CONSEQUENCE MODELLING OF POOL FIRE OF BULK STORED CRUDE IN TANK FARM

Sobhag , Vaibhav, Ritik, Sudhir, Vidit, Sujeet (B.Tech fire technology and safety engineering)

IES IPS Academy, Indore (M.P)

Abstract

There are various type of hazard in crude oil storage area such as BLEVE, UVCE, POOL FIRE, JET FIRE, etc. From the annual reports, case studies and research papers of previous years were analysed for knowing the possible scenario during storing and during flow of crude oil. The result helps to develop safe and healthy environment at work place. Our aim in this project is to do hazard identification, risk assessment and calculated the consequences of the specific hazard at CTF. Some general recommendations are also suggested. Here we are mainly focusing on the research of the flame structure of the oil tank fire, the radiation characteristics and the failure of the target tank.

Keywords: RISK ASSESSMENT, HAZOP, CONSEQUENCE MODELLING

AUTHOR FOR CORRESPONDENCE E-MAIL:

dangisobhagya42@gmail.com Mob: 8889012005

rsprajapati@ipsacademy.org Mob: 9575538038

INTRODUCTION

A suite of models were integrated to predict the potential of a large liquid hydrocarbon storage tank fire escalating and involving neighbouring tanks, as a result of thermal loading. A steady state pool fire radiant heat model was combined with a further model, in order to predict the distribution of thermal loading over the surface of an adjacent tank, and another model was incorporated to predict the thermal response of the contents of the adjacent tank.

In order to predict if, or when, an adjacent tank will ignite, the radiant heat from the fire received by the adjacent tank must be quantified. There are a range of mathematical models available in the literature to calculate the radiant heat flux to a specified target and each of these models is based on assumptions about the fire.The performance of three of these models, which vary in complication, was analysed (The single point source model, the solid flame model and the fire dynamics simulator computational fluid dynamics model) and, in order to determine the performance of each model, the predictions made by each of the models were compared with actual experimental measurements of radiant heat flux. Experiments were undertaken involving different liquid fuels and under a range of weather conditions and, upon comparing the predictions of the models with the experimental measurements, the solid flame model was found to be the one most appropriate for safety assessment work. Thus, the solid flame model was incorporated into the thermal loading model,in order to predict the distribution of radiant heat flux falling onto an adjacent tank wall and roof.

LITERATURE REVIEW

1) Process Saf. Environ. Prot. 2018 [1]

Twentyeight accidents involving major fires and/or explosions, which have occurred across the world in tank farms storing flammable liquids, have been studied. The focus has been on determining, a) what were the distances between the tank which failed and the tank(s) which were damaged or could have been damaged due to fire/explosion in the former; b) what were the distances prescribed as safe by prevailing codes/standards/models between the concerned tanks, and c) whether the tanks were relocated in a safer way by the concerned industry after the accident. The study also identifies some of the codes, standards, and models which appear to provide more realistic safe distances for the given tank types/sizes.

Chemical process industries (CPI) often deal with hazardous chemicals and/or processes which give rise to the risk of major accidents (Khan and Abbasi, 1998a; Lees, 2005). Even though great advances have taken place in the science and technology of process safety, major accidents continue to occur because of ever-larger inventories handled across the world. There are also more and more new processes being operated under the hazardous conditions of very high/low temperatures and/or pressures (Rigas and Amyotte, 2013; Abbasi et al., 2013), which generate risk.

2) Omran Ahmadi, Hadi Pasdarshahri 2019

In this study, the Fire Dynamics Simulator (FDS) is adopted to simulate tank and dike pool fires in a tank farm. These simulations are performed in order to evaluate the potential for secondary fire events in nearby storage tanks based on the resulting incident radiative heat flux. As a precursor to the tank farm fire scenario case studies, the model is compared with experimental data of 1 m crude oil pool fire and 30 m and 50 m diameter kerosene pool fires. These comparisons are made to validate the modeling approach ahead of the application of the modeling to a problem of practical interest. The results of the FDS are consistent with experimental data. The FDS results indicate that the studied dike pool fire has the potential of triggering the domino effects in the tank farm, but not so true in the case of the tank fire. Quantitative results obtained by FDS modeling can be used in quantitative risk assessment of a tank farm and determination of safe inter-tank separation distances.

Pool fire is generally a turbulent non-premixed diffusion flame that is developed by the combustion of material evaporating from a layer of liquid (Branley and Jones, 2001). Spill fire in a trench and fire in a storage tank are common large pool fires of liquid fuels. In addition, a pool fire also occurs on the surface of the flammable liquid spilled onto the water. The term pool fire not only is used for liquid fuels, but it is also applied to describe the burning of solid fuels. Pool fire, as classified in Fig. 1, depends on forming situations, such as the presence or absence of confinement, the type of location, and the medium on which the pool exists (Vasanth et al., 2014).

Pool fire is one of the most common type of fire accidents in chemical process industries (Persson and Lönnermark, 2004; Reniers and Faes, 2013). Buncefield, UK (2005), Sitapura, India (2009), and Puerto Rico, USA (2009) are the examples of very large and persistent pool fires which occurred in tank farm (Mishra et al., 2013). In tank farm, fires in the large-scale tank have two main features: First, the large-scale tank fires are difficult to douse and causes huge material loss. Second, these fires may lead to domino effects as a result of thermal radiation (Cozzani et al., 2009; Mannan and Lees, 2005).

CASE STUDY JAIPUR FIRE

The Jaipur oil depot fire broke out on 29 October 2009 at 7:30 PM (IST) at the Indian Oil Corporation (IOC) oil depot's giant tank holding 8,000 kilolitres (280,000 cu ft) of oil, in Sitapura Industrial Area on the outskirts of Jaipur, Rajasthan, killing 12 people and injuring over 200. The blaze continued to rage out of control for over a week after it started and during the period half a million people were evacuated from the area. The oil depot is about 16 kilometers (9.9 mi) south of the city of Jaipur The incident occurred when petrol was being transferred from the Indian Oil Corporation's oil depot to a pipeline. There were at least 40 IOC employees at the terminal, situated close to the Jaipur International Airport) when it caught fire with an explosion. The Met department recorded a tremor measuring 2.3 on the Richter scale around the time the first explosion at 7:36 pm which resulted in shattering of glass window nearly 3 kilometers (1.9 mi) from the accident site.

The fire was a major disaster in terms of deaths, injury, loss of business, property and man-days, displacement of people, environmental impact in Jaipur, the capital city of the Indian state of Rajasthan and a popular tourist destination. As per eyewitnesses having factories and hotels around Indian Oil's Sitapura (Jaipur) Oil Terminal they felt presence of petrol vapor in the atmosphere around 4:00 p.m. on 29 October 2009. Within the next few hours the concentration of petrol vapor intensified making it difficult to breathe. The Ayush Hotel in the vicinity of the terminal asked all its guests to vacate the Hotel to avert any tragedy. The police, civil administration and fire emergency services were oblivious of the situation developing in Indian Oil Terminal. Around half past six the staff in the terminal had contained the leak and flow of petrol panicked and reported the matter to nearby Sanganer Sadar Police Station. Within the next 30 minutes the local police chief and District Collector were on the spot along with Indian Oil General Manager, but with no plan to deal with the situation. The nearby industries, which were running second shifts, were cautioned to vacate the area. At 7:35 p.m. a huge ball of fire with loud explosion broke out engulfing the leaking petrol tank and other nearby petrol tanks with continuous fire with flames rising 30–35 m (98–115 ft) and visible from a 30 km (19 mi) radius. The traffic on adjacent National Highway No. 12 was stopped leading to a 20 km (12 mi) long traffic jam. The Jaipur International Airport is just 5 km (3.1 mi) away from the accident site.

Both the Army and experts from Mumbai were employed on 30 October 2009 to contain the fire, which started when an oil tanker caught fire at the depot in the Sitapura Industrial Area. The district administration disconnected electricity and evacuated nearby areas to limit the damage.[10] The fire still raged on 31 October 2009, in the Indian Oil Corporation Depot, at Jaipur, after a defective pipe line leak that set fire to 50,000 kilolitres (1,800,000 cu ft) of diesel and petrol out of the storage tanks at the IOC Depot.[11] By then, the accident had already claimed 11 lives and seriously injured more than 150.[11] The

District Administration and Indian Oil Corporation had no disaster management plan to deal with this kind of calamity. The local fire officers were ill equipped to deal with fire accidents of this magnitude. They remained onlookers and no efforts were made to breach the terminal wall to get closer to kerosene and diesel tanks to cool them with water jets.

Area Of Study

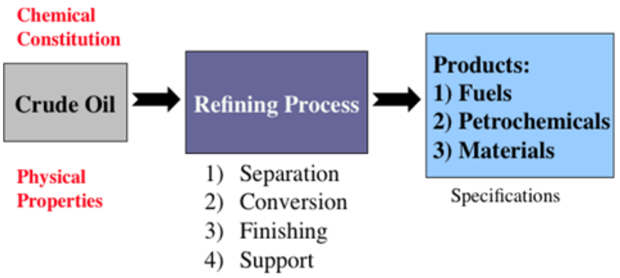
This research features three independent but interrelated parts:

A) First is the to carry out Hazard & Operability Study (HAZOP) to identify potential hazards .

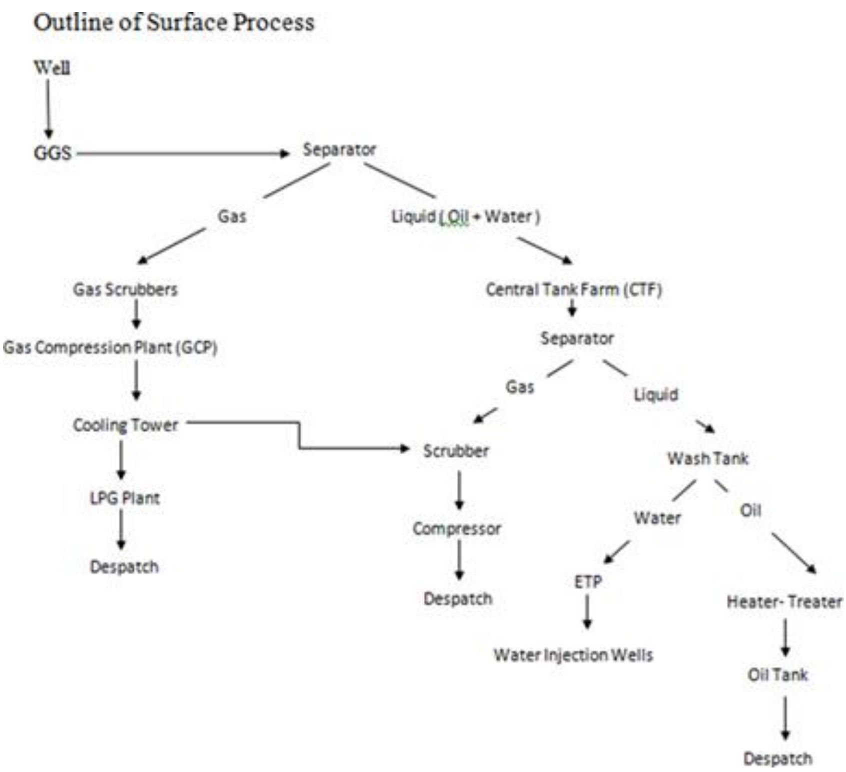
B) Second is the development of a Event tree model and Risk assessment (Event tree analysis) with the help of historical data.

C) Third is the development of a model that predicts the response of the contents of a storage tank adjacent to a pool fire . Specifically, the response model determines the conditions under which the vapours of a flammable liquid in a fire-exposed tank will be released into the atmosphere. The various thermo-physical processes that occur inside a storage tank, as a result of exposure to radiant heat flux.

refinery process



Outline Of Surface Process



Methodology

A) Here the hazop study is taken around the tank farm and two process is taken:
1.From Heater Treater to the tank .
2.From the tank to dispatch.

B) Event tree analysis (ETA) is a forward, bottom up, logical modeling technique for both success and failure that explores responses through a single initiating event and lays a path for assessing probabilities of the outcomes and overall system analysis. This analysis technique is used to analyze the effects of functioning or failed systems given that an event has occurred.

C) Consequence modelling refers to the calculation or estimation of numerical values (or graphical representations of these) that describe the credible physical outcomes of loss of containment scenarios involving flammable, explosive and toxic materials with respect to their potential impact on people, assets, or safety functions.

Pool fires is common fire type resulting from fire over pool of liquid. It tend to be localised in effect and are mainly of concern in establishing potential for domino effects and employee safety. Models are available to calculate various components — burning rate, pool size, flame height, flame tilt and drag, flame surface emitted power, atmospheric transmissivity, thermal flux, etc.

Methods are available to assess the consequences of the incident outcomes, For assessing the effects -on human beings, consequences may be expressed in terms of injuries and the effects on equipment/property in terms of monetary loss.

The effect of the consequences for release of toxic substances and/or fire can be categorized as:

a) Damage caused by heat radiation on material and people,

b) Damage caused by explosion on structure and people, and

c) Damage caused by toxic exposure.

The consequences of an incident outcome are assessed in the direct effect model, which predicts the effects on people or structures based on predetermined criteria. The method increasingly used for probability of personal injury or damage is given in Probit analysis.

The Probit is a random variable with a mean 5 and variance 1 and the probability (range O-1) is generally replaced in Probit work by a percentage (range 0-100) and the general simplified form of Probit function is:

P r = a + b lnV

Where Probit Pr is a measure of percentage of variable resource, which sustains injury or damage and variable V is a measure intensity of causative factor which harms the vulnerable resource.

The causative factor V:

a) for fire is thermal intensity and time,

b) for explosion is overpressure, and

c) for toxic gas release is toxic dose.

The constants a and b are calculated from the experimental data, which are also available in methods for determination of possible damage to people and objects resulting from release of hazardous materials [see Foreword (0], The percentage of fatality with the Probit value (Pr)calculated from the equation can be obtained using the chart and table given in the methods for determination of possible damage.

Result

Here the HAZOP study is taken around the tank farm and two process is taken.

Transfer of Oil from HT to Storage Tank:

S.No	Facilities	HT To Storage Tank			HAZOP Sheet No	1
	Node	Transfer Of Liquid From Heater Treater to Storage Tank			Drawing / Diagram No.	
	Parameter	Guidewords (Deviation)	Possible Causes	Consequences	Safeguard Measures / Existing Facilities	Action / Corrective measures required
1.1	FLOW					
1.1.1		NO	*No crude in HT. *Outlet valve of HT may bd closed. *Line leakage. *Inlet valve of storage tank may be closed.	No crude oil will reach to storage tank.	*LC is provided at the HT. *PSV is provided on the HT. *BV is provided at the storage tank . *SCADA monitoring system is provided. *SOP	*Adherence to the SOP and maintenance practice required.
1.1.2		LESS	*Less crude oil in the HT. *Outlet valve of the HT may be Partially closed. *Inlet valve of the storage tank may be partially closed. *Heavy leakage at pipeline.	*No flow of crude oil *Operability Problem	As above	
1.1.3		MORE	*High discharge from Separator. *Malfunction LC/PG.	*Leakage at flanges/joints. *Chances of pressure rise into the pipeline. *Overfilling of storage tanks. *Crude oil spillage may occur.	*GV provided in the line. *LCV provided on the HT. *Vents/BV are provided on the storage tank for release of entrained gases. *Dyke wall provided around storage tanks.	*LAH should be hooked up through annunciator to audible hooter/ lamps.

For Oil dispatch through oil dispatch pump :

S.No	Facilities	Storage tank outlet to oil dispatch pump			HAZOP Sheet No.	2
	NODE	Transfer of oil through oil dispatch pumps			Drawing / Diagram No.	
	Parameter	Guidewords (Deviation)	Possible Causes	Possible Connsequence	Safeguard Measures / Existing Facilities	Action Required
2.1	Flow					
2.1.1		No	*No Oil in the storage tank. *No sufficient pressure inside the storage tank *Pipeline valve (Gate valve) closed *Leakage in pipeline.	*Pump will run idle and may overheat. *Process gets stopped. *Operability Problem.	*Overload protection is provided to pump motor. *Strict Supervision & Pipeline is in place maintenance.	Pump tripped on tank low level to be provided
2.1.2		Less	* Low level of oil in storage tank. *Pipeline valve (Gate valve) partially closed. *Leakage Through pipeline	* Operability problem. * Production loss	*Level indicator provided *Pressure gauge provided. *PSV provided at discharge of pump. *Overload protection is provided to pump motor. *Regular maintenance Practices followed.	As above
2.1.3		More	*More pressure in storage tank.	*Operability problem * Pressure rise in the pipeline.	* Pressure gauge is provided. * Breather valve Provided on tank. *Overload protection is provided to pump motor.	
2.2	Pressure					
2.2.1		Low	*Suction / Discharge of pump may be low. *Leakage in pipeline *Less quantity of product in tank. *Pump malfunctioning *Air lock condition	*Low production operability problem.	Bypass line with valve Is provided to discharge & suction section.	Adherence to SOP
2.2.2		High		No Issue		
2.3	Temperature	High/Low		No Issue		

Effect of Fire

The effect of fire on a human beings is in the form of burns, There are three categories of bums such as ‘first degree’, ‘second degree’ and ‘third degree’ bum. Duration of exposure, escape time, clothing and other enclosures play active role while calculating the effect of fire, however, the primary considerations are duration of exposure and thermal intensity level.

The heat radiation levels of interest are:

a)4 kW/m2: Causes pain if unable to reach cover within 20s,

b)4.7 kW/m2: Accepted value to represent injury,

c)10 kW/m2: Second degree bum after 25 s,

d)12.5kW/m2: Minimum energy required for melting of plastic,

e)25 kw/m2: Minimum energy required to ignite wood,

f)37.5 kW/m2: Sufficient to cause damage to the equipment,

g)125 KJ/m2: causing first degree bum,

h)250 “KJ/m2: causing second degree bum, and

i)375 KJ/m2: causing third degree bum.

The thermal effect can be calculated with the help of Probit equation for which constants a and b are available. The thermal intensity and duration of exposure gives the value of V The general equation for the Probit function is:

P r = a + b lntI4/3,t is duration of exposure and I is thermal intensity.

Reference

[1] Chen Zhen , Analysis for combustion properties of crude oil pool fire (2014)

[2] Fire and Explosion Strategy - Issue 1 Pool Fires

[3] Omran Ahmadia, Seyed Baghe, Mortazavia Hadi, Pasdarshahrib Hassan, Asilian Mohabadi Consequence analysis of large-scale pool fire in oil storage terminal based on computational fluid dynamic (CFD) (2019)

[4] J Robert taylor, Systematic Lessons Learned Analysis for Oil and gas Plant (2015)

[5] . The LASTFIRE project (Large Atmospheric Storage Tank Fires), Jun

[6] Zalosh , Fire protection and fire engineering (Feb,2008)

[7] IS 15656:2006 HAZARD IDENTIFICATION AND RISK ANALYSIS — CODE OF PRACTICE