Fireworks: Explosion risk Vs. class 1.4 definitions

RAFELCOFER CATASTROPHE SUMMARY

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1. BACKGROUND

13th may of 2000 a fireworks storage in Enschede, Holland ignites and explode, results 400 houses were destroyed and 1000 damaged, 18 dead, 3 missed and 947 injured, 11 people in intensive care, (4 firefighters are killed, 3 from the first engine and 1 from the second). 15th may of 2000 a fireworks enterprise in Spain ignites and explode, results seven dead, 35 constructions inside of the enterprise terrain missed and several buildings affected in the near village.

Both enterprises starting the accident with a little fire, and latter an explosion erased the entire enterprise and your surrounded.

Meanwhile, internationals regulations classify fireworks in the class division 1.4 and established some things like that:

Division 1.4 Explosives with no significant blast hazard

Where is the problem then?

2. INTRODUCTION

We are walking in the millennium, we can remember the science fiction films in the eighty decade, the millennium was presented like the fantastic year, where the technology reached the maximum level and sophisticated tools was handled in all scenarios.

So, now we are in the millennium, in some terrain we are in the peak of the technology development, certainly the news system and tools have increased in quality and efficiency, but in the other side, when we are speaking about the real scenarios of emergencies aspects, things change, in this field, prevention systems and protocols has been established supported in theory concepts, experts groups, which in general not include operative experts decide, based in your theory experience, standards for handled accident in real scenarios, results can it see, explosives with no significant blast hazard (for example fireworks), can destroy dozens of humans lives and to demolish an entire quarter.

3. REPORT

The first target of this report is to evaluate the accident happened in Rafelcofer (Valencia) when an enterprise of pyrotechnic products (which we know as fireworks) was exploding, with the result of seven people dead. In the second side we want show and comment the effects happened in the accident, different tested methods to evaluate the blasting consequences, and to contrast it with the actual rules about this products.

In Spain they are more than 250 enterprises related with the manipulation of pyrotechnic products, most of them located in the Valencia Community.

The experts consider that the regulation codes in this matter are very demanding, but it is still necessary to intensify more the measures of security on this sector considered of high risk.

15th may of 2000, at 16:04 o'clock, an alarm was received in the Central Command which report a series of explosions in the

pyrotechnics enterprise called "Vicente Borredá" in the east coast of Spain, in the municipality of Rafelcofer. This enterprise have an approximately surface of 13500 m^2. Inside the enterprise terrain 35 constructions existed, 28 of those which contained pyrotechnic material.

The facility are located in the countryside 600 meters Southeast direction to the border of the village.

Three big explosions had taken place with approximately 2 seconds among them. The first units of firefighters arrived to the place 15 min. later, finding the installation razed by the explosion, and several members of the Police and volunteers inside of the risk area.

The first evaluation showed a double emergency situation; a forest fire and the research and rescue of the victims at same time that the different fire focuses in the facility area are extinguish.

The three initial explosions had left great quantity of explosive material spread in the intervention area, and several detonations was happened at same time that the victims were carried out.

The rescue task were made with relative speed due to the help give for the owner of the enterprise which knew the approximate location where the victims could be, it allowed to transfer the victims until the sanitary teams located at 300 m approximately in the safety zone.

When more resources were arrived, two commandment post were established, one for mange the extinction of the forest fire and the main one for manage the intervention in the pyrotechnic zone. The forest fire was controlled at 20:55 o'clock affecting to a surface of 4 hectares.

At 20:30 o'clock they had recovered 5 bodies without life, 1 great burnt that died two days later and some less serious wounded. The following morning was found the last victim's body.

When the fire forest was extinguish and the victims rescued, an assessment to the zone was made, and the result was the following:

Inside of facility area they are a magazine of approximately 4 m X 3 m in whose interior they are about 3000 Kg of pyrotechnic material without blasting, this quantity were equivalent approximately to 1500 Kg of gunpowder. To this it is necessary to add an uncertain quantity of pure heavy metals in salts form.

The building containing this materials were in a state of critical stability, with the roof displaced from your normal position, walls with big slopes and deep fissures along the walls.

Most of the explosive was in plastic bags and packed in cardboard boxes, it is bookcases lead in the walls, their position can be consider like very unstable.

The contained material in this magazine could to explode for percussion, not being necessary the fall of the construction; it would be enough with which some package falls with some speed.

In front of this situation three possible alternatives are considered:

1. Flood with water: Not acceptable.

The execution of this alternative required to made a contention wall or some other type of waterproof or half waterproof barrier around the magazine, of approximately 2 m height and later filling it with water. After a prudential time which the material are submerged, this it could be take out under sure conditions. This alternative was not estimated in the others for the following questions:

a. Building the wall will take many time of personnel near to the magazine.

b. In case that the wall are executed, when flooding it with water would unstabilized the magazine and to originate a not controlled explosion.

c. Due to the type of having packed, bags of plastic and cardboard, the time needed for to wet the material it could be guaranteed only by a very high times of immersion.

d. The presence of heavy metals, susceptible to reacting with water producing H_2 and heat, it could be enough to cause the explosion in the initial moments.

2. Manual Extraction of the explosive material and transport to safe place: Not estimated.

This alternative involved that several people work in an area of high risk during the needed time to displace 3000 Kg in small packages, entering and leaving an unstable construction. The assumed risk was very high, because was need to stabilise the construction at first in an appropriate way for ensure the structure and working safety, but they were practically impossible. If during the extraction it failed the structure or it fell some explosive package the possibilities of survival of the responders they were practically null.

3. Controlled Detonation: Estimated.

This proposal were considered as the most simple and sure execution, also this way were the only one that guaranteed the control of the detonation in the time. The technical in explosive of the Civil Police, they should enter in the magazine, to place the detonators artefacts and to decide the detonation of them in a time.

We knew that this detonation would cause a forest fire, but this not would be a big problem because we could easily controlled, having the appropriate extinction means in advance. Nevertheless, the biggest concern was the effect that the detonation would have on the houses of the town of Rafelcofer, approximately 600 m. to the site of explosion.

Two vulnerability assessment were carrying out concerning to the people and goods, which will by develop more later, one was made by the Civil Police and the other side for the Fire Service of Valencia Metropolitan Fire Brigade. When the assessments were concluded, the Integrated Commandment Centre of the Community considered that it was an assumable risk, since it was expected a low probability of break of glasses and non structural damages in houses, without presence of projectiles.

4. VULNERABILITY ASSESMENT

We don't intend made an exhaustive study of the methods for estimate explosion effects, but we need made some considerations for refresh the actual conditions for estimating effects with the available mathematical algorithms.

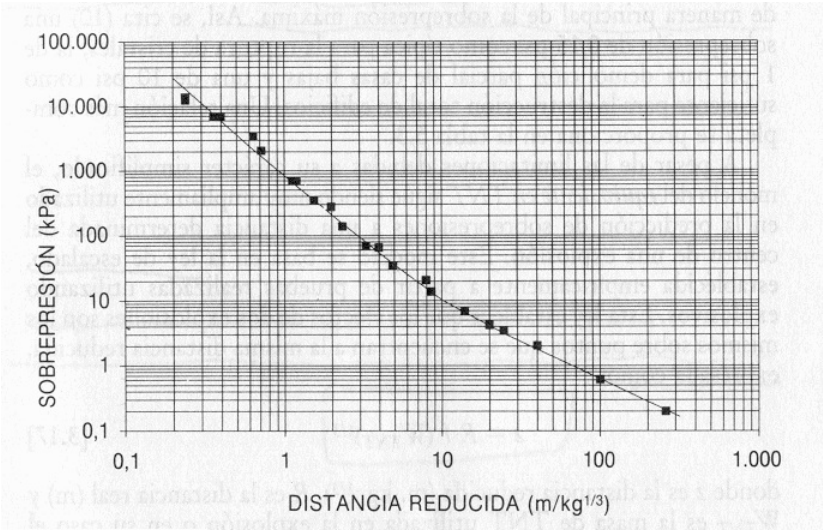
For estimate the effects of an explosion in function of the distance should have in consideration that, although they also influence factors like the speed of the increase of pressure, the duration of the positive phase and the later negative phase, the damage happened by an explosion depends mainly of the maximum overpressure value.

Two method were used for the assessment, both based in the TNT equivalent mass, the first one using this value with the empirical scaling law and the algorithm of reduced distance, and the last one using the algorithm of Lee and building the curve distance-overpressure for the specific scenario of this accident, the results are presented following.

In spite of the limitations dues to the simplified character, the model of the TNT equivalent continues being the most thoroughly used in the overpressures estimation at a distance give of the explosion centre. This model is based on the scaling law, established empirically from the carried out tests using explosives. This law establishes that the effects of two explosions are the same on the points that they are at the same reduced distance, expressed as:

$$Z = R/(W_{TNT})^{1/3}$$

where Z is the reduced distance ($m.Kg^{-1/3}$), R is the real distance and W_{TNT} it is the mass of TNT used in the explosion or in its case the equivalent mass in TNT of the liberated energy. Strictly, the scaling factor is the cubic root of the energy instead of the explosive mass, but for an explosive in particular usually supposes that the liberated energy is proportional to the involved mass.



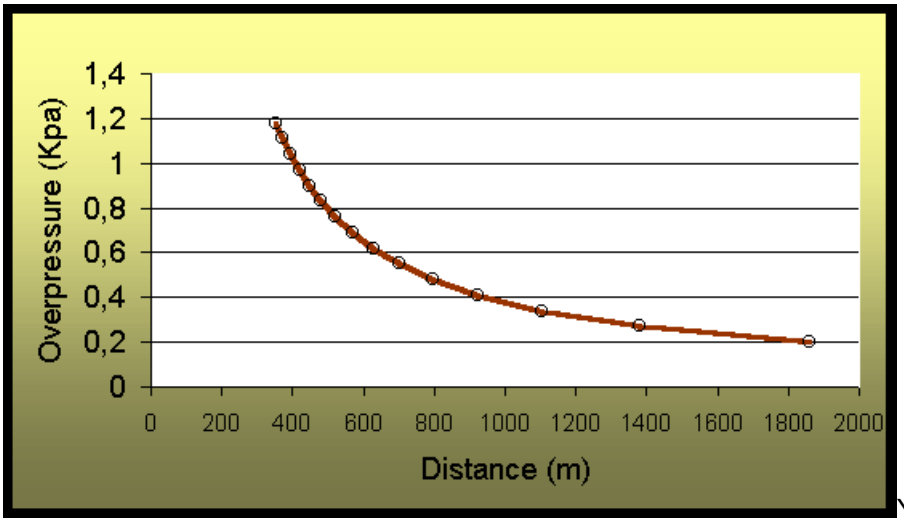
The procedure to establish the effects from an explosion to a distance give begins with the calculation of the involved energy, expressed in equivalent mass of TNT. With this calculated date the reduced distance is calculated dividing for $(W_{TNT})^{1/3}$ and we estimate the overpressure using the graph 1 that contains data of diverse bibliographical references (1),(2),(3). once obtained the overpressure to a certain distance, the vulnerability of people and facilities can be considered without difficulty, you can consult some Explosion Overpressure Damage Estimates table from fire engineering publications or similar.

The main interesting question from the point of view of the security was the first houses of Rafelcofer, located at 600 m. Two calculations were carried out; the first one supposing that the entire explosive mass was TNT and another calculating the real equivalent of 1500 Kg of gunpowder that taken in account the combustion heats (Q_c(TNT) = 15.12 MJ/Kg and Q_c(gunpowder) = 2.4 MJ/Kg), corresponding at 240 Kg of TNT.

The second method are established using the Lee algorithm which have this form:

$$X = m_{TNT}^{1/3} \exp(3.5031 - 0.7241\ln(Op) + 0.0398(\ln Op)^2)$$

Were, X= Distance to given overpressure, ft and O_p = peak overpressure, psi



You can build a curve of overpressure versus scaled distance, taking in account the same value of equivalent mass of TNT.

To know the real data, three seismograph they were placed gauged to capture and to register all sign that overcome a vibration level of 1 mm/sec or 109.6 dB of air wave. To the device located in Rafelcofer many signs they arrived before the explosion (helicopters, heavy vehicles, etc.) this causes the saturation of their memory and it could not capture the explosion sign. The other two devices were located in the Alquería de la Comtessa (1000 m) and in the highway (1625 m).

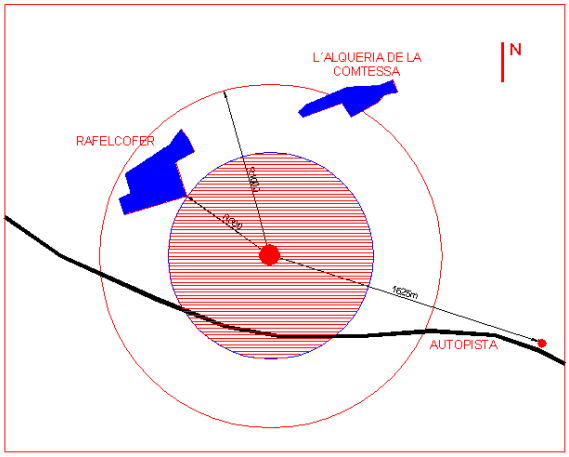
The calculated data front the real dates are discussed later in this document.

5. PREVENTION MESURES AND WORKING PROCEDURES

Once concluded the tasks of rescue and forest fire control in the first day of emergency, two day later was made the controlled detonation of the explosive material in the risk area.

Since the try option in front of the not exploded magazine was the controlled detonation and knowing the foregone consequences: possible forest fire, damages in buildings of the town, damages in the explosives experts for premature detonation, you proceeded to the elaboration of a Plan of Performance.

In the first time was defined the intervention area and the safety area. In the Spanish Emergency Planes the threshold overpressure value for mechanical phenomena it determines the intervention area for a 125 mbar, which according to the equivalent study of security is a distance of 100 m.



To avoiding unnecessary risks a safety area was established at 600 m., being the access restricted to the necessary and indispensable personnel for the performance on the explosive. The rest of means, firemen, emergency health services and police, they would be in an area between 600 to1000m.

The procedure to be carried out was the following:

1. Build of a wall of sand sacks of approximately 3m of high for 9 of long, surrounding the magazine.

2. Cut of roads and highway.

3. Checking the intervention area for avoiding the curious people.

4. Placement of detonators artefacts.

5. Detonation.

6. Checking and intervention in the towns if it is need.

7. Checking by the explosive technical of the intervention area to assuring that no explosive rests are spreading in the field to allow the entrance of the rest of the responders.

8. Control on the forest fire.

The intervention of firefighters in the intervention area was foreseen after the checking tasks, whenever doesn't take place a premature detonation. In that case, we had prepared a team of firefighters with a medical ambulance to act before the revision of the alert area.

The device were 3 urban engines, 3 forest engines, 6 brigades of forest firefighters, helicopter with forest firefighters team, a technical team compound for an architect and several surveyor, 5 medical ambulances, medical helicopter and more than 100 Civil Police and Local Policemen. The Integrated Commandment Centre of the Community was established in the town of Rafelcofer.

The detonation took place at 14:04 o'clock. a forest fire took place and we could actuate on this at 14:30 o'clock, being given had controlled at 17:43 o'clock. an approximate surface of one hectare Burned. In the town it was not necessary to actuate on the structures, although they were revised a good smaller number of damages.

6. Estimated calculations versus real effects

The results of the vulnerability assessment given that the houses near to the centre of explosion (600 m) they would suffer an overpressure between 0.6 and 1.5 Kpa. Under these conditions the foregone damages could be break of glasses, blinds and smaller structural damages in the most unfavourable case. These near houses were evacuated. In the rest of the area people was confined inside yours houses, as well as the opening of blinds and retreat of windows, with the purpose of offering the smallest resistance to the step of the shock wave.

Calculated overpressures, mainly the calculated for 240 Kg of TNT, they approach very much to the real ones, we should be conservatives when valuing these results, mainly for the great number of approaches made due to the uncertain values like the followings:

1. The quantity of explosive is approximate, as well as its composition

2. The explosion was not a perfect half circumference, since the magazine was in the hillside of a mountain.

3. The sacks of sand wall made around the magazine to minimise the shock wave.

4. Due to the physical behaviour of the explosions, is normal that the result of the different models that can be used to carry out these studies, approach with the distance. The distances considered in this catastrophe, between 600 and 1625 m, are relatively big compared with the explosive mass. It is very probable that at shorter distances the difference between the calculated date and real dates differ more than a large distances.

After verifying the damages taken place by the explosion, we can say that they approached sufficiently to those foreseen, being the most serious breaks of blinds, glasses, some reinforcement roof and non structural cracks.

OVERPRESSURE TABLE (Kpa)				
	1500 Kg TNT	LEE MODEL	240 Kg TNT SCALING LAW	REAL DATES
RAFELCOFER (600m)	1.5	0.65	0.6	--------
ALQUERIA (1000 m)	0.65	0.37	0.35	0.253
AUTOPISTA (1625 m)	0.4	0.23	0.2	0.193

7. Conclusions

We are presented the different phase in a real accident happened a few moths, your aspect is very same to the others related accidents with fireworks, in this rapport you can see different methods for evaluate and compare this with the real dates gauged "in the site", also you can see different images and pictures about the "controlled explosion" and the catastrophic effects to this.

The question is: Really a 1.4 Class division can be take in account like a "

Explosives with no significant blast hazard"?. At last civil people an firefighters dead for this no significant hazard, we can think: certain regulations of dangerous goods are correctly estimated?.

(1). Bodhurtha, F.P.: *Industrial explosion prevention and protection*. Mc Graw-Hill. New York. 1980.

(2). Lees, F.P.: *Loss prevention in the process industries*. Butterworth-Heinemann. London .1980.

(3). CCPS (Centre for chemical process safety): Guidelines for chemical process quantitative risk analysis. AIChE. New York. 1989.

Appendix.

Before


After

Damages