Improved Calculation of Fire-Fighting Water-Flow Requirement – The Key To Strategic Management of Fire-Hydrant Provision

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Introduction

This paper summarises the key findings from research that aimed to both identify the circumstances that have led to the introduction of hydrant rationalisation schemes within the United Kingdom (UK) and investigate issues that have the potential to influence the strategic management of fire-hydrant provision.

Background

Fire brigades in the UK have a duty under the Fire Services Act 1947 to ensure the provision of an adequate supply of water for fire-fighting purposes. As the primary source of supply, fire hydrants are of great importance to fire-fighters but they have cost implications for fire authorities. Brigades have traditionally determined fire-hydrant provision according to the perceived fire risk. Prior to 1998 there was little national guidance available to provide commonality of approach in respect of fire-hydrant provision. Adoption of local policy probably contributed to over-provision of hydrants in some areas. Certainly, according to Catton (1988,p.30), most brigades believed that they were responsible for too many hydrants.

Impetus for hydrant rationalisation gained momentum in 1991, when political influence and commercial incentive earnestly encouraged water companies to meet stringent leakage reduction targets through the introduction of water-management systems. These included the provision of valves to control pressure and flow on key water mains within District Metered Areas (DMAs), so serving to limit the risk of pressure-induced damage and losses should leakage occur. From a fire brigade perspective water-management schemes have the potential to restrict the flow of fire-fighting water drawn from hydrants, especially those situated within the same DMA.

To assist in the process of assessing appropriate hydrant provision the Local Government Association (LGA), in partnership with the water industry group Water UK (WUK), published guidance in 1998 that suggested the ideal-minimum level of fire-fighting water supply required for various occupancy types. Her Majesty's Fire Service Inspectorate (2001,p.78) (HMFSI) cites the guidance as a method that brigades can adopt to determine the required fire-fighting water-flow requirement. The other methods recommended by HMFSI are calculation of the flow necessary to support an estimated number of jets, and use of a method developed by the Iowa State University, based upon the compartment volume.

Estimation of the fire-fighting water-flow requirement is essentially a matter of risk-assessment. Risk-assessment forms the central theme of future fire brigade emergency cover provision, the system that is currently being developed by the Fire Research And Development Group (FRDG). The group's objective is to create a system that determines emergency-response provisions that are suitable for realistic worst case-planning scenarios. (Anon 1999). Their work does not currently make specific reference to the calculation of fire-fighting water-flow requirement.

Failure to secure water supplies, sufficient to sustain an effective fire-fighting attack, has the potential to create serious difficulties for fire brigades. Water shortage can prevent the implementation of effective fire-fighting tactics, increase the risk of substantial fire losses and draw into question the adequate discharge of a brigade's legal duty. Whilst Everton (1997) concludes that the judiciary presently seem unwilling to support actions brought against fire authorities that fail to secure, or effectively use, fire-fighting water supplies, the possibility of a future legal challenge, in an increasingly litigious society, cannot be ignored.

Logically, the determination of an adequate fire-fighting water supply relies upon meaningful assessment of the flow rate required to meet the worst-case planning scenario. Systems currently recommended for determining water supply requirement in the UK do not take into account the individual peculiarities of risk premises. An acclaimed methodology, used by the North American Insurance Services Office (1974) (ISO), does take such issues into account. This system has not previously been considered for use in the UK.

Research Objectives And Methodology

The objectives of the research were to:-

- Ascertain the degree to which UK fire brigades are using the LGA/WUK guidance to assist in the management of hydrant provision;

- Ascertain brigades' confidence in, and opinion of, risk-based assessment of fire-fighting water-flow requirement;

- Investigate the potential for improving the calculation of UK fire-fighting water-flow requirement through use of the ISO system.

To assist evaluation of the first two objectives a questionnaire was circulated to all 58 UK fire brigades. A total of 54 brigades responded to the survey. Semi-structured telephone interviews were conducted to clarify information from recipients where required. Investigating the potential for improved calculations of fire-fighting water-flow requirement necessitated comparison between output generated from the systems currently recommended for use in the UK and that predicted by the ISO methodology. Premise and fire-fighting data from 70 fire-incident case-studies provided realistic information for that purpose.

In order to provide recommendations capable of assisting the strategic management of fire-hydrant provision the research also needed to establish the factors that affect fire-fighting water-flow requirement and water-supply provision.

Issues Relevant To Fire-Fighting Water-Flow Requirement

Fire-fighting water-flow requirement is heavily influenced by the physical properties of the risk premise. Other issues, however, also have to be considered. (Rimen 1990) notes that the use of high-pressure hose-reels and modern fire-fighting techniques has reduced water usage within the last 50 years. The choice of an appropriate fire-fighting tactic, which Salka (2001) points out can be either offensive or defensive depending upon whether the fire can be tackled and extinguished or simply surrounded and contained, is recognised by Särdqvist (1996,p.14) as being reliant upon the availability of adequate resources, including water supply.

The speed at which a fire develops determines the resources required to extinguish it. For Peterson (1999) there is no doubt that modern day materials are responsible for the increased speed of fire development, which he observes often reaches the point of flashover within five minutes of ignition. Research in the USA led him to conclude that fire departments have only a 50% chance of preventing total compartment or building loss once the fire size reaches $86m^2$. Sprinklers are widely reported, by Davis (2000,p.27), Law (1998) and Särdqvist (1998,p.52) to substantially reduce both fire losses and the quantity of fire-fighting water needed to control an incident.

The benefits of early suppression are acknowledged throughout much of the USA by the acceptance that the fire-fighting water requirement can be reduced by at least 25% where buildings are fitted with sprinkler systems. The advantages are considered to be so profound that municipal planners in Plano, Texas require all buildings, having floor areas over $558m^2$, to be provided with sprinkler protection.

The need for extended use of sprinkler protection in the UK, especially in large commercial buildings, has long been vocalised by prominent fire service figures: Williamson (1994); Eastwood (1996); Halstead (1998); Dickerson (1998) and Shiel (1998). Despite this Pigot (2001) recognises that, 'the UK installs barely one-tenth the number of sprinklers per head of the population, as does the USA'.

Surprisingly, evidence from the author's research suggests that only 34% of UK fire brigades seem willing to formally acknowledge the benefits of sprinkler protection when assessing the fire-fighting water-flow requirement. This view is difficult to reconcile but might be explained by the fact that specialist staff, rather than senior managers, predominately provided the information upon which the statistic is founded. Conjecture that the view is not that of brigade policy makers infers that water supply and fire protection strategies are not homogeneously considered or communicated within most brigades.

Issues Relevant To Fire-Fighting Water-flow Provision

The amount of water used during a fire-fighting operation is limited by the flow available, this is usually the quantity that can be provided from the public distribution system. In the UK this could, theoretically, be as little as 9 litres per minute, well below the level required to supply an effective fire-fighting jet but, nevertheless, within the statutory minimum that water companies must provide to domestic consumers. The assumption that even this rate of flow will always be available is questionable given the assertion made by Standing (1999,p.43) that climatic change provides the potential for disruption to water-resource systems. An issue that, he suggests, is not adequately considered within brigades' strategic planning activities.

In the USA, water distribution systems are designed to provide satisfactory fire-fighting water supply provision. Notwithstanding that, Cozad (1981,p.185) emphasises that care must be taken to ensure that hydrants are not located on small-diameter or dead-end mains that are incapable of providing useful output. Taking Cozad's predictions for friction loss into account, it is possible that UK hydrants situated on dead-end mains that exceed 118m in length, could provide such poor hydraulic efficiency as to be incapable of contributing effectively to the fire-flow requirement. This should be a matter of fundamental importance to the strategic management of hydrant provision but is, in reality, considered by less than one third of UK fire brigades when hydrant installation is authorised.

A hydrant's operational value must be judged not only by its position but also by the flow characteristic of the supply drawn from it. The LGA/WUK guidance (1998,p.9) suggests that water companies' knowledge and expertise should ensure that brigades are provided with the means to assess and predict the extent to which the water distribution system can provide an adequate fire-fighting water supply. Similarly HMFSI (2001,p.35) clearly expects brigades' to determine availability of water supplies from the data provided by water companies. With only 21% of brigades able to verify that they have complete confidence in the accuracy of hydrant flow data made available to them, and with 52% of brigades stating that they try to establish flow rates for themselves from previous records or independent tests, it is apparent that the LGA/WUK aspirations and HMFSI expectations are not being realised.

Whilst, then, many factors have the potential to influence both the quantity of fire-fighting water required and the efficiency of its discharge from the distribution system, determination of an effective means for the calculation of fire-fighting water-flow requirement remains unresolved.

Effective Calculation Of Fire-Fighting Water-flow Requirement

The publication of the LGA/WUK guidance in 1998 was designed to assist the determination of adequate water supply and hydrant provision. Statistical evidence confirms that 73% of brigades in England and Wales have adopted the guidance. Survey results suggest that a relationship could exist between use of the guidance, introduction of reduction strategies and the achievement of hydrant rationalisation.

Whilst 68% of brigades seem confident that they can adequately assess fire-fighting water-flow requirement, it is apparent that 76% do not calculate, through use of any structured means, the supply required to sustain effective fire-fighting operations, even though 94% of brigades questioned support the view that use of structured risk-assessment methodology would assist determination of necessary supplies.

Reluctance on the part of brigades to embrace the fire-fighting water-flow calculation methodology recommended by HMFSI raises important questions regarding the suitability and efficiency of those techniques. Comparative examination, through fire-incident case study analysis, suggests that all of the existing systems recommended for use have limitations that restrict the degree of confidence that can be placed in the results attained from them.

The LGA/WUK guidance was designed to suggest the ideal-minimum fire-fighting water supply required for generic occupancies rather than actual risk premises. This makes it very inflexible for use in assessing water-flow requirement in buildings of different sizes and complexity. The guidance was not designed to adequately predict the water supply needed to tackle serious fires. Its aim was simply to suggest the flow rates that might be required by the first crews attending an incident.

The Iowa "building volume" method is relatively simple and quick to use but produces excessive flow rate predictions for large premises and, in comparison with the other systems, it predicts very low flow rates for small premises.

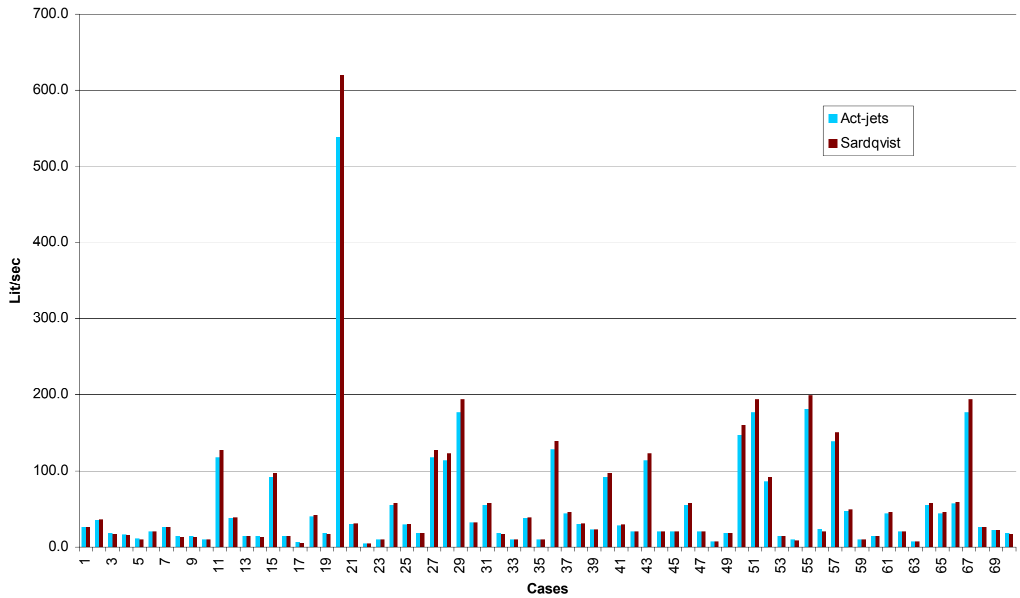
Calculating the flow required to supply an estimated number of jets appears to offer a pragmatic solution but few, if any, UK fire engines are equipped with meters to record the accumulative fire-fighting water-flow used at an incident. Therefore, the calculation of the flow required to tackle an outbreak of fire within a given premise must rely upon the experience of the assessor and the subjective appraisal of the occupancy risk and the fire-fighting tactic that might be deployed. With so many variables results are inconsistent and of little practical value.

Difficult though these limitations make it, fulfilment of the author's research objective required analytical comparison of each system against the results produced from the USA's Insurance Services Office methodology. This could not be achieved in respect of the flow rates required for an estimated number of jets unless a more consistent method of assessment could be established. A solution was found to be available within research work previously undertaken by a Swedish fire officer.

Alternative Calculation Of Estimated Jets Flow

Särdqvist (1996,p.14) identified that the success of an offensive fire-fighting operation is reliant upon the heat absorption capacity of the extinguishing media that is available, exceeding the heat release rate of the fire. Whilst scientific calculation of this is not possible on the fire-ground, Särdqvist (1998,p.48) realised that data from empirical research could be used to provide explanation of the relationship that existed between effective fire-fighting water-flow rate application and the fire area. Using that logic, data from the fire-incident case studies were used to establish the relationship between the fire area and the flow required by the 'actual-jets' used at the case-study incidents. The resultant equation, when used to project the fire-fighting water-flow requirement for the entire areas of the case-study premises, produced results that correlated significantly with those predicted by the application of Särdqvist's equation. (See Figure 1).

Figure 1: Fire Flow Comparison – Särdqvist and Actual Jets Equations



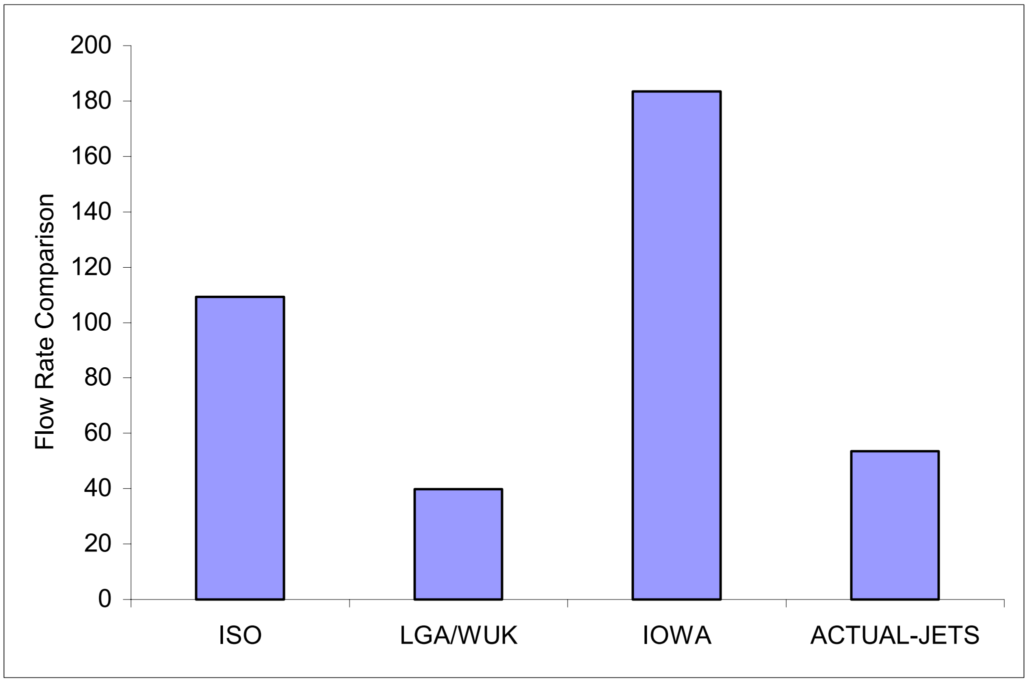
Analysis of the research data confirmed that the 'actual-jets' equation provides a tangible alternative method of calculating the fire-flow requirement for an estimated number of jets working within a defined fire area. Use of actual data also provides a degree of assurance that the projections reflect the needs of current fire-fighting tactical response. A limitation, however, is that the system cannot take into account extremes in the risk of a premise or the compensatory features provided, such as sprinklers.

The North American Insurance Services Office Methodology

The fire-fighting water-flow calculation systems recommended for use in the UK differ substantially from the ISO system that is widely used in the USA. Unlike its UK counterparts it is comprehensively formula-driven, taking into account the specific details of individual risk premises, floor area, construction type, occupancy risk, fire exposure hazards and protection afforded by sprinkler systems.

When compared with the UK systems (refer Figure 2) it was found that the ISO system projects water supply requirement values that are virtually three times those of the LGA/WUK guidance and almost twice those produced by the 'actual-jets' methodology (the system deemed by this research to provide the most credible projection of realistic assessment). The ISO values were, however, only 60% of those predicted by the Iowa State University formula. Analysis of the fire risk and fire-fighting techniques deployed in Plano, Texas, suggests that ISO predictions cater for the larger diameter hose, often used by North American fire-fighters, and the greater fire-fighting flow rates needed to control incidents in the timber-framed buildings that predominate in the USA.

Figure 2: Comparison Between ISO and UK Methodologies For Calculation of Fire-Fighting Water-flow Requirement



The ISO system is highly structured, relying heavily upon the input of premise and occupancy data by trained insurance assessors. Use of an ISO-type system in the UK would require provision of training and the commitment of substantial duty time if the input of information were to be undertaken by fire service personnel. There would also be a need to compile statistics to assist with the accurate assessment of UK occupancy risk and exposure hazards.

The research suggests that the ISO system would require substantial amendment before use on this side of the Atlantic. This would require the permission and possibly the assistance of the Insurance Services Office. Given the complexity of the procedure used, it is unlikely that it would provide a cost effective system for general use in the UK.

Conclusions

Brigades in the UK must be able to realistically assess fire-fighting water-flow requirement if they are to comply with their legal duty to secure the provision of adequate fire-fighting water supply and, at the same time, successfully implement an efficient strategy for the management of fire-hydrant provision.

The existing systems, offered for use by HMFSI, are not capable of satisfying that need. Predictions from those systems are either incompatible with known fire-ground requirements, or are so subjective in nature as to be of no practical use. An alternative system, which is widely used in the USA, is complex to administer and does not, in its present form, predict flow-rates that are likely to be required at UK risk premises.

An improved system for the calculation of flow-rates required by fire-fighting jets has been identified by this research. It produces realistic fire-flow-rate predictions for worst-case planning scenarios through interpretation of risk-area dimensions. The technique, which could be administered easily by competent operational fire service personnel, is flexible enough to be able to quickly generate useful data for the majority of risk premises routinely encountered in the UK.

Recommendations

There is much that can be done to improve the strategic management of fire-hydrant provision. The research concludes that the following recommendations need to be considered to assist the process. There should be:

- Increased utilisation of sprinkler protection in buildings over $558m^2$, to reduce the need for extensive fire brigade intervention when fire does occur in such premises;
- Acknowledgment within HMFSI publications that the 'actual-jets' fire-fighting water-flow calculation equation provides an alternative means of determining water supply requirement.
- Closer co-operation between brigades and the water industry to assist fire brigade managerial decision making processes relating to hydrant provision;
- Better co-ordination of fire safety and fire-hydrant policies within brigades;
- Acknowledgement within brigades' strategic water planning procedures that periods of drought or peak demand could adversely influence availability of fire-fighting water supply;
- Acknowledgement by HMFSI that there is risk of diminished hydraulic performance from hydrants situated on small-diameter and dead-end mains;
- Inclusion of fire-fighting water-flow assessment methodology within the developing FRDG emergency cover model;
- Consideration given to the provision of flow meters on pumping appliances, in order to improve availability of operational flow-rate data.

Final Thought

John. F. Kennedy once said, 'Anyone who can solve the problem of water will be worthy of two Nobel Prizes, one for peace and one for science'. Success in the strategic management of fire-hydrant provision may never achieve scientific acclaim but it would assist in providing peace of mind to future fire service leaders.

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