VENTING OF GASEOUS EXPLOSIONS

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An experimental investigation has been performed into the venting of methane-air explosions in heating plants. The investigation was performed on a realistic scale in a 38.5 m^3 enclosure.
The first part of the experimental programme concerns the influence of the "usual" parameters such as the vent opening area, the vent opening pressure, the ignition location and the vent opening configuration.
The second part of the investigation concerns the influence of factors related to heating plants. Thus the effect of introducing a large obstacle i.e. the central heating apparatus and the effect of venting through a dormer window (heating plants are often located in the cellar of a building allowing explosion venting via a dormer window only) are investigated.
Keywords: experiments, gas explosions, venting, overpressures, heating plant, measurements.

INTRODUCTION

A significant proportion of the fuel used in central heating systems is natural gas. In spite of regulations with regard to the gas burners and burner control systems applied in the heating systems and safety standards regarding the correct installation of gas pipework there is always a chance of a gas release and a subsequent gas explosion.
One of the most common ways to mitigate the explosion effects in order to protect the heating plant and the building in which the heating plant is located is gas explosion venting.
In one of the outer walls a weak area is introduced that will act as a blow-out panel or membrane allowing unburned gases and combustion products to flow out in case of an explosion. If the vent opening has been designed appropriately the explosion generated pressure will be limited to values below the damage threshold of the heating plant which will also prevent parts of the building in which the heating plant is located from failing. A serious accident in this respect was the Ronan Point accident in 1968 (1).
As shown by several reviewers (2, 3, 4) methods to calculate the appropriate vent opening size result in a wide variety of vent area predictions in spite of similar starting conditions. The majority of the design methods are based on experiments which because of several reasons do not allow extrapolation beyond the experimental range. One of the main reasons is the scale of the experiments. If the experiments are performed on a small scale several explosion enhancing mechanisms cannot occur. As a result explosion overpressures remain comparatively low as well as the vent areas predicted by vent design criteria evolving from these experiments.
Explosion enhancing mechanisms that have been noticed in large scale experiments performed in the past are:

- turbulence generation in a shear layer (5, 6)
- oscillatory combustion (7, 8, 9, 10)
- Taylor instabilities (5, 6)

Further, more recently the effect of ensuing explosions outside the enclosure on the inside explosion was investigated (11). Possibly the external explosions impede the flow out of the enclosure and trigger flame instabilities inside the enclosure.
Despite the complexity of the venting process, application of venting is a very cheap and simple way to limit the effects of explosion. Therefore it was decided to perform experiments on a realistic scale as far as heating plants are concerned. With regard to the aim of the investigation methane was used as flammable gas. Relatively large vent openings and low opening pressures of the vent were applied in order to obtain low reduced overpressures as domestic structures cannot withstand high overpressures.
The first part of the experimental programme concerns the influence of the "usual" parameters such as the vent opening area, the vent opening pressure, the ignition location and the vent opening configuration.
The second part of the investigation concerns the influence of factors related to heating plants. Thus the effect of introducing a large obstacle, i.e. the central heating apparatus, and the effect of venting through a dormer window (heating plants are often located in the cellar of a building allowing explosion venting via a dormer window only) are investigated.

In this paper a survey of the results of the experimental investigation will be presented.

EXPERIMENTAL SET-UP AND PROCEDURE

The experiments were carried out in a concrete enclosure of 4.0 m x 3.7 m x 2.6 m = 38.5 m^3 (see Figure 1). The enclosure was provided with a vent opening. The wall in which the vent opening is present consists of a construction of steel beams supporting sheets of 2 cm thick plywood. The sheets can be pushed in slots in the beams. In this way single and multiple vent openings can be created with a variable vent area. A maximum vent area of 6.72 m^2 can be made. Prior to gas filling the wall provided with the vent area was completely sealed with thin polyethylene sheeting. Polyethylene sheeting has a static failure pressure comparable to, e.g., normal glass windows
As a flammable gas methane (Commercial Purity) was used. The methane was introduced at three locations. Fans mixed the gas with air. The gas concentration was monitored at three different locations inside the room. The gas concentration sensors developed at the Prins Maurits Laboratory are based on detection of changes in heat conductivity of the gas.
One minute before ignition the fans were switched off.
The ignition source consisted of a continuous inductive high voltage spark generated by a 12.5 kV transformer (duration 0.1 - 0.5 s).
Pressure transducers (Druck, type PDCR) were mounted at 3 locations on the walls and on the roof; only on the vent wall no transducers were installed. Outside the enclosure three blast gauges (Druck, type PDCR) were placed at 0 m, 7.5 m and 17.5 m from the opening respectively. A video camera registered the flame emerging from the room. A high speed camera (Locam) was used to register the development of the combustion process inside the room. To this end the room had been provided with two windows.
The signals from the pressure transducers and the blast gauges were amplified and recorded on an FM tape recorder (SE Labs) together with signals from the moment of ignition and the moment of rupture of the vent sealing.
The recorded signals were digitalized for further analysis.
In general the effects of the parameters on the venting process were related to the maximum of the pressure after the vent opened. For oscillatory peaks an average value of the pressure was used. This average pressure was obtained by adequate numerical filtering of the measured pressure-time histories.

RESULTS AND DISCUSSION

General

Figure 2 shows an example of a characteristic measured pressure-time history in an empty room filled with a 10 % v/v methane-air mixture ignited in the centre of the room. The room had been provided with a 5,2 m^2 vent opening sealed with a single polyethylene sheet.
The pressure-time history was measured in the centre of the rear wall of the room. The pressure-time history measured during these types of experiments exhibits a double peak behaviour. The first pressure peak is due to the failure of the vent cover. The second pressure peak resulted from the oscillatory type of combustion as found before by several investigators in these type of experiments (7-10). The acoustic wave can easily be recognized superposed on the pressure-time history.
The amplitude of the first pressure peak will depend on the strength of the vent cover. When one polyethylene sheet is used to seal the vent opening the first pressure peak varies between 2 and 10 kPa. This value is slightly dependent on the vent area.

One test was performed in which the vent cover was removed 2 seconds before ignition. During this particular test the first peak reached a value of 10 kPa. The occurrence of the first peak in this situation coincides with the moment the flame emerges from the opening.
Comparison to an identical test in which a polyethylene foil was used as a vent cover shows that the first peak in the test without foil coincides with a pressure peak in the test in which the foil was used.
Both peaks are comparatively steep and probably can be attributed to a minor explosion of unburned gas pushed out of the enclosure into the open. This gas cloud will be turbulent stimulating combustion. Although no cameras were placed outside the enclosure to record this phenomenon an externally generated pressure peak can be traced back from the pressure recordings measured inside. The two pressure peaks mentioned above appear to reach the rear wall pressure gauge approx. 5 - 10 ms later than recorded on the pressure gauge installed at the vent opening position. The 5 - 10 ms time is in agreement with the time a pressure wave needs to travel a distance of 4 m in hot combustion gases. This supports the suggestion made above. This suggestion was first made by Harrison and Eyre (11).

The second and generally also the maximum pressure peak in each experiment is due to the oscillatory type of combustion inside the room. An acoustic wave generated during the combustion process enhances the combustion resulting in high overpressures indicating a positive feedback mechanism.
This positive feedback mechanism during the oscillatory type of combustion has been described by Markstein (12). The frequency of the acoustic wave can be obtained from a frequency analysis of the signal showing a maximum at 120 Hz which coincides with the fundamental mode of the room when the wave stands between the two side walls. Also higher harmonics can be distinguished.
As the repeatibility of this feedback mechanism is not very good also the maximum pressures show a large scatter. Using a centrally ignited 9.5 % v/v methane-air mixture and a 4.8 m^2 vent area provided with a single polyethylene sheet the maximum overpressure was found to vary between 6 and 13 kPa in five identical tests.

Gas concentration

A limited number of experiments have been performed to investigate the effect of the methane-air concentration on the maximum overpressure. In these particular tests the vent opening was sealed using a single sheet of polyethylene foil.
Results are depicted in Figure 3. In spite of occasionally higher pressures at the stoichiometric composition (9.5 % v/v) a methane-air concentration of 10 % v/v was used in the remainder of the programme.
This choice was also based on the fact that 10 % v/v mixtures seem to be more sensitive to oscillatory combustion than the stoichiometric mixtures (13).

Vent opening area

In Figure 4 the maximum overpressures measured in a centrally ignited room have been compared to the Bradley-Mitcheson safe recommendation for initially covered vent openings (3). As the Figure shows pressures are overestimated by the Bradley and Mitcheson criterion. This is as expected as the Bradley and Mitcheson criterion is intended to give an upper bound.
In comparison to the smaller vent openings the pressures measured in tests using fairly large openings (> 5.2 m^2) are high. The pressures especially measured at vent opening sizes of 5.2 m^2, 4.8 m^2, 4.1 m^2 and 3.5 m^2 are very low. The reason for this anomaly is not clear yet although the tests where these relatively high pressures occurred were attended vith very strong oscillations indicating a strong oscillatory feedback mechanism.
The rate of decrease of the overpressures with vent opening area in the experiments seems to be similar to the one predicted by the Bradley and Mitcheson criterion.

Variation of the vent opening pressure

Some tests have been performed to investigate the influence of the pressure at which the vent opening is released on the maximum overpressure generated later on during the course of the explosion. Using several layers of polyethylene sheet or a single sheet of plaster plate the opening pressure was varied within a limited range: from 0 to 10 kPa. The effect of the vent opening pressure on the maximum overpressure is illustrated in Figure 5. In these tests a vent opening area of 4.1 m^2 was used. The Figure shows that there is no distinct influence. The variation of the maximum overpressure in this range of vent opening pressures can be attributed to variations during the oscillatory mode of combustion.

Using plaster plate as a vent cover causes the pressure inside the enclosure temporarily to be under atmospheric after failure of the plaster at approx. 10 kPa (see Figure 6). This results in a flow inwards through the enclosure causing a Taylor instability at the rear side of the flame clearly visible on the high speed recordings. The Taylor instability disappeared as soon as the pressure inside the enclosure was above atmospheric pressure again.

Ignition source location

Some experiments have been performed to investigate the effect of ignition source location. The ignition source was effected at three locations, viz. at the rear wall, in the centre of the enclosure and near the vent opening. Using a 5 layer-polyethylene vent cover sealing a vent opening of 4.1 m^2 the maximum overpressure inside the enclosure varied from 13 kPa (central ignition), to

19 kPa (rear wall ignition) to 22 kPa (vent opening ignition). In case of using plaster as a vent cover a maximum overpressure of 11 kPa was found for both igniting at the vent cover and in the centre of the enclosure. Using a 2.5 m^2 vent opening overpressures of 53 kPa and 63 kPa were found for igniting in the centre of the enclosure and near the vent cover respectively. From these findings it appears that the ignition source location has a minor influence on the maximum overpressure generated during vented explosions.
On the other hand the pressure-time histories measured for the various ignition source locations are completely different as illustrated in Figure 7. Igniting in the centre results in a pressure-time history comparable to the one shown in Figure 2. Ignition near the vent opening also results in a pressure-time history with a maximum pressure occurring during a phase of oscillatory combustion although this moment is slightly delayed in comparison to the central ignition case. Igniting the mixture at the rear wall results in a completely different explosion course. The maximum is due to an explosion of the unburned mixture outside the enclosure vented during the early stages of the explosion in the enclosure. The blast wave caused by the external explosion propagates in the surroundings but also into the enclosure. The short pressure spike due to the external explosion causes a temporarily increase of the pressure inside the enclosure as well. From this moment on combustion products are vented increasing the volumetric flow through the vent resulting in a gradual decrease of the pressure in the enclosure.

Vent opening shape

Some experiments have been performed using vent openings of various shapes. An example of one of the vent openings that have been used is shown in Figure 8. In all cases one sheet of polyethylene was used to seal the vent (vent area 3.0 m^2) and ignition was effected in the centre of the room.
The pressure-time histories that were measured for the various vent opening shapes were all alike. The maximum overpressures that were measured were within a range of 32 - 37 kPa.
From these findings it can be concluded that the shape of the vent opening is not very important.

Influence of a single obstacle in the enclosure

Some tests have been performed in which a single large obstacle was placed in the enclosure as a simulation of a central heating apparatus. During these tests various parameters were varied such as the vent opening area, the ignition source location, the location of the obstacle within the enclosure and the orientation of the obstacle in the enclosure.
The obstacle is a rectangular steel box with dimensions: height 1.5 m, width 0,75 m and length 1.5 m. To ensure stability of the box during the experiments the box was filled with water. When the box is placed in an orientation such that the length of the box is parallel to the vent opening wall the box blocks about 23 % of the section of the enclosure. Placing the box in an orientation such that the width of the obstacle is parallel to the vent opening wall the box blocks about 12 % of the section of the enclosure.
In general the ignition source was effected at the rear wall of the enclosure in these experiments. All tests were performed using a single sheet of polyethylene to seal the vent opening.

One of the pressure-time histories that were measured is shown in Figure 9. The pressure-time history exhibits three pressure peaks. The first peak is due to the release of the vent cover. The third peak is due to the oscillatory type of combustion which under these circumstances occurs as well in contradiction to tests without the box and rear wall ignition. The second peak is attributed to an explosion outside the enclosure supported by turbulence generated both in the wake of the box and at the vent opening.

Variation of the vent opening area in tests in which the box was placed in the centre of the enclosure (long side parallel to the vent opening wall) resulted in a slight increase of the second peak. Using vent opening areas of 3.1 m^2, 5.2 m^2 and 6.7 m^2 second peak pressures of 9 kPa, 12 kPa and 13 kPa were found respectively.

The second pressure peak gradually increases when the distance of the box from the ignition source is increased. Using a vent opening area of 5.2 m^2 the second peak pressure was found to increase from 6 kPa in case of a distance between the centre of the box and the ignition source of 0.875 m, to 12 kPa in case of a relative distance of 1.975 m and to 11 kPa in case of a distance of 2.625 m. For large distances between box and ignition source the maximum overpressure during the course of the explosion is determined by the second peak pressure due to the box.

If the ignition source location is chosen to be directly behind the box instead of igniting at the rear wall the second pressure peak is much lower, viz. 7.5 kPa as could be expected from the much less intensive and smaller turbulent field that is generated in the wake of the box in this situation.

Changing the orientation of the box in the enclosure resulted in much lower overpressures.

In general it can be concluded that the presence of a single large obstacle inside of the enclosure only has a minor influence on the explosion effect.

Obstruction of venting

The effect of venting through a dormer window (heating plants are often located in the cellar of a building allowing explosion venting via a dormer window only) has been investigated in tests in which in front of the vent opening a large wall was erected parallel to the wall of the enclosure with the vent opening. The distance of the wall to the vent opening varied from 2.10 m up to 3.35 m. The height of the wall was 2 m. The wall was connected to the enclosure by two walls on each side of the vent opening and perpendicular to the wall parallel to the vent opening. The enclosure was provided with a 5.2 m^2 vent opening. In the centre of the enclosure the box was placed.
The experiments showed that the walls had no influence on the venting process at all. Further it appeared that the effect of the obstruction on the maximum overpressure in the enclosure for various distances between the rear wall and the obstruction to the vent opening is of minor importance.

Blast wave generation

In addition to the internal pressure load the external effects of vented explosions have also been investigated. In each test the blast wave generation was measured at distances of 0 m, 7 m and 17.5 m from the vent opening.
Figure 10 shows an example of a blast wave signal measured at a distance of 7 m from the vent opening of a test in which the mixture was ignited in the centre of an empty enclosure. As a comparison the signal of a rear wall ignited explosion in an empty room is also shown.
The two signals show some characteristic differences due to the different behaviour of the explosions. In case of a central ignition (Figure 10a) the blast pressure-time history consists of a first short duration spike followed by a longer duration signal on which the internally generated acoustic waves are still visible. The second part of the signal is inevitably due to the oscillatory type of combustion during the explosion. The first pressure peak coincides with the moment the flame emerges from the vent opening resulting in an external explosion as described before and proposed by Harrison and Eyre (11). There seems to be no contribution from the failure of the

polyethylene cover. As far as far field blast from centrally ignited explosions is concerned the two blast waves seem to be equally important, i.e., the blast from the external explosion and the blast from the internal explosion.
In this respect the second blast pressure-time history shown in Figure 10b is completely different. The blast wave caused by the external explosion propagates in the surroundings but also into the enclosure. The first pressure peak due to the external explosion is far more important than the part due to the internal explosion. In general it seems that for rear wall ignited explosions the external explosion determines the blast coming off vented gas explosions.
In Figure 11 the blast overpressures measured in various tests have been plotted as a function of distance measured from the vent opening.
This was done for explosions in an empty enclosure. For all cases, the blast from the external explosion has been given. For the low vent opening pressure also the blast due to the oscillatory mode of flame propagation has been plotted (internal explosion).

Flame jet development

Using the video camera it was established that depending on the experimental conditions flame jets with a maximum length of 18 m could emerge from the vent opening.

CONCLUSIONS

From the experiments the following conclusions can be made:

- For methane-air explosions centrally ignited in a large-scale enclosure without obstacles the oscillatory type of combustion determines the maximum overpressure.
- There seems to be no effect of the opening pressure of a vent cover on the further course of a vented methane-air explosion if the vent opening pressure is in the range of 0 to 10 kPa.
- The position of the ignition source seems to have a limited effect on the maximum overpressure generated in methane-air explosions in a large-scale vented enclosure without obstacles in spite of the fact that more than one mechanism determine these overpressures.
- For methane-air explosions ignited at the wall opposite to the wall where the vent opening is located the maximum overpressure is determined by an external explosion.
- The shape of the vent opening in a large-scale enclosure seems to have little influence on the maximum overpressures generated during methane-air explosions in this enclosure and vented through the openings.
- The presence of a single obstacle in the enclosure increased the overpressure with regard to the empty enclosure only in case the distance between the ignition source and the obstacle is large.
- The strength of blast waves generated by vented explosions seems to be determined by external explosions. These become important when the ignition source is located far from the vent opening resulting in large turbulent gas clouds pushed out of the enclosure due to the combustion inside.

In order to design vent opening areas on vented enclosures and heating plants in particular it seems appropriate to use the Bradley and Mitcheson criterion for initially covered vents (3). In Figure 12 all results obtained in the present experiments have been plotted in comparison to the criterion, showing that the criterion constitutes the maximum under all experimental conditions including the presence of the heating apparatus as long as the apparatus does not block the vent opening.

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FIGURE CAPTIONS

Figure 1 Front view of enclosure showing the vent area, the vent cover and blast gauges in front of the enclosure.

Figure 2 Pressure-time history measured in an empty room provided with a 5.2 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited in the centre of the room. The vent opening was sealed with a single sheet of polyethylene.

Figure 3 Maximum overpressure as a function of methane-air concentration due to central and rear wall ignited explosions. Vent opening area 4.8 m^2 and 3.76 m^2 vent cover: a single sheet of polyethylene.

Figure 4 Comparison of vented explosion pressures from centrally ignited methane-air explosions with the Bradley and Mitcheson criterion for initially covered vents.

Figure 5 Influence of vent opening pressure on the maximum overpressure generated by centrally ignited methane -air explosions in the enclosure provided with a 4.1 m^2 vent opening.

Figure 6 Pressure-time history measured in an empty room provided with a 4.1 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited in the centre of the room. The vent opening was sealed with a single sheet of plaster plate.

Figure 7 Pressure-time histories measured in an empty room provided with a 4.1 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited in the centre, at the rear wall and at the vent opening of the room respectivley. The vent opening was sealed with 5 layers of polyethylene sheeting.

Figure 8 An example of a vent opening configuration that has been used to investigate the effect of the shape of the vent opening on the overpressures that are generated in the enclosure in vented methane-air explosions.

Figure 9 Pressure-time history measured in the enclosure provided with a 3.1 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited at the rear wall of the enclosure. The vent opening was sealed with a single sheet of polyethylene. In the centre of the room a rectangular box was placed as an obstacle.

Figure 10 Examples of blast pressure-time histories measured at a distance of 7 m from the vent opening during experiments in an empty room provided with a 4.1 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited in the centre (a) and at the rear wall (b) of the room respectively. The vent opening was sealed with 5 layers of polyethylene sheeting.

Figure 11 Blast peak overpressures measured as a function of distance for several experiments. The points at 1 m are 0 m values.

Figure 12 Comparison of vented explosion pressures from all methane-air explosions in the enclosure with the Bradley and Mitcheson criterion for initially covered vents.

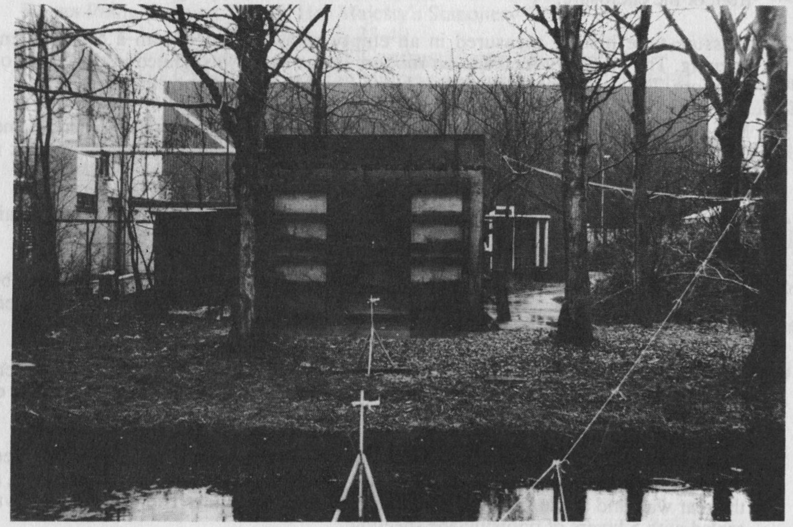


Figure 1 Front view of enclosure showing the vent area, the vent cover and blast gauges in front of the enclosure.

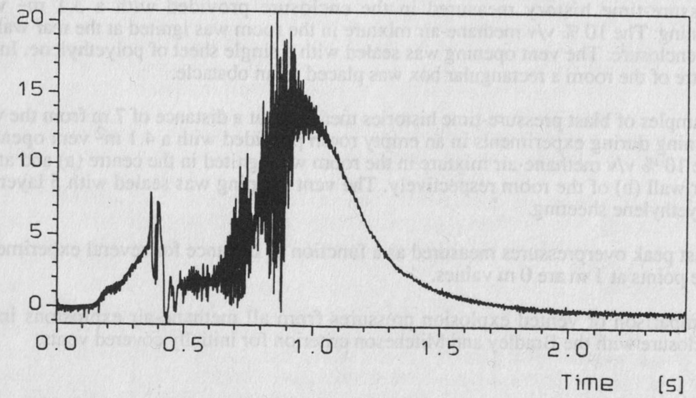


Figure 2 Pressure-time history measured in an empty room provided with a 5.2 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited in the centre of the room. The vent opening was sealed with a single sheet of polyethylene.

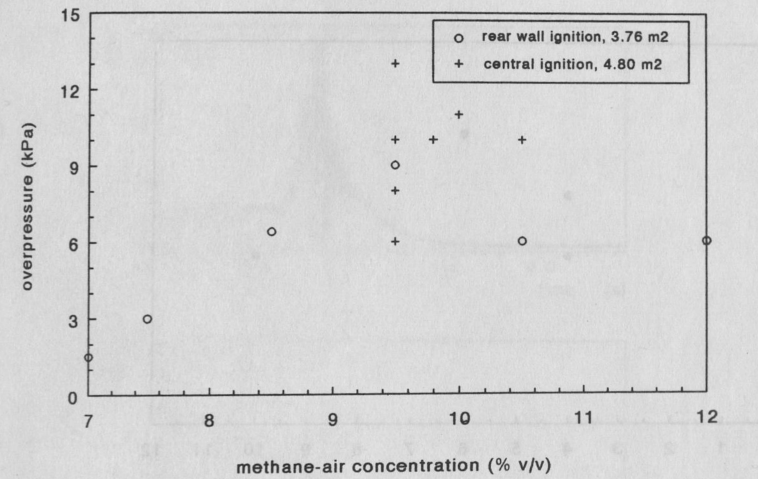


Figure 3 Maximum overpressure as a function of methane-air concentration due to central and rear wall ignited explosions. Vent opening area 4.8 m^2 and 3.76 m^2 vent cover: a single sheet of polyethylene.

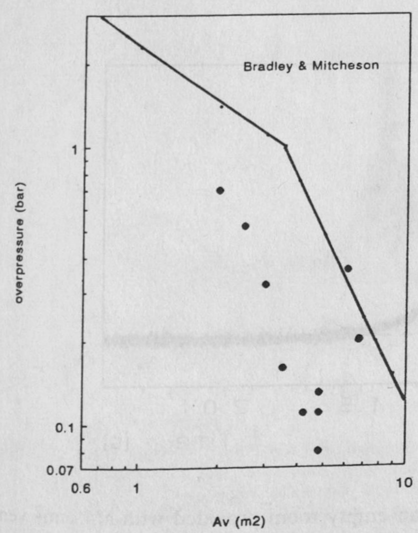


Figure 4 Comparison of vented explosion pressures from centrally ignited methane-air explosions with the Bradley and Mitcheson criterion for initially covered vents.

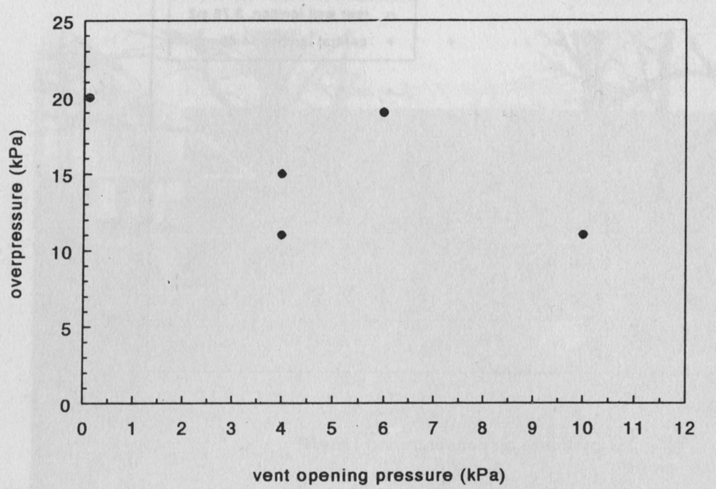


Figure 5 Influence of vent opening pressure on the maximum overpressure generated by centrally ignited methane -air explosions in the enclosure provided with a 4.1 m^2 vent opening.

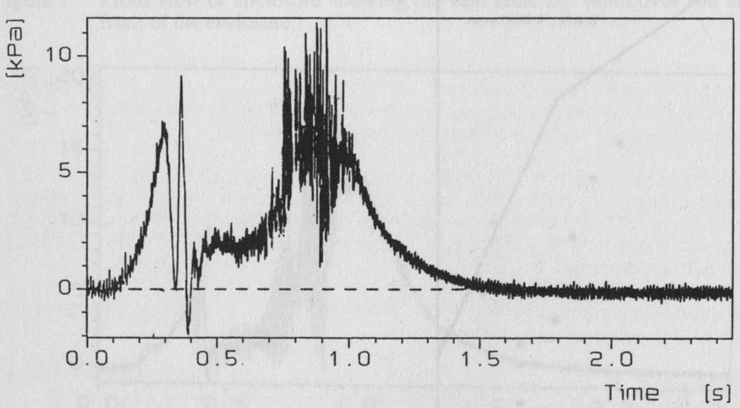


Figure 6 Pressure-time history measured in an empty room provided with a 4.1 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited in the centre of the room. The vent opening was sealed with a single sheet of plaster plate.

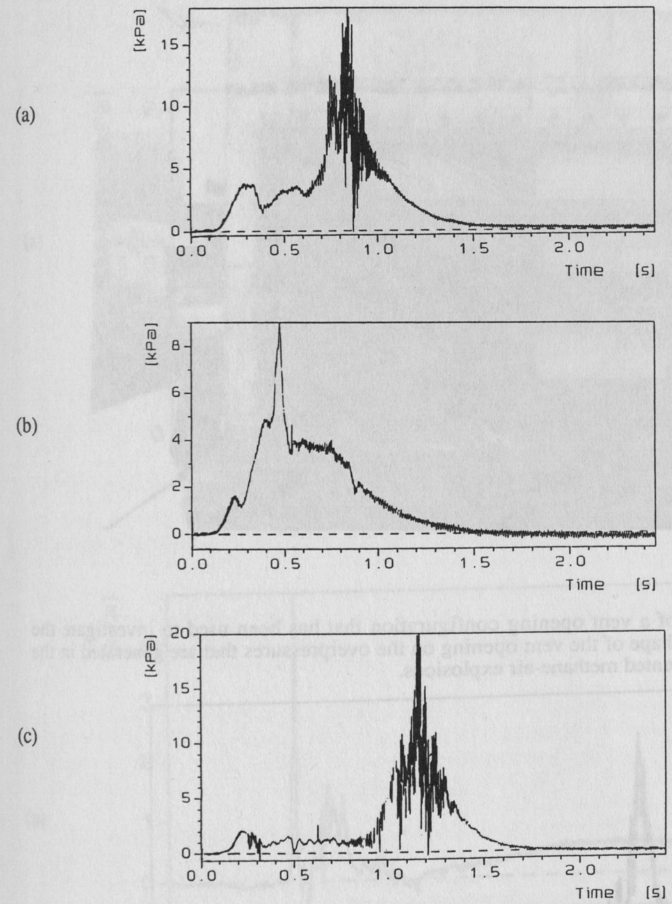


Figure 7 Pressure-time histories measured in an empty room provided with a 4.1 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited in the centre (a), at the rear wall (b) and at the vent opening of the room (c) respectivley. The vent opening was sealed with 5 layers of polyethylene sheeting.

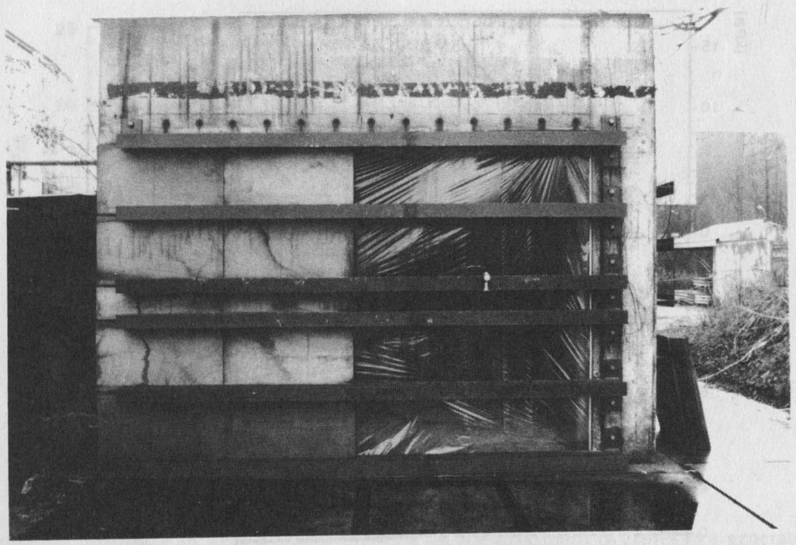


Figure 8 An example of a vent opening configuration that has been used to investigate the effect of the shape of the vent opening on the overpressures that are generated in the enclosure in vented methane-air explosions.

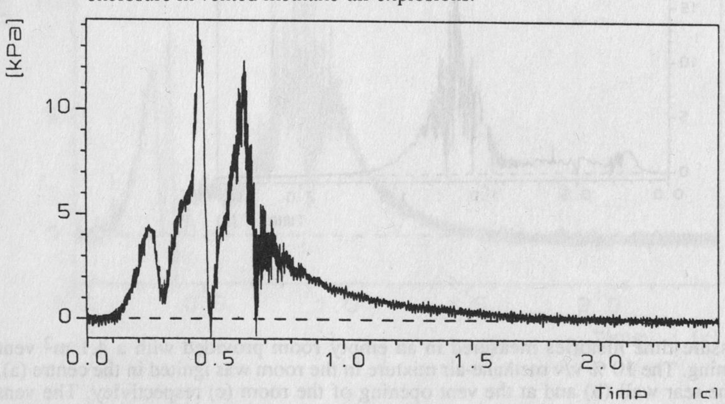
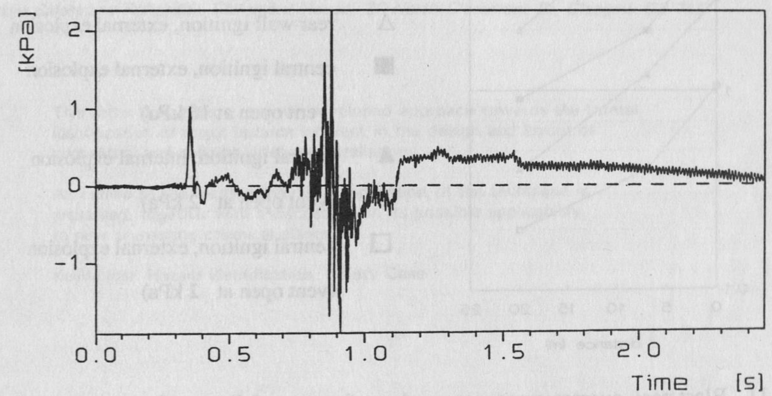


Figure 9 Pressure-time history measured in the enclosure provided with a 3.1 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited at the rear wall of the enclosure. The vent opening was sealed with a single sheet of polyethylene. In the centre of the room a rectangular box was placed as an obstacle.

(a)



(b)

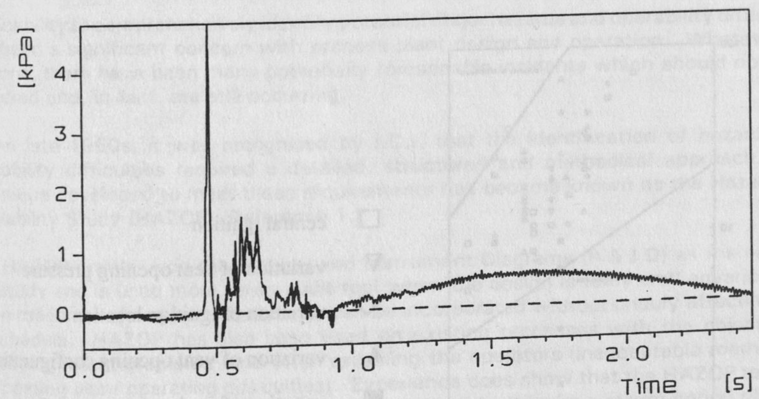


Figure 10 Examples of blast pressure-time histories measured at a distance of 7 m from the vent opening during experiments in an empty room provided with a 4.1 m^2 vent opening. The 10 % v/v methane-air mixture in the room was ignited in the centre (a) and at the rear wall (b) of the room respectively. The vent opening was sealed with 5 layers of polyethylene sheeting.

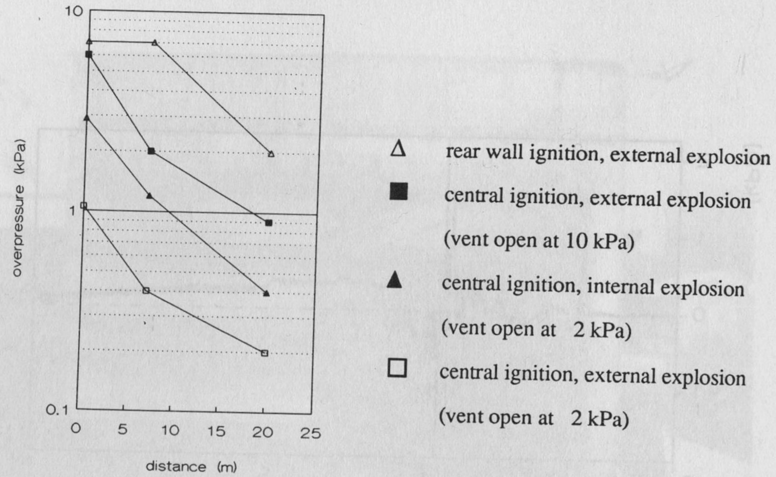


Figure 11 Blast peak overpressures measured as a function of distance for several experiments.

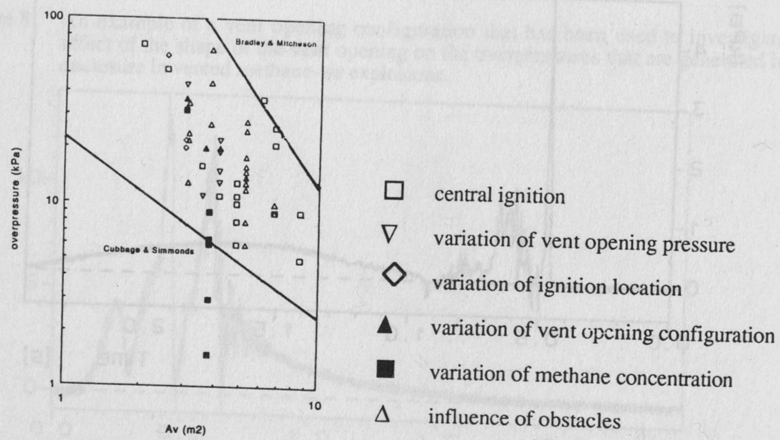


Figure 12 Comparison of vented explosion pressures from all methane-air explosions in the enclosure with the Bradley and Mitcheson criterion for initially covered vents.

CAN WE IDENTIFY POTENTIAL MAJOR HAZARDS?

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This paper discusses a recently developed approach towards the formal identification of major hazards inherent in the design and layout of conceptual and existing offshore installations.

An outline of the methodology and application of the technique is presented, together with a discussion on its possible applicability to new or existing chemical plants.

Keywords: Hazard Identification, Safety Case

1.0 INTRODUCTION

Our inability to comprehensively identify potential major hazards and operability difficulties has been a significant concern with process plant design and operation. Whatever the reasons, there have been many potentially foreseeable incidents which should not have occurred and, in fact, are still occurring.

In the late 1960s, it was recognised by I.C.I. that the identification of hazards and operability difficulties required a detailed, structured and methodical approach. The technique developed to meet these requirements has became known as the Hazard and Operability Study (HAZOP) (Reference 1.)

The HAZOP draws upon the Process and Instrument Diagrams (P & I D) as the basis of the study and is used more as an audit tool when the design is fairly well advanced but when moderate changes to the system can be incorporated without unduly affecting cost or schedule. HAZOP has also been used on existing processes with the objective of identifying latent problems (and often revealing the operators unacceptable methods of overcoming plant operating difficulties). Experience does show that the HAZOP tends to identify fairly basic design and operational flaws and faults with a return period of about 10 to 100 years. However, while it is an invaluable design audit tool, HAZOP was not developed for analysing a new concept in terms of layout or operational interaction.

The identification of major hazards, which will tend to have a return period of more than 100 years can be haphazard and is very much dependent on the experience and background of the design team.

The CIMAH Regulations (Reference 2) states in schedule 1: