Risk assessment of Atmospheric Column Overhead Product Drum

Dib khawla (1)*, ZENNIR Youcef (2), Hichem Bounezour (3)
(1) LRPCSI Laboratory,University of 20th August 1955, Skikda, Algeria.
k.dib@univ-skikda.dz;
(2,3) Automatic Laboratory, University of 20th August 1955, Skikda, Algeria.
y.zennir@univ-skikda.dz; h.bounezour@univ-skikda.dz

Abstract: The risk analysis plays an important role in the risk management process. Its objective is to identify significant adverse consequences, then assess their severity in order to decide on measures to control the risk. Our study involves conducting a risk analysis related to an un-stabilized naphtha separator ball from the Topping unit located at the Skikda refinery. We applied the HAZOP approach to identify accident scenarios that could be generated by this hazardous equipment. The modeling of the consequences of the chosen phenomenon, which is the BLEVE, was carried out using the PHAST software.

Keywords: Component, Drum, HAZOP, PHAST, Risk assessment.

1. INTRODUCTION

The objective of our work is to conduct a risk analysis related to an industrial process, specifically the accumulator vessel of the atmospheric distillation column V.3 at the TOPPING unit of the Skikda refinery. This includes modelling the consequences of the chosen phenomenon, which is the BLEVE, to determine the impact zones (overpressure, radiation) of the accident scenario.

Risk assessment provides decision-makers and responsible parties with an improved understanding of risks that could affect achievement of objectives, and the adequacy and effectiveness of controls already in place. This provides a basis for decisions about the most appropriate approach to be used to treat the risks. The output of risk assessment is an input to the decision-making processes of the organization.

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation. The manner in which this process is applied is dependent not only on the context of the risk management process but also on the methods and techniques used to carry out the risk assessment[1].

Risk management should involve identifying and controlling risks before loss occurs. A workplace or organization may be looked at through a systems approach when considering risk management [2].

The risk management process is shown in Figure 1.

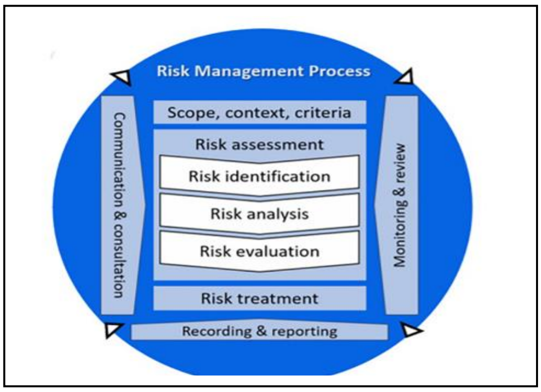

Fig 1. Risk management process[3]

HAZOP study is a highly disciplined procedure that identifies how a process may deviate from its design intent [4].

It is a structured analysis of a system, process, or operation for which detailed design information is available, carried out by a multidisciplinary team. This is done by using a set of guidewords in combination with the system parameters to seek meaningful deviations from the design intention. [5]. Hazard and Operability Analysis is a qualitative tool to identify process deviations and examine their possible causes, consequences and appropriate safeguards to help prevent the deviation from occurring [6]. the figure 2 represents study procedure.

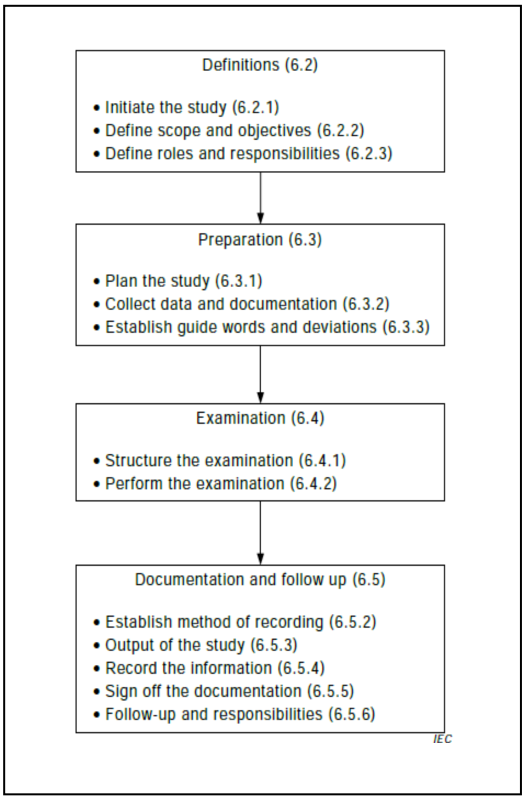

Fig 2. The HAZOP study procedure [7]

PHAST is a software used to assess situations that present potential risks to personnel, facilities, and the environment, and to measure the severity of these situations. PHAST belongs to a range of products developed by DNV Software, recognized as a global leader in the evaluation of major industrial accident risks. Naturally, it has been adopted by numerous leading international companies and governments as a valuable decision-making tool in the field of industrial risk and public safety. PHAST examines the progression of a potential incident from the initial leak to dispersion in the far field, including modelling the spread and evaporation of spills, as well as flammable and toxic effects.[8]

PHAST is a software used to assess situations that present potential risks to personnel, facilities, and the environment, and to measure the severity of these situations. PHAST belongs to a range of products developed by DNV Software, recognized as a global leader in the evaluation of major industrial accident risks. Naturally, it has been adopted by numerous leading international companies and governments as a valuable decision-making tool in the field of industrial risk and public safety. PHAST examines the progression of a potential incident from the initial leak to dispersion in the far field, including modelling the spread and evaporation of spills, as well as flammable and toxic effects.[8]

2. METHODOLOGY

The methodology adopted for this study involves a structured approach to assess risks and predict potential impacts. First, a detailed functional description of the studied system was developed to understand its operational characteristics and dependencies. Next, a risk analysis was conducted using the Hazard and Operability (HAZOP) methodology, allowing for a systematic evaluation of potential hazards and their likelihood within the system. Finally, accident scenarios were simulated to establish potential impact zones, providing insight into the spatial extent of risks and aiding in the development of targeted mitigation strategies. Figure 3 summarizes the methodology steps

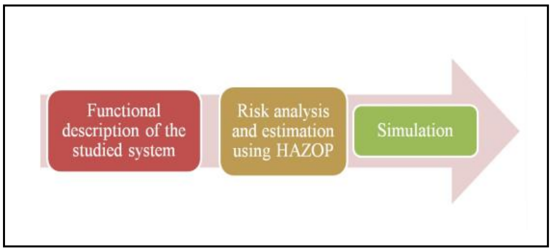

Fig 3. Methodology steps.

2.1 PROCESS DESCRIPTION

Column overhead vapours consist of Off Gas, LPG and Naphtha having Boiling point range of180C. Atmospheric column is operated at a pressure of 1.8 kg/cm2g and 172°C. Overhead

vapours from column overhead are going through line 44”-P 10-1160-A6A-IH to various exchangers for cooling purpose. 12 Nos of PSVs 10-PSV-28 A~L with set pressure of 4.0

kg/cm2g have been installed on overhead vapor line to relive the overpressure to flare system. The temperature of column overhead is indicated by 10-TI-81 and is controlled by 10-TIC-16 which acts in cascade on the 10-FIC-40 ascended on the line of reflux in overhead of column 12”-P-10-1901-A1A-IH. High / Low pressure alarm 10-TAH /TAL -16 has also been provided for column overhead. Column overhead pressure is indicated and recorded respectively by 10-PI-1755 and 10-PI-13. 10-PI-1755 has also been facilitated with High-High Pressure Alarm (10-PAHH-1755). The overhead circuit of Atmospheric Column consists of hot reflux to the atmospheric column. The system consists of two overhead accumulators, the first one operating at 135.4°C and the second drum operating at 40°C. Hot reflux avoids low temperature and hence water condensation wherein HCl can condense out and can cause accelerated corrosion - most inherent to crude column overhead. Overhead vapour goes to shell side of Crude/ ATM Column Overhead Exchanger (10-E-93A-H) (Ref: PID-1011B). The exchangers have been arranged in 4-Parallel 2-Series module.

Whole group of exchangers can be bypassed by opening the bypass valve on line 24"-P10- 1121-A6A-IH. The Temperature of vapours is reduced to 135°C from 172 °C. Temperature of

exchanger outlet vapours can be monitored by 10-TI-1180. This temperature indicator is also attached with tube side temperature control loop. During passing through these exchangers vapours are partially condensed. The partially condensed vapour is taken to ATM Column Reflux Drum (10-V-2A) (Ref: PID 1019) for separation. 10-V-2A is a horizontal drum with ID of 4.7 m and TL of 11.4 m. Drum is operated at a pressure & Temperature condition of 1.3 kg/cm2g & 135°C respectively. Pressure of the 10-V-2A is indicated by 10-PI-56. In the 10-V- 2A overhead two phase fluid is separated. Separated vapor is sent for further cooling. The condensed liquid consists of water and oils phases. Drum is provided with a water boot. Interphase level in the water boot is controlled by 10-LIC-7 which controls the water flow to vessel ATM Column Overhead Product Drum (10-V-3A). This control gives high & low level alarm 10-LAH-7 & 10-LAL-7 to control room. Oily phase liquid is pumped back to the column

as a reflux via Atmospheric Column Reflux Pump (10-P-73 A/B). Reflux flow is controlled by 10-FIC-40 which is in cascade with column overhead temperature control (10-TIC-16). Atmospheric Column Reflux Pump (10-P-73 A/B) has also been provided with steam turbine to continue running in case of emergency. MP steam will be used to run this turbine. 10-

FIC-40 has also been provided with low & high flow alarm. Reflux liquid level in 10-V-2A is controlled by split control 10-LIC-6. 10-LIC-6 controls the level of Atmospheric Column Reflux Drum (10-V-2A) using two control valves by split range. At high level (80%-100%), the partial reflux flows to the 10-EA-1 A-L inlet via 10-LV-6. At low level (0%-20%), the unstabilized. [9]. Figure 4 representsDiagram of the overhead drum and operating conditions are listed in Table 1.

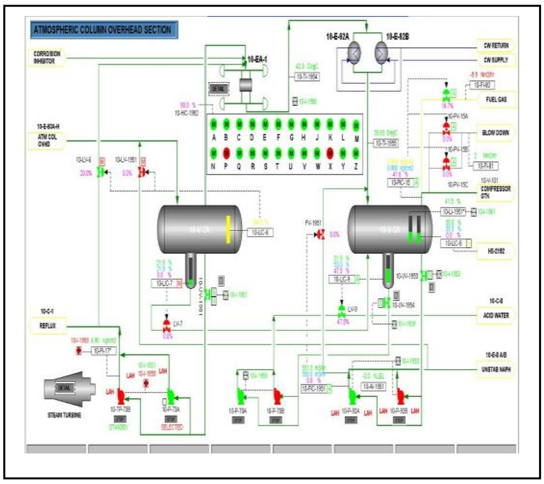

Fig 4. Diagram related to the atmospheric overhead reflux drum [10].

Table 1operating conditions of the drum [11].

Equipment		Pressure vessel
Volume (m³)		122
Operation	**Temperature (°C)**	40
	Pressure (kg/cm2)	0.06
Design	**Temperature (°C)**	70
	Pressure (kg/cm2)	4

2.2 RISK ANALYSIS AND ESTIMATION USING HAZOP METHODOLOGY

A Hazard and Operability (HAZOP) study is a systematic evaluation performed to identify causes that could result in undesirable consequences to personnel, facilities, and the environment.Sonatrach's risk assessment criteria (Risk Matrix) was used throughout to assess the severity and likelihood of each identified Cause/Consequence pairing. The six-by- five risk ranking matrix is shown in table 2.Items identified with a risk ranking of less than 'H' required action(s) to be recorded to further mitigate the risk, while rankings of 'L' did not require a Recommendation/Action Item. Items identified with a "M" risk ranking may have Recommendation(s)/Action(s) to reduce the risk further to ALARP. Risk ranking H requires a recommendation on all occasions.Table 2risk matrix [12-16].

Table 2 risk matrix

	Likelihood				
Severity	0	1	2	3	4
0	**L**	**L**	**L**	**L**	**L**
1	**L**	**L**	**L**	**M**	**M**
2	**L**	**L**	**M**	**M**	**M**
3	**L**	**M**	**M**	**H**	**H**
4	**M**	**M**	**H**	**H**	**H**
5	**M**	**H**	**H**	**H**	**H**

Rank	Ranking description	Mitigation measures
L	Low	No mitigation action required, however, recommendation may be considered for further improvement
M	Medium	Verify hazard has **engineering**/administrative control in place or recommend to improve **engineering/**administrative control
H	High	Mitigate hazard by implementing engineering control and if necessary administrative control to reduce risk ranking to acceptable level

The categories of likelihood are presented in table 3.

Table 3 likelihood category

Category	Likelihood
0	Negligible **(>100 years)**
1	> 20 years
2	4 to 20 years
3	6 months to 4 years
4	< 6 months

Consequence categories are presented in table 4.

Table 4 consequence category [12].

Category	Severity (Personnel)	Severity (Asset loss US$)	Severity (Environment)
0	No injury or health effect	<1,000	No spill/release
1	Slight injury or health effect	1,000–10,000	Slight spill/release
2	Minor injury or health effect	10,000–100,000	Minor spill/release
3	Major injury or health effect	100,000 – 1million	Major spill/release // Internal impact
4	One to three fatalities	1million - 10million	Major spill/release/ External Impact
5	Multiple fatalities	>10million	Catastrophic loss

For our study we have chosen the most vulnerabledeviation which can lead to catastrophic accidents (high pressure in the atmospheric overhead drum.

Intention: Uncondensed Naphtha vapors from the Atm Reflux Drum (at approx 400 Te/hr) passes through fin fan cooler EA-1A-L (outlet 48 deg C) and water cooler E-92A/B (outlet 40 deg C), before entering Atm Column Overhead Product Drum V-3. Unstabilized Naphtha from V-3 is pumped via P-3A/B, passing through heat exchangers (E-8A/B, E-9, E-10A/B), and then to two parallel Naphtha Stabilizers. Overhead vapours are sent to Flare Compressor KO Drum V-101 for recovery, and sour water produced is collected at the water boot and pumped via P-70A/B to AWS. Off-gas from V-3 passes via split range to Flare and makeup gas is added to the Compressor section.Table 5 represents the findings of risk analysis outlined in the HAZOP sheet.

Table 5 HAZOP analysis "high pressure inside the drum v3.

Node : U10 - Atm Reflux Drum outlet to outlet of Atm Column Overhead Product Drum

Naphtha flows to 10-V-2A via 10-LV-1951. Overhead vapors from 10-V-2A go to air coolers Atmospheric Distillation Overhead Product Condenser 10-EA1-A~L. These air coolers partially condense the vapors by reducing the temperature to 48°C from 135°C. Corrosion Inhibitors are injected in the Air Cooler inlet line to protect the equipment. Air cooler outlet temperature is indicated by 10-TI-1954. Partially condensed fluid moves to shell side of ATM Column Overhead Product Trim Cooler (10-E-92 A/B) for further condensation. These exchangers have been arranged parallel and exchanging heat via cooling water. During passing through this exchanger, temperature of partially condensed product is further reduced to 40°C. 10-E-92 A/B has been installed with a safety valve 10-PSV-30 on the shell side and 10-PSV-29 A/B on the tube side. Temperature and pressure of the 10-E-92 A/B are indicated by 10-PI-1955 and 10-TI-1955 respectively. The condensed product from 10-E-92A/B is taken to Atmospheric Column Overhead Product Drum (10-V-3A) for further separation. [8].

Parameter : PRESSURE

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R
High	Pressure	PV15(b/c) stuck closed	-Immediate increase in pressure and temperature in the drum V-3 - Explosion /BLEVE	Bypass available PAH on PIC-15 sounds alarm PSV-30, set at 4.0kg/cm2g, relieves to flare	5	1	H
		Overflow in V3	Level rises in V-3, and overflows forward to the Compressor KO Drum	Spare pump available on separate power supply Pump status indication and alarm FAL on FIC-52 and FIC-2151 on Stabilizer Feed LAH on LIC-8 sounds alarm on Atm Product Drum PAH on PIC-15 sounds alarm Atm Product Drum PAH on PI-13 sounds alarm on CDU Overhear	3	2	M
		Loss of fin fan on EA-1(A-L)	Reduce condensation of overhead product causing increase in pressure in Reflux Drum and vented to blowdown, and possible low flow of product and loss of reflux, causing overpressure	LAL on LIC-8 sounds alarm PAH on PIC-15 sounds alarm Atm Product Drum PSV-30, set at 4.0kg/cm2g, relieves to flare	3	1	M

2.3 SIMULATION

Simulate accident scenarios to determine impact zones by PHAST. After identifying consequences, PHAST is used to analyze situations that present potential hazards to life, property and the environment and to quantify their severity.Consequences may then be managed or reduced by design of the process or plant, modification to existing operational procedures, or by implementing other mitigation measures [8].

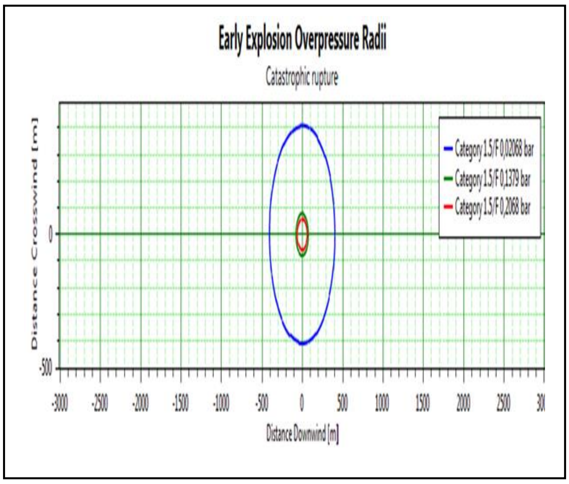

Fig 5. Early explosion overpressure vs distance

Based on the trend of the explosion overpressure curve in relation to the downwind distance presented in the figure, it is observed that the explosion overpressure reaches its maximum value of [19 bar] at the initial stage. Subsequently, a decrease in explosion overpressure is noticed down to [0.315 bar] at a distance of [410.22m]. In the case of continuous release, the curve's shape remains constant, and the explosion overpressure reaches its minimum value, which is [0.314 bar].

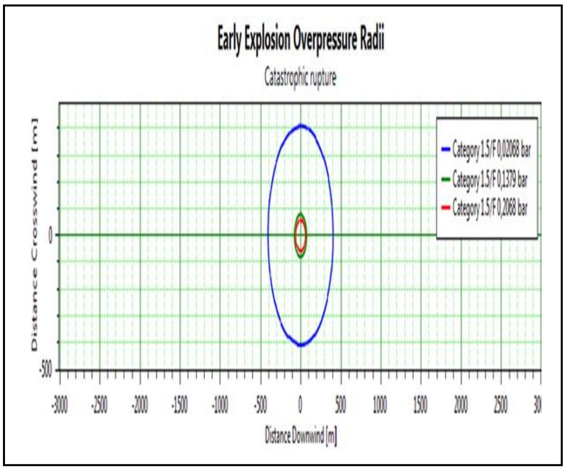

Fig 6. early overpressure radii

The above figure illustrates that the overpressure effects can impact the area at an approximate distance of [400.10 m] from the accident source. In other words, the safety distance from the accident source is [400.10 m].

Fig 6. Areas threated by overpressure effects

The above figure represents the areas affected by the propagation of bleve and their expansion seconds after the occurrence. In the table 6we represent the results of the simulation.

Table 6. simulation results

Data	**Result**
Explosion energy	**68409.66KJ**
Over pressure distance:	
▪ **0.2068bar** ▪ **0.1379bar** ▪ **0.02068bar**	▪ **113.90m** ▪ **28.87m** ▪ **22.22m**
failureintervalspecenergy	**-26.30KJ/Kg**
specfinaleintervalenergy	**-68.80KJ/Kg**
Temperaturefinal	**9.38°c**
liberationmassive	**844.64m**
interest concentration	**7493.30ppm**
Line concentration is calculated at an averaging time	**18s**
fireball ray	**28.95m**
fireball duration	**4.91s**
maximum exposure time	**20s**
flame emissive power	**131.47kw/m2**
fireball level at high altitude	**57.91m**

3. CONCLUSION

Following the risk analysis using the HAZOP method for hazard identification and modelling the consequences in terms of impacted distances using the PHAST software, the following recommendations have been proposed:

- Automate the deluge system.

- Install a PAHH alarm at the PT-15 transmitter.

- Add a LALL alarm at the LT-1951 transmitter.

-Install LAHH on 10-V-3 to trip Flare Gas Compressor K-101 --Provide an effective preventive maintenance program for all equipment;

-Check the equipment safety integrity level by following another SIL study;

-Periodic inspection of all equipment including EIPS

References

[1] ISO/IEC 31010, Risk Management – Risk Assessment Techniques, International Standard, 2009.

[2] G. Taylor, K. Easter, and R. Hegney, Enhancing Occupational Safety and Health, Elsevier Butterworth-Heinemann, ISBN 0 7506 6197 6, 2004.

[3] International Organization for Standardization, ISO 31000: Risk Management – Guidelines, version 2018.

[4] J. L. de la Mata and M. Rodriguez, "Abnormal Situation Diagnosis Using D-higraphs," ESCAPE20, Elsevier B.V., 2010.

[5] S. Bouasla, Y. Zennir, and E. Mechhoud, "Risk Analysis Using HAZOP - Fault Tree – Event Tree Methodology," Algerian Journal of Signals and Systems (AJSS), 2020.

[6] American Bureau of Shipping, Risk Assessment Applications for the Marine and Offshore Industries, May 2020.

[7] International Electrotechnical Commission, IEC 61882: Hazard and Operability Studies (HAZOP Studies) – Application Guide, Edition 2.0, March 2.

[8] PHAST, Process Hazard Analysis Software (2016), available at: www.dnvgl.com/software.

[9] [9] J.M. Song, Operation and Maintenance Manual for CDU 10, Skikda Refinery, 2012.

[10] B.S. Kim, DCS Graphics Static Layout Printouts, 96 pages, 2011.

[11] Process Data Sheet for Atmospheric Column Overhead Product Drum.

[12] T.P. Sin, Hazard and Operability Study (HAZOP) Report, Unit: 10, 30, 1120, 700, 701, Skikda Refinery, 2010.

[13] *R. Bendib, E-A. Mechhoud, M. Rodriguez, Y. Zennir,* "A systematic approach for risk assessment in LPG storage tanks area-Skikda refinery". Algerian Journal of Environmental Science and Technology, vol.9, n° 1, pp.1-10, 2023

[14] Seif El Islam Bouasla, Youcef Zennir, EL-Arkam Mechhoud , Risk Analysis Using HAZOP -Fault Tree – Event Tree Methodology Case Study: Naphta Stabilizer-A Reflux Drum (LPG separation) in RA1K, Vol.5,Issue2, pp.98-105, 2020.

[15] Riad Bendib , Youcef Zennir , EL-Arkam Mechhoud , Salah Bouziane , Risk assessment for a steam generator (1050 G1)Skikda refinery Algeria, using HAZOP and RQA methods. IEEE International Conference on Advanced Systems and Emergent Technologies (IC_ASET), 2019, pp. 262-267.

[16] CHEBLI Sarra,TOLBA Chérif, ZENNIR Youcef, "Risk assessment of an LNG storage tank release Case study of LNG storage unit in Skikda LNG terminal", Algerian Journal Of Signals And Systems (Ajss), Vol. 7, Issue 2, 2022, pp.53-60