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# Modeling and study of the explosion of gas storage tanks in compressed natural gas fuel stations (CNG)

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## Abstract

Due to the high pressure of natural gas compression for use in cars, there is always a possibility of danger such as explosion and fire. In this article, the possible scenario of the explosion in the storage tanks of the station has been investigated. First, the explosion in a single 80-liter tank and then the explosion in a group of tanks that form a domino incident are modeled. The results show that at a distance of 2 meters from the explosion site of a single tank, the pressure continues up to 4 bar and the probability of fatality of people in this distance is 99%. At a distance of 16 meters from the explosion site of a group of tanks, the pressure will reach 20 bar and the fatality of people in this range will be 99%. In both modeling modes, the amount of radiation heat flux reaches 37.5 $kW/m^2$. The results of the research can be used to improve safety in the correct use of compressed natural gas and the correct positioning of station equipment.

**Keywords:** natural gas, explosion of tanks, simulating the outcome, risk assessment, fatality.

## 1. Introduction

The growth of energy consumption has caused problems such as air pollution and the production of greenhouse gases. With more than 22 million cars in 1401, Iran is one of the most energy-consuming countries, especially in the transportation industry [1]. The expansion of gas resources in Iran has caused to increase the desire to use of natural gas as an alternative fuel in cars. So that Iran currently consumes an average of 23.5 million cubic meters of CNG fuel, with 2556 CNG stations, it is among the top five countries in the world in this case [2]. The closure of some CNG fuel supply stations due to the decrease in reliability and failure of its equipment causes some accidents. In a study conducted by Parvini and Kordrostami [3] on the CNG storage tank, the CNG storage tank on the manipulated car could not withstand the pressure of 200 bar and led to an accident. In the modeling of the explosion, it was shown that with a pressure of 18 bar, a person exposed to this pressure, who is one meter away from the explosion, will be killed. In this article, the modeling of the explosion of a sample CNG tank is done and its results are expressed, as well as the domino scenario due to the explosion in the batch tanks is investigated, so far no research has been done about it.

## 2. Methodology

In this article, a sample of a CNG station is investigated in order to determine the safety of equipment and consumers and simulation the consequences of a sudden explosion of the CNG station's batch storage tanks with PHAST[1] software. The reservoirs studied in this research include all the batch reservoirs of the site that have the function of natural gas storage. There are 45 of these tanks, with a volume of 80 lit, a weight of 107 kg, and a working pressure of 245 bar to 248 bar. The tanks of the station are all metal and are designed according to ISO 9809-1 and ISO 9809-2 standards. A study conducted by Mahdavi and Lavasani [4] on the reliability evaluation of the CNG station, the storage tanks have a reliability of 0.83 and a failure rate of 0.000077.

## 3. Verification

In this research, it has been tried to model all the events that may occur due to the tank explosion, the release of raw materials, fire radiation and blast wave and analyze the results. The selected scenario is a sudden rupture due to rusting, tank tampering or internal cracks. The solution of the problem is based on the mathematical equations of the problem and the results are presented in the form of graphs. To measure the validity of the

[1] Process Hazard Analysis Software Tool

simulation results of the PHAST program, the results of the work of Parvini and Kordostami [3] have been used, so that the results obtained from the PHAST program in the present work are consistent with the results of Parvini et al. By comparing the results, it can be found that the dispersion distance of methane gas with a pressure of 200 bar in the article of Parvini and Kordestami [3] up to a radius of 3.5 meters is consistent with this research with a reservoir pressure of 250 bar and the dispersion radius of methane gas up to a radius of 5 meters "Figure 1".

## 4. Results and Discussion

In the scenario of rupture of CNG tank, due to high pressure, all materials are instantly discharged and an explosion occurs. "Figure2" shows the maximum pressure changes according to the distance from the explosion center. The explosion causes a pressure of up to 20 bar, the nearest person who is within 2 meters of the explosion will die immediately. At a pressure close to 4 bar, the risk of death increases to 99%. In the design of the CNG station, tanks are placed in groups with a distance of at least 5 cm. At the moment of the explosion, the pressure reaches 20 bar up to a distance of 2 meters, and the pressure wave continues up to a radius of 16 meters with a pressure of 0.6820 bar; which will indicate the destruction of the surrounding facilities. Due to the lack of domino accident modeling, it is assumed that in the explosion of a tank, all the tanks will be ruptured and a chain accident will occur due to the severity of the primary incident. This assumption is considered very conservative and based on modeling and explosion intensity in a tank. According to "Figure 3", the safe margin according to the diagram, is the intermittent distance to the pressure of 4 bar on the vertical axis and 16 meters on the horizontal axis. Therefore, the distance of 16 meters from the tank can be considered as the maximum allowed distance or as a safety margin. The maximum pressure of 20 bar will continue up to a distance of 10 meters and the person closest to this distance will be killed that it is shown in "figure 4". The 17.66 meter radius of the red zone shows the radiation intensity of 37.5 kW/m$^2$, which is the danger zone and will cause the death of people exposed to radiation. The amount of radiation up to a radius of 67 meters (blue area) will be 4 kW/m$^2$. Thermal radiation caused by the explosion of batch tanks can be very worrying. The thermal radiation of 37.5 kW/m$^2$ can cover a radius of 55 meters, which will make the consequences of the accident very wide, so that the radiation of 4 kW/m$^2$ will continue up to a radius of 216 meters. The amount of thermal radiation and its consequences are shown in "Table 1" [5].

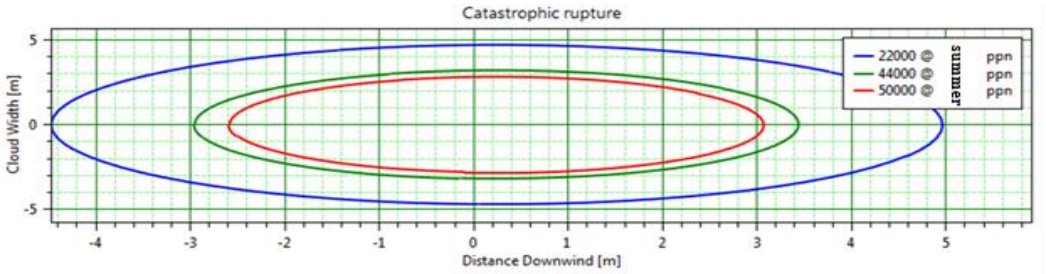


**Figure 1. The gas cloud mass released by the explosion**

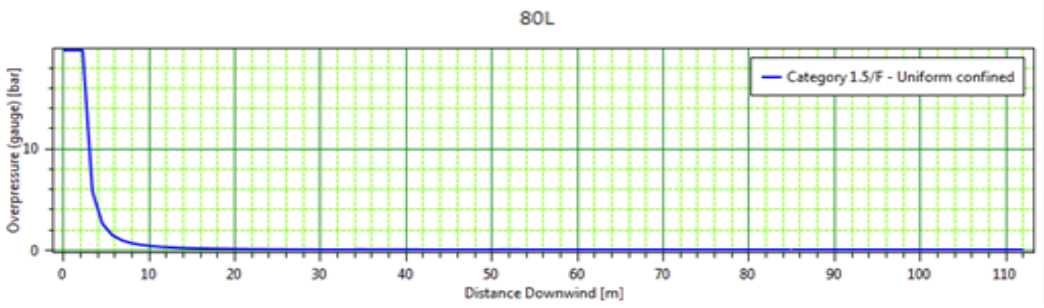


**Figure 2. Pressure changes according to the distance from the explosion center**

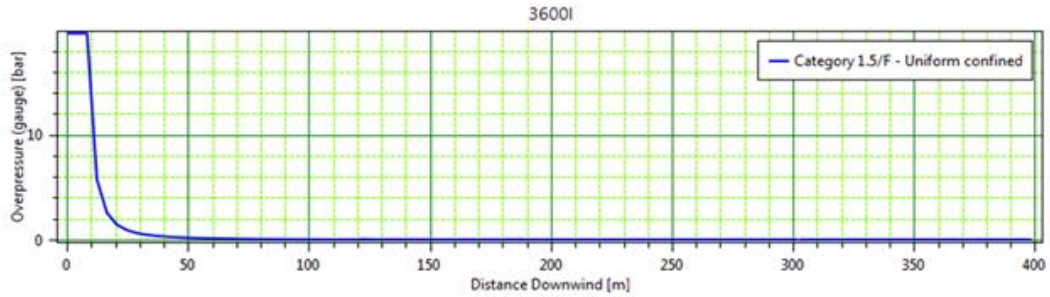


**Figure 3. The effect of pressure versus distance in the explosion of batch tank**

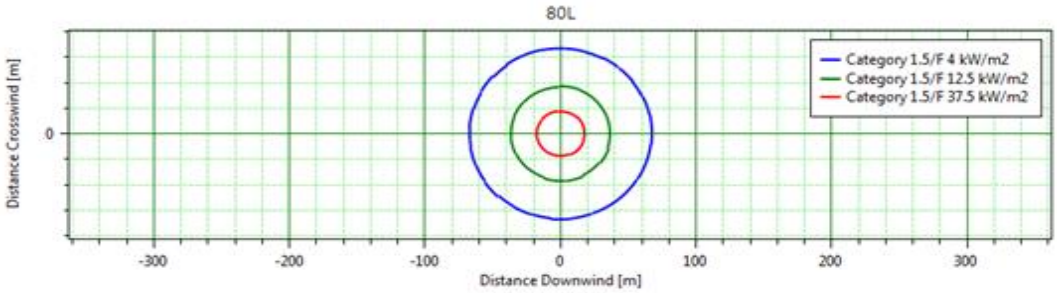


**Figure 4. The amount of radiation in stable weather conditions**

**Table 1. The effects of radiant heat flux on humans and buildings [5]**

| Radiation ($kw/m^2$) | Consequences |
|---|---|
| 70 | the fatality100% |
| 37/5 | Instant fatality of people in 8s ,destruction of houses |
| 35 | Human damage and fire |
| 20 | Serious injury to people |
| 12/5 | Risk of fatality and damage to equipment |
| 4 | Pain and burning |

## 5. Conclusions

In the present work, the explosion of fuel storage tanks in a fuel distribution station was modeled and compared in two forms single tank (80 liter tank) and batch tanks (including 45 tanks) and the conditions of the accident in case of an accident in one of them were investigated. In tanks where the pressure of stored gas reaches 250 bar, the intensity of the explosion causes rupture in other tanks. In this simulation, modeling was done assuming a pressure of 250 bar and a total volume of tanks of 3600 liters. The results show that in both modeling modes, the amount of thermal radiation reaches 37.5 kW/m$^2$ and the radiation extends up to a radius of 18 meters in the explosion of a tank and up to a radius of 55 meters in a group explosion. Tanks lead to damage to buildings and people around in this area. At a distance of 2 meters from the explosion site of a tank and at a distance of 16 meters from the explosion site of a group of tanks, there is a 99% chance of people dying. The results of this research can be used in the correct positioning of station equipment, especially multi-purpose stations (petrol and CNG) and prevent the consequences of an accident in the form of a domino.

## 6. References

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