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Assessment of Fire and Explosion Risks Associated with the Gas Dryer at the Alrar Gas Complex in the STAH Region of Sonatrach - Algeria

Dr Hariz Samia[1], Boulemnadjel Abdelmalek[2]

[1]Research laboratory in Industrial Prevention (LRPI), Institute of Hygiene and Safety industrially, University of Batna 2 (Algeria).
[2]Research laboratory in Industrial Prevention (LRPI), Institute of Hygiene and Safety industrially, University of Batna 2 (Algeria).
Email: S.hariz@univ-batna2.dz, abdelmalek.boulemnadjel@gmail.com

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ABSTRACT:

The aim of this article is to carry out an assessment of the risks of fires and explosions in the field of hydrocarbons, which have harmful impacts on the safety of people, property and the environment, in the gas dehydration system at the Alrar gas complex in the STAH region of the SOUNATRACH Company. In order to control these risks, we used quantitative and semi-quantitative approaches to concretize the accident scenarios.
Preliminary risk analysis (PRA) and overpressure risk analysis (APR) must be used in order to evaluate the thermal and overpressure effect distances of the hazardous phenomena based on the PHAST program. We were able to determine the dangerous phenomena that are likely to follow the occurrence of undesirable occurrences that are caused by a combination of system faults, drifts, or external attacks thanks to the preliminary risk analysis (PRA). We estimated the probabilities of occurrence of the central feared events and the probabilities of occurrence of their consequences

Keywords : Risk management, Explosion, Fire, PHAST software, Energy, Gas companies, Sonatrach.

1. Introduction

As in all industrial activities, the hydrocarbons sector presents risks of various kinds, especially the risks of fire and explosion, the effects and impacts of which can be serious. For this reason, the safety of installations must be ensured through prevention and protection measures [1]. To reduce these risks, preventive safety measures (aimed at reducing the probability of an accident occurring) and/or protective measures (aimed at reducing the severity of the consequences) must be put in place. The main principles to be respected are clearly "no accidents, no harm to people and no damage to the environment", as required by the HSE policy at the Alrar gas complex: "To develop a preventive approach to HSE risk management, which should result in a reduction in the number of accidents and incidents involving health, safety and the environment". We can therefore say that risk management is one of the fundamental components of a company's success, whether in economic or environmental terms. It is an iterative process based on risk analysis, a stage which enables an initial risk assessment to be identified and carried out[2][3][4].

Risk assessments are very important, as they are an integral part of a good health, safety and environment management plan. The purpose of this work is to determine the logical priorities for action and targeted improvement measures, and to eliminate the risk or reduce its level by introducing controls and adapting appropriate precautions where necessary, in order to create a safe workplace [5][6][7].

Without understanding, the risks and dangers we wish to guard against, prevention cannot be effective. Our work involves identifying and assessing the industrial risks associated with a gas dehydration system (dryer), in order to put in place the regulatory and technical resources needed to control these risks and ensure production at the same time.

To achieve our objectives, we used a number of analysis and evaluation tools, as well as PHAST software for simulation.

2. Literature Review

The literature shows that the risks of fire and explosion are currently major concerns in many sectors, particularly in the oil and chemical processing industries, as well as forest fires, which have increased in frequency in recent years [8][9][10]. These risks can have catastrophic consequences in terms of loss of life and property. Numerous risk management approaches are essentially required to mitigate the scale and severity of these risks, which can be classified into several key areas. Statistics also show that explosions and fires in the hydrocarbon sector account for the highest number of major accidents, as evidenced by incidents such as the Piper Alpha disaster, which resulted in 167 deaths and extensive material damage [11][12]. Hydrocarbon risk assessments focus on identifying potential explosion scenarios and implementing preventive measures to protect personnel, installations and the environment [12][13][14]. In the same context, exposure risk analysis is essential for assessing the vulnerability of structures [15][16]. New methods incorporating spatio-temporal data to improve the accuracy of risk assessments and thus enable dynamic evaluations of fire threats [17][18] . Fire and explosion risk assessment in chemical plants uses semi-quantitative index methods to identify hazardous processes. These methods can be used to select the most appropriate safety measures and improve risk management strategies [19][20]. The application of tools such as HAZOP and PHAST to the modelling of fire and explosion scenarios makes it possible to estimate potential damage and formulate effective prevention strategies [21]. Despite the significant progress that has been made in many risk assessment methodologies, it remains difficult to guarantee exhaustive coverage of all potential hazards, particularly in complex industrial environments. It is essential to adapt the continuous improvement in risk management practices that will be needed to cope with evolving threats.

3. Methodology

The risk analysis approach used in integrated methods such as ARAMIS or LOPA corresponds to the entire risk estimation process described in the AFNOR documentation. According to the phases of identifying hazards and vulnerable elements, outlining accident scenarios and risk control strategies, and estimating likelihood, the method offered by conventional tools like RPA, FMECA, or HAZOP is more constrictive [22]. As far as unintentional risk analysis (figuring out the effect thresholds of hazardous occurrences) is concerned, figuring out the relationship between the hazard and the probable damage severity can be considered a precondition [23].
Following the risk assessment (or estimation) phase, the evaluation phase consists of comparing the estimated risk with decision criteria. This phase can take various forms: comparison of the risks with a level of risk acceptability, prioritization of scenarios to identify those that should be treated as a priority, etc.
It is crucial to emphasize that risk analysis is a step that comes before the evaluation stage, which is defined as comparing the estimated risk with decision criteria that are created in a different process but that nevertheless influence the format of the risk analysis results. Evaluation is sometimes used in place of assessment or estimation. A decision-making process includes risk analysis, which addresses the demands of stakeholders (clients and decision-makers), who must be precisely identified.

3.1 Equipment Studied

The Alrar unit compressor station has several gas pressure vessels. In order to represent them, the V-121(A/B) gas dryers will be studied in more detail. This one is chosen because it is located at the end of the gas compression process, and therefore at high pressure (64 bar). These dryers are used to prevent the formation of hydrate, which can cause blockages in piping, valves, exchangers and other equipment. The compressed gas is dried until the water dew point is reached (below -46°C), by passing it through a dehydrating bed in the form of a molecular sieve. The V-121(A/B) gas dryers work in a complementary way: one dries the gas while the other regenerates. To do this, the gas first passes through a heater before passing through the dryer. The gas then passes through the regeneration gas separator, which returns the different phases of the gas upstream to the compression process. The characteristics of the dryer are shown in the table below:

Table 1 V121 Dryer Characteristics [24].

Building by	**RILEY.BEA/RD**
Type of installation	V-121 gas dryers (A/B)
Year of construction	1980
Substance	Feed gas
T service (°C)	27
P service (bar)	64,9 /62,3
P calculation (bar)	76,5
Corrosion thickness (mm)	4
Radiography	Yes
Volume (L)	70484
Surface area (m²)	104
Weight (kg)	220017

Total unladen weight (kg)	143405

3.2 Detailed Description of the Feed Gas Dehydration Section and Preparation of a Dryer

The feed gas is dried to prevent plugging problems due to low-temperature icing in the downstream cooling and expansion section. The gas leaving the V-121 is dehydrated in one of the gas dryers (V-121A/B) fitted with molecular sieves. (One is in service for gas drying while the other is in the regeneration cycle). The dehydrated gas is filtered by the gas filter (F121) to remove impurities and dust, then cooled in the exchanger battery E-141 (7°C), E-142 (-15°C), E-143 (-23)°C, E-144(-34°C). The operating time for each dryer is calculated for 12 hours, during which time the second dryer is regenerating. The regeneration gas is taken downstream of the F-121 filter, then heated to a temperature of 274ºC by hot oil circulation on the tube side of the E-122 heater and passed into the dryer. The wet saturated regeneration gas leaving the dryer passes through the E-123 air cooler to be cooled to 60°C. The water and condensed hydrocarbons are separated from the gas in separator V-122. The water is drained into the sludge tank. The liquid hydrocarbons are sent for recycling upstream of flash drum V-103. The regeneration gas is compressed by the regeneration gas recycle compressor (blowers C-121A/B to join the gas at the inlet of exchanger E-101)[24]. The gas used during cooling is the same as that used for heating, except that it bypasses the E-122 heater. V-121A/B gas dryers are regenerated according to the following cycle: Adsorption 12 hours, Heating 15 minutes , Regeneration 05 hours, Cooling 03 hours and Standby 04 hours.

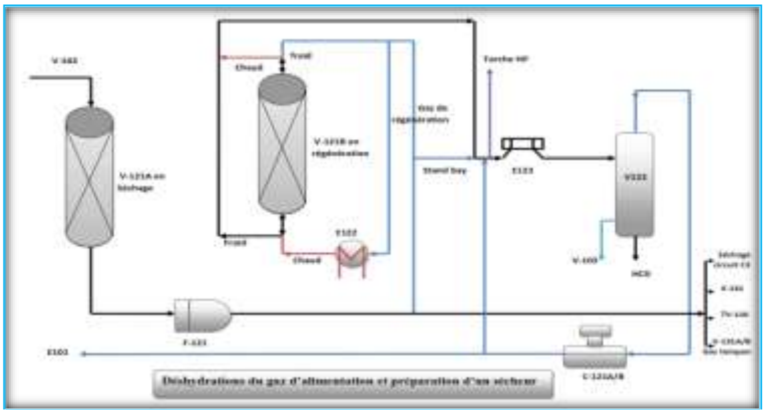

Figure 1 Schematic Diagram of Feed Gas Dehydration and Dryer Preparation [25]

4. Discussion of the Results

Analysis of the risks associated with the dehydration system (gas dryer)

Table 2: Application of RPA

N	Causes	Initiating event	Plant hazardous event	Dangerous	F	G	R	Existing safety barriers
1	water saturation of the molecular sieve	Clogging of the line downstream of the dryer or the F121 filter	-Pressure increase in V121 dryer -Leak -Rupture -gas loss	-fire -VCE explosion	3	3	[illegible]	Pas
2	Hardware failure	KV 104 or KV103 Locked closed	-Increase in pressure upstream of the valve (dryer level). -Line break or dryer. -Release of gas	-fire -VCE	1	3	[illegible]	-KV 104 position indicator (with alarm). -PSV

3	Hardware failure	KV 102 or KV 103 Locked open	-Increased pressure -Dryer line rupture -gas liberation	-fire -VCE	1	3	[illegible]	-KV 104 position indicator (with alarm) -PSV
4	Impact with vehicle	External aggression	Leak/break on dryer	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	Mechanical stress during the construction phase on the site or domino effect	Damage dryer and connecting elements	Rupture on dryer pipe dryer inlet	fire VCE	1	4	[illegible]	-Operator detection work. -Procedure for making installations safe prior to maintenance + pre/post-work inspection -Use of fire-fighting equipment
6	Internal corrosion	Damage to dryers and connecting elements	Leak on dryer	fire VCE	2	2	22	-Design rule (API), suitable material -Operator detection rounds, -Use of fire-fighting equipment
7	External corrosion	Damage to dryers and connecting elements	Leak on dryer	fire VCE	1	2	[illegible]	-Design rule (API), suitable material -Detection by operator rounds, -Use of fire-fighting equipment
8	Hardware failure	Worn valve flange seal or leaking pipe seal	Flange gasket leak	fire VCE	1	2	[illegible]	Fire (UV) -Use of fire-fighting equipment
9	Human error following maintenance work	Poorly tightened flange on dryer	Leaking flange seal on dryer	fire VCE	1	2	[illegible]	-Works Control, -Supervision and monitoring of work by Terminal staff. -Ensuring the safety of the installations during the work, with consignment, -Verification of the work carried out before the installations are put back into service (leak test), -Use of fire-fighting equipment...
10	Operating error during maintenance work	No gasket (not replaced) or gasket incorrectly refitted or gasket not suitable	Leaking flange seal on dryer	fire VCE	1	2	[illegible]	-Works control, -Supervision and monitoring of work by Terminal staff. -Ensuring the safety of the installations during the work, with consignment, -Verification of the work carried out before the installations are put back into service (leak test), -Use of fire-fighting equipment...

This analysis shows the various consequences relating to the malfunction of each sub-system of the gas dehydration system. It was used to draw up a criticality grid of the scenarios likely to occur in the dehydration system. The table below shows the pairing (Severity; Frequency) established during the risk analysis.

Table 3: Risk Assessment Matri

	Frequency 4	**Frequency 3**	**Frequency 2**	**Frequency 1**
Severity 4		3-4		
Severity 3			2-3	1-3
Severity 2			2-2	1-2
Severity 1				

4.1 Interpretation of RPA Results

The main advantage of the Preliminary Risk Analysis is that it enables a relatively rapid examination of hazardous situations on the dehydration system (gas dryer). The PRA also enabled us to highlight the central dreaded event that requires more detailed study. The preliminary risk analysis (PRA) enabled us to identify the hazardous phenomena likely to occur following the occurrence of undesired events, themselves resulting from the combination of malfunctions, drifts or external attacks on the system. It also enabled us to rank these accident situations in terms of probability of occurrence and intensity, and to select the hazardous phenomena that could lead to a major accident**.**

4.2 Study of a Gas Dryer Failure Scenario
4.2.1 Description of Feared Events

The feared event is a complete and instantaneous breakdown of the dryer. The scenario studied is therefore the loss of containment of a large quantity of gas. Leakage from the connection is also studied. The feared hazardous phenomena are a delayed explosion (VCE), a flash fire, a fireball and a flaming jet.

4.2.2 Controls, Regulation and Safety in Place
The dryers (V-121 A/ B) are fitted with PSV-107A and PSV-107 B. The lines downstream of these dryers are equipped with:

- PSV-714 B;
- PV-742 A and B (operated on the basis of information supplied by the P-742 IC sensor) with flow redirection to the torch.

Other prevention/protection measures are present in the equipment area:

- Fire hydrant network
- Reinforced fire valve (RIA)
- Dry powder extinguishers
- Inspection
- Mobile response resources (mixed lorry, cannon lances, motor-driven pumps)
- Work and travel permits
- ATEX zone.

4.3 Analysis of Failures and Probabilities of Occurrence
The main failure modes for pressure equipment are:

- External leak (including rupture) through equipment walls, welds or fittings
- Hot rupture following the effects of a fire (e.g. BLEVE)
  The main causes of pressure equipment failure are mechanical failure (typically due to operational overload, fatigue, accessory failure, material or construction failure) and corrosion, although most failures are caused by individual components. Many failures of pressure equipment or reactors are due to specific reactions with the contained fluid.
- Smith reports that 93% of pressure equipment failures are due to crack formation, and in 71% of cases, the crack occurred at the weld or at a hot spot in the equipment. Virtually all the weld cracks were at attachment or discontinuity locations. Over 40% of the cracks came from equipment showing defects even before it was put into service, and 32% were due to fatigue (which could also be the result of a pre-existing defect).
- Finally, external aggression, human error and excess pressure are also possible causes.

The calculations of generic failure frequencies are based on data extracted from the Handbook Failure Frequencies 2009. The Handbook Failure Frequencies is based on historical data from a number of representative pieces of equipment. The Handbook, Failure, Frequencies, gives the following failure probabilities for pressure equipment:

Table 4: Frequencies of Failure Types.

Type of failure	Failure frequency [/equipment/year]
	Process and other installations
Small leak 0.1 < d ≤ 10 mm deq = 10 mm	1.2 10-4
Average leakage 10 < d ≤ 50 mm deq = 25 mm	1.1 10-5
Large leak 50 < d ≤ D max deq = D L max	1.1 10-5
TOTAL LEAKAGE	$1.42\ 10^{-4}$
REPTURE	$6.4\ 10^{-6}$
Total	**1.48 10-4**

4.4 Frequency of Occurrence of Consequences

The consequence tree shown below gives the probability of occurrence of each consequence linked to the event. These frequencies of occurrence are based on the leak frequencies calculated above and on the ignition and explosion probabilities taken from the Handbook Failure Frequencies 2009. These ignition and explosion probabilities depend on the nature of the product released and the extent of the loss of containment.

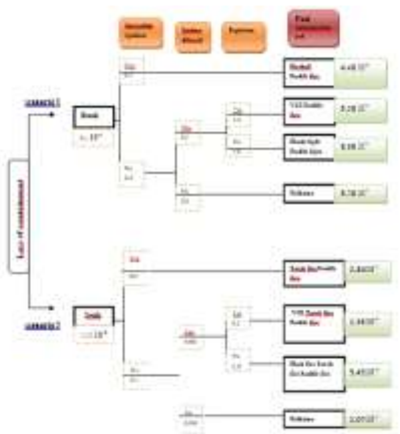

Figure .3 ADE Diagram of the Two Containment Loss Scenario

Table 5. Frequencies of Hazardous Phenomena

Dangerous phenomenon	Frequency
VCE	1.9 10-6
Fireball	4.48 10-6
Torch fire	3.52 10-5
Flash light	6.26 10-6
Puddle fire	4.10 10-5
Pollution	1.13 10-5

Excluding events that are not feared because they have a negligible frequency of occurrence, i.e. a frequency of occurrence of less than $10^{(-6)}$/year, the following table of feared events emerges.
All the phenomena have a frequency of occurrence above the acceptability threshold, so it is necessary to analyse their consequences. Pollution is the subject of a specific scenario.

4.5 Analysis of the Consequences of Event
All possible accidents can be classified according to the physical effects they cause. They are listed in the table below.

Table 6. Physical Effects of the Accident

Physical effect	Scenario
Pressure relief	
VCE explosion	✓
Explosion in a building or in machinery, sewers, etc.	
Physical explosion at or above boiling point	
Runaway reaction	
Internal explosion of an atmospheric storage tank	
Thermal radiation	
Fireball	✓
Puddle fire	
Jet ignites	✓
Flash Fire	✓
Boilover	
Dispersion of a toxic gas	
Release of a toxic gas (toxic to humans or the environment)	
Formation of toxic fumes	
Release of asphyxiant gas	
Formation of toxic gases following the reaction between incompatible	

4.6 Effect Distances
The effects for the various consequences are shown in the tables and diagrams below. For each consequence, only the weather conditions giving the largest effect zones are shown. The plans generally include two types of curves, the
The "feather" represents the range of the event, taking into account the most frequent wind direction, and the "effect" represents the area covered, taking into account winds in all directions.
The following table shows the overpressure effect distances associated with the VCE phenomenon following a catastrophic failure of the dryer. The contours of the effects on humans are illustrated on the satellite map.

Table 7 Overpressure Effect Distances Associated With the VCE Phenomenon

verpressure level (mbar)	Distances of effect in metres			
	Summer day	Winter day	Summer night	Winter night
25	261	251	252	257
50	158	151	151	154

160	76	69	70	71
300	53	48	48	48

The center of explosion calculated by the model is between 1 and 19 meters, depending on weather conditions. The furthest possible point of ignition is 40 meters.
The weather leading to the most critical effect distances is Summer Day.

Figure 4 Modelling the Effect of VCE

The following table shows the thermal effect distances and characteristics associated with the fireball phenomenon following a catastrophic failure of the dryer. The contours of the effects on humans are illustrated on the satellite map.

Table 8 Thermal Effect Distances and Characteristics Associated With the Fireball Phenomenon

Radiation level (kW/m²)	Distances of effect in meters			
	Summer day	Winter day	Summer night	Winter night
Effects on humans				
6,3 (2.5)	213	224	224	230
16,2 (6.4)	127	133	133	137
25,3 (10)	94	100	100	103
Domino effects				
8	188	198	198	203
32	79	84	84	87
Characteristic of fire mud				
Radius (m)	36			
Duration (s)	5,8			
Maximum height (m)	72			

The weather leading to the most critical effect distances is Winter Night.
In view of the short duration of the fireball (< 20 sec), the heat flux thresholds must be recalculated as follows: I= (S) * (20/t)3/4
With I the new threshold, S the old threshold and t the time in seconds.

Figure 5 Modelling the Fireball Effect

The following table shows the thermal effect distances and characteristics associated with the phenomenon of a flaming jet following a large Flash Fire leak.
The contours of the effects on humans are illustrated on the satellite map.

S	I for t = 5.8 s
2.5 kW/m	6.3 kW/m
6.4 kW/m	16.2 kW/m
10 kW/m^2	25.3 kW/m

Table 9: Thermal Effect Distances and Characteristics Associated With the Flaming Jet Phenomenon

	Summer day	Winter day	Summer night	Winter night
Effects on humans				
2.5	59	59	60	60
6.4	49	48	48	47
10	46	44	44	43
Domino effects				
8	48	46	46	45
32	39	36	36	34
Characteristic of the family				
Length (m)	36	33	32	31
Duration (s)	600			

The emissive power of the flame calculated by the model varies between 206 and 254 kW/m^2 depending on the weather conditions.
The weather leading to the most critical effect distances is Summer Night.

Figure 6 Modelling a Flaming Jet

The following table shows the distances reached by the characteristic concentrations of a Flash Fire for a rupture, i.e. the Upper Flammable Limit and the Lower Flammable Limit. The contours are shown on the satellite map.

Table 10: Distances Reached By Concentrations Characteristic of A Flash Fire

	Concentration distances in metres			
	Summer day	Winter day	Summer night	Winter night
LSI	13	12	12	11
LII	27	23	22	20

Experience shows that the effect of thermal radiation is fairly limited, and that the lethal effect is determined by the distance to the LFL (Lower Flammable Limit). However, anyone in the path of the burnt gases is likely to suffer a lethal effect with a high probability, and no one outside the flammable cloud can suffer a lethal thermal effect.
The weather leading to the most critical effect distances is Summer Day.

Figure 7 Flash Fire Modelling

Each hazardous event is characterized by a specific kinetic sequence of events. Depending on this kinetics, the impact of the event and the possibilities for limiting it may be more or less significant. The impact of long but immediate events can generally be reduced by applying appropriate evacuation and protection methods. In the case of rapid but delayed phenomena, evacuation possibilities are limited, and the response after the event will consist of limiting the damage and protecting targets following secondary fires. The emphasis should be on prevention rather than protection. The kinetics of possible phenomena are shown in the table below.

Table 11 Kinetics of Possible Phenomena

Dangerous phenomena	Phenomena family
VCE	Very fast
Fireball	Fast but delayed
Flaming jet	Long but immediate
Flash Fire	Very fast

The effect zones for the thresholds relating to domino effects (160 mbar and 300 mbar) reach 76 meters and 53 meters respectively, covering a large part of the facilities. A ***VCE-type*** explosion is likely to cause serious damage to most of the equipment. However, the presence of gas detectors, if they trigger an ESD, limits the risk of a domino effect linked to a VCE. For a fireball, the zone of effect for the threshold of 8 kW/m^2 reaches 203 meters, and the zone of effect for the threshold of 32 kW/m^2 reaches 87 meters. The duration of the fireball (6 seconds) makes it an extremely rapid but short-lived phenomenon. During this short period of exposure, only the equipment included in the fireball (36-meter radius) is considered potentially damaged. The domino effect will be characterized by a leak followed by the immediate ignition of the released fuel. The effects of the flaming jet will depend very much on the direction of the torch. In this scenario, the damage threshold for protected equipment (32 kW/m^2) reaches 39 m, while the damage threshold for unprotected equipment (8 kW/m^2) reaches 48 meters. The torch could cause significant damage over a distance of around 36 meters (flame length) and reach the control room if the direction of release corresponds. The most effective way to combat this phenomenon is to cut off the power source. The presence of gas and fire detectors, if they trigger an ESD, helps to limit this phenomenon. In the case of flash fire, the thermal effect is limited by the short duration of the event. There are no domino effects to be feared in the event of a flash fire.

4.7. Butterfly Knot (Measurement Matching)

All the relevant prevention and protection measures for this scenario have been included in the graph below.

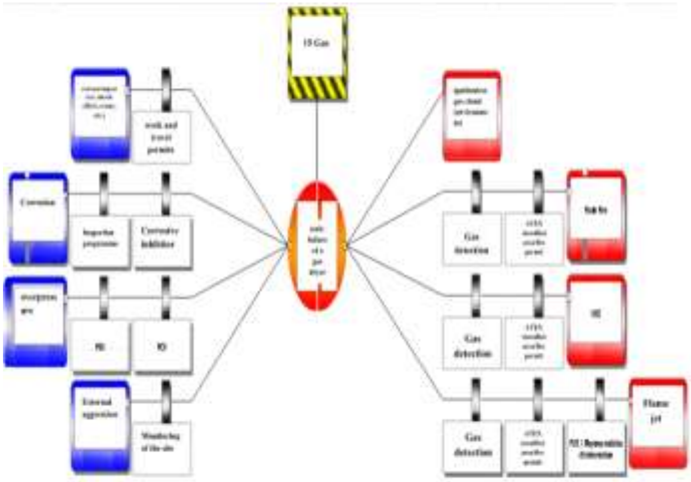

Figure 8 Dread Event Butterfly Diagram

5. Conclusion

In conclusion, it can be said that our study constitutes an overall approach to assessing and identifying the risks presented by the dehydration system at the Alrar gas complex. With regard to the risk analysis tools used in this study, the results show that the use of RPA, which has the advantage of being economical in terms of time spent and does not require a very detailed description of the system studied, enabled a relatively rapid examination of the hazardous situations for the dehydration system. This method highlighted the central hazardous event requiring a more detailed study. The quantitative assessment based on the event tree enabled us to estimate the probabilities of occurrence of the central dreaded events and the probabilities of occurrence of their consequences. The PHAST software was used to assess the thermal and overpressure effect distances of the hazardous phenomena. These results show that the impact of a major accident would be far-reaching and would endanger all personnel, facilities and the environment, highlighting the need to develop prevention and protection measures. It can also be concluded that the risk associated with the VCE phenomenon is deemed unacceptable due to its seriousness. The control room is very close to the compressor station. However, the gas detectors installed in various places on the site will detect the formation of a gas cloud and trigger the alert to limit the risks associated with the phenomenon. The risk associated with the fireball phenomenon is also deemed unacceptable due to the very close proximity of the control room to the compressor station. The risk associated with the flaming jet phenomenon is considered ALARP due to its low probability (5.0 $^{10-3}$ /year). The zone of effects of serious consequences, direct or indirect, immediate or long-term, reaches sensitive areas such as the control room. Given the protective measures in place, the duration of a torch fire is estimated at a maximum of 10 minutes, the time needed to detect and stop the leak. The risk associated with the flash fire phenomenon is deemed to be ALARP due to the low severity of the phenomenon (due to its short duration) and its probability (8.4 $^{10-4}$ /year). Gas detectors installed at various locations on the site will detect the formation of a gas cloud and limit extent. The main recommendation for this scenario is to check that the control room is fireproof and blastproof in order to protect the occupants and, if necessary, to take the necessary measures to bring the control room up to standard. Installing gas detectors and fire (UV) with an automatic general shutdown of the installations in the event of an alarm with sectioning and depressurization of the equipment would limit the duration of leaks. It is also important to ensure an effective maintenance and inspection system for gas and fire detectors

6. References

1. Yong Bai & al, Risk management for structural failures due to fires, Risk Assessment and Management for Ships and Offshore Structures, 2024.
2. Lei Xu & al, Numerical research on the smoke spread process of thin-tall atrium space under various ceiling heights, Elsevier 2021.
3. U Barua & al, Integration of Proactive Building Fire Risk Management in the Building Construction Sector: A Conceptual Framework to Understand the Existing Condition, Buildings, 2024.
4. M Dandoulaki & al, Disaster risk management and spatial planning: evidence from the Fire-Stricken Area of Mati, Greece, Sustainability, 2023.
5. Shaw R & al, Land Use Management in Disaster Risk Reduction: Reduction Practice and Cases from a Global Perspective, Springer: Tokyo, Japan, 2017.

6. United Nations (UN), The Sendai Framework for Disaster Risk Reduction 2015-2030, Available online: https://www. Preventionweb.net/publications, 2023.
7. United Nations (UN), Transforming Our World: The 2030 Agenda for Sustainable Development; UN General Assembly Resolution; UN: New York, NY, USA, 2015.
8. Lazoglou, M. Resilience as a Spatial Planning Parameter against the Effects of Climate Change: The Significance of Greek Medium Coastal Cities and the Role of Modern Technologies. Ph.D. Thesis, National Technical University of Athens, Athens, Greece, 2022.
9. Z Parvar & al, Integrating meteorological and geospatial data for forest fire risk assessment, Journal of environmental management, Elsevier, 2024.
10. MS Ahmad, Comparative analysis of analytical hierarchy process (AHP) and frequency ratio (FR) models for landslide susceptibility mapping in Reshun, NW Pakistan, Kuwait Journal of Science, 2023.
11. F. Ahmadi Mirghaed & al, Decision scenarios using ecosystem services for land allocation optimization across Gharehsoo watershed in northern Iran, Elsevier, 2020.
12. Yong Bai & al, Risk Assessment and Management for Ships and Offshore Structures, Elsevier, 2024.
13. E. Bagheri Rad & al, Nutritional Quality and quantity of available forages relative to demand: a case study of the goitered gazelles of the golestan national park, Iran, Elsevier, 2015.
14. R. Chanda & al, Two-decadal climate impacts on growth of major forest types of Eastern Himalay, .Elsevier, 2024
15. E. Çolak & al, Evaluation of forest fire risk in the Mediterranean Turkish forests: a case study of Menderes region, Izmir, Elsevier, 2020.
16. Xiaowei Zang & al, Contemporary Fire Safety Engineering in Timber Structures: Challenges and Solutions, Fire, 2024.
17. Jian Rui Feng & al, Dynamic risk assessment framework for industrial systems based on accidents chain theory: The case study of fire and explosion risk of UHV converter transformer, Elsevier, 2022.
18. C. Chen & al, integrating safety and security resources to protect chemical industrial parks from man-made domino effects: a dynamic graph approach, Elsevier, 2019.
19. B. Gjorgiev & al, Identifying and assessing power system vulnerabilities to transmission asset outages via cascading failure analysis Elsevier, 2022.
20. Danzi & al, Software-Defined Microgrid Control for Resilience Against Denial-of-Service Attacks, IEEE Transactions on Smart Grid, 2019.
21. C. Picoco & al, A framework for verifying dynamic probabilistic risk assessment models, Elsevier, 2020.
22. J. Xing & al, A framework for dynamic risk assessment with condition monitoring data and inspection data, Elsevier, 2019.
23. X Li & al, Vulnerability assessment of storage tanks exposed to simultaneous fire and explosion hazards, Elsevier, 2023.
24. Alrar complex document, Sonatrach, 2022.
25. PID gas dryer, Sonatrach, 2022