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Paper presented at 7th International Symposium on Loss Prevention and Safety Promotion in the Process Industries, Taormina, Italy, 4-8 May 1992.

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REPORT

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TITLE

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ABSTRACT

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KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Fire	Brann
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SELECTED BY AUTHOR(S)	Jet fire	Jet brann
	Test	Prøvning

A TEST METHOD FOR JET FIRE EXPOSURE

1. INTRODUCTION

Impinging jet fires from high pressure gas leakages represent a severe hazard on offshore platforms and in onshore process plants. The devasting results from such fires were seen in the Piper Alpha disaster. In the subsequent inquiry by Lord Cullen [1], the limitations of current fire test methods for passive fire protection was highlighted. One recommendation of that inquiry was that the industry should develop improved tests. This paper describes an initiative by SINTEF and Shell towards that goal.

2. BACKGROUND

Existing, standard, fire resistance tests are carried out in a furnace environment, operating under time-temperature conditions defined by the relevant fire curve, to represent (but not reproduce) a fire. There are two principle types of fire test, those for cellulosic, basically wood, fires and those for hydrocarbon fires. These lead to 'A' and 'H' ratings respectively, for given lengths of time.

Various national fire tests exist which represent cellulosic fires. They are all essentially equivalent and several are harmonised via international standards.

Although there is no internationally recognised hydrocarbon fire test standard, the Mobil and NPD time-temperature curves are widely used, as is the interim standard proposed by UK DEn which is broadly intermediate between these two.

These hydrocarbon fire tests are based on furnace temperature rather than heat flux and although the total heat flux may be similar to that generated within a fire, the wider range of fire variables, such as the balance of radiative and convective heating, high gas velocities and thermal shock are not specifically included or controlled. These are major factors with regard to the performance of passive fire protection in actual fires, and in particular jet fires, and are probably best addressed by tests which feature direct, or high velocity, flame impingement.

The main requirement in defining a flame impingement fire test is a manageable, reproducible and well-characterised flame in which conditions can be related to those in actual fires. This requirement is addressed in this paper where we describe and compare a laboratory-scale test with large-scale experiments.

3. LARGE SCALE EXPERIMENTS

3.1 Large scale jet fire research

In order to assess the response of structures subjected to impingement by a large scale jet fire, Shell Research Ltd and British Gas plc jointly conducted a comprehensive experimental research project[2,3]. The project was co-funded by the Commission of European Communities, under their Research Programme on Major Technological Hazards.

Experiments were conducted in which natural gas and two-phase propane jet fires impinged horizontally onto either an empty, 0.9 m diameter, pipe or an empty, 13 tonne, LPG storage vessel, positioned over a range of distances relative to the point of gas release.

The natural gas releases had discharge pressures from 1.2 to 58 bara and flow rates from 3 to 10 kgs^{-1}, the lowest pressure discharge was sub-sonic and the others sonic. The propane releases were at a pressure of 9 bara with flow rates of 1.5 to 22 kgs^{-1}.

Heat flux density distributions over the structures were obtained directly using an array of forty total heat flux sensors located at their surfaces. The radiative heat flux to the impingement targets and the target metal temperatures were also measured. The direct heat flux measurements were supplemented by measurements within the flame of gas temperatures and velocities.

The heat flux density distribution was found to be complex and was dependent upon both flame type and position in the flame. Heat fluxes in the fames studied were in the range 50 to 300 kWm^{-2} for the sonic natural gas flames and 50 to 250 kWm^{-2} for the propane flames.These total heat fluxes were lower than previously assumed and the area of maximum heat flux were small in comparison to the total engulfed area.

3.2 The performance of passive fire protection in large jet fires

Following the experiments described above, the same jet fire facility was used to evaluate the performance of passive fire protection on structural steelwork in the Shell Offshore Flame Impingement Protection Programme[4]. The objective of the programme was to determine directly the response of full-size, unprotected and passively fire protected, structural steel members to impingement for one hour by a representative, large natural gas flame. The test flame, about 20 m long, was an ignited 3 kgs^{-1} sonic release of natural gas. This flame had been characterised in the jet fire research programme, enabling the test specimen to be placed where there was known to be a representative total heat flux with substantial convective and radiative components, gas velocities and turbulence intensity.

Two generic types of fire protection were evaluated, cementitious and intumescent, on two structural members, tubulars and I-section universal columns. The tests demonstrated that both types of passive fire protection can provide significant protection against an impinging jet fire. They also highlighted the importance of features such as erosion by the high velocity jet that are not present in the furnace based tests.

These tests, underpinned by the jet fire research described above, provide benchmark results in a large scale fire that can form a sound basis for the development of a more manageable ways to evaluate the performance of passive fire protection in jet fires.

4. LABORATORY SCALE FIRE TEST

4.1 Background of a laboratory test

SINTEF made a first approach to jet fire testing of fire protective materials in 1986, testing panels with a sonic propane jet impinging on a flat plate. The tests comprised fire water applications at intervals, to simulate the combined effect of fire and fire fighting action. This test has given name to an intermediate set of specifications used to some extent to represent a jet fire, the so-called SAGA specifications.

A jet impinging on a flat plate may reproduce the erosive effect on the fire protection material, but the total heat flux to the panel is dependent on the gas release rate. In the first tests the flame thickness was less than 0.5 m at its maximum, which gives radiative heat fluxes far from maximum.

To obtain a high velocity and a high radiative heat flux simultaneously, a new test specimen geometry was constructed. An I-girder was protected with an intumescent material and this was tested with a jet impinging onto the web of the girder. This gave a recirculating flame, combining high velocity with high radiative heat flux. This performance demonstration was done for British Petroleum, and a set of experiments comprising heat flux, temperature and velocity measurements were done prior to the test of the intumescent coating(5).

The I-girder produced a recirculating flame but a lot of the flame escaped either side of the test specimen. The girder was then blocked at the ends and the resultant box-like geometry object produced a concentrated fireball in front of the specimen. This configuration forms the basis of the test method described below.

4.2 The test configuration

The geometry of the test configuration is shown in figure 1. The size allows laboratory testing with the advantages of a reproducible and weather independent procedure. Figure 2 is a photograph of a test in progress and shows the shape of the flame.

4.2.1 The fuel release system

The test fuel is propane. It is released at sonic velocity through a nozzle, as pure gas without a liquid fraction. This requires the pressure drop from the nozzle exit to the ambient to be above the critical for sonic flow, about 1.8 [bar]. The propane must be supplied to the nozzle in gas phase. This is obtained by using an evaporator. The mass flow rate is 0.3 kg/s.

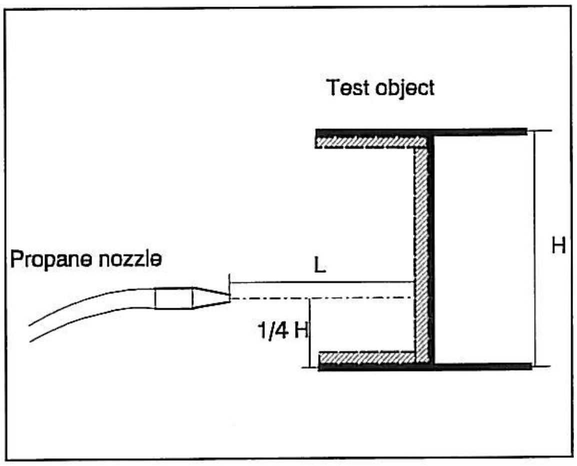

Figure 1. Arrangement for impinging jet fire test.

4.2.2 The test box

The propane jet issues into the box-like target, standing at an angle of 90° to the jet axis. The box dimensions are: width : W = 1.5 m, height : H = 1.5 m, and depth : D = 0.45 m. The jet axis has been aimed centrally at 1/2 and 1/4 H, and at distances of L = 1.0 m, 1.5 m and 2.5 m from the wall of the box. This configuration turns the jet and produces a flame in front of the box with a diameter of about 2 m.

4.2.3 Test objects

Objects to be exposed to the jet fire can be located either at the wall of the test box, or immediately in front of the box.

Wall linings and insulation materials:

The rear wall of the test box is replaced by the test object, which is insulated as it will be used in practice. The ambient conditions at the unexposed side of the tested object are specified by the geometry of the test box and are not to be additionally cooled.

I-girder:

I-girders of dimensions close to 1.5 m web height may be tested as a part of the test box, the upper and lower flanges forming the top and bottom part of the test box.

Pipes and structural sections:

Pipes with diameter less than 0.5 m may be tested by mounting them across the front of the box, at 3/4 height.The heat fluxes and erosion effects in this position have to some extent been quantified but further work needs to be done to find the optimal test conditions.

Other objects:

Constructions of other geometry may also be tested. The exposure to the jet has to be decided in each case. The flame shall impinge the object in a way that combines high radiative heat flux and velocity at critical positions on the object, and in a way that creates possible intrusion of the flame into the connections and seals of the object's fire protection.

4.2.4 Test duration

Tests can be carried out for several hours, only restricted by the full tank capacity. Ad hoc performance tests of 3 hour duration have been performed.

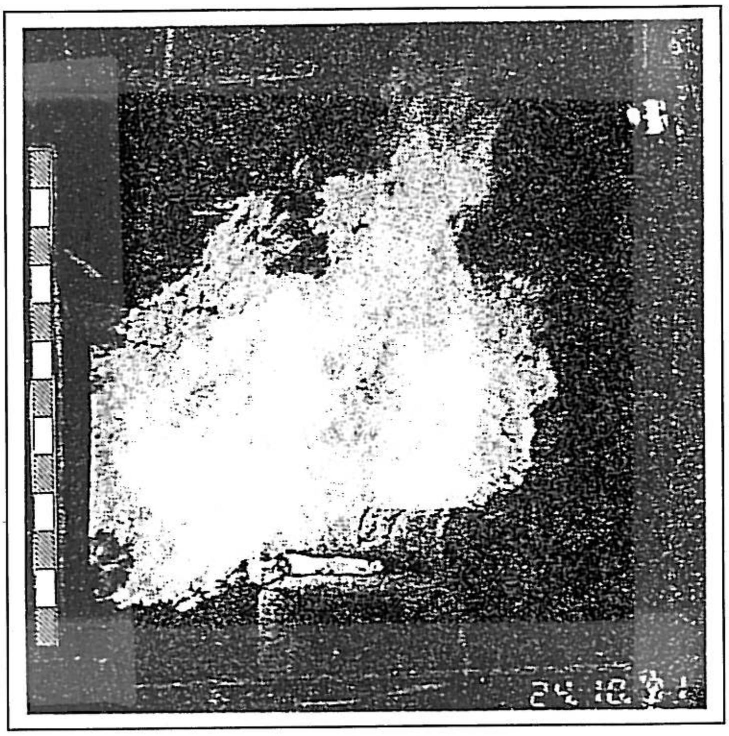

Figure 2 Flame shape and size in a laboratory jet fire test

4.3 The fire characteristics

In a series of experiments, incident heat fluxes to the wall of the box were measured using the same circular-foil total heat flux gauges and ellipsoidal radiometers used in the large scale experiments described in section 3. An array of twelve total flux gauges and two radiometers were mounted in the wall. These instruments were calibrated against a black-body radiation heat source before and after the tests, both in Norway and in the UK.

A typical heat flux distribution over the wall, derived from the array of twelve total heat flux gauges, is shown in Figure 3. In this example the nozzle was positioned at 1/4 H from the bottom, at L = 1 m from the wall, attacking at an angle of 90°.

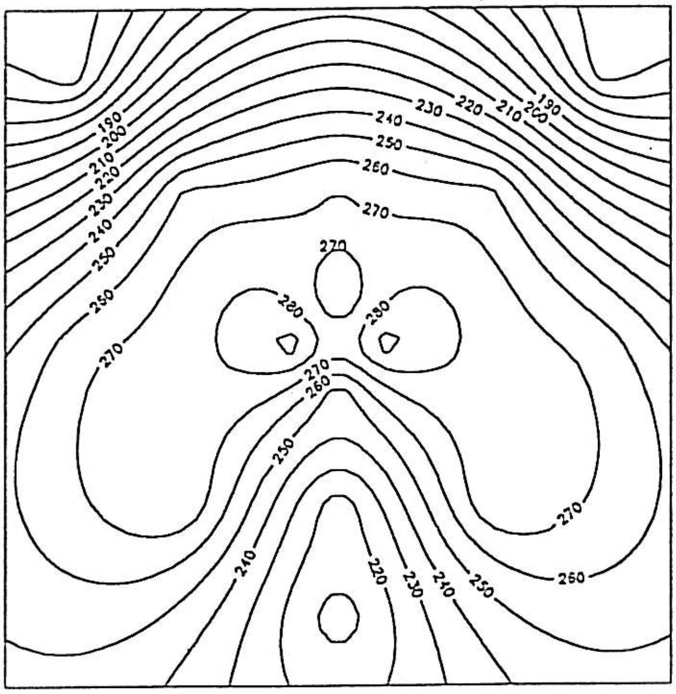

Figure 3 Distribution of heat flux density over the wall of the test box, measured by circular-foil total heat flux gauges.

The average flux over the whole surface was 240 kW/m^2. The radiant flux measured near the centre of the plate was 150 kW/m^2, 51% of the total heat flux measured at the same location.

Similar measurements have been made for impingement at 1/2 H and at distances L = 1.0 m, 1.5 m and 2.5 m from the wall of the box.

In a separate series of experiments using the same geometries, velocities and temperatures were measured close to the wall of the box. Velocities were measured using bi-directional probes. The probes were positioned to measure velocities flowing across the surface of the wall. Typical velocities were found to be about 30 m/s in regions where the temperature was above 1200 °C.

5. COMPARISON OF TEST CONDITIONS

In the large flames produced by high pressure natural gas releases, high velocities in the flame and hence high convective fluxes to impinged objects result from the sonic jet. In the laboratory scale fire test a sonic jet is also used. The key to simultaneously achieving a high radiative flux at small scale is the geometry of the box into which the jet is fired. This confines the flame, producing a fireball and a longer radiative path length in front of the specimen than would otherwise be the case.

The choice of propane as a fuel for the laboratory test is both convenient and its greater propensity than natural gas to produce soot and hence luminosity may also contribute to achieving a high radiant flux.

A detailed comparison of the conditions found in the laboratory scale fire test and the large scale experiments will be the subject of a further publication when the results have been fully analyzed. However, at this stage we can state that the heat flux densities, both radiative and convective, velocities and temperatures are of the same magnitude.

6. CONCLUSIONS

The comparison of results obtained in the laboratory-scale fire test with those measured in large-scale jet fires indicates that many of the important effects can be reproduced at a manageable scale.

The laboratory-scale fire test described could form the basis of a fire test method for jet fires that would complement the furnace based hydrocarbon fire test.

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