BLEVE Performance of Fire Protection Coating Systems on Dangerous Goods Tanks in a Test Fire

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***Abstract*—How can the risk of a BLEVE be reduced? That is the main question based on different research projects. In various large scale fire tests fire protection coating systems were used of different manufacturers. The degree of the coating as well as the layer thickness and the processing were varied. These experimental configurations were partly tested with and without pressure relief valve. The pressure relief valves were not protected again the thermal Load from the test fire. The ambition is to find a minimum of the thickness from the fire protection coating witch delay a BLEVE up to 90 minutes. Here are given the most interested configurations of tanks in fire and a description of the test-rigs.**

***Index Terms*—BLEVE, fire protection coating, isolation, test rigs, large scale fire test**

I. Description of Problem

Only a limited amount of information and data on how transport tanks for the carriage of dangerous goods perform in a fire are available from incidents and accidents, or are derived from model observations.

In some cases, the requirements for means of containment in the regulations are worded as protective aims or, as in the case of hazards resulting from fires, are only contained in certain sets of regulations. The effectiveness of the measures taken is tested or in individual cases is assumed if certain types of construction or rules are observed.

How a tank actually performs only emerges when there is an accident or incident. There are complex reasons why a tank fails in a fire. For example, this can be due to material fatigue, flaws in the materials, corrosion, cracks, non-permissible pressure or existing damage from a previous accident. The dangers in a BLEVE are from flying debris, the high pressure wave and the thermal radiation from the fire-ball. This can lead to significant damage to the surrounding area. For this reason, it is important to find out how fire protection insulation performs in conjunction with safety valves and to analyse, intensify and confirm these findings.

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II. Fire Protection Coatings

Organic fire protection coatings, so-called thin-film systems, are passive fire protection systems. Inorganic fire protection coatings are mostly too heavy and for this reason, are not used.

All fire protection coatings have the task of mitigating heat transmission into the tank.

In coating systems based on epoxy resins, the protective layer is formed by the application of liquid or paste-like coating materials. The system can be applied by spraying (airless procedure) or by being smoothed on.

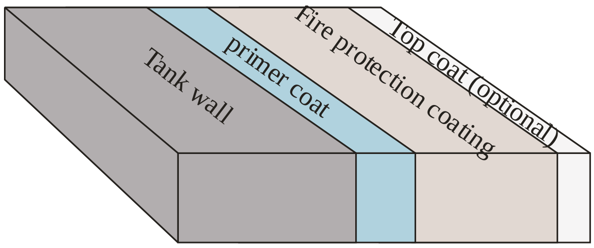

Figure 1. Constitution of a fire protection coating on a tank wall

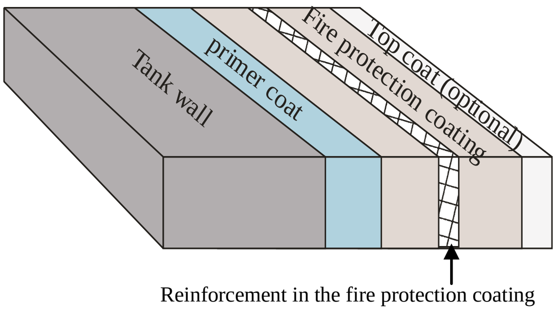

Figure 2. Constitution of a fire protection coating on a tank wall with reinforcement

Under the effects of fire, the coating (protective layer) expands and the heat flow is obstructed. The coating thus protects the tank from excessive heating and hence from the threat of a BLEVE. In so doing, the volume of the coating expands to several times its original thickness.

A typical constitution of a fire protection coating is shown in Fig. 1. Fig. 2 shows a fire protection coating with reinforcement layer.

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In many cases, thin-film systems are provided with armouring (reinforcement) worked into the middle of the coating or into the outer third. This consists of a wire mesh or a non-metallic fleece and is used to prevent the formation of cracks as far as possible, particularly on domed surfaces.

As the workmanship, for example the preparation of the tank surface and compliance with the conditions required by the manufacturer, have a vital impact on how the coating performs in the event of a fire, these tasks have to be carried out by a qualified expert company.

At present, there are three different types of coatings.

Intumescent fire protection coatings [1] are based on epoxy resin and in a fire, they react independently by foaming up as a result of a thermal load at a temperature of around 150 – 200 ℃, thereby forming an insulating layer. The foamed coating forms a barrier layer, thus reducing the heat input.

Sublimation fire protection coatings [2] on the other hand release gases under thermal load, which absorb the heat flow. In this case, large quantities of thermal energy are needed to transform the coating directly from the solid to the gaseous aggregate state without liquefying beforehand (phase transformation). In the process, this transformation is used to build up a layer which absorbs and blocks the heat flow.

Ablation coatings [3] are based on endothermic processes. The transmission of heat is delayed by the extraction of chemically bonded water from the fire protection coating.

Table I gives an overview of the different types of coating.

TABLE I. TYPES OF COATING

Type of coating	Effect
Intumescent	Foam up as a result of thermal load and form a non-flammable insulating layer.
Sublimation	As a result of thermal load, gases are released which absorb the heat flow. In this case, large quantities of thermal energy are needed to transform the coating directly from the solid to the gaseous aggregate state without liquefying beforehand (phase transformation).
Ablation	This endothermic process delays heat transmission by extracting chemically bonded water in the fire protection coating.

III. TEST RIGS

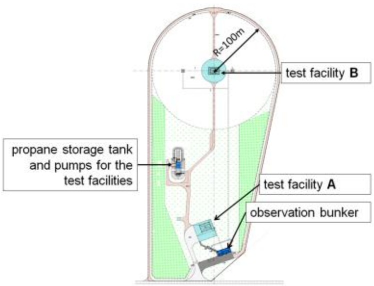


Figure 3. Fire test rigs on the TTS

This phenomenon is tested by the Federal Institute for Materials Research and Testing (BAM) in two different test rigs (A and B) which are located at the Technical Safety Test Site (TTS) in Horstwalde. Fig. 3 gives a overview of the test area.

Test rig A is used only for non-destructive testing. Destructive testing is carried out at test rig B.

Test rig A has a burn area of 12 m x 8 m. The heat source is liquid propane in a flexible circular-burner (water cooled). In order to reduce the influence of external wind, sheet metal elements are used. The maximum mass for test objects is 200t.

Figure 4. Test fire in test facility B for destructive testing

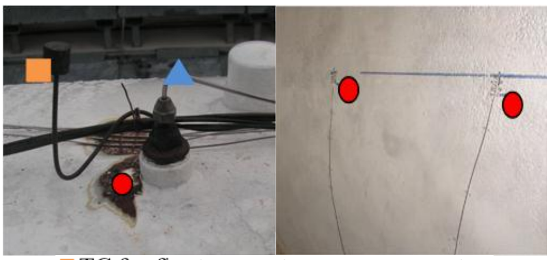
Test rig B Fig. 4 has a burn area of 12 m x 8 m. This is subdivided into 26 rows of nozzles, each with 16 nozzles.

The mass flow of liquid propane, the number of burner rows used and the number and type of burner nozzles are used to control the amount of heat and to ensure that the test samples are completely fired from underneath.

The technical equipment of test rig B enables heat transmission of up to 110 kW/m^2 to be achieved. The test sample is positioned over the burn area in such a way that it is fully engulfed in the fire. The height of the test sample above the burner nozzles, the number of nozzles and the mass flow set in the fire test were predetermined in tests at BAM. The settings chosen achieve a median heat transmission of 75 kW/m ^{2}in the test sample.

In order to reduce the influence of external wind and at the same time to catch pieces of the destroyed means of containment, windbreak elements are used. The ambient air flow nevertheless emerges as a temperature deviation caused by the wind. The maximum mass for small test objects is 20 t, for vehicles 40 t.

IV. STORAGE TANK FIRE TESTS



■ TC for fire temperature measurement

● TC for wall temperature measurement

▲ TC for inside temperature measurement

Figure 5. Measuring points (example)

All described tests are carried out in test rig B.

For the real scale Investigation the storage tanks was fitted with thermocouples (TC see Fig. 5) in- and outside. The thermocouples and pressure measurement were used to determine the temperature and the internal pressure. In addition, the burner pressure and the mass flow of the liquid propane mixture used to direct the fire at the test sample were recorded throughout the whole duration of the test.

The test tank was filled with 1375 l of liquid propane (this corresponds to a filling degree of 50%) after it had been rinsed several times with nitrogen.

Figure 6. 2,75m ³Storage tank with fire protection coating before the test (example)

Figure 7. 2,75m ³Storage tank with fire protection coating after the test

Fig. 6 shows a typical tank before the test and in Fig. 7 is for example a tank with fire protection after a test.

Three different configurations have been tested in large-scale fire tests.

- Without fire protection coating and safety valve
- With fire protection coating without safety valve
- With fire protection coating and safety valve

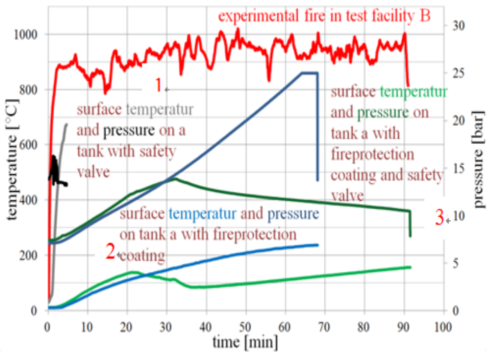


Figure 8. Various large scale fire test configurations

The results of the tests are shown in Fig. 8. The main information (temperature of the experimental fire in test stand, temperature, inside pressure and test duration) of each configuration is exposed.

For the protection of the test rigs abort criteria were defined. These were verified with the help of a FEM program with limit analysis. With help of the Fig. 9 can estimate a critical range (temperature and/or inside pressure) of the Tank.

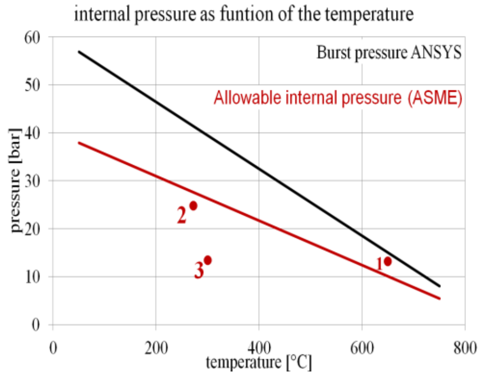


Figure 9. Internal pressure as function of the temperature

The 1st configuration [4] only with relief valve failed after only few minutes catastrophically.

A fire resistance time from over 60 min. has the 2nd configuration [4] with fire protection coating. The test analysis shows that the test could have continued for some minutes without a BLEVE occurring.

The 3rd experimental [5] configuration with fire protection coating and pressure relief valve was stopped after 90 min duration of test. Here it is to be recognized that for the tank no critical state was reached. The test analysis shows that the test could have continued for some minutes without a BLEVE occurring.

V. Conclusion

The evaluation of the tests has shown that it is necessary to protect a tank with a fire protection coating in a fire. If a pressure relief valve is included it has to be protected again the high temperature, since to otherwise no specification-moderate condition can be ensured. The relief valve does not show typical Zick Zack curve (pressure over the time) in this case.

The duration time in the test fire depends also of the thickness, the manufacture and the processing of the fire protection coating material.

References

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[3] German Institute for Construction Engineering: *Zulassungsgrundsätze für Ablationsbeschichtungen–Fassung Mai* (Approval principles for ablation coatings–May 1996 edition), Berlin, 1996.

[4] Research and development project: BLEVE (Boiling Liquid Expanding Vapour Explosion) in dangerous goods tanks–

investigations into the performance of tank constructions and equipment, particularly thermal and fire protection insulation in the event of fire (Sponsored by the Federal Ministry of Transport, Building and Urban Development BMVBS, Germany)

[5] Research and Development Project: Investigations to the Behavior of Tanks in Particular Thermal Coating in the Case of Fire (Sponsored by Ministère de L'Écologie du Développement Durable, des Transports et du Logement)

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