and advised me as well as providing feedbacks during my undergraduate program.

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CHAPTER 1 : INTRODUCTION

1.1 Background

Many unexpected fires occur each year and cause fatality and property damage which costs billions of dollars. This is includes fires in the refinery or plants. Statistics showed that oil and gas industry comes second after fire fighters in deaths from workplace fires and explosions, (Soraghan, 2014). Safety has become the priority for oil and gas industry in order to protect their workforce and property. Oil and gas industry deals with large amount of hydrocarbons which are highly flammable. A reliable research and functional fire fighting system are needed in order to overcome these fast growing hydrocarbon fires.

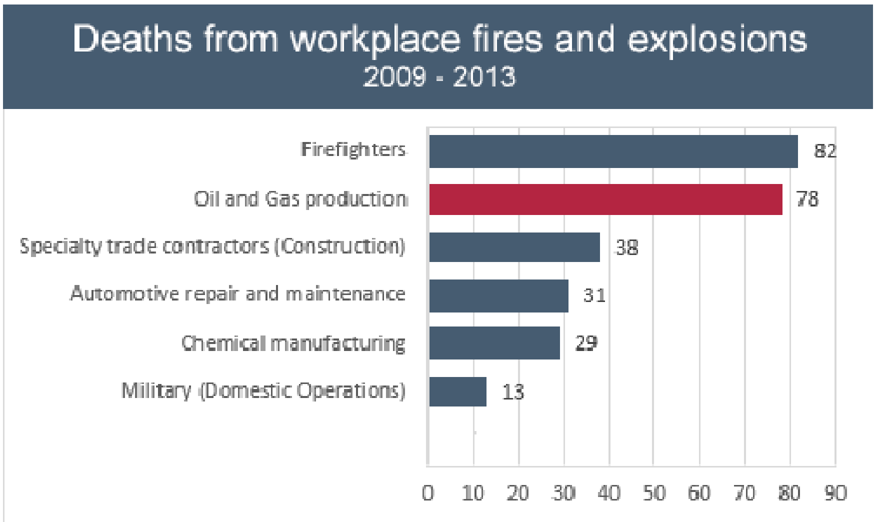

Figure 1: Death from workplace fire and explosions, (Soraghan, 2014)

Malaysia is a middle-income country. It has transformed itself since the 1970s from a producer of raw materials into an emerging multi-sector economy. Based on Malaysia Economy Profile in 2014, it has stated that oil and gas sector contributes 32% of government revenue in 2013. This shows that oil and gas sector play important role in country's economy. Any loss or accident in oil and gas sector may affect significantly to country's economy.

Water is the best fire fighting agent because it has low cost, readily available and effective. Water can control and suppress unwanted fires whether it is a small incident or a large industrial fire. Water suppresses fires by heat absorption and also by oxygen deprivation. However, during fire fighting operation is in progress, heat released from the fire can radiate to surroundings. Radiation is the one of main reasons of fire between fuels. In oil and gas industry, when fire occurs in a fuel tank, many believe that the fire fighters are able to control the fire once the fire fighting operation is in progress. However, in reality, while fire fighting operation is in progress, the fire in the tank will continue to radiate heat to adjacent tanks which may cause fire spread. Therefore, in this study, safe boundary distances for preventing ignition by fire radiation between the tanks facing each other are examined.

1.2 Problem Statement

Oil refineries handle and store a large amount of hydrocarbon. The risk of hydrocarbon fire is very high. Although refineries have high level safety measures, the risk index cannot be eliminated completely. Hydrocarbon fire are fast growing and very dangerous as it spread and may cause severe damage. Property worth millions will be lost and lives will be in jeopardy.

Fire releases a certain amount of heat energy. This heat release rate from a burning tank can ignite other fuel at its surrounding. Although water is used to put down the fire and as the fire fighting operation is in progress, the tank will continue radiating heat to the adjacent fuel or tanks. This will cause fire spread. There is no study available to investigate effect of distance between tanks on fire spread when fire fighting operation in progress.

1.3 Objectives

The objectives of this project are as follows;

a) To model fire spread between hydrocarbon tanks in oil refinery facility by using CFD Fire dynamics simulator software and investigate the fire spread to adjacent tanks while fire fighting operation in progress.
b) To investigate the safe distance between tank that should be maintained in order to prevent fire spread.

1.4 Scope of study

The scope of study of this project includes;

a) Basic of Fire Dynamics and Fire Engineering
Understanding the basic terms and principle in fire dynamics and fire engineering. It includes the behaviour of fire and smoke, heat transfer and characteristic of fuel.

b) Fire Dynamic Simulator software
This software will be used to simulate and analyse the behaviour and heat transfer of fire in the refinery.

i. To model real tank in oil and gas refinery and simulate the fire.
ii. Use heat release equation which calculated the reduced heat release rate when water is used to fight the fire.
iii. Model the same tank but with the reduced heat release rate and vary the distance between tanks.

1.5 Feasibility of the project

The researcher has established the plan to accomplish the project within its time constraint during Final Year Project I and Final Year Project II. During FYP 1, the researcher plans to get the basic knowledge of the fire fighting engineering and to be familiarized with the simulation software CFD-FDS. Moreover, the researcher plans to develop the preliminary model using the CFD software in order to model and run the simulation. Afterwards, developing the fully-scaled model during FYP2 will be accomplished. Then, the researcher will analyse the results and findings to determine the effect of distance between tanks on fire spread for refinery facilities. The two semesters are expected to enable the researcher to complete the project within its time constraints. Project Gantt chart presents the project timeframe.

CHAPTER 2 : LITERATURE REVIEW

2.1 Fire Safety Design

Over years, fire safety design of a structure or facilities in oil and gas is questioned. With technologies have expanded over the years, there are two type of design in designing buildings or structures which are prescriptive design and performance based design. Developed countries such as New Zealand, Australia and England have led the move towards performance-based design.

Prescriptive based fire safety desgin provides fire safety by prescribing a combination of specific requirements. For example, design of fire safety measures which comply with the prescriptive regulatory requirements such as flow rate and pressure of fire fighting water. Limiting dimension is also prescribed in prescriptive based design. Prescriptive codes specify exactly what steps need to be taken to achieve the safety requirement.

On the other hand, performance based design allow freedom in designing where it provide more effective and efficient fire safety solution. The idea behind performance based design is that the designers can use any solution wanted, as long as it meets the goal stated in the performance based code. The goals of a performance based code are usually in very broad terms. One of the example of performance based design is by doing fire modelling.

Fire modelling is constantly evolving and becoming more popular. However the fullest range of data does not currently exist that would allow a performance based approach to be used for fire protection purposes. There are other modelling programs such as structural modelling that have proven close to approximate real world conditions. Fire models though are still inconclusive and inconsistent. The design condition of fire protection always change based on the design of plant of refinery. Fire protection has to meet the requirement in order to overcome safety issues.

Performance based design appear to be gaining in popularity. This type of design approach can highlight and solve safety issues such as fire spread. In this project, performance based design are practiced where it needs simulation and analysing the fire safety design. Fire Dynamics Simulation software (FDS) are one of the method in designing a performance-based design.

2.2. CFD-FDS Software

Fire Dynamic Simulator or FDS is a computational fluid dynamics (CFD) model of fire-driven fluid flow. It is the first software version was released early February in 2000 (Smardz, 2006). FDS allows developing models for solving practical problems in fire protection and providing solution from the simulation so that designers or engineers can come with a solution for more safe and protected fire safety systems. Each element is treated individually and the effects of the elements surrounding it are determined through a series of mathematical relationships based on the conservation of mass, species, energy and momentum (Davis, 2000).

Further, modelling using CFD-FDS software is very essential as it consider a tool of the performance-based design. Computer simulation software allows engineers to establish similar conditions of the reality into the model, analysing the model and acquire accurate results which help to the safety fire system designs. Nowadays, most of the engineers apply the principle of perspective-based design and they lack of using advanced software. Moreover, engineers tend to use analytical assessment for fire safety systems design through the use of equations obtained experimentally. Hence, engineer will apply the most suitable formulas obtained from almost similar conditions of that experiment.

Many benefits can be obtained by using this software rather than using analytical assessment methods. One of the benefits is by applying the performance-based design principle with typical condition of reality and assuming the worst case scenario can only be accomplished using the computer software. CFD-FDS software is suitable to be us when the system is complex and needed more analysis. It allows applying all reality conditions into the model and analysing the system to attain very high and reliable results. On the other hand, analysing a particular systems using obtained formulas from other experiments can directly give results with low accuracy since, of course, it is not typically the same conditions of both systems (Shih et al, 2000).

Moreover, engineers will be able to save cost and time. It is impractical to build a tank and then test the facilities by burning it. Hence, the engineer could develop a model, using CFD-FDS software, of that particular tank or facilities and apply similar conditions of the reality into the developed model.

This software will be used in this project in order to simulate and analyse the behaviour of fire which leads to investigating the effect of distance on fire spread at the refinery.

2.3 Fire Behaviour

The fire size accuracy is important in solving problems in fire engineering. The traditional nature of fire behaviour can categorized mainly three phases. Referring to figure 2 the three phases are growth, fully developed and decay.

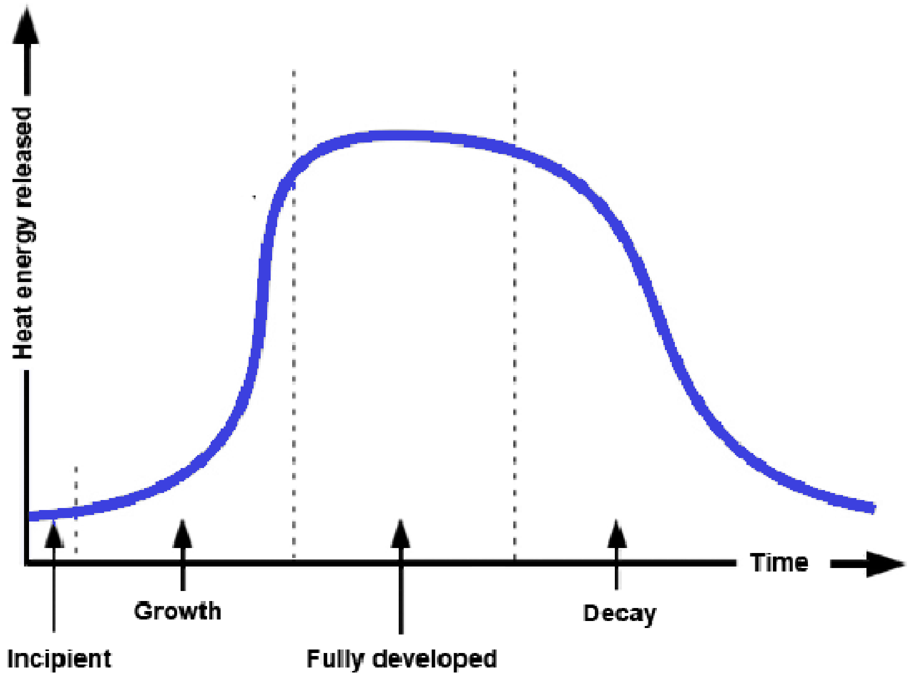

Figure 2: Heat Energy Released of fire, by The National Institute of Standards and Technology (NIST), 2013. Adapted from www.nist.gov.

Understanding the fire behaviour is important in fighting the fire. The behaviour of heat energy release also can be determined. It is the energy needed to change the temperature of an object such as when heat added, temperature will increases while when heat is removed, temperature decreases. Fire fighters common practice is to control the fire at growth phase in order to prevent fire spread.

Heat Release Rate (HRR) is the rate at which fire releases energy which is also known as power. HRR is measured in units of Watts (W). Methods for experimental HRR calculation can be classified into three categories according to the fire parameters that can be measured which are the mass of fuel, the mass of oxidant or products involved in the combustion reaction and the amount of heat transferred from the fire to the surroundings (Pretrel et al, 2013). The third method will be used in this project.

2.4 Radiative Heat Transfer

Radiation is the main cause of spread of fire between fuels in open space (Carlsson,1999). The behaviour of hydrocarbon fire is different from normal fire in buildings or open fire. Hydrocarbon fire transfers heat 70% by radiation and 30% by convection.

Ignition due to radiation is the most common way for fire to spread between fuels and can happen at much greater distances than by direct flame contact and convection, (Carlsson 1999). A body with a certain temperature, T, emits heat energy, P, to the surroundings at all times, (Carlsson 1999). This transfer of energy can be described by equation below. The emitted heat energy is expresses in terms of energy emitted per second an area unit, i.e. J/sm2 or W/m^2.

$$P = \varepsilon\sigma T^4 \tag{1}$$

where:

P : emitted radiation [W/m^2]
ε : emissivity of the radiating surface
σ : Stefan-Boltzmann constant = 5.67×10-12 W/m^2 K^4
T : temperature of object [K]

From equation 1, it can be concluded that since the temperature is taken to the fourth power, it is obvious that the temperature was the greatest impact on the total amount of emitted radiation. Since the emitted radiation is from a burning object, hence the tank separation distance is dependent on the fire temperature to the power of four. This factor should be investigated thoroughly in a performance based design.

2.5 Water as Extinguishing Mechanism

Water is commonly used to fight fire involving flammable gas or liquids and combustible liquids or solids. As mentioned before, these types of fire will transfer heat 70% by radiation and 30% by convection and conduction. Davis (2000) stated that water quantity figures for protecting radiation exposures of between 1 to 10 litre/m^2/minute, depending on the impinging radiation levels. However, this figure is valid for fires in building with different type of fuels.

Relevant duration and maximum amount of firewater required to fight a fire can be estimated by analysis and modelling of potential fire scenario. For hydrocarbons fire scenario water usually not considered as extinguishing medium but it is used mainly for cooling purposes in order to control the fire.

According to the analysis done by Rigolio (2010), criteria for modelling the duration of a scenario can be established starting from assumptions on the amount of flammable or combustible liquids or solids contained in the plant or refinery and taking into account factors like liquid burning rate, evaporational effects, properly designed fire fighting systems and process isolation devices.

In Rigolio's (2010) study, only liquid pool fire and dust fire scenario were analysed. Jet fire scenario due to flammable gas release has been considered not significant in the context. Types of scenario that may occur in process plant are flammable liquid fire, combustible liquid fire, Liquefied Petroleum Gas (LPG) fire and combustible powder fire. The first three scenarios are closely related to this project.

According to Davis (2000), there are various ways in calculating amount of water in distinguishing and controlling fire. Method that is closely related to this project is the Iowa State University method. The Iowa State University method defines that the amount of water needed to extinguish a fire based on the water ability to absorb the energy or its ability to displace oxygen when it changes state. In this project, definition of the amount of water needed to extinguish a fire based on its ability to absorb the energy released is closely related. A formula by The Iowa State University assumes that 80% of the applied water is converted to steam and that it is applied within 30 seconds. The formula is based on several Danish studies and some real fire tests conducted at ISU. The equation assumes the complete compartment is on fire.

When water is discharge by the fire fighters to control and distinguish the fire, the heat release rate of the fire will be reduced. This reduced heat released rate can be calculated using formula obtained from Society of Fire Protection Engineers Handbook.

$$\dot{Q}_{(t-t_{act})} = \dot{Q}_{(t_{act})} \exp\left[\frac{-(t-t_{act})}{3(\dot{w})^{-1.85}}\right] \qquad (2)$$

Where

$\dot{Q}_{(t_{act})}$: heat release rate at the time water discharged (kW)

$\dot{Q}_{(t-t_{act})}$: heat release rate at the time following the water discharge (kW)

$\dot{w}$: the water flow density (mm/s)

t : any time following the water discharge

Based on equation 1, it can be seen that water flow density can affect the heat release rate of the fire. The higher amount of water will reduce higher heat release rate. Therefore, right amount of water is needed in order to fight fire.

CHAPTER 3 : METHODOLOGY

3.1 Research Methodology

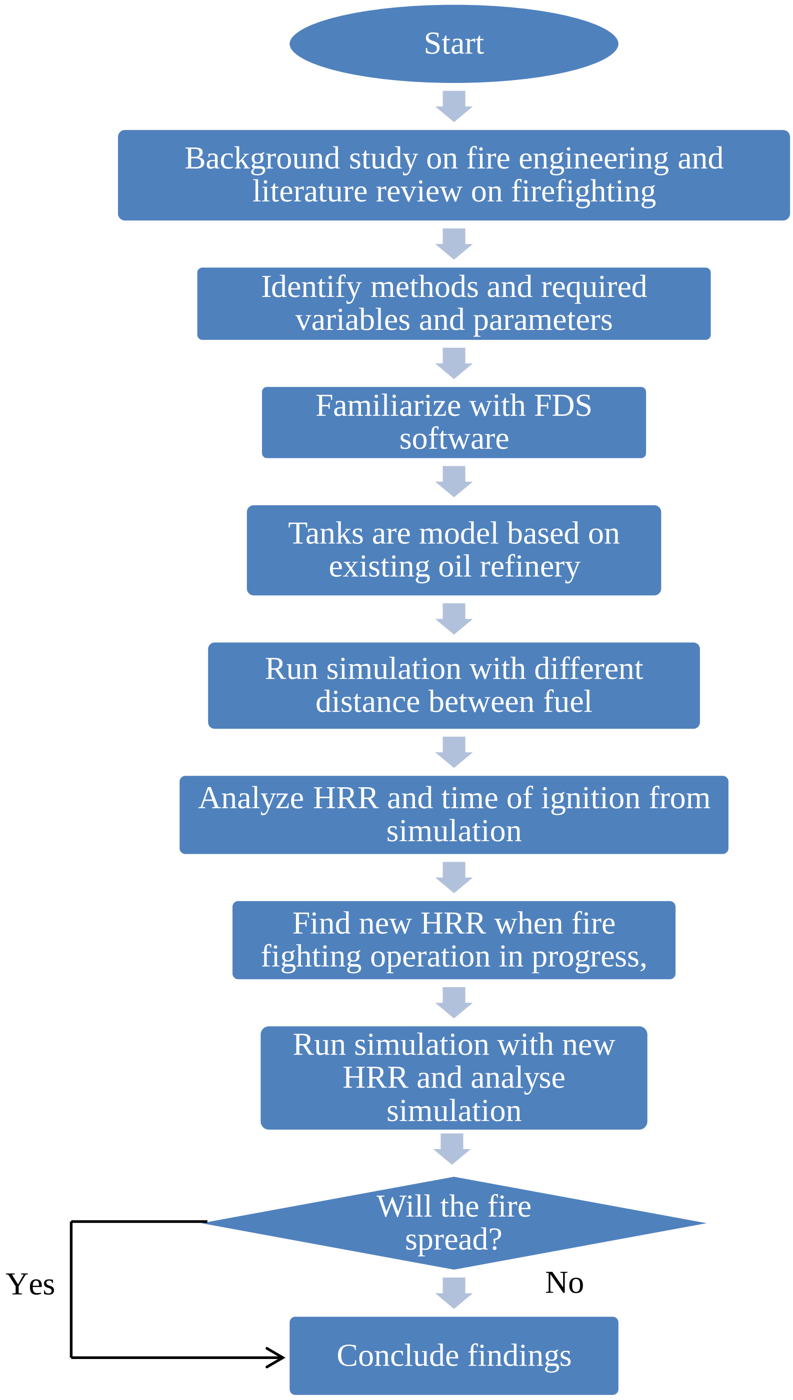

Figure 3: Flow of project

3.2 Gantt Chart and Key Milestones

Table 1: Gantt Chart and Key Milestones for FYP1

No	**Detail/Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1.	Selection of Project Topic														
2.	First meeting with supervisor														
3.	Introduction to Fire Engineering														
4.	Planning of the flow of project with supervisors														
5.	Submission of Extended Proposal						●								
6.	Mock presentation														
7.	Proposal Defence														
8.	Introduction to FDS Software														
9.	Modelling and simulation														
10.	Submission of Interim Draft Report													●	
11.	Submission of Interim Report														●

Table 2: Gantt Chart and Key Milestones for FYP2

No	**Detail/Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1.	Modelling and simulation														
2.	Progress report							●							
3.	Problem shooting and analyse data														
4.	Pre-SEDEX											●			
5.	Draft Dissertation														
6.	Technical paper												●		
7.	Dissertation													●	
8.	Mock presentation														
9.	Oral Presentation														●
10.	Thesis														●

3.4 Tools & Software Required

a) Fire Dynamic Simulator

FDS is a computational fluid dynamics (CFD) model. Appropriate for low-speed, thermally-driven flows of smoke and hot gases generated in a fire is solved using the equation of the Navier-Stokes equations.

b) Microsoft Word

This software used for documentation of drafts and reports for this final year project.

c) Microsoft PowerPoint

This software is used in delivering the project in proposal defence, pre-SEDEX and Viva.

3.5 Fire Dynamic Simulator

In order to achieve reliable results using this software, there are basic procedures that need to be followed. Below is the process flow of the procedure;

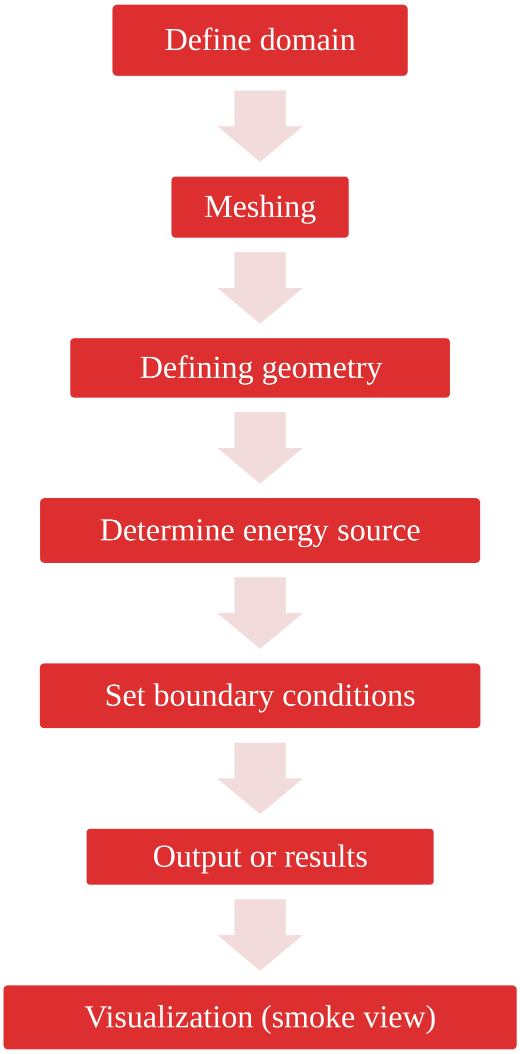

Figure 4: FDS procedure

Based on figure 4, there are a few steps of FDS procedure that have to be followed which are define domain, meshing, defining geometry, determining energy source, set boundary conditions, output or results and visualization or smokeview.

The procedure starts with define domain. Domain is a specified area that will be studied and analysed in this project. An area of the refinery is chosen in order to start modelling in the FDS software. After defining the domain, number of mesh is chosen. Theoretically, finer mesh will give more accurate results. However it will consume more time and this will lead to unpractical analysis. A suitable mesh should be used to make sure the viability of the results.

The next step is defining geometry. The geometry of tanks in the refinery is determined in order to be modelled in the software. The geometry of tanks is circular and its dimension is recorded. In FDS input file, geometry is defined as obstruction. Obstruction can be constructed by defining coordinates in the input file. Therefore, only rectangular shape of obstruction or geometry can be constructed. Combination of obstruction can be done to get a circular geometry.

Determining energy source is the next step. In this context, energy is the heat release energy emitted by the burning tank. The position of energy is determined and the amount of the heat energy release is also defined based on the tank of refinery. Next, boundary condition is defined. Boundary condition is important as different boundary condition will give different results.

After all the steps and modelling are done, simulation can be run and results or output can be obtained. Results are presents in excel. Results are also presented in smokeview. Smokeview is a part of the software where is provides visualization of the simulation

CHAPTER 4 : RESULT AND DISCUSSION

4.1 Model development

In order to start the project, important data have to be collected. Two tanks containing petrol is chosen to be modelled and simulated using FDS software. Only two tanks are modelled for the simulation because the area of a real refinery is too big and will take a very long time for simulation. However, the concept of defining heat release rate, temperature of adjacent tanks, distance between tanks and amount of water can be related to the whole refinery.

The details of the tanks in that area such as dimension and volume of the tanks are determined while petrol is chosen as the type of fuel contained in the tanks. The details tabulated in table 3.

Table 3: Tank details

No.	Tank	Type of fluid	Size (m)	Volume (m^3)
1.	A	Petrol	2.1 diameter x 1.2 height	6359
2.	B	Petrol	1.5 diameter x 1.2 height	3498

Volume and type of fuel, the properties of fuel chosen is essential. Petrol is chosen because petrol tanks are used in real application in refineries. The ignition temperature of petrol is 37˚C. The properties of the petrol are tabulated in table 4.

Table 4 : Burning rate data from *SFPE Handbook of Fire Protection Engineering(2002), 3rd Edition.*

Type of fuel	Density (kg/m^3)	Total burning rate ($kg/s/m^2$)	Net calorific value (MJ/kg)
LPG	585	0.099	46.0

This information of fuel properties is also used in order to estimate the heat release rate from the tank that is burning. The heat release is important parameter and needed in for simulation. Formula of estimating the heat released rate is obtained from Society of Fire Protection Engineers

(SFPE) Handbook of Fire Protection Engineering. Equation 2 is used for estimating heat released rate of the fire.

$$Q = m^{"} \Delta H_{c,eff} (1 - e^{-k\beta D}) A_{dike} \quad (3)$$

Where,

Q : pool fire heat release rate (kW)

m" : mass burning rate of fuel per unit surface area (kg/m^2-sec)

$\Delta H_{c,eff}$: effective heat of combustion of fuel (kJ/kg)

A_{dike} : surface area of pool fire (area involved in vaporization) (m^2)

kβ : empirical constant (m^{-1})

D : diameter of pool fire (m)

Below are the values calculated using the formula above.

Table 5 : Calculated heat release rate

Tank	Barrel (gallon)	Area (ft2)	Heat Release Rate Per Unit Area, HRRPUA (kW)
A	1679999	5281	1333
B	923999	2642	1137

The new heat release rate when fire fighting operation started is also needed in order to run the simulation. By having this new heat release rate, observation can be made from the simulation whether the fire at the tank will spread to adjacent tank. The formula used for estimating the new heat released rate is obtained from Society of Fire Protection Engineers (SFPE) Handbook of Fire Protection Engineering.

$$\dot{Q}_{(t-t_{act})} = \dot{Q}_{(t_{act})} \exp\left[\frac{-(t-t_{act})}{3(\dot{w})^{-1.85}}\right] \quad (2)$$

Where

$\dot{Q}_{(t_{act})}$: heat release rate at the time water discharged (kW)

$\dot{Q}_{(t-t_{act})}$: heat release rate at the time following the water discharge (kW)

$\dot{w}$: the water flow density (mm/s)

t : any time following the water discharge

Common practice of fire fighting protection in oil refinery, the flow rate of firewater in fire fighting pipeline is 94 liter/s. This will be used as water flow density in the formula while time of water discharge is assumed to be 7 minutes. This is because oil refinery will have its own fire truck and Emergency Response Plan (ERP) team as back up before fire fighter arrived.

4.2 Modelling

As important data has been collected, the modelling can be done using Fire Dynamics Simulator (FDS). Inputs needed in the FDS are size of domain, heat release rate per unit area (HRRPUA) and tanks are constructed based on its dimensions. These inputs will be written in FDS input file as shown in figure 5. Complete FDS input file is presented in Appendix A.

Input file is the pre-processor of the simulation. The pre-processors is in notepad which consist of commands which enable FDS to build the model. FDS can only produce blocks of obstructions using coordinates in a domain. Since the tanks are circular, it is a challenge to construct a cylinder in the software. Blocks with small width, different length and same height are developed in order to construct a cylinder tank.

Next stage would be the processor of the simulation where FDS software solves the Navier-stokes and energy equations. Lastly is the post-processor which is the visualization by smokeview. Figure 6 and figure 7 are side and top view of FDS Smokeview.

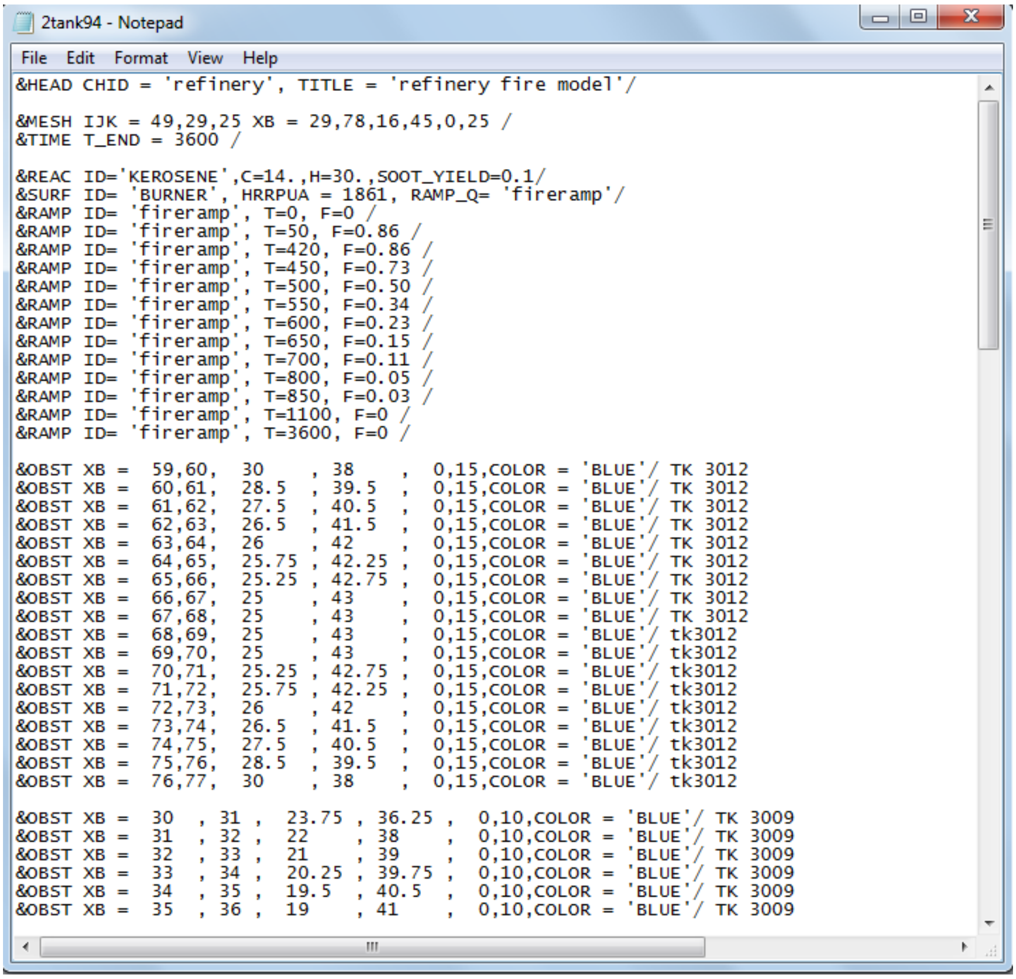

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Figure 5 : Screenshot of FDS input file

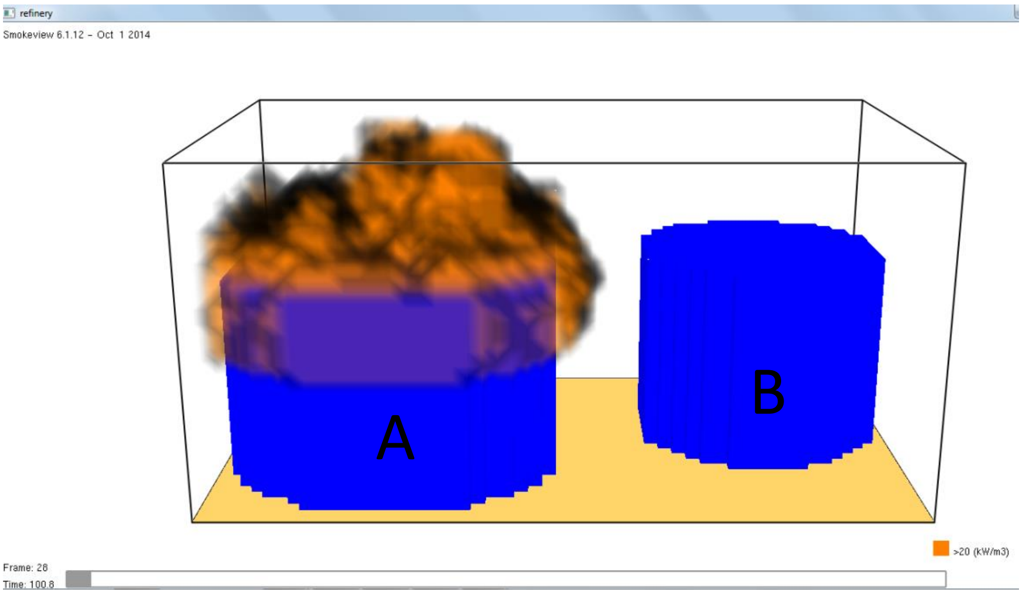

Figure 6 : Screenshot of side view of FDS simulation

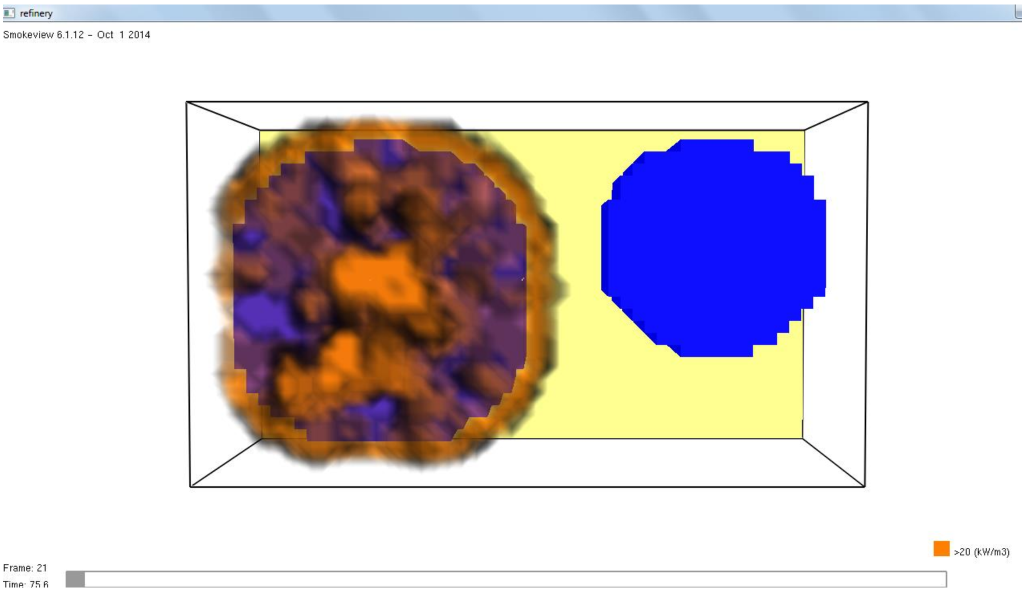

Figure 7 : Screenshot of top view of FDS simulation

4.3 Result

The results are obtained and tabulated into graphs. Heat release rate and temperature of tank is observed and analysed.

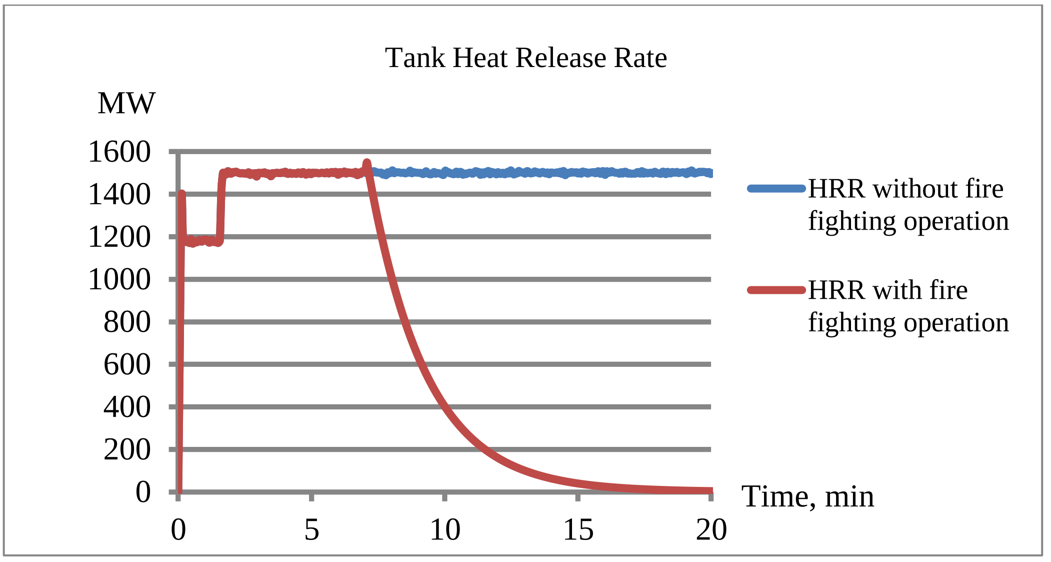

Figure 8 : Graph of tank heat release rate

Graph 8 shows heat release rate of the tank. Blue coloured line is the heat release rate of the tank without fire fighting operation. The heat release rate increases rapidly when the fire started. While the red coloured line is the heat release rate of the tank with fire fighting operation. The heat release rate decreases gradually starting at time of 7 minutes which is when the fire fighting operation starts.

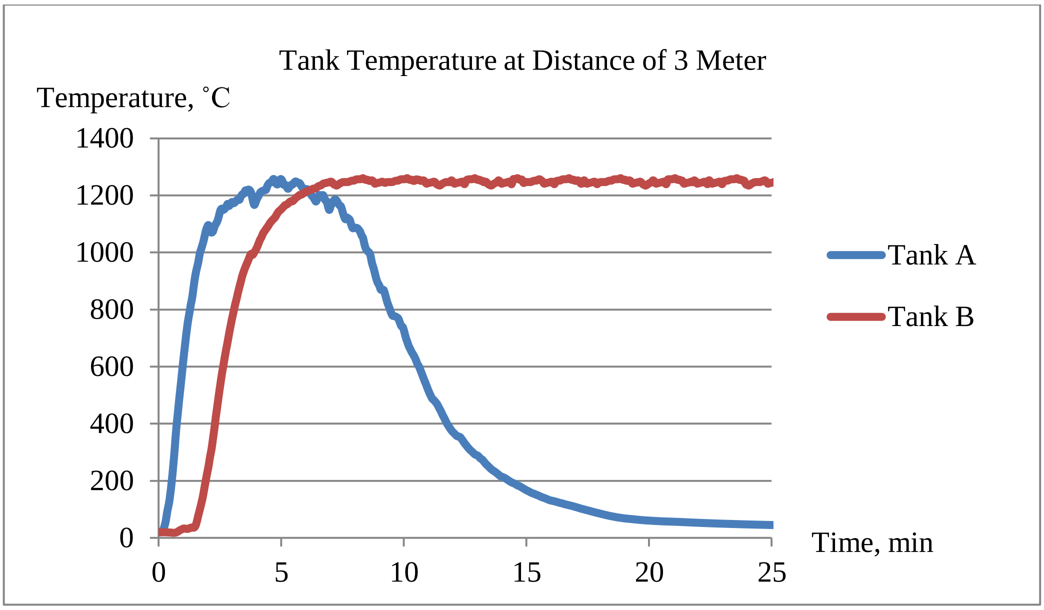

Figure 9 : Graph of tank temperature at distance of 3 meter

Figure 9 is the temperature of Tank A and Tank B at a distance of 3 meter. Blue coloured line represents Tank A which is the tank that is burning while red coloured line represents Tank B which is the adjacent tank. Temperature of Tank A increase gradually initially and starting to decrease gradually at 470 seconds as fire fighting operation starts. Tank B temperature reached 37˚C at 86 seconds and continue to increase rapidly. The temperature becomes constant at 360 seconds which is at temperature around 1200˚C. This indicates that fire spread to Tank B at 86 seconds.

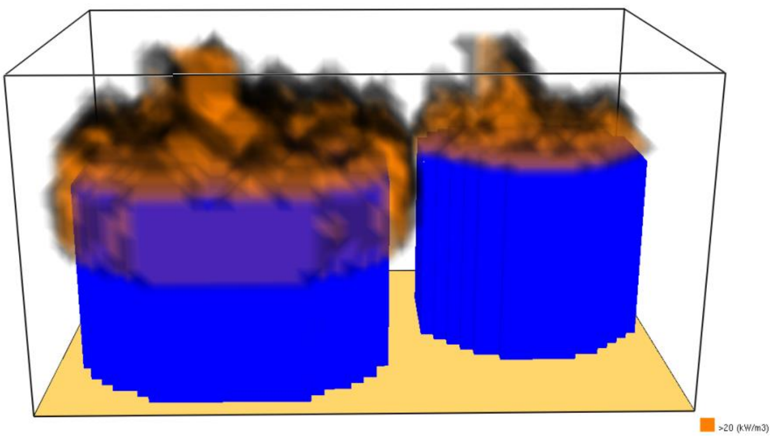

Figure 10: Smokeview of fire spread for distance of 3 meter.

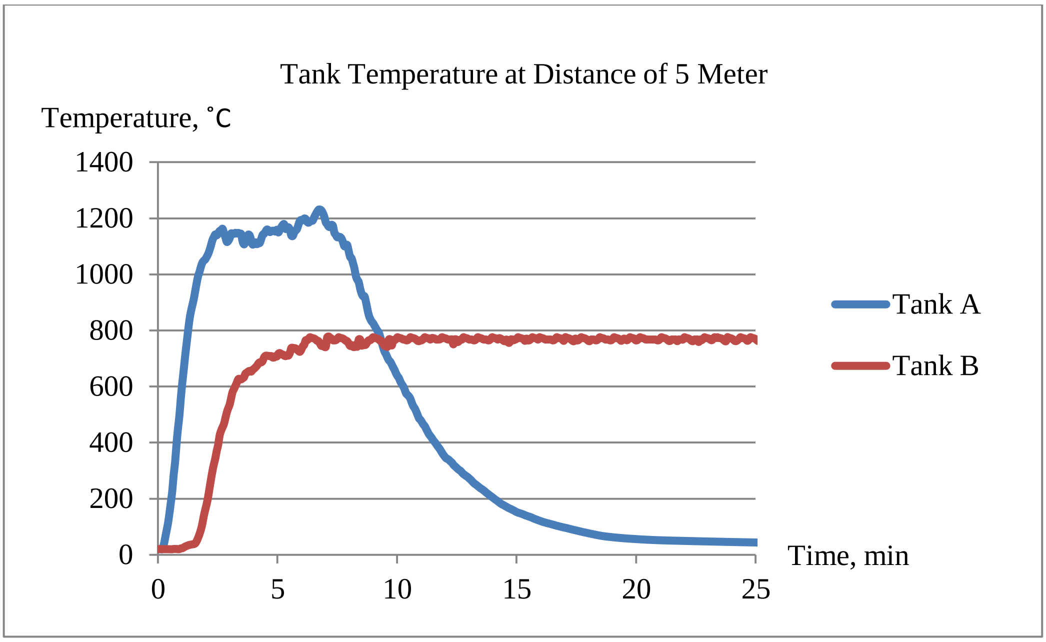

Figure 11 : Graph of tank temperature at distance of 5 meter

Figure 11 is the temperature of Tank A and Tank B at a distance of 5 meter. Blue coloured line represents Tank A which is the tank that is burning while red coloured line represents Tank B which is the adjacent tank. Temperature of Tank A increase gradually initially and starting to decrease gradually at 470 seconds as fire fighting operation starts. Tank B temperature reached 37˚C at 94 seconds and continue to increase rapidly. This indicates that fire spread to Tank B at 94 seconds. The temperature becomes constant at 385 seconds which is at temperature around 770˚C. The temperature of Tank B is not as high as distance of 3 meter and takes longer time to reach 37˚C because of its distance is further. Less radiation of the fire of Tank A is affected to Tank B.

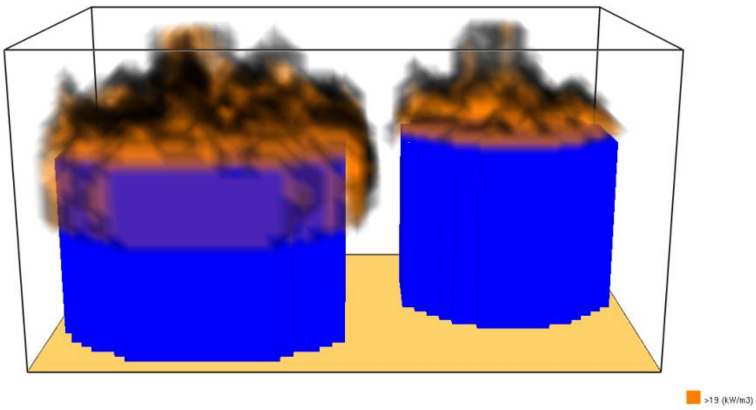

Figure12: Smokeview of fire spread for distance of 5 meter.

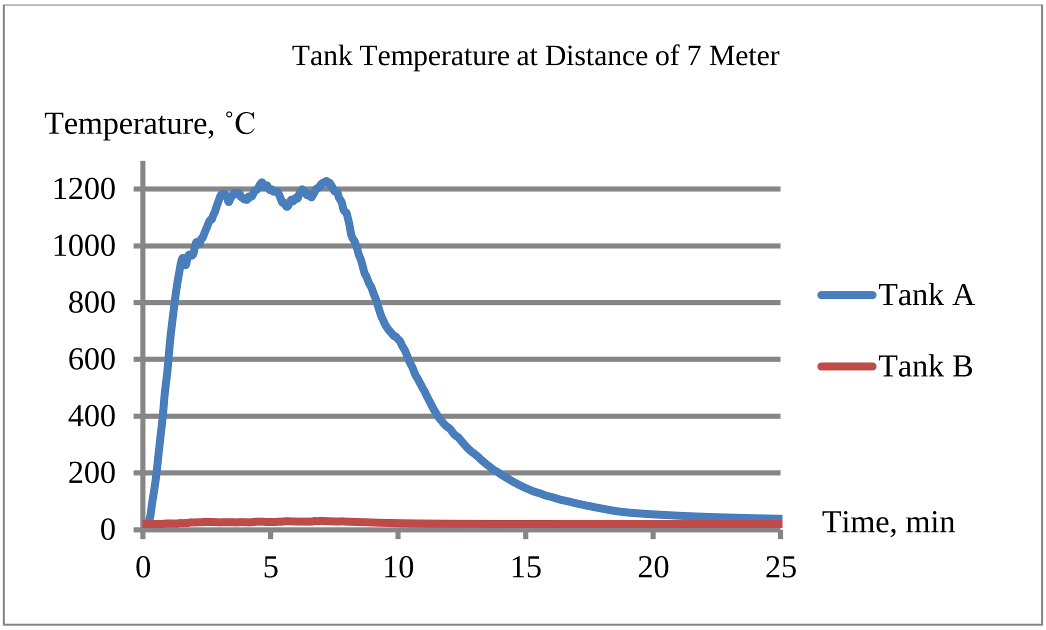

Figure 13 : Graph of tank temperature at distance of 7 meter

Figure 13 is the temperature of Tank A and Tank B at a distance of 7 meter. Blue coloured line represents Tank A which is the tank that is burning while red coloured line represents Tank B which is the adjacent tank. Temperature of Tank A increase gradually initially and starting to decrease gradually at 470 seconds as fire fighting operation starts. Tank B temperature does not reach 37˚C. This indicates that there is no fire spread to Tank B.

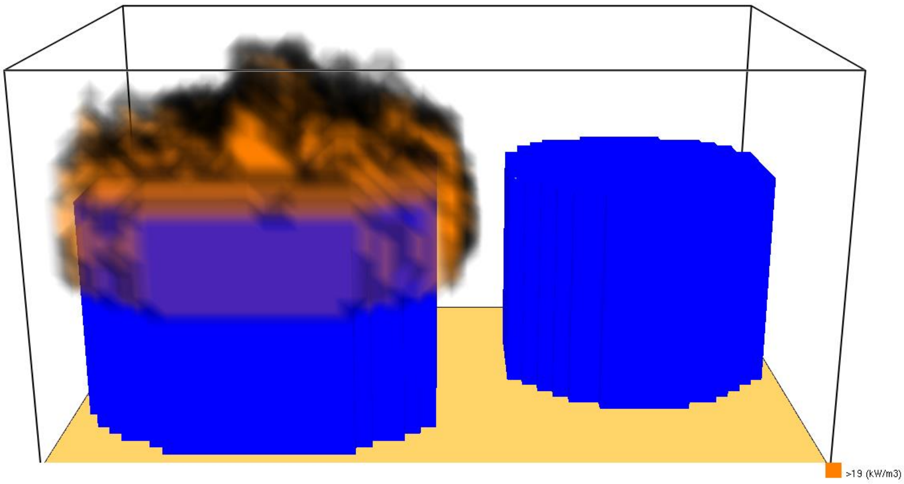

Figure 14: Smokeview of no fire spread for distance of 7 meter.

CONCLUSION

Fires in oil refineries that handle and store hydrocarbons are evidently undesirable. It is important to control fires in oil refineries as any accident or loss will cause workers life and country's economy.

Safe boundary distance between tanks containing hydrocarbon can be study using Fire Dynamic Simulator software. It is proven in the simulation that fire can spread to adjacent tank even when fire fighting operation is in progress. As results are obtained from the simulation, fire spread at 86 seconds with distance of 3 meter while fire spread at 94 seconds with distance of 5 meter. However, there's not fire spread at distance of 7 meter.

These results can be concluded that the safe boundary distance is 7 meter for tanks containing petrol. Any distance less than 7 meter would need further study on its fire safety design.

This project is at its preliminary stage. Many improvement and detail specifications can be done. Many oil refineries in Malaysia were built 20 years and have go through many changes in its plant design. Oil refineries fire protection system can benefit from this project.

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APPENDIX A

Modelling of FDS

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