

# Acetylene Cylinders in Fire

A study of Acetylene cylinder incidents in London **2004-2008**

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6<sup>th</sup> March 2009

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## Executive Summary

This report provides details of a 5 year study of Acetylene cylinder incidents within the London Fire Brigade (LFB) area, the conclusions drawn, the actions taken in response and the subsequent outcomes of those actions.

The implementation in 2003 of new national guidance for dealing with Acetylene cylinders involved in fire had led to massive disruption being caused to London.

The LFB sought solutions to mitigate this disruption and, in 2006, led the creation of a National Stakeholder Group for Acetylene in Fire (NSG) to identify best practise for preventing and resolving Acetylene cylinder incidents.

A LFB database was created of all cylinder incidents from 1<sup>st</sup> January 2004 to 31<sup>st</sup> December 2008. This made it possible to investigate every LFB Acetylene cylinder incident within this period to determine reasons for the decision making processes employed by operational crews, to plot timelines during these incidents and to understand operational actions.

Knowledge shared through the NSG has been studied to better understand the behaviour of Acetylene cylinders in fire and the reasons why they ultimately fail.

By 2007 the combination of information gained enabled the LFB to implement procedures which have led to dramatic improvements being made in:-

- a) A reduction of the frequency of Acetylene cylinder incidents in London from an average of one incident in every 14 days in 2004 to one every 42 days in 2008, and
- b) The resolving of operational incidents more effectively when they do occur, the average length of the disruption dropping from 19 hours on average in 2004 to an average of just 2hours 15 minutes in 2008.

These improvements have been made whilst working within the **existing guidelines** of the national Fire Service Manual.

## Introduction

In October 2003 new guidance for the Fire Service for dealing with Acetylene cylinder incidents was published - The Fire Service Manual Volume 2 – Fire Service Operations - Acetylene Cylinder Incidents

Nationally each Fire and Rescue Service (F&RS) then used this document to draft their own Standard Operating Procedure. In London this has resulted in Policy Note 376 - Cylinder Procedure.

The new national guidelines involved (amongst other procedures) implementing a 200m radius Hazard Zone at the incident for up to 24 hours. Whilst creating a safer system of work for operational crews, at many incidents, implementation of this procedure created severe disruption in the surrounding area. Such disruption would certainly have prejudiced safety away from the immediate incident and by tying up emergency service resources

By August 2005 the disruption being caused by Acetylene cylinder incidents in London was becoming more and more frequent and severe. Consequently the decision was taken to undertake a work stream to identify any possible improvements that could mitigate the disruption caused by Acetylene cylinder incidents.

The initial scoping of this project sought to determine several key factors:-

- Why was there disruption now? - It had not been occurring prior to the change in guidance
- What is the specific risk associated with Acetylene cylinders and why do they ultimately fail at incidents?
- Could any further improvements be made to our new operational response? – Within existing guidelines.
- What could be done to prevent Acetylene incidents from occurring?

Research of existing statistics and data on the frequency and causes of Acetylene cylinder incidents was undertaken. However, it quickly became apparent that there was very little information available on the subject.

Consequently, in the absence of any national statistics on Acetylene cylinder incidents, a database and survey of all cylinder incidents in London was begun in June 2006. This research was backdated to include all incidents since 1<sup>st</sup> January 2004 and continued until 31<sup>st</sup> December 2008.

Furthermore, to raise awareness of the issues involved, the LFB hosted a “Safe Cylinder” seminar at City Hall in November 2006. As a direct result of this the National Stakeholder Group for Acetylene in Fire (NSG) was formed to share best practice and research ways to mitigate the disruption caused by these incidents.

One of the first tasks undertaken by the NSG was the compilation and sharing of all known information and previous research on the behavior of Acetylene cylinders in fire.

By the summer of 2007 analysis of the information from the database and study of the information from the NSG had identified the main causes of the disruption. In addition potential improvements in the safe use, storage and transportation of Acetylene had been identified.

Likewise a study of the investigations and timelines of Acetylene cylinder incidents had identified where improvements to the existing operational procedures could be implemented.

Consequently On the 12<sup>th</sup> August 2007 the LFB launched a “Safe Cylinder” campaign in the media highlighting how users of Acetylene could help prevent incidents occurring.

Simultaneously improvements to operational procedures were introduced which had dramatic effects in reducing the frequency of these incidents and the length of time that the 200m hazard zone was in place at these incidents (the major cause of the disruption).

The outcome has been that the disruption caused to London has been massively reduced without compromising Firefighter safety.

## Disruption

Within the time of this case study there were several incidents that have caused not just disruption with subsequent financial loss, but actually caused lives to be put at risk.

The incident that occurred at **Blue Anchor Lane SE1** at 09:56 hrs on 23<sup>rd</sup> May 2007 highlights this issue. A fire broke out in a railway arch under the main line track into London Bridge station and Acetylene cylinders were subsequently confirmed as involved.

At approximately 10:15 a 200m hazard zone was established which closed the 8 National Rail lines running above the arch.

This closed the three out of the four main line terminals in and out of south- east London – London Bridge, Cannon Street and Charing Cross. It is estimated that over 900,000 commuters had used these station to travel in to London that day.

By 18:00hrs as people left work to return home and were turned away from these stations they subsequently travelled to the only remaining station that remained open – Victoria, causing extreme over crowding on the platforms and station concourse.

At the subsequent Network Rail debrief of this incident, the senior British Transport police officer present stated that he feared that people would be “pushed off the platforms” and that he had “another Hillsborough” on his hands. The decision was taken to close Victoria station on safety grounds.

Within one hour the four closest Underground Stations; Victoria, Sloane Square, St. James’s Park and Green Park also had to be closed.

It should be noted that the fire had been extinguished and cooling of the cylinders involved commenced by 15:30 hrs.

The incident at **Pensbury Place Clapham** at 13:29 hrs on 16<sup>th</sup> March 2007 resulted in the closure of the main lines in to and out of Waterloo International station. Eurostar had to be cancelled and lines remained closed for over 36 hours. Network Rail had to pay £1.4 million in costs for the line closure. The cylinder that caused the closure was eventually identified as containing Propane.

The incident at **York Road, Kings Cross** at 08:36 hrs on 26<sup>th</sup> June 2006 closed Kings Cross mail line station for over 48 hours. Trains were backed up to Broad Street Station in Birmingham, causing Train delays and cancellations as far away as Edinburgh. Crews did not approach the cylinder for over 36 hours.

The incident at **Winslade Mews Paddington** at 16:18 hrs on 16<sup>th</sup> October 2006 caused the closure of St. Mary Hospital in Praed Street for over 24 hours. The Accident and Emergency facility (one of the busiest in London remained close throughout this period. In addition over 800 out-patient appointments were cancelled. The cylinder that caused the closure was eventually identified as containing Mapp gas.

These are just a few examples of the disruption and dangers that Acetylene incidents have caused.

It is almost impossible to quantify the true financial cost of these incidents. Local Authority Emergency planning offices have had to be mobilised on numerous occasions involving costs for re-housing and feeding evacuated people, overtime for staff and other expenses.

It is estimated that the cost to local businesses closed or from staff being unable to work must at least run into millions, if not tens of millions.

It is not known what happened to patients who were diverted from the nearest A&E department. It is known that several Road Traffic Incidents have occurred following road closures following incidents.

The incident in Blue Anchor Lane demonstrated the very real risk that the public can be put at by the implementation of extended Hazard Zones.

### **Why was this disruption being caused?**

The very obvious initial question was - what had changed? Prior to 2004 this disruption quite simply had not been happening

The following areas were investigated:-

- The number of cylinders in use today - Were there now more cylinders in use?
- The manufacturing of cylinders - Were they of poorer quality today?
- The training of DA users - Were the operatives less well trained?
- Guidelines and legislation - Had there been a detrimental change to guidance or legislation?

With the exception of the fire service guidance for dealing with acetylene incidents, the answer to all of these questions was “no”, in fact in some areas such as user training and guidance issued, they had significantly improved.

It was the rigid implementation of the revised Fire Service procedure that was causing the disruption.

# Change in Fire Service Operational Procedures

Prior to October 2003 it had been Fire Service practise to carry out the following operational procedures for incidents involving Acetylene cylinders:-

- Implement a 100m hazard zone
- Cool the cylinder for an indeterminate period
- Manually test the cylinder for heating
- Place the cylinder in a “water bath” for 12 hours.

Several events led the Fire Service to change the operational procedure at Acetylene incidents. However the UK was alone in making such change and the rest of the world still operates safely on largely the same methodology which used to operate in the UK. The two events below were somewhat misinterpreted.

The first was the death of an Officer in Oxfordshire in 1987 when an Acetylene cylinder he was standing next to failed.

The second was an incident at the Health and Safety Laboratories (HSL) in Buxton in 1996 when an Acetylene cylinder was identified as still hot after 18 hours.

The need for an initial 200m hazard zone is not disputed. Several instances have been recorded where parts of an Acetylene cylinder have travelled in excess of 100m after failing.

## **Fatal Incident**

In 1987 an incident occurred where an Acetylene cylinder failed causing fatal injuries to Fire Officer John Wixey.

A fire had taken place in a workshop involving two Acetylene cylinders. Crews arrived and within 5 minutes had extinguished the fire. However, the crews then immediately proceeded to move the cylinders, laying them both down. The fire crews were standing next to the Acetylene cylinders, which were visibly steaming when one of them failed.

The cylinders had been involved in a severe fire. They had received only minimum cooling. As is now known moving the cylinders would have fed the decomposition process with tragic results.

The Accident Report of the incident notes that the crews did not follow the existing guidance (at the time). The crews should have cooled the cylinders in situ and not moved them until satisfied that they were cool.

### Buxton Incident

In 1994, the HSL at Buxton had been carrying out tests to determine if fusible plugs were a viable safety factor for Acetylene cylinders. The tests determined that fitting of fusible plugs is not effective and they are no longer fitted in the UK.

Fusible plugs tend to leak and once a plug has failed the movement of the Acetylene gas would feed decomposition if it was taking place. If there was an ignition source then this could ignite the contents of the cylinder.

However several critical actions took place which affected the outcome and which were greatly misinterpreted:-

- As a supposed precaution at the end of a day's experimentation and before going home the cylinder valve was opened to vent a cylinder which had been subjected to a "bonfire" test - If decomposition is taking place this will prevent the monolithic mass performing its function and will aid decomposition by drawing fresh gas over the affected area.
- The cylinder was laid down from the vertical – this would have the effect of "stirring" the contents again fuelling further decomposition.
- The cylinder was not adequately cooled – following the test it was placed in a plastic dam. When localised heating occurred due to decomposition it caused the plastic dam to melt and the water to escape.

When staff returned the next morning (the cylinder was not monitored overnight) and the cylinder inspected (18 hours later) it was discovered that the cylinder wall had "bulged" locally.

It is ironic that this was one of the key reasons that the 24 hour rule was introduced as despite the sequence of events stated, the **cylinder still did not fail**.

It is suggested that had the valve not been opened, nor the cylinder re-orientated and had it been adequately cooled then the localised heating would have been removed, the decomposition process would have been stopped by the construction of the cylinder and bulging of the cylinder wall would not have taken place.

However, these events ultimately resulted in the concept of the 200m – 24 hour hazard zone.

The Fire Service Manual provides comprehensive details on dealing with Acetylene cylinder incidents (although it is now accepted that there are some erroneous statements within it). However, the majority of FRS personnel when questioned believed that a 200m hazard zone must be implemented, it should not be reduced and that that this should remain in place for a minimum of 24 hours whilst the cylinder is continuously cooled.

Whilst it is recognised that these procedures provide a very safe system of work for operational crews at an incident, it is now contended that these conclusions erred too far on the side of safety. The resulting disruption actually causes far more potentially dangerous conditions for the public in the surrounding affected areas.

# Findings of Study

## Research

BAM, the German Federal Materials Test Institute, are the leaders in the field of Acetylene knowledge. They test and type approve all European Acetylene cylinders.

In June 2007 BAM gave a presentation to the NSG confirming the previous knowledge of the behaviour of Acetylene cylinders in fire and also detailing their latest findings on decomposition in Acetylene cylinders. This confirmed the analysis of their research documents, provided by the NSG, revealing why Acetylene cylinders ultimately fail in fire.

An Acetylene cylinder fails in a fire because the rising internal pressure overcomes the falling tensile strength of the steel cylinder and the cylinder splits. This causes the contents to be released which can then ignite, outside of the cylinder, with a resulting fireball. This causes the typical “Banana” or “Tulip” condition of a failed Acetylene cylinder.

An Acetylene cylinder shell is designed (within the heat treatment of the steel) to split in ductile mode (not in brittle mode) and consequently does not typically fragment (the most pieces found post incident is five). However, the valve assembly can be projected for some distance away from the cylinder. The resulting fireball and blast zone can cover a 25m area.

There is a direct correlation between the temperature and internal pressure of the cylinder that causes failure. The BAM tests reveal that at ambient temperature a 4mm steel DA cylinder failed at an internal pressure of 142 bars. However at 300 degrees Centigrade a cylinder failed at 80 bars. At 600 degrees Centigrade a cylinder failed at 30 bars.

Obviously as the temperature increases, the internal pressure will increase, which in turn causes the internal temperature to rise and thus the pressure increases. Eventually a “runaway” condition will be reached and the steel cylinder will lose its tensile strength and the cylinder will fail.

However, the application of copious amounts of water will cool the cylinder shell, which in turn will reduce the internal pressure and thus the temperature will drop and the steel regain its tensile strength.

Consequently if the cylinder shell is at ambient temperature (regardless of if decomposition is taking place) the cylinder is in no immediate danger of failing providing:-

- a) The cylinder is not reheated
- b) The cylinder is not moved
- c) Cooling continues to be applied

It should be noted that Steel begins to lose its tensile strength at approximately 300 degrees Centigrade which is below the approximate temperature at which decomposition may be initiated in an Acetylene cylinder.

### Statistics

From 1st January 2004 to 31st December 2008 there were 471 cylinder incidents in London.

91 (19%) of these incidents involved Acetylene cylinders, a further 11 incidents involved unidentified cylinders that had to be treated as Acetylene. (See Appendix 1)

This caused 2,149 hours of disruption to London (over 144 days). Disruption is calculated as the number of hours the 200m Hazard Zone is in place.

All 102 Acetylene (or suspected Acetylene) incidents involved road closures. In addition 19 incidents involved the closure of rail or tube lines. A further 4 incidents involved the closure of water-ways or canals and 1 the closure of Battersea Heliport.

A minimum of 12,000 people were evacuated from homes or businesses because of these incidents during this period.

### Cylinder Failure

A total of 128 Acetylene cylinders were involved in 91 incidents. Only 4 of these cylinders failed. A study was initially carried out, to find out how many cylinders failed in the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> hour etc. up to the 24<sup>th</sup> hour. It quickly became apparent that all the cylinders failed while the fire was in progress and before cooling was applied. (See Appendix 2)

No Acetylene cylinder has ever failed after receiving substantial (1 hour) cooling.

### The Wet Test

The term “wet test” is used to describe the assessment process carried out on an Acetylene cylinder to determine its current status, however it is not very well described in the Fire Service manual. The Wet Test involves wetting the cylinder and looking for rapid drying out and/or steaming off, and a temperature check with a Thermal Image Camera (TIC).

Consequently the LFB now refer to the process of assessing the condition of an Acetylene cylinder as the “Cylinder Assessment Process”. This involves cooling the cylinder for one hour, then carrying out a wet test. This is repeated after 15 minutes and then again after a further 15 minutes. Cooling is not reapplied during these two periods. This provides an opportunity for an increase in temperature caused by decomposition to register on the cylinder shell.

341 Wet tests were carried out on 124 cylinders. Every test was “passed”. No cylinder showed signs of reheating after passing the wet test. The highest recorded temperature was 32 degrees Centigrade which was the ambient temperature that day.

In addition it was noted that crews were not carrying out a wet test because they could not see the entire cylinder (as per guidance). It is now recognised that this was inappropriate. Steel is one of the best conductors of heat available. It would be impossible for one end of a cylinder to be near the critical temperature (300C) and the other to be at ambient temperature (below 30C).

### Use of Acetylene

Initially, at 71% of the incidents, cylinders were in storage and not in use as previously believed. Only 14 (23%) of incidents occurred whilst the cylinder was in use. This led us to target the safe storage of cylinders in a Safe Cylinder campaign with dramatic results. NB This data was not available for the first 9 of these incidents. (See Appendix 3)

There are other metal cutting and welding technologies that could be used in some circumstances, but none can match the high flame temperature which Oxy-Acetylene provides or its flexibility across its spectrum of applications. It welds metals other options cannot and it cuts metals more quickly.

Also, being lighter than air, Acetylene is the only oxy-fuel option allowed in underground work. For example there are over 40 hot cuts carried out on the London Underground network every night. If Acetylene were banned (as once proposed) then it is estimated that the network would come to a halt within a week.

### Mechanical Shock

It is the considered expert opinion of the BCGA that the mechanical shock alone of a Road Traffic Incident (RTI) to a cold Acetylene cylinder which remains intact and has not been exposed to fire, will not initiate decomposition. Such a cylinder may be safely lifted and removed to quickly clear the RTI.

This opinion is supported by much empirical evidence from the BCGA who undertook a physical survey and examination of damaged Acetylene cylinders which have suffered impacts. More significantly, BAM have conducted extensive testing and type approval of all acetylene cylinder types used in Europe.

As part of their work, BAM has been conducting very severe “impact resistance testing” of Acetylene cylinders on behalf of the CGA (Compressed Gases Association, USA). This test is based on detonating an explosive charge, secured to the side of the cylinder, as an extreme and reproducible way of simulating impact/shock.

Cylinders so tested have been thoroughly examined and have shown no signs of Acetylene decomposition.

At the 6 incidents in London where Acetylene cylinders were believed to have been subject to mechanical shock they all passed wet tests and there was no evidence to suspect that decomposition had been initiated.

Crews are now trained to assess if a mechanically shocked cylinder has been involved in fire and if not to treat the cylinder the same as an unheated cylinder.

The BCGA further confirm that **globally** there is no evidence that it is possible to initiate decomposition from mechanical shock alone to an undamaged unheated cylinder.

## Cylinder Identification

Initially there had also been a problem where operational crews were not correctly identifying cylinders. This led to incidents lasting over 24 hours that were subsequently discovered not to involve Acetylene cylinders.

Furthermore there were incidents where operational crews were not approaching cylinders even after they had been cooled for one hour and consequently wet tests were not being carried out.

Both of these factors were due to then current belief that, if decomposition had been initiated, the cylinder could fail without warning, at any time in the next 24 hours. Consequently crews were not approaching cylinders to identify and assess the condition and temperature of the cylinder and consequently not reducing the hazard zone when safe to do so.

The BCGA were very quick to react to this information when informed via the NSG. Within a matter of weeks they had recommended to their members to fit reflective tape to Acetylene cylinders identifying them as Acetylene and providing the name of the owner of the cylinder. This has now been developed further with some manufacturers providing a reflective collar to Acetylene cylinders.

## Hazard Zone Management

At many incidents it was identified that crews were implementing a “blanket” 200m zone, not taking into account local topography or substantial cover to reduce the initial zone accordingly.

There were other incidents where crews having approached the cylinder, did not reduce the hazard zone despite the fact that there was no evidence that the cylinder had been involved in the fire or if it had been, that the cylinder was unlikely to have reached the critical temperature to initiate decomposition.

There were two incidents where the cylinder had already failed but the 200m hazard zone was maintained for a 24 hour period and cooling of the area continued with fire-fighting jets. (See Appendix 4)

## **BCGA Competent Person procedure**

The database also identified that operational staff were not always using the BCGA Competent Person (CP) system as efficiently as could be. Prior to August 2007 the CP was contacted for advice at only 16 incidents out of 73 attended (22%).

In addition on several occasions when the CP was called their advice was not always acted upon with crews reverting to the 24 hour cooling despite the CP assuring that the cylinder was now cool.

This was not consistent with other operational systems in place. If a dangerous structure is discovered on the fireground, it is practise to request the attendance of a "Borough Surveyor" to assess the condition of the structure. Likewise if an unknown substance is discovered the attendance of a "Scientific Advisor" is requested to analyse it. In both instances the advice of the "expert" is invariably taken and the incident managed accordingly.

One of the main difficulties with the procedure is that the very first step is for crews to identify the owner of the cylinder and then to contact that companies CP.

Unfortunately at the majority of incidents crews were struggling to identify even the type of cylinder, let alone the manufacturer. Consequently, as an interim measure, an arrangement was reached with BOC based at Guildford in Surrey, that BOC would offer advice or attend all cylinder incidents regardless of the owner.

This greatly simplified the procedure and showed immediate result in the frequency of crews requesting (and taking) advice from the CP.

## Conclusions – Preventing Incidents

### Preventing incidents - Safe Cylinder campaign

The conclusion drawn was that raising public awareness and preventing incidents go hand in hand.

The majority of incidents occur whilst cylinders are in storage. Consequently it was decided to target users of Acetylene with a campaign to promote the safe storage, use and transportation of Acetylene cylinders.

With a specific view to preventing cylinder incidents, and working in conjunction with Islington Council, BCGA and CFRA, the LFB have designed and produced a leaflet for the safe use and storage of Acetylene.

Drawing from the database the critical issues for best practise for the safe storage and use of Acetylene have been highlighted in this leaflet. The leaflet is designed for distribution to identified Acetylene users.

Copies of this leaflet have been circulated to all London Boroughs to ensure a consistent and standardised approach across London is adopted. The leaflet covers the following areas:-

- The legal requirements under DSEAR and the RRO for Acetylene users
- The need to use alternatives or contractors where possible
- The safe storage of Acetylene and the need to be aware of its location at all times
- Promoting the fitting and use of Flash Back Arrestors
- Best practise for the safe use and transportation of Acetylene

### RRO Enforcement

To back up the publicity and awareness campaign the Fire Safety Policy group within the LFB has also implemented new procedures. In the future when carrying out a Fire safety audit of premises using Acetylene under the Regulatory Reform Order (Fire Safety) 2004 (RRO) - Inspecting Officers will: -

- Ensure that Acetylene is taken in to account in the Fire Risk Assessment of premises.
- That staff have received training in the use of Acetylene equipment
- That all cylinders are stored as per industry guidelines
- That premises have suitable signage where cylinders are stored
- Reinforce the message that the fitting of Flash Back Arrestors are mandatory
- Consider Improvement and Enforcement notices where premise are found to be lacking

In addition Senior Fire safety officers were mobilised to confirmed cylinder incidents, with a view to considering prosecution of premises where guidelines have not been followed.

## Conclusions – Resolving Incidents

### 1) The major cause of disruption

The major cause of disruption is the implementation of a 200m radius hazard zone. The longer this is in place the greater the disruption.

**The early reduction of the size of the Hazard Zone is the most critical area for mitigating the disruption at Acetylene cylinder incidents.**

If this area of the procedure is managed properly then the disruption caused can be significantly reduced.

### 2) Why an Acetylene cylinder fails

Whilst an Acetylene cylinder is involved in fire there is a very real danger that it will fail. When Acetylene cylinders have failed parts of the cylinder have travelled over 150m. Accordingly the initial implementation of a 200m radius hazard zone is essential.

If an Acetylene cylinder has been involved in a fire there is a possibility that the decomposition process may have been initiated. The previous understanding had been that if decomposition had been initiated that the cylinder could fail without warning, at any time in the next 24 hours.

However there is no empirical evidence that an Acetylene cylinder has ever failed after having been cooled back to ambient temperature, even if decomposition was taking place.

Decomposition is a relatively slow process producing only 40% of the energy of combustion. There is no evidence that cylinders can go instantly from ambient temperature to failure.

At the end of 2007 four of the NSG parties agreed to fund research to be conducted by BAM. First results at the end of 2008 indicate (amongst other facts) the following:-

- Porous mass type is an insignificant variant, its heat capacity being swamped by that of the solvent content. This greatly simplifies the ongoing work. The porous mass is, however, a thermal insulant. This means that it takes time to get significant heat from a fire into the body of a cylinder, but also means it takes time also to get such heat back out by cooling
- That the decomposition reaction needs at least 350c to get it started. This means unless a cylinder has been subject to the direct and full heat of a fire it is not at risk of decomposition.
- Polymerisation of acetylene can start to occur at below 300c, but whilst this reaction is also mildly exothermic, it is a pressure reducing reaction, as gaseous acetylene turns to liquid and then solid species

The empirical evidence shows that when decomposing Acetylene cylinders have been cooled back to ambient temperature but then have not received any subsequent cooling, the cylinders have bulged nearest to where decomposition is taking place but have not failed. This heating process would be clearly visible through TIC observation.

### 3) When to reduce the Hazard Zone

Cooling an Acetylene cylinder back to ambient temperature will allow the strength of the shell to be restored. Consequently it would be reasonable to say that the cylinder is in no immediate danger of failing. Every cylinder tested after one hour cooling was at ambient temperature neither did they show signs of re-heating after having been cooled back to ambient temperature.

The 200m hazard zone is only required if the cylinder is in danger of failing, if the cylinder shell is at ambient temperature it is in no immediate danger of failing provided that:-

- a) The cylinder is not reheated
- b) The cylinder is not disturbed
- c) Cooling continues for 24 hours

Consequently the hazard zone only needs to be big enough to prevent the cylinder becoming reheated or being disturbed and to allow cooling to continue. The zone could therefore be reduced to as little as 5 to 10m

### 4) Cooling of cylinders

The evidence of the database gave us confidence that our cooling methods were effective. Indeed the BAM research states that “only moderate” cooling is sufficient to stop the decomposition process.

Therefore we were able to reduce the Hazard Zone at a much earlier stage of the incident. It is this that has been the risk critical factor in mitigating the disruption.

The previous concern that decomposition may be taking place becomes almost irrelevant because the evidence shows that even if decomposition is taking place our methodology is sufficient to control the process and prevent cylinder failure.

It was previously believed that to cool a cylinder effectively, the whole of the cylinder needed to be visible. Again the evidence of the database gave us confidence that this was not the case.

In addition if a cylinder has not been engulfed in fire it is extremely unlikely that decomposition will have been initiated. At several incidents the cylinders have been monitored and allowed to air cool. It has not been necessary to water cool for 24 hours.

### 5) Mechanical shock

It had previously been believed that mechanical shock could initiate decomposition. It is now understood that it is **not** possible to initiate decomposition in an undamaged, unheated cylinder by mechanical shock.

Venting or moving a heated cylinder may feed decomposition, if it has started, but will not **initiate** decomposition.

## Actions

Following on from the conclusions drawn from the research collected and the empirical evidence gathered from the LFB Acetylene database the following actions were taken:-

### HMEPO Training

The LFB have over 6,000 operational Firefighters, the implications for training the entire work force in the improved procedures would have resulted in an unacceptable delay in implementing the improved procedures for dealing with Acetylene cylinders.

The LFB has 48 specialist Hazardous Material and Environmental Protection Officers (HMEPO). These officers were already on the pre-determined attendance (PDA) for cylinder incidents. Consequently the decision was taken to train the Brigade's HMEPOs in the following areas:-

- Initial Hazard Zone management
- In identifying Acetylene cylinders
- The BCGA Competent Person scheme
- How to deal with a cylinder involved with mechanical shock alone
- How and when to carry out a Wet Test
- The actions to take when a cylinder has passed a Wet Test
- The importance of early reduction of the Hazard Zone
- Subsequent cooling of the cylinder
- The QinetiQ Remotely Operated Vehicle (ROV) Service (see below)

This training was delivered in conjunction with BOC, who provided training input on the technical aspects of Acetylene and the CP procedure.

All other operational staff were advised that HMEPOs had received this specialist training and that Incident Commanders should liaise closely with the HMEPO when resolving Acetylene cylinder incidents.

These improved procedures have subsequently been incorporated into basic training for Trainee Firefighters and Officer Development input.

### ROV Service

To assist crews to resolve incidents a trial was undertaken of Remotely Operated Vehicles (ROV) within the LFB area.

The service was provided by QinetiQ a private company based in Farnborough Hampshire. They provided a 24/7 Blue light response service, with a view to attending Acetylene (or unknown) cylinder incidents anywhere in London within 3 hours.

The initial trial subsequently proved to be a success and a 2 year service has now been provided from November 2008.

QinetiQ provide three ROVs carried in one vehicle, the basis of this service is that the ROV's can be deployed to

- Identify the contents of a cylinder
- Provide information as to if the cylinder has been involved in a fire
- Identify if the cylinder is currently heated
- Carry out a wet test and observe the results

The ROVs can be deployed in areas where crews would otherwise be exposed to unacceptable risks. Furthermore the ROVs can remain deployed within the Hazard Zone to relay constant real time information to the Incident Commander.

Whilst it is anticipated that crews should be able to resolve 90% of incidents by conventional means there have been instances where the ROV service has been invaluable in the early resolution of incidents.

### Intervention and Blast Mitigation devices

Alongside these actions the LFB has also researched other intervention techniques such as cold cutting and trepanning to resolve cylinder incidents. In addition the LFB have liaised on trials of blast mitigation devices to contain the products of cylinder failure.

Tests carried during these trials provided some interesting outcomes. Acetylene cylinders were deliberately heated to cause failure to test a blast mitigation product.

Initially single burners were applied to a cylinder. After one hour the cylinder had absorbed the majority of the energy and the temperature was only at 45 degrees centigrade. When multiple burners were applied at a later test, the cylinder failed (in "Banana" mode) in less than 10 minutes.

This confirms the understanding that Acetylene cylinders are very efficient at absorbing heat as per their design. Furthermore when rapidly heated they fail in ductile mode. This concurs with the empirical evidence which suggests that the majority of Acetylene cylinders fail whilst the fire is in progress and rarely due to the effects of decomposition.

To date it has not been possible to identify a technique or any equipment that satisfies the requirements for deployment, reliability and safety at cylinder incidents. Consequently the LFB have been unable to recommend an operational trial of any of these techniques.

## Outcomes

The outcome of these actions has been very encouraging. Following on from the launch of the Safe Cylinder campaign in August 2007 the frequency of Acetylene cylinder incidents in London were reduced from an incident every 14 days to an incident every 42 days.

Although this has subsequently increased to an incident every 28 days this is not now as critical as it had been previously.

Prior to August 2007 the average length a Hazard Zone was in place at an Acetylene incident (and hence disruption was caused) was 19 hours, since the launch of the improved procedures this average has dropped to 2 hours 15 minutes.

Hours of disruption have been reduced from a peak of 589 hours (over 24 days) in 2004 to just 49 hours in 2008. (See Appendix 5)

Furthermore in 2005 there were 140 hours of disruption caused by incidents that turned out not to involve an Acetylene cylinder. In 2008 there was not a single instance of crews being unable to identify a cylinder.

There has not been a 200m Hazard Zone maintained for 24 hours at an incident since 22<sup>nd</sup> April 2007.

This was also the last time crews failed to identify the contents of a cylinder until the 24 hour cooling was completed.

## Summary

By August 2005 the disruption caused in London by Acetylene cylinder incidents was becoming more and more severe and was actually causing a risk to the public.

This disruption had only started in October 2003 when the LFB introduced revised operational procedures following the publication of the revised Fire Service manual.

The LFB undertook a program to review all aspects of procedures for dealing with Acetylene cylinder incidents.

Although a working group had been in existence for over 12 months, in November 2006 the LFB were instrumental in the formation of the National Stakeholder Group for Acetylene in fire.

In partnership with the NSG the LFB reviewed all existing research on Acetylene.

The LFB created a database of all cylinder incidents in London from 1<sup>st</sup> January 2004.

Following on from the outcomes of this research and new information in August 2007 the LFB undertook improvements in the operational response to Acetylene cylinder incidents.

Simultaneously a prevention campaign was undertaken to reduce the frequency of incidents.

The LFB were able to dramatically reduce the frequency and severity of incidents by more intelligently applying current and existing procedures.

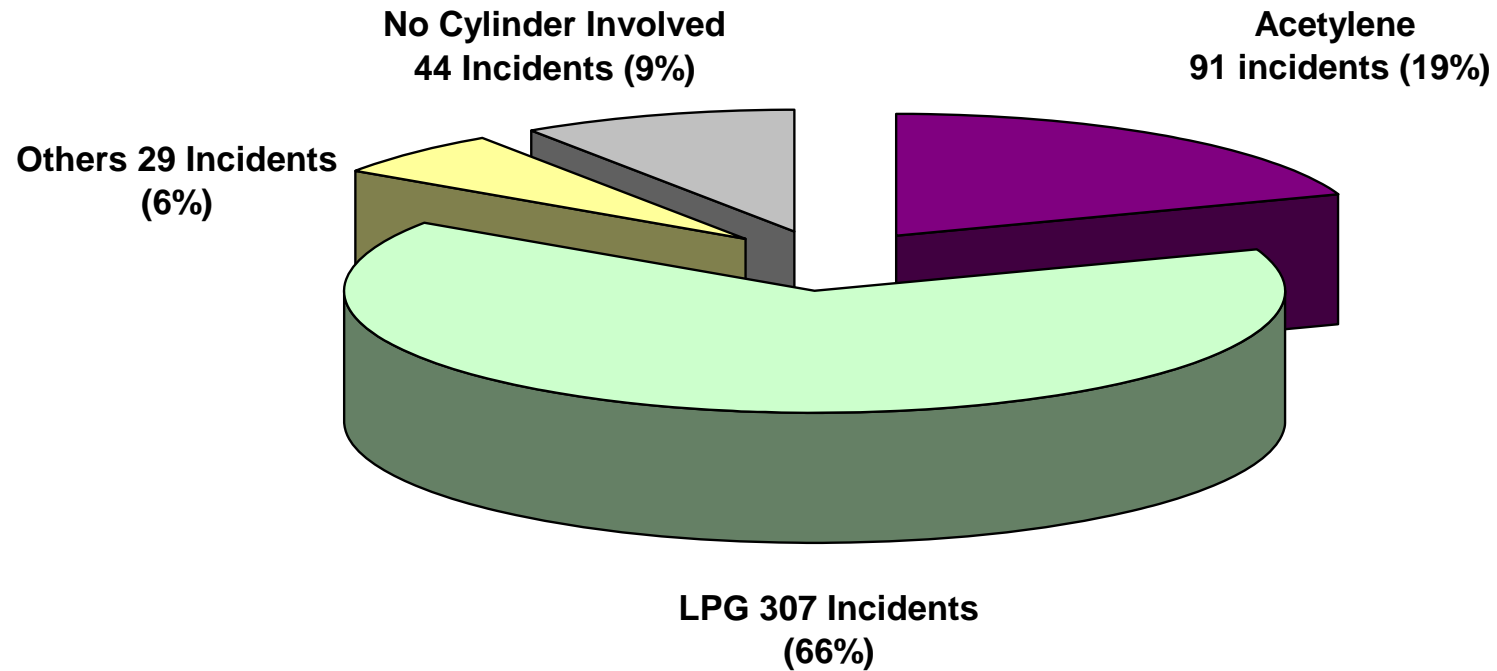
The following additional knowledge has been established:-

- 1) Mechanical shock alone can not start decomposition in an unheated, undamaged cylinder
- 2) Cooling for 1 hour will reduce the cylinder shell to ambient temperature
- 3) The whole of the cylinder does not need to be visible for cooling to be effective
- 4) Once a cylinder has been cooled back to ambient temperature there is no evidence to suggest that it will subsequently fail
- 5) If a cylinder has not been subjected to direct flame impingement, after cooling back to ambient temperature, 24 hour water cooling is not necessary.

Appendix 1

Chart showing all cylinder incidents in London 2004-2008 by contents (See page 12)

**London Fire Brigade  
471 Cylinder Incidents  
2004-2008**

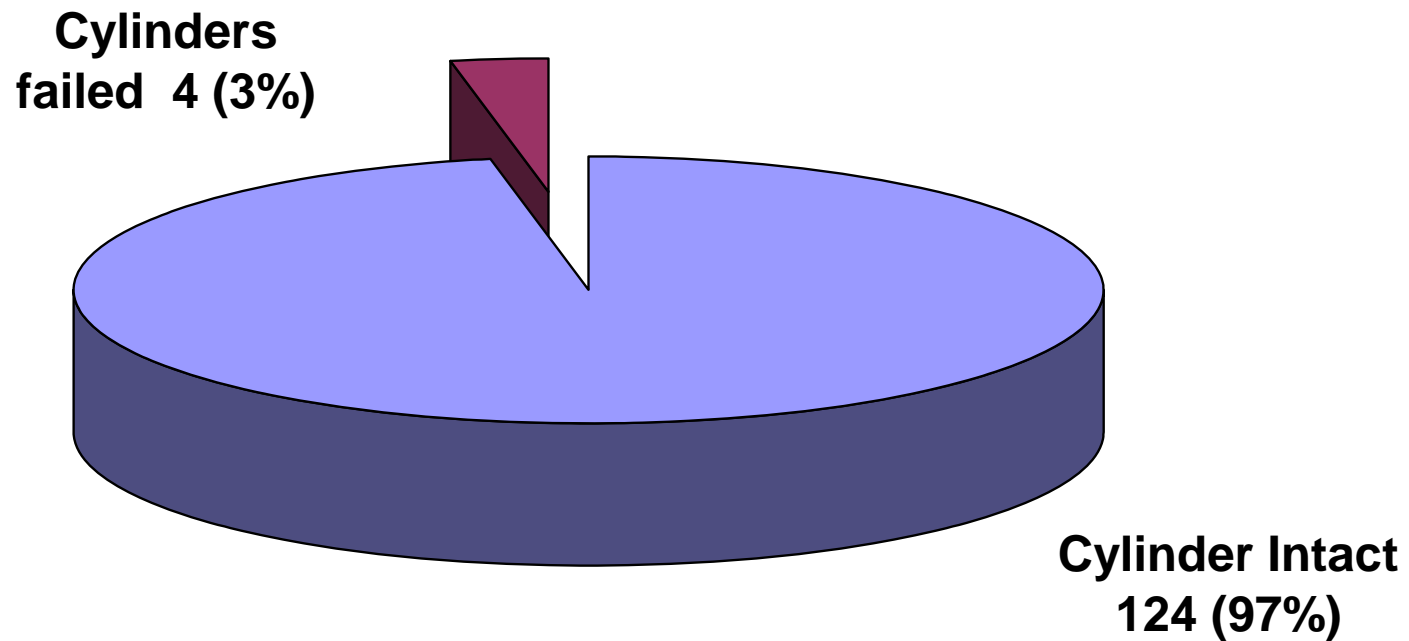


Appendix 2

Chart showing all Acetylene cylinder failures in London 2004-2008 (See page 12)

# DA Cylinder Failures

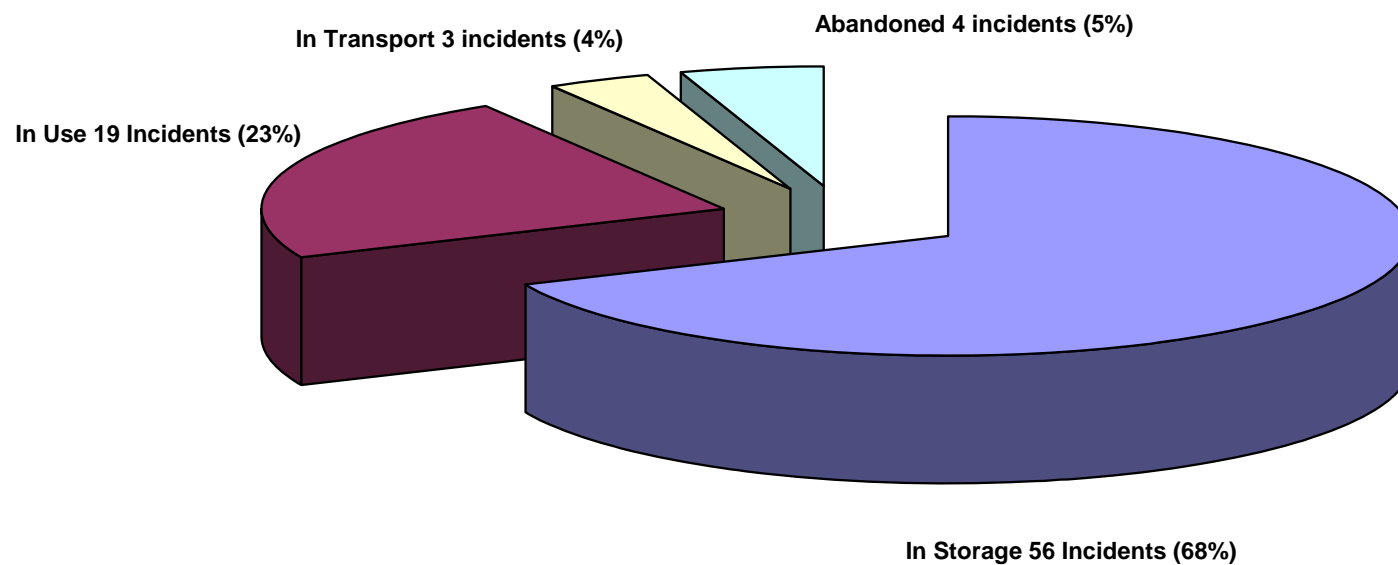
128 cylinders at 91 Incidents  
2004 to 2008



Appendix 3

Chart showing all Acetylene cylinder incidents in London 2004-2008 by status (See page 13)

## Status of Acetylene Cylinders at Incidents LFB 2004-2008

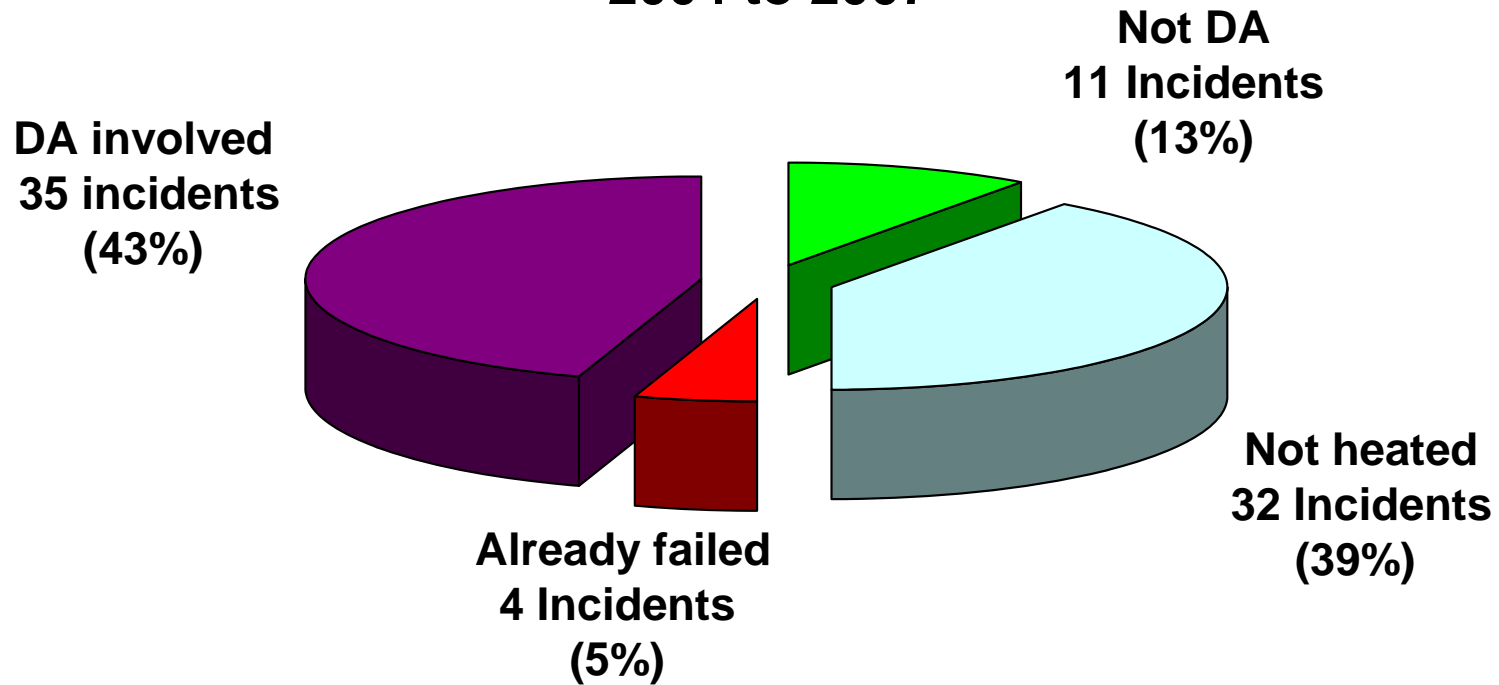


Appendix 4

Chart showing all Acetylene (DA) cylinder incidents in London 2004-2007 by outcome (See page 14)

# Incident Outcomes

82 Incidents  
2004 to 2007

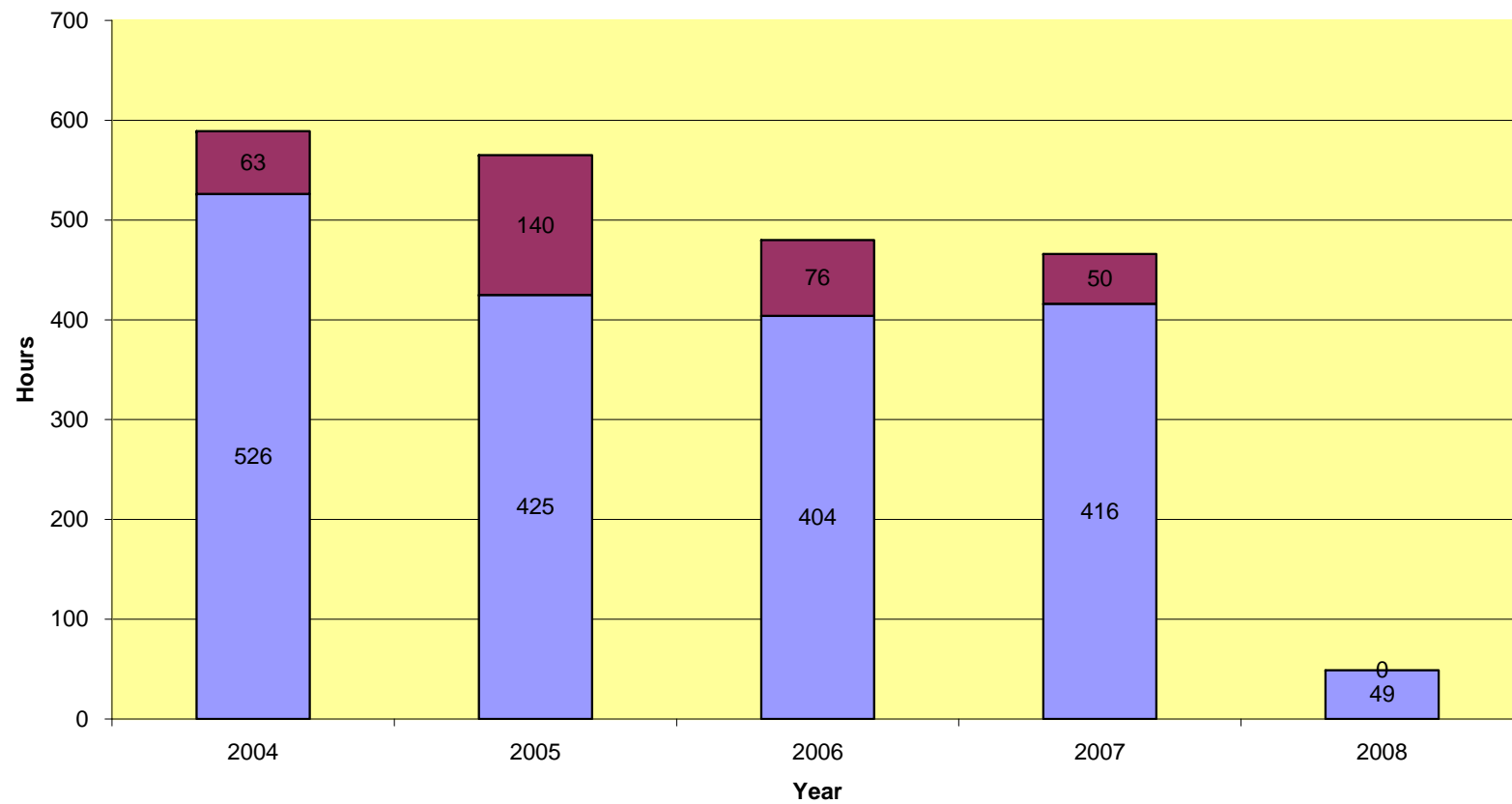


Appendix 5

Hour of Disruption caused by Acetylene (DA) incidents in London 2004-2008 (See page 21)

## Hours of Disruption 2004 -2008

DA incidents & as per DA incidents



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