RECENT J. (2019), 58:056-063
https://doi.org/10.31926/RECENT.2019.58.056

Study of the Conformity and Dimensioning of an Anti-Fire Network in a Hydrocarbon Depot

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Abstract
Fire is, in many respects, a devastating element that once unleashed can be the cause of both human casualties and significant material damages. Indeed, fire claims the lives of many victims and destroys property and environment every year. The losses are in the majority of cases very heavy and especially when the fire hits a hydrocarbon structure. The Hydrocarbon industry is unfortunately on a daily basis the target of this unforgiving enemy that can turn everything into ashes in just few moments. Consequently, the task of fighting and extinguishing of pot or tank fires is often a difficult and time-consuming process. The use of fluid gases or hydrocarbons at temperatures close to their ignition temperature can therefore make each plant, workshop, transport, or even activity as dangerous and any failure can cause a devastating fire. The causes of this type of fire are various and of different origins. The most common are the natural causes such as lightning, floods, earthquakes in addition to technical causes ex, leaks and organizational or human ones such as overflow during filling, maintenance or welding. Hence, the increasing interest in research and accidents analysis and the continuous development of fire extinguishing means. One of the factors that make the task of providing reliable and comprehensive overview of preventive measures more challenging is the multiple uses of hydrocarbons in a large array of working situation. In this context, we will study the dimensioning of the anti-fire network and its conformity with the applicable regulations at the level of the fuel area of the oil company NAFTAL EL KHROUB. Our work aims to answer the questions that are always asked: what are the measures to take to eliminate or reduce the consequences of this risk in the event of an accident? As fields of application, we have chosen NAFTAL, which is a joint-stock company, subsidiary of SONATRACH, whose mission is the marketing and distribution of petroleum products.

Keywords
fire, hydrocarbons, compliance, damage, anti-fire-network, dimensioning

1. Introduction

Security has become a major concern in industrialized countries [1, 2]. The safety results reflect the quality of the overall organization of the company. Indeed good results generate confidence among customers, shareholders, financial analysts and residents living near production facilities [3, 4]. Although these concerns are not new to industrial companies, industrial safety and the protection of the environment have become for all companies major strategic issues exactly like economic and social performance. The fact that liquid gas or hydrocarbons can be used at temperatures close to their ignition temperature puts each plant, workshop, storage and transportation of hydrocarbons in hazardous situations where explosion and / or fire are the main consequences [5]. At the present time, fire is a destructive element causing many human casualties and significant damage with very high costs, especially in the chemical and hydrocarbon industries where the risk is even higher and can turn everything to ashes in a matter of moments [6]. Adding the fact that the multiple uses of hydrocarbons in different working situation hinders the endeavour of providing a detailed and comprehensive overview of preventive measures to tackle the different work situations [7, 8]. Nevertheless, it is possible to identify the key features of the measures to be taken in different examples. Thus, fighting and extinguishing tank fires are often difficult processes that take tens of hours when they are overcome [9]. This is why the research and analysis of accidents is evolving increasingly in an attempt to master fire-extinguishing means. In this context, our objective in this work is the evaluation of a fire safety network and its compliance with the regulations in force at the fuel department of the company.

2. CBR El-K Hroub Constantine District Presentation

NAFTAL is a joint-stock company, subsidiary of SONATRACH, whose mission is the marketing and distribution of petroleum products. The fuel branch is one of the three branches of NAFTAL. It is responsible for the supply, storage and delivery of aviation, marine and land fuel (fuel: gasoline, regular and premium, leadless, diesel, kerosene and JET A 1) as well as lubricants and marine and aviation greases. The fuel branch in its aviation and marine activities has obtained ISO 9001 2000 certification since August 2005. The CBR district is part of the NAFTAL unit of Constantine, it is classified among the major strategic districts of NAFTAL, located on an area of 24 hectares, located 21 km from the Wilaya (district) of Constantine precisely the common axis of BOUNOUARA, its main task is to supply the fuel needs of the eastern part of Algeria (gasoline regular and premium, leadless, diesel, kerosene and JET A 1), Figure 1 [10].

Fig. 1. Ground plan of the study area

The district has a storage fleet for petroleum products composed of 12 tanks for five different fuels: regular gasoline, premium gasoline, leadless gasoline, diesel, and kerosene or Jet gas. The products come from the Skikda refinery located 105 km from the centre by a multi-product pipe of 12 inches.

The fuels branch is certified ISO 9001/2008, ISO 14001/2004 and OHSAS (Occupational Health and Safety Assessment Series) 18001/2007 since the year 2012 [11]. Through this certification and as part of the continuous improvement, the aviation and marine activities provide better quality services in order to optimize customer's satisfaction.

3. Risk Identification

If a hardware and / or human failure occurs, the dangerous product can leak out from their containers and spread into the atmosphere, creating a toxic cloud, fire and / or explosion usually ends in a disaster (human casualties, material and / or environmental damage) [4, 12]. The consequences can exceed and spread and touch other neighbouring facilities (dominoes effect) and the accident becomes major.

Refineries are henceforth classified as "high threshold" for most of their activities. Hazard studies for new or modified installations, revisions or additions to the hazard studies required by the regulations will allow the mapping of the zones of effect and thus the hazards around these installations. [13] Therefore, to meet these industrial and corporate expectations, preserve the sustainability of the company and ensure its operational performance [12], and even are competitive in the national and international market, a danger study is required. The risks that may occur within the district are [13, 14, 15].

3.1. Risk of Boil-Over

The boil-over is a phenomenon that can occur during prolonged fire in a tank containing Category C products, usually several hours or even several tens of hours after the start of the fire. The boil -over is a phenomenon involving the fire of an atmospheric reservoir, and causing the vaporization of a bottom of water, free water or emulsion in the mass of hydrocarbons. The vaporization of the water at the bottom of the tank causes a very rapid expansion (1700 to 2000 litters of steam per litter of liquid water) acting like a piston and expelling the hydrocarbons out of the tank generating a large fireball.

3.2. Flash fire

Free-field combustion of a hydrocarbon / air mixture ignited by a low-energy source, the flame front moves at low speed (less than 12 m/s) and does not generate a surge wave.

3.3. UVCE (Unconfined Vapour Cloud Explosion)

Combustion of a hydrocarbon / air mixture where the flame front crosses the mass of gas with subsonic celerity (relative to the medium upstream of the combustion wave); if the flame encounters repeated obstacles, the combustion accelerates, resulting in an increase in the speed of the front flame and generation of a shock wave.

4. Describe the Potential Hazards of the Site

The products implemented on the site are diesel and gasoline. They are stored and transferred at ambient temperature and pressure. These fuels mainly present fire hazards as well as explosion hazards but only for gasoline (the diesel flash point, higher than 55 °C, being higher than the normal temperature conditions). Table 1 presents the dreaded events and associated hazards linked to the implementation of these products [16].

Table 1. Characterization of potential site hazards

Equipment in question	Dreaded events	Hazardous phenomena
Bins	Leak, Fire, Explosion Overflow; Lightning Static electricity Advanced corrosion	Water and soil pollution, bowl fire, tank explosion for diesel: Boil over for gasoline: flash fire, UVCE
Loading / unloading	Leakage and pouring Static electricity	Water and soil pollution, fire for gasoline: flash fire, UVCE
Product line	Leakage, corrosion and rupture	Water and soil pollution, groundwater for gasoline: flash fire, UVCE
Pompeii produced	Flight; Static electricity	Water and soil pollution, groundwater for gasoline: flash fire, UVCE
Bowl	Sealing (Sealant)	Water and soil pollution for gasoline: flash fire, UVCE

5. Network Dimensioning: Case Considered [16]

The circular for November 09th 1989, article 12 considers the largest dock containing the largest tank. Thus, the dock with the largest bowl is No. 1; the thanks of the dock which causes the greatest risk are the 11,000 m^3 tanks 8, 10 and 11, Figure 2.

There is an 11000 m^3 tank located in the bowl 2 but this bowl is the smallest. This is why our study will consider the tank 10 of the bowl 1 as a study case, because it is the worst case; the tank 10 located between the two large tanks 8 and 11 in the dock 1. The dock 1 has 05 tanks with fixed roof gasoil storage and unleaded gasoline. Dock 1 stores associated category B and C products, ICPE bill of materials 1430 (October 2007) states that in a similar case all products will be considered as the most vulnerable product category with the lowest point of lightening entry. Thus, the entire dock will be considered Category B at the point of light gasoline less than zero, Re 1430 of the ICPE bill of materials of October 2007 [17]. In addition, if flammable liquids are stored in the same holding pan or handled in the same shop, they are considered to be flammable liquids of the most inflammable category.

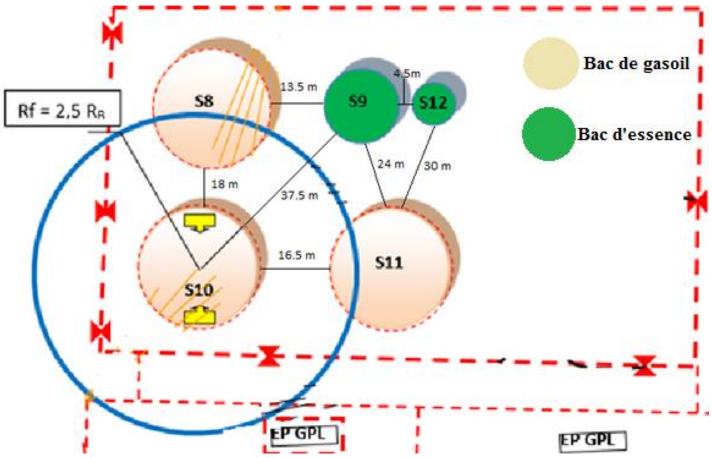

Fig. 2. The fictitious radius of the tank and the distance between the walls of the tanks

5.1. Water network

5.1.1. Evaluation of the regulatory water flow

According to the circular of March 21st 1975, article 602, pages 94, the regulatory flow Q is the sum of the cooling rate Q_{ref} and the flow Q_2 required for the production of foam: $Q = Q_{ref} + Q_2$.

The cooling rate Q_{ref} is equal to the sum of the cooling rate q_1 of the tank assumed to be on fire and the cooling rate q_2 in a close place of the backs. The cooling rate q_1 of the tank on fire for a liquid hydrocarbon product of category B is 15 l/min/m circumference. The exposed docks that must be considered are the docks located within a radius r_f called fictitious radius [13].

The results of calculation of the flow of water and the mouse are indicated in the Table 2.

Table 2. Water flow for cooling and foam

Tank	Circumference (m)	Side surface (m^2)	q_1 (l/min)	q_1 (m^3/h)	q_2 (l/min)	q_2 (m^3/h)	Q_2 (m^3/h)
8	100.794	1475.62	/	/	1844.52	110.67	/
9	61.23	896.4	/	/	/		/
10	100.794	1475.62	1511.91	90.71	/		161.77
11	100.794	1475.62	/	/	1844.52	110.67	/
12	35.796	393.04	/	/	/		/

5.2. Foam network

5.2.1. Application rate calculation

The circular of May 06, 1999, keeps the first conditions of the circular of 09 Nov 89, but defines the rate of application as [17]:

$$T_a = \left(T_{\exp} \times K\right) + 0.5, \quad \text{in [l/m}^2\text{/min]} \tag{1}$$

where: T_{exp} – experimental application rate;

K – an operational coefficient which characterizes the response capacity specific to each site:

$$K = 1 + \left(f_1 + f_2\right). \tag{2}$$

The experimental application rate for a class I film-forming emulsifier is T_{exp} = 2 l/m^2/min.

According to Circular of 06/05/99 [17], the values of the increases (f_{1i}) whose sum determines the factor f_1 are given in Table 3.

Table 3. Calculation of factor f_1 ($f_1 = \sum f_{1i}$)

Designation	State on the site	f_{1i}
Accessibility alongside the bowls	Two inaccessible sides	0.5
Congestion in the bowls	Five bordering bins and piping	0.2
The range of the throwing spear	Obstacle walls	0.25
Climatology	wind	0.1
Number of impact points	/	0

The value of the factor f_1 is:

$$f_1 = \sum f_{1i} = 0.5 + 0.2 + 0.25 + 0.1 + 0 = 1.05 \tag{3}$$

According to Circular of 06/05/99 [17], for the analyzed case the factor f_2 has the value $f_2 = 0$.
The value of the operational coefficient K is easily determined:

$$K = 1 + (1.05 + 0) = 2.05 \tag{4}$$

Under these conditions, rate of application T_a has the value

$$T_a = (2 \times 2.05) + 0.5 = 4.6\,, \quad \text{in [l/m}^2\text{/min]} \tag{5}$$

5.2.2. Calculation of the foam flow

The largest pot of the deposit is the pot 01 containing the tanks 8, 9, 10, 11 and 12. The surface of the pot is 9405 m^2. The largest tanks are tanks 08, 10 and 11 with a diameter of 32.1 m.

The study focuses on the tank no. 10, whose surface area is S = 809,28 m^2.

According to the circular of March 21st 1975, for this tank the volume of foam necessary for the back on fire is V_m = 161.77 m^3 (see Table 2).

5.2.3. Calculation of the foam volume V_m

The concentrate foam must be at least equal to that necessary to cover the area of the largest holding tank (non deducted tanks) containing Category B, C1 or Dl hydrocarbons by a thickness of 0.40 meters of foam (Article 37.21), meaning

$$V_m = 0.4 \times S\,. \tag{6}$$

The pot 01, the largest in the warehouse, has the surface S = 9405 m^2. According to relationship (6), the necessary foam volume is V_m = 0.4 × 9405 = 3762 m^3.

5.2.4. Calculation of the volume of the foaming solution

The expansion coefficient of the concentrate foam used is F = 6, and is and is the ratio by volume of foam V_m and volume of foaming solution V_{Sm}:

$$F = \frac{V_m}{V_{Sm}}\,. \tag{7}$$

Cunoscând volumul necesar de foam şi coeficientul de expansiune F se determină volumul necesar pentru foamining solution:

Knowing the necessary foam volume and the expansion coefficient F, the volume required for the foamining solution is determined: $V_{Sm} = V_m / F$ = 3762 / 6 = 627 m^3.

5.2.5. Calculation of the amount of foam concentrate

The concentration C of emulsifier used in the centre is 6%. An E amount of emulsion is required to obtain a V_{Sm} volume of foaming solution:

$$E = C \times V_{Sm}\,. \tag{8}$$

Knowing C = 6% = 0.06 and V_{Sm} = 627 m^3, it is determined that is required an amount of emulsion $E = 0.06 \times 627 = 37.62$ m³.

5.2.6. Calculation of the service pressure

They are known or determined P – the available pump pressure and ΔH – the pressure drop at the most unfavourable pole. Depending on these two sizes, the pressure p is determined:

$$P = p + \Delta H \quad \Leftrightarrow \quad p = P - \Delta H \,. \tag{9}$$

The flow rate Q of the pump is dependent on the pressure p:

$$Q = y \times \sqrt{p} \,. \tag{10}$$

Using the previous formulas one can establish the results presented in Table 4.

Table 4. Determination of diameters of cooling and foam pipes

Tanks	Cooling flow medium (m³/h)	Water flow rate for foam (m³/h)	Diameters of water pipes	Diameters of foam pipes
Pot 01				
BAC 10	90.71	161.77	4 "	4 "
BAC 08	110.67	161.77	4 "	4 "
BAC 11	110.67	161.77	4 "	4 "
BAC 09	67.23	59.69	4 "	4 "
BAC 12	29.47	20.40	4 "	4 "

6. Dock Fire Scenario Study

The dock 10 of diesel is the largest ferry and is the more vulnerable given the state of the bowl 1 and the size of the tanks. The dock 10 on fire, the adjacent dock to be cooled is the bins 11 and 08, Figure 3. The results are presented in Table 5.

Table 5. Water and foam concentrate needed

Tanks	Water flow tray on fire (m³/h)	Water flow tray next door (m³/h)	Water flow required for foam (m³/h)	Regulatory flow (m³/h)	Water reserve (m³)	Quantity of emulsifier (m³)
10	90.71	/	161.77	473.82	1421.46	37.62
08	/	110.67	/			
11	/	110.67	/			

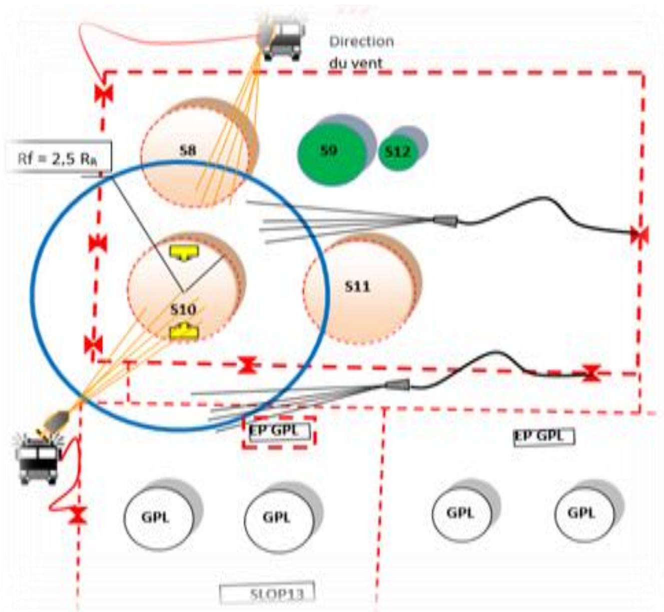

Fig. 3. Scenario: Fire on fixed roof of the tank Gasoil no. 10

7. Emergency Plan

Action to be taken simultaneously just after the cessation of exploitation:

- Activate the foam chambers by ensuring a foam film on the entire surface of tray no. 10 in fires with a thickness of 20 cm in order to eliminate the supply of oxygen;
- Cool the fire tray with available fixed or mobile installations (watering crowns, water lances);
- Establish a water curtain to protect the bins inside the cylinder fictional or by means of crowns and water lances.

8. Conclusion

The fire systems at the Naftal warehouses must be subject to compliance studies in accordance with the standards in force since a fairly large number of warehouses are old and since the feedback of experience at international level brought further improvements in the field of sizing. Now, some standards and obligations are imposed by strict regulations in the workplace, but these rules are not immutable. The compliance of the fire protection networks has since been revalued by the direct managers and is part of the policy of the companies.

In this context, our present work responds to the study of the dimensioning of a fire safety network and its compliance with the regulations in force at the level of the fuel district of the company NAFTAL EL KHROUB. As a result, this article will have to be considered as a step of continuous improvement in the management of industrial risks in the means and procedures necessary to control these risks, or even to help those responsible for setting up a control policy i.e. maintenance and action in prevention.

9. Recommendations

The following security measures must be appropriate for storage:

- Realization of floating screen inside the fixed tanks storing gasoline to reduce the quantity of vapour emitted by the product;
- Renovation of facilities by installing remote gauging systems and a control room with synopsis;
- Isolation by positive safety valves, automatic closing of supply valves;
- Installation of alarm boxes of very low level and very high level (LALL / Lahh);
- Check valve installation on product receipt and delivery lines;
- Installation of the pressure and temperature sensors on the pumps;
- Separate the rainwater network from the tank purge system to increase the water tightness of the curettes';
- Regular monitoring by the inspection of all equipment;
- Systematic monitoring of all the pumps maintenance (vibrations, noises, general condition);
- Establishment of a liquid or gaseous hydrocarbon leak detection network;
- Distribution of liquid hydrocarbon detectors and vapour detectors in curettes' to detect leaks with alarms;
- Installed the dome loading station by transforming it into a source loading station with solenoid valves and counter to avoid overflows and vapour emissions.

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