Original Research Article

Risk Assessment in Petrochemical Units with PHAST

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ABSTRACT

In this work, process events of a demo plant and an industrial plant were modeled, hazardous process areas were detected and alarm areas including site margin and boundaries affected by process incidents were determined. Accordingly, the site boundary should have a distance of 170 m and 339 m from the north, 185 m and 411 m from the south, 180 m and 426 m from the east, 172 m, and 453 m from the west from the equipment for the demo plant and industrial plant, respectively. Likewise, the effective boundary should be 211 m and 546 m from the north, 228 m and 553 m from the south, 223 m and 634 m from the south, and 215 m and 595 m from the west from equipment for the demo plant and industrial plant, respectively.

Introduction

In the early years of expanding industrial activities, safety engineering manifests as learning from incidents to improve future designs. Based on the experiences and to prevent similar incidents, process engineers published their learning in the form of design codes. Due to the limited range of industrial activities at this time, generally, occurred incidents are limited to specific equipment or ultimately the boundaries of factories. However, after the rapid growth of the chemical and oil industries at the beginning of the sixties, the number and scope of the impact of industrial incidents increased significantly [1-2]. These issues led to the recognition of safety engineering as a key branch in the field of engineering. According to the need in the last years of the sixties, methods for identifying process risks such as the well-known HAZOP method were invented and presented [3-4]. However, incidents in industrial units still occur despite mandatory safety laws and inventing methods to identify and assess risks. Iran has also experienced significant industrial incidents in the course of industrialization. Even the best industrial units with the latest design findings and the most experienced operating personnel are not immune to incidents. The incident of fire

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and explosion in a refinery in Texas, USA in 2005, which led to the death of 15 people and billions of dollars in damage, is proof of this claim [5]. One of the pillars of risk management is the risk assessment. Risk assessment is a tool at the service of the risk manager or analyst, based on which he can prioritize the risk and identify a suitable area for risk reduction. Risk assessment can be done quantitatively or qualitatively. Quantitative risk assessment is usually used for complex systems and when qualitative assessment cannot provide sufficient information to the risk analyst. Quantitative risk assessment methods in the oil, chemical, and petrochemical industries were introduced in the eighties and evolved. These methods were initially used in the nuclear, aerospace, and electronics industries, and then they were used in process industries with changes [6,7]. Risk assessment is a widely used method to manage effective tools for safety to reduce risk caused by various incidents, but the possibility of some incidents never disappears. This algorithmic method is applied for quantitatively and qualitatively assessing the risk caused by different incidents where it is economically affordable. The beginning of the method application is related to the nuclear, aviation, and electrical industries in the early 1980s. Quantitative risk assessment is mostly used when qualitative risk assessment cannot accurately predict risk in process units [8-10]. The aim of study, according to the introduced risks, considerable scenarios is to introduce the demo plant and the industrial unit of one of the production units of the petrochemical industry, and then the selected scenarios are used in terms of risks and consequences of explosion, combustion, and their effect in determining the site boundary and effective margin.

Demo plant unit

By examining the results of the consequence modeling, it was decided to rank the equipment based on the hazards of different fires and explosions. By identifying high-risk equipment, more measures can be taken for their safety to reduce the incidents possibility with high financial and life consequences. Accordingly, in Table 1, the equipment of the demo unit is rated in terms of high risk.

One of the risks that can exist in process industries is the release of toxic substances into the environment, which can endanger the health of employees and people around them. Likewise, this unit has materials whose toxicity risk can be checked. Toxic substances in this unit are methanol, dimethyl ether, propane, pentane, and hexane. Methanol can be dangerous due to its storage and high volume in case of leakage. Table 2 indicates dangerous concentrations of methanol according to toxicity criteria.

Note that if a person is exposed to a concentration of 50,000 ppm of methanol for one to two hours, this concentration can cause his death. PHAST software can express the probability of death in terms of distance for toxic substances in its database. Figures 1 and 2 depict the probability of death in the summer and winter seasons, respectively, for the scenario considered for the methanol storage tank [9, 10].

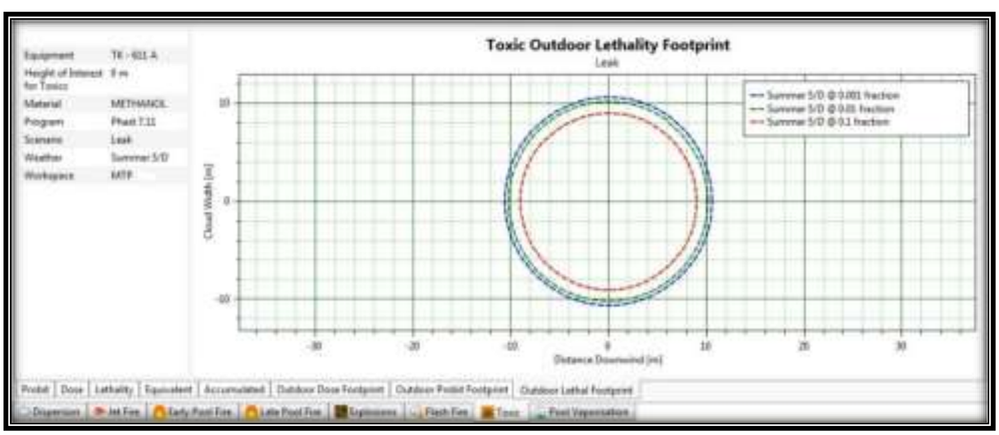

Figure 1: Probability of death for methanol leakage in the summer season for the demo unit

Table 1: Rating of high-risk equipment for a demo unit

Rank	Erupting fire	Sudden fire	Pool fire	Vapor cloud explosion
1	D-421	T-511	TK-641 A/B	T-511
2	T-511	D-421	D-101	TK-631 A/B
3	D-491 A/B/C/D	D-491 A/B/C/D	TK-611 A/B	D-421
4	D-101	TK-631 A/B	_	D-491 A/B/C/D
5	D-531	TK-621 A/B	_	TK-621 A/B
6	T-551	D-531	_	D-531
7	D-551	T-551	_	E-553
8	TK-631 A/B	E-553	_	D-551
9	E-553	D-551	_	T-551
10	E-112	D-553	_	E-542
11	T-521	E-542	_	D-533
12	T-561 A/B	C-531	_	E-512
13	E-542	T-561 A/B	_	D-101
14	TK-621 A/B	D-101	_	T-531
15	D-533	T-521	_	E-562
16	TK-641 A/B	D-112	_	T-521
17	D-112	TK-641 A/B	_	C-531
18	D-532 A/B/C/D/E/F	E-112	_	E-522
19	T-531	E-562	_	C-402
20	C-531	E-522	_	E-543
21	T-541	E-512	_	E-112
22	C-402	D-532 A/B/C/D/E/F	_	D-112
23	TK-611 A/B	T-531	_	D-532 A/B/C/D/E/F
24	D-492	C-402	_	D-411
25	C-401	T-541	_	T-541
26	R-111	E-543	_	T-521
27	_	T-511	_	FH-141
28	_	D-492 A/B/C/D	_	R-111
29	_	D-411	_	E-352
30	_	C-401	_	E-157
31	_	FH-141	_	D-492 A/B/C/D
32	_	TK-611 A/B	_	D-311
33	_	R-111	_	_
34	_	E-352	_	_
35	_	T-311	_	_
36	_	E-157	_	_
37	_	R-151	_	_
38	_	D-311	_	_

Table 2: Dangerous concentrations of methanol according to toxicity criteria

Toxicity criterion / Substance type	IDLH (ppm)	ERPG-1 (ppm)	ERPG-2 (ppm)	ERPG-3 (ppm)
Methanol	6000	200	1000	5000

According to the results obtained from the considered scenario, in both seasons and the direction of the wind up to a distance of twelve meters from the leakage site, there is a possibility of death due to inhalation of methanol.

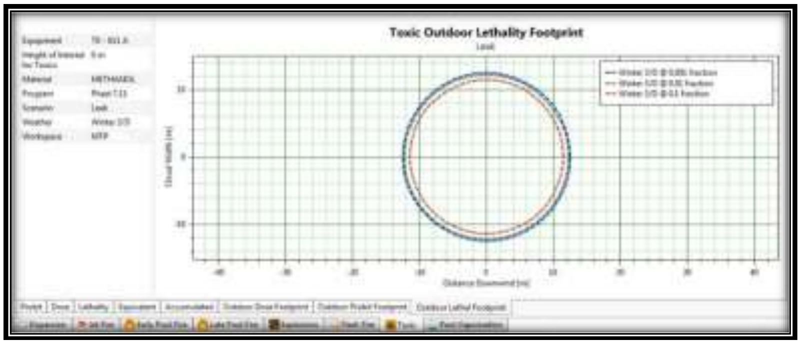

Figure 2: Probability of death for methanol leakage and in winter season for demo unit

Industrial unit

By examining the results of the consequence modeling, it was decided to rank the equipment based on the hazards of different fires and explosions. By identifying high-risk equipment, more measures can be taken for their safety to reduce the possibility of incidents with high financial and life consequences.

Accordingly, in Table 3, the equipment of the unit is ranked in terms of high risk. One of the risks that can exist in process industries is the release of toxic substances into the environment, which can endanger the health of employees and people around them. This unit also has materials whose toxicity risk can be checked. Toxic substances in this unit are methanol, dimethyl ether, propane, pentane, and hexane. Methanol can be dangerous due to its storage and high volume in case of leakage. Figures 3 and 4 demonstrate the probability of death due to respiratory exposure to methanol for the leak in the summer and winter season. Accordingly, people who are upwind of the leak site up to 9 meters away face a 99% chance of death due to the high concentration of methanol in this area. People who are up to 38 meters away from the leak and in the direction of the wind have a 10% chance of death. For people who are up to 48 meters away from the leakage site, their probability of death is 1%, and for people who are up to 55 meters away from the leakage site and in the direction of the wind, their probability of death is 0.1%. In these cases, for people who are exposed to methanol, the best thing to do is to move in a direction perpendicular to the wind, so as not to be exposed to a high dose of methanol. The distance that can play a role in determining the boundary of the site; the distance is 48 meters, which indicates a 1% chance of death.

According to the results from the studied scenario, in both seasons and the direction of the wind up to a distance of twelve meters from the leakage site, there is a possibility of death due to inhalation of methanol. Based on the consequence modeling, it was decided to rank the equipment based on the hazards of different fires and explosions. By identifying high-risk equipment, more measures can be taken for their safety to reduce the possibility of incidents with high financial and life consequences. Accordingly, in Table 4, the equipment of the unit is ranked in terms of high risk.

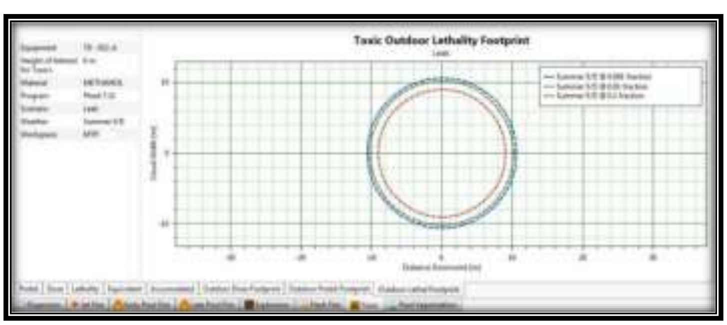

Figure 3: Probability of death for methanol leakage in the summer season for industrial unit

Table 3: Rating of hazardous equipment for industrial unit

Rank	Erupting fire	Sudden fire	Pool fire	Vapor cloud explosion
1	D-4091 A/B	Tk-6013 A/B	T-4051	Tk-6013 A/B
2	Tk-6013 A/B	D-5612	D-1113	D-4091 A/B
3	D-5612	D-4091 A/B	D-1112	D-5612
4	D-1112	Tk-6014	Tk-6011	Tk-6014
5	Tk-6015	D-5312 A/B	Tk-6015	Tk-6012 A/B
6	Tk-6014	Tk-6012 A/B	D-6011	D-1112
7	D-1113	T-4051	D-3511	T-4051
8	T-4051	Tk-6015	-	Tk-6015
9	Tk-6012 A/B	D-112	-	D-5312 A/B
10	D-5411	D-5411	-	T-5211
11	D-6011	T-5211	-	D-5411
12	D-5312 A/B	C-4010 3. stg	-	T-5311
13	E-5212	T-5311	-	T-5611
14	T-5211	T-5611	-	T-5511
15	D-5313 A/B	T-5511	-	T-5417
16	D-5511	T-5417	-	C-4010 3. stg
17	T-5511	C-4010 4.stg	-	C-4010 2. stg
18	T-5417	D-4031	-	D-4031
19	D-5212	C-4010 2.stg	-	D-1113
20	D-4041	E-5212	-	E-5212
21	T-5611	D-1113	-	C-4010 4. stg
22	D-5111	T-5111	-	T-5111
23	T-5311	D-5313 A/B	-	D-6011
24	Tk-6011	D-4021	-	D-5313 A/B
25	C-4010 3.stg	D-4041	-	T-5411
26	D-5311	D-4092 A/B	-	D-4021
27	D-3511	D-5311	-	D-4041
28	T-5411	T-5411	-	D-5212
29	C-4010 2.stg	C-4010 1.stg	-	D-5111
30	D-4031	D-5212	-	T-3111
31	C-4010 4.stg	D-6011	-	D-4010
32	T-5111	D-4011	-	D-5311
33	R-1111	D-5111	-	C-4010 1. stg
34	FH-1214	C-5311	-	D-4011
35	D-4021	T-3111	-	D-4092 A/B
36	T-3511	D-4010	-	D-5511
37	C-4010 1.stg	D-5511	-	Tk-6011
38	D-4011	E-5312	-	C-5311
39	D-4092 A/B	Tk-6011	-	E-5312
40	R-1151	FH-1214	-	FH-1214
41	T-3111	R-1111	-	D-3511
42	D-4010	D-3511	-	D-3111
43	C-5311	D-3111	-	R-1111
44	D-3111	R-1151	-	R-1151
45	E-5312	T-3511	-	-
46	-	D-3113 A/B	-	-

Table 4: Rating of high-risk equipment for the industrial unit

Rank	Erupting fire	Sudden fire	Pool fire	Vapor cloud explosion
1	D-4091 A/B	Tk-6013 A/B	T-4051	Tk-6013 A/B
2	Tk-6013 A/B	D-5612	D-1113	D-4091 A/B
3	D-5612	D-4091 A/B	D-1112	D-5612
4	D-1112	Tk-6014	Tk-6011	Tk-6014
5	Tk-6015	D-5312 A/B	Tk-6015	Tk-6012 A/B
6	Tk-6014	Tk-6012 A/B	D-6011	D-1112
7	D-1113	T-4051	D-3511	T-4051
8	T-4051	Tk-6015	-	Tk-6015
9	Tk-6012 A/B	D-112	-	D-5312 A/B
10	D-5411	D-5411	-	T-5211
11	D-6011	T-5211	-	D-5411
12	D-5312 A/B	C-4010 3. stg	-	T-5311
13	E-5212	T-5311	-	T-5611
14	T-5211	T-5611	-	T-5511
15	D-5313 A/B	T-5511	-	T-5417
16	D-5511	T-5417	-	C-4010 3. stg
17	T-5511	C-4010 4.stg	-	C-4010 2. stg
18	T-5417	D-4031	-	D-4031
19	D-5212	C-4010 2.stg	-	D-1113
20	D-4041	E-5212	-	E-5212
21	T-5611	D-1113	-	C-4010 4. stg
22	D-5111	T-5111	-	T-5111
23	T-5311	D-5313 A/B	-	D-6011
24	Tk-6011	D-4021	-	D-5313 A/B
25	C-4010 3.stg	D-4041	-	T-5411
26	D-5311	D-4092 A/B	-	D-4021
27	D-3511	D-5311	-	D-4041
28	T-5411	T-5411	-	D-5212
29	C-4010 2.stg	C-4010 1.stg	-	D-5111
30	D-4031	D-5212	-	T-3111
31	C-4010 4.stg	D-6011	-	D-4010
32	T-5111	D-4011	-	D-5311
33	R-1111	D-5111	-	C-4010 1. stg
34	FH-1214	C-5311	-	D-4011
35	D-4021	T-3111	-	D-4092 A/B
36	T-3511	D-4010	-	D-5511
37	C-4010 1.stg	D-5511	-	Tk-6011
38	D-4011	E-5312	-	C-5311
39	D-4092 A/B	Tk-6011	-	E-5312
40	R-1151	FH-1214	-	FH-1214
41	T-3111	R-1111	-	D-3511
42	D-4010	D-3511	-	D-3111
43	C-5311	D-3111	-	R-1111
44	D-3111	R-1151	-	R-1151
45	E-5312	T-3511	-	-
46	-	D-3113 A/B	-	-

Figure 4: Probability of death for methanol leakage in the winter season for industrial unit

Results and Discussion

One of the risks that can exist in process industries is the release of toxic substances into the environment, which can endanger the health of employees and people around them. This unit also has materials whose toxicity risk can be checked. Toxic substances in this unit are methanol, dimethyl ether, propane, pentane, and hexane. Methanol can be dangerous due to its storage and high volume in case of leakage.it shows the probability of death due to respiratory exposure to methanol for the leak in summer. Therefore, people who are upwind of the leak site up to 9 meters away face a 99% chance of death due to the high concentration of methanol in this area. People who are up to 38 meters away from the leak and in the direction of the wind have a 10% chance of death. For people who are up to 48 meters away from the leakage site, their probability of death is 1%, and for people who are up to 55 meters away from the leakage site and in the direction of the wind, their probability of death is 0.1%. In these cases, for people who are exposed to methanol, the best thing to do is to move in a direction perpendicular to the wind, so as not to be exposed to a high dose of methanol. The distance that can play a role in determining the boundary of the site; the distance is 48 meters, which indicates a 1% chance of death.

Conclusion

Based on the results, the effective margin from the north side should be 211 meters away from the equipment location. The effective margin in the southern part of the site should be 228 meters, the eastern part 223 meters, and the western part should be 215 meters away from the equipment location. The effective margin is shown on the location map of the mentioned unit. Likewise, the effective margin from the north side should be 546 meters away from the equipment location. The effective margin in the southern part of the site should be 553 meters, the eastern part 634 meters, and the western part should be 595 meters away from the equipment location. The effective margin is shown on the location map of the industrial unit. In general, by creating a dyke around the storage tanks containing flammable materials, the liquid released in the environment will spread less and the surface exposed to evaporation will be less. Therefore, with fewer vapors, the consequences of a pool fire will be reduced in addition to reducing the consequences of a pool fire. It can be further effective in reducing the consequences of sudden fire and steam explosion.

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