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Hazard Control Management on Optimization Layout of Vent Stack at Offshore Platform

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ABSTRACT

The flaring is a normal practice in the oil and gas industry to achieve a safe and reliable process during the emergency situation. This situation is a routine practice for oil and gas production by controlled burning of natural gas. The burning process can cause hazards by explosion or at the very least surrounding environment will be affected by heat radiation during vent stack burning operation. Hence, investigation of the gas flaring produced by the vent stack is needed to tackle these problems. This paper presents designing a safe vent stack position in the limited space of oil and gas platform with considered the heat radiation produced by the vent stack. The simulation will be done by using flaresim software to predict the heat contour, heat radiation, and gas dispersion. The results proved that the optimal position of vent stack with water sheild gives a better heat radiation.

Keywords:
Vent stack, heat radiation, gas flaring, gas dispersion, gas simulation, safe design

1. Introduction

Gas flaring is the controlled burning of natural gas in the course of routine oil and gas production operations. This burning occurs at the end of a flare stack or boom and cause hot to surrounding environment. Oil production at upstream and downstream phases can't avoid the gas flaring as for example, in 2010 the total of oil produced in the world was 87.2 million barrel per day and estimation of gas flaring 137.3 billion cubic meters for the same year, the average emission factor was 4.3 cubic meter per barrel of oil produced as shown in Table 1 [1].

Gas flaring will cause inconvenient environment to workers. The surrounding area will become noise and hot because of heat distribution by gas flaring. Very hot environments can be dangerous to health. Workers will exposure to heat in workplace and can cause source to occupational illness especially to oil and gas operator where to operate and maintenance work. Gas flaring can cause heat stress to oil and gas worker. The environment temperature will rise and workers need to

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maintain his body temperature to normal. Heat stress can occurs when body is overheated and losses its ability to cool itself by sweating. This situation can cause heat stroke, heat exhaustion and even death. It also can affect the worker performance job, risk the health of workers that can cause injuries and accident because of dizziness. More than that, the effect of heat stress by gas flaring will decrease mentally and physically operator's work execution and dangerous to them if they work with machine or at height. [2] Acute health impact. Heat Stroke, Heat Syncope, Other heat illness, chronic health impact. Possible link to kidney, liver, heart, digestive system, central nervous system & skin problems. Gas flaring by vent stack or burner boom will cause different of temperature contour, emit thermal radiation and spread of gas dispersion. All of these effect are hazards to oil and gas operators who work on the production platform especially near to vent stack and risk to helicopter to landing in helideck area. Thermal radiation effect will warm the skin then becomes painful. After that, effect of 2 degree burn will affect the skin depth of burn increasingly with time at stable of radiation level. Eventually, all the skin thickness will burn and underlying flesh will start to damaged and at 3 degree burn will start. The gas flaring will give HSE and hazard issue on work in hot conditions and explosion. It also will effect offshore equipment if not organized well. The vent stack must place at suitable place with safety and health aspect must be considered.

Table 1
Gas Flaring, Oil Production And Average 5-Year Emission For The Period Of 2007-2011 for Top 20 Gas Flaring Countries

Gas flaring, oil production and average 5-year emission factor for the period of 2007–2011 for top 20 gas flaring countries.

Country	2007 Gas flaring (Bcm/y)	2007 Oil pro. (Mbbl/d)	2008 Gas flaring (Bcm/y)	2008 Oil pro. (Mbbl/d)	2009 Gas flaring (Bcm/y)	2009 Oil pro. (Mbbl/d)	2010 Gas flaring (Bcm/y)	2010 Oil pro. (Mbbl/d)	2011 Gas flaring (Bcm/y)	2011 Oil pro. (Mbbl/d)	5-year EF (cm/bbl)
Russia	52.3	9878	42	9797	46.6	9934	35.6	10,157	37.4	10,239	**11.7**
Nigeria	16.3	2353	15.5	2169	14.9	2212	15	2459	14.6	2555	**17.8**
Iran	**10.7**	**4039**	**10.8**	**4177**	**10.9**	**4178**	**11.3**	**4243**	**11.4**	**4265**	**7.2**
Iraq	6.7	2097	7.1	2385	8.1	2399	9	2403	9.4	2629	**9.3**
USA[1]	2.2	8469	2.4	8564	3.3	9134	4.6	9685	7.1	10,136	**1.2**
Algeria	5.6	1967	6.2	1955	4.9	1910	5.3	1881	5	1863	**7.7**
Kazakhstan[2]	5.5	1446	5.4	1431	5	1542	3.8	1609	4.7	1638	**8.7**
Angola	3.5	1747	3.5	1979	3.4	1908	4.1	1948	4.1	1800	**5.4**
Saudi Arabia[3]	3.9	10,249	3.9	10,782	3.6	9819	3.6	10,642	3.7	11,264	**1.0**
Venezuela	2.2	2682	2.7	2656	2.8	2510	2.8	2405	3.5	2489	**3.0**
China	2.6	3956	2.5	4037	2.4	4067	2.5	4363	2.6	4363	**1.7**
Canada	2	3449	1.9	3344	1.8	3319	2.5	3442	2.4	3597	**1.7**
Libya	3.8	1845	4	1874	3.5	1790	3.8	1789	2.2	502	**6.1**
Indonesia	2.6	1041	2.5	1065	2.9	1053	2.2	1039	2.2	1016	**6.5**
Mexico[4]	2.7	3500	3.6	3184	3	3001	2.8	2979	2.1	2960	**2.5**
Qatar	2.4	1121	2.3	1204	2.2	1213	1.8	1441	1.7	1641	**4.3**
Uzbekistan	2.1	112	2.7	110	1.7	107	1.9	107	1.7	106	**51.0**
Malaysia	1.8	705	1.9	731	1.9	694	1.5	683	1.6	626	**6.9**
Oman	2	715	2	760	1.9	819	1.6	870	1.6	891	**6.1**
Egypt	1.5	674	1.6	706	1.8	729	1.6	717	1.6	726	**6.2**
Total top 20	**132.4**	**62,045**	**124.5**	**62,909**	**126.6**	**62,337**	**117.3**	**64,861**	**120.6**	**65,306**	**5.4**
Other countries	**22**	**22,281**	**22**	**22,530**	**20**	**22,255**	**20**	**22,297**	**19**	**22,267**	**2.5**
Global	**154.4**	**84,326**	**146.5**	**85,439**	**146.6**	**84,593**	**137.3**	**87,158**	**139.6**	**87,573**	**4.6**

The study from Diaz *et al.*, [3] trying to solved problem of toxic gas dispersion affecting humans in control room. Two methods have been used in this research, the first method is deterministic and stochastic, the random effect of meteorological conditions and reported to database on the toxic dispersion. The second method is Monte Carlo where to estimate the directional risk distribution for a given release scenario. The deterministic approach is based on the worst scenario where the stochastic meteorological condition is reduced to calm conditions.

Researchers [4] have developed new approach to optimizing the facility sitting and layout for fire and explosion. The structure collapse one of disaster that need to be avoided, structure collapse can be started from property damages by fire or explosion accidents that source from flammable material in the structure or the structure itself is flammable material. Study from [5] produce method designing safe layout with various safety distance measure using risk index that produce MILP approach. In additional, the author proposed modified individual risk index when a person work or near to dangerous equipment in the facilities.

Researchers [6] have produced a set of piecewise differentiable equation from graphical description and converted into complete formulation to produce optimization layout with some variables consideration to affecting the index. Result from the formula is mixed integer non-linear program (MINLP), the result can be solved by GAMS code. This research is continuity from the domino hazards index used that introduced by Tugnoli, Khan, Amyotte, and Cozzani [7], to produce domino effects based on hazards caused by a unit in a given layout. The study from [8] a stochastic approach for risk analysis in vapour cloud explosion. The method used in this study is stochastic approach to evaluate the risk vapor cloud explosion. Stochastic factor that is liable to vary or change are used calculate the chance of vapour cloud to explosion where the frequency of the release, probability of immediate ignition, probability of delayed ignition, probability of vapour cloud explosion given a delayed ignition, and meteorological factor also has be considered.

Researcher [9] used bow tie analysis method for fire and explosion risk developed for hazardous unit instead of predetermined worst-case scenario. In the chemical plant safety is very important especially in designing stage and operation of the plant. MINLP model have used in this study to optimization plan layout with safety consideration problem with GAMS to solve the MINLP problem.

2. Risk Assessment Analysis

Job safety analysis will describe hazard of job task, event or operation that can cause or create of problem and the risk can be calculated by severity and probability. Table 1 shows risk assessment standard. The first column is severity of harm and the first row is probability of harm. The severity can be divide into 6 stages and categorize by environmental impact to surrounding, financial impact to company and injury or ill health to workers. The probability of harm also divided into 6 categories. The first category is unlikely or unknown where the event to occur is not expected to occur. The second category of probability is remote where the situation is remotely possible but known occurrence. The third category is occasional where the situation could occur but probably not more than once. The fourth is probable where the situation is likely to occur occasionally more than once. The fifth category of probability to harm is frequent where the situation is likely to occur regularly. The sixth category of probability of harm is highly likely where the situation likely to occur regularly or always present.

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Table 1
Risk Assessment Analysis Matrix

RISK ASSESSMENT / INCIDENT MATRIX					PROBAILITY OF HARM					
	RISK	ENVIRONMENTAL IMPACT	FINANCIAL IMPACT	INJURY/ ILL HEALTH	Unlikely/ Unknown Not expected to occur 1	Remote A remotely possible but known occurrence 2	Occasional Could occur but probably not more than once 3	Probable Likely to occur occasionally, more than once 4	Frequent Likely to occur regularly 5	Highly Likely Likely to occur very regularly/ always present 6
SEVERITY OF HARM	1	Minimal pollution effect, contained locally	< £1,000	Injury requiring first aid only Slight health effect, not affecting performance or causing absence.	1	2	3	4	5	6
	2	Minor pollution, slight or negligible impact, negligible remedial/ recovery work.	> £1,000 < £5,000	Injury/ Minor health effects require treatment by medically qualified person, effects are reversible - Short term absence from work, complete recovery.	2	4	6	8	10	12
	3	Pollution with some onsite impact & recovery work. Some local media interest	> £5,000 < £50,000	Life threatening injury/ Major health effect to individual requiring medivac to hospital facilities. Irreversible health damage without loss of life - Long term absence, part recovery.	3	6	9	12	15	18
	4	Significant pollution with offsite impact & recovery work. Some local and regional media interest.	> £50,000 < £100,000	Major injury or Major health effects to several persons - life threatening Long term absence with incomplete recovery	4	8	12	16	20	24
	5	Massive pollution with significant site impact & recovery work. Regional / National media interest.	> £100,000 < £1,000,000	Fatality or permanent disablement from occupational illness or disease	5	10	15	20	25	30
	6	Massive pollution with significant recovery work. Global media interest.	> £1,000,000	Multiple Fatalities or multiple permanent disabling injuries from occupational illness or injury	6	12	18	24	30	36
LOW RISK	Risk may be acceptable, however review to see if risk can be reduced further.									
MEDIUM RISK	Task should only proceed with appropriate line management authorisation after consultation with specialist personnel and the assessment team. Where practicable, the task should be redefined to take account of the hazards involved or the risk should be reduced further prior to the task commencing.									
HIGH RISK	Task must not proceed. Task must be redefined or further control measures put in place to reduce risk. The controls should be reassessed for adequacy prior to task commencement.									

Table 2
Risk Assessment Analysis Related Burner Boom / Vent Stack

NO	Operation/ Event	Identified Hazard	Probable Harm	P	S	R	Required Controls	*P	*S	*R
1	Hydrocarbons under pressure, possibility of leaks and over-pressurising pipe work.	Fire	Loss of rig, explosion, and loss of personnel.	3	6	18	Equipment fit for purpose, certified and pressure tested. Use of ESD pilots and buttons and pressure relief valves. All other hot work suspended.	1	4	4
		Heat Radiation	Equipment damage	4	4	16	Use of rig cooling system. Appoint fire watchers. Check wind direction. Watch out for hot spots.	1	2	2
		Light Radiation	Damage to eye sight	4	2	8	Awareness at toolbox talks. Make personnel aware of dangers	1	2	2
		Fall out from flare pollution	Damage to the environment	4	5	20	Awareness at Toolbox talks. Personnel made aware to report any fall out to well test supervisor. Assign flare watcher. Ensure adequate air to burners for proper atomization.	2	3	6
2	Flaring operations	Fire/Explosion Lack of water cover if fire occurs.	Personnel injury Equipment damage	4	6	24	Backup deluge provided by fire pump/Ballast pump/Sea service pumps/Emergency fire pumps.	3	4	12
3	Normal flaring operations under permit to work.	Fire/Explosion Lack of water cover if fire occurs.	Personnel injury Equipment damage	4	6	24	Hot Work Permit. Backup deluge provided by fire pump/Ballast pump/Sea service pumps/Emergency fire pumps. Appointed fire watchers. Appropriate fire extinguishers.	3	4	12

3. Results and Discussion

Table 2 shows flaring operation produce or create high risk at R=24 which it can cause personnel injury and equipment damaged. After required control have been done to this operation, the risk is reduced to 12, but still in medium zone. Engineering control must take place, to make sure the flaring operation will not harm to operator. Flaring operation can’t be eliminate because the gas need to be burned to make sure the gas will not cause other problem such as methane cloud that is very dangerous to atmosphere. The engineering solution can be applied to study the heat radiation produce from flaring, and make some contour of the heat radiation. The heat radiation can be reduced by water shield and mostly reduced the risk of flaring operation. The engineering method is very important to make sure the heat radiation can be reduced.

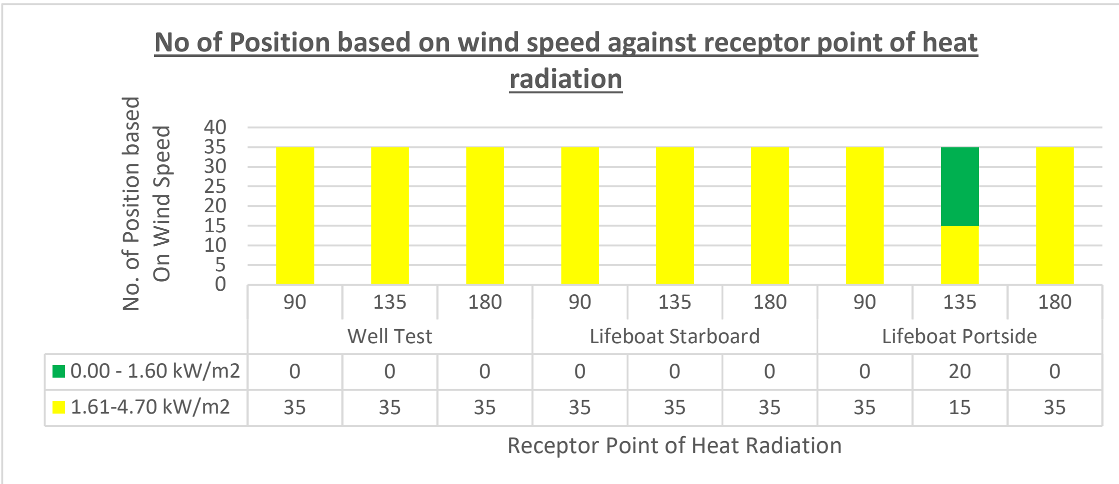

Fig. 2. Number of Position Based On Wind Speed against Receptor Point of Heat Radiation

Figure 2 shows number of position based on wind speed againt receptor point of heat radiation. The best place for burner boom position is where all the result of receptor point in green zone. The high result of receptor point in green zone will cause less place of receptor point to focus in reduce the heat radiation. Based on the results obtained, the best position for burner boom is at 135^0.

Table 3 shows result of heat radiation with and without water shield at burner boom at 135^0 Position. Result without water shield is only 85 places in yellow zone (81%) and 20 places already in green zone (19%). Result with water shield is 5 (4.76%) places in yellow zone and 100 (95.24%) places in green zone.

Figure 4 shows position of burner boom at the MODU aft. As we can see the burner boom can be at 90^0,135^0, and 180^0 angle and the best angle is at 135^0 as discussed in Figure 2. From the figure, the red line is equipment layout area for well test area where all equipment and operator will work in this area. The area approximate is $400m^2$ and all equipment must be in this area. The arrangement of equipment depend on the hazardous and non-hazardous area, process flow, piping, weight, equipment dimension, ventilation, utility system, and many more to obtain optimization layout. The flaring operation as described in risk assessment analysis can be dangerous to equipment and worker. This optimization equipment layout can’t be achieved if all the area in yellow zone where it can harm operator and equipment. The best position of burner boom is at MODU aft where it outside from MODU and far from MODU receptor point, and the burner boom can be rested at 0^0 when the MODU move from one place to another place. More than that, we can see position of crane cabin, lifeboat station 1 and 2 at portside and starboard of the MODU.

Table 3
Result of Heat Radiation at Burner Boom 135^0 Position with and Without Water shield

	Wind Speed (m/s)	Release Rate Incident Heat Radiation							
		Gas (mmscf/d)	Oil (bbl/d)	(WS) Well Test Area	(NWS) Well Test Area	(WS) Lifeboat Starboard	(NWS) Lifeboat Starboard	(WS) Lifeboat Portside	(NWS) Lifeboat Portside
No Wind	NA	40	803	1.03	1.93	1.03	1.96	1.00	1.6
East	1	40	803	1.03	1.94	1.03	1.96	0.99	1.6
	5			1.03	1.95	1.03	1.96	1.00	1.61
	10			1.33	1.97	1.03	1.96	1.54	1.63
	15			1.53	2.01	1.03	1.98	1.57	1.65
	25			1.61	2.1	1.03	2.04	1.63	1.71
Mean				1.31	1.99	1.03	1.98	1.35	1.64
North East	1	40	803	1.03	1.94	1.03	1.96	1.00	1.6
	5			1.03	1.94	1.03	1.95	1.00	1.61
	10			1.03	1.96	1.03	1.95	1.00	1.62
	15			1.03	1.99	1.03	1.96	1.00	1.63
	25			1.03	2.03	1.03	1.98	1.57	1.66
Mean				1.03	1.97	1.03	1.96	1.11	1.62
North	1	40	803	1.03	1.93	1.03	1.96	1.00	1.6
	5			1.03	1.94	1.03	1.95	1.00	1.6
	10			1.03	1.95	1.03	1.95	1.00	1.6
	15			1.03	1.96	1.03	1.95	1.00	1.61
	25			0.96	1.97	1.03	1.96	1.00	1.62
Mean				1.02	1.95	1.03	1.95	1.00	1.61
North West	1	40	803	1.03	1.93	1.03	1.96	1.00	1.6
	5			1.03	1.93	1.03	1.96	1.00	1.6
	10			1.03	1.94	1.03	1.96	1.00	1.6
	15			1.03	1.94	1.03	1.97	1.00	1.6
	25			1.03	1.95	1.03	1.97	1.00	1.6
Mean				1.03	1.94	1.03	1.96	1.00	1.60
West	1	40	803	1.03	1.93	1.03	1.96	1.00	1.6
	5			1.03	1.93	1.03	1.97	1.00	1.6
	10			1.03	1.93	1.03	1.98	1.00	1.6
	15			1.03	1.94	1.03	2	1.00	1.6
	25			1.03	1.95	1.03	2.02	1.00	1.6
Mean				1.03	1.94	1.03	1.99	1.00	1.60
South West	1	40	803	1.03	1.93	1.03	1.96	1.00	1.6
	5			1.03	1.93	1.03	1.98	1.00	1.6
	10			1.03	1.94	1.3	2.01	1.00	1.6
	15			1.03	1.96	1.8	2.04	1.00	1.61
	25			1.03	1.99	1.96	2.1	1.00	1.63
Mean				1.03	1.95	1.42	2.02	1.00	1.61
South	1	40	803	1.03	1.93	1.03	1.96	1.00	1.6
	5			1.03	1.94	1.03	1.98	1.00	1.6
	10			1.03	1.95	1.03	2.01	1.00	1.62
	15			1.03	1.98	1.55	2.06	1.00	1.63
	25			1.04	2.05	2.03	2.17	1.01	1.68
Mean				1.03	1.97	1.33	2.04	1.00	1.63

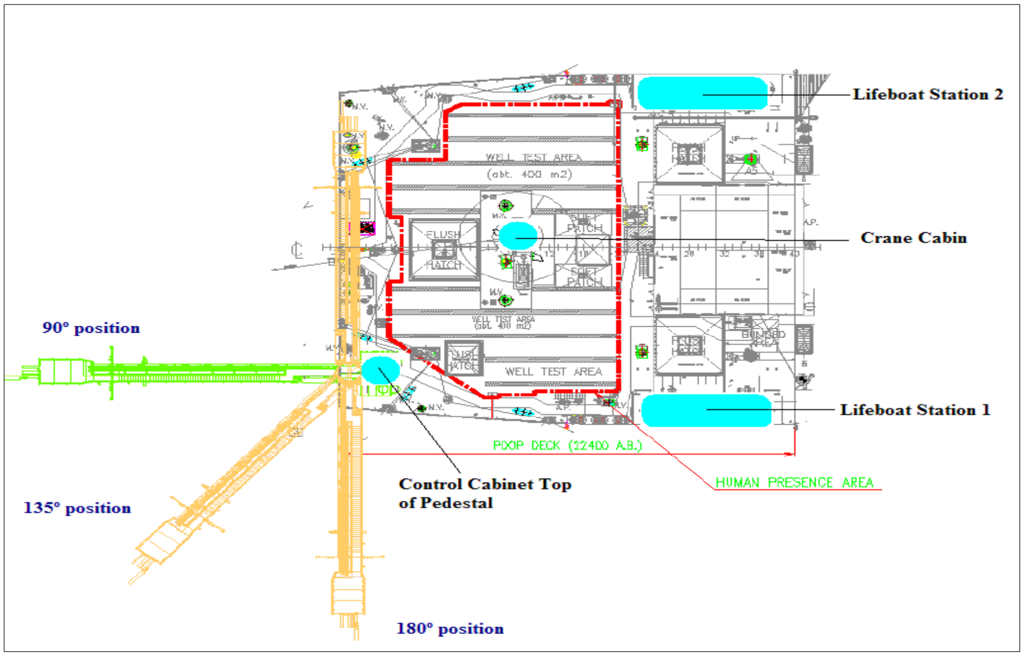

Fig. 4. Positioning of Burner Boom at 90,135^{0,} and 180 with receptor point at MODU aft

4. Conclusion

This paper presents an inclusive review of optimization layout of well test or LPS on offshore platform through Autocad and Flaresim simulation software to discover heat radiation on MODU. The vast number of heat radiation area with variation of wind speed and direction give the result more precise based on real situation. This research project can improve the occupational safety and health for operator working at oil and gas platform by reducing hazard of heat radiation with the implementation of optimization layout safe design and decreasing of surrounding heat radiation by engineering control method. The optimization layout also increase operator work time in work area while the burner boom burn gas or oil at once it will increase quality and productivity of operator and management also can minimized budget to buy special personal protective equipment for heat radiation. The future recommendation of this study is to obtain the real record of heat radiation produced by burner boom and heat radiation detector can be installed at work area to give warning alarm when radiation is more than 1.6kW/m^2.

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