On the protection of process equipment from fire exposure. A study on the effect of different means of protection.

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Fire in process plants might occur for several reasons. During the industrial history fire has caused huge damage and loss of live as well as loss of economy and resources.

Even in the best-operated process plant there might be small accidents. The difference between a minor event and a disaster is the ability to prevent escalation. It is crucial that process equipment containing flammables or poisoning material will maintain its integrity during a fire. For that reason the process components and pipes have to be designed to resist fire exposure in a time period sufficient to mitigate the event. This can be done by several means.

In this article an overview is given, showing the different means for protection of process equipments and pipes. A demonstration case is presented showing the effect using the different means of protection.

1 Demonstration case.

The demonstration case consists of a vessel exposed to fire according to the new procedure for design of process safety systems. The background for the procedure is outlined by H. Olstad and G. Berge (2006). The procedure is fully described in Scandpower (2004). The following definitions apply:

Length of vessel: 3,2 m Inner diameter: 1,6 m Wall thickness: 50 mm Orifice inner diameter: 12 mm Material: Carbon steel, yield stress 455 MPa Background heat load: 100 KW/m2 Point load: 350 KW/m2	Composition in mol fractions:	
	C1: 0.758679891 C2: 0.100594099 C3: 0.057798812 IC4: 0.005236129 C4: 0.015506998	IC5: 0.00231598 C5: 0.002416675 C6: 0.000503474 C8: 0.003423623 C10: 0.00352431 H2O: 0.05

Heat load is kept constant during calculation.
The vessel is filled with oil and gas. The liquid level is 0.5 m. The vessel is horizontal.
For this particular case yield stress is used as disintegration criteria. When applied stress is equal or above the yield stress the vessel is said to disintegrate. Utility Tensile Stress might alternatively be used.

2 Protection means and effects.

Protecting a process segment from exposure of fire is about maintaining integrity until disintegration of the segment no longer leads to escalation of the accident. Increased thickness of shell material or insulation is a way to postpone disintegration of components. If the breakdown does not lead to escalation, sooner or later the fire will cease. The major issue for all protection strategies is to buy time and prevent disintegration until certain criteria is achieved. Dependent on the character of the process plant and protection strategy, different criteria is set.

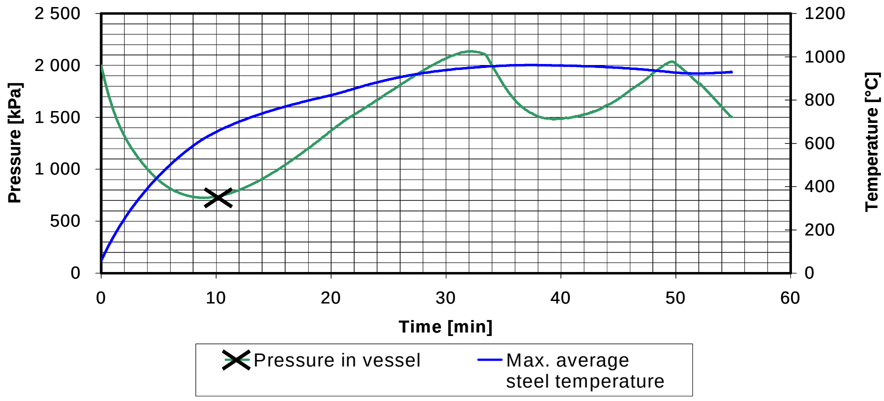
The following means is used to maintain integrity of equipments:

- Increased wall thickness
- Increased gas release rate (to vent system)
- Change of material in equipment shell
- Use of insulation
- Drainage of liquid in equipment

Active fire protection is not considered here. It has the effect of reducing heat load to the equipment. On the Norwegian continental shelf it is not allowed to take creditability of the effect of firewater due to the risk of failure to the firewater system.

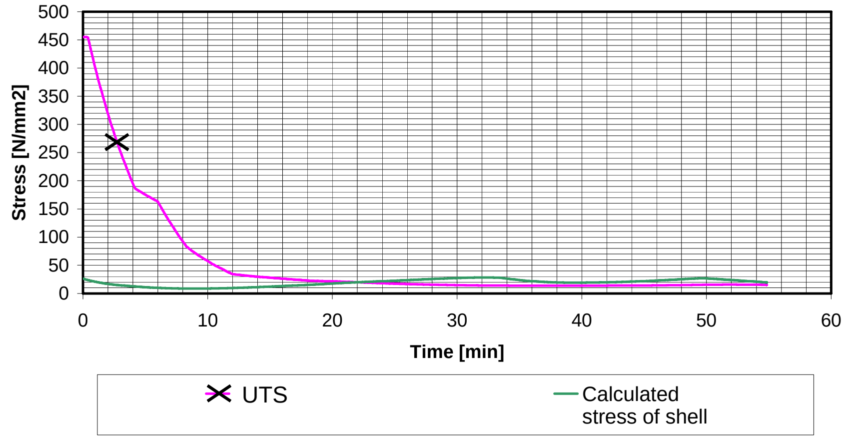
To study the effect on a vessel exposed to fire, VessFire is used to calculate the different means applied on the demonstration case described above. The computer code is described by G. Berge (1998) and verified against experiments reported in G. Berge, and Ø. Brandt (2003a), G. Berge, and Ø. Brandt (2003b) and G. Berge, H.T. Olstad (2004). VessFire is designe to give the thermomechanical responce of process segment equipments and pipes when exposed to heat.

2.1 Base case.

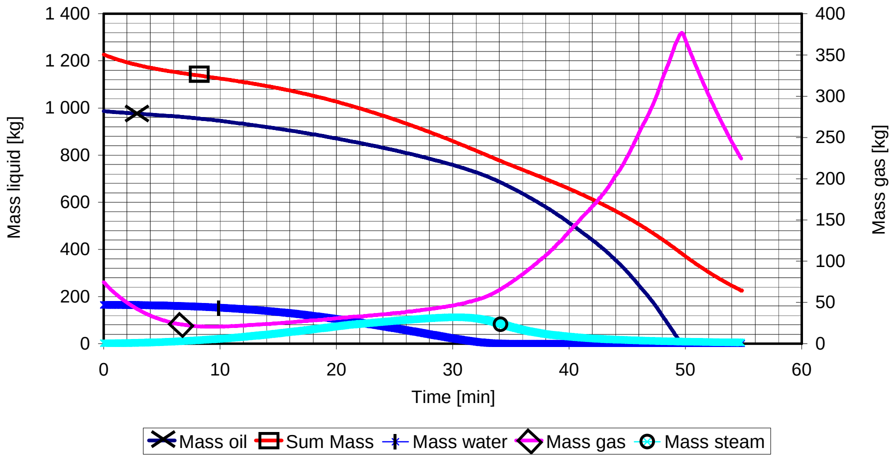


The figure above illustrates the pressure history for the demonstration case. That means no insulation and unit absorption coefficient.

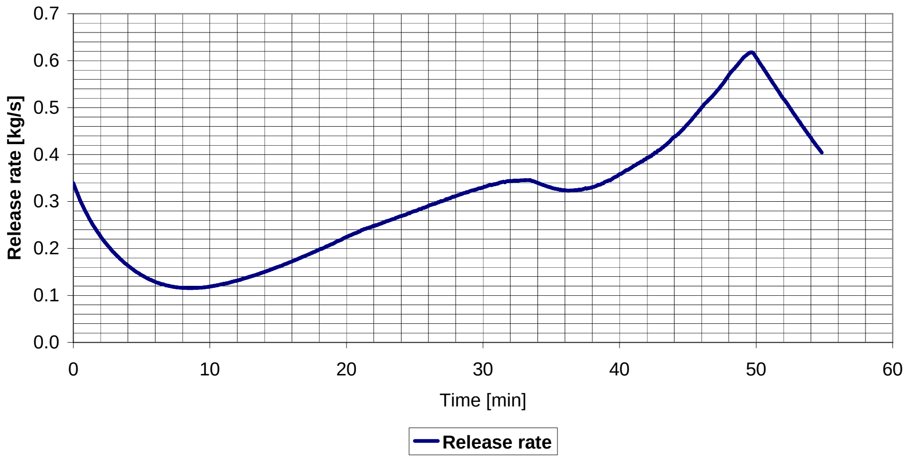
The stress analysis result is shown below. At its base conditions the vessel will disintegrate after about 20 minutes.



The mass balance for oil, gas water and water mist is illustrated below. When the vesel is empty there is no potencial for escalation if it disintegrate.

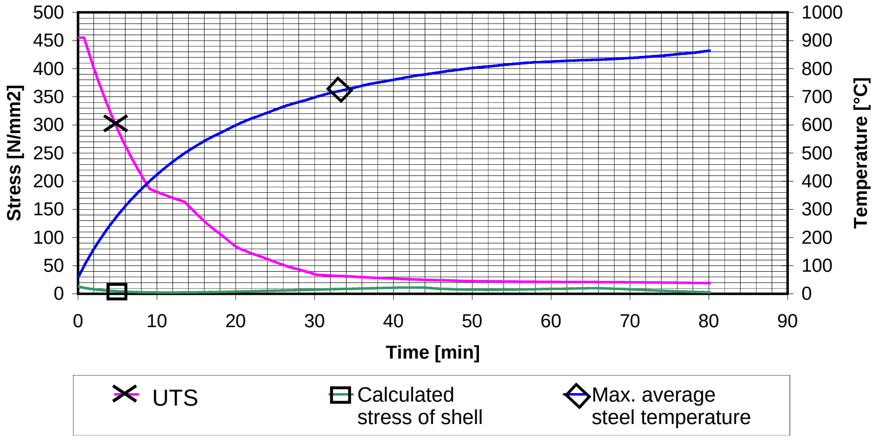


The release rate for the base case is shown in the figure below. As can be seen the rate increases after 10 minutes due to boiling of the inventory and the temperature increase in the gas phase.



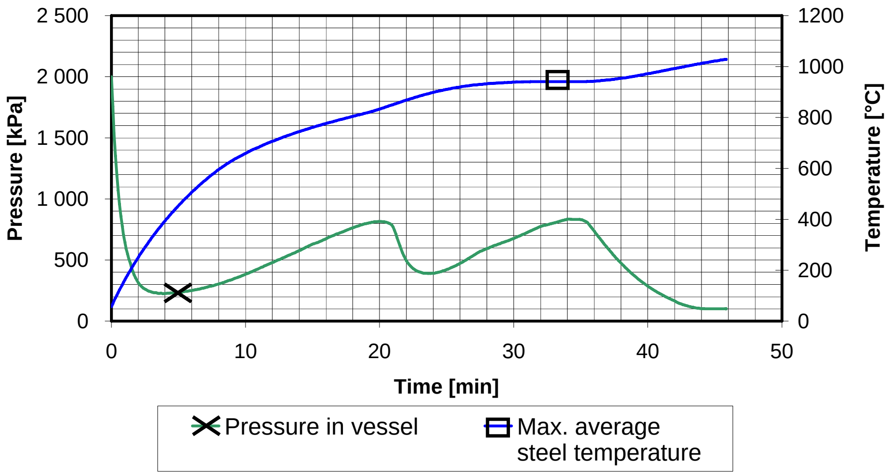
2.2 Increased wall thickness

If the wall thikness is increased from 50 mm to 100 mm the vessel will survive as shown in the figure below. All other parameters are maintained from the base case.



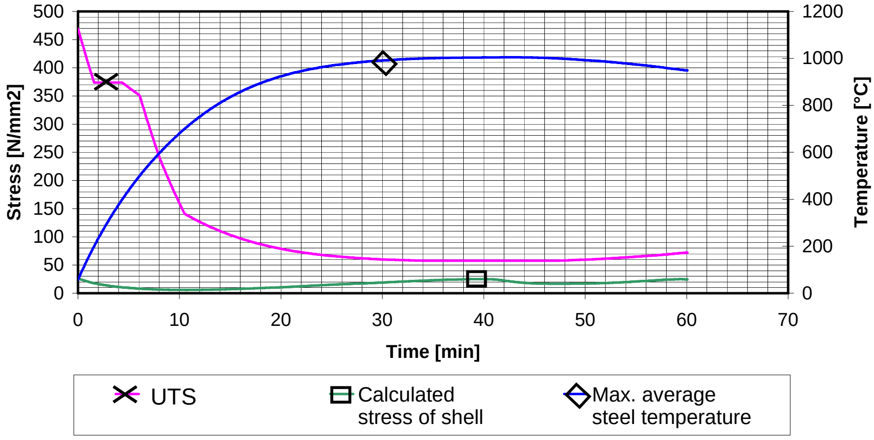
2.3 Increased gas release rate (to vent system)

Increasing the orifice from 12 mm to 20 mm causes the vessel to survive, but the initial release rate increases from 0.34 to 0.94 kg/s. The release rate will nevertheless fall faster due to faster evacuation of mass from the vessel. The vessel will be emptied after 44 minutes compared to the base case that will need more than 60 minutes to empty. The figure below shows the pressure history for the case.



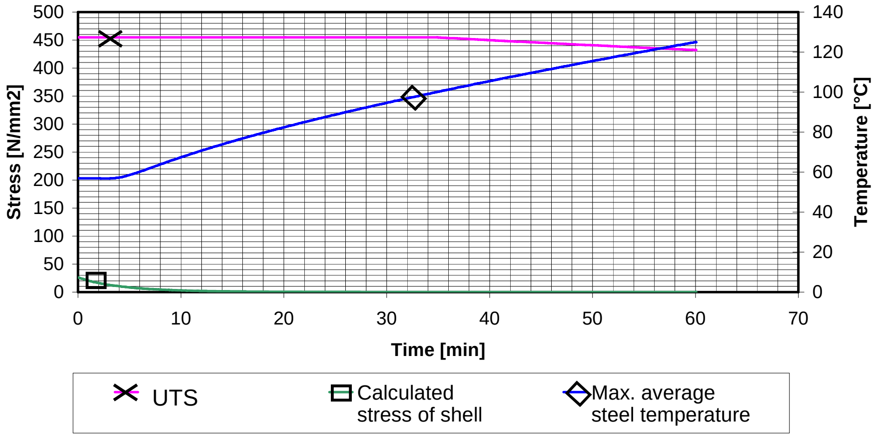
2.4 Change of material in equipment shell

Changing material form carbon steel to Duplex with yield stress of 515 MPa also cause the vessel to survive. The evaporation process is also prolonged with about 10 minutes.



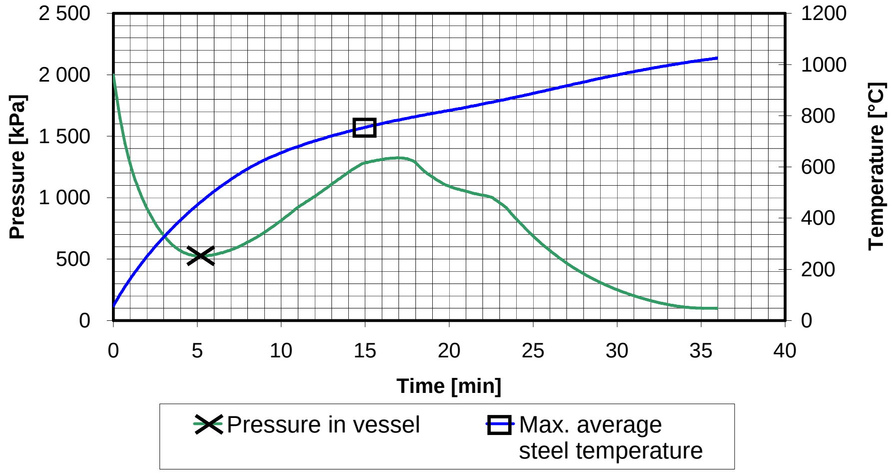
2.5 Use of insulation

Use of insulation postpones the heating process substantially. This is shown in the figure below. After 60 minutes of exposure the maximum temperature of the shell is only about 120 °C. A drawback using insulation is that it makes inspection difficult. Corrosion hidden by the insulation material is a well-known phenomenon. This might in itself be safety problem. When using insulation it is also a need for maintenance.



2.6 Drainage of liquid in equipment

In addition to evacuation of gas, the liquid content could be drained. The result is shown in the figure below. It is used a 10 mm opening in the lover part of the vessel as drainage. The vessel survive and the time to empty it is reduced to about 35 minutes.



3 Conclusions

Different means to maintain integrity of process equipment exposed to fire is presented above. Some means are more efficient than others. Insulation is quite efficient, but not preferred due to cost and inspection problems. Where possible, drainage of liquid is quite efficient as it remove mass faster than if the liquid should be build away. Exposure time is of cause an important parameter. Continually exposed, a segment is not safe before it is emptied, that means also the liquid content. Segmentation of the process is an efficient mean to reduce the exposure time. It can be concluded that, well planed and designed, it is possible to maintain integrity of a process plant during an accidental event.

4 References

H.T. Olstad and G. Berge, 2006, Risk of fire in process industry. Progress in legislation and standard development on the Norwegian continental shelf. CISAP-2, Naples, Italy.

Scandpower AS, 2004, Guide for Protection of Pressurised Systems Exposed to Fire, www.scandpower.no.

G. Berge, 1998, A Calculation System for the Blowdown of Process Segments and Process Equipment Exposed and Unexposed to Fire. www.Petrell.no.

G. Berge, and Ø. Brandt, 2003a. Analysis of fire load. Report no. NBL A04108. SINTEF NBL AS.

G. Berge, and Ø. Brandt, 2003b, Fire load on process equipment, NBL report no., NBL A03111. SINTEF NBL AS.

G. Berge, H.T. Olstad, 2004, On Heat Load For Engineering Purpose Related To Process Industry. Proceedings of the 23rd International Conference on Offshore Mechanics and Arctic Engineering . OMAE 2004.