Process Equipment Exposed to Fire.

A Case Study on the Behaviour of a Fire Exposed LNG Segment.

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When pressurized equipment is exposed to flames, the main task of the safety system is to depressurize the exposed segments before any part of the equipment ruptures and cause possibly escalation.

A new and more to the point guideline has been developed for designing of depressurization systems to protect fire exposed process equipment. The guideline has the added advantage of being very suitable for computer simulations. This makes the design of new segments and the verification of existing ones an easy task for the process and safety engineers as they can iteratively find an optimal solution in compliance with the current guidelines.

As liquefied natural gas (LNG) is an increasingly popular method of transporting and storing energy, the safety aspects of such sites need to be assessed. Not only have these energy containers moved significantly closer to rural areas and therefore raises some concerns for civilians, but the temperature and storage technology also differ from ordinary gas processing plants.

This article describes a case study of a fire exposed LNG segment. Computer simulation is used to determine the behaviour of the segment and the effect on safety issues.

1. Introduction

1.1 New Guidelines

Over the last years much work has been put into developing more accurate and specific guidelines for the handling of depressurisation of fire exposed pressure vessels. See H.T. Olstad and G. Berge (2006) and Scandpower (2004).

1.2 Simulations

The recent advances in adopting these specific guidelines for the calculation of depressurization of segments exposed to fire have made it more attractive to use simulations to calculate such scenarios. When simulations are relatively fast an optimal design complying with the guidelines can be found without spending too much time on the process. VessFire is a dedicated simulation system that fully applies to the new procedures. The system is described in G. Berge (1998) and has been verified in the work by G. Berge, and Ø. Brandt (2003a), G. Berge, and Ø. Brandt (2003b) and G. Berge, H.T. Olstad (2004).

1.3 LNG

By definition LNG is a hydrocarbon composition consisting of at least 90% methane. The composition is kept at a low temperature of approximately 213 K in order to keep the pressure at about atmospheric pressure.

2. A Fire Exposed LNG Segment

The simulations were performed using VessFire. VessFire is a system for simulation of thermomechanic response of process segments exposed to fire. It simulates heat conduction in the equipment and pipes and performs stress calculations of the 3-dimensional shell. Simultaneously, the system simulates the inventory by treating the gas and liquid phases separately. The two phases are linked through evaporation, condensing, heat transfer and evacuation (for blowdown simulations).

2.1 Vessel conditions

The case is summarised in table 1. The composition consists of 95% methane and thus qualifies as LNG. The operating pressure simulated is 1 bar and gives a demonstration of how the composition behaves as the pressure rises above 1 bar due to the heating of the vessel.

Table 1: Vessel and inventory data for the simulation case.

Vessel	Unit	
Diameter	mm	1600
Length	mm	3200
Wall thickness	mm	50
Material	-	Carbon Steel
Yield stress	MPa	455
Surface emissivity	-	1.0
Outside surface heat transfer coefficient	J/m2K	30

Inventory	Unit	
Operating pressure	kPa	100
Operating temperature	K	213
Hydrocarbon level in vessel	mm	500
Water level in vessel	mm	100

Hydrocarbon composition	Component	Mole fraction
	C1	0.95
	C2	0.025

	C3	0.025

Outside conditions	Unit	
Temperature	K	283

Blowdown valve	Unit	
Inner diameter	mm	12
Contraction factor	-	0.8
Time to full open	s	0
Back pressure	kPa	100

2.2 Heat loads

The heat exposure is defined according to the guidelines Scandpower (2004) as summarised in table 2. This is the definition of a jet fire. The principle is that the local peak heat load shall stress the material without affecting the overall temperature rise. The background heat, on the other hand, is responsible for the temperature rise in the vessel.

Table 2: Heat loads for the simulation case.

Heat type	Time [s]	Heat exposure [kW/m2]
Background heat	3600	100
Peak heat	3600	350

2.3 Results

Figure 1 shows the pressure rise in the vessel together with the maximum average temperature of the vessel shell. Figure 2 shows the corresponding stress in the shell. In this case the vessel will most likely break since the calculated vessel stress becomes greater than the yield stress. The point where these to stresses cross each other corresponds to the bump on the pressure curve in figure 1. The reason for the bump can be seen in figure 3, which illustrates a sudden evaporation of the oil in the vessel. This is a typical phenomenon, which is illustrated in figures 4 and 5 where it can be seen that the release rate is constant and the amount of gas is increasing.

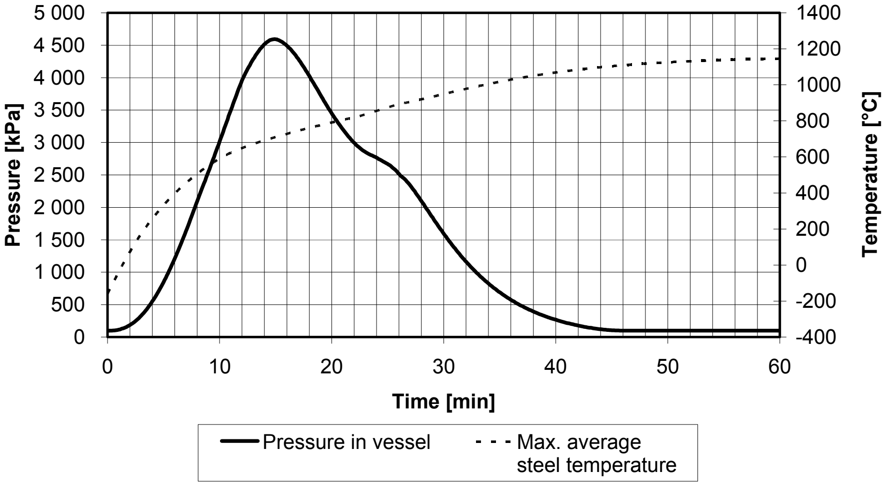

Figure 1: Time variation of the internal pressure of the vessel and the average temperature of the vessel shell.

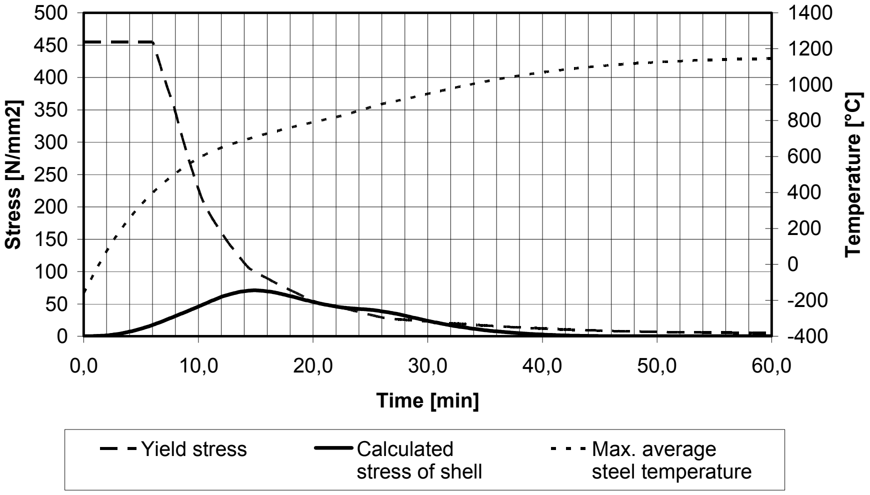

Figure 2: Time variation of the yield stress, the applied stress and the average temperature of the vessel shell.

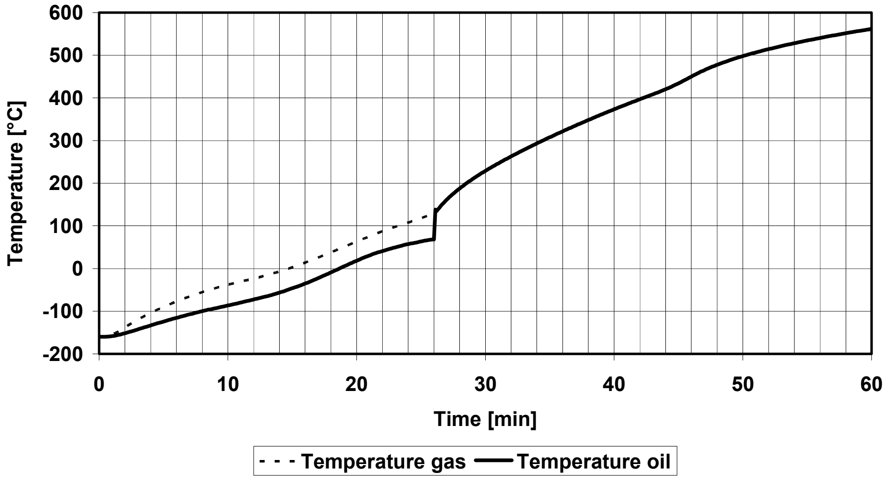

Figure 3: Time variation of the oil and gas temperature. After 26 minutes all liquid is evaporated.

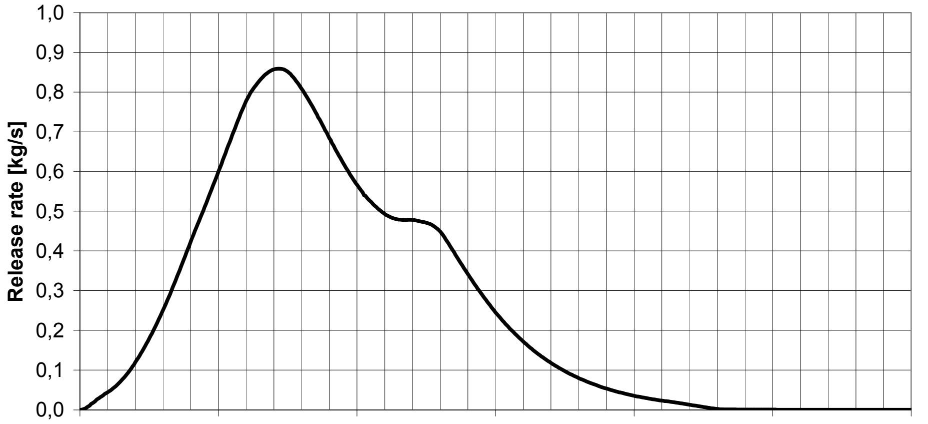

Figure 4: Time variation of the vessel release rate.

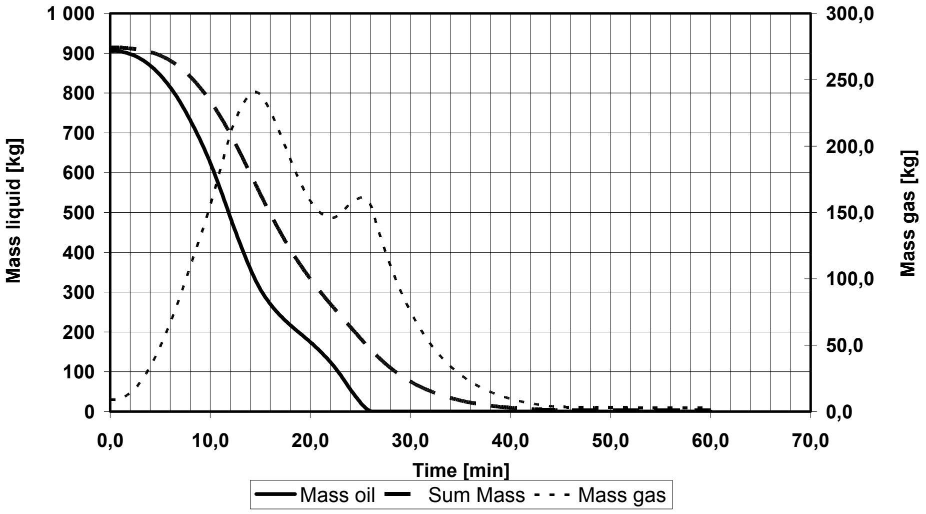

Figure 5: Time variation of the mass balance in the vessel.

2.4 Conclusions

This simple case study illustrates how simulations can be helpful in estimating the outcome of fire scenarios where pressure equipment is being exposed. With respect to the simulation system there is no real difference between calculation of a common process segment, e.g. a separator, and a vessel containing LNG. The main difference is the temperature and the pressure.

The advantage doing blowdown simulations of this kind is that more accurate information is achieved. More optimal planning and protection of equipment makes risk lower to a lower cost.

3. References

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