# Risk Analysis and Assessment of Butane-Propane Splitter Column in the Skikda Refinery Petroleum Plant

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**Abstract:** Risk analysis and assessment are extremely important in the petrochemical sector to prevent potential risks. This study was carried out at Gas platform (unit No 30) of Skikda refinery Algeria, with the aim of predicting and estimating the effects of major explosions in the propane and butane Splitter column and estimating the possible human and environmental consequences of the containment loss. The methodology developed here is based on a combination of HAZOP presentation and PHAST tool. First, HAZOP is used to capture the responsible derivations of operating parameters to produce the worst consequences. Related Causes, safety barriers and some recommendations are carried out in a HAZOP sheet which represents all of that. Then the major scenarios detected by the worst consequences have been studied and modeled by PHAST software. The modeling process is completed by simulating the principal effects (Jet fire, BLEVE, UVCE) resulting from two scenarios in the form of two potential leaks on the bottom and the head of a gas separator column containing butane and propane respectively. The results are shown on the region map to indicate the exact threaten zones. Finally, a comparison in terms of effects between the two scenarios is performed and some conclusions are extracted.

**Keywords:** Risk, Threaten zones, HAZOP, PHAST, Major scenarios

## 1. INTRODUCTION

As part of Algeria's overall development strategy, industrialization plays a leading role by creating the industries necessary and essential for an independent national economy.

Official statistics indicate that no less than 4,000 high-risk industrial installations identified are located in the middle of the urban fabric which represents only 1.7% of the total area of Algeria where the vast majority of the population resides, and that Oil and gas activities in Algeria represent 80% of the major risks (fires, explosions and toxic risks).

Algerian Petroleum industry is governed by an asset of laws and rules which focus on the need to guarantee the protection of facilities, workers, residents as well as the protection of the environment, especially after the two major industrial accidents which are the explosion of liquefied natural gas tank on the oil port of Skikda and the explosion of two storage tanks at the Skikda oil terminal of Skikda, which are the most fatal accidents in the history of petrochemicals industrial plant in Algeria[1-4].This can cause serious risks that need to be controlled and minimized [5-6].

Diver's techniques are applied to identify and analyze hazards and performance of safe systems to control and minimize the occurrence of undesirable scenarios that may affect the manufacturing and operating facilities in the oil and gas industry.

The most used techniques for risk analysis and safeguard measures performance in chemical processing industries are: preliminary hazard analysis (PHA), hazard and operability study (HAZOP), failure modes and effect analysis (FMEA), fault tree analysis (FTA), event tree analysis, event tree analysis (ETA); where each of these has advantages and drawbacks.

In this paper, we have chosen to apply HAZOP. However, this method has the ability to take into account risks associated with operating parameters such as temperature, pressure, flow rate, level, etc. Therefore, it is perfect for processes circulating fluids and manipulating the above parameters.

Liquefied petroleum gases (LPG) are considered as a by-product of oil and gas activities. LPG has established itself mainly thanks to its specific characteristics, its flexibility of use, as a fuel in many applications, the reasonable cost of its storage and transport, its security of supply, its competitive price, and other advantages from an ecological point of view. To these purposes, the Skikda refinery is committed to boosting its development policy and finding the best way to meet the needs of all its customers.

The aim of our work is to improve the safety of a propane and butane splitter column Naphta Stabilizer. This work is based on a HAZOP study to assess the risks in the selected Naphta stabilizer located in Skikda refinery (the refinery located in the east of Algeria, it contains nine boilers so that the study can be generalized to include the remaining boilers) which is the largest refinery in Africa with a treating capacity of 16.5 million of tons per year.

Thanks to the HAZOP method, all the expected dangerous scenarios will be examined, and at the end the PHAST software is used to simulate the effects of dangerous scenarios on the environment of the site's neighboring the petrochemical platform [7].Several recommendations are raised to help in improving the safety of this critical area.

## 2. MATERIALS AND METHODS

Our methodology is performed by following the following procedure:

First, the system is described and only the propane and butane splitter column is considered. This primordial step is essential because it provides the necessary information to understand the system function in hand to determine its weak points, which can produce dangerous scenarios. Secondly, HAZOP is applied to identify the possible deviations, their causes and their consequences as well as the existing safeguards. In this phase, we will be able to extract the dangerous scenarios that may affect the system in case that the system protection measures are not sufficient, and by the way additional safety protection measures are recommended. The results will be shown in a HAZOP sheet.

In the final step, the dangerous accident scenarios were carried out by simulating their effects using the PHAST software, in order to indicate the thermal, suppression and toxic perimeters, as well as the consequences on Human health, material losses, and environmental pollution.

### *2.1 RA1KSkikda refinery*

The Skikda Refinery RA1K, is the most important refinery in Algeria. It is located in the east of Algeria in the industrial zone 7 km east of Skikda and 2 km from the sea. Its surface after rehabilitation has become 235 hectares and has a mission to transform the crude oil coming from Hassi Messaoud. The refinery is mainly divided into two production trains; with a treating capacity of 16.5 million tons per year. Each train includes one CDU (crude distillation unit called U 10 and U11) and gas plant units called U30 and 31. The crude is first separated into three main components in the CDUs, which are light components (gases), Naphta and residues (heavy components). This study was carried out at the Gas plant (unit No 30) of Skikda Refinery [8].

### *2.2 Case Study (C3/C4 splitter section)*

The Column C3 is composed of 30 trays with a full capacity of 2500 $m^3$. It receives the basic products of the De-ethanizer, which are a mixture of C3 and C4, at tray11, under the flow control by (30-FIC1152) at the temperature of 91°C and the pressure13.7kg/cm².

The condensed liquid, which is propane, flows through the reflux drum 30 V4 from where part of it is pumped back by the MP 53 A / B as reflux to the column under flow control. Another part of the condensed vapor is pumped as propane product to the propane storage under level control of the reflux drum cascaded with flow control 30-FIC 1251) via the valve (30-FV1251) installed on the oil return line. Back pressure controller downstream of the total condenser maintains the column pressure [8-9].

The bottom liquid, which is butane, flows to the Kettle type reboiler 30-E 52. Necessary vapor flow for the column is generated with the help of Hot Oil on the tube side.

The bottom product of Butane from the column exchanges heat with the feed De-ethanizer column and that process gets partially cooled. The remaining cooling is achieved in the butane trim cooler 30-E12.The Pressure Safety Valve (PSV) protects the column against overpressure on the top vapor outlet.Propane is obtained as a product from the top of the C3/C4 splitter column. The column C3 is shown in figure 1.

All safety systems of the studied plant are described and represented in Table1.

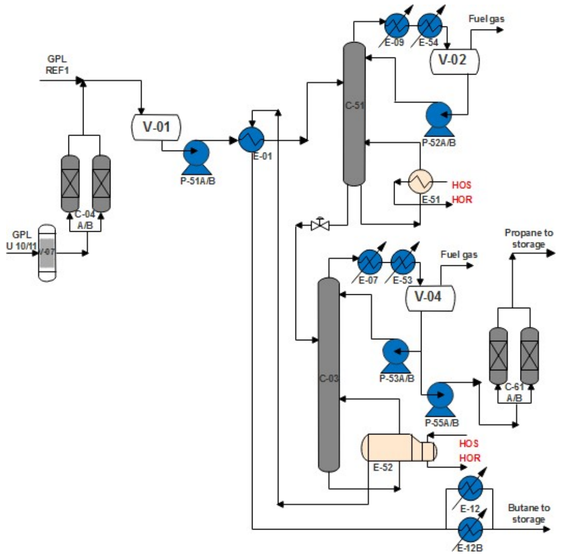


Fig.1 Diagram of the Column C3/C4 Splitter

Table1 Different safety systems for the protection of the splitter column C3

| **Safety systems** | **Landmark** | **Description** |
|---|---|---|
| Pressure Safety Devices | PSV1253 | Quickly release gases to avoid overpressure |
| Interlock | I-1251 | ActivatedbyLALL-1251 ActiontotripP-55A/B2and P-53A/B2 ActivatedbyLAHH-1251close UV-1253 |
| | I-1257 | Activated by PAHH- 1257 A/B/C(2outof3) Actionon:closeUV-1257and 1258 OpenTV-1251B |
| Alarms | FAH-1251 | Hot oil return from E-52,FV-1251 |
| | FAL-1251 | Hot oil return from E-52,NbFV-1251 |
| | FAH-9C-3 | Flowaspiration,FV-9 |
| | FAL-9C-3 | FlowaspirationFV-9 |
| | FAH-1252 C-3 | Flowaspiration,FV-1252 |
| | FAL-1252 C-3 | Flowaspiration,FV-1252 |
| | PAH-1256 | Pressuretop,PV-1256 |
| | PAL-1256 | Pressuretop,PV-1256 |
| | PAHH-1257A | Pressure top, UV1257 /UV1258/TV1251B |
| | PAHH-1257B | PressuretopUV1257/UV1258 /TV1251B |
| | PAHH-1257C | PressuretopUV1257/UV1258 /TV1251B |
| | LAH-8 E-52 | V-8Level |
| | LAHH-8 E-52 | V-8Level |
| | LAL-8 E-52 | V-8Level |
| | FAH-13 | butaneFlow |
| | FAL-13 | ButaneFlow |
| | TAH-1251 C-3 | Temperaturevalve TV-1251 A/B |
| | TAL-1251 C-3 | Tempeature valve TV-1251 A/B |
| | TAH-22 C-3 | TemperaturetopofcolumnC3 |
| | TAL-22 C-3 | TemperaturetopofcolumnC3 |

*2.3 Risk analysis*

As detailed earlier, HAZOP is a risk analysis tool that can be used to identify and estimate risks especially for the chemical process circulating fluids. It is classified as a qualitative method used to identify the potentially hazardous events and operating problems presented in the process. The HAZOP technique operates on the premise that hazard does not occur if the process is always operated within its design intention [10]. The basic concept of HAZOP study after taking a full description of all process parts is to discover what deviation from the intention of the design can occur and what their causes and consequences are from a safety and operability point of view. This is done systematically by adopting keywords that represent the potential derivation of any of the existing parameters in the unit under study. The study is also highly useful in identifying hidden hazards, design limitations and operation difficulties. The Final stage of the HAZOP study is to adopt the necessary recommendations aimed at improving safety and limiting the dangers extracted during the previous steps [11].

Modeling with software is very important to predict the extent of material release range and simulate its consequences.

PHAST (Process Hazards Analysis Software) is a powerful consequence analysis software tool with extensive modeling capabilities for hazard analysis and assesses arrange of flammable and toxic effects. PHAST uses the dispersion and effects models, making it a powerful simulation and consequence analysis software tool [12].

## 3. RESULTS AND DISCUSSIONS

*3.1 Identify major risks by HAZOP*

As stated earlier, the first goal for using HAZOP is to identify different accident scenarios that may occur in the C3/C4 Splitter column. In our case, two deviations were selected (more pressure and more flow). The results of the HAZOP study for propane and butane splitter column in Gas Plant II (unit 31) are given in Table 2.

The fourth column of the table indicates the most dangerous situations extracted from the case of more pressure in column C3, those situations may be caused by the malfunctioning of the flow valve FV9 and the pressure valve PV9. The consequence of the combination of these causes is considered the most dangerous scenario since it may affect not only the column C3 and industrial zone but also the environment and persons in a long distance far from the industrial zone.

### *3.2 Modeling the Consequences of Scenarios*

Scenario definition is one of the first steps in risk assessment that predicts possible events.

In the present study, the scenarios are defined from HAZOP analysis.

Due to wear and defects that can occur in the system, there is a possibility of propane or butane leaking from various parts of the source, such as leaks from connecting pipes or sudden puncture.

Depending on the operating conditions of the splitter column C3, the consequences of the blast wave and the intensity of the radiation of a possible explosion are studied.

Table2 HAZOP sheet for the splitter C3 node

| Node: C3/C4 splitter section | | | | | |
|---|---|---|---|---|---|
| **Equipment/ Operations : Splitter C3** | | | | | |
| Para-meter | Deviation | Causes | Potential Consequences | Safety barriers | Recommendations |
| Press-ure | Overpress-ure | -FalseindicationFT-9<br>- FV-9doesnotopen<br>- False indication PV1256<br>-PV-1256doesnot open<br>- False indication PV 1257 A/B/C (at least 2/3)<br>- UV1257/ 1258 blocked open<br>-TV1251B blocked closed<br>- False indication PI37<br>- loss of reflux caused by stopping the reflux pumps MP53 | - Overpressure<br>- Bursting<br>- jet fire<br>- UVCE | -FIC-9<br>-PAHH-1256(2outof 3) with PSHH - 1257A/B/CprovidedinD CS.<br>- On actuation of PAHH(2out of 3) interlockI1257 will bypass hot oilto E52<br>-PAHH<br>- Closing of the supplyvalves Hot oil UV1257/1258<br>- Opening ofTV1251B<br>- ClosingTV1251A<br>- Safety valve PSV 1253 | - Instrumentation loop checkprogram<br>- Transmitter calibration<br>- Preventive maintenance program<br>- Inspection valve |
| Flow | High flow | - UV1162blockedopen<br>- FalseindicationLT6<br>- False indication FT1252<br>- FV 1252 valve doesnot close<br>- Significantarrival of theproduct from thereboiler<br>- UV1275 and 1258 blocked<br>-TV1251A/ B valves do notopen<br>- FV 1251 valvedoes not open<br>- False indication FT151 | - Overpressure<br>- Bursting<br>- Jet fire<br>- UVCE | -FAH-1252<br>- FIC-1252<br>- LIC-6<br>- Opening of UV1253 (ball valve to fuel gas)<br>- Emergency stopprocedure | - Instrumentation loop check program<br>-Transmitter calibration<br>- Preventive maintenance program |

The different scenarios examined in this study are:

- A propane leak at the outlet of the splitter column C-3 head to the E7 A/B exchangers with diameters (15mm)
- A butane leak at the outlet of the bottom splitter C3 to the E52 exchanger

To appreciate the impact of the obtained consequences, we simulate threat zones of thermal and overpressure effects related to the UVCE, and the dispersion of pollutants resulting from propane release using PHAST.

Then, it depends on the condition of the leak and the probability of ignition to determine what could happen, so there are three cases:

- UVCE (Unconfined Vapor Cloud Explosion): delayed ignition of gas leak.
- Jet fire: Instant ignition of Pressurized leak.
- Overpressure BLEVE.

### *3.3 Modeling scenarios using PHAST software*

*1) First Scenario: Leakage of butane at the bottom of column C3*

The modeling results in climatic conditions (5D, 1.5 D, 1.5 F). The characteristics of the leaking the first scenario are grouped together in the following table.

Table3 The assumptions of the first scenario

| | |
|---|---|
| Product | Butane |
| Phase | Gaz |
| Quantityof product in column | 8066 kg |
| Pressure | 12 bar |
| Temperature | 90 °C |
| Flow | 386 Kg/s |
| Heightof the break from the ground | 5 m |
| Leak direction | Horizontal |
| Leak diameter | 150 mm |
| Duration of the leak | 8 s |

*a) Jet Fire*

Figure 2 indicates three different levels of vulnerability for eruptive jet fire in 5 D, 1.5 D and 1.5F climates. According to the data obtained, people or equipment that are approximately meters radius from the release source are going to be destroyed due to radiation from the eruptive fire [13].

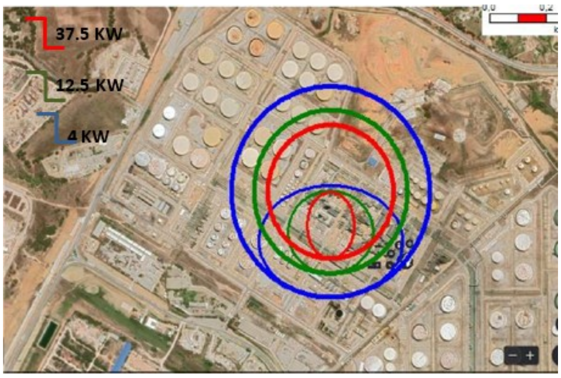


Fig.2 Thermal effects of jet fire in bottom of column

According to Fig. 2 and Table 3 it can be seen that the jet fire due to the leakage of butane at the bottom of the column could reach a distance of 223m with a thermal effect of 37.5 kW/m$^2$ and a flame length of 176m.

Distances and threat zones related to the thermal effects resulting from butane leak in Splitter column C3 are shown in Table 4.

Table4 Distances threaten by thermal effects of the jet fire for leakage from the bottom of column C3

| Climate | Distance | Threshold kW/m$^2$ |
|---|---|---|
| 5D | 223 m | 37,5 |
| 1,5D | 273 m | 12,5 |
| 1,5 F | 353 m | 4 |

*b) BLEVE*

Results of Blast over pressure effects are shown in Fig.3.

Fig.3 BLEVE Over pressure effects of butane on the refinery

Figure 3 illustrates different blast-wave over pressures in different contours that correspond to diverse damage degrees from over-pressure in a natural gas explosion [14]; these damages are related to two important values of pressure which are: 0, 02068 bar and 0, 2068 bar. The first value (0, 02068 bar) can cause limited damage to humans and structure.

*c) UVCE*

Figure 4 shows the three areas affected by the UVCE.

According to Fig. 4, it is noted that the propane explosion at the head of column C3 for butane could reach a maximum distance of 307.4 m with an over-pressure effect of 0.02068 bar; which can affect urban areas and other units causing a domino effect.

Fig. 4 Early explosion overpressure radiation (surface plan)

2) *Second Scenario:* Leakage of propane at the head of column

The characteristics of the leak for the second scenario are grouped together in the following table.

Table5Theassumptionsofthefirstscenario

| | |
|---|---|
| Product | propane |
| Phase | Gas |
| Quantity of product in column | 469 kg |
| Pressure | 12 bar |
| Temperature | 38 °C |
| Flow | 57.37Kg/s |
| Height of the break from the ground | 16 m |
| Leak direction | Horizontal |
| Leak diameter | 150 mm |
| Duration of the leak | 8 s |

*a) Jet Fire*

To appreciate the impact of the obtained consequences, we simulate threaten zones of thermal effects related to the jet fire resulting from propane release using PHAST. The results of thermal effects are shown in fig.5.


Fig.5 Thermal effects of jet fire in head of column

Distances and threat zones related to the thermal effects resulting from propane leak in splitter column C3 are shown in Table 6.

Table 6 Distances threaten by thermal effects of the jet fire for leakage from the head of column C

| Climate | Distance | Threshold kw/m$^2$ |
|---|---|---|
| Category 5D | 124 m | 4 |
| Category 1,5D | 90 m | 12,5 |
| Category 1,5 F | 68 m | 37,5 |

*b) BLEVE*

The BLEVE results are illustrated by Fig.6.

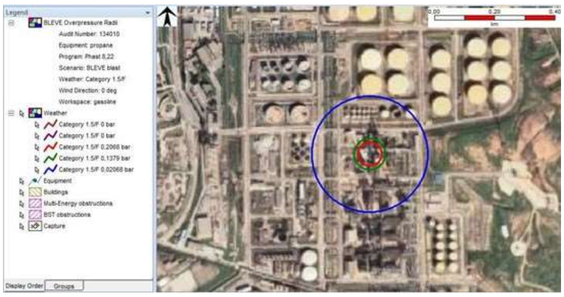

Fig.6 BLEVE Over pressure effects of propane on the refinery

Figure 6 shows the distance for various weather conditions for a BLEVE blast-wave over pressure. For 0,02068 bar and 1.5/F category, the distance from the explosion center is 191,2m (blue contour). For the 0.1379 Bar, the distance from the explosion center is 39.11 m (green contour). For the 0.1379 category, the distance from the explosion center is 51,27m (red contour).

*c) UVCE*

The reported explosion over pressures are illustrated in Fig.7.

Fig. 7 Early explosion overpressure radiation of propane on the refinery

Fig. 7 corresponds to UVCE explosion radiation for leaking propane. The results indicate that the fatal zone was shown with blue contour (1, 5/F category) with distance of 119,2m and 0.02068 bar; it can cause catastrophic consequences that can go beyond the surrounding complexes; these effects lead to severe damages for human, environment, structure and financial loss [15].

*3.3 Comparison of scenarios*

Many flammable products are used in the industrial area; this may have an effect on other facilities. At Skikda's refinery, the splitter column C3 contains butane and propane. In this part of the study, the effects of the scenarios chosen for modeling are compared in order to identify the most dangerous product.

The comparison of potential events of jet fire, UVCE and BLEVE are presented in Fig.8, Fig.9 and Fig.10 respectively. According to the PHAST result, the most important distance and effect were observed for butane at the bottom of the splitter column.

According to the results of Fig. 8, the jet fire can emit large amounts of heat for butane, causing property damage, injury or death in a much larger area than the radius of fire

According to Fig. 9 and Fig. 10 which show different overpressures levels and distances of UVCE and BLEVE respectively, we notice that the intensity of overpressure is more important in BLEVE and especially for butane with a diameter of 331m for 0.02 bar which demonstrates serious consequences for human life, environment and buildings.

These comparisons indicate that the chemical characteristics of the product have an important influence on blast-wave over-pressure explosion; therefore, this depends on the atmospheric conditions.

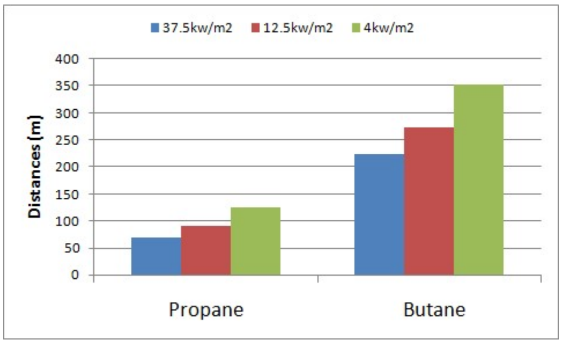


Fig.8 ComparisonofThermaleffects ofjet fire

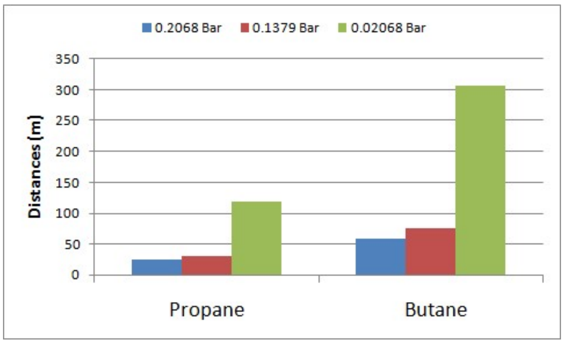


Fig.9Comparison of Thermal effects of UVCE

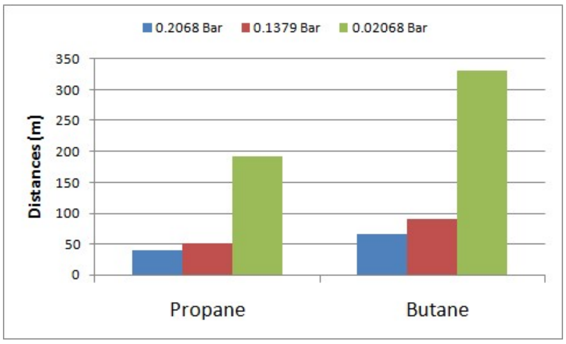


Fig.10 Comparison of Thermal effects of BLEVE

## 4. CONCLUSION

Like any facility classified for environmental protection, the Skikda refinery poses a risk to workers, equipment, and the environment, which has been proven by our risk assessment study.

The aim of our study is to present a systematic methodology to identify and reduce the potential risks in the butane propane splitter column C3 located in Skikda refinery, Algeria.

To achieve this goal the following operations have been performed: HAZOP was used in order to identify the most critical components and scenarios using guide words and deviations. Each possible deviation is examined by identifying its causes and consequences.

In order to understand hazard severity of products contained in splitter column C3, PHAST software was used to model, simulate and predict fire and explosion hazard effects in that area: Jet fire, UVCE and Blast BLEVE. The catastrophic release due to leaking is the worst-case accident scenario for the storage system. The UVCE and BLEVE are the most probable and the most dangerous consequences of the scenario, respectively.

The present work has shown that the most dangerous product in the splitter column is butane.

The results obtained from this study allowed us to state control and preventive measures for reducing and limiting the fire and explosion accident at the head of the splitter column in order to save human life and prevent risk of installations to avoid the financial loss in the considered petrochemical plant.

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