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Reports of informal working groups

Follow up to the work of the informal working group on reducing the risk of a BLEVE – simulations of the behaviour of tanks exposed to fire in complement to document ECE/TRANS/WP.15/AC.1/2017/42

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Model for the thermal response of Liquefied Petroleum Gas Tanks subjected to accidental heat input

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Summary

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Introduction

Reminder of previous work: reliability of the model demonstrated

• Previous work [1]:
  • development of a predictive tool to study the behaviour of different configurations tanks
  • demonstration of reliability of the model by comparison with BAM experiments (2013)

Tank subjected to full fire engulfment

Evaluation of a valve efficiency - Calculation results

- Reminder: these results have been presented at RID ADR Joint meeting 03-2017
- Common PRV considered (diameter 2” and $P_{\text{opening}}$ 16.5 bar) on LPG tank: volume 31$\text{m}^3$, filling rate 50%
- Thermal loading: full fire engulfment

$\Rightarrow$ **Safety valve is not efficient in that case**

![Full fire engulfment](image-url)

Results considering a common safety valve: risk of BLEVE
Tank subjected to full fire engulfment

Evaluation of a valve efficiency - Calculation results

- Test of an ideal safety valve on the same tank with the same thermal loading
- This safety valve set to low pressure (8 bar) is not efficient:
  - A very low applied stress is observed as expected
  - Failure is due to a sharp fall of Yield stress of steel
  - This result can be generalized to all filling rate

Results considering an ideal safety valve (set to 8 bar): risk of BLEVE due to sharp fall of Yield stress of steel
Tank subjected to full fire engulfment

Evaluation of thermal coating and increased steel thickness - Calculation results

- 2 other protections are tested: thermal coating and increasing steel thickness of shell to 3 cm
- Thermal coating can avoid or delay BLEVE but several issues are raised concerning use on trucks:
  - no retrofit about ageing
  - behaviour with vibrations
  - behaviour with various climatic conditions
  - etc...
- Increasing steel thickness of shell is efficient to avoid BLEVE, but 3 cm thick shell are needed (unfeasible)

Results considering a thermal coating: no risk of BLEVE

Results considering a 3 cm thick shell: no risk of BLEVE
Conclusion about tanks subjected to full fire engulfment

Conclusion on the PRV/thermal coating efficiency (RID ADR Joint meeting 03-2017)

- Valves are not efficient for some scenarios (ex: full fire engulfment)
- Other protections (thermal coating or increasing of shell thickness) may delay/avoid BLEVE but may present issues (ageing, cost, etc...)

Full fire engulfment
Calculation on tanks subjected to fire on lower part

New calculation assumptions

• Calculations led on tanks with safety valve only and subjected to a smaller size fire (localized on lower part of tank)
• New calculations are therefore led considering a smaller size fire scenario with the following conservative parameters:
  • Pool fire on lower part of tank
  • Fire reaches immediately intense burning on the entire length of the truck and has an infinite duration (a real fire can have a duration of 3 hours, and an intense burning of 30 minutes)

[2] CFPB, Feu de pneus et de cabines sur des citernes GPL, Mai 2010
Calculation on tanks subjected to fire on lower part
New calculation assumptions

• Characteristics of the LPG tanks (same as those considered at *RID ADR Joint meeting 03-2017*):
  • Volume: 31 m³
  • Common PRV – pressure relief valve- (diameter: 2” & Popening: 16.5 bar)
• 3 scenarios are calculated for 3 filling rates (great influence on results): 85%, 50% and 30%

*Example of heating of a tank*
*filling rate: 30 %*
Calculation on tanks subjected to fire on lower part

Calculation results

Filling rate: 85% – safety valve efficient **no BLEVE**

Filling rate: 50% – safety valve **NOT** efficient, *BLEVE*

Filling rate: 30% – safety valve **NOT** efficient, *BLEVE*
Calculation analysis

- Previous results show the great influence of filling rate on results
- The impact of filling rate is explained below:

Large Fire on liquid phase (Pool fire)

The steel shell in contact with the gas phase is **not** impacted by the fire

Filling rate: 85%

The steel shell in contact with the gas phase is impacted by the fire

Filling rate: 30%

In that case, most of blast scenarios can be excluded with a standard PRV

In that case, the blast risk is high (included case where the tank is equipped with an ideal PRV)
Conclusion

• **Full fire engulfment:**
  - Safety valve only can not protect tank because of mainly the reduction in the steel resistance due to high temperature
  - Tank with an appropriate safety valve and a thermal coating could survive a full fire engulfment until it empties completely

• **Fire on lower part only – tank equipped with a common pressure relief valve:**
  - Pressure relief valve may avoid or delay BLEVE for tank with high filling rate
  - BLEVE may occur for low filling rate, due to heating of shell in direct contact with gas

• **Way forward:**
  - Assess the maximal fire a tank equipped with the best safety valve would survive even under low (unfavorable) filling ratio conditions
  - Compare this fire with the fire most likely to happen. This « typical » fire can be estimated thanks to:
    • Refined modeling of fire using a computational fluid dynamics software (FDS – Fire Dynamics Simulator) to obtain better precision on distribution of heat fluxes for 3D tank modeling
    • Statistical assessment to estimate the most likely fire hypothesis
  - This will allow to assess the efficiency of safety valves in terms of risk reduction even if they would not ensure total resistance to fire in 100% of the cases