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Paul Coxon
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4 July 2008
Your Ref. PC-08-264
Our Ref. 122084

Dear Paul

Gas System Pressure Venting Tests 8th April 2008

Thank you for your letter dated 16th June 2008 and accompanying CD detailing the AFP report and information related to the gas system discharge tests conducted on the 8th April 2008 and witnessed by BRE Fire and Security.

The test work has provided valuable new data on pressure venting for gas systems. Dissemination of the work and results to those involved within the gas system industry (and more widely to the fire safety community generally) would be actively encouraged by BRE. The work provides a base for the drafting of a formal specification that could be used by standards organisations and third party approval bodies for the assessment and verification of gas system pressure relief devices.

Please find included in Appendix A to this letter a qualified opinion and assessment of the tests and AFP report.

I trust this is satisfactory and would be pleased to receive any further comments from you.

Yours sincerely

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Senior Consultant
For and on behalf of BRE Global
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Appendix A – Gas System Pressure Venting Tests, 8th April 2008

A.1 Introduction

Fixed gaseous extinguishing systems are used widely in a variety of applications to protect a risk from fire. Upon activation, systems discharge agent into a volume through a nozzle (or nozzles) to flood the entire space with gas. Systems broadly fall into two categories, inert agent and chemical agent systems. The flooding of enclosures with gas can generate potentially dangerously high pressures (both positive and negative) within a room, particularly in the presence of a fire. Appropriate pressure relief venting is therefore critical to the safe operation of gas extinguishing systems.

A series of gas system pressure venting tests was undertaken by AFP Air Technologies LLP on the 8th of April 2008. Tests were conducted in a steel container at AFP's facility at South Goringlee Farm House, Harbolets Road, West Chiltington, West Sussex, RH20 2LG, see Figure 1. The testing was supported by LPG Fire Ltd, 7 Top Angel, Buckingham Industrial Park, Buckingham, MK18 1TH, who provided the gas systems.

Figure 1 – Steel container facility for gas systems tests

Room integrity testing was conducted, prior to system discharge tests, by G & D Fire Protection Ltd, Connect House, 21 Willow Lane, Mitcham, Surrey, CR4 4NA. In attendance for the tests included, Mr Paul Coxon (AFP), Mr Chris Coxon (AFP), Dr Tim Nichols (LPG), Mr Colin Uzzell (G & D) and Mr Kelvin Annable (BRE Fire and Security). The test work has been reported by AFP and the AFP test report is included in Appendix B.

Although there are British and International standards for the design and installation of gas systems, the pressure relief venting necessary for such systems is not rigorously assessed or specified in these standards. There are no formal standards to enable a thorough assessment of the design and operation of gas system pressure relief vents.

Appropriate pressure venting is important because it can prevent structural damage to a room in the event of a gas discharge. Conversely, if a room has too much 'leakage' there is the potential for gas systems to fail to maintain appropriate concentrations of gas, thereby potentially resulting in systems being unable to extinguish fires. Therefore it is also important that protected volumes are tested for 'room integrity' so that a determination of the area of leakage in a room can be specified. This also allows for a 'gas hold time' to be calculated. That is, after discharge of an agent, the time in which an appropriate concentration of gas will be maintained before the agent 'leaks' to atmosphere. Determination of the integrity of a room, in conjunction with the design of a gas extinguishing system, allows for the calculation of appropriate pressure relief venting. It is recognised that pressure vents with the ability to be fully calibrated in real systems offer a significant advantage. That is, if a vent can be tested in the fully open position with a standard room integrity test kit, a better understanding of the performance of the vent is obtained. This additionally allows for an assessment of the claims made by manufacturers/suppliers for free vent area and vent opening pressures (in the absence of any such specifications in a formal standard).

It is understood by BRE that AFP Air Technologies wished to progress the science of gas system pressure venting. AFP therefore conducted a series of tests and commissioned BRE Fire and Security to witness the tests and provide a qualified opinion and assessment of the work. It was also envisaged that this work could provide a base from which a more formal standard specification for the design and operation of gas system pressure vents could be developed.

A.2 Description of test facility

The test facility comprised an ISO steel container with a wooden partition across the width providing a test room with a volume of 43 m^3 (measurements not formally verified by BRE), see Figure 2. The test room was instrumented to allow for continuous measurement and recording of pressure, temperature, air flow and pressure vent blade operation (degree of opening). Room oxygen concentration was also measured but not recorded. Datasheets and information related to the instruments used was supplied to BRE. Tests and pressure vent blade operation were video recorded as appropriate and supplied to BRE in the form of a compilation video.

Figure 2 – Test room

A.3 Room integrity testing conducted

A number of room integrity tests were conducted by Mr Colin Uzzell of G & D. This provided AFP with independent room integrity testing data and an accompanying report, see Appendix C. G & D report that the testing was carried out in accordance with the procedures in BS ISO 14520 Annex E Door fan test for determining of minimum hold time. The door fan test kit is shown in Figure 3.

Figure 3 – Room integrity testing equipment

A.3.1 Description of tests conducted

The equipment was installed into the test room doorway. The G & D report states that both 'set-up' and 'gauge zeroing' was performed. The unit was used to both over pressurise and under pressurise the room to determine leakage. The following tests were conducted:

1. Sealed room integrity; determination of estimated leakage area (ELA)
2. Room integrity with installed pressure relief vent; determination of estimated leakage area
3. Gradual increase in room pressure to determine initial vent blade opening pressure
4. Determination of room pressure necessary to fully open pressure vent blades

Tests 2, 3 and 4 were conducted with 3 different pressure vents. Potentiometers were used to determine the degree of opening of each vent blade, (this was not formally verified by BRE).

A.3.2 Products tested

The 3 different vents used for tests were as follows:

1. AFP's 'HXD300' vent, 300 x 300 mm opening and 3 vent blades, see Figure 4.
2. AFP's 'SHX300' vent, 300 x 300 mm opening and 3 balanced weighted vent blades, see Figure 5.
3. AES vent, 300 x 300 mm opening and 4 'top' hinged 'bottom' weighted vent blades, see Figure 6.

Figure 4 – AFP's HXD300 vent

Figure 5 – AFP's SHX300 vent

Figure 6 – AES vent

A.3.3 Results

The test conducted with a sealed room resulted in a determined ELA of 0.0089 m^2 and gas system retention time of 46.5 minutes. Table 1 below summarises the results with the vents installed.

	HXD300 vent	SHX300 vent	AES vent
ELA	0.0106 m^2	0.0106 m^2	0.0097 m^2
Retention time	31 mins	31 mins	43 mins
Initial vent open[1]	79 Pa	80 Pa	170 Pa
Maximum tested opening[1]	72° open at 241 Pa	86° open at 96 Pa	15-20° open at 500 Pa
Free vent area[1]	0.055 m^2 at 241 Pa	0.067 m^2 at 96 Pa	0.016 m^2 at 500 Pa
[1] This information is not required specifically in ISO 14520.			

Table 1 – Summary of integrity test results

A.3.4 Discussion of integrity test results

All 3 vents added to the determined leakage area from the room (and therefore resulted in decreased gas retention times). However, the AES vent added a very small amount of leakage. The additional leakage attributable to AFP's HXD and SHX vents was also small and the calculated retention time was three times in excess of minimum retention times (10 minutes). The leakage through the vents was considered acceptable and did not significantly compromise the integrity of the test room.

Both the HXD and SHX vents demonstrated effective opening and provided free vent areas, approaching the maximum possible, at room pressures under 300 Pascals.

The AES vent required a significant pressure to initiate a blade opening (~170 Pascals). The free vent area, even at ~500 Pascals was a small percentage of the possible free vent area of the vent. The measured vent area (determined from the degree of blade opening) at 500 Pascals was only approximately 20 % of the maximum free vent area of the device.

It was possible to fully calibrate the SHX vent using the integrity test equipment used (that is, to the point where the vent blades are fully open). The ability to fully calibrate the operation of a pressure vent in actual installations would offer additional data and provide confidence in the vents ability to appropriately mitigate room pressures in the event of a system discharge.

A.4 Gas discharge testing conducted

A series of 8 gas discharge tests were conducted by AFP on 8th April 2008, see Table 2. LPG Fire supplied cylinders for the tests. 7 tests with a single IG-55 container, nominally pressurised to 300 bar (see Figure 7), were conducted along with a further test with HFC-227ea agent, nominally pressurised to 42 bar.

Further to the tests on 8th April a subsequent programme of tests was conducted by AFP but not witnessed by BRE. It is understood by BRE that this included tests to investigate 'cascade' venting arrangements and a test with a sealed test room (no venting) with an HFC-227ea agent discharge.

Test[1]	Details
1	IG-55 discharge, HXD300 pressure vent (Discharge Test 2, AFP report)
2	IG-55 discharge, SHX300 pressure vent (Discharge Test 3, AFP report)
3	IG-55 discharge, AES pressure vent (Discharge Test 4, AFP report)
4	IG-55 discharge, open hole 300 x 300 mm (Discharge Test 1, AFP report)
5	IG-55 discharge, HXD300 pressure vent, ISO container doors closed (not reported in AFP report)[2]
6	IG-55 discharge, SHX300 pressure vent, ISO container doors closed (not reported in AFP report)[2]
7	HFC-227ea discharge, HXD300 vent installed for underpressure[2], SHX300 vent installed for overpressure[3] (Discharge Test 6, AFP report)
8	IG-55 discharge, no venting (Discharge Test 5, AFP report)

[1] Test numbering in chronological order.
[2] Tests 5 and 6 were 'cascade' venting tests and were not directly detailed in the AFP report.
[3] The bottom blade of each vent was taped closed to provide an appropriate vent area.

Table 2 – Summary of discharge tests conducted on the 8th April 2008 and witnessed by BRE Fire and Security

Figure 7 – Installed IG-55 container

A.4.1 Results

Table 3 below summarises the test results.

Test	Agent	Vent arrangement	Minimum pressure (Pa)	Maximum pressure (Pa)	Air flow through vent (m/s)
1	IG-55	HXD300	0	349	10.4
2	IG-55	SHX300	0	252	10.4
3	IG-55	AES	0	790	7.3
4	IG-55	Open hole 300 x 300 mm	0	219	11.4
5	IG-55	HXD300, container doors closed	0	~500	n/k[1]
6	IG-55	SHX300, container doors closed	0	2938	n/k[1]
7	HFC-227ea	HXD300 (underpressure) & SHX300 (overpressure)	-164	130	8.4
8	IG-55	No venting	0	1,700	n/a[2]

[1] n/k is not known
[2] n/a is not applicable

Table 3 – Summary of discharge tests 8th April 2008

A.4.2 Discussion of discharge test results

The HXD and SHX vents demonstrated effective pressure relief in the room upon discharge of IG-55 and mitigated pressures to levels below 500 Pascals. The peak room pressure generated with the SHX vent was comparable to the peak pressure measured with an open hole (only 33 Pascals greater). The HXD vent (acting as an underpressure relief device with one blade taped closed) and the SHX vent (acting as an overpressure relief device with one blade taped closed) provide effective pressure relief upon discharge of an HFC-227ea chemical agent.

Upon discharge of an IG-55 cylinder the pressures in the test room exceeded 500 Pascals with the AES pressure relief vent fitted (790 Pascals). The operation of the vent did not demonstrate effective pressure relief.

Tests 5 and 6 demonstrated that cascade venting into limited volumes needs to be considered. Significant pressures were generated by closing the doors of the ISO container. It was also observed during testing that the backpressure generated in the volume external to the room of discharge had an affect on the operation of the vents. That is, they were observed to open and close in an unpredictable manner. The influence of this may need further consideration.

The importance of overpressure protection by relief venting for gas systems was demonstrated. An IG-55 discharge generated dangerously high pressures with a sealed test room.

A.5 BRE review of AFP report

AFP presents a 'general philosophy' underpinning the work. The points made are summarised by BRE below:

- Gas system pressure venting is 'under specified' and in need of development
- Pressure venting is critical to the safe operation of gas systems
- Venting is an issue for all gas systems; both inert and chemical agents
- The benefits of having pressure vents that can be fully calibrated during room integrity testing are outlined
- AFP sought a qualified opinion from an independent third party (BRE) to assess the operational performance of selected pressure vents
- Test data relating to pressure vent operation is desirable and needed to provide the base for input into a formal specification

BRE agree with the above points and support the development of research, test data and work towards formal specification for gas system pressure vents.

The instrumentation used for the work and calibrations undertaken by AFP have not been formally verified. BRE support the qualitative test results and associated observations of the tests lend to confidence in the presented data and the enclosure pressures given in the report.

The AFP report is unclear on some details:

- Tests 5 and 6 do not appear to have been directly reported by AFP in the report although the graph included under AFP report Discharge Test 5 is believed to have resulted from Test 6 (see paragraph below). There is reference to further testing investigating cascade venting arrangements, however, BRE have not been supplied with any further data or reports related to this work.

- The presentation of Test 8 (Discharge Test 5 in the AFP report) is considered confusing as it appears to combine the results of Test 8 and Tests 5/6 which were conducted with different venting arrangements.

Discharge Test 7 in the AFP report was not witnessed by BRE. However, the result does indicate the importance of both under and overpressure protection relief venting for the chemical agent system tested. The data demonstrates that dangerously high pressures (both positive and negative) can be achieved with discharge into a sealed test room.

The AFP report draws a number of conclusions which are summarised by BRE below:

- The work provides new test data.
- The stated free vent area of a vent can be misleading; the specification given by a manufacturer or supplier may not correlate with the hydraulic software calculation specified area. It is the ability of the vent to open and provide effective pressure relief that is critical to mitigating pressures.
- The actual design and operation of a pressure vent has a significant impact on the room pressure generated on discharge of a gas system.
- The room pressures generated during discharges with the tested AES vent were of concern.
- It may be possible to reduce the calculated free vent area (in hydraulic software calculations) for a particular risk based on the results and demonstration of suitability of a particular pressure vent.
- Live test discharges are the best way to test pressure vent operation.
- Inert and chemical agents both require pressure venting.

BRE considers that the AFP report overall presents the testing undertaken in a fair manner.

A.6 Further work

Further work could also be identified; it should be noted that all the testing was conducted ‘cold’, that is, there was no fire present. In an actual live fire scenario the expected pressures upon discharge of an agent (and potentially in the room prior to discharge) are significantly increased and appropriate pressure venting arrangements are critical to the safe operation of systems. Further tests in the presence of test fires could be considered.

The implications of cascade venting needs to be appropriate addressed and further investigation of the influence of backpressure (pressure external to the protected volume) could be considered.

No measurements were taken (and it would be difficult to achieve any such measurements) of the volume of gas (and particularly agent) vented from the protected room. However, the quantity of agent vented during discharge with AFP's HXD and SHX vents installed is likely to have been higher than the AES vent (measured air flow velocities were higher, and free vent areas were larger). It is considered important that software used to calculate room design concentrations properly calculates (and compensates for) agent loss through the operation of pressure relief vents.

It is also understood by BRE that AFP wish to further investigate the influence of having protected (separate) volumes at differing room pressures and the associated leakage from one volume to another.

A.7 Summary and forward Look

The test work has provided valuable new data on pressure venting for gas systems. Dissemination of the work and results to those involved within the gas system industry (and more widely to the fire safety community generally) would be actively encouraged by BRE. It is also considered appropriate that the work should be presented to the ISO TC21/SC8 committee for consideration and possible development. The work provides a base for the drafting of a formal specification that could be used by standards organisations and third party approval bodies for the assessment and verification of gas system pressure relief devices.

Appendix B – AFP report (appendices supplied to BRE but not included here)

AFP
AIR TECHNOLOGIES LLP

Test Report

Pressure Relief Vents

High-X 100 Verification 08/04/2008

General Philosophy

The world of pressure venting for Fire Fighting Gaseous Extinguishing Systems is an area where there are no standards for the operation or construction of these devices.

Gaseous Extinguishing Systems are well regulated with Standards and Approvals worldwide. This has caused many issues over the years as the requirement for relieving the pressure produced when a gas system discharges in a risk is critical to the safe operation of the Gaseous Extinguishing System and prevents structural damage of the protected risk from occurring.

Pressure Relief Venting is as critical to any Gaseous Fire Extinguishing Systems as the system itself. If pressure venting is not provided or if it is incorrectly applied STRUCTUAL DAMADGE to the protected risk can occur.

The issue of pressure venting is not just an area for Inert Gas System (IG55, IG01, IG100, IG541 and Co^2 etc) but also Chemical Agents (FM200, FE25, Novec etc) as shown in a number of tests carried out with FM200.

In our product development we have being working with Retrotec, a leading global Room Integrity Testing Equipment supplier to provide a pressure vent that can be fully calibrated in a live system when the risk is integrity tested to verify the opening pressure of the vents. Further that the pressure vent fully opens with airflow and with out being opened by hand. A natural consequence was to carry out a number of tests to provide us with not just verification of the operation of our range of pressure vents but to obtain data in a number of areas including cascade venting. As a result the new version of our popular High-X 100 HXD pressure vent called the SHX Pressure vent was born and we wanted to compare it with the market.

At AFP Air Technologies LLP we believe so strongly in our products that we sought a qualified opinion from BRE Fire & Security (incorporated within BRE Global) a sister company of BRE (Building Research Establishment) Ltd on the actual operational performance of our High-X100 HXD and New SHX pressure vents.

There is limited test data available to support claims from manufactures on the free vent areas and back pressures produced on pressure venting products used in the market. Without such evidence the claims made by manufacturers are unreliable.

Working with the industry bodies we conducted a number of tests designed to show operational effectiveness from which a standard that will govern these products can be produced. It is hoped that the tests carried out will provide the basis for a test protocol for world wide approval. The tests were witnessed by BRE Fire and Security who have been commissioned by AFP to provide a qualified opinion on the test work. BRE will provide a letter report to AFP shortly. In the future it way be possible for the test work undertaken to provide input into a standard that will govern these products and allow for formal LPCB (or other) third party approval.

This document outlines the series of tests that can be replicated by any of the Pressure Vent Manufacturers to prove the effectiveness of the operation and performance of their products.

Test Layout

The tests rig used was a 40 foot steel container with a heavy duty wooden partition fitted to provide a test room volume of 43m^3. This volume is the size required for one IG55, 300 bar inert gas cylinder and was felt to represent a standard inert gas system whether it is IG55, IG541, IG100 or IG01.

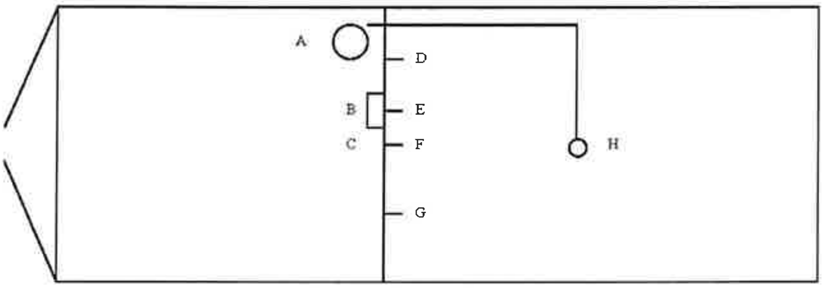


Figure 1 plan view of test rig

A) Gas cylinder location.
B) Pressure vent location
C) Pressure vent blades were monitored for position using Conductive Potentiometers
D) Temperature and humidity sensor
E) Air flow sensor (monitoring air flow through the middle of the vents
F) Differential pressure
G) Static Pressure Gas discharge nozzle

Gas Calculation

We were supported in the tests by LPG UK LTD (DrTim Nichols) who provided IG55 and FM200 for the tests. Each system was designed by LPG using VDS Software. Calculations were produced for the IG55 system tests and for the FM200 tests. Calculation sheets are attached in appendix A

Data Collection

All data apart from the risk oxygen levels were recorded automatically using a chart recorder. All the sensors and equipment were newly calibrated and details of all items used is listed in appendix B

Video Evidence

All tests were videoed and a CD/DVD containing the full video of the tests is included in appendix C

Products Tested

The Tests were carried out on our High-X 100 pressure vent the HXD300 and our new SHX300 balanced Weighted Pressure Vent.

The SHX300 pressure vent has been designed to allow for full calibration via a Room Integrity Test as discussed above.

We also carried out a test on a 300mm x 300mm square hole to determine the pressure of the risk as a benchmark and to verify the VDS calculation and a top hinged bottom weighted pressure vent manufactured by AES. We used this AES pressure vent as a benchmark that represents the type of pressure vent used and supplied to the industry by a number of suppliers historically.

We also carried out a number of Cascade Venting Tests which are documented in a separate report.

Tests carried out and witnessed by BRE Fire and Security

Firstly we identified details of the tests we wanted to carry out and circulated them to BRE, LPG and Retrotec (G&D). These tests are as followed:-

SHX Pressure Vent Being Tested

Room Integrity tests

Integrity test 1

To measure the integrity on the test enclosure with the pressure vent hole blanked off.

This was to calibrate the test enclosure and provide a natural room leakage figure.

Integrity Test 2

We removed the blanking panel and installed our HXD300 pressure vent. This test was to measure the leakage area of the closed vent.

Integrity Test 3

This test was to determine the opening pressure on the HXD300 pressure vent. This was determined when the chart recorder monitoring when the vent blade position first showed movement.

Integrity test 4

This test was carried out on our HXD300 pressure vent to determine at what pressure the vent blades were fully open.

The above tests were carried out on our new SHX300 pressure vent and a top hinged bottom weighted (AES) 300 pressure vent.

All tests were monitored using the data collection sensors and the chart recorder as well as the information from the Integrity Test System.

Gas Discharge Tests

We then move on to the actual live gas discharge test section. These tests we to verify the operation of each pressure vent in a live situation on a like for like bases.

We wanted to under stand the relationship between free vent area and back pressure.

Discharge Test 1

To carry out a live IG55 discharge with an open 300mm x 300mm hole prviding a free vent area (FVA) of 0.09m^2 which is the un-obstructed FVA of the opening of the three pressure vents.

The VDS Calculations provided us with a required FVA of 0.83m^2 for a 500 Pascal limit. For this calculated FVA the closest pressure vent size was the HXD300, SHX300 and the AES300 pressure vents which all have a 300mm x 300mm opening.

The results are detailed below.

Discharge Test 2

This test was the first test with a pressure vent fitted. We fitted our HXD300 pressure vent and carried out a live IG55 Discharge and monitored the results.

As with the above Integrity Tests we monitored all aspects of the system, Pressure Vent Blade Position, Air Flow through the Vent, Risk Pressure, Temperature etc.

The results are detailed below.

Discharge Test 3

We fitted our SHX300 pressure vent and carried out a live IG55 Discharge and monitored the results.

As with the above Integrity Tests we monitored all aspects of the system, Pressure Vent Blade Position, Air Flow through the Vent, Risk Pressure, Temperature etc.

The results are detailed below.

Discharge Test 4

We fitted the AES300 pressure vent and carried out a live IG55 Discharge to determine a bench mark and monitored the results.

As with the above Integrity Tests we monitored all aspects of the system, Pressure Vent Blade Position, Air Flow through the Vent, Risk Pressure, Temperature etc.

The results are detailed below.

Discharge Test 5

We fitted a blanking panel to seal the test rig and carried out a live IG55 Discharge and monitored the results.

As with the above Integrity Tests we monitored all aspects of the system, Pressure Vent Blade Position, Air Flow through the Vent, Risk Pressure, Temperature etc.

The results are detailed below.

Discharge Test 6

We repaired the test rig and carried out a live FM200 Discharge with two pressure vents fitted, one for negative pressure and one for positive pressure. We fixed the bottom blades of the two vents so that they would remain closed as we believe that FM200 requires about half the FVA of an inert gas system and monitored the results.

As with the above Integrity Tests we monitored all aspects of the system, Pressure Vent Blade Position, Air Flow through the Vent, Risk Pressure, Temperature etc.

The results are detailed below.

Discharge Test 7

We fitted blanking panels to seal the test rig and carried out a live FM200 Discharge and monitored the results.

This was to determine the likely pressure tat can be reached in a Chemical agent discharge if there is no or very little venting.

As with the above Integrity Tests we monitored all aspects of the system, Pressure Vent Blade Position, Air Flow through the Vent, Risk Pressure, Temperature etc.

The results are detailed below.

INTEGRITY TEST RESULTS

Detailed Results of Integrity Test Phase
By Retrotec (G&D Ltd)

Test 1 - Room Integrity Test

A standard Room Integrity Test was carried out To BS ISO 14520 Enclosure Integrity Procedure (2006) which provided following Results:-

Risk Volume	43.013m^3
Actual Risk Leakage	0.0089m^2
Predicted Retention Time	46.5 min

Test 2 - High-X100 HXD300 Pressure Vent

A standard Room Integrity Test was carried Out to determine the leakage area of our HXD300 Pressure vent and the risk.
Results:-

Risk Volume	43.013m^3
Actual Risk Leakage	0.0106m^2
Predicted Retention Time	37.8 min

Test 3 - High-X100 SHX300 Pressure Vent

A standard Room Integrity Test was carried Out to determine the leakage area of our HXD300 Pressure vent and the risk.
Results:-

Risk Volume	43.013m^3
Actual Risk Leakage	0.0106m^2
Predicted Retention Time	31.2 min

Test 4 – AES 350 Pressure Vent

A standard Room Integrity Test was carried out to determine the leakage area of the AES300 Pressure vent and the risk.
Results:-

Risk Volume	43.013m^3
Actual Risk Leakage	0.0097m^2
Predicted Retention Time	42.5 min

Test 5 – HXD300 Pressure Vent

The Retrotec Fan pressure was then increased to determine the point at which the Vent blades started to open and were as fully open as the kit could get them.

Vent Blades opened	79 Pascal's
72% FVA Open	241 Pascal's

Test 6 – SHX300 Pressure Vent

The Retrotec Fan was then increased to determine the point at which the vent blades started to open and were fully open at:-

Vent Blades opened	80 Pascal's
Fully Open (85%FVA)	95.5 Pascal's

Test 7 – AES300 Pressure Vent

The Retrotec Fan pressure was then Increased to determine the point at which the vent blades started to open and were as fully open as the kit could get them.

Vent Blades opened	170 Pascal's
9% FVA Open	429 Pascal's

AES 300 fan test with holding kit in as pressure gets to 429 Pascal's

Conclusion of Integrity Tests

The SHX was the only product, which performed in a way that can be tested in a live system using a Retrotec Room Integrity Test Kit. It provided a high enough opening pressure to allow the room integrity test to be carried out with out the SHX300 opening and then fully opened at a pressure that was deemed low enough to be tested in a live system.

The G&D Integrity test results and report written by Mr Colin Uzzell and the Logging Data is located in appendix D

Discharge Tests

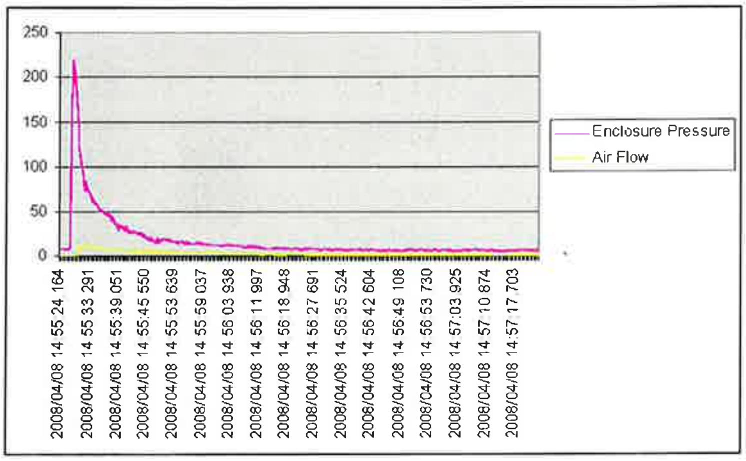
Live IG55 Discharge Tests Summary

Test 1 – Open hole test

Photo of Open Hole Test
Hole size 300mm x 300m giving a FVA of 0.09m^2

The VDS Software Calculations package provided us with a free vent area for the risk at a pressure rating of 500 Pascal's of 0.083m^2.

A full discharge of the gas with a 300mm x 300mm square hole providing 0.09 m^2 of Free Vent Area (FVA). This equalled the exact full and unobstructed opening area of all the pressure vents tested. We needed to determine the risk pressure with an open hole as a bench mark of the VDS Calc's and to determine the back pressure of the vents to be tested so that we could calculate the co-efficient of each unit and have an understanding of the safety factors used.



The maximum pressure reached in the test enclosure was 219.4571 Pascal's (Pa).

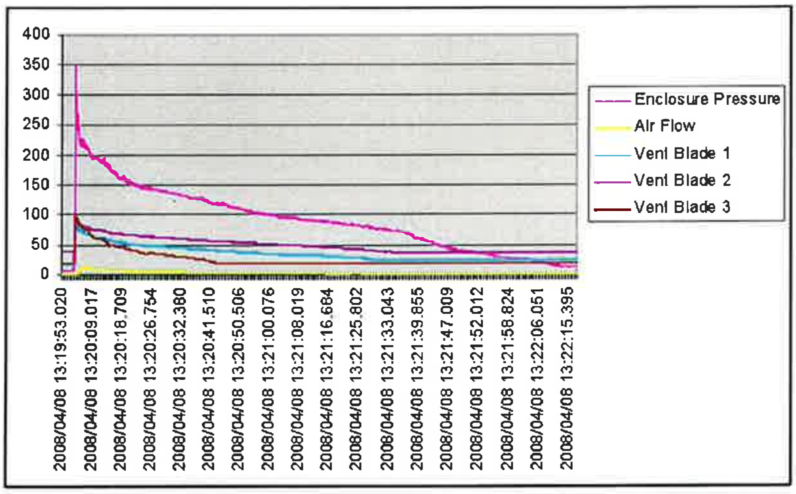
The Oxygen Level went down to 12.6%
Air flow though the hole was 11.388 mps

This gave us the base pressure which was more than half the pressure limit of 500 Pa

Test 2 – High-X 100 HXD300 pressure vent

Photo of HXD300 fully open in live gas discharge

The HXD300 pressure vent was then installed and linked up to the recording device so that the vent blade positions could be accurately monitored and a discharge test carried out. This verified that the pressure vent fully opened and that the peck pressure in the enclosure reached 350 Pascal's.

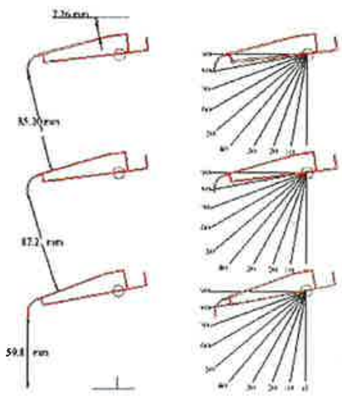


Results

Enclosure Pressure	349.2461 Pascal's
Air Flow through the pressure vent	10.37546 mps
The pressure vent fully opened	80% of FVA

This performed with in the maximum 500 Pa pressure and gave a good safety margin.

Blade Positions at Peak Pressure of 349 PA.
As shown on HXD 300 GD data logging sheet.
At 13:20:00.828



	Voltage.		Blade Gap.		X .0003 for FVA. (Blade width 300mm)	
Blade 1.	101.6v		85.2mm		.0256m2	
Top gap			7.26mm		.0022m2	
Blade 2.	102.7v		87.21mm		.0262m2	
Blade 3.	98.9v		59.8mm		.0179m2	

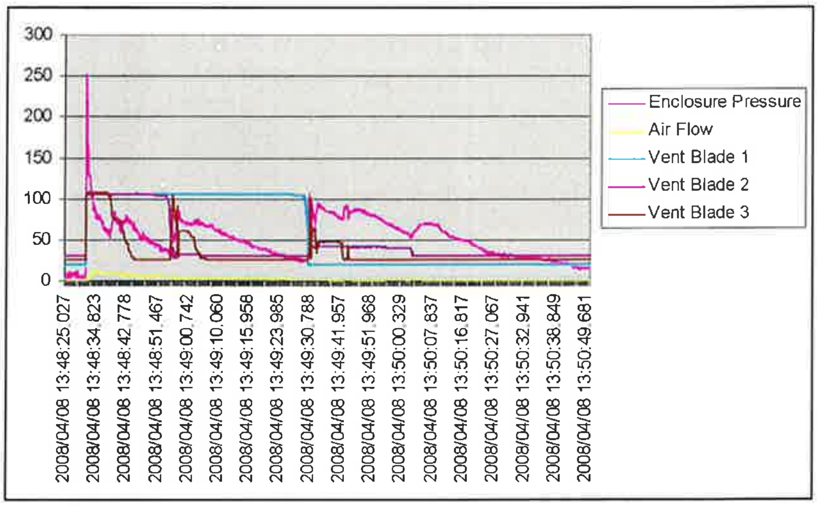
[illegible] .072m2

FVA As % of Vent Size.
(.3x.3m2 or .09m2) 80%

Test 3 – New SHX300 Balanced Weight Pressure Vent.

Photo of SHX 300 fully open in live gas discharge

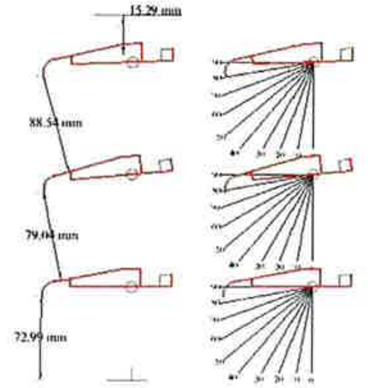
The SHX300 pressure vent was installed and a gas discharge carried out.



Results

Enclosure Pressure	251.7729 Pascal's
Air Flow through the pressure vent	10.37014 mps
The pressure vent fully opened	Yes

Blade Positions at Peak Pressure of 251 PA.
As shown on SHX 300 GD2 data logging sheet.
At 13:48:29.845



	Voltage.	Blade Gap.	X .0003 for FVA. (Blade width 300mm)
Blade 1.	104.7v	88.5mm	.0266m2
Top Gap		15.3mm	.0046m2
Blade 2.	100.3v	79mm	.0237m2
Blade 3.	107.1v	73mm	.0219m2

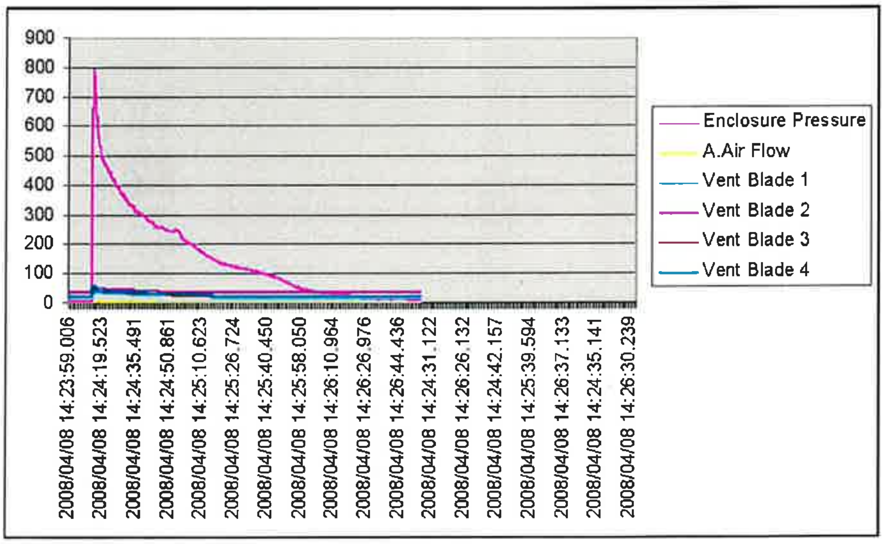
TOTAL FVA .077m2

FVA As % of Vent Size. (.3x.3m2 or .09m2) 85%

Test 4 – The AES300 pressure vent (Top Hinged Bottom Weighted Type)

Photo of AES300 pressure vent with risk pressure at 790 Pascals. Vent in maximum open position.

The AES300 vent was then installed and the same discharge test was carried out.

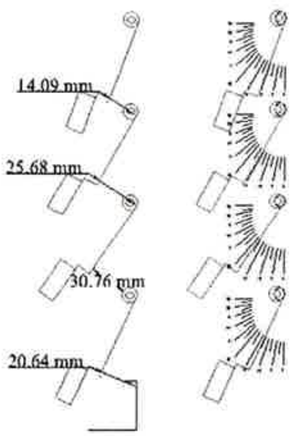


Results

Enclosure Pressure	790.2576 Pascal's
Air Flow through the pressure vent	7.30933 mps
The pressure vent fully opened	NO

The vent blades did not open more then 30% and the risk peck pressure exceeded 500 Pascal's.

Blade Positions at Peak Pressure of 790 PA.
As shown on PAES 300 GD data logging sheet.
At 14:24:11.909



	Voltage.	Blade Gap.	X .0003 for FVA. (Blade width 300mm)
Blade 1.	45.6v	14.1mm	.0042m2
Blade 2.	61v	25.7mm	.0077m2
Blade 3.	57v	30.8mm	.0092m2
Blade 4.	52.5v	21.0mm	.0063m2

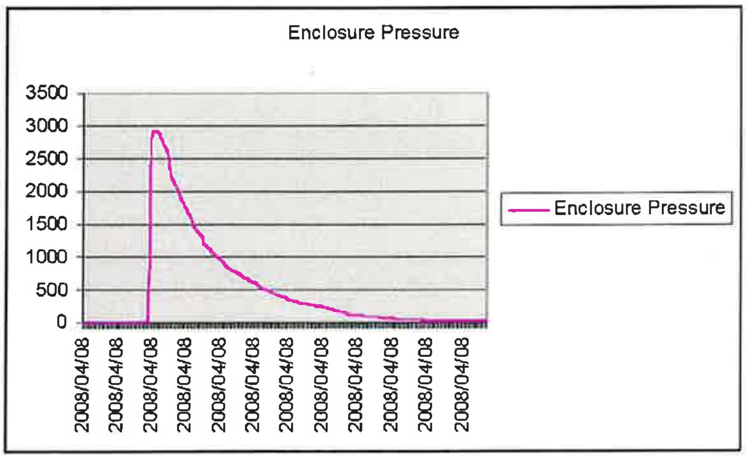
TOTAL FVA	.0274m2
FVA As % of Vent Size. (.3x.3m2 or .09m2)	30%

Test 5 – IG55 No Venting Test

Photo of IG55 discharge with no venting risk pressure reached 1700 Pa

This test was carried out using IG55 Inert Gas with out any pressure venting to see what pressure the enclosure would reach before any damage was caused.

The first test reached 1700 Pascal's pressure before the risk was damaged. We then repaired the risk and carried out our first Cascade Vent Test with the container doors closed but with a very small amount of leakage and an SHX-300 Pressure vent in the inside wall. The following chart shows the resultant risk pressure.



Results

Enclosure Pressure 2938.263 Pascal's

No Pressure Vent Fitted

Test 6 – FM200 Discharge test

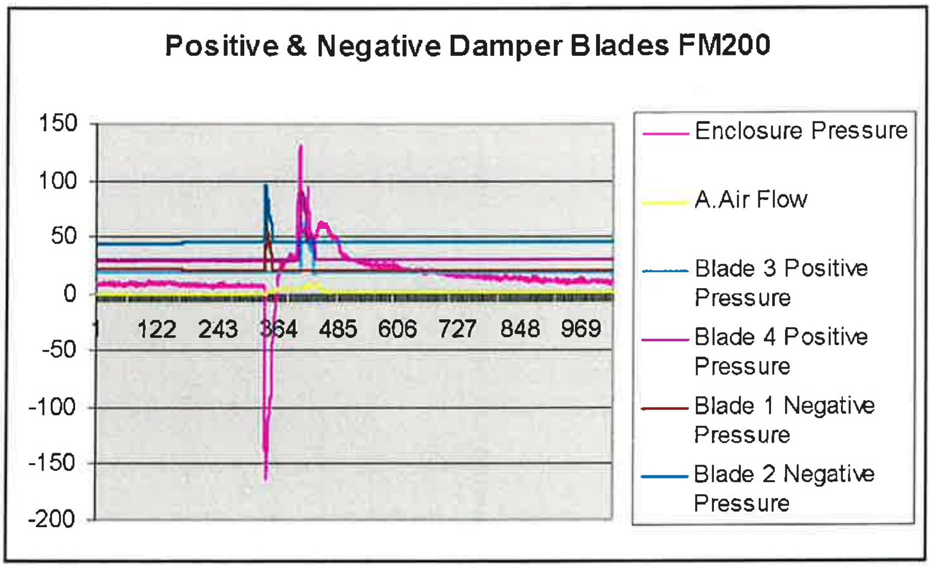
Photo 1 of FM200 Negative Pressure Vent Opening (Bottom blade locked shut)

Photo 2 of FM200 Positive Pressure Vent Opening (Bottom blade locked shut)

With 2 x HXD300 pressure vent installed.

This test was to show the operation of our Pressure Vents for positive and negative pressure venting.

The system used two vents but we fixed one blade in each vent closed as the Free Vent Areas required was less than the above inert gas tests. Both vents were operated and the peek negative pressure reached was as followed:-

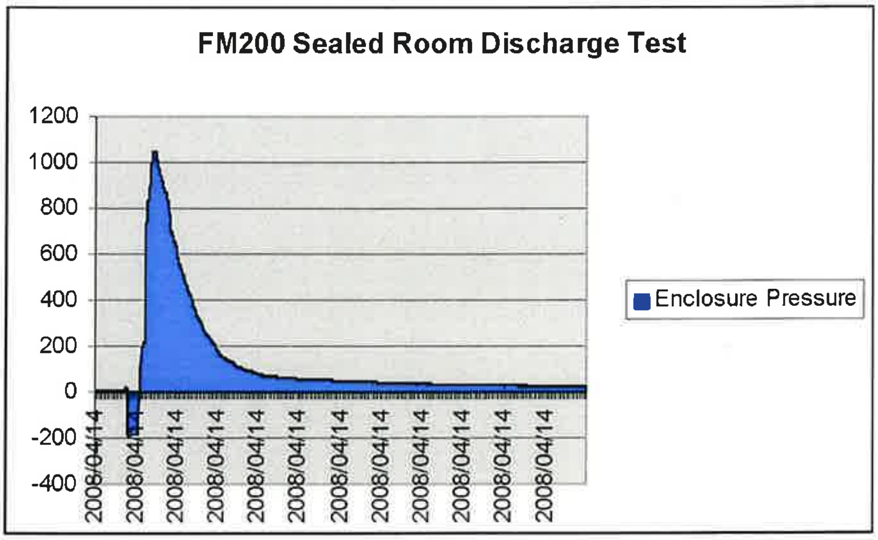


RESULTS OF FM200 TEST

Enclosure Pressure	Neg – 163.987 Pascal's Pos + 129.9446 Pascal's
Air Flow through the pressure vent	+8.42154 mps
The pressure vent fully opened	NO
The vent blades open 45-50%	

Test 7 – FM200 discharge test no venting

This test was carried out to determine the expected maximum pressure that could be experienced in an average risk. The risk was sealed and a 42 bar FM200 system discharged.



Results

Enclosure Pressure	Neg – 184.3109 Pascal's (gauge limit exceeded) 500 to 600 Pa expected
	Pos + 1044.477 Pascal's
Air Flow through the pressure vent	No Vent Fitted
Risk Temperature	19.5 to 10.32^{0}C

The pressure monitor used exceeded its negative pressure limits at -184 Pascal's pressure but the graph would suggest that the negative pressure could have reached between 500 and 600 Pascal's pressure.

The positive pressure of the enclosure of 1044 Pascal's exceeded the 500 Pascal limit of the enclosure. Pressure venting is required.

Conclusion

These tests provided new data which proved to us that the only way to test a pressure vent for performance was in a live gas discharge test. We found that although all the pressure vents tested provided the expected free vent areas the most surprising area was the back pressure created in the protected risk.

What is extremely difficult to calculate is the relationship between a pressure vents ability to react and open to a gas discharge and the time it takes for the venting gas to become lamina and accelerate to full flow through the vent compared to the speed at which a the volume of discharging gas is entering the risk and producing a positive pressure. This is evident from the markedly different results between the AES300 and the SHX300, both being pressure relief dampers with similar potential free vent areas.

It is evident that free vent area, whilst an important part of the calculation is not the most essential part in performance of the system since the most important aspect is the vents ability to react and open at the low pressures a risk is not to exceed.

With the HXD 300 the back pressures were within the expected areas we suspected but it was the AES (Top Hinged Bottom Weighted Type) Vent that gave an extremely high level of back pressure at 790 Pascal's and in fact on the slow motion video the wall can be seen to flex (see enclosed DVD). This could have devastating consequences on a risk rated at 500 Pascal's.

We carried out other tests which form part of the Cascade Venting tests which suggested that this type of Top Hinged Bottom Weighted pressure vent is not practically suitable for risks under 500 Pascal's as the increase in size i.e. free vent area is not linear and no mater how large the unit the back pressure in the risk is unlikely to reduce much below 500 PA this is backed up by the integrity test data above which showed at 429 Pa the AES vent only provided 9% (0.0084m^2) FVA.

With our existing HXD300 pressure vent the maximum pressure reached was 350 Pascal's and was even better with our new SHX300 balanced pressure vent which only reached a maximum pressure of 251.8 Pascal's.

With the new SHX pressure vents it may be possible to reduce the FVA required for 500pa rated risks but this would need to be backed up by multiple tests with each agent. Note that these tests do not suggest that FVA can be reduced for 250pa and further testing is also required in this area. The pressure results cannot be extrapolated down in a linier fashion since increasing vent size, whilst acting to reduce the pressure spike, is not proportional to the decrease in pressure.

The only way to test pressure vents is in a live discharge testing as there is no other way to fully test and determine the units back pressure and performance.

These tests have also proved that it is not just Inert Gases such as IG55, IG541, IG01 and IG100 that need pressure venting but the Chemical Gases, such as FM200, Novec, FE25 etc require venting as well.

The FM200 tests provided us with independent test data that if venting is not provided the risk pressures can reach unacceptable levels that could cause structural damage.

Most of the data on the market from tests carried out by the Loss Prevention Council (LPC) and data available from manufacturers are test with designed leakage.

It was important for us AFP Air Technologies LLP to gain an understanding of the effects and pressures produced with chemical agents.

We are not suggesting that natural leakage should not be used, only that as with Inert Gases the LPC recommend that the protected risk is sealed as tightly as possible by an approved contractor and the correctly pressure vents fitted.

To this end we have put into production our new DuFlow™ Pressure Vent which allows pressure relief for positive and negative pressure.

The Next Step

Following these tests and as a result of the data verified a European Standard or at least guidance from LPCB, VDS, APSAD and the BFPSA urgently needs to be formulated to provide a basis for third party verification that all pressure vents sold on the market meet certain levels of performance.

We at AFP Air Technologies LLP believe that this testing sets the bench mark for all pressure vent products and can easily be formulated into a testing standard.

It is not as simple as using a fan to open the pressure vent at certain pressure as this will not determine the risk back pressure that can be produced and only live discharge testing can achieve a true result.

Appendix C – G & D report (appendices supplied to BRE but not included here)

G & D FIRE PROTECTION LTD

Connect House
21 Willow Lane
Mitcham
Surrey
CR4 4NA

Phone: 020 8288 1275
Fax 020 8288 1276
Email colin.uzzell@fireprotectionuk.org

ROOM INTEGRITY TEST REPORT

OF THE

IG-55 SYSTEM

PROTECTING THE

TEST CELL

South Goringlee Farm House
Harbolets Road
West Chiltington
West Sussex
RH20 2LG

Date of Test: 08/04/2008

Report by
COLIN UZZELL

....

Company Registration No: 4400938
VAT Registration No: 468743306

Fire Industry Association

Fire Industry Association

OUTLINE

The purpose of the test was to carry out independent testing and to ascertain the additional leakage through various Pressure Relief Dampers.

A test cell was used which is a transportation container with a partition wall installed to create a enclosure with the volume for the assumed gaseous system i.e. 1no IG-55 cylinder filled 32Kg

The volume was re-measured while on site, and a Room Integrity test was carried out to provide a bench mark for the estimated leakage within the protected area.

Various PRD where then installed within the partition wall and a Room Integrity retest carried out to prove the increase in the estimated leakage area.

The result times achieved are with a supposed minimum protected height of 2.0m

The retention times although of value are just for test purposes and the difference in the ELA was the important criteria for the test

Once the above had been ascertained the pressure within the area was increased to check at what pressure the vent(s) would open in a test condition.

All of the vents used where fitted with floating pots on each vain, to ascertain from a calibration chart submitted by AFP to what angle each vain opened.

A pressure probe was also installed to ascertain the airflow through the vents on opening.

Results and full report below:

1.0 INTRODUCTION

The major cause of discharge tests being deemed to be failures has been the excessive leakiness of protected enclosures. High leakage rates allow gaseous extinguishing agents to rapidly escape from an enclosure and result in the desired concentration of extinguishant only remaining in the enclosure for a short period.

Integrity testing, which employs technology and techniques originally developed for use in the energy conservation field, has been recognised as an alternative method for testing the leakiness of enclosures protected by a gaseous extinguishant, which can then be sealed, and can also be used to measure the "total leakage area" of the enclosure. This is the sum of the areas of all the individual cracks and openings through which air (and hence gaseous agents) will pass into or out from an enclosure. Working under the auspices of the National Fire Protection Association (NFPA) in the United States, a number of researchers in the field have developed retention prediction formulae which use measurements from fan pressurization tests to predict agent retention times.

A computer programme using these formulae was used to predict the retention time at a particular height in each enclosure tested. A short report detailing the results of the testing in each vent test is attached and printouts of the test results are provided in Appendix One.

2.0 SUMMARY & CONCLUSIONS

Integrity testing of the Test Cell was undertaken on the 08/04/2008. For the purpose of the test it was assumed that the area was protected by an IG-55 total flooding extinguishing system. Testing was carried out in accordance with BS ISO 14520 Enclosure Integrity Procedure (2006).

The results achieved within the enclosure are detailed below:

Enclosure	Test No:	Nett Volume (m^3)	Initial Conc. (%)	Room Height (m)	Measured Leakage Area (m^2)	Leakage Distribution	Predicted Retention Time (minutes)
Test Cell	1	43.013	41.27	2.409	0.0089	50/50	**46.5**
Test Cell	2	43.013	41.27	2.409	0.0106	50/50	**37.8**
Test Cell	3	43.013	41.27	2.409	0.0106	50/50	**31.2**
Test Cell	4	43.013	41.27	2.409	0.0097	50/50	**42.5**

Test #1 was carried out to ascertain the leakage area for the Test Cell
Test #2 was carried out with a HXD 300 PRD Vent fitted to ascertain additional leakage area i.e. Room + Vent
Test #3 was carried out with a SHX 300 PRD Vent fitted to ascertain additional leakage area i.e. Room + Vent
Test #4 was carried out with a PAES 300 PRD Vent fitted to ascertain additional leakage area i.e. Room + Vent

2.1 Leakage Areas Defined

An enclosure's Equivalent Leakage Area (ELA) is the total area of leaks within the room. The ELA is equivalent to the size of a hole required in a flat plate to give the same flow rate as the test pressure. The Below Ceiling Leakage Area (BCLA) is the leakage in the walls and floor and ceiling slabs through which agent would normally leak out. The test was performed at a pressure equal to the theoretical maximum pressure that would be created by the agent/air mixture after discharge, NOT the brief spike at agent discharge.

3.0 TEST CELL

3.1 Pre-test Inspection & Measurement

A short pre-test inspection was carried out of the Test Cell. No major leakage sites were identified and the test proceeded. The volume of the protected enclosure was calculated to be 43.013m³. The proposed IG-55 cylinder would contain a charge of 32Kgs, which would give an initial concentration immediately after a discharge of 41.27% at a normal operating temperature of 20°C.

3.2 Door Fan Installation

A single fan unit was installed in the entrance doorway and the enclosure was both pressurized and de-pressurized. 'Set-up' and 'gauge zeroing' was performed according to the manufacturer's instructions. The pressure probe outside the Test Cell was positioned 5 metres away from the airflow streams created by the blower unit to ensure that turbulence did not affect the pressure.

3.3 Test Results

Test #1

The Equivalent Leakage Area (ELA) for pressurization and de-pressurization, measured in the integrity test for the **Test Cell** was **0.0089m²**.

The measured area was assumed to exist in the worst possible Below Ceiling Leakage Area (BCLA) configuration for retention time – namely 50% of the total at the top of the enclosure and 50% at low level. This gives an area of **0.0044m²** as upper leaks and **0.0044m²** as lower leaks.

This would give a **satisfactory** predicted retention time of **46.5 minutes** at a height of **2.0 metres** above the floor slab. This corresponds with a proposed protected height, which was therefore selected as the height of interest.

Test #2

A HXD 300 PRD vent was then installed within the partition wall and the test recalculated.

The Equivalent Leakage Area (ELA) for pressurization and de-pressurization, measured in the integrity test #2 for the **Test Cell** was **0.0106m²**.

The measured area was assumed to exist in the worst possible Below Ceiling Leakage Area (BCLA) configuration for retention time – namely 50% of the total at the top of the enclosure and 50% at low level. This gives an area of **0.0053m²** as upper leaks and **0.0053m²** as lower leaks.

This would give a **satisfactory** predicted retention time of **31.2 minutes** at a height of 2.0 **metres** above the floor slab. This corresponds with a proposed protected height, which was therefore selected as the height of interest.

From the above results we can conclude that by the introduction of the HXD 300 PRD Vent an additional 0.0017m^2 of leakage was recorded.

Test #3
A SHX 300 PRD vent was then installed within the partition wall and the test recalculated.
The Equivalent Leakage Area (ELA) for pressurization and de-pressurization, measured in the integrity test #3 for the **Test Cell** was **0.0106m^2**.

The measured area was assumed to exist in the worst possible Below Ceiling Leakage Area (BCLA) configuration for retention time – namely 50% of the total at the top of the enclosure and 50% at low level. This gives an area of **0.0053m^2** as upper leaks and **0.0053m^2** as lower leaks.
This would give a **satisfactory** predicted retention time of **31.2 minutes** at a height of 2.0 **metres** above the floor slab. This corresponds with a proposed protected height, which was therefore selected as the height of interest.

From the above results we can conclude that by the introduction of the SHX 300 PRD Vent an additional 0.0017m^2 of leakage was recorded.

Test #4
A PAES 300 PRD vent was then installed within the partition wall and the test recalculated.
The Equivalent Leakage Area (ELA) for pressurization and de-pressurization, measured in the integrity test #4 for the **Test Cell** was **0.0097m^2**.

The measured area was assumed to exist in the worst possible Below Ceiling Leakage Area (BCLA) configuration for retention time – namely 50% of the total at the top of the enclosure and 50% at low level. This gives an area of **0.0049m^2** as upper leaks and **0.0049m^2** as lower leaks.
This would give a **satisfactory** predicted retention time of **42.5 minutes** at a height of 2.0 **metres** above the floor slab. This corresponds with a proposed protected height, which was therefore selected as the height of interest.

From the above results we can conclude that by the introduction of the PAES 300 PRD Vent an additional 0.0008m^2 of leakage was recorded.

3.4 Data Used To Predict Retention Times
See copies of computer printouts in Appendix One.

4.0 VENTING

4.1 Pressure Relief / Venting Requirements

High pressures occur at discharge and need to be controlled or compensated for if the extinguishing ability is not to be impaired. It is important that consideration be given to provide pressure relief in areas where structural damage may occur if there is not sufficient venting to allow for localized spike pressures in the event of a discharge.

Test #2 HXD 300 PRD Vent

The pressure relief vent was installed and a vent test carried out.
For the calculation of the pressure relief surface area the common wall strengths of 100 Pascals have been employed throughout the enclosure. Although this is very low we assumed this as a worst case scenario. If the structural strength of the enclosure changes then the vent area will alter accordingly. The recommended venting area for the enclosure based on the CleanAgent 2001 CEA4008: 1997 -08 equations based on **room and vent** leakage is **0.0745m^2**.

During the test it was found that the vent started to open at 79pascals, approx 35^0 open at 140pascals, and was found to be approx 72^0 open at 241pascals allowing for a true free vent area of 0.05472m^2 at 241pascals.
During the above test the flow pressure through the vent was measured to be 9.13m/sec.
Following the Room Integrity test, IG55 discharge tests where carried out in conjunction with LPG Fire and the vents performance monitored. The enclosure had a spike pressure of 350pascals and the flow pressure through the vent was measured to be 10.33m/sec during discharge.

Test #3 SHX 300 PRD Vent

The pressure relief vent was installed and a vent test carried out.
For the calculation of the pressure relief surface area the common wall strengths of 100Pascals have been employed throughout the enclosure. Although this is very low we assumed this as a worst case scenario. If the structural strength of the enclosure changes then the vent area will alter accordingly. The recommended venting area for the enclosure based on the CleanAgent 2001 CEA4008: 1997 -08 equations based on **room and vent** leakage is **0.0746m^2**.

During the test it was found that the vent started to open at 80pascals, approx 40^0 open at 87pascals, and was found to be approx 86^0 open at 95.5pascals allowing for a true free vent area of 0.06708m^2 at 95.5pascals.
During the above test the flow pressure through the vent was measured to be 7.12m/sec.

Following the Room Integrity test, IG55 discharge tests where carried out in conjunction with LPG Fire and the vents performance monitored. The enclosure had a spike pressure of 220pascals and the flow pressure through the vent was measured to be 12.15m/sec during discharge.

Test #4 PAES 300 PRD Vent
The pressure relief vent was installed and a vent test carried out.
For the calculation of the pressure relief surface area the common wall strengths of 100Pascals have been employed throughout the enclosure. Although this is very low we assumed this as a worst case scenario. If the structural strength of the enclosure changes then the vent area will alter accordingly. The recommended venting area for the enclosure based on the CleanAgent 2001 CEA4008: 1997 -08 equations based on **room and vent** leakage is **0.0745m^2**.

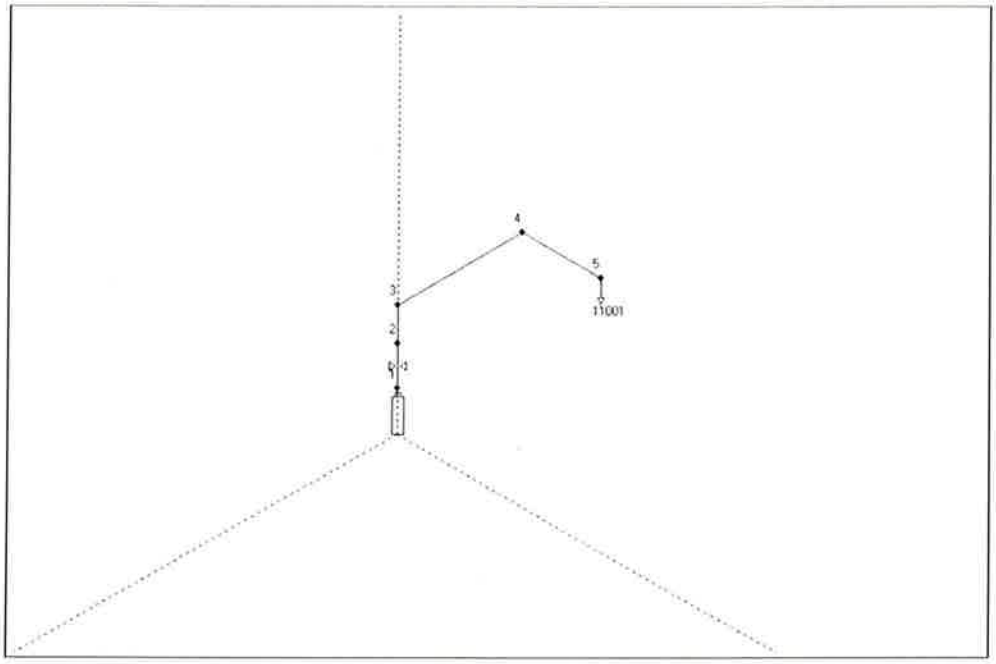
During the test it was found that the vent started to open at 170pascals, and was found to be ONLY approx 15-20^0 open at 500pascals allowing for a true free vent area of 0.016008m^2 at 500pascals.
During the above test the flow pressure through the vent was measured to be 2.68m/sec.
Following the Room Integrity test, IG55 discharge tests where carried out in conjunction with LPG Fire and the vents performance monitored. The enclosure had a spike pressure of 795pascals and the flow pressure through the vent was measured to be 7.33m/sec during discharge.

4.2 Data Used To Predict Peak Pressures

See copies of computer printouts in Appendix One.

Appendix D – Flow calculations for IG-55, HFC-227ea and pipe layout diagram

Project:	Coxon
Project-No:	Test System
Building:	
Object:	
Contractor:	
Owner:	Paul Coxon
Project engineer:	Nigel James
Date:	06/03/2008
Altitude above sealevel:	10 m
Regulation rule for calculation of IG55 quantities:	ISO 14520-1, Edition 2000
Pipe catalogue:	LPGDiametros.rkl
Component catalogue:	LPGComponentes.arm
Nozzle catalogue:	LPGDifusores.noz



Pipesystem data:

Section-No:	Starting-node	Endnode Nozzle	Length [m]	Height [m]	Pipetype	Diameter [mm] **	Fitting *	Component code	Component coefficient	Nb of containers IG55 quantity
1	0	1	0.400	0.400	22	18.8		-	-	0.0
2	1	2	0.600	0.600	11	20.9	R	-	-	0.0
3	2	3	0.500	0.500	11	20.9		-	-	0.0
4	3	4	3.815	0.000	11	20.9	E	-	-	0.0
5	4	5	1.200	0.000	11	20.9	E	-	-	0.0
6	5	11001	0.100	-0.100	11	20.9	E	-	-	0.0

* C=Component, B=Bend, T=T-Piece, E=Elbow, R=Restrictor
** If a pipe diameter is equal zero see the extra table of the calculated diameters

Legend of pipetypes

Type	Pipeclass	Pipe roughness
22	SCH 80	hose
11	SCH 40	galvanized

Nozzle data:

No.	Calculation zone	Diameter [mm]
11001	Test Module	13.8

Legend of nozzles and restrictor:

Type	Number of orifices	C1	C2	C3	C4	C5	C6
1 Nozzle 1	1	-1.050	0.067	0.119	0.000	0.000	0.000
Restrictor		-0.400	0.090	-0.007	0.000	0.000	0.000