Economic Commission for Europe

Inland Transport Committee

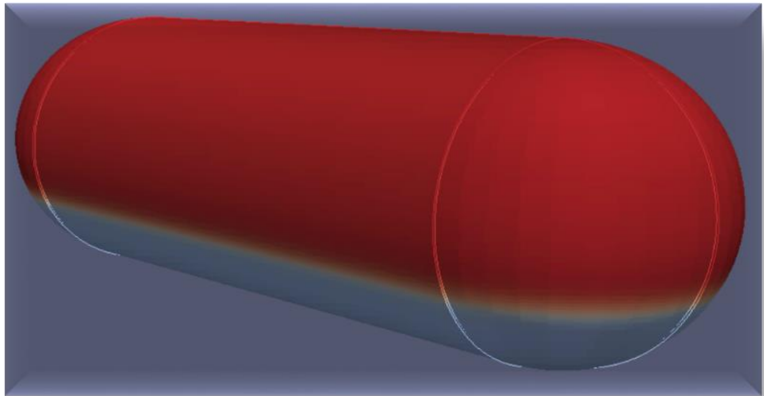
Working Party on the Transport of Dangerous Goods

Joint Meeting of the RID Committee of Experts and the Working Party on the Transport of Dangerous Goods **26 September 2017**
Geneva, 19–29 September 2017
Item 7 of the provisional agenda
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

Transmitted by the Government of France

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



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RID ADR JOINT MEETING 09-2017

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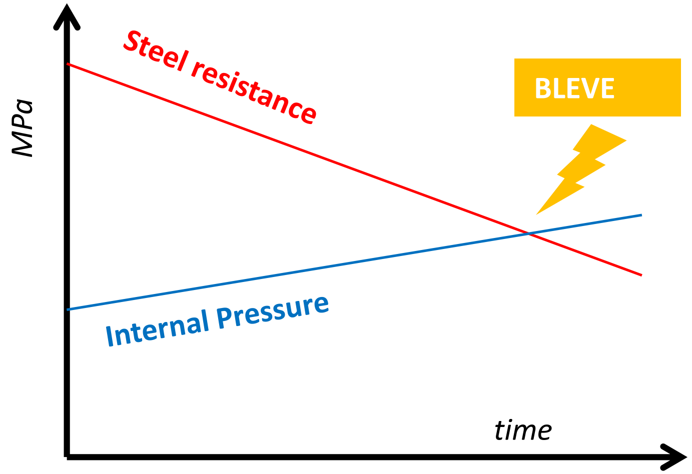
Summary

- Introduction
- Tank subjected to full fire engulfment
  - Evaluation of a valve efficiency
  - Evaluation of thermal coating and increased steel thickness
  - Conclusion on the PRV/thermal coating efficiency
- Calculation on tanks subjected to fire on lower part
  - New calculation assumptions
  - Calculation results
  - Calculation analysis
- Conclusion

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)



Behavior diagram of the tank

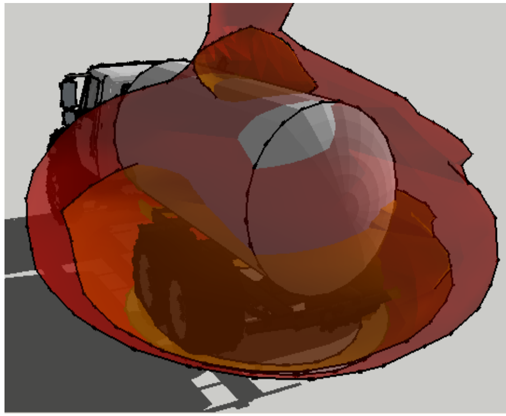
[1] Working Party on the Transport of Dangerous Goods, Bern, 13-17 March 2017

Tank subjected to full fire engulfment

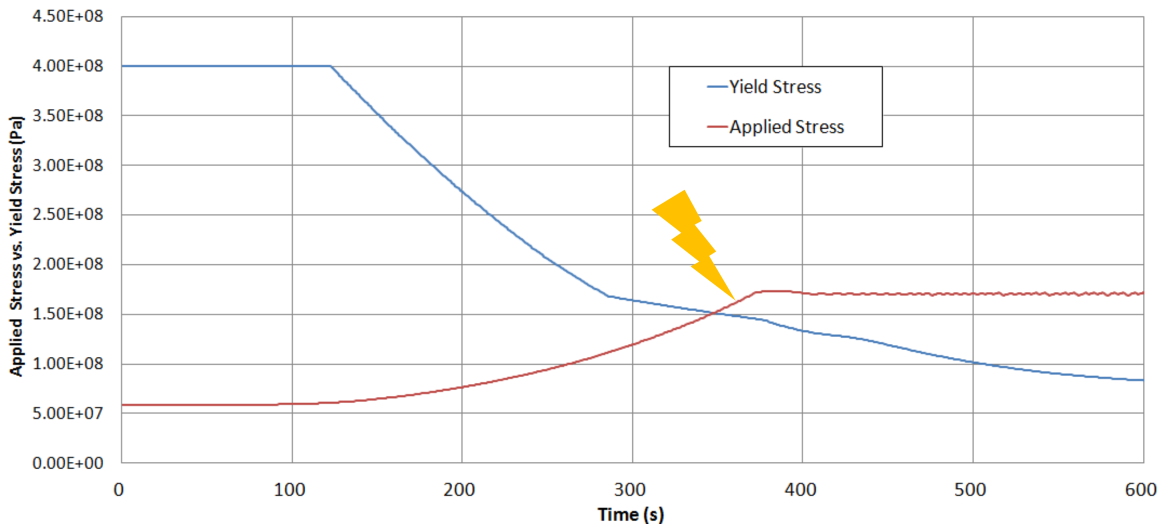
Evaluation of a valve efficiency - Calculation results

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

=> **Safety valve is not efficient in that case**



Full fire engulfment



Results considering ***a common safety valve*** *:* ***risk of BLEVE***

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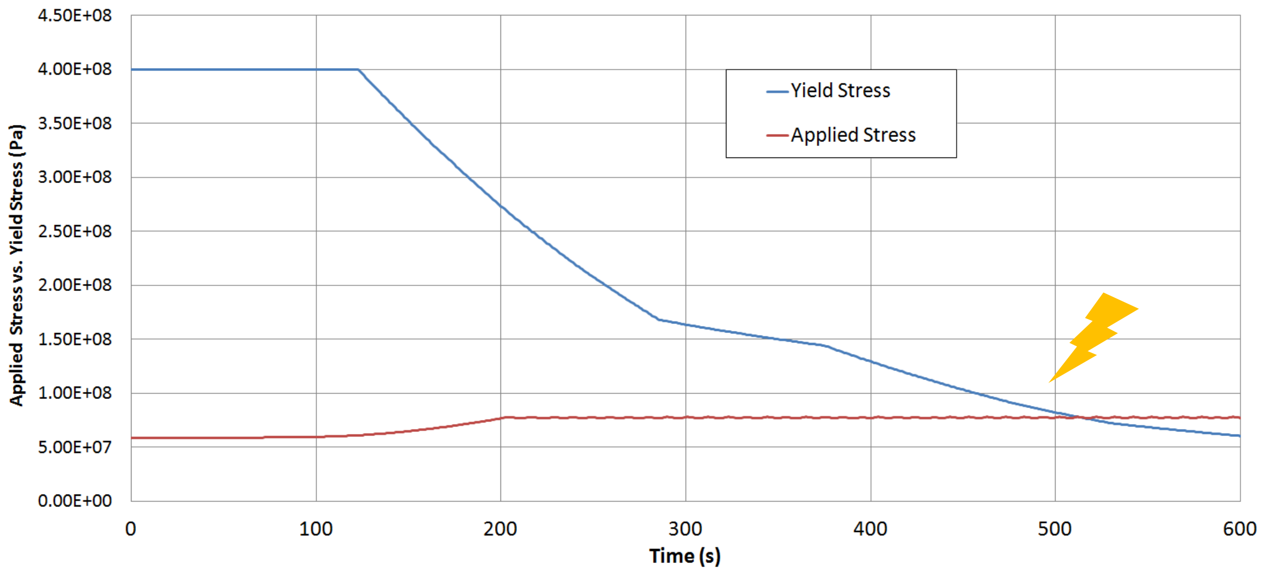
Evaluation of a valve efficiency - Calculation results

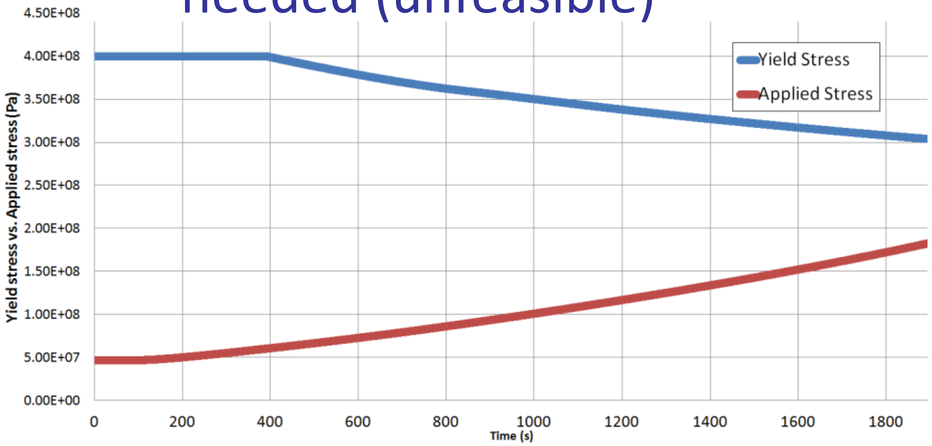
- Test of an ideal safety valve on the same tank with the same thermal loading
- This safety valve set to low pressure (8 bar) is not efficient:
  - A very low applied stress is observed as expected
  - Failure is due to a sharp fall of Yield stress of steel
  - This result can be generalized to all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



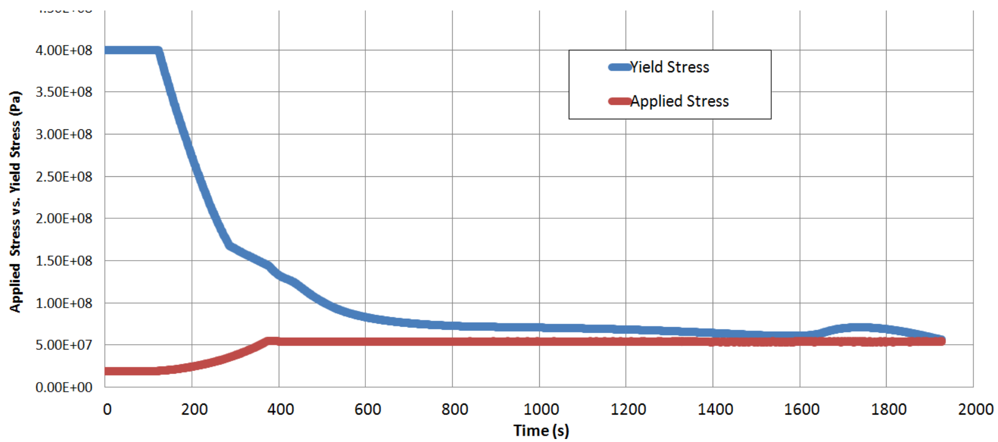
Results considering ***an ideal safety valve (set to 8 bar)*** *:* ***risk of BLEVE due to sharp fall of Yield stress of steel***

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*

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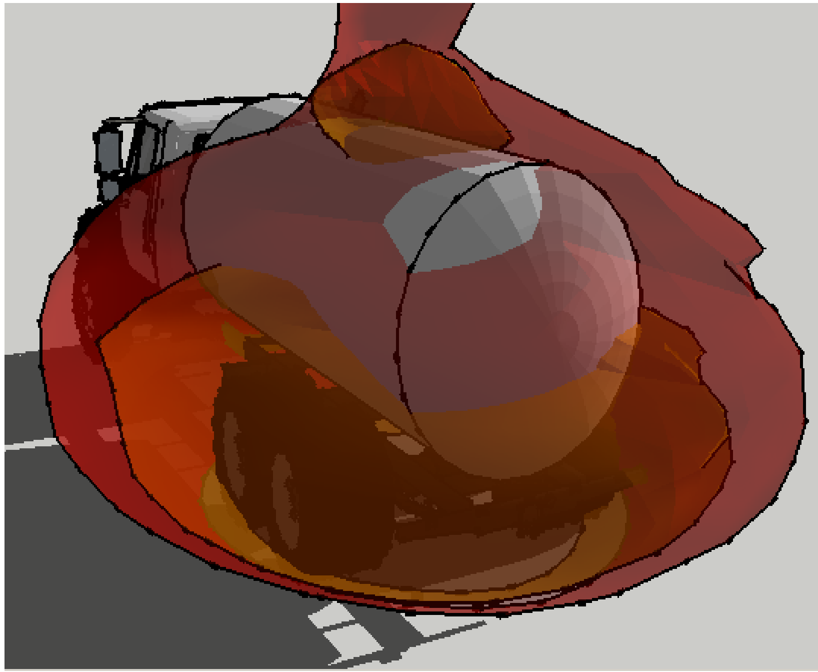
Conclusion about tanks subjected to full fire engulfment

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

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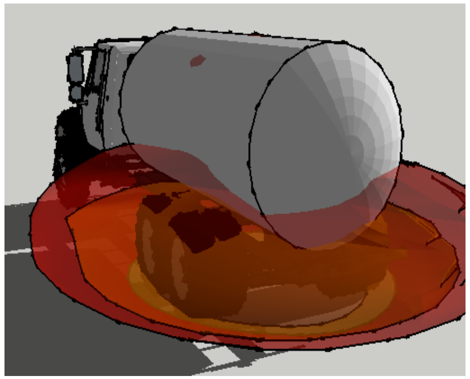
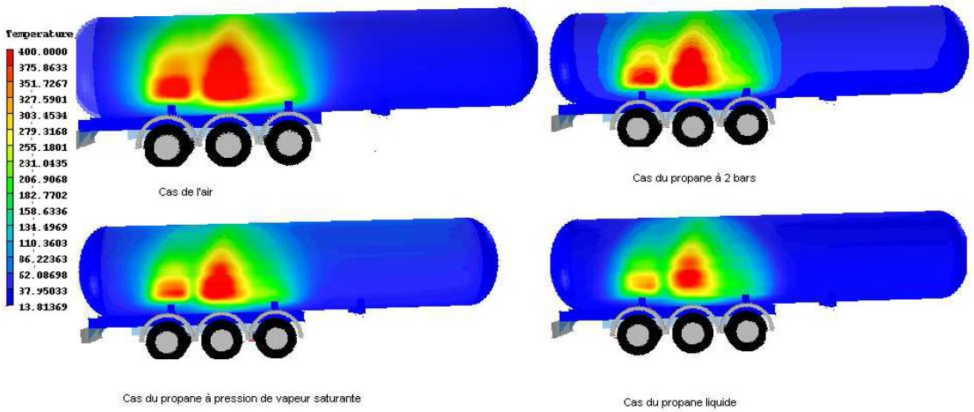
New calculation assumptions

- 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)



Large fire localized on lower half of tank
- Conservative hypothesis-

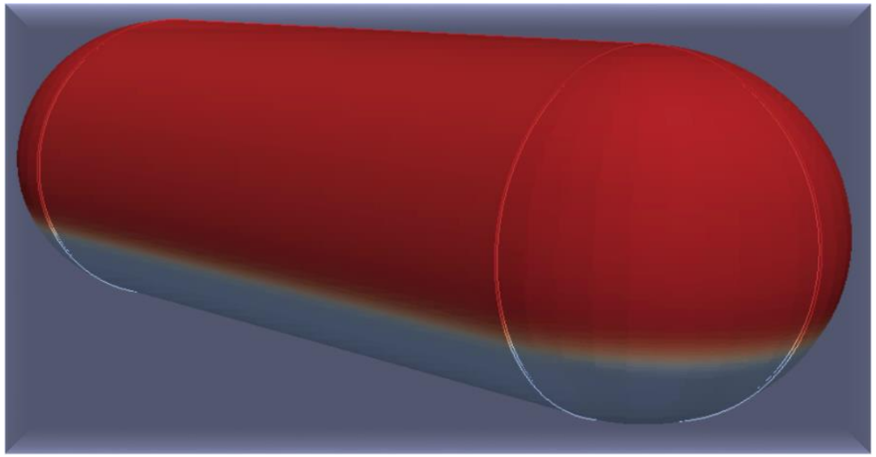


Calculation of real fire spreading [2]

[2] CFPB, Feu de pneus et de cabines sur des citernes GPL, Mai 2010

New calculation assumptions

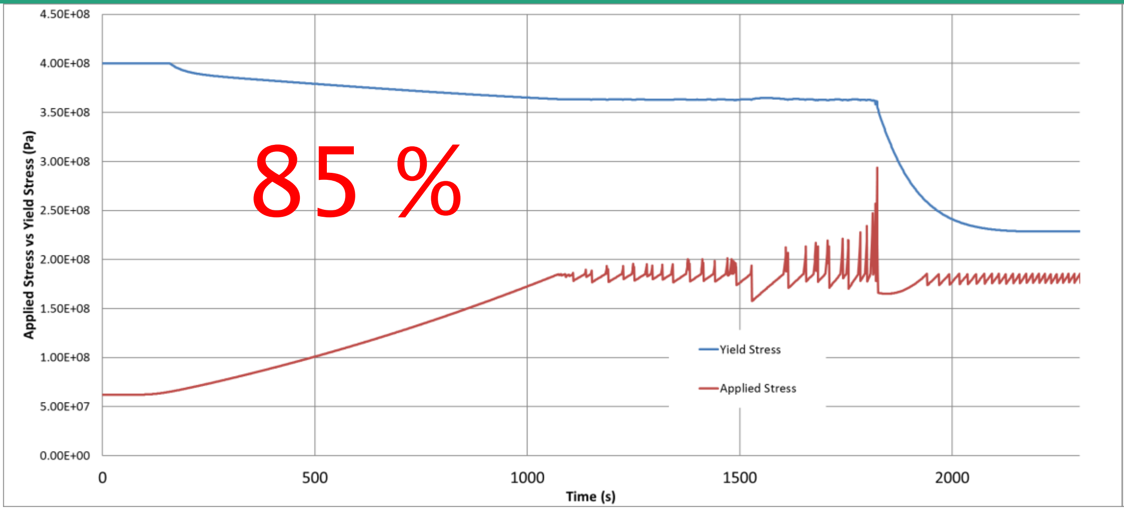
- Characteristics of the LPG tanks (same as those considered at *RID ADR Joint meeting 03-2017*):
  - Volume: 31 m^3
  - Common PRV – pressure relief valve- (diameter: 2'' & Popening: 16.5 bar)
- 3 scenarios are calculated for 3 filling rates (great influence on results): 85%, 50% and 30%



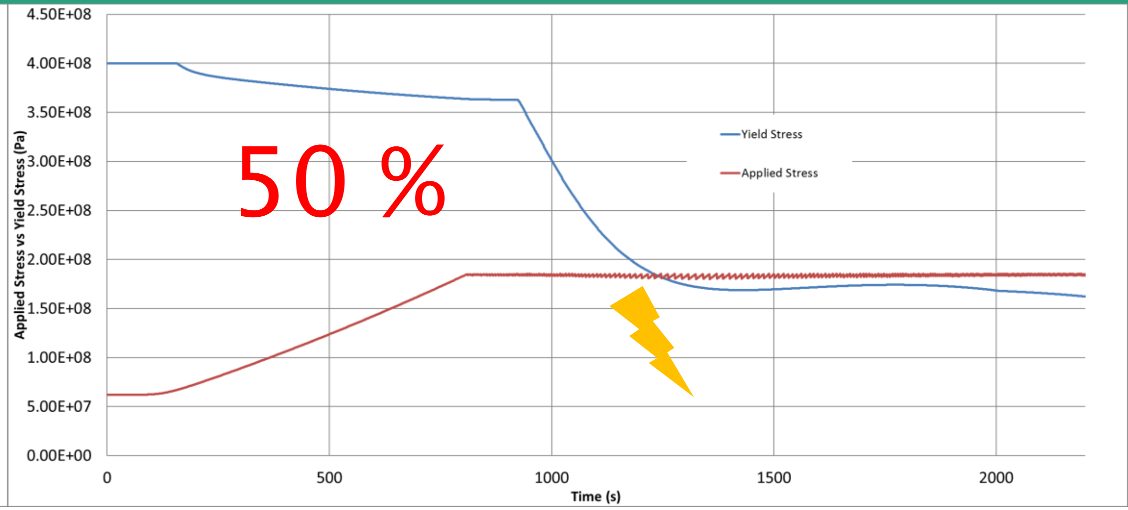
Example of heating of a tank
filling rate: 30 %

Calculation on tanks subjected to fire on lower part

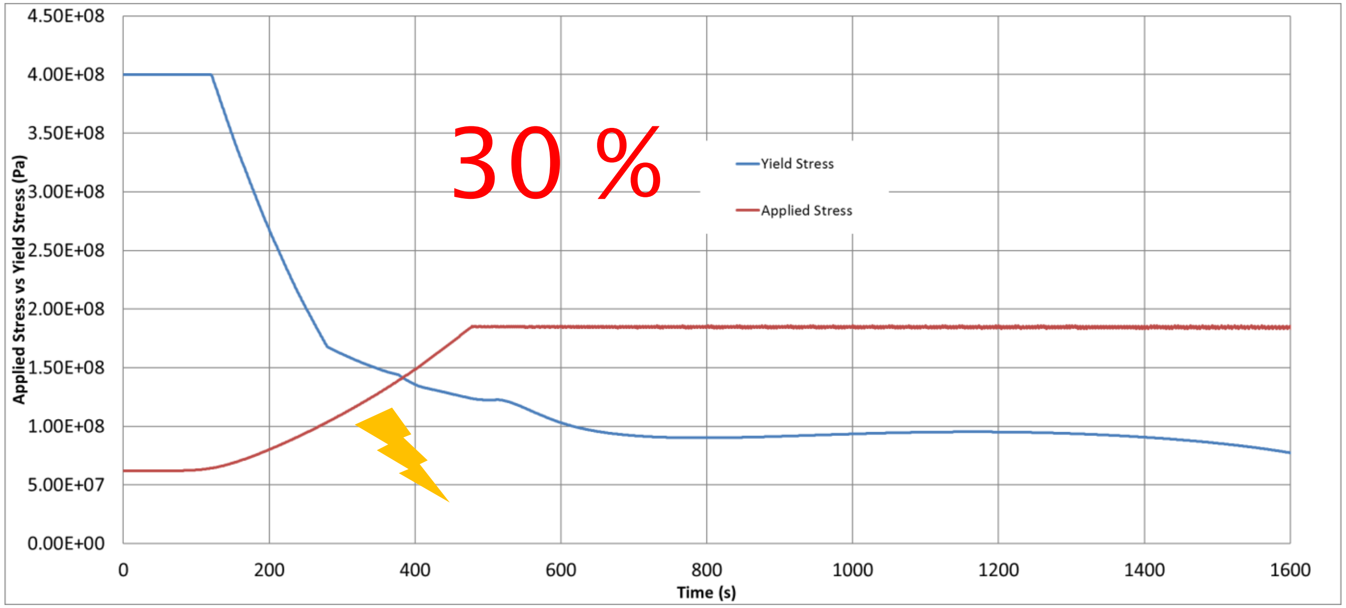
Calculation results



Filling rate: 85 % –safety valve efficient no BLEVE



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



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

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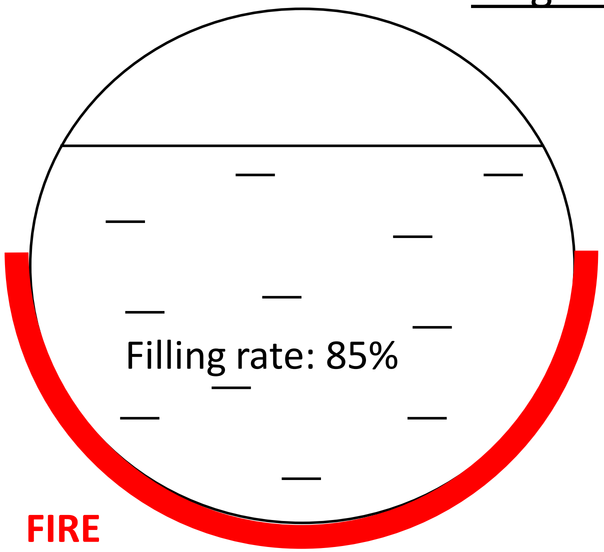
Calculation on tanks subjected to fire on lower part

Calculation analysis

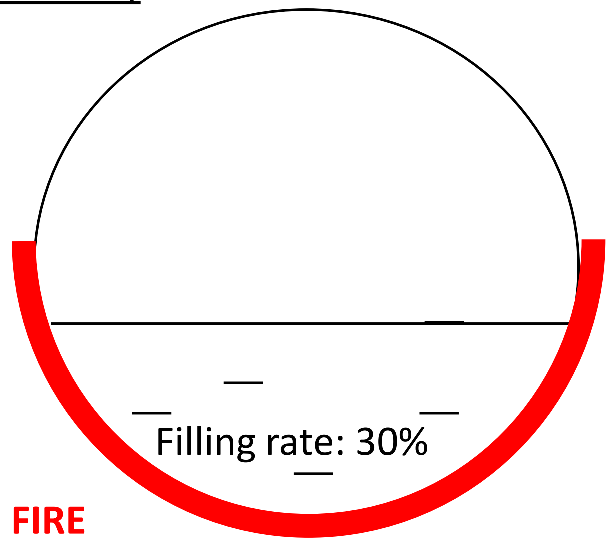
- Previous results show the great influence of filling rate on results
- The impact of filling rate is explained below:

Large Fire on liquid phase (Pool fire)



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

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



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

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