RECENT DEVELOPMENTS WITH ALIBI, A MODEL FOR SITE SPECIFIC PREDICTION OF LPG TANK BLEVE FREQUENCY

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The concept behind the ALIBI model was first introduced to a technical audience in 1988 at the European Seminar on the Pressurised Storage of Flammable Liquids in London. Since that time it has been developed by SRD (now AEA Technology Consultancy Services) on behalf of HSE (MHAU). Although the structure of the model has remained largely unchanged, efforts have been made to refine the modelling within it. The main effort in refining the modelling has been with the response of LPG tanks to jet flame impingement, and this is described in the paper.

Key Words - BLEVE, Risk Assessment, Fault Tree Analysis

INTRODUCTION

The Major Hazards Assessment Unit (MHAU) is part of Technology and Health Sciences Division of the Health and Safety Executive (HSE). HSE is the principal enforcing authority for Health and Safety legislation in Great Britain.

The work of the MHAU includes the provision of advice to Local Planning Authorities (LPAs) on the advisability of proposals for the development of land around Hazardous Installations. These installations include fixed sites, such as oil refineries, and certain cross-country pipelines. This advice has been available to LPAs over the last 20 years, although the basis on which HSE has been consulted has changed over the years.

The chemical industry which operates these installations is a rapidly changing and technologically advanced industry, and the methods used by MHAU must continually be developed to match the industry that it complements.

MHAU has always advised on a risk basis, taking into account both consequences and likelihood. However it has not always used fully quantified risk assessment (QRA) as the basis for its advice. Current advice is QRA based for most toxics assessments. In the case of advice around Liquefied Petroleum Gas (LPG) installations, advice is based on consequences from a range of possible hazardous events.

MHAU is moving towards a QRA basis for all its advice to LPAs and ALIBI (**A**ssessment of **L**PG **I**nstallations leading to **B**LEVE **I**ncidents) is part of the strategy to achieve that goal. It is intended to use ALIBI in conjunction with LPG RISKAT[1] to provide a QRA capability for installations where LPG is stored in bulk.

THE NEED FOR ALIBI

Initial work with LPG RISKAT used fixed, generic frequencies for the major events of BLEVE and cold catastrophic failure leading to Vapour Cloud Explosion (VCE) or flash fire. Consideration of the contributions of the various events to the calculated risk at various distances showed that BLEVE was the major contributor to risk at the distances of interest. For this reason, it was decided that use of a generic frequency for BLEVE was a weakness that should be eliminated in the long term.

There is a second important factor. The initiating event for BLEVE is loss of containment leading to jet flame impingement on the tank. The likelihood of BLEVE is expected to be strongly dependent on the layout around the tank of pipework fixtures, fittings and any transfer facilities, as these features would be significant locations for possible jet flames. An assessment method which was not capable of discriminating between sites with greatly differing layout would be open to criticism.

EARLY DEVELOPMENT OF ALIBI

ALIBI was initially developed under the HSE/SRD Research Agreement which has its origins in the work that the Safety and Reliability Directorate of the United Kingdom Atomic Energy Authority (SRD) did for HSE at the time of the Canvey Island studies[(2)(3)]. Much of the detail of the model has already been published[(4)].

For the purposes of this paper it is only necessary to appreciate that the model is based on the evaluation of a complex fault tree where the base events are possible releases of LPG from pipework fixtures, fittings and transfer operations. The fault tree includes features to take account of the effectiveness and reliability of mitigatory measures such as water sprays and operator intervention. The latter might be expected should a release occur during transfer operations.

The kernel of the model is a set of times to BLEVE of the tank, initiated by jet flames of three standard sizes originating in one of seven assumed locations. The assumed locations are the centres of the numbered areas shown diagramatically in Figure 1. Each of the bands around the tank is 2 m in width. The seventh area is the top of the tank. These BLEVE times are compared to the time taken for emergency action which brings the effect of the jet flame under control. Should the emergency action time be less than the assumed time to BLEVE, that route to BLEVE is assumed not to occur and makes no contribution to the predicted BLEVE frequency. A sound prediction of the time to BLEVE for each flame size and location is, therefore, important if the model is to have any validity.

The times to BLEVE were generated using the computer code ENGULF[(5)] which was also developed under the HSE/SRD Research Agreement.

PROBLEM AREAS

Early work with the computer implementation of the model, showed that the predicted BLEVE frequency was very sensitive to several factors.

One factor was the choice of thermal flux assumed in the ENGULF modelling. The prediction of BLEVE frequency could vary by several orders of magnitude if the flux assumed in the ENGULF modelling was varied by 50 kWm^{-2}. A wide range of thermal flux values could be found in the literature and there was little consensus as to the most appropriate value for the configurations being modelled.

The ENGULF modelling was also problematical because the code only allows one thermal flux value to be used in the calculations. This flux value can be thought of as being used for two purposes in the calculations. It is used as one input to model the reduction in strength of the tank shell due to increasing temperature, and hence predict the variation of burst pressure over time. It is also used as one input to model the increase in temperature of the tank contents, and hence predict the variation of tank internal pressure over time. When the latter pressure exceeds the former the model assumes the tank will BLEVE. This is illustrated diagramatically in Figure 2. The majority of references in the literature quote peak values for fluxes and occasionally some type of average value. It was thought that using the same value to model both aspects was an oversimplification.

A second factor was how to give credit for the effectiveness and reliability of the water sprays that are fitted to the majority of large LPG tanks. The initial approach for effectiveness, outlined in reference (4), was to reduce the flux used in the ENGULF modelling by 50 kWm^{-2} for all the 'sprays operate' cases in the fault tree. In respect of reliability, a range of values of failure on demand was adopted. The value used was based on a checklist of spray system design attributes. Recent work[(6)] has shown, for methane flames, that a high velocity flame is capable of preventing the establishment of a water film over substantial areas of tank surface. This has cast doubt on the validity of the original assumption of how to model effectiveness.

A third factor was the choice of emergency action time. Choice of a value in a particular case would be subjective and quite small changes in the assumed value would lead to major changes in the prediction of BLEVE frequency.

The model utilises a single value and so does not take account of variations in circumstances. For example, if the emergency action is being taken by the Fire Services, their time to travel to site is likely to vary over the diurnal cycle due to changing traffic patterns. In addition the time taken after arrival to become effective would be expected to be variable and depend on incident specific factors including the size of the jet flame.

CURRENT SOLUTIONS

Modelling of jet flames impinging on LPG tanks and the thermal response of the tank is still a difficult subject area. However, research work carried out over the last few years has provided some clarification. Ongoing research such as the JIVE European collaborative work(7) will hopefully clarify things further.

At present the most useful data for improving ALIBI has been found in the collaborative work of Shell and British Gas(8). This has been used to define, for each of the three flame sizes used in ALIBI, three fluxes which can be used in the ENGULF modelling. These are:-

a) An instantaneous maximum value. This is the highest value observed at any location where the flame impinges on the tank, irrespective of duration.

b) A point average value. This is the highest average value taken from those observed at any single location where the flame impinges on the tank, over the period of the trial.

c) An area average value. This is the average value taken over the whole area where the flame impinges on the tank, over the period of the trial.

Deriving these figures from the trials data required discussion with the authors and the application of judgement.

Once these figures had been derived the ENGULF modelling was repeated. This was carried out using the point average value of flux. The instantaneous maximum value was not used in the calculations. In addition, the assumed area of impingement was reduced in the ratio of the 'area average' value divided by the 'point average' value. This reduced the heat input to the tank and simulated the lower, area average, flux value for the modelling of rising internal pressure.

The problem of the effectiveness of water sprays is to be tackled by commissioning further research along the lines of reference (6). Shell/British Gas have been approached to provide a proposal to investigate the behaviour and performance of water sprays using the same experimental arrangements but with propane jet flames. This work will be supplemented by the results coming from work being carried out under the JIVE project. However the JIVE work is being carried out on small tanks with water spray configurations which, necessarily, have substantially smaller spray bar spacing than that encountered on LPG tanks where the use of ALIBI is intended.

The proposed Shell/British Gas work will investigate the full range of three flame sizes and three 'stand-off' distances from the tank with a propane jet flame. It is not anticipated that all combinations of flame size and distance will be investigated. An adaptive trial program is to be developed to determine which combinations are capable of disrupting the water film and to what effect.

The problem of the choice of emergency action time, and the fact that it acts as a go/no go switch in the fault tree, is intrinsic to the model in its current form. Current work on the model is concentrating on the areas of appropriate thermal flux and water spray effectiveness.

It is anticipated that the approach that will be adopted for emergency action time is to run the model using a distribution of times so as to represent the variability of actual performance. It is hoped that a simple triangular distribution will be sufficient.

The existing implementation of the ALIBI model as a computer code is still essentially a prototype. It has been cumbersome in use and will no longer run in conjunction with other software in MHAU. For this reason work has recently started on the reimplementation of the model using AEA Technology's current fault tree software with a customised data input facility.

FUTURE WORK

The model currently can only be applied to propane due to the limitations in knowledge outlined above. It is also limited to horizontal tanks. It is anticipated that ALIBI it will be extended to cover butane following the completion of current work. Extension to vertical tanks and spheres is not likely in the short term.

The generic model in ALIBI was originally developed by extending previous research which considered a specific horizontal LPG storage tank[9]. This strategy of considering a specific case prior to developing a generic model has not only been applied to horizontal LPG tanks. Research has recently been completed which has considered BLEVE frequency of an LPG road tanker during a delivery. This is, in turn, a candidate for conversion to generic model.

AUTHORS NOTE

The views expressed in this paper are those of the author; and, except where the context indicates, not necessarily those of HSE.

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Figures

Figure 1

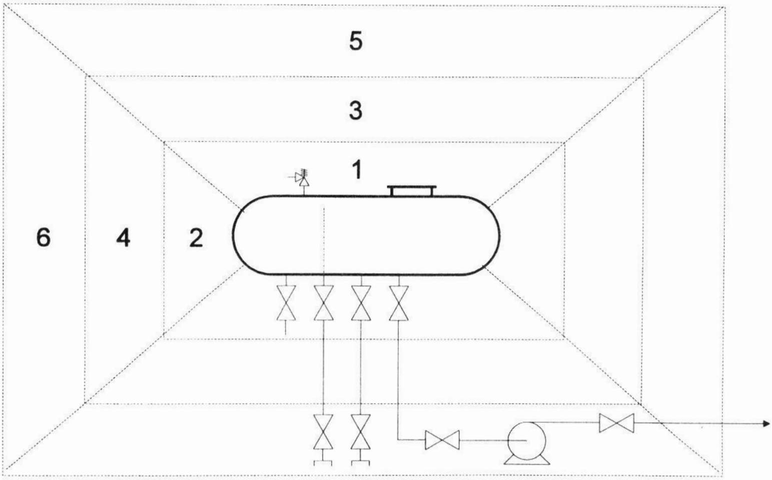

Figure 2