Health and Safety Executive

HSE information sheet

Modelling of pool fires in offshore hazard assessments

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Introduction

This information sheet provides guidance on modelling of pool fires hazards on steel decking. Initial experimental work at the Health and Safety Laboratory (HSL), Buxton has indicated that pool fires not contained by a bund are liable to cause severe deck plate buckling and possible weld shear.

Background

Recent experimental work[1] at HSL has highlighted a failure mode that is not generally taken into account when pool fires are analysed in a fire attack hazard assessment within an offshore safety case. Running pool fires are burning pools of liquid that are unrestrained by any wall or bund and are hence able to move depending on the surface gradient. Severe buckling of the steel plate has been observed during all the pool fires tests.

Experimental Description

A 10m square steel plated platform, constructed to offshore standards, has been used to investigate the mobility of an unrestrained pool fire. In the majority of offshore safety cases pool fires are modelled as static fires with a fixed radiation flux. The experimental programme was designed to observe a series of pool fires of varying sizes and to measure their movements as the fires develop. In tests using continuous flows of diesel at 20 $l.min^{-1}$, significant damage occurred to the simulated offshore deck. This included severe plate buckling and weld shear.

It is uncertain whether such damage would occur in practice, as this would be dependant on a number of factors including; the size of open deck surfaces; and whether plates were fully welded to cross members. However it should be noted that the pool fire had a liquid volume flowrate of 20 litres per minute for about 5 minutes. In practical terms “a small fire” but it caused damage significantly above expectations.

During the experiment the degree of deformation of the deck was sufficient to raise it upwards by about 200 mm and to fail both fully welded deck seams and stitch welds. In one case, burning fuel was able to flow through a split in the deck. The implications are clear:-

- deck splitting could cause a vertical fire spread and associated escalation not currently modelled in safety cases.

- deck buckling could cause pool fires to continually move across deck plates as they buckle, in an unpredictable manner.

Temperatures of approximately 600^{o}C were measured in the deck plates in the vicinity of the fire at 4 $l.min^{-1}$ Isopar K liquid fuel after about 200 seconds, with fire diameter reaching just over 1m in this time. Temperatures varied around the fire area and were very dependant on wind strength and direction. The temperature-time profile was very similar for the 20 l.min fire although the fire diameter was larger and the flaming more severe.

Bunded pool fire tests

Following earlier investigations into the behaviour of unrestricted spills, it was decided to investigate whether bunding arrangements could be provided on the test deck. In practice the use of bunding both aids recovery of spilt liquids and restricts the extent of spread of spills depending on the size / volume of the bund and the fluid release rate.

A predicted pool size (fire) for the 20 $l.min^{-1}$ experiment was estimated at 7m diameter. As spills are of a relatively long duration (more than a few seconds), it is legitimate to ignore drag effects on liquid flow and thus pool area can be predicted using the following equation:

$$\text{Pool Area} = \frac{\text{Volume spilt}}{\text{Volume of fluid per m}^2 \text{ of pool}}$$

The volume of fluid per m^2 of pool = 10000 cm^2 x pool depth in cm.

Liquid spills will expand on a surface until they achieve a certain critical thickness. For non-porous relatively smooth surfaces such as steel decks, a typical pool depth will be 1 mm for non-viscous liquids. On this basis, each square metre of pool will hold 1000 cm^3 of liquid. If the spill of escaping liquid is ignited, the rate of pool spread is no longer simply a function of rate of fuel input, but is now governed by the <u>balance</u> of fuel input vs fuel burn-off rate.

As the pool increases in area, the proportion of fuel burning off increases until it eventually matches the rate of input. At this time the pool should remain constant in size. This was illustrated in the experiments.

Liquid containment bunds and flame spread

Several experiments were also carried out using a 1m diameter steel bund for a comparison with unrestrained pool fires. The objective was to measure deck plate temperatures likely to occur with a bunded fire, and to demonstrate the effectiveness of containment bund in limiting fire severity and fire spread.

Implications of the pool fire tests and fire protection system offshore

Offshore installations may have bunding arrangements underneath vessels of sizable flammable inventory e.g. separators and KO drums. Bunding is designed to contain spillages/leaks from vessels and connections to limit the spread of any flammable liquids. When combined, aqueous film forming foam (AFFF)/deluge and bunds are highly effective in extinguishing pool fires in very short timescales. Additionally, since the flammable layer floats on top of the contained deluge water the heat transfer onto the supporting steel deck is negligible.

Unfortunately on ageing installations, due to corrosion under lagging, many duty holders now remove the passive fire protection (PFP) from the lower areas of vessels, to minimise corrosion and to allow ease of access for non destructive testing (NDT). The protection by water deluge becomes more significant in situations where PFP/lagging has been removed.

Approach to the Modelling of offshore pool fires

In any situation handling significant inventories of flammable or combustible liquids the possibility exists of accidental spillage and fire. The development and properties of such fires are predicted using, often simple, mathematical models to provide input into risk assessments and emergency response criteria. For simplicity, these models usually assume a circular pool of uniform depth, spreading on a uniform surface.

If the pool is formed because of a steady-state leak, then the final size of the pool is dependant upon the balance between the rate of fuel release and the rate of fuel consumption in the fire. Thus, in the absence of any disturbing factors, an equilibrium position will be reached where the fire increases in area until the rate of burn-off equals the rate of release.

When fire scenarios are analysed and modelled, credit may be claimed for the protection systems described above. However when AFFF/deluge is used without bunding the pool formed will spread over large areas and stops only when it meets physical barriers. Without bunds the protective water layer is not in place and the supporting steel deck is vulnerable to thermal loading and stress.

Very high stresses are developed in unprotected steel plates as the steel temperature increases. This refers to both walls and decks. A cause of these high stresses is the very rigid periphical structural members to which the walls and decks are attached. The induced thermal expansion is not relieved at its edges and hence buckles the deck (or walls).

It is recommended that when pool fires are modelled for situations that do not include a bund and AFFF/deluge system protection, stress calculations are undertaken to evaluate the potential for deck and wall distortion. If stress value indicate high distortion rates appropriate remedial measures will need to be put in place to minimise escalation potential and risks to persons from fire attack within that area.

Account also needs to be taken of the lateral movement of flammable pools around the deck and also leakage through the decks and possible escalation scenarios. Wind speed and strength is another factor that has a significant effect on the temperature in the steel deck and should be included in the overall consequence analysis.

Modeling of pool fire formation and development also needs to account for spillage and pool size growth. As demonstrated by the bunded experiments at HSL a fire diameter of 1m will grow significantly larger if the liquid is not contained.

Action required

It is recommended that the information and advice on pool fire behaviour given in this sheet, and the supporting research report, is noted and fire attack scenarios reviewed.

Fire attack analysis in all future offshore safety cases will be assessed using the findings of this research. Thorough reviews of safety cases should consider this information. Remedial measures will be reviewed in detail using this new knowledge.

Relevant legal requirements

Health and Safety at Work etc Act 1974 (HSWA), Sections 2 & 3

Offshore Installations (Safety Case) Regulations 2005 (SCR05), Regulation 14

Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995 (PFEER) Regulations 5, 9, 12 and 13

Offshore Installations and Wells (Design and Construction etc) Regulations 1996 Regulation 5

References

[1] The development of running pool fires in simulated offshore decking
PS/08/08. Aubrey Thyer, Diane Kerr, Mark Royale, Deborah Willoughby

Further information

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