Risk Assessment of a Gas Plant (Unit 30 Skikda Refinery) Using Hazop &Bowtie Methods, Simulation of Dangerous Scenarios Using ALOHA Software.

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Abstract: Process plant and chemical processes are complex and large systems, consisting of thousands of devices interacting with each other [76][45]. The structure of this type of industrial plants lead to difficulties in process control, hence deviations from the operation objectives or desired states. These deviations creates abnormal situations that drive products out of specification, increased operational costs, shut downs and even worse they can cause accidents, which may lead to damages of equipment, environment and affect the health. identifying hazards is fundamental for ensuring the safe design and operation in process plants. Based on the idea of learning from accidents, several techniques and standards are available to identify hazardous situations and help companies to build up strategies to avoid the hazards. In this s work we present a study based on two methods BOWTIE and HAZOP methods applied for an LPG a plant for gas separation located in SKIKDA refinery which is considered as the most important refinery in Algeria where the treatment capacity reaches more than 15 millions tones per year of crude oil. Several recommendations raised from our study to improve the safety of the plant particularly since it is considered as an old plant start working since 1980. The study is completed by simulating the deduced dangerous scenarios using ALOHA software.

Keywords: Safety, probabilistic risk assessment, outcome frequency, event tree analysis

1. INTRODUCTION

With increasing of labor and equipment costs and with the drastic rises of energy prices, it is important to operate ay process plant so as to maximize the economic performance. The optimal economic performance depends on many factors that affect the plant operation and safety. Process plant and chemical processes are complex and large systems, consisting of thousands of devices interacting with each other The structure of this type of industrial plants lead to difficulties in process control, hence deviations from the operation objectives or desired states. These deviations creates abnormal situations that drive products out of specification, increased operational costs, shut downs and even worse they can cause accidents, which may lead to damages of equipment, environment and affect the health and safety of personnel. Therefore, the overall performance of such industrial plants can be summarized into two key words: Control and safety. Based on the idea of learning from accidents, several techniques and standards are available to identify hazardous situations and help companies to build up strategies to avoid the hazards [2],[8][11]. Each proposed methodology has its own limitations due many factors that can be summarized in the following points [2] [8]:

• The application domain of some methods is limited, and with the complexity of industrial plants, the give recommendations will not assure the required safety.

• The generalization of some methods will lead to complex, difficult and time consuming studies.

2. HAZARDOUS AND OPERAILITY METHOD (HAZOP)

A HAZOP study [3], is a highly disciplined procedure meant to identify how a process may deviate from its design intent. It is defined as the application of a formal, systematic critical examination of the process and the engineering intentions of new or existing facilities to assess the potential for malfunctioning of individual pieces of equipment, and the consequential effects on the facility as a whole. Its success lies in called nodes, so ensuring the analysis of each piece of equipment in the process. According to Keltz [8]. " it is the recommended method for identifying hazards and problems which prevent efficient operation". Executing the method relies on using guidewords (such as, no, more, less) combined with process parameters (e.g., temperature, flow, pressure) that aim to reveal deviations (such as less flow, more temperature) of the process intention or normal operation. This procedure is applied in a particular node, viz., as a part of the system characterized for a nominal intention of the operative parameters. Having determined the deviations, the expert team explores their feasible causes and their possible consequences. For every pair of cause-consequence, safeguards must be identified that could prevent, detect, control, or mitigate the hazardous situation. Finally, if the safeguards are insufficient to solve the problem, offering recommendations must be considered [13],[15]

2. HAZOP METHODOLOGY

The flowchart of Fig 1 describes the methodology that should be followed to perform a deeply HAZOP analysis [6],[9] . The following terms are generally used in any HAZOP study

- Nodes: are sections to that a P&ID is divided and then each section is studied, usually nodes are equipment items, however, if nodes are too small so various devices may be joined in a single node.
- Deviation: each line of the node is analyzed applying certain deviations. These deviations results from the combination of a guide word with a property of the line such that:

Guide Word+ Property= Deviation

Table 1 summarizes the guid words, and properies which generally used in HAZOP study [4],[7],[12]

Table 1 HAZOP guide word

Parameter	Deviation
Flow	No/Less
	More
	Reverse
	Misdirected
Pressure	More
	Less
Temperature	More
	Less
Level	More
	Less
Phase/Composition	Different
Operations	Star-up
	Maintenance
	Shut-down
	Sampling
Other	Instrument Air failure
	Fire case
	Tube rupture

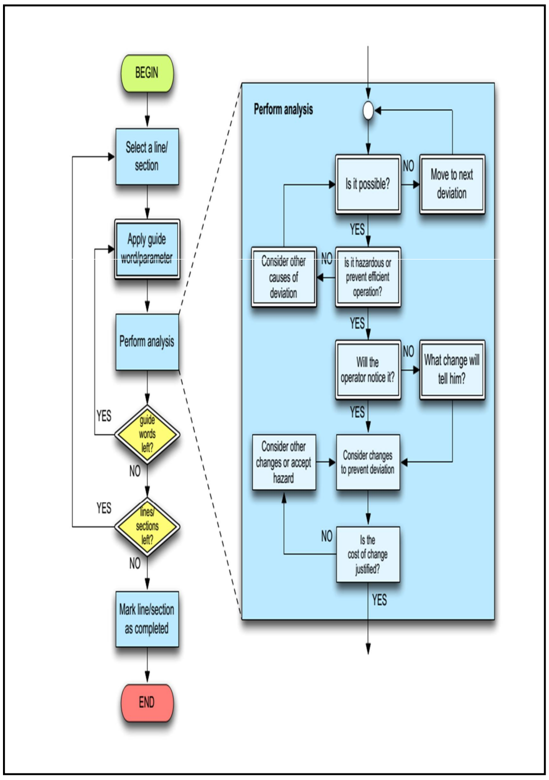

Fig. 1 HAZOP procedure

3. BOWTIE ANALYSIS FOR RISK ASSESSMENT

The Bowtie analysis is a qualitative risk assessment methodology that provides a way to effectively communicate complex risk scenarios in an easy-to-understand graphic format and shows the relationships between the causes of unwanted events and the escalation potential for loss and damage. Bowtie can display the commands, which prevent the Top event from happening primarily, specific to each threat and also the recovery measures that are ready to limit possible effects once the Top event has been accomplished, specific for each credible result

4. ADVANTAGES OF A BOWTIE ANALYSIS

The main advantages of the approach to adopting Bowtie shown in Fig. 2 in the risk analysis are [1]:

- Provides a solid technique and measure of comprehensive identification of all risk events n promo an understanding of their reciprocal reasons.
- Uses a format in the form of an easy-to-understand scheme to communicate the cause and effect relationships underlying

more complex risk scenarios for a wide range of the industrials particularly stakeholders.

- It helps to clearly demonstrate the level of

- Allows verification and connection to relevant sections of the management system that support controls (including critical security elements and critical safety activities);

- Increases the awareness of the workforce on the risks associated with their facility and how they are managed; and
- Uses the knowledge and expertise of the workforce, which best understands the actual state of operation of existing controls and threat

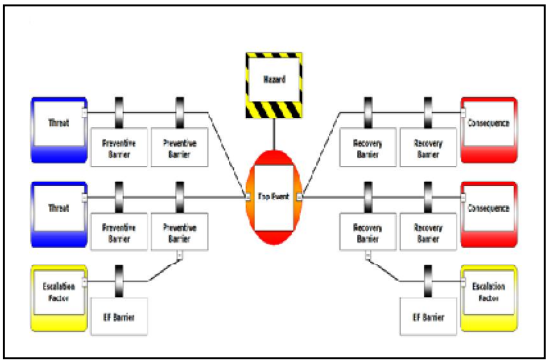

Fig. 2 BOWTIE diagram

A. BOWTIE PROCEDURE

To manage the risks, a helpful feature is that of the risk status. The risks are assigned one of three statuses: 1) inactive risks, when these have been identified but not accepted as actively applicable in the risk register; 2) active risks, are those that are currently recognized as open threats to or opportunities for the project; 3) past risks, are those have been assessed to no longer pose a threat or opportunity to the project's objectives [5].

For quantitative risk analysis, there are three types of risk's magnitude (exposure):

- pre-treatment (the magnitude of the risk if nothing is done),
- post-treatment (the magnitude of the risk successfully implemented) and
- target exposure (if all accepted treatments are implemented, preferably based on realistic assessments of the effects on probability and impact of the risk by each accepted treatment) [2]

5. ALOHA SOFTWARE

ALOHA® [1] is the hazard modeling program for the CAMEO® software suite, which is used widely to plan for and respond to chemical emergencies. ALOHA allows you to enter details about a real or potential chemical release, and then it will generate threat zone estimates for various types of hazards. ALOHA can model toxic gas clouds, flammable gas clouds, BLEVEs (Boiling Liquid Expanding Vapor Explosions), jet fires, pool fires, and vapor cloud explosions. The threat zone estimates are shown on a grid in ALOHA, and they can also be plotted on maps in MARPLOT®, Esri's ArcMap, Google Earth, and Google Maps. The red threat zone represents the worst hazard level, and the orange and yellow threat zones represent areas of decreasing hazard (Fig 3)

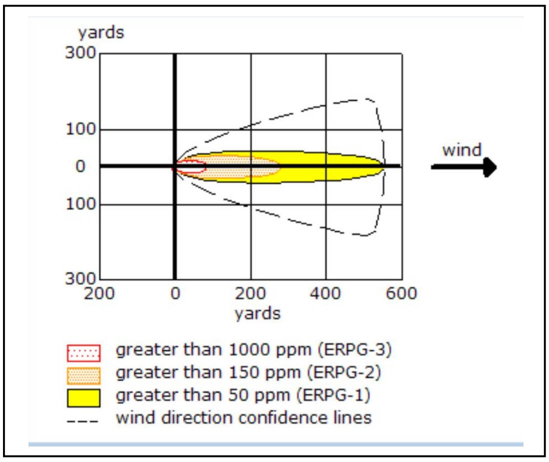

Fig. 3 Typical ALOHA representation.

6. PROCESS DESCRIPTION

SKIKDA refinery is the biggest refinery in Algeria such that 70 % the Algerian hydrocarbons products are produced in this refinery, the treatment capacity reaches 15 Millions of tones per year. The refinery consists of two main trains each includes one crude distillation (CDU) and LPG unit. The crude distillation units (called TOPPING) are units 10 and 11 the LPG plants are units 30 and 31 the crude is first separated in the CDUs and fed to the LPG plants. LPG is received at Gas Plant-I (Unit 30) from CDU-I (Topping) Unit 10. This stream is saturated with water and may even contain little amount of free moisture. This moisture needs to be removed prior to sending it to the

Propane and butane recovery sections. It is desired to have a flexibility to line up the LPG from Topping Unit 10 to Gas Plant-II (Unit 31).A jump over is provided between Unit 30 & Unit 31 to achieve this. LPG from Topping unit 10 first passes through the Coalescer V-7 where all the free moisture is separated. The separated free water is drained through a level control valve working on the interface level in the coalescer. The saturated LPG then is passed through the LPG drying columns C-4 A/B. These Molecular Sieve bed dryers work on a batch mode. One column is in drying service while the other is under regeneration. As soon as the drying column is saturated with water, the flow is switched over to the other column, which is ready after regeneration. The duration of the absorption phase depends on the type of treated crude and will range from 8-24 hours. The duration of the regeneration phase is about 7 hours. Regeneration operation involves draining of the column, depressurization, regenerating with hot gas, cooling and refilling with LPG [14]. Fig 4 shows a DCS (Distributed control system) statistic view of the major equipment of unit 30.

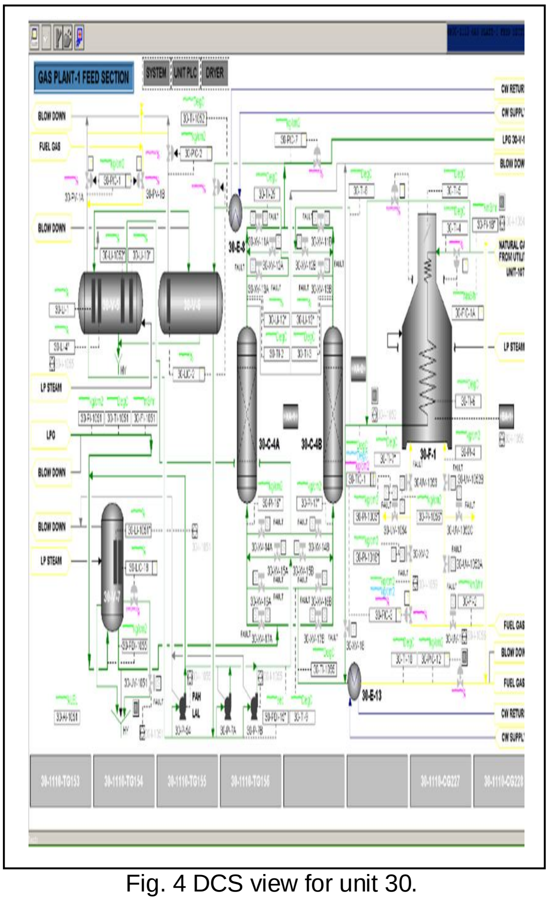

Fig. 4 DCS view for unit 30.

It should be noticed that the second gas plant unit U31 has the same architecture and capacity of U30. Moreover there is a small unit called unit 104 is dedicated for gas treatment but with small capacity.

7. RESULTS AND DISCUSSIONS

In our study we consider the HAZOP of the total gas plant unit 30 where the following nodes are considered. In the same node we may consider more than one stream, i.e in the process flow diagram we may handle two products so each will be considered alone.

1. **Node 1**: LPG from CDU-1 and CDU-2 to inlet of LPG Feed Accumulator, including Dryer.
2. **Node 2:** De-ethaniser column
3. **Node 3:** C3/C4 Splitter
4. **Node 4:** Regeneration gas system
5. **Node 5:** LPG drain and storage system

From the remarks deduced from the application of HAZOP study on the whole unit which means the application of HAZOP for all mentioned unit we end up a main dangerous scenario that may happen and lead to explosion is an overpressure in the accumulator (knowing that this phenomenon may happen in the storage tank but these tanks belongs to another unit).

So we focus our discussion only on **Node 1** where the accumulator is included, and the explosion scenario is expected.

Table 2 summarizes the HAZOP study and the necessary recommendations.

Fig-5 shows Bowtie diagram for the scenario of an explosion in the accumulator due to an over pressure in the accumulator whereas

Fig 6 and 7 show the ALOHA modelling of this scenario along with the areas that will be affected by the explosion and distances.
In the paper only the recommendation sheet is indicated (that means only where the dangerous situation is expected).

Table 2 HAZOP recommendation sheet

Deviation	Causes	consequences	Safe guards	P	G	R	Recommenadtions
No/Less Flow (LPG	- UV-1163 malfunction to clause due to instrument air loss - Malfunction of pump MP-51 A/B LPG feed pump. - Leackage in heat exchanger	The level in the accumulator will increase which will cause an overpressure and apperance of LPG in the dfuel gas line Dammage in the tubing of E-1	FAL 4 low flow alrm in the FIC-4 in the feed of De-ethaniser . - Level alarm High in the accumulator Feed LAH -3 - LAHH 1152 High high alarm wih the interlock I-1164 that causes the the fully close of UV-1164 in the line LPG to FG. - Runing indication for the moto-pump in DCS . - PSV of Butane sphere	4	0	T	
More flow	- Accidently the by pass is open	Low level in the bottom of the accumulator	- Flow alarm High in FIC-4 - Level alarm low in LIC-3	1	2	A	
Low Pressure	- The PT-1159 gives bad reading	PV-1164B will open and PV-1164° will close which will cause a loss of gas to blow down . that will cause a low level in the accumulator the fact may lead to cavitation of pumps P-51 A/B	Low alarms in DCS for the following - LAL in LIC 3 - FAL in in FIC-1152 - FAL in FIC 4 The state indication for PT 1159 in case itis malfunction (it will be shown in violet color)				
More (high pressure)	- The same as more flow case						
Less temperature	- No possible cause						
More temperature	- External leackage in LPG line	Possible of fire in case other condition	AAH (high alarm in the gaz detector AI-11511	3	1	T	Provide an automatic sprinkler system in the pump P51A/B controllerd by the gas detector (redundant system)
Less Level	- Draining valve to the system (OWS) is open	Loss of C3 and C4 to atmosphere with the possibilite of fire	The operators assistance in the daining operation is satrted.	3	1	T	- Gas detectors should added near drainig valve
More level	- The same as low flow case						

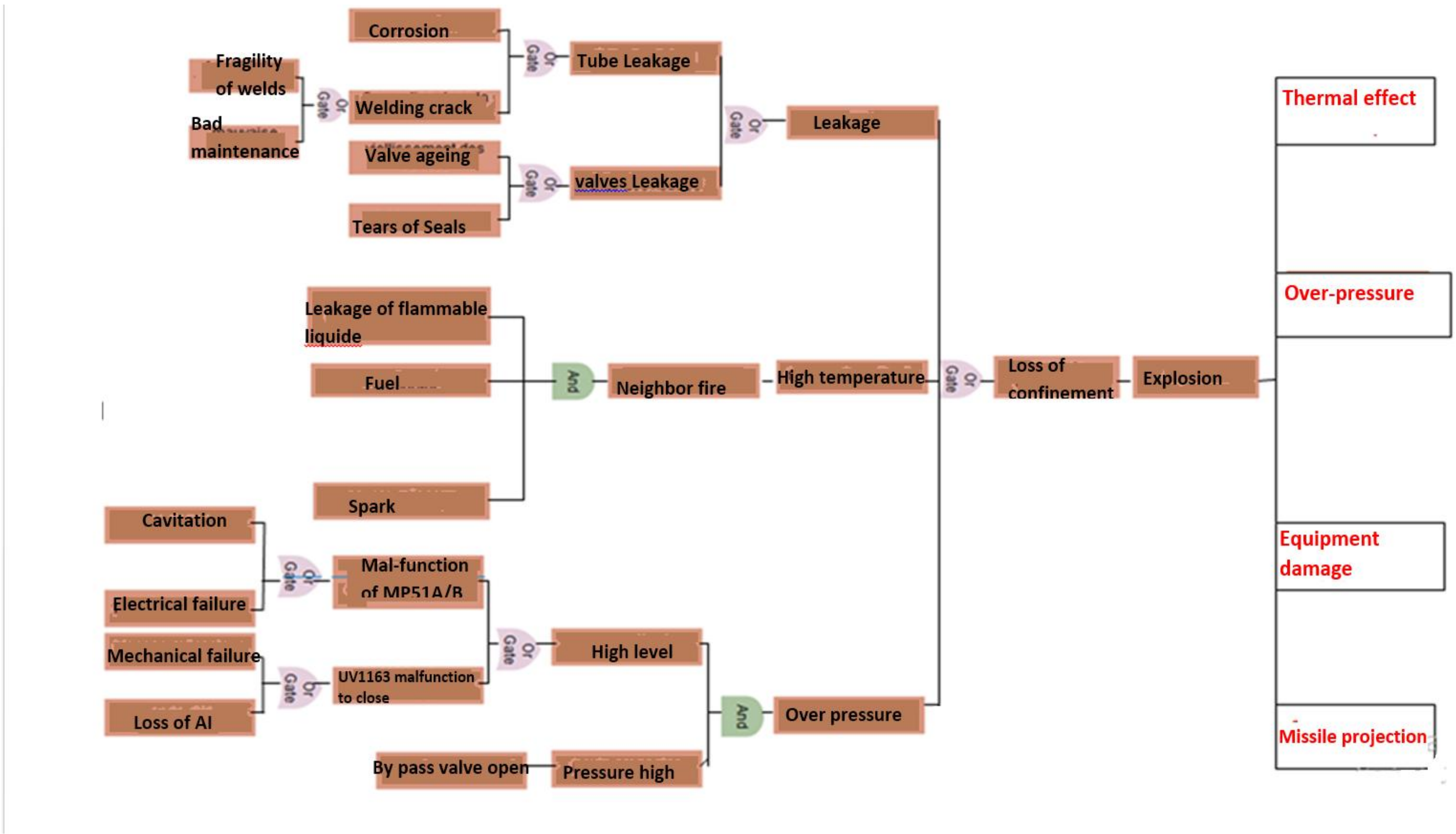

Fig-5 Bowtie diagram for accumulator explosion scenario

ALOHA simulation for an explosion in ACC V1

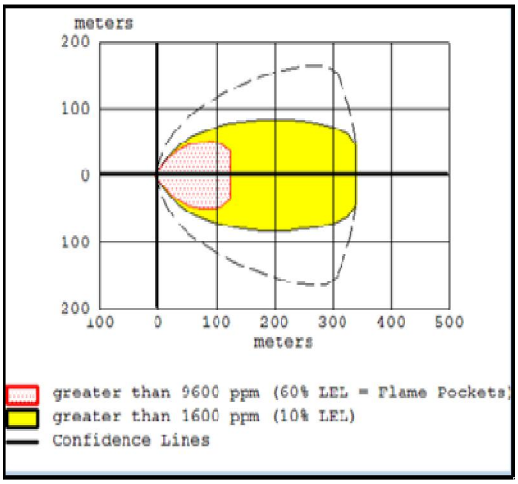

Fig. 5 The threat zone due to explosion in accumulator V 1

Fig. 6 The threat zone due to explosion in accumulator V 1 (real data)

As it is shown in the figures any explosion may lead to a damage of many facilities in the refinery , the fire may be extended to other units U10,U11, U1050, and the pipe way , this may extend the fire to other units or may cause problem to near town buildings

8. CONCLUSION

The aim of our study is to improve the safety an LPG plant (unit 30) in SKIKDA refinery , the followed procedure consist of preparing a HAZOP study where all scenarios are examined and the necessary recommendations are raised. After that one dangerous scenario which is the explosion of the accumulator V1 is considered and BOWTIE diagram is constructed for this scenario in order to show all possible causes and highlight the existing safeguards. And at the end and using ALOHA the effect of a possible explosion is modeled the results show that this scenario will affect the global refinery since the pipe way is located in the red zone which means that the fire will be extend to reach other units such as crude distillation and different units tankage zone, even the building which belongs the town near the industrial zone will be affected by this explosion.

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