John Ivison & Associates Ltd.

6251 Thomson Terrace
Maple Bay, Duncan, BC V9L 5R1 Canada
+1 778 898 1909
JohnIvison@JohnIvison.com

Fire Performance Based Design
Building Code Analysis
Heritage Rehabilitation Programmes
Forensic Investigation

John Ivison P Eng. CP FSFPE

FPE Bulletin 3: Water Supplies for Fire fighting

Figure 1: Typical fire pump arrangement taking suction from reservoirs.

Introduction:

Much confusion exists as to what is an acceptable water supply for firefighting. Historically, water supply was tied to the 'fire risk'.

Fire risk can be defined as the product of the frequency of a fire and the consequences resulting therefrom. This requires integration over the range of possible fires and the resulting impacts.

The fire risk may often be confined to a single building. However, on the municipal scale of risks, all other risks such as transportation, outside storage and electrical/gas distribution stations need to be taken into account in assessing the need for water and logistical resources to fight fires/facilitate rescue. Although these are not specifically included in the fire flow calculations it does illustrate why the municipal demand has to account for risks on a larger scale than the typical building. Consequently, the definition of a water supply in these situations is typically not confined to a building but rather reflects the 'risk spectrum' in the municipality.

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Figure 2: Risks- such as this exhibition- fall outside the definition of a building.

The difference and scale of fire fighting on the municipal scale has led to the myth that methods of determining fire fighting water supplies are overly conservative in comparison to individual building needs. In fact, the reality is that while the focus of those who design buildings has to be on the building they are considering, we cannot design water supply infrastructure based on the assumption that fire will not spread beyond the building. In fact, the performance over a municipality reflects the inventory of existing buildings and not just the new structures brought on stream over time.

Risk at the municipal level is influenced by the prevailing risk culture. It is generally recognised that up to 95% of risks are behaviourally influenced. Whereas the building code sets out risk as an occupancy and construction issue the uncertainty at the municipal level whether we like it or not has led to a conservative approach to expected response to fires largely based on experience and feedback from real fires. As uncertainty arises largely as an outcome of human failures there is a limit to prevention and limits through effective design.

Also as you can see from Figure 3, the actual fire risk may increase as buildings age. Building risk may increase as a result of additions and other changes which may challenge assumptions made at the time the building was new. As the majority of buildings are existing the fire flow for new buildings may be significantly less than the block risk that arises from a mix of relatively new and older structures.

For this reason, both in the US and Canada, there are recognised municipal standards that have been developed to enable a robust infrastructure to be designed to respond to the scale of fires anticipated. The general approach used varies in terms of the scale and character of the place as well as the emergency response organisation. Traditionally the level of public fire protection is graded on a scale (in Canada 1-10) and this is typically reviewed and revised as the risk changes over time.

This means that fire risk for a single building or complex is one thing, municipal risk is something entirely different. Also, the larger fires taken on a macro basis need only meet a residual water pressure of around 138 Kpa (20 psig) reflecting the fact that flows are normally boosted by fire apparatus.

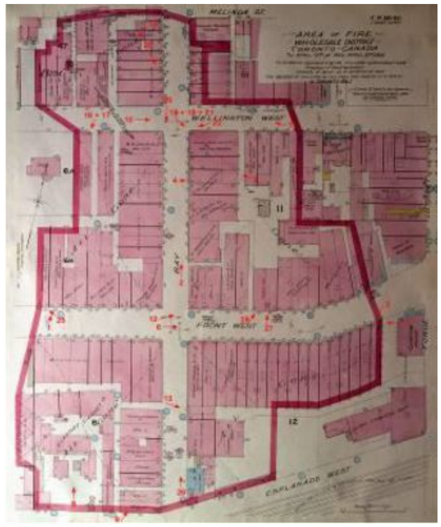

Figure 3: typical block risk diagram used to develop municipal risk profile: Courtesy Fire Underwriters' Survey

Experience with assessing fire risk is essential if the assessment of water supply needs is to be realistic.

Figure 4: remote recreational facility

Typical scenarios where specialist assessments are often undertaken to determine fire flow and design water supplies include:

- Townsites requiring improvements in the water supplies for fire protection (for instance historic towns, logging/construction camps).
- Expansion of town or city supplies into new subdivisions/infill development- often for housing (sometimes with limited capacity or dead-end mains)

Figure 5: Expansion of this subdivision in West Vancouver in the 1980s was sprinklered (to NFPA 13D).

- Water supplies for larger scale industrial sites/unusual structures

Figure 6: Listed pier structure with poor fire service access.

All of the above require an holistic assessment of the fire potential. In cases where all the buildings are protected by automatic sprinklers other factors come into play. Most standards of public protection take account of reductions in the fire flow arising from sprinkler protection afforded to the buildings. In the municipal context, relaxations in the extent of protection (such as NFPA 13R) provided as economic incentives to encourage the use of sprinklers need to be taken into consideration. For instance, if roof spaces and other areas are not sprinklered then there is a degree of risk associated with fires entering those areas. This has been borne out in recent fires. Nevertheless, if single dwellings are involved then credits (around 50%) may be possible provided significant other risks are not present.

Figure 7: Fully involved fire in a building under construction.

In the case of suburban areas, the use of sprinklers has been used to mitigate risk in cases where fire response is extended due to urban sprawl. In these cases, relaxations in both building code provisions as well as access and hydrant spacing have been utilised. Typically, smaller mains might be permitted as the result of lower fire flows. These flows however, are still significant relative to sprinkler demand and sprinkler pipe sizing.

Where increasing density utilises 4-6 storey wood frame construction fire flows may rise, and risk in construction may need to be addressed. Historically however, this risk has been accepted based on the benefits of wood frame in terms of cost effective residential construction. The scale of recent 4-6 storey construction projects have brought this somewhat into question.

Where anomalies occur in an area that is predominantly of lower fire risk it is often the practice to mitigate the risk by protecting the property to a higher standard. These are regarded as risk anomalies. For instance, this may occur in areas where supermarkets and other risks have been introduced into largely residential areas. For these situations, the FUS or ISO requirements are not typically fully applied unless other factors are at play.

In the case of industrial sites, more reliability is typically required due to the industrial processes and insurer requirements based on the exposure to loss. Design of water supplies in these situations would involve at least two supplies and often tertiary and quaternary supplies.

Figure 8: Water supplies in this instance were split to improve reliability and facilitate maintenance

Analysis of these situations is beyond the scope of this paper but more information can be obtained by calling our office. In these situations, more reliability is required than mandated by the National Building Code of Canada (NBCC).

Some provisions of the current code go against historic principles that correlated reliability requirements with fire risk. For instance, there is no credit under any FUS or ISO standard arising from the use of standpipe and hose systems. This is in part as a result of the fact that fire flow standards reflect the reactive nature of fire service operations and often the lack of internal fire suppression.

Now that we have provided this overview we should now look at what is mandated under the NBCC.

NBCC requirements:

3.2.5.7 of the NBCC requires an adequate water supply for every building. Sentence 3.2.5.7(1) references Appendix A which attempts to clarify what is meant by an adequate water supply. The reference under previous editions of the NBCC to the Fire Underwriters' Survey has been removed and the US standard only is referenced- as a useful document- in the Appendix.

Sentence (2) relaxes this situation for buildings sprinklered in accordance with 3.2.5.12 or buildings with a standpipe system complying with 3.2.5.7 (1). The FUS and ISO standards address risk arising from individual sprinklered buildings, exposures and other factors most importantly construction, area, occupancy as well as the number of storeys. The order of magnitude of fire flows using these methods significantly exceed the water supply needs of sprinkler systems. As such they again reflect the magnitude of risk in the context of failure to control the fire.

In the case of sprinklered buildings, risk is not entirely eliminated- there is a finite probability of failure- and external risks and other factors can intervene to create fires that go beyond the scale of internal fires. No credit is typically provided for a standpipe system as such systems are reactive and it may be difficult to quantify the difference between the use of hydrants and standpipes on the fire.

Figure 9: Sprinkler system manifold for a large facility.

Appendix A of the NBCC references many natural and man-made sources of water. If natural sources feed automatic sprinkler systems and private hydrants, special consideration is required to ensure that fish are protected and that other matter from the natural sources (weeds and algae for instance) do not enter the system, blocking nozzles or fire apparatus. Reference standards such as NFPA 20 for fire pumps discuss strainers and suction arrangements to minimise this risk. Salt water pumping systems such as those used on piers and wharves or coastal mills are subject to corrosion and contamination from fish, vegetation as well as silting which can wear out pump seals. Consequently, the design of such systems is often focussed on minimising emergency starting of these pumps in preference to pumps using other- such as potable-supplies.

A similar problem can be experience with reservoirs, suction tanks and ponds which become subject to growth and nurturing of aquatic species. This is reduced if the systems are designed to prevent stagnant water by turn over of the contents. This is relatively easy to achieve with tanks and reservoirs. In the case of rivers and other natural sources special consideration is required. Automatic flushing of the suction arrangement by back-flushing with water can prevent ingress of fish and other matter.

The starting sequence of multiple supplies using pumps is important to ensure inadvertent starting of pumps. In particular where a combination of municipal supplies with private supplies is available, it is typical to run the mains (looped or tree formation) on potable water to minimise potential contamination by other supplies from private or natural sources. To prevent inadvertent starting of pumps the mains are usually kept at an artificially high pressure- through jockey or service pumps- so that, when sprinklers discharge, there is a rapid drop in pressure to enable pumps starting at a pressure reasonably below the maintained pressure on the system.

The reliability of size of water supplies becomes a concern where factors affect the fire risk. For instance, if there is no fire department then additional capacity is advisable depending on the capability of any on-site resources. Also, the choice of private self-draining standpipes over hydrants may be suitable if the fire department has limited capability/training with large hoses.

Figure 10: fire Service training using ground monitor

Figure 11: Lack of sprinklers in one area led to this conflagration/total loss of a fully sprinklered building.

In situations with multiple supplies, fire flow is less of a concern as dependence may be as much on private supplies as on the municipal supplies. It is noted that if a supply from the authority or private water supplier needs to be boosted then it is generally regarded as a ‘poor’ water supply although adequate for certain situations where the risk magnitude is acceptable. This usually relies on some capability of the supply to meet sprinkler demand alone without hose demand included.

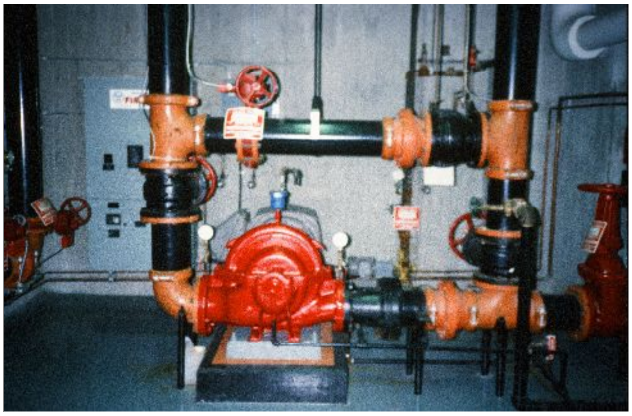

Figure 12: Booster pump (electric drive)

The NBCC Appendix A indicates that consideration should be given to ensure that water sources are accessible to fire department equipment. This is typically only necessary where fire departments take suction from these supplies as their source of water. This is typically not required when fire protection is automatic from private sources and the supply forms part of an integrated fire protection/fire fighting strategy. However, where combination supplies are utilised it is important to consider the role of the fire service, compatibility of private equipment (such as hydrants) with fire department appliances and equipment. For certain structures, fire service access may be limited to such an extent (for instance on piers served by railways with no roadways per se) that the fire strategy must compensate in terms of system design and reliability.

The NBCC references the duration of supplies at 30 minutes. This may be acceptable for low to moderate risks, using the referenced criteria. For private supplies, one has to consider the degree of reliance on the supply, available fire service or on-site fire fighting resources and potential for depletion of the supply. The minimum private supply- with no secondary supply- will typically have to consider hose and sprinkler use for at least 2 hours except for small isolated risks. This is less of a concern where the fire service has other supplies to supplement the on-site needs. In certain instances, there may be significant external risks which are not insured in the same risk market as buildings. In this instance, some consideration has to be given for reasonable fire fighting in these situations. In certain cases, some provisions may be a condition of insurance.

Figure 13: significant external risk: unprotected log storage (covered by a different insurer)

The referenced standards in the NBCC Appendix represent widely different approaches to public fire protection. Curiously the main referenced standard in Canada- Fire Underwriters' Survey is not referenced although it is commonly used in most towns and cities in Canada. It should be noted that NFPA 1142 is a rural fire fighting standard is used mostly in areas which lack conventional infrastructure. Reliance in these situations is often on suction supplies- particularly where conventional water distribution systems are not available. In these circumstances, unusual risks introduced may require special consideration due to the impact on the existing fire service resources.

Summary

In the scale of risks at the municipal level, the sole risk is not buildings. The assessment of fire risks in towns and cities have evolved holistic standards of protection which reflect the scale of risks and the need to address failures over a wider area as well as changes in the magnitude of risk. This approach is reflected in public fire protection standards in the US, Canada and elsewhere although the UK has vastly different requirements.

While there have been improvements in the fire performance of building materials in recent years, increased use and density of wood in new structures has to be considered in the spectrum of fire risks. However, the mandating of sprinklers as a general strategy to mitigate risk suggest that in urban centres, the magnitude of fire service resources can be moderated to a substantial degree by the concept of protected buildings.

Even with the mitigation of fire risks in individual buildings the context of these risks in the urban environment still has to be considered.

The design of water supplies for public fire protection is a well-established sector of engineering. However, when public supplies are insufficient in capacity, flow or duration then special consideration is required. For single structures, it is reasonable to assume that fire flow should be sufficient for sprinklers and hose streams. However, where multiple or complex structures exist or where the magnitude of the risk escalates due to age, construction type, lack of adequate fire service response, financial impact of loss over a large area etc. then special consideration is typically required.

Figure 14: Project meeting to discuss fire protection needs of a facility.

The issue of water supply and sprinkler reliability becomes a key issue particularly in certain cultural situations (historic sites) or unusual facilities such as large manufacturing plants with relatively high potential losses.

As the magnitude of risk is best addressed retrospectively, by the analysis of failures leading to fires, any focus of individual buildings as the ‘fire risk’ can be problematic; fire department resources and infrastructure cannot be designed on the basis of buildings alone.

Conflagrations have occurred periodically in history and fire and building codes as well as public fire protection have developed in response to fire losses individually and collectively when fires cross boundaries and develop out of control.

As the risk evolves over time, any mandating of water supply should reference available standards of public fire protection that take into account the changing demographic of risk.

Prepared By:

John Ivison

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