Research Journal of Applied Sciences 10 (10): 587-593, 2015
ISSN: 1815-932X


# Gua Musang Unexpected and Rarely Inferno Incident: A Case Study

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**Abstract:** This study is to investigate a rare case of incident which caused a pool fire accident at petrol station involving human life, property and environment. A pool fire is one of the emerging source of risk which tremendously could do harm to human. The incident caused eleven victims which nearly 60% burn and property damage. Justification of the incident has been carried out by using a software known as Area Locations of Hazardous Atmospheres (ALOHA 5.4.2) to compute from significant datas to quantify the risk and magnitude of the pool fire probability effect not just onset but offset of the vicinity which engulfing the Petrol Station (PS). The inputs including data of meteorology, chemical material of data sheet, geographical site, source data and threat zone. Investigators gathered all the information by monitored, visited, interviewed and investigated the effected site which is a petrol station; province of Gua Musang, Malaysia. Result from the software and investigation will give a crystal and vivid anecdote of the magnitude of effected scenario to human, property and environment. Furthermore, it also generated a good respond in formulate the best solution of mitigation to regards any risk emerging at petrol station and its vicinity.

**Key words:** Petrol station, onset and offset, pool fire, risk, mitigation

## INTRODUCTION

Rapidly growth of emerging down stream of petroleum industry such as petrol station become a pandemic. This support by the advancement of technology in exploring, operation, drilling, pipeline, oil tanker and state the art of machinery which collaboration between multi-government organization of oil production under one OPEC and AOPEC (Khan *et al.*, 2002). In another hand, Malaysia itself of its output gross for retail sales of automotive fuel contributed about 4.812 million (7.2% out of overall gross out in retail sector). This represent the growing of the industry especially in petrol station trader.

Due to the increasingly of demamd of fuel, there is always a tendency of emerging risk. Cases of accidents engulfing petrol station in Malaysia is quite low in number but a case of pool fire is very rare. A petrol station is non-major hazard facility which the threshold is <100.000 tonnes of substance.

However, a special care should be taken into consideration from the early stage of design, construction, installation and maintenance of its component so that they remains safe and scure through out the life cycle of the petrol station from the uncertainty and complexity of risk.

Hazards isn't stand alone source of fire but frequently are the combination of hazards which could have contribute to the high magnitude of accidents. To minimize hazard, a tool to quantify risk assement is needed to be used (Arendt and Lorenzo, 2000). Therefore, Quantitative Risk Assesment (QRA) (Papazoglou *et al.*, 1992) tool has been adopted to use a software known as ALOHA 5.4.2 to interprete the magnitude of the effected area and pool fire.

## CHRONOLOGY OF ACCIDENT

A team of investigators has been dispatched to the scene to investigate. The chronology of accident as below:

- April 2, 2014: about 9.30 p.m., there was a row of food stalls engulf with fire reported beside the petrol station at Gua Musang, Province of Kelantan. A row of shops in Gua Musang shell petrol station explosion
- Informed that an overflow of fuel U97 from the dipping hole while processing of unloading petrol from a road tanker to the storage tank

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- An overflow petrol suspected has been pool downwards toward to a row of foods nearby
- An overflow petrol flowed downdwards to the stretch of road and a row of food stalls situated at KESEDAR SQUARE
- Overflow of the fuel flowed more that 50 m in distance
- Overflow of the fuel accumulate at the row of the stalls; activities of cooking dishes
- A huge fire broke out and spreaded has been caused 11 people injured mostly people who were eating their supper at the stalls area, damaging 3 motorcycles and 4 cars

## SCENARIO: FUEL UNDOWNLOADING AND REFILLING PROCESS

The process of undownloading and refilling fuel into the underground storage tank with a diameter of 30 m radius at approximately, around 9.30 p.m. A 6 inches flexible polymer hose is used to channel fuel from a road tanker into the underground storage with fuel up to 6 m level as shown in Fig. 1.

The incident of an overflow fuel suspected approximately, 15 min after undownloading and refilling process. However, the operator fail to secure and stop the flowing of the fuel due to malfunction of safety alarm and failure in shut down the safety valve Fig. 2.

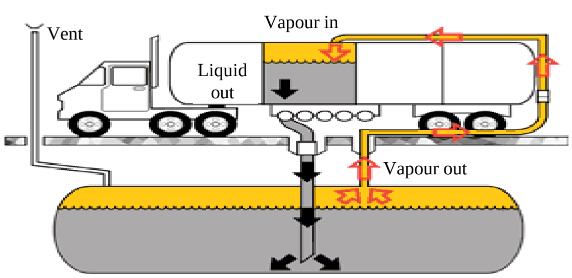


Fig. 1: Process of undownloading and refilling of fuel into underground storage. Adopted and modified from: http/www/c-store.com.au/images/articles/2008/VR1.1

## CHARACTERISTIC OF HAZARD

Hazard is the potential source of harm. Meanwhile, harm means a physical injury or damage to the people, property or environment or a combination of it. Either directly or indirectly. Futhermore, risk is a combination of the probability of occurrence of harm and the severity of that harm (ISA, 1998) and (Center for Chemical Process Safety (CCPS), 2000).

The hazardous of chemical typically at petrol stations including products and its Globally Harmonise System (GHS) characteristic in Table 1. Petrol station hazards found:

- Petrol is the most common hazardous chemicals that public interact with
- Flammable liqid spills can occur during refuelling customer vehicles
- Flammable gas can be released during LPG/Autogas filling operations
- Leaks and spills can occur during tank filling operation such as tanker vehicle transfer
- Flammable liquids and gases present a fire and explosion hazard when storing and handling material
- Uncontrolled ignition sources pose significant risks during fuel dispensing and tansfering operation

Table 1: Hazardous of chemical at petrol station

| Products | Globally Harmonise System (GHS) |
|---|---|
| Liquid Petroleum Gas (LPG) | Flammable gas category 1 |
| Unleaded Petrol (ULP) | Flammable liquid category 2 |
| Premium Unleaded Petrol (PULP) | Flammable liquid category 2 |
| Diesel | Flammable liquid category 2 |

Adopted from Down and Robert. Perry's chemical engineers' handbook: eight edition

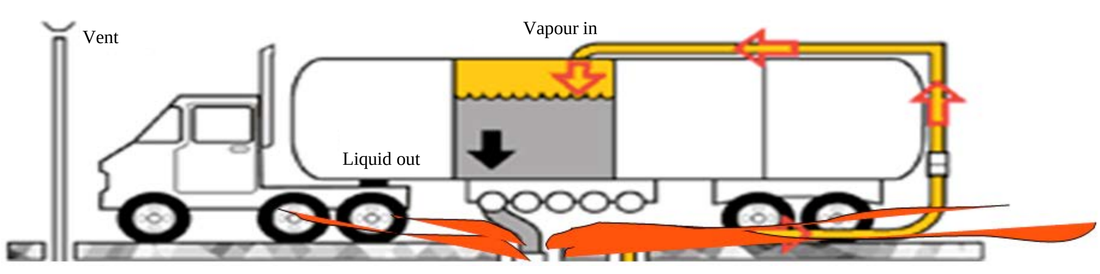


Fig. 2: An overflow of fuel. Adopted and modified from: http/www/c-store.com.au/images/articles/2008/VR1.1

## SOURCE OF EVENT PROCESS

The source of event can be category as below:

- Liquid releases
- Flash point
- Pool fire

**Liquid release:** Liquid releases can be characterised by either being contained, allowed to runoff or spread to lower surface elevate on. If there are highly volatile, dissipation by the vaporization may occur when the vaporization rate equal the spread rate. Depending on the viscosity of non volatile liquid, they will spread out immediately and form into a pool of liquid that is somewhat localised to the immediate area. The higher the viscosity, the longer it will take to spread. A pool of calm water will spread under the influence of gravity until limited by suface tension, typically giving the minimum oil slick thickness of 10 mm on the water. A pool on the water will also drift in the direction of wind and current. If not ignition occurred, the lighter ends will evaporate and eventually the residual oil will be broken up by wave action and bacteriorlogical digestion. During the evaporation of the lighter fraction, combustible vapours may form immediately above the oil spill or a short distance.

Liquids under pressure (pipeline leaks, pump seal failure, etc.) will be thrown some distance from the point source while atmospheric leakage will emit at the point of release. The other characteristic of liquid release is their flash point. High flash point liquid, not operating above their flash point temperature are inherently safer than low flash point liquid. Most liquid fire are relatively easy to contain and suppress while gas fire are prone to explosion (Kim *et al*., 2014). Possibility if extinguished and source point are not issolated. Liquid release are characterised by the following features:

**Leaks and drips:** Leaks and drips are characterised by small diameter release of high frequencies. There are typically caused by corrosion and errosion failure of piping, mechanical and maintenance failures of gasket and valve.

**Streams:** Medium size releases of moderate to low frequencies. Typically small diameter pipe opening that have not be adequately close, i.e., sample of drain lines.

**Sprays and mist:** Medium sized releases of moderate frequencies that are mixed immediately into air upon releases. Typically pipe gasket, pump seal and valve system failure under high pressure. On occasion releases occur from flare stacks.

Table 2: The chemical flashpoint

| Materials | Flash point |
| --- | --- |
| Hydrogen | Gas |
| Methane | Gas |
| Propane | Gas |
| Ethane | Gas |
| Butane | -60°C (-76°F) |
| Pentane | <22°C (-7°F) |
| Hexane | -22°C (<-7°F) |
| Heptane | -4°C (25°F) |

Adopted from Down and Robert. Perry's chemical engineers' handbook: eight edition

**Ruptures:** Large releases of very low frequencies. Typically vessel, tank pipe line or hose failure from internal, external or third party sources and fire condition, i.e., BLEVE condition (Abbasi and Abbasi, 2007).

**Flash point:** The lowest temperature of are flammable liquid at which it give of sufficient vapour to form and inginitable mixture with the air near the surface of the liquid or within the vessel used. The flash point has been commonly determined by the open cup or close cup method but recent research has yielded higher and lower flash point dependent on the surface area of the ignition sources. Because of this aspect America Standard Testing Material (ASTM) and others standard test method has been recently withdrawn. They are under review until an adequate determination of a practical and comprehensive standard is composed and agreed upon. Common petroleum materials with some of the lowest flash point under normal condition are listed in Table 2.

**Pool fire:** A pool fire occurs when spill of liquid flammable material forming a liquid pool is ignited. Pool fire have some characteristics of a vertical jet fire but their convective heating wrom the will be much less. Heat transfer to objects impinged or engulfed by pool fires is both by convection and radiations. Once a pool of liquid is ignited, gas evaporate rapidly from the pool as is it heated by the radiation and convective heat of the flame. This heaating mechanism create a feed back loop whereby more gas becomes vaporise from the liquid surface. The surface fire increaces in size in a continuing process of radiation and convection heating to the surrounding area untill essentially the entire surface of the combustible liquid is on fire. The consequences of a pool fire are represented numerically by a flame zone surrounded by envelope of different thermal radiation level. Heat transfer rates to an equipments or structure in the flame will be in the range of 30-50 $kW/m^2$ as (Fig. 3). Geometry of a pool fire depends on the release area:

- Open area flat land, slope, water body
- Bounded area such as a dike or bund

Fig. 3: Pool fire

Burning rate:

- Burning rate increase with pool diameter
- Constant burning rate may be assumed for a liquid pool >1 m diameter

Vertical burning rate Burgess *et al*. (1961):

$$\dot{y}_{max} = 1.27\times10^{-6}\frac{\Delta H_c}{\Delta H^*} \quad (1)$$

Modified heat of vaporization:

$$\Delta H^* = \Delta H_v + \int_{T_a}^{T_{BP}} C_p dT \quad (2)$$

Mass burning rate may be estimated from the product of vertical burning rate and fuel density:

$$m_B = \rho\dot{y} \quad (3)$$

In the absence of density information mass burning may be estimated from:

$$m_B = 1.0\times10^{-3}\frac{\Delta H_c}{\Delta H^*} \quad (4)$$

Typical mass burning rate:

- Gasoline: 0.05 kg/$m^2$ sec
- LPG: 0.12 kg/$m^2$ sec

Pool size depend on the release either in an open area or bounded area for open area:

$$D_{max} = 2\sqrt{\frac{\dot{V}_L}{\pi\dot{y}}} \quad (5)$$

For bounded area the maximum size ($D_{max}$) will be as big as the bounded area, flame size:

$$\frac{H}{D} = 42\left(\frac{m_B}{\rho_a\sqrt{gD}}\right)^{0.61} \quad (6)$$

Where:
H = Flame height (m)
D = Pool equivalent diameter (m)
$m_B$ = Mass burning rate (kg/$m^2$ sec)
$\rho_a$ = Air density (1.2 kg/$m^3$ at 20°C and 1 atm pressure)
g = Gravity acceleration (9.81 m/$sec^2$)

Flame tilt and drag:

- Wind may tilt the flame affect separation distance to receptor
- Strong wind may shift (drag) the flame and move the flame base to new location

## INVESTIGATION PROCESS

The process are involving in gathering information through monitoring, investigating, interviewing people, collecting datas and interprete the root cause of the accident. The process explain as:

**Hazard identification:** Petroleum and chemical related hazards can arise from the present of combustible of toxic liquid, gases, mist or dust in the work environment. Common physical hazard include ambient heat, burn, noise, vibration, sudden pressure changes, radiation and electric shock. Various external sources such as chemical biological or physical hazard can cause work related injuries or fatalities.

It is the process of recognizing the existence of a hazard and the possible ways of realization of the hazard. Involves:

- Events
- Incidents
- Incident outcomes

**Fault tree analysis (risk assesment):** Figure 4 showing the release of the flammable of material and the rate of the occurrences per year.

**Output from the ALOHA 5.4:** All datas has been gathered and computed:

**Chemical data:**
- Chemical name: Isooctane
- Molecular weight: 114.23 g $mol^{-1}$

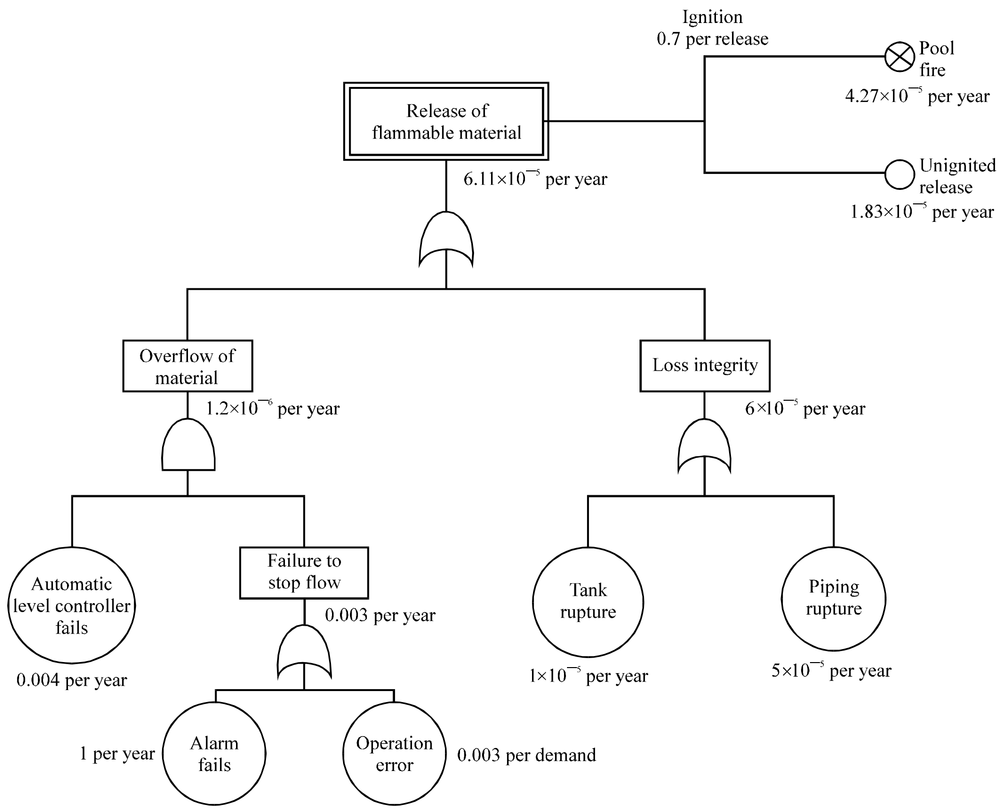


Fig. 4: Fault tree anaylsis (Adopted from yellow book, 2005)

- PAC-1: 300 ppm
- PAC-2: 300 ppm
- PAC-3: 5000 ppm
- LEL: 9500 ppm
- UEL: 60000 ppm
- Ambient boiling point: 99.2°C
- Vapor pressure at ambient temperature: 0.082 atm
- Ambient saturation concentration: 82.132 ppm or 8.21%

**Atmospheric data (manual input of data):**

- Wind: 1 m $sec^{-1}$ from WNW at 10 m
- Ground roughness: open country
- Cloud cover: 5 tenths
- Air temperature: 30°C
- Stability class: B
- No inversion height
- Relative humidity: 75%

**Source strength:**

- Leak from short pipe or valve in horizontal cylindrical tank
- Flammable chemical is burning as it escapes from tank
- Tank diameter: 3 m
- Tank length: 7.82 m
- Tank volume: 55.276 L
- Tank contains liquid
- Internal temperature: 30°C
- Chemical mass in tank: 37.80 tons
- Tank is 90% full
- Circular opening diameter: 0.10 m
- Opening is 0.50 m from tank bottom
- Max flame length: 21 m
- Burn duration: ALOHA limited the duration to 1 h
- Max burn rate: 339 kg $min^{-1}$
- Total amount burned: 20.213 kg
- Note: the chemical escaped as a liquid and formed a burning puddle
- The puddle spread to a diameter of 8.2 m

**Threat zone:**

- Threat modeled: thermal radiation from pool fire
- Red: 19 m---(10.0 kW/$m^2$ = potentially lethal within 60 sec)
- Orange: 30 m---(5.0 kW/$m^2$ = 2nd degree burns within 60 sec)
- Yellow: 48 m---(2.0 kW/$m^2$ = pain within 60 sec)

Figure 5 showing the thermal radiation generated from the pool fire and the colour represent of the potential effect to the human, property and environment.

Meanwhile, the figure below showed that source strength (burn rate) cause by the pool fire. It showed that in 1-5 min the fire started to grow up to 340 kg min$^{-1}$. Then, the fire gradually maintain the growth in an hour's time Fig. 6.

Figure 7 show the distance of the fuel flow from the petrol station slip away to a row of food stalls (KESEDAR Square) approximately, 56.5 m by using goole map distance calculator.

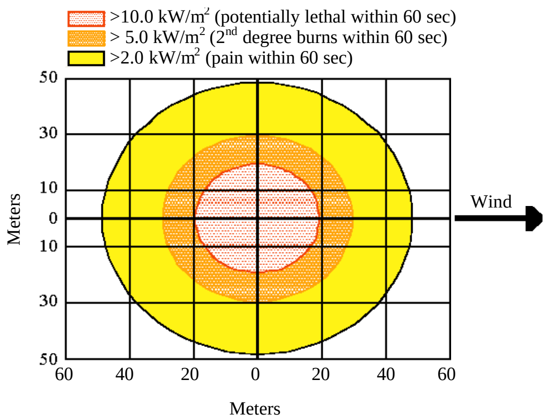


Fig. 5: Threat modeled: thermal radiation from pool fire

**Probit analysis:** The Probit Analysis Summary (PAS) is shown in the following showed the possibility of percentage of death with the distance. If the distance is far from the petrol station so the less effect to the people Table 3.

Table 3: The probability of analysis

| x (m) | Er (kW/m$^2$) | Probit | FD | Death (%) | Probability of incident/year | IR |
|---|---|---|---|---|---|---|
| 5 | 45.94 | 6.87 | 0.969 | 97 | 4.27E-05 | 4.14E-05 |
| 10 | 40.20 | 6.42 | 0.922 | 92 | | 3.93E-05 |
| 15 | 34.46 | 5.89 | 0.813 | 81 | | 3.47E-05 |
| 20 | 29.93 | 5.41 | 0.659 | 66 | | 2.81E-05 |
| 25 | 24.71 | 4.75 | 0.403 | 40 | | 1.72E-05 |
| 30 | 20.92 | 4.19 | 0.208 | 21 | | 8.87E-06 |
| 40 | 15.20 | 3.10 | 0.028 | 3 | | 1.21E-06 |
| 50 | 11.33 | 2.09 | 0.002 | 0 | | 7.79E-08 |
| 75 | 6.08 | -0.03 | 0.000 | 0 | | 1.04E-11 |

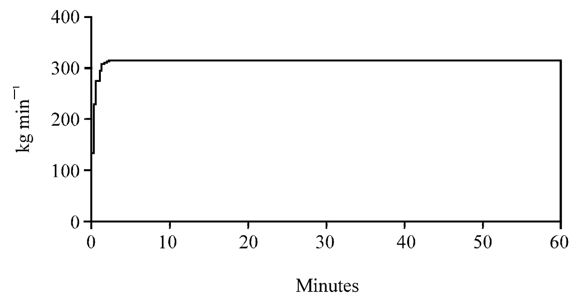


Fig. 6: Burn rate of pool fire


Fig. 7: Distance of petrol station to a rows of food stalls (KESEDAR SQUARE)

## RESULTS

Thus, result from the investigation depicted that eventhout by calculating the distance of the shell petrol station to row of food stalls is approximately, 56.2 m and by computed data from ALOHA 5.4.2 showed that probability of percentage of death starting from the 40 m could do severe harm to human, meanwhile, threat zone explained that potential death distance is 19 m.

However, approximate time of 9.30 am, there were activities of cooking and preparing late night supper since KESEDAR SQUARE is open for 24 h due to its function as (Stop and Rest Area) stopver.

The flow of the petrol from the undownloading and refill process has been cought with trigger/source of fire at the food stalls that cause the fire broke out. A massive pool fire stretched all the way about approximately, 56.2 m. The source strength of fire is approximately, 350 km $\text{min}^{-1}$.

## CONCLUSION

Therefore, the outcome from the investigation of this case truely showed that a pool fire has caused a disaster and threat to human life. So, an effort of mitigation must be taken to prevent the risk of the pool fire not just people but also to property and environment such as installation of siren of alarm, bund-avoid from the spillage of the fuel to other area, keep distance any activities that might could cause fire.

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