MODELING OF HYDROGEN AND METHANE DISPERSION PROCESS IN PIPELINE USING COMPUTATIONAL FLUID DYNAMIC (CFD)

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STUDENT'S DECLARATION

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Dedication

To my family, lectures and friends

ACKNOWLEDGEMENT

I would like to thanks the following people and organisations;

- My supervisor Miss Siti Noraishah Ismail for her guidance through an effective well-arranged weekly meeting.
- University Malaysia Pahang for providing me facilities to do this project.

ABSTRACT

In this era of globalisation and modernisation, natural gas is becoming one of the most wanted natural resources in many industries basically for cooling and heating purpose. Due to the high demand, transporting natural gas via pipeline is the best way to fulfil the demand for natural gas. Hence, it is very important to transport natural gas via pipeline with safety precaution. Meanwhile, in future hydrogen gas has the capability to become one of the important energy resources for many industries. This will create an economy call hydrogen economy. It is expected hydrogen can become main source of energy to replace fossil fuels and can be transported via pipeline to meet customers demand. However, the physical properties of methane and hydrogen are totally different and also the safety to supply hydrogen via pipeline is taken into consideration. Therefore, this paper is aim to study about the dispersion effects of hydrogen and methane and do comparison among both gases. In this paper we will be using Computational Fluid Dynamic (CFD) software to detect leakage when transporting methane and hydrogen gas. The model that will be use is environmental area 240 m wide and 80 m high. Two 30 m wide and 20 m high buildings are placed to represent factory building. Underneath, a part of pipeline is modelled as a source where methane and hydrogen gases are released. The 2 m diameter pipeline is filled with either hydrogen gas or methane gas at pressure 11 bars. The leak in the pipe is located at x= 0 m. This study will be done by using different scenarios at different time interval which is at time 1s and 7.5s and different wind speed; 0 m/s, 5m/s, 10m/s ad 15 m/s. The results show that, the rate of dispersion of hydrogen is higher compare to methane and methane tends to be more on the surface of the ground where ignition is possible. Using Computational Fluid Dynamic (CFD) is the best method to study about leakage of methane and hydrogen gas due to low cost involve rather than building up pipeline network to test the situation which is something irrational to be done. From this study, it can be clearly seen that the rate of dispersion of hydrogen will be higher compare to methane due to the gases properties like density and buoyancy force. Thus, it is feasible to transport hydrogen via pipeline due to higher dispersion effect compare to methane.

Key words: methane, hydrogen, dispersion, hydrogen economy, Computational Fluid Dynamic (CFD)

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LIST OF ABBREVIATIONS

CFD	Computational Fluid Dynamic

1 INTRODUCTION

1.1 Motivation and statement of problem

In 2010, an explosion of natural gas pipeline in San Bruno, California killed 8 people and destroyed 38 homes (Phillips et al., 2012). This incident gave a great impact to the society and the environment. Another incident of methane leakage happened in Ghislenghien, Belgium on the 30th July 2004 where 15 people were killed in this devastating accident. This accident happened when a construction worker pierced a major underground gas distribution line. Due to the maximum release rate, the total chemical energy released to the environment reaches value as high as several GW thermal equivalent (Wilkening and Baraldi., 2007).

Recently, hydrogen is foreseen by many researchers as an essential renewable energy resource in the future. Thus, it will increase the usage of hydrogen in the future and creating an economy called **hydrogen economy**. It is expected hydrogen can become main source of energy source to replace fossil fuels and can be transported via pipeline to meet customers demand. However, the physical properties of methane and hydrogen are totally different and also the safety to supply hydrogen via pipeline is taken into consideration. This method of transporting is totally different from today scenario, where smaller amount of hydrogen are either produced at the site or transported by road tanker. Transporting hydrogen via pipeline will only be accepted by the society if and only if this method does not create any major obstacles to the society as well as the environment.

Currently, the existing pipelines are designed to transport natural gases which have totally different properties as compared to hydrogen. Hence, using the same pipelines to transport hydrogen may cause problems to the pipelines network. For instance, hydrogen embrittlement of steel, could lead to an accelerated growth of micro cracks (Elaoud and Hadj-Taieb., 2009). The cracking could cause leakage in the pipelines which will cause trouble. To overcome this situation it is important to study accidental release of methane and hydrogen from pipeline under same circumstances. Building up a pipelines network to test the situation is something irrational due to the high cost. Thus, numerical simulation (Computational Fluid Dynamic), CFD is used as an alternative method to detect any leakage in the pipeline network. Using this simulation is a new approach in this field, since this simulation had been used to study the details of the release jet or the effect of a downward directed release jet impinging on the floor of the crater (Wilkening and Baraldi., 2007).

1.2 Objectives

The following are the objectives of this research:

- To study and compare the effect of methane and hydrogen gas dispersion process in an underground pipeline.

1.3 Scope of this research

The following are the scope of this research:

i) 2-D simulations will be used to compare both hydrogen and methane gas dispersion in terms of density, diffusivity, and viscosity.

ii) The research will be conducted using Computational Fluid Dynamic, CFD.

iii) The pipeline is assumed to be underground.

1.4 Main contribution of this work

i. Is it feasible to transport hydrogen gas via pipeline because the rate of dispersion of hydrogen gas is higher compare to methane gas. Thus, it is safe to transport hydrogen gas via pipeline. Hence hydrogen gas can be used as an alternative fuel to replace natural gas in future which will result in hydrogen economy.

ii. Lower rate of dispersion of methane could result in combustion as well as explosion if the gas in contact with any ignition source like spark. This incident will totally effect the environment and also people. Hence, using this software many combustions and explosions can be avoided.

iii. Malaysia can commercialize hydrogen production in large scale and transport it via pipeline if and only if hydrogen is less dangerous to the people and the environment. Hence hydrogen gas can be used as an alternative fuel to replace natural gas in future which will result in hydrogen economy.

1.5 Organisation of this thesis

The structure of the reminder of the thesis is outlined as follow:

Chapter 1 provides a description about the objective and scope of the project. It also explains about motivation and problem statement of the project. Not only that, it also explain the contribution of this project to the people and the environment.

Chapter 2 gives a review about the gases being used which is the hydrogen and methane gas. The physical and chemical properties of the gas also being discuss in this chapter. Besides that, the usage of both gases is being summarized. In addition, the concept of dispersion is discussed. Lastly the usage and previous study about CFD is being discussed.

Chapter 3 is about the method and material that is being used in this project. The detail of how to run the software is discussed in this chapter. The condition to run the software is also being discussed. The parameter that will be used is also stated in this chapter. The simulation model of this project is also shown is this chapter,

Chapter 4 is the result and discussion where the result obtains is shown in 2D simulation and the rate of dispersion of methane and hydrogen is being discussed.

Chapter 5 is conclusion where from the research it can be seen that the rate of dispersion of hydrogen is wider and it is feasible to use hydrogen as a fuel in the future.

2 LITERATURE REVIEW

2.1 *Concept of dispersion*

The leakage of hazardous gas for instance methane into the air is a common problem faced by most of the country. Dispersion is a process where the gas will mix with the surrounding air whereby creating a new molecules which might be hazardous to the environment (Fardisi and Karim, 2011). For instance, when methane leakage occur, this gas tend to react with oxygen in air which will cause combustion and releasing carbon dioxide gas to the air which will cause greenhouse effect.

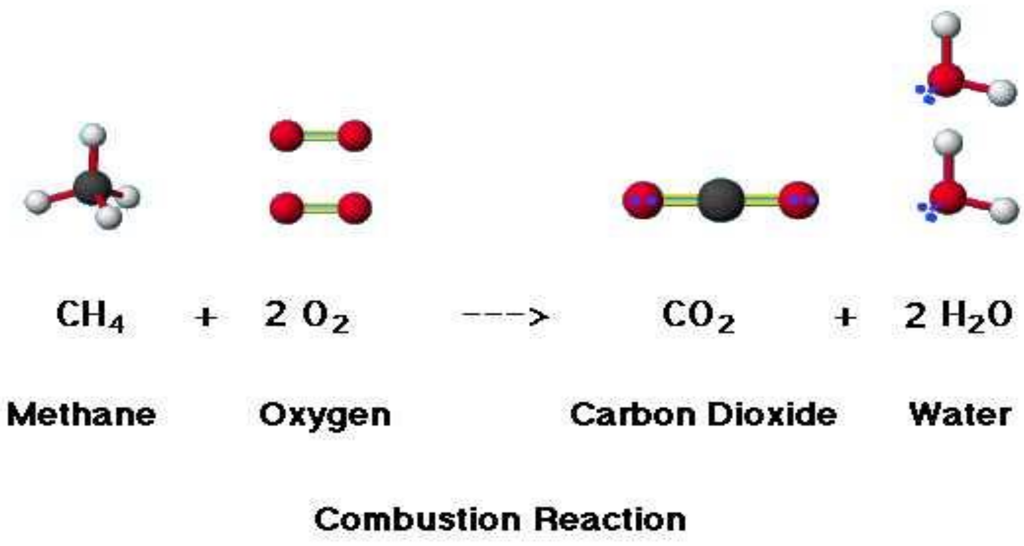


Figure 2-1: Combustion reaction of methane

Whereas, release of hydrogen gas to the surrounding, will form a hydrogen-air cloud and part of it also could be flammable. The condition of hydrogen-air cloud for instance the flow field, the level of spatial congestion can significantly show the strength of explosion that may occur (Papanikolaou et al., 2010). In year 1984 a massive hydrogen gas explosion happened in Polysar, Canada where three people were killed and many injured (Lee., 2001).

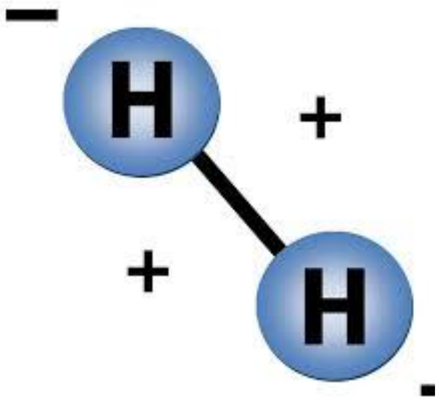
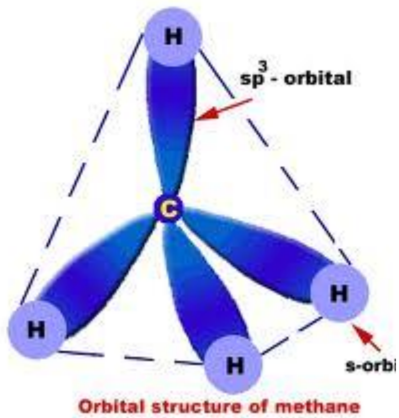
The rate of dispersion is affected by many factors for examples density, diffusivity, buoyancy force and viscosity. Dense gases and vapours are much heavier than air. The main force for the migration of dense gases is due to gravity; therefore the dispersion normally follows the gradient of the terrain. A dense gas cloud can travel long distances before naturally mix with the air. Long dispersion distances create greater areas of danger. Dense gases are not easily disturbed by the wind speed. (www.draeger.com)

Next, when the fluid has higher diffusivity it tends to disperse faster due to the capability of the fluid to penetrate among the air particles .Viscosity is a measurement of how resistant a fluid is to attempt to move through it (Anderson., 2010). Fluid with higher viscosity tends to disperse slower because of the strong bonds that attached the fluid molecule together.

2.2 *Physical properties of methane and hydrogen gas*

The properties of hydrogen and methane is shown in Table 1

Table 2-1: Physical properties of hydrogen gas and methane gas

Molecules	Hydrogen (H_2)	Methane (CH_4)
Atomic number	1	-
Atomic weight	1.00782519(on ^{12}C scale)	-
Chemical structure	H-H	$C\text{-}H_4$
Molecular weight	2.0159	16.043
Appearance	Colourless, odourless at room temperature	Gas, odourless and colourless at room temperature
Density	0.0899 kg/m^3	1.819 kg/m^3
Melting point	-259.35 °C	-182.5 °C
Solubility (in H_2O)	0.0214 vol/vol	0.054 vol/vol
Boiling point	-252.9 °C	-164 °C
Compressibility factor	1.001	0.998
Viscosity	0.0000865 Poise	0.0001027 Poise
Structure		

*(http://encyclopedia.airliquide.com)

2.3 *Methane and hydrogen gas*

In this world of modernization, one of the major problems faced by the world is greenhouse effect which leads to global warming as well as drastic climate change. The main contribution to this problem is excessive release of carbon dioxide. However, this problem is becoming more terrible with the release of methane gas. Methane gas also contributes to the global warming as well as depletion of ozone layer. Methane is 21 times more heat-trapping that carbon dioxide (Mark., 2012). According to the Figure 2-2 below, methane is the second highest gas that contributes to ozone depletion after carbon dioxide.

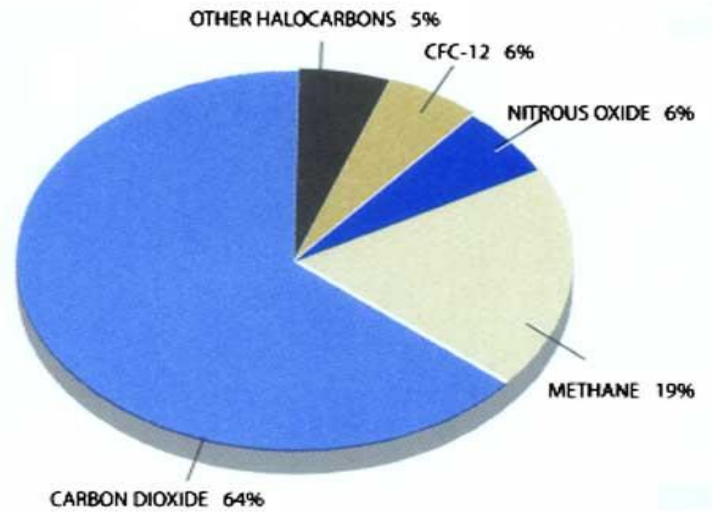


Figure 2-2: Amount of gases contributing to ozone depletion

One of the statistic showed that in 2005, the total greenhouse gas emission in U.S were 7260 Tg. This value increased by 16.3 % from 1990 to 2005(EPA., 2007). Methane is released from many industries all over the world. For example, natural gas industry is one of the industries which released higher amount of methane.

Table 2-2: Estimation of Methane Emission in Natural Gas Industry (Kirchgessner et al., 2007)

Source	Year	Estimate(Tg/yr)
Hitchcock and Wechsler (1972)	1968	7-21
Keeling (1973)	1968	40-70
Ehhalt and Schmidt (1978)	1968	7-21
Sheppard et al. (1982)	1975	50
Blake (1984)	1975	50-60
Seiler (1984)	1975	19-29

Methane gas is not only released purposely from industrial work but also due to some leakage in methane gas pipeline, this gas is being released to the environment. For instance, on 30th July 2004, 15 were killed in Ghislenghien, Belgium due to leakage of methane gas which leads to severe explosion (Wilkening and Baraldi., 2007). Figure 2.3 shows amount of methane gas leakage accident from year 1993 up to year 2012. The bar graph shows that in year 2005 highest accident reported.

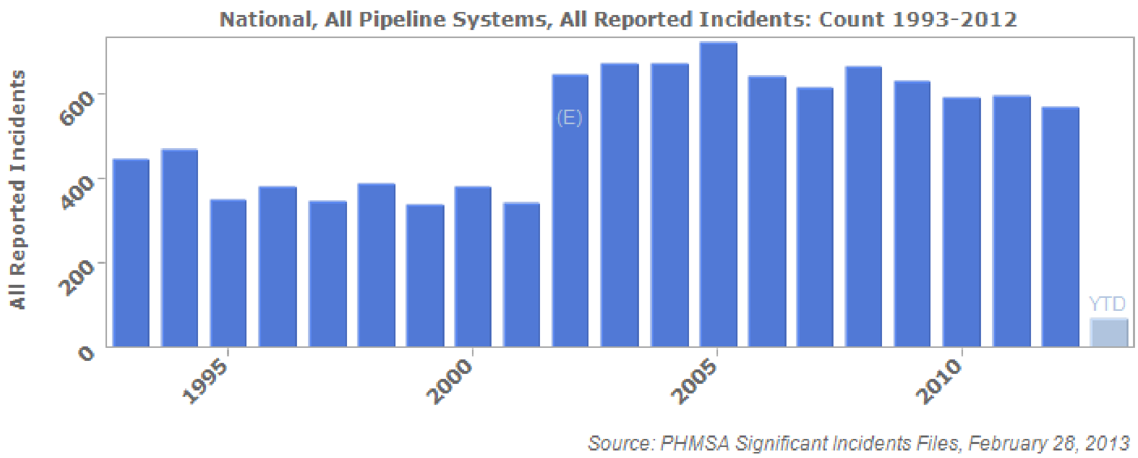


Figure 2-3: Reported Methane Gas Leakage Accident From 1993-2012.

(* http://primis.phmsa.dot.gov/comm/reports/safety)

Thus, it is clear that methane gas is hazardous to the environment and society. In order to avoid this scenario from prolonged, an economy using hydrogen should be developed in the future. This is because hydrogen has high conversion efficiency and clean combustion product (Zheng et al., 2010). Besides that, hydrogen gas helped to solve many issues like reducing the air pollution rate. The burning of hydrogen to obtain fuel does not release high amount of carbon dioxide gases compare to natural gas and the combustion product is water molecules which is not harmful to the environment. Hence, it will reduce the rate of air pollution. Besides that, hydrogen is a gas which can be easily produced, for example by electrolysis of water or by gasification of biomass (Venetsanos et al., 2007).

However, using hydrogen gas in a larger proportion will affect the environment in some ways. For example, hydrogen itself can act as greenhouse gas where it could extend the lifetime of methane gas in the atmosphere. Besides that, hydrogen gas can undergo chemical reaction in the stratosphere which will form molecules called Hydrochlorofluorohydrocarbons(HCFC) which will contribute to the depletion of ozone layer. Thus, it is very essential to prevent both gases from leaking to the environment.

2.4 *Usage and application of methane and hydrogen gas*

There are many sectors using methane gas for example industrial sector, commercial sector and many more. Figure 4 shows the statistic of the usage of methane gas in 5 sectors.

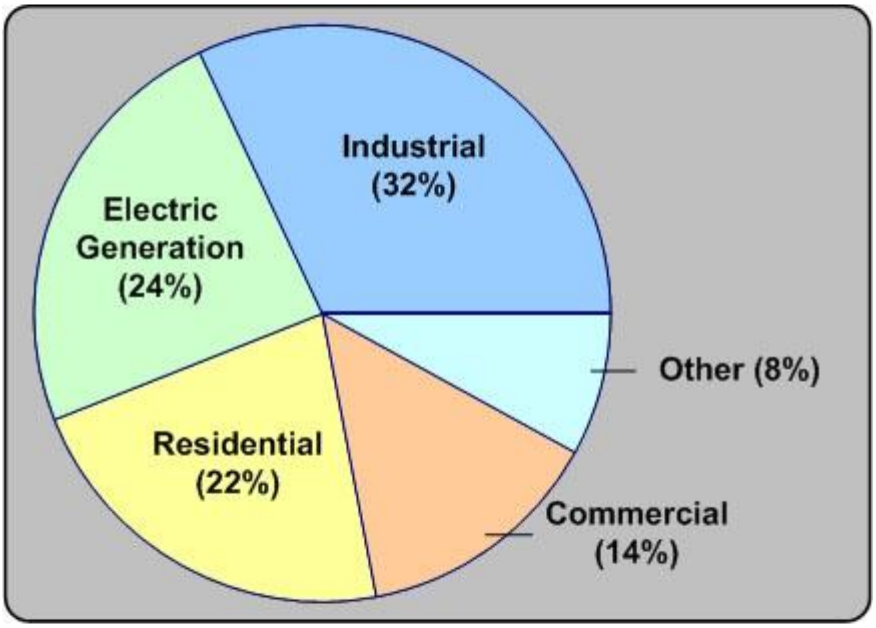


Figure 2-4: Natural Gas Use by Sectors

*(Source: EIA - Annual Energy Outlook 2002)

In residential sector natural gas are used for heating and cooking. Cooking using natural gas is more beneficial because it is easy to control temperature. The commercial sector includes public and private enterprises, like office, schools, churches, restaurants, and government buildings. The major uses of natural gas in this sector include space heating, water heating, and cooling. Not only that, natural gas is also use to generate electricity for plants.

Hydrogen gas has many uses. For example, it is use to process fossil fuels. Hydrogen fuel cells convert hydrogen gas and oxygen gas into water through ionization process. Electrons pass through an external circuit and are harnessed as electricity. Using hydrogen has advantages because its efficiency is more than doubled and the by product is only water and heat which does not harm the environment. In addition it is used to produce ammonia which is commonly used in household cleaning product. Hydrogen gas is also use to produce hydrochloric acid which is widely being used in industry. Hydrochloric acid is used in the production of chlorides, for refining ore in the production of tin and tantalum. It is also being use for pickling and cleaning of metal products in electroplating, in removing scale from boilers. Besides that, HCL is also use as a laboratory reagent. Meanwhile it also acts as a catalyst and solvent in organic syntheses in the manufacture of fertilizers and dye (www.epa.gov). Moreover, a hydrogen is use to support emerging applications based on fuel cell technology along with other ways to use hydrogen for electricity production or energy storage (Lipman., 2011).

2.5 *Computational Fluid Dynamic (CFD)*

Computational Fluid Dynamic (CFD) is normally used to investigate the effect of different parameter of variables product which is fluid which is being transported using pipeline on various distances and condition (Shehadeh et al., 2012). Previously many studies have been done about gas dispersion using FLUENT, GAMBIT and many more. Hence, in this paper CFD will be use. The model that will be use is inviscid. This software normally used to solve equation for mass, momentum, energy, and species mass fraction. This CFD tool is used to determine the effect of different properties of hydrogen gas and methane gas on the dispersion process. Not only that, this tool is used to study the effect of different release scenario, geometrical configuration and atmospheric condition.

Table 2-3: Previous studies using CFD

Author	Year	Objective
Shehadeh et.al	2012	To study the effect of velocity magnitude (V),total pressure(P),turbulence intensity (I) to the leakage flow rate
Mohamed F. Yassin	2011	To study pollutant concentration distribution simulated I the present work, indicated that the variability of roof shape
Papanikolaou et.al	2010	CFD modelling to determine accidental release of hydrogen and combustion
Kashi and Shahraki	2009	To study effect of vertical temperature gradient, wind speed to the leakage flow rate of pipeline using CFD modelling.
Yuenbin et.al	2007	Gas leakage in a room of a residential building is numerically simulated based on CFD technique.
Venetsanos et.al	2007	CFD modelling of hydrogen release dispersion and combustion for automotive scenarios.

3 METHODOLOGY

3.1 Overview

This paper is about detecting hydrogen and methane leakage in a pipeline network using Computational Fluid Dynamics (CFD). The model that will be use is inviscid. This software normally used to solve equation for mass, momentum, energy and species mass fraction. This CFD tool is used to determine the effect of different properties of hydrogen gas and methane gas on the dispersion process. Not only that this tools is also used to study the effect of different release scenario, geometrical configuration and atmospheric condition. First and foremost, a 2D-simulation was performed for methane gas release. The first 2D –simulation for methane is done by assuming that the wind is blowing at 5m/s, 10m/s and 15 m/s for different time, t limit. The first simulation is done at t=1s and the second simulation is at t=7.5s. The second scenario is done by assuming there is no wind and other condition remains the same at the time, t=1s and t=7.5s after the release. The flammability limits are shown from 5.3% to 15%. Then, the 2D simulation is done by using hydrogen gas. The first scenario is that the wind blow at the rate of 5m/s,10m/s and 15m/s at time, t=1s and t=7.5 s and the second scenario is no wind condition at the time t=1s and t=7.5 s. The flammability limit is shown from 4% and 74 %. Then, the result of both gases is being compared and a conclusion is derived about the properties of the two gases. It is clear from the modeling exercise performed in this work that CFD is a promising method for modeling the leakage of methane and hydrogen from a pipeline network. Furthermore, the CFD method is certainly less expensive than the experimental characterization studies.

3.2 Simulation model and parameter

Figure 3.1 shows environmental area 240 m wide and 80 m high. Two 30m wide and 20 m high buildings are placed to represent factory building. Underneath, a part of pipeline is modelled as a source where methane and hydrogen gases are released. The 2m diameter pipeline is filled with either hydrogen gas or methane gas at pressure 11 bars. The leak in the pipe is located at x=0m. The computational grid has a total of 71300 cells with minimum spacing of 1 cm at the release position and 1.5 m at the far field boundaries. This method is then repeated with different wind condition and time. Table 3.1 shows different condition and time use to run the simulation model.

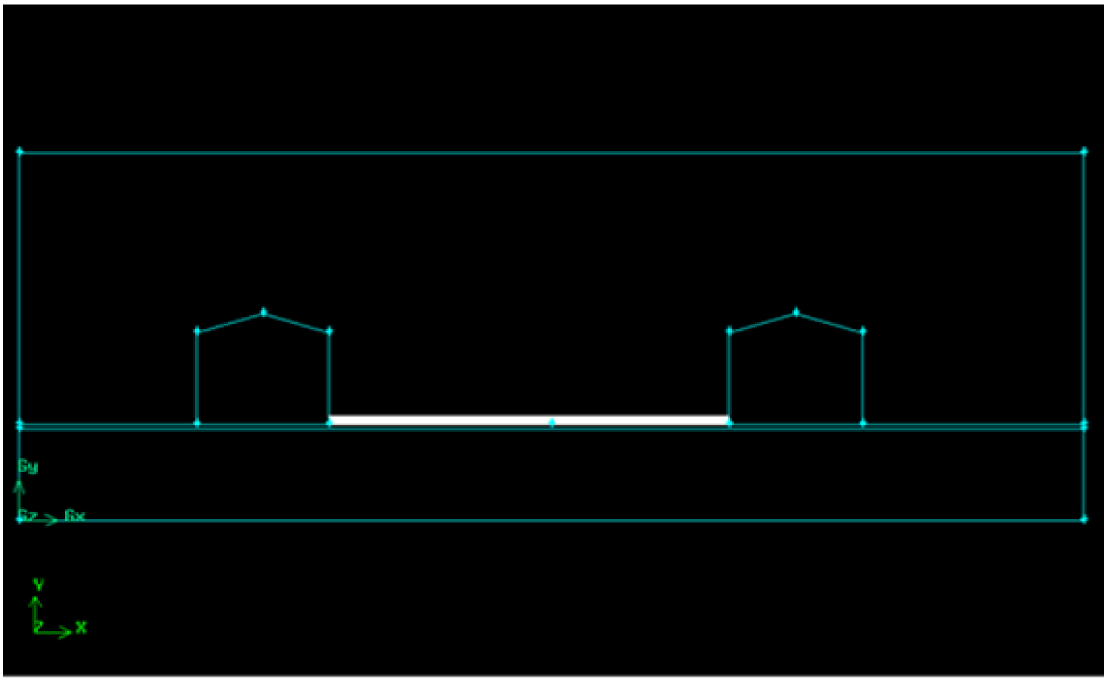


Figure 3-1: Simulation model

After the drawing has been done, it is the meshed as shown in Figure 3-2. It is meshed using CFD (Gambit) software.

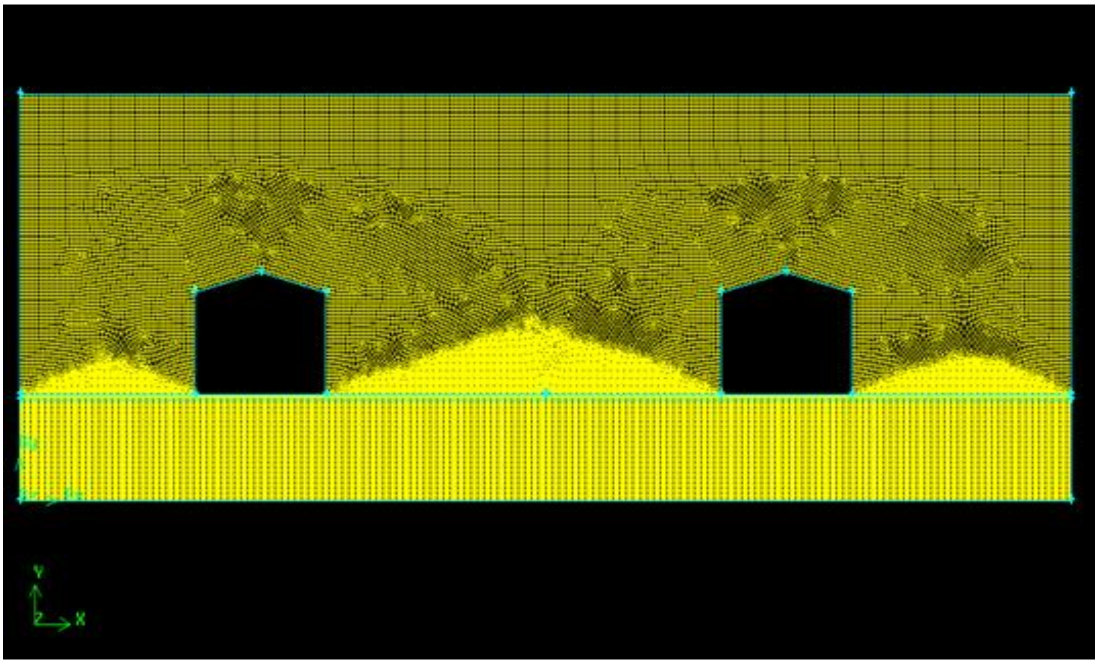


Figure 3-2: Meshed drawing in Gambit

Then, the drawing is exported to the fluent software. The contour obtain is filled in Table 3-1.

Table 3-1: Simulation model at given condition

	Hydrogen, H2		**Methane, CH_4**	
Time, t/s	**t=1**	**t=7.5**	**t=1**	**t=7.5**
Wind speed,5m/s				
Wind speed,10m/s				
Wind speed 15m/s				
No wind				

In this study, several parameters will be used as shown in Table 3-2.The Methane gas and hydrogen gas is release at rate of 1200 m/s and pressure 11 bar. After the simulation is being done the result will be compared with Table 3-2 to understand about gas dispersion.

Table 3-2: Mean combustion properties of hydrogen and methane.

	Hydrogen	Methane
Density(kg/m_3)(NTP)and relative to air (-)	0.0838, 14 times lighter than air	0.6512, 1.8 times lighter than air
Lower heating value (kJ/kg)(chemical thermal energy)	119 972	50 020
Flammability limits (vol. %)in air	4-74	5.3-15
Stoichiometric concentration in air (vol. %)	29	9
Maximum laminar burning velocity(m/s)	3.25	0.44
Relative radioactive heat transfer (%)	5-10	10.33

4 RESULTS AND DISCUSSION

4.1 Methane release

The release rate of methane is 1200 m/s. This is a 2D-simulation, in which the third direction is not specified. High upward velocity of methane through the 20cm hole causes the formation of expanding jet. The jet has enough impulse to penetrate into the environment. This can be clearly seen in the case where methane is being release from the 20cm hole in an underground pipeline in Figure 4-1 without the presence of wind and the time is 1s after methane start to release from the hole.

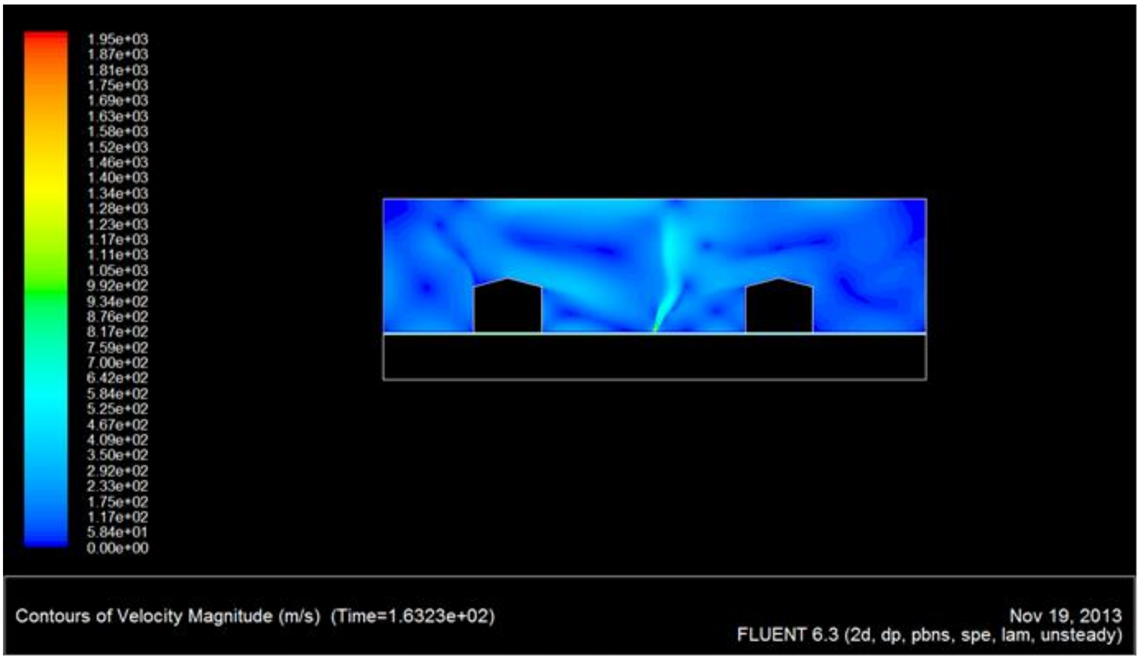


Figure 4-1: methane release with no wind condition, time 1s

From Figure 4-1, it can be seen that the methane release under high pressure through the hole can shoot up higher than the height of the surrounding building. The methane that has been released is slightly towards right building although there is no wind. This is because, the density of methane is 0.66 kg/m^3 is heavier, thus the gas cannot travel too high to the atmosphere. Due to no wind condition, the methane is not transported sideways. In no wind condition buoyancy force are more important. Without wind, the jet develop some own reticulation in which it is able to trap some of the methane gas near one of the building.

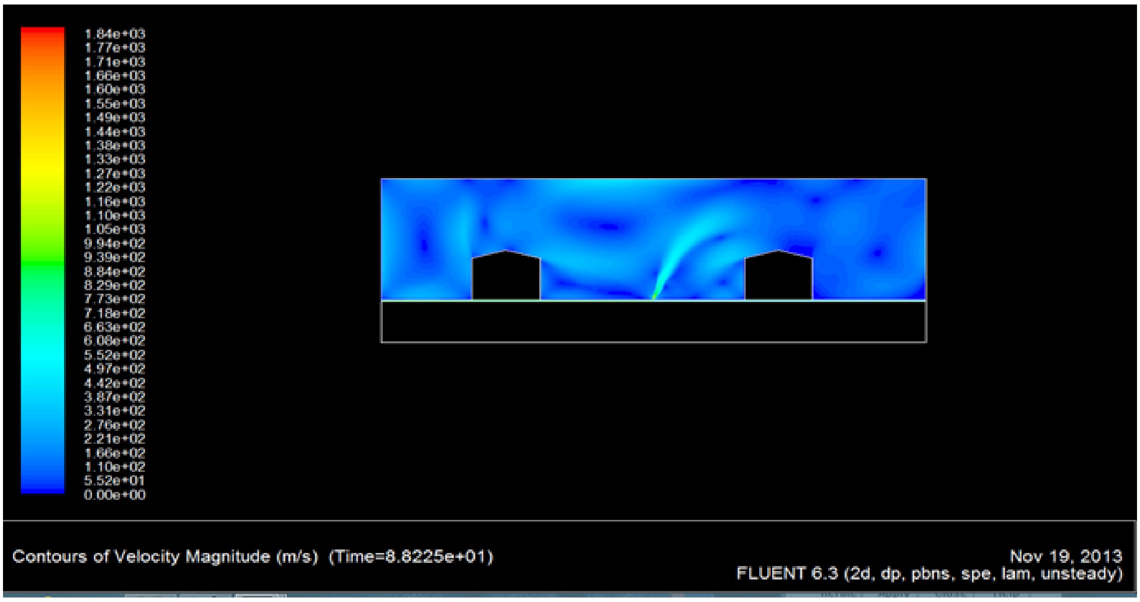


Figure 4-2: methane release with no wind condition at time 7.5 s

Figure 4-2 shows methane concentration after 7.5s after the release. Now, the height of the jet have decline showing that the rate of release of methane also decreases. Due to the time factor some of the methane disperses into the surrounding air. In the case with wind, blowing from left to right, the jet impulse is also higher after 1s of release and wind speed 5m/s (Figure 4-3). But due to the wind blowing from left to right the methane has been pushed towards the right building and causing the mixing of methane gas with the air. Meanwhile, Figure 4-4 shows methane concentration at time 7.5s after the release. Now, the jet is not strong enough to go higher up and it is driven up by the wind condition and buoyancy. As the time moves on, the mixing of methane and air is higher. Figure 4-5 to 4-8 shows concentration of methane for different wind speed 10m/s, 15m/s at release time 1s and 7.5s. As the wind speed increase the mixing or dispersion rate of methane into the air is higher.

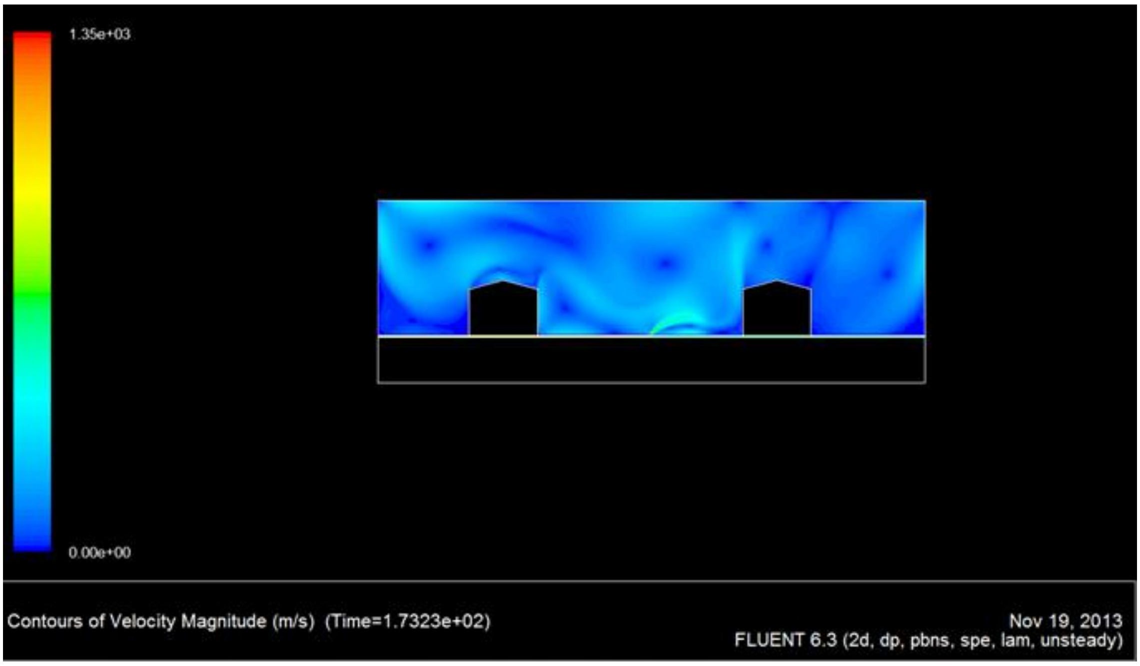


Figure 4-3: methane release with wind speed 5m/s at time 1s

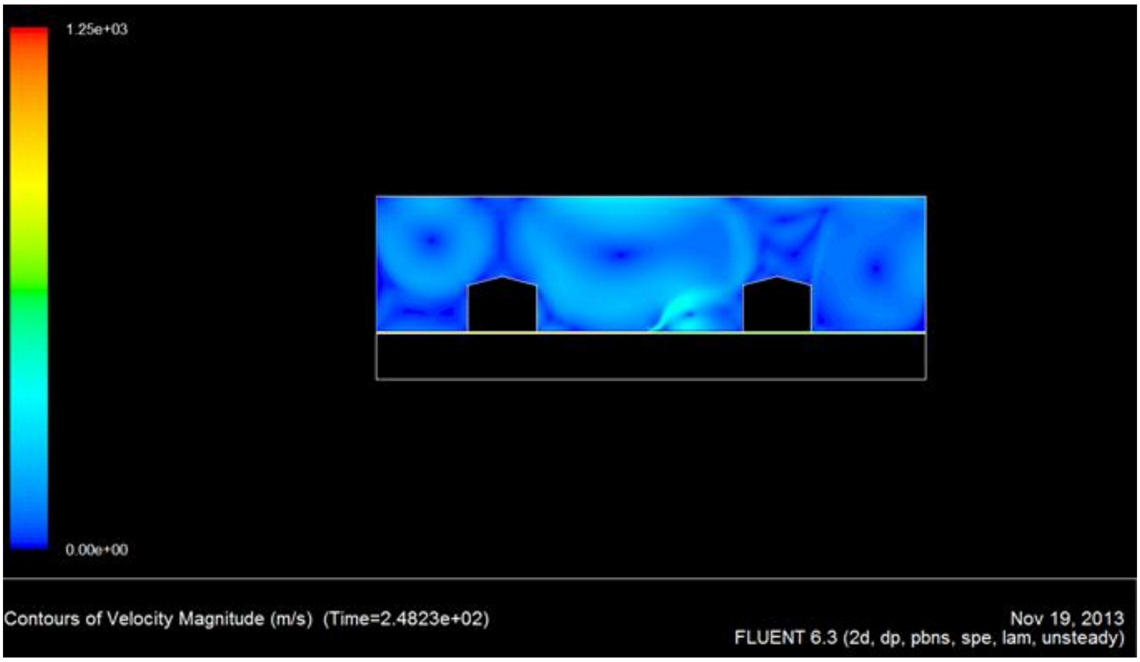


Figure 4-4: methane release at time 7.5s, wind speed 5m/s

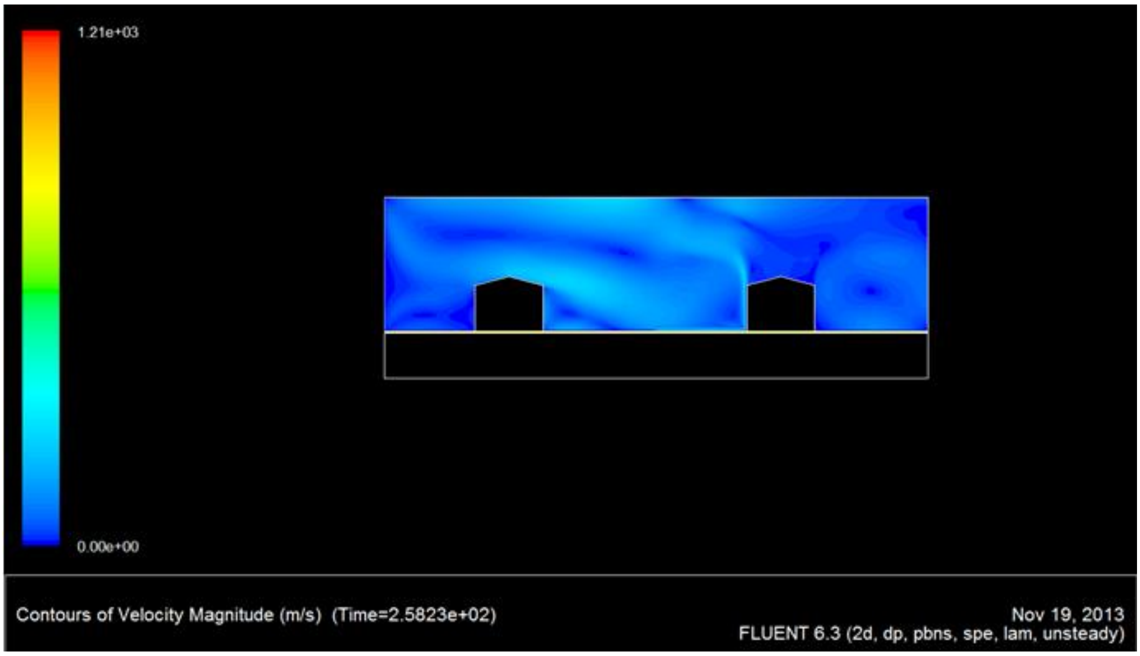


Figure 4-5: methane release at 1s, wind speed 10m/s

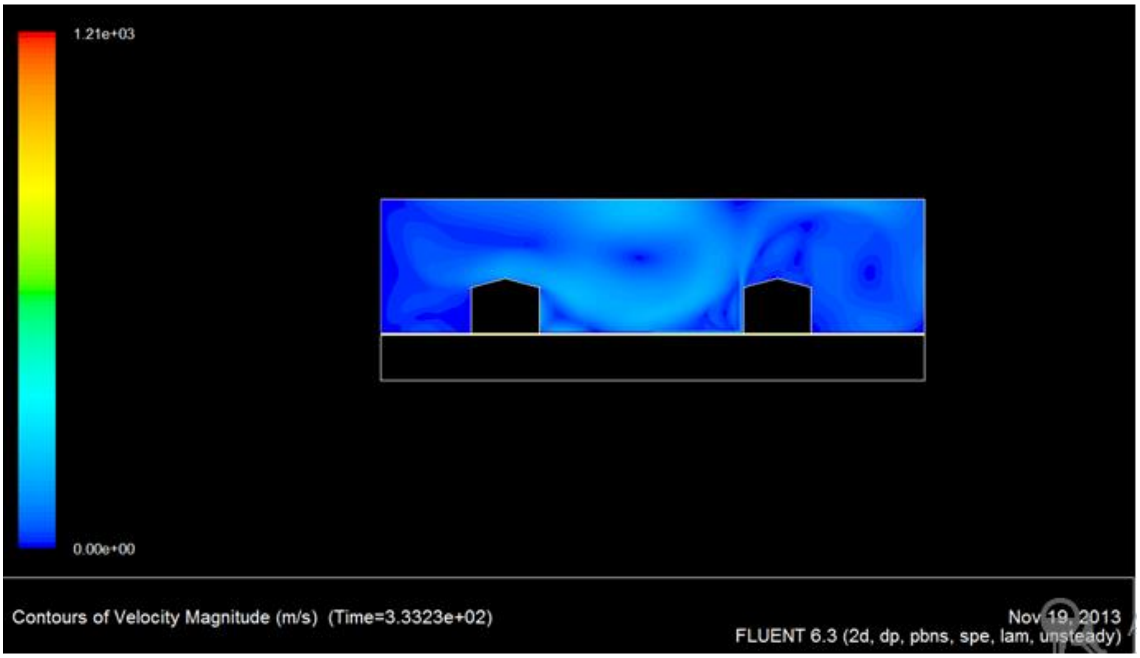


Figure 4-6: methane release at 7.5s, wind speed 10m/s

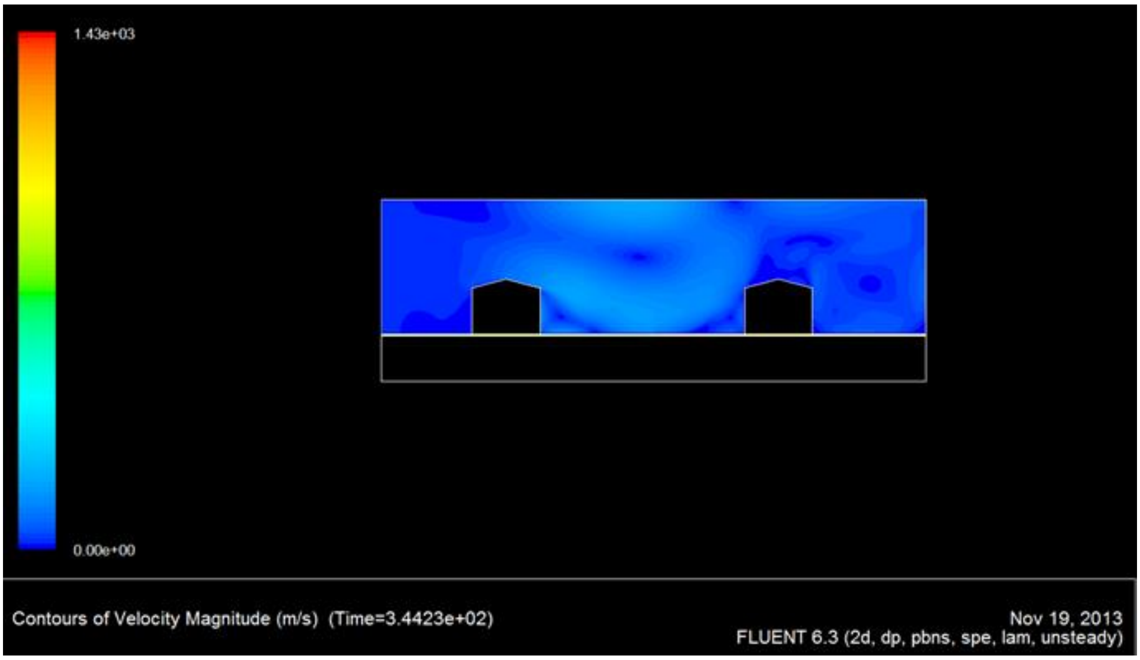


Figure 4-7: methane release at 1s, wind speed 15m/s

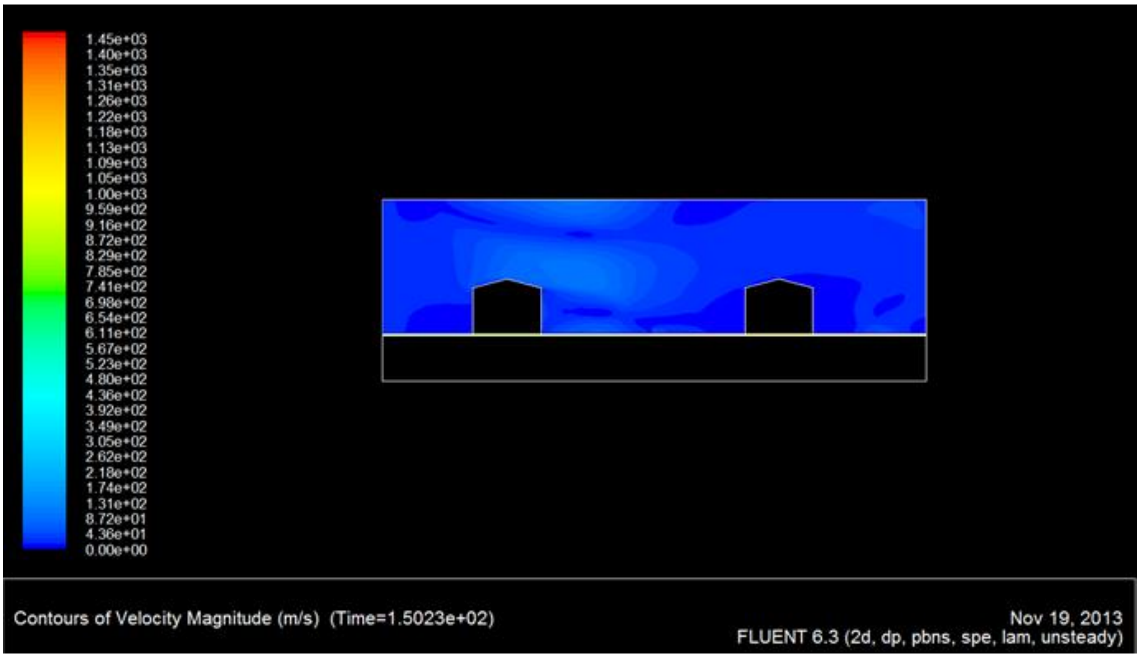
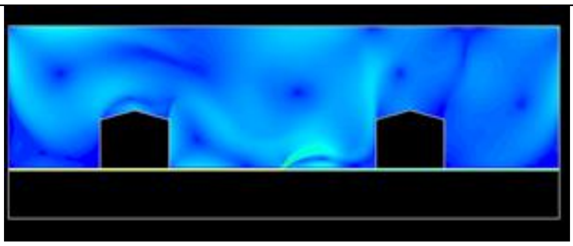
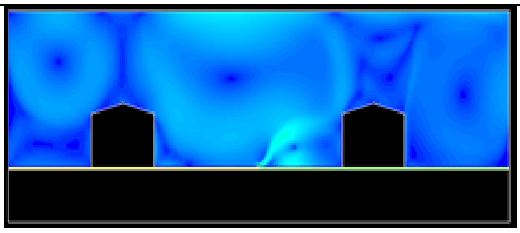
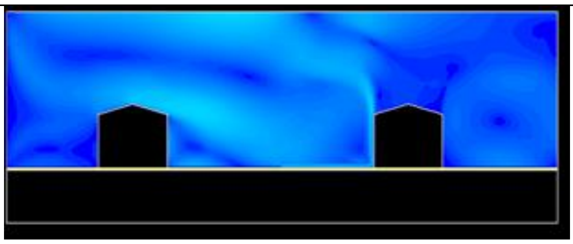
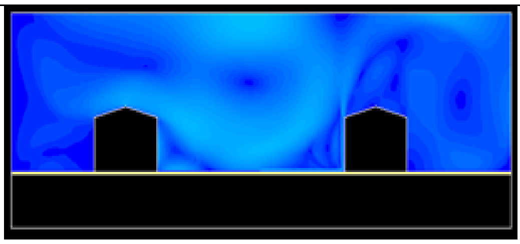
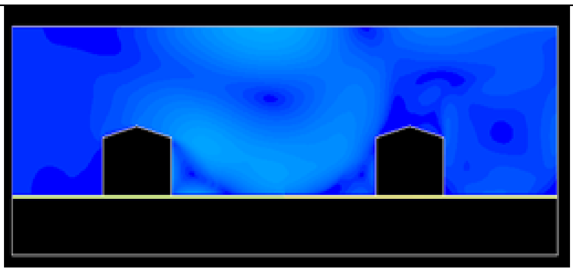
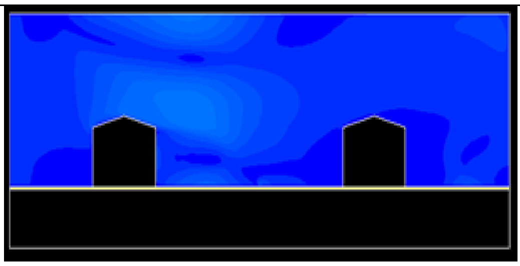
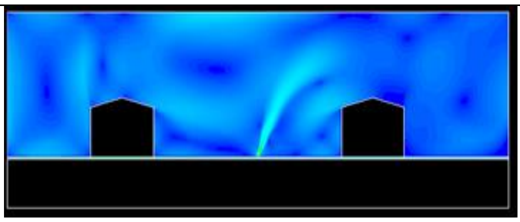


Figure 4-8: methane release at 7.5s, wind speed 15m/s

Summary of methane dispersion is shown in Table 4.1

Table 4-1: summary table of dispersion of and methane.

	Methane	
Time ,t/s	t=1	t=7.5
Wind speed, 5 m/s		
Wind speed, 10m/s		
Wind speed, 15m/s		
No wind		

4.2 *Hydrogen release*

For hydrogen pipeline scenario, same condition has been applied. Where the pipeline pressure is 11 bar and the release rate is 1200 m/s. The first hydrogen case is no wind condition with other condition remains unchanged. Figure 4-9, shows no wind condition for hydrogen release at time 1s. Without wind the jet shot up straight to the air and it is only affected by buoyancy force. In this scenario also, the jet develops its own reticulation in which it able to trap some hydrogen. Not only that, the amount of hydrogen close to the ground is less. Whereas for hydrogen the rate of dispersion is different compare to methane gas. Due to the light weight of hydrogen the gas is disperse more and mix with the air molecules although there is no wind to mix the hydrogen and air together. As the times goes by, at time 7.5s (Figure 4-10), the jet impulse is reduce causing the height of the hydrogen release decline as well. Besides that, the rate of hydrogen mix with air also increases.

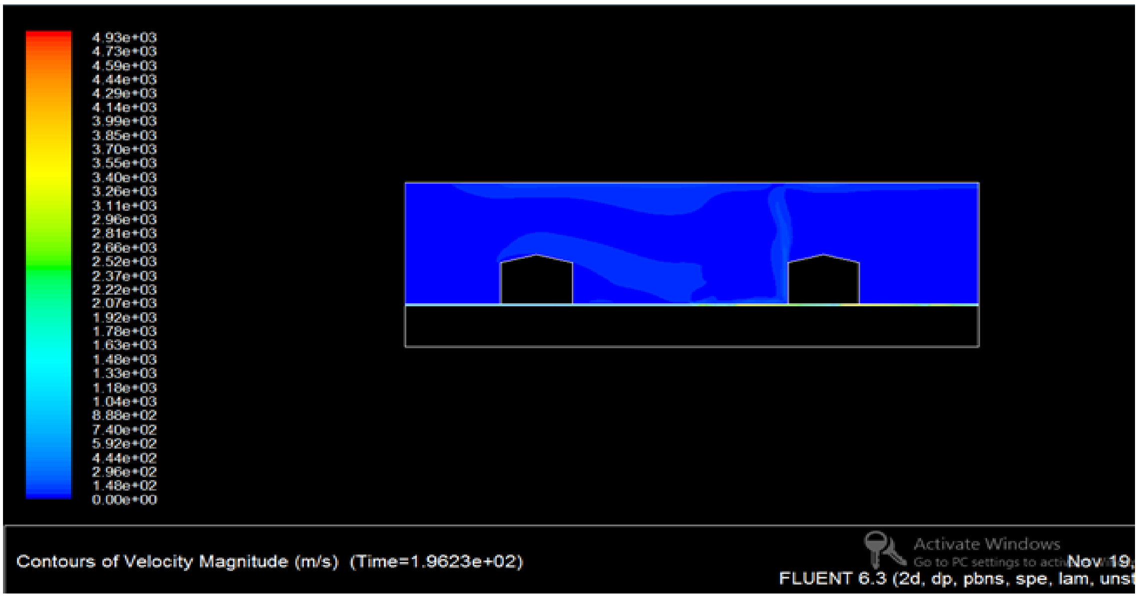


Figure 4-9: hydrogen release with no wind condition at 1s

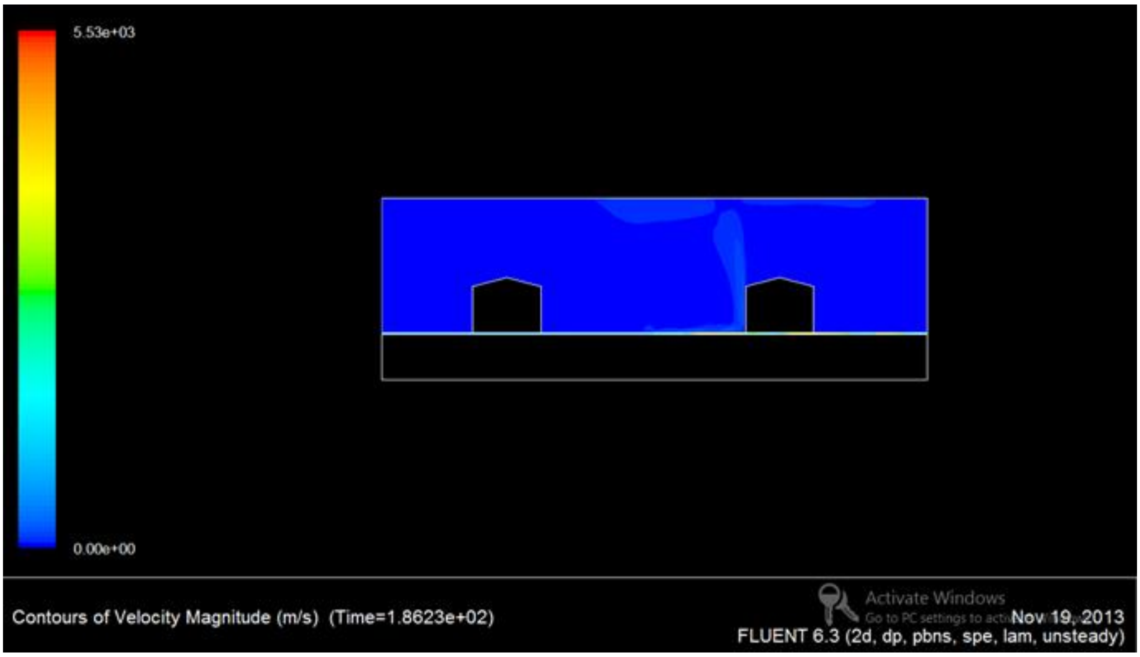


Figure 4-10: hydrogen release with no wind condition at 7.5s

In second case with the presence of wind, at time 1s and wind speed 5m/s,(Figure 4-11) the jet impulse is not strong as compare to without wind. This is basically due to the wind condition and buoyancy force. The hydrogen gas is found to be more disperse into the surrounding air and less hydrogen found near to the building or ground. As the time reaches 7.5 s, the hydrogen seems to mix with the surrounding air (Figure 4-12). As the wind speed increases, at time 1s and 7.5 s, hydrogen gas mix with air molecules and ultimately causing rapid increase in dispersion as show in Figure 4-13 to Figure 4-16.

Figure 4-11: hydrogen release at 1s with wind speed 5m/s

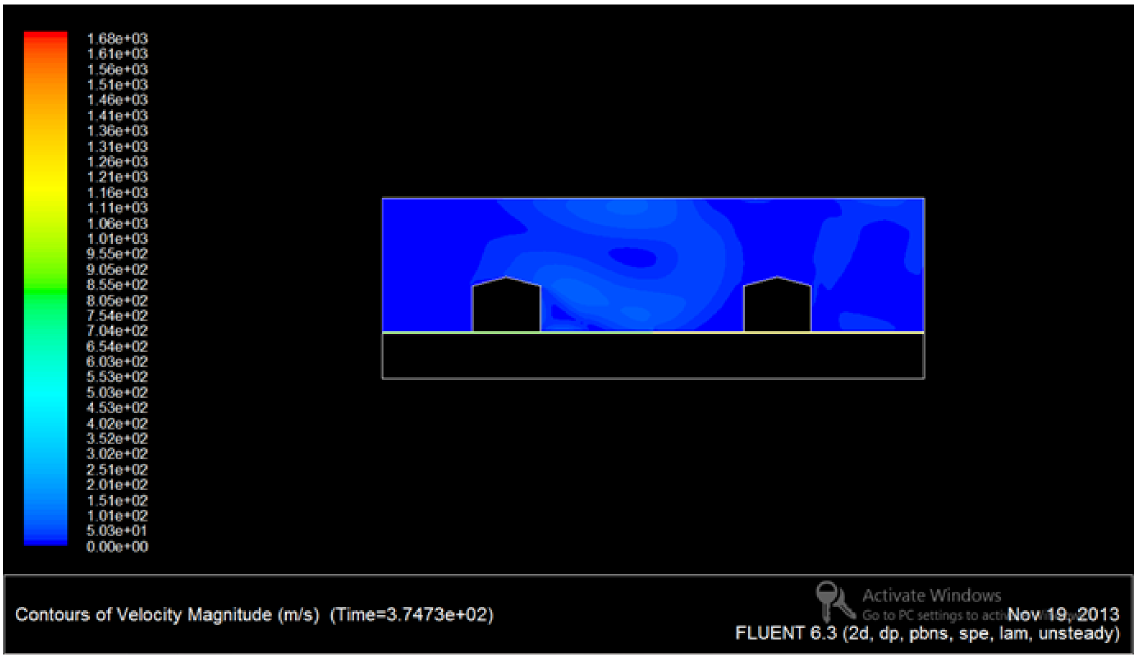


Figure 4-12: hydrogen release at 7.5s with wind speed 5m/s

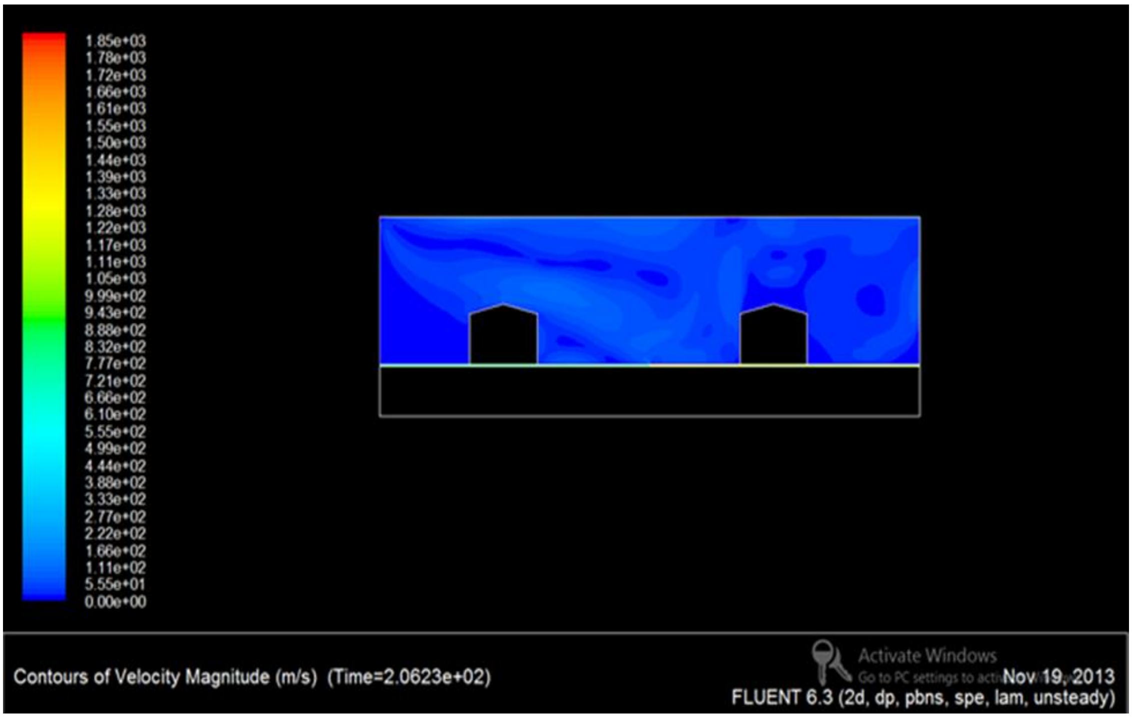


Figure 4-13: hydrogen release at 1s with wind speed 10m/s

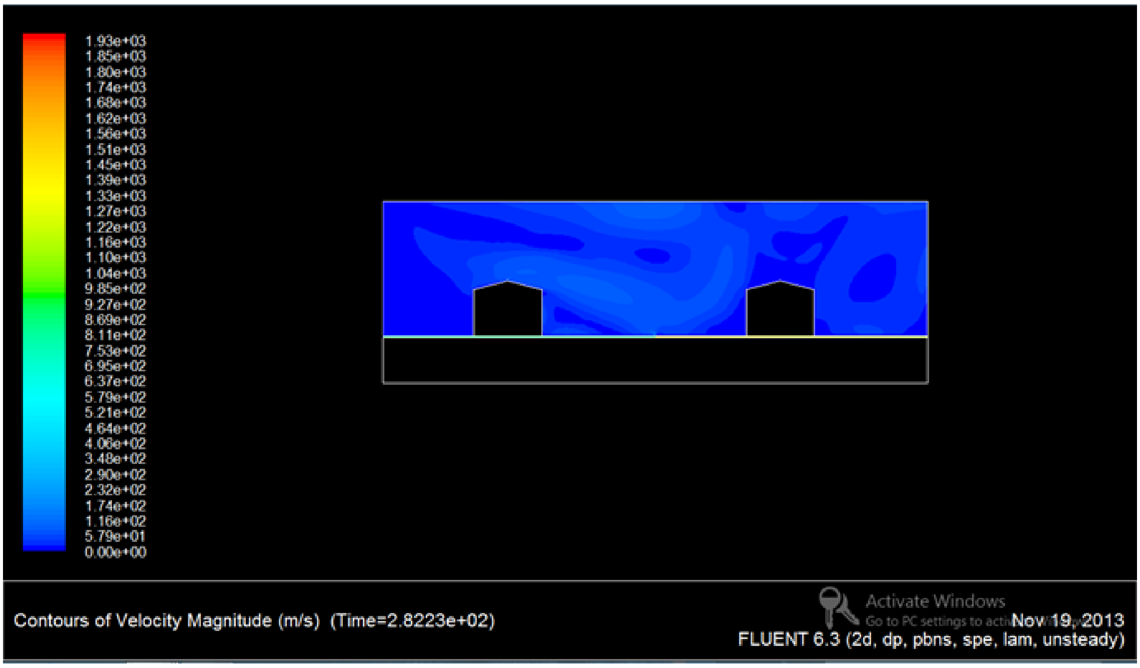


Figure 4-14: hydrogen release at 7.5s with wind speed 10m/s

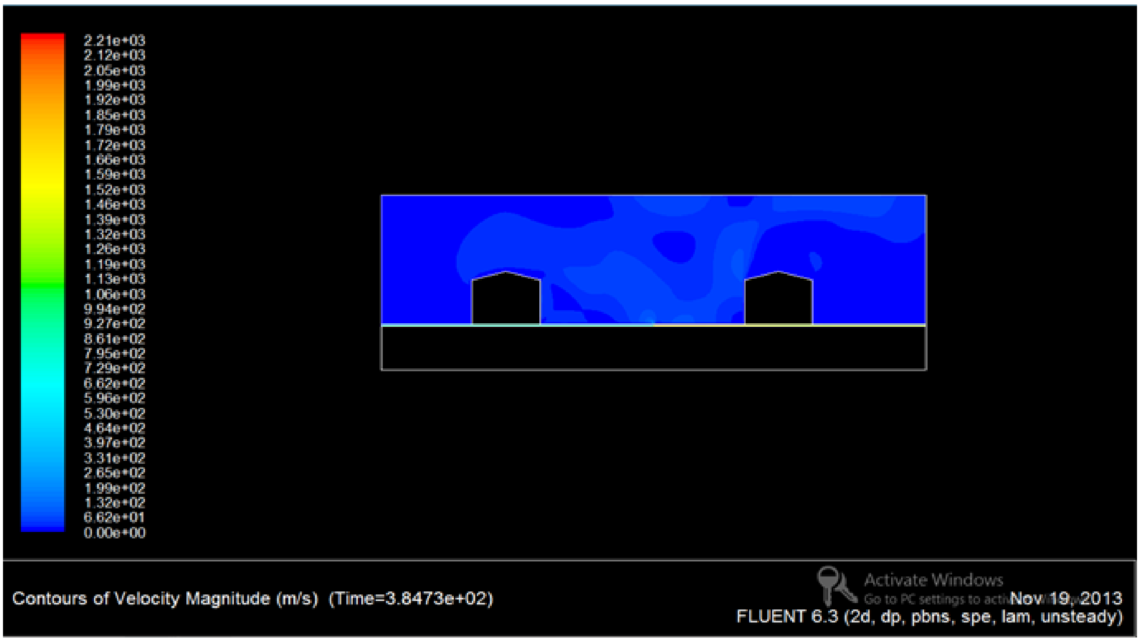
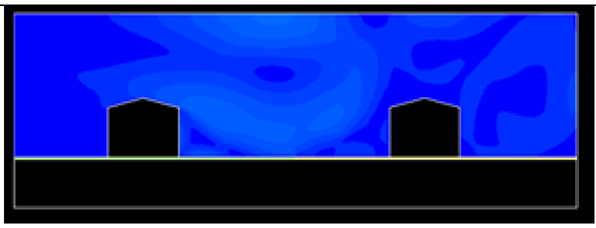
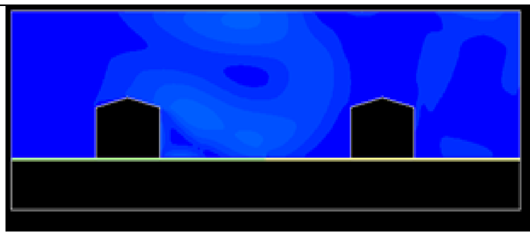
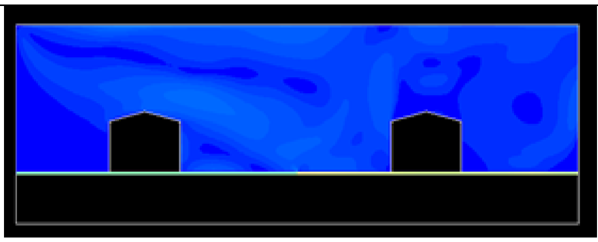
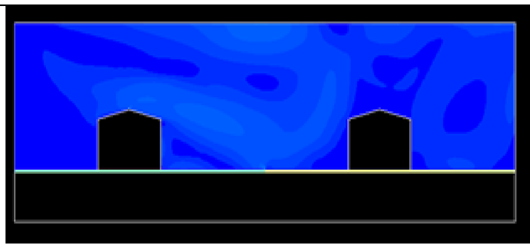
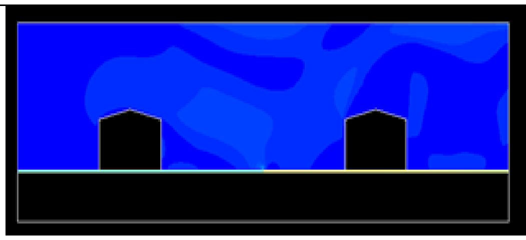
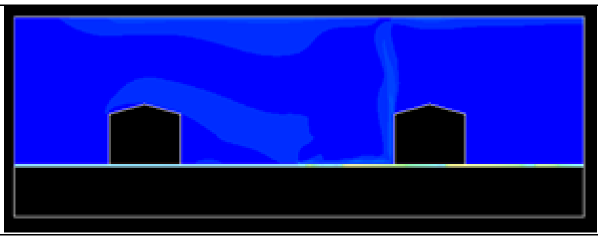
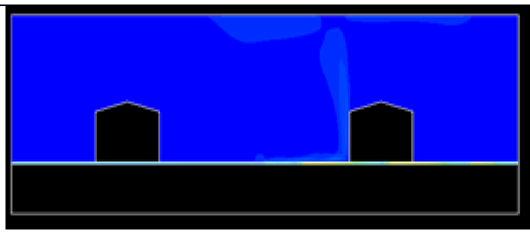


Figure 4-15: hydrogen release at 1s with wind speed 15m/s

Figure 4-16: hydrogen release at 7.5s with wind speed 15m/s

Table 4-2: summary table for dispersion of hydrogen

	Hydrogen	
Time ,t/s	t=1	t=7.5
Wind speed, 5m/s		
Wind speed, 10m/s		
Wind speed 15m/s		
No wind		

4.3 *Comparison between hydrogen and methane release*

The release rate of hydrogen and methane gas is 1200 m/s with the pipeline pressure of 11 bar. However both gases have different rate of dispersion due to some factors. The density of hydrogen gas is 0.085kg/m^{3,} whereas methane density is 0.66 kg/m^3, the different in density of both gases clearly show that hydrogen gas have higher buoyancy force compare to methane gas. Besides that, due to lower density of hydrogen, the jet velocity tends to be higher causing the jet impulse to shot up higher compare to methane as show in Figure 4-17(hydrogen) and Figure 4-18 representing methane when there is no wind condition and at time 1s.

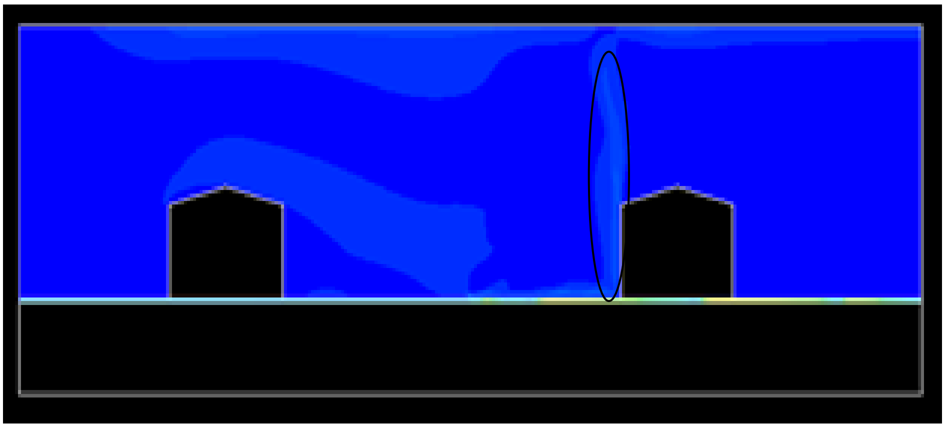


Figure 4-17: hydrogen release at 1s with no wind condition

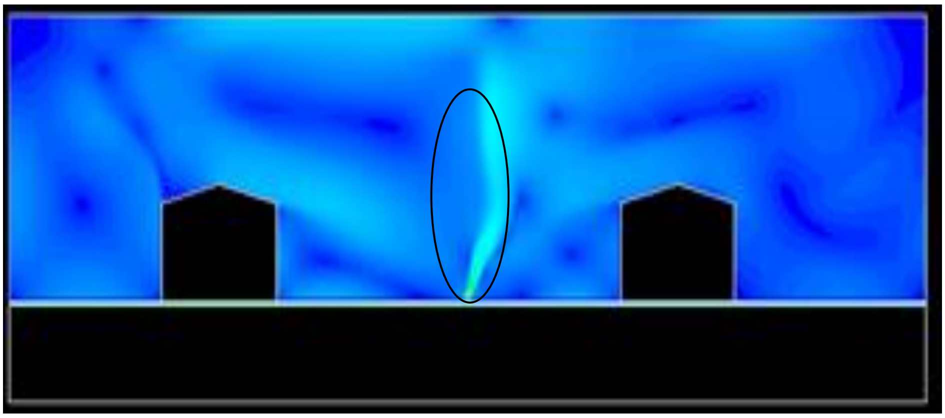


Figure 4-18: methane release at 1s with no wind condition

Moreover, it can be clearly seen that more methane can be found close to the ground compare to hydrogen. This is definitely dangerous, due to higher probability of ignition which may result in great impact to the local community. Figure 4-19 and 4-20 shows clear picture of the statement. The concentration of methane is higher at the point close to the ground meanwhile for hydrogen the concentration is lower.

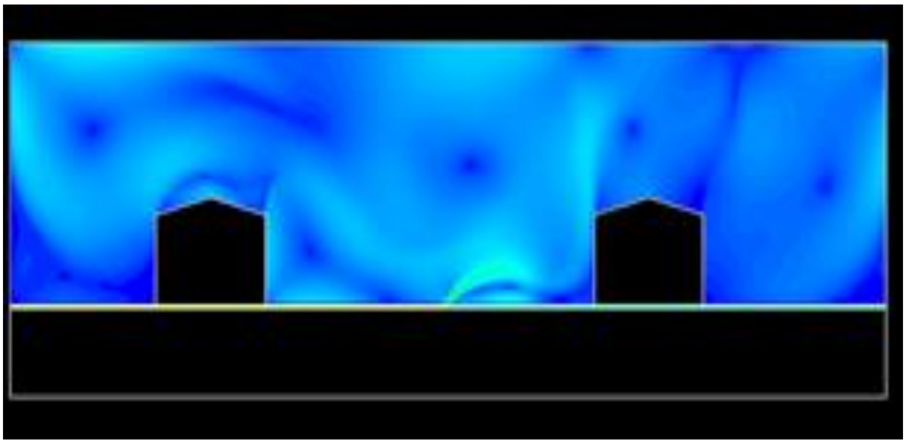


Figure 4-19: methane release at time 1s at wind speed 5m/s

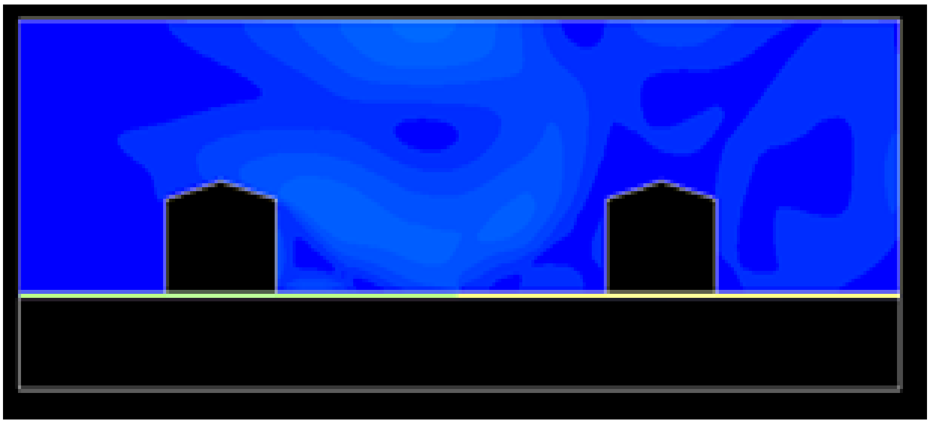


Figure 4-20: hydrogen release at time 1s at wind speed 5m/s

Table 4-3: summary of hydrogen and methane dispersion release at 1s

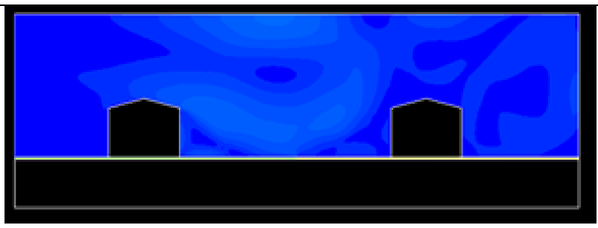
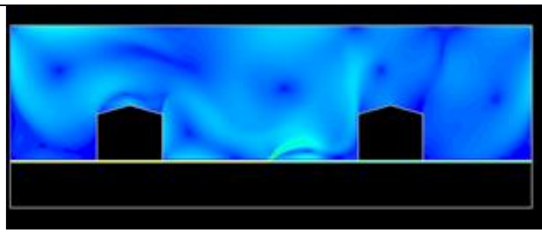
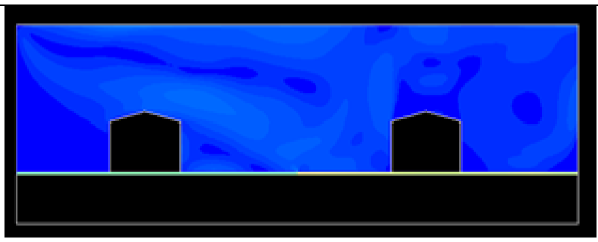
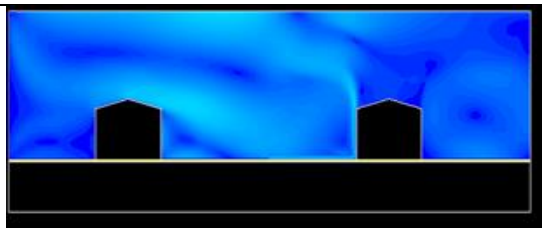
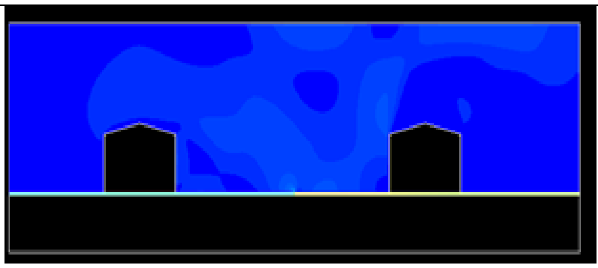
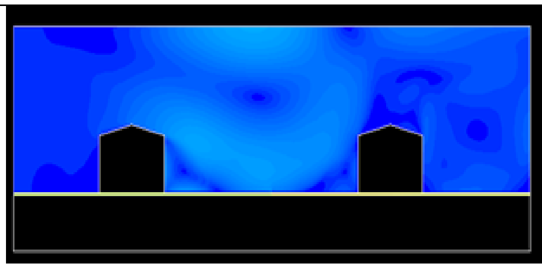
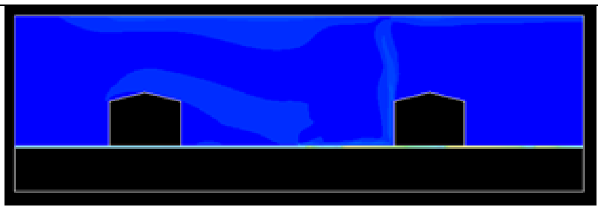
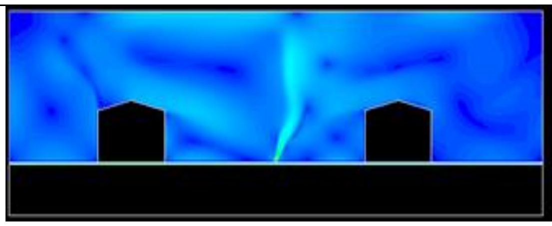
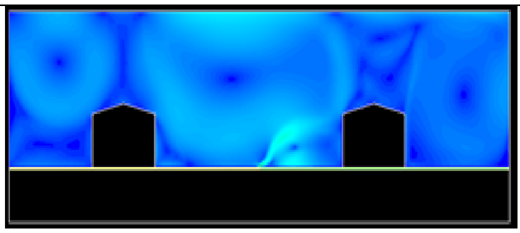
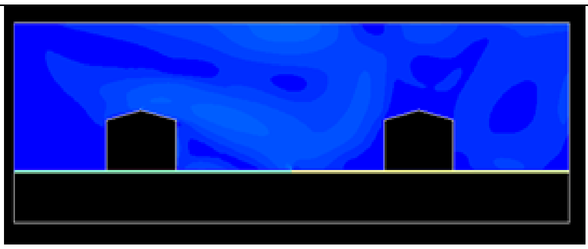
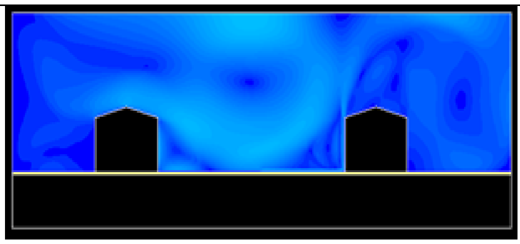
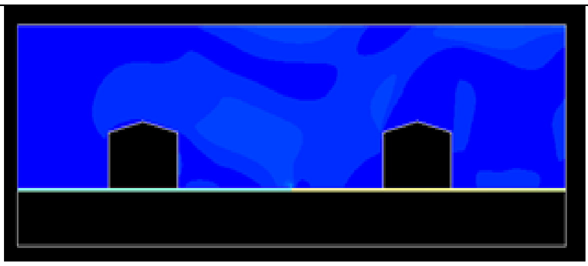
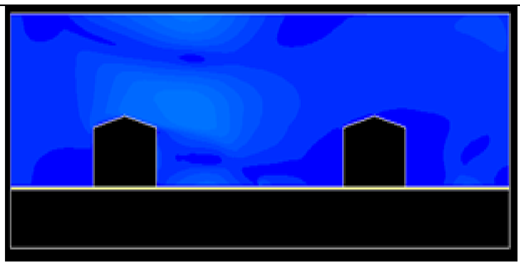
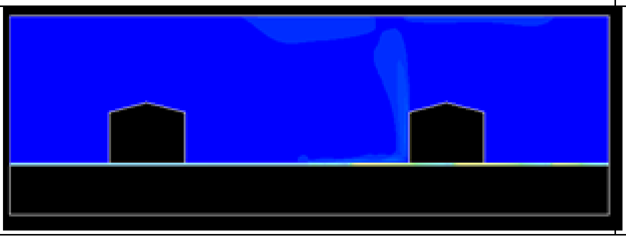
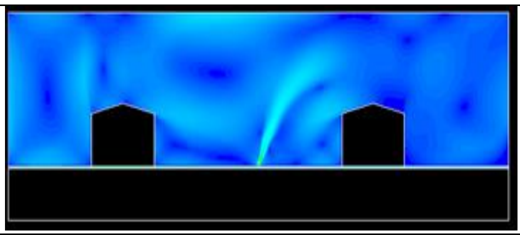
	hydrogen	methane
Time ,t/s	t=1	t=1
Wind speed, 5m/s		
Wind speed, 10m/s		
Wind speed 15m/s		
No wind		

Table 4-4: summary of hydrogen and methane dispersion release at 7.5s

	hydrogen	methane
Time ,t/s	t=7.5	t=7.5
Wind speed, 5m/s		
Wind speed, 10m/s		
Wind speed 15m/s		
No wind		

Based on the previous research, methane gas is found to be more on the surface due to higher density and low buoyancy force compare to hydrogen (Benard et al., 2013). Hydrogen gas tends to disperse more compare to methane which can be found on the surface during steady condition. According to one of the study done by Wilkening and Baraldi, the dispersion of methane when there is wind blowing at the speed of 10 m/s is as shown in Figure 4-21.

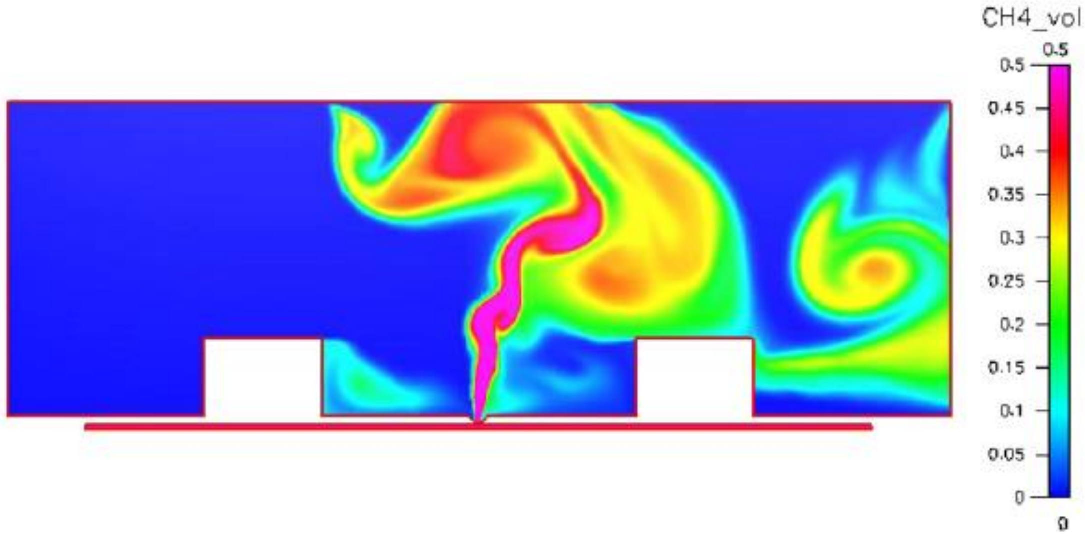


Figure 4-21: methane release at wind speed 10m/s

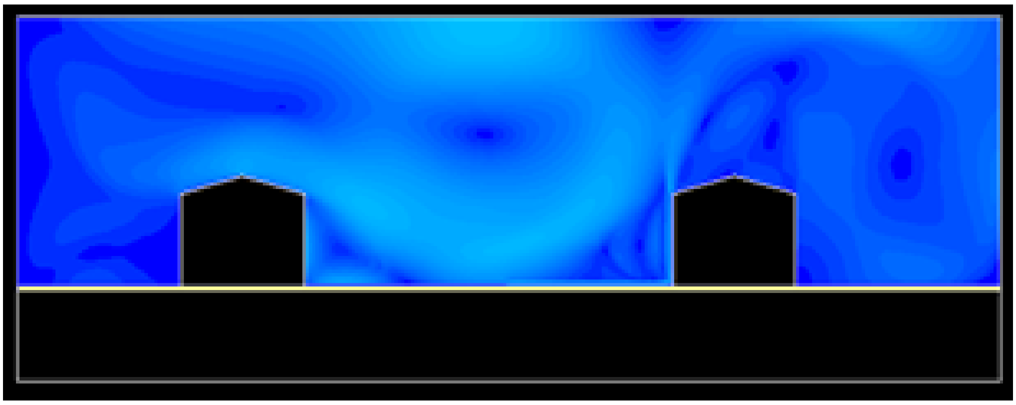


Figure 4-22: methane release at time 7.5s at wind speed 10m/s

When figure 4-21 is compared with the result from this research (figure 4-22), the result obtain through the research is acceptable because the more methane found to be mixed with the air due to the wind speed. Unfortunately, the difference in the roof shape causes the dispersion contour not to be the same, this have been discuss by Yassin in the journal entitle Impact of height and shape of building roof on air quality in urban Street canyons. Based on Yassin's journal the dispersion of methane and hydrogen gas also affected by the type of building roof. According to his study, the dispersion for slanted roof will be as Figure 4-23.

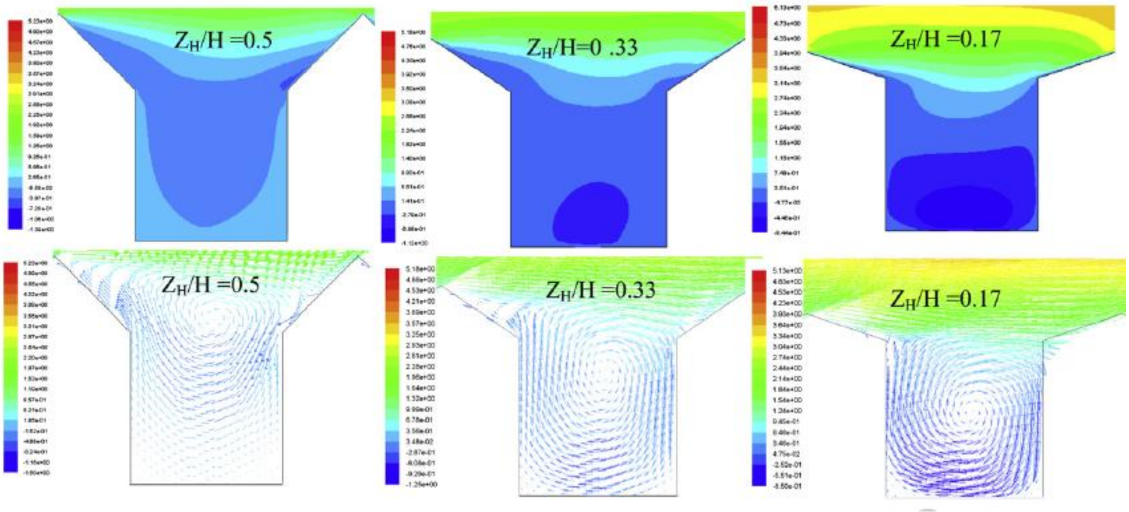


Figure 4-23: Dispersion model for slanted roof type

This dispersion contour is similar to the result obtain from this research as shown in figure 4-24.

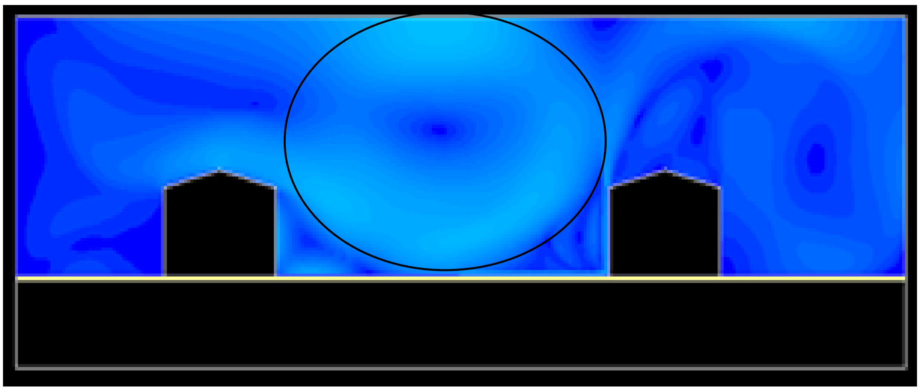


Figure 4-24: Dispersion model for methane gas at 7.5s for 10m/s wind speed

Thus, our simulation results for both hydrogen and methane are within the range predicted by Benard *et al.* and Wilkening and Baraldi 2007 as well as Yassin.

When 1200 m/s of methane or hydrogen gas is released it will produce a gas cloud at the release point. The density of gas and prevailing wind will move the gas cloud in a predetermined manner. Hydrogen gas which has smaller density which is 0.083kg/m^3 which is lower than the density of air will tend to float ,whereas methane with density of 0.6512 kg/m^3 which is a bit heavier than hydrogen will sink and can be found more on the surface of the ground. Irrespective of whether the gas cloud is buoyant or dense the uniformity of the gas cloud is not constant and changes with distance and time. As the gas disperses from the point of release a gas plume is formed. The concentration within the plume changes constantly. As the gas plume moves further from the point of release the concentration will be decreasing. From the result above, it can be clearly seen that, hydrogen gas is safer to use because it have lighter density hence it will not remain on the ground where ignition is possible. Unfortunately, if the leak hydrogen is exposed to the ignition source the damage it will result is much worse than for methane. Meanwhile, the methane gas with higher density tend to sink and can be found more on the surface of the ground where it may get in contact with ignition source and can lead to explosion or the gas might expose to the local community. Thus, it is wiser to use hydrogen as our main fuel compare to natural gas and the hydrogen economy is feasible in the future. (Wilkening and Baraldi., 2007)

5 CONCLUSION

5.1 Conclusion

This project is about the dispersion process of methane and hydrogen gas when there is a leakage in a pipeline. From this project we can clearly see that hydrogen gas disperse faster and wider compare to methane gas. This is because hydrogen gas has lower density compare to methane gas. Hence it will disperse faster into the air compare to methane which is denser and it tends to remain at the ground. When methane gases which remain on the ground are in contact with any ignition source combustion might happen or even result in explosion. Thus, it is feasible to transport Hydrogen in future via pipeline due to higher dispersion effect compare to methane.

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