

Identification the Effect of Modified Heat Radiation Model to Human Based on Feyzin Disaster

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The broad definition of BLEVE is that any liquefied vapour can cause a BLEVE. It can occur on catastrophic failure of a vessel containing even high-pressure hot water in a steam boiler, which is above its atmospheric boiling temperature. Such explosions can be very destructive of plant and equipment because they give rise to fragments from the exploding vessel. Any mechanism of catastrophic vessel failure include an impact damage, exposure to fire, fatigue, corrosion, and flawed construction can give rise to a BLEVE. A BLEVE also can give rise to a fireball. In this thesis, we are identified the effect of thermal or heat radiation toward human in Feyzin, France. By giving the parameters such as the distance of the explosion sources, time exposure and heat radiation value, the percentage of lethality found. We are proposed seven models, which is Point Source Model by Hymes and Lees, Static Model by TNO and CCPS, Dynamic Model, Maurer Correlation Model and Pool Fire Model. We are comparing the nearest value approach the data report from French Ministry of the Environment (ARIA, 2008). Besides, this thesis also discussing the relation between heat radiation with distance and time exposure where contributes and affecting the probit value and lethality.

Keywords— BLEVE, heat radiation, Feyzin, France, Explosion, fire.

I. INTRODUCTION

A Major Accident Hazard is very common things in the chemical industry in the world. Based on this cases, meaning and definition through that accident. For United Kingdom Legislation, fire, explosion and the emission of hazardous substance where involve fatality and a severe injury to an individual person or in a group and community.

There are many factors to cause the death especially when the incident happen will cause the extremely danger toward human. It can be fast and slow, but the effect will be happen. Respiratory system will influence by the emission of toxic substance. (Health and Safety Executive, 2016). In 2013, the resources and procedure such as environmental risk tolerableness from COMAH installation, where it produce the guideline to handle the major accident and finding the tendency of accident during the operation. It also provides threshold of primary hazard, based on severity and the frequency of the event.

The damage given by three categories, which is damage to the area or designated location, ecosystem or populations of habitats in the area. Then, a damage to the construction building and last to the marine or aquatic environment (HSE, 2016). The heat radiation is the phenomena when the boiling liquid expansion vapour explosion (BLEVE) occur and the fireball produce on it. The heat radiation has a range on the specific area (kilometre) with the damage that involve for human and the surrounding. In term of impact to the chemical plant industry, it has a loss to the plant with the equipment damage and the loss of production. If the accident is

severe, it need a lot of time to repair the plant. The most dangerous is when the accident involving an injury or death to human. The types of chemical will involves in this accident is hydrocarbon type such as Propane, Butane, Ethane and so on. Because it has the branching of Carbon in the composition. In term of economy, there are a big loss of product until the value in a million US dollars (Mitsuo Kobayashi, 1980). Heat radiation incident was happen a lot in a different companies or chemical industries. The entire incident was related with the same chemical properties which is higher flammable and dangerous to the human. Thus, in a section we are introducing a several different location indicates the explosion event happen.

II. METHODOLOGY

A. BLEVE

Boiling Liquid Expanding Vapor Explosion (BLEVE) defined as a misstep of a huge liquid container into the pieces at a moment where the temperature of the liquid in the container is more than the boiling point at atmospheric pressure (K.Eckhoff, 2014). Other than that, Cunningham stated the other definition of BLEVE where the release of explosion an expanding vapor and boiling liquid where a container hold the pressure of liquefied gas fails tragically (Birk and Cunningham, 1994). Other definition from Center for Chemical Process Safety in 1999 is an emission of a large mass of substances and pressurized liquids. Then, BLEVE start from the rupture of a vessel while a containing a liquid reach above its atmospheric boiling point. BLEVE mechanism are few and often rely on very limited experimental information. Therefore, the step of BLEVE was state in the flowchart below:-

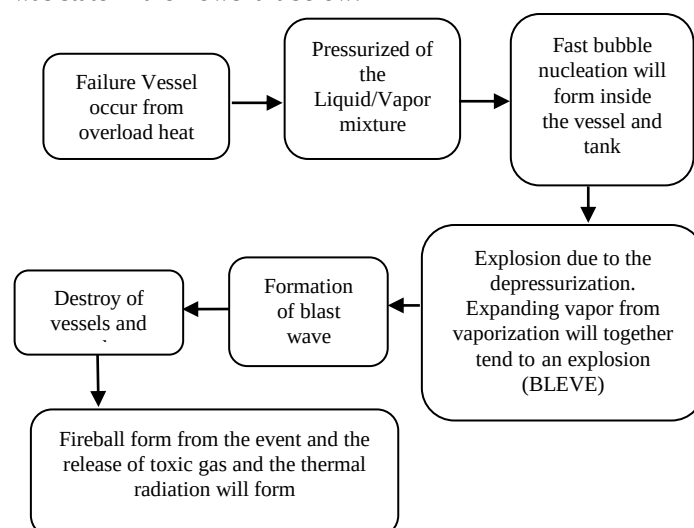


Figure 1.0: BLEVE mechanism

Usually, the substance involved is flammable, it will result a cloud of a substance and ignite after BLEVE occurred. After that, it will form a fireball and if the material are toxic, a major area will be contaminated. Thus, there are many conditions required for BLEVE where that condition must be available to form a BLEVE. Firstly, a liquid must be in the tanks or vessels. A various characteristics for the liquid in the container such as flammable, toxic and corrosive. Next condition is the liquid must be closely tight in the container. Then, the temperature in the container must be above from its boiling point at atmospheric pressure. That situation will occur when a container of liquid is tightly closed. It will cause the increment of pressure value and increasing of vapor pressure is accompanied by an elevated boiling point.

B. Feyzin Case Study Chronology

A huge leakage of liquefied petroleum gas occurred during an uncontrolled operation to achieve a target from 1200 m³ pressurised spherical propane (Kletz, 1999). The spherical tank was one of eight on the site in Feyzin, France used to supply liquefied igneous gas. The sample points provided on the vessels were inoperable so an illegal but usual procedure used in where the samples collected through the drainage valves (Gill, 2008).

The liquefied substances drained from the base of the spherical tank through valves where it connected in series with the other valve connected to the spherical tank and the lower valve open to the atmosphere. When no movement emerged by the valve, this is because the blockage immediately cleared and the gushed out of propane. The workers unable to close the valve including the upper valve and the lower valve. As a result, the lower valve became frozen. A huge leak of LPG followed with a vapour cloud at range 1 m deep disperse over 150m from the vessels. The workers decided to leave the immediate area of the tanks and to end traffic on a nearby road.

Nevertheless, the gas burst into flames and the storage sphere engulfed in the fire that followed. The tank was on plane ground so that any substance that leaked from the vessel will increase the tendency of explosion (Shallcross, 2012). The workers who in at the site were inexperienced in dealing with this situation and failed to stabilize the leaking sphere. The sphere was fixed with a lot of water system but the capability is only half the amount of water required (Mannan, 2005; HSE, 2010).

It seems that the freezing of the valve caused the leakage by the drain work. However, the freezing is a result and not a cause in fact. For LPG, in this case propane, the temperature drops to -40°C if the pressure is lowered to atmospheric pressure. At this temperature, not only is the moisture in the air frozen, but the moisture also reacts with LPG, forming a solid hydrate. The hydrate formation does not require an extremely low temperature. Apparently, either the valve handle was stuck by the frozen moisture or the valve could not be closed tightly because of the hydrate formation (M.Kobayashi and M.Tamura).

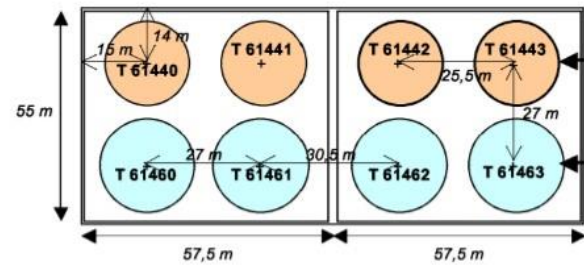


Figure 1.1: Plant Layout Spherical Vessels

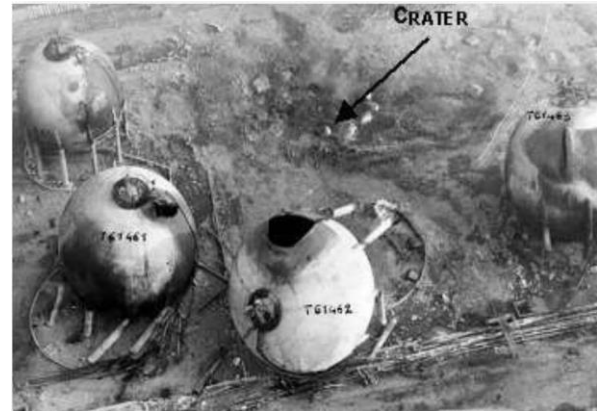


Figure 1.2: Feyzin Disaster Consequences Picture

Secondly based on Masamitsu Tamura, it is presumed that the leakage of LPG spread along the ground and was ignited by a vehicle that was driving down the main road. The substances vapour thought to have been ignited by a cigarette of the driver or the high temperature of the engine of the vehicles. Although the direct factor of the ignition is that stopping of the traffic was delayed, the fundamental problem seems to be the layout of the area. The construction of the highway had permitted with only a distance of slightly over 50m from the group of enormous LPG tanks. In this situation, when a large amount of LPG leaked, the LPG vapour flows along the highway. The main causes of the ignition are the distance regulation was insufficient and there was no dike around the tanks. Besides, another possible cause of the ignition is the theory that a static electricity spark occurred when the LPG began spouting from the relief valves. However, if the ignition occurred at the first stage of the leakage, a fire should have occurred, but an explosion should not have happened because enough LPG might not ignite because the LPG concentration will be higher than the explosion limit. Therefore, it is considered that the possibility of the static electricity theory is low (M.Kobayashi and M.Tamura).

Next, before the accident assumed that the destruction and explosion of the LPG tank would not occur even if the tank were wreathed with fire. This is because the pressure relief valve as a safety valve would operate and decrease the tank pressure when the tank pressure rose by vaporization of the LPG remaining in the tank due to tank heating. Therefore, in fact the tank exploded, scattering many fragments of various sizes. The explosion of the tank explained by the BLEVE phenomenon, which has already been introduced above (M.Kobayashi and M.Tamura).

Based on ARIA Report from France Environmental Ministry. The explosion happen twice when the tank T61443 and T61442 was explode by BLEVE event. At first, T61443 influences the second explosion. In the 50 m at T61443, report stated the fatality around that area is 18 people.

Table 1.0: Spherical storage condition at Feyzin, France

Tank	Material Involved	Volume (m ³)	Pressure
Spherical Vessel • T61443 • T61442 • T61441 • T61440	Propane	Total volume: 1,218 m ³ Current maximum volume: 1,090 m ³	18.7 bar
Spherical Vessel • T61463 • T61462 • T61461	Butane	Total Volume V _i = 2,038 m ³ Current maximum volume: 1,816 m ³	7.97 bar
Tank	Propane and Butane	161 m ³	28.05 bar

(ARIA Report, 2008)

C. Heat Radiation Model

Static Model [TNO, 1997]

First, the model used to be the one of the results is the Static Model by TNO, 1997. This model are most popular to calculate and find all the parameters such as mass of flammable substances when the BLEVE happen, the time duration of exposure, the surface emissive power and the view factor (Andre Laurent, 2016). The intensity of heat radiation equation used like this equation:-

$$q = E_p F_g \tau$$

Where the q is intensity of heat radiation (kW/m²), E_p is Emissive Power (W/m²), F_g is View Factor and τ is atmospheric transmissivity. For view factor, the equation given below.

$$F_g = D^2 / 4L^2$$

Where D is diameter of fireball (m), L is distance from the center of the fireball (m). For atmospheric transmissivity τ , the value can found from the equation below:

$$\tau = 2.02(P_w X)^{-0.09}$$

P_w is the water partial pressure (N/m²), and the X is the space from the flame surface at the object (m). Other equation is surface emissive power, which is:-

$$E_p = \frac{m f_s (\Delta H_c - \Delta H_v)}{4\pi R_B^2 t_B}$$

Where m is the mass of substance (kg), f_s is radiation fraction, ΔH_c is Heat of combustion (kJ/kg) and heat vaporization (kJ/kg), R_B is radius of fireball (m) and t_B is

time of exposure (second). To find the radiation fraction, by following this equation:

$$f_s = 0.00325 P_v^{0.32}$$

Where, P_v : Pressure of vessel. The time exposure equation must follow this equation:

$$t_B = 0.852 m^{0.26}$$

Static Model [CCPS, 1994]

For the Static Model by CCPS, the equation and is applicable to find the intensity of heat radiation and view factor respectively. However, the surface emissive power is different which is:

$$E_p = \frac{m f_s (\Delta H_c)}{4\pi R_B^2 t_B}$$

Where m is the mass of substance (kg), f_s is radiation fraction, ΔH_c is Heat of combustion (kJ/kg) and heat vaporization (kJ/kg), R_B is radius of fireball (m) and t_B is time of exposure (second) (Andre Laurent, 2016). To find the radiation fraction, by following this equation:

$$f_s = 0.27 P_{RUP}^{0.32}$$

Where, P_v : Pressure of vessel. The time exposure equation must follow this equation:

$$t_B = 2.6 m^{0.167}$$

Dynamic Model [Martinsen and Marx, 1999]

For the Dynamic Model, it has a similar with the formulation equation with Static Model. As a result, Martinsen and Marx at 1999. The surface emissive power equation is:-

$$E_p = \frac{m f_s (\Delta H_c)}{0.8884\pi R_B^2 t_B}$$

Where m is the mass of substance (kg), f_s is radiation fraction, ΔH_c is Heat of combustion (kJ/kg) and heat vaporization (kJ/kg), R_B is radius of fireball (m) and t_B is time of exposure (second) (Andre Laurent, 2016). To find the radiation fraction, by following this equation:

$$f_s = 0.27 P_{RUP}^{0.32}$$

P_v : Pressure of vessel. The time exposure equation must follow this equation:

$$t_B = 0.9 m^{0.25}$$

Point Source Model [Hymes]

This is the Point Source Model by Hymes. This model is quite different with the other model because the different value of intensity of heat radiation (kW/m²) (Abbasi & Abbasi 2007).

$$q = \frac{2.2\alpha\tau f_r \Delta H_c M^{0.67}}{4\pi L_2^2}$$

In this model, by assuming the α is equal to 1 and m is the mass of substance (kg), f_s is radiation fraction, ΔH_c is Heat of combustion (kJ/kg) and heat vaporization (kJ/kg), R_B is radius of fireball (m), τ is atmospheric transmissivity and t_B is time of exposure (second). In addition, by assuming the f_r value is 0.4.

Point Source Model [Lees]

This is the Point Source Model by Lees. This model is quite different with the other model because the different value of intensity of heat radiation (kW/m²) (Andre Laurent, 2016).

$$q = \frac{\alpha\tau f_r Q}{4\pi L_2^2}$$

In this model, by assuming the α is equal to 1 and m is the mass of substance (kg), f_s is radiation fraction, ΔH_c is Heat of combustion (kJ/kg) and heat vaporization (kJ/kg), R_B is radius of fireball (m), τ is atmospheric transmissivity and t_B is time of exposure (second). In addition, by assuming the f_r value is 0.4.

Maurer Correlation Model

For the intensity of heat radiation equation (1) are used. Maurer Correlation Model state that the different equation to find the emissive power which is (Crocker & Napier, 1988):-

$$Ep = 0.25 \varepsilon \sigma T_f^4 (D/S)^3$$

Where Ep surface emissive power (kW/m²) is, ε is flame emissivity; σ is Stefan-Boltzmann constant, which is $5.67 \times 10^{-8} \text{ kW/m}^2 \text{ K}$. T_f is a flame temperature (K), diameter D (m) and S is length from the center of the sphere to the target (m). The duration time for exposure is

$$t = m^{-0.5}$$

Where m is mass of substances in kg.

Pool Fire Model

Pool Fire Model proposed from Casal, 2008 where the equation of intensity of heat radiation (q) in kW/m² was state below:-

$$q = \frac{mfsH_c\tau}{4\pi x^2}$$

Where x is the distance of heat radiation to the receptor (m) is for mass of substances (kg), f_s is radiation fraction, H_c is heat of combustion of substance (kJ/kg), τ is atmospheric transmissivity. In this model, the estimation of duration time of exposure is 5 second.

Finally, by using the Eisenberg 1975 equation, the probit value can be calculate by giving the heat radiation value from the various models. The probit equation has a

own specification value to deal with the lethality range. The lethality value can affect the condition and level of injury of human. If the lethality value approaching to 100%, the human condition almost died and the level injury of human is very high. All the result shown after all the calculation performed.

III. RESULTS AND DISCUSSION

Based on the calculation by using the all equation given, the outcome of the calculation performed below:

Table 1.1: Static Model by TNO Analysis Data

Static Model by TNO				
Distance	Time Exposure (s)	Heat Radiation	Probit	Lethality (%)
30	2.06296	52.6323	6.66968	95
35	2.14732	50.5646	6.63582	95
40	2.22318	48.8394	6.60649	95
45	2.29231	47.3662	6.58062	95
50	2.35598	46.0863	6.55748	94
55	2.41509	44.9583	6.53654	94
60	2.47035	43.9526	6.51743	94
65	2.52230	43.0474	6.49985	93
70	2.57137	42.2259	6.48357	93
75	2.61791	41.4752	6.46842	93
80	2.66221	40.7850	6.45424	93
85	2.70450	40.1472	6.44093	93
90	2.74500	39.5549	6.42837	93
95	2.78386	39.0028	6.41650	93
100	2.82123	38.4860	6.40527	93

Table 1.2: Static Model by CCPS Analysis Data

Static Model by CCPS				
Distance	Time Exposure (s)	Heat Radiation (kW/m ²)	Probit	Lethality (%)
30	4.5572	104.003	11.9134	100
35	4.6746	101.393	10.9962	100
40	4.7787	99.183	10.9776	100
45	4.8725	97.274	10.9611	100
50	4.9579	95.598	10.9464	100
55	5.0365	94.106	10.9332	100
60	5.1093	92.765	10.9210	100
65	5.1773	91.548	10.9099	100
70	5.2410	90.435	10.8995	100
75	5.3010	89.412	10.8899	100
80	5.3577	88.464	10.8809	100
85	5.4116	87.584	10.8725	100
90	5.4629	86.762	10.8645	100
95	5.5118	85.991	10.8570	100
100	5.5587	85.267	10.8498	100

Table 1.3: Dynamic Model Analysis Data

Dynamic Model				
Distance	Time Exposure (s)	Heat Radiation (kW/m ²)	Probit	Lethality
30	2.1063	55.6615	6.91345	98
35	2.1890	53.5573	6.88089	97
40	2.2633	51.7989	6.85269	97

45	2.3310	50.2959	6.82781	97
50	2.3932	48.9883	6.80556	97
55	2.4509	47.8349	6.78543	96
60	2.5048	46.8056	6.76705	96
65	2.5554	45.8783	6.75015	96
70	2.6032	45.0361	6.73450	96
75	2.6485	44.2660	6.71992	96
80	2.6916	43.5575	6.70629	96
85	2.7327	42.9023	6.69349	96
90	2.7729	42.2936	6.68142	95
95	2.8097	41.7258	6.67000	95
100	2.8460	41.1941	6.65917	95

Table 1.4: Maurer Correlation Model Analysis Data

Maurer Correlation Model				
Distance	Time Exposure (s)	Heat Radiation (kW/m ²)	Probit	Lethality
30	7.4387	4200	24.8643	100
35	8.1470	2644.8	23.5226	100
40	8.8148	1771.8	22.3604	100
45	9.4492	1244.4	21.3352	100
50	10.0552	907.2	20.4181	100
55	10.6368	681.5	19.5885	100
60	11.1971	525.0	18.8312	100
65	11.7386	412.9	18.1345	100
70	12.2633	330.6	17.4895	100
75	12.7728	268.8	16.8890	100
80	13.2685	221.4	16.3272	100
85	13.7517	184.6	15.7995	100
90	14.2233	155.5	15.3020	100
95	14.6844	132.2	14.8314	100
100	15.1356	113.4	14.3850	100

Table 1.5: Point Source Model by Hymes Analysis Data

Point Source Model By Hymes				
Distance	Time Exposure (s)	Heat Radiation (kW/m ²)	Probit	Lethality (%)
30	4.46477	426.45	15.7696	100
35	4.58120	313.31	14.7857	100
40	4.68451	239.87	13.9335	100
45	4.77756	189.53	13.1819	100
50	4.86237	153.52	12.5094	100
55	4.94038	126.87	11.9011	100
60	5.01270	106.61	11.3458	100
65	5.08015	90.84	10.8350	100
70	5.14341	78.32	10.3629	100
75	5.20302	68.23	9.9217	100
80	5.25940	59.96	9.5098	100
85	5.31292	53.17	9.1229	100
90	5.36386	47.38	8.7581	100
95	5.41253	42.52	8.4131	100
100	5.45907	38.38	8.0857	99

Table 1.6: Point Source Model by Lees Analysis Data

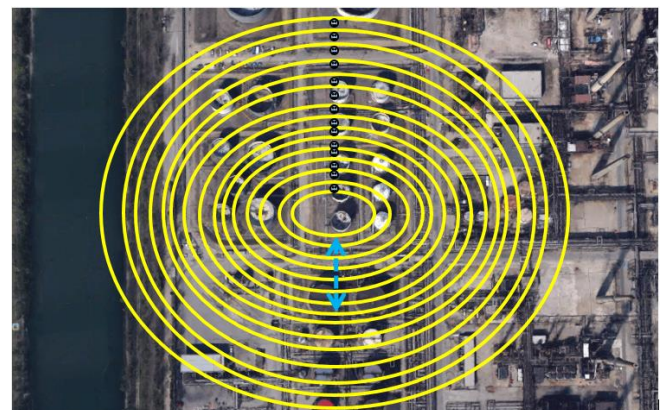
Point Source Model By Lees				
Distance	Time Exposure (s)	Heat Radiation (kW/m ²)	Probit	Lethality
30	7.4387	109.908	12.4600	100

35	8.1470	80.749	11.6431	100
40	8.8148	61.823	10.9355	100
45	9.4492	48.848	10.3114	100
50	10.055	39.567	9.7530	100
55	10.636	32.700	9.2480	100
60	11.197	27.477	8.7869	100
65	11.738	23.412	8.3627	100
70	12.263	20.187	7.9700	99
75	12.772	17.585	7.6044	99
80	13.268	15.455	7.2624	98
85	13.751	13.691	6.9411	98
90	14.223	12.212	6.6382	95
95	14.686	10.960	6.3517	91
100	15.135	9.891	6.0799	86

Table 1.7: Pool Fire Model Analysis Data

Pool Fire Model				
Distance	Time Exposure (s)	Heat Radiation (kW/m ²)	Probit	Lethality
30	7.4387	2057.178	22.4342	100
35	8.1470	1511.390	21.6179	100
40	8.8148	1157.160	20.9097	100
45	9.4492	914.307	20.2855	100
50	10.055	740.584	19.7272	100
55	10.636	612.053	19.2221	100
60	11.197	514.294	18.7613	100
65	11.738	438.215	18.3369	100
70	12.263	377.849	17.9442	100
75	12.772	329.148	17.5786	100
80	13.268	289.290	17.2366	100
85	13.751	256.257	16.9153	100
90	14.223	228.575	16.6124	100
95	14.684	205.148	16.3259	100
100	15.135	185.146	16.0541	100

After that, by using all the analysis data, the illustration data needed to show the effect and consequences based on the value of heat radiation from each models. The blue line indicates the result from ARIA report in 2008 where it state the lethality of firefighter is in that area around 30 until 50 meter. The all illustration shown below:

**Figure 1.3:** TNO Illustration Data

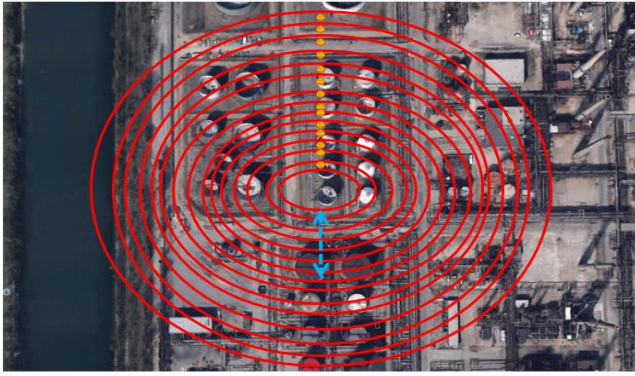


Figure 1.4: CCPS Illustration Data

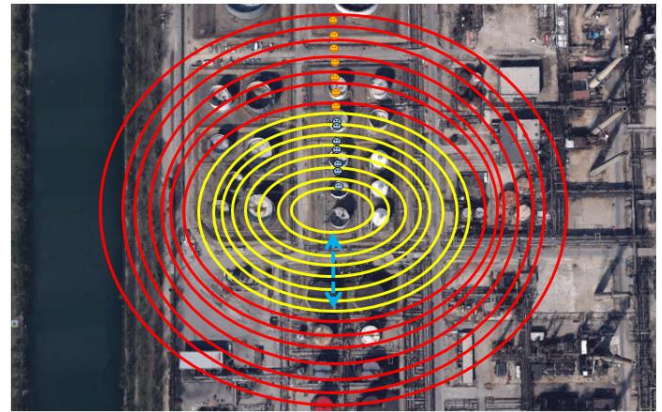


Figure 1.8: Lees Illustration Data

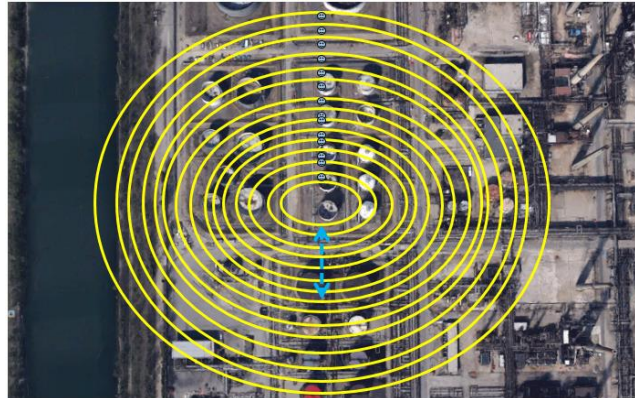


Figure 1.5: Dynamic Model Illustration Data



Figure 1.9: Pool Fire Illustration Data

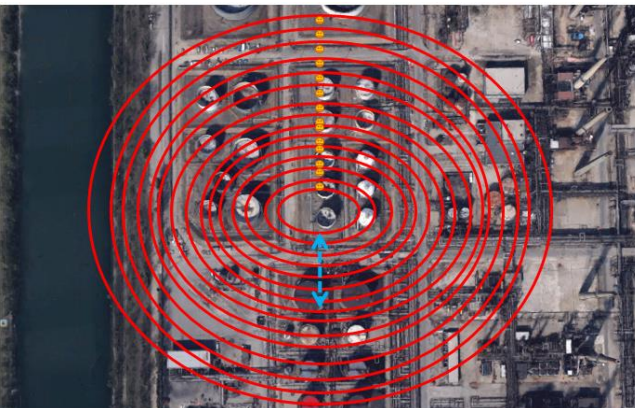


Figure 1.6: Maurer Correlation Illustration Data

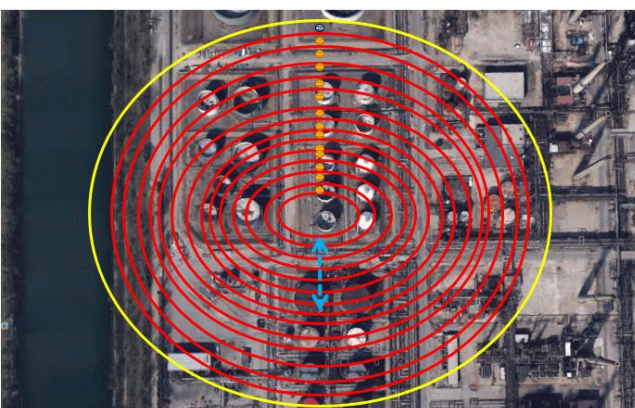


Figure 1.7: Hymes Illustration Data

Based on the illustration data, the red line indicates the higher heat radiation value while yellow line indicates the moderate value of heat radiation. Both of the line relate the level of injury and the lethality. The red human sign means the human at that area will died while the black human sign means the human still alive but will having the higher injury.

From the outcome, the Point Source by Lees is more accurate because of the approximate value of the heat radiation at the distance 30 m until 65 m where that area state the possible human death and after the 65 m from the explosion area, it shows there are nobody death in the area but will face the injuries. Therefore, for the recommendation of this scenario, there are some precautions and risk mitigation found to avoid the lethality and minimize the hazard and injury on a human. First, distance more the vessel T61442 with T61443 to avoid the second explosion. From the calculation, the tank (T61442) must located more than 50 m from the tank T61443 to avoid the second explosion. This is because the first explosion supply energy to hit the other tank where it can affect the pressure condition inside the tank and if the distance between the sources is too high, the second explosion will not happen.

The relation is from the heat radiation and the distance of the object or human. From this scenario, the more heat radiation release is come from the Maurer Correlation Model where it has more than 4000 kW/m² at the first 30 m from the explosion area. However, the least emission of heat radiaon is come from Static Model by TNO. Based on the figure 1.10, the increment of human distance to the

explosion point will show a reducing amount of heat radiation. From this figure also state where the Maurer Correlation Model, Pool Fire Model, Static Model by CCPS and Point Source Model by Hymes are not tally with the ARIA report where the heat radiation received to human at distance 50 m and above must not make a human died (ARIA, 2008).

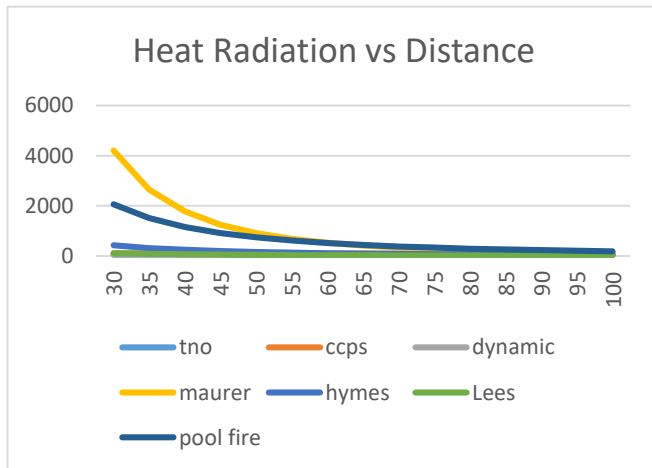


Figure 1.10: Heat radiation against distance

Besides, the relation between time exposure and distance is directly proportional where the more distance taken, the time exposure of the heat radiation will increase. At this condition, the human where in the long distance will get the low heat radiation dose while the human are near to the explosion will get the higher value of heat radiation where the human will die. The relation between time exposure and the distance shown below in figure below.

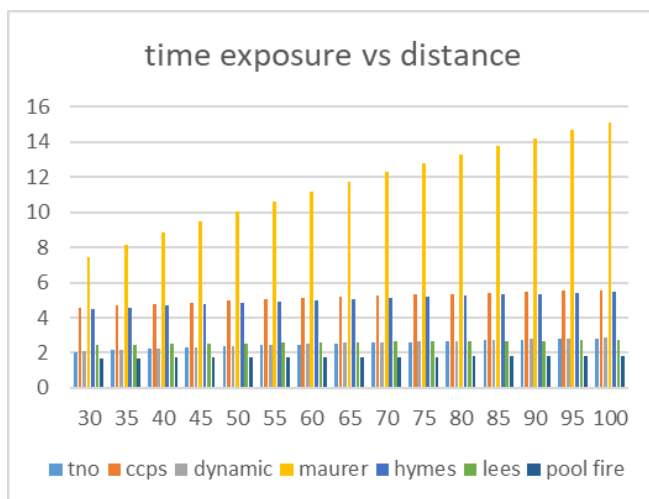


Figure 1.11: Time exposure against distance

By comparing the analysis data and illustration with the ARIA report, the analysis accepted by given the correct value of lethality of human at 50 m from the explosion sources. Based on ARIA report, the total human death is 18 person where two firefighter is in 50 m to the vessel explode. The heat radiation model used proved that scenario where the human near to the vessel die by receiving the higher heat radiation value with the shortest time exposure.

However, for the recommendation of this scenario, there are some precautions and risk mitigation found to avoid the lethality and minimize the hazard and injury on a human. First, distance more the vessel T61442 with T61443 to avoid the second explosion. From the calculation, the tank (T61442) must located more than 50 m from the tank T61443 to avoid the second explosion. This is because the first explosion supply energy to hit the other tank where it can affect the pressure condition inside the tank and if the distance between the sources is too high, the second explosion will not happen. Second, the owner and operator must do the maintenance tightly do ensure and identify the malfunction alarm and other detector including the valve of each equipment. This is can prevent the spilled out the propane substance at T61443 where the operator want to close it but it does not function. Therefore, if the alarm and all the safety equipment is in the good condition, the first BLEVE will not happen and nobody died and injured.

Third, rearrange the location of the spherical vessel in that plant. This is because this plant is actually too near with the villages and the main road where all people use that road every day. Until now 2018, the refinery was located at the same place and do not change the plant location since the big accident in January 1966. Although the explosion or fire is not always happen but there are still have the environmental issues such as the air pollution come from the plant. The sensitive and high flammable materials must be handle in the area that far from the community and people. This is because, if the sudden accident happen, it will reduce the problem in order to monitor the outside of the plant.

IV. CONCLUSION

From the outcome, the Point Source by Lees is more accurate because of the correct value of the heat radiation at the distance 30 m until 65 m where that area state the possible human death and after the 65 m from the explosion area, it shows there are nobody death in the area but will face the injuries. For heat radiation effect, all the models used has disadvantages and need to relate with the suitable condition. With the analysis that, the most suitable heat radiation model is Point Sources Model by Lees. The calculation can used to manipulate the distance of the explosion sources. It will apply to control and avoid the hazard that will happen to the plant.

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