FIRE FIGHTING INNOVATIONS AND TECHNOLOGY- HOW WE CAN LEVERAGE THE NEW TECHNOLOGY TO IMPROVE THE EFFICIENCY OF THE FIRE FIGHTING SERVICE

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ABSTRACT

Public water supply systems are usually designed not only to provide sufficient water for domestic, commercial and industrial demands, but also to provide the water that may be needed to fight fires. Although the actual amount of water used in a year for fire fighting is relatively small, the rate of use is large. In many cases the potable demand is not critical and the supply for fire fighting purposes will generally determine the pipe sizes required for a water supply network.

Provision of the fire fighting requirement comes with a noticeable cost to every water utility and there is much anecdotal evidence indicating that 30% of the capital cost of water supply infrastructure is attributed to the provision of fire fighting capability. For Auckland City, that equates to approximately $900 million compared to total annual insured fire losses of approximately $120 million. A recent study undertaken by the National Research Council Canada (NRCC) has concluded that it was more cost effective to provide a tanker supply for fire fighting rather than increasing the size of the water reticulation system (Davis, 2000).

In New Zealand, the flow rate and quantity of fire fighting water is determined by a Code of Practice (CoP) issued by the New Zealand Fire Service (SNZ PAS 4509: 2008). Advanced fire fighting techniques and technology is being researched in different parts of the world and some of these techniques, such as the use of Compressed Air Foam (CAF), are reporting a 35%-50 % reduction in water usage. This could potentially lead to the design of "slimmer" water networks and more efficient use of available water resources in addition to a substantial reduction in infrastructure costs.

This paper will try to assist utilities in developing a better understanding of the fire fighting operations, fire fighting water requirements and the potential advances in fire fighting technology and the impact of these advanced technologies on the utilities' day-to-day management of their systems. The paper will discuss available methods for estimating fire fighting requirements and their association with the current fire fighting techniques, which could be used for further discussions with the New Zealand Fire Service (NZFS).

KEYWORDS

Vigiles, Tactics, NZFSC, Brigade, Tactics, CoP, CAF,TIC, HPD

1 INTRODUCTION

1.1 HISTORY OF FIRE FIGHTING IN NEW ZEALAND

In 6 A.D. after a disastrous fire in Rome, Emperor Caesar Augustus established the first organised fire brigade known as the Vigiles. The Corp of Vigiles consisted of ex-slaves who were trained in firefighting and served as watchmen of the city during the night. Firefighters used hooks, pick-axes, ladders and ropes as equipment. They also brought their own water to the fire using buckets. Fire codes were developed and enforced and a 4% tax was levied on the sale of slaves to pay for the Corp of Vigiles. The modern day fire service is a direct result of the Vigiles.

Like many of the world's fire brigades, the early history of the New Zealand Fire Service is marked by the development of insurance companies. Specifically, during the period between 1840-1860 fire insurance companies imported manually operated water pumps that were used to fight fires on the premises of companies they insured.

The significant cost of privately resourcing New Zealand's firefighting measures led insurance companies to apply pressure on local and central government for the public responsibility of fire management.

In 1854, the first New Zealand volunteer fire brigade was formed in Auckland. With nothing but buckets to start with, the brigade soon upgraded to manual pumps after these were provided by the Auckland City Council and insurance companies.

In 1949 however, as a partial response to the disastrous Ballyantyne's Fire in Christchurch of 1947, the Fire Services Act established the Regional based Fire Service Council with Chief Fire Officer, Secretary and officials. This was superseded in 1975 with the passing of the Fire Services Act. The Act established the New Zealand Fire Service Commission, charged with the restructuring of the Fire Service from under local authority management into a service with centralised financial and strategic control.

On 1 April 1976, all fire authorities were dissolved and the Commission was vested with full responsibility for the Fire Service throughout New Zealand.

In more recent years, the function of the New Zealand Fire Service Commission (NZFSC) has been refined through the introduction of the Fire Services Amendment Act in 1990. This Act split the Commission into three part-time commissioners, and together with changes in area and regional structures introduced over the course of the 1990s, let to a tumultuous decade.

The NZFS is funded by the fire service levy. Section 48 of the Fire Service Act 1975 requires insurance companies, insurance brokers, and others to collect a levy on all contracts of fire insurance, and to remit this to the NZFS Commission. The levy rate is reviewed annually by the Minister of Internal Affairs, and the levy is payable on all insurance contracts covering New Zealand property against loss from fire.

The last few years have seen the Fire Service develop as a mature organisation comprising:

- 346 fire districts (urban);
- 440 fire stations;
- 960 fire appliances (approx);
- 1707 career firefighter positions;
- 7000 urban volunteer firefighters;
- 524 management and support positions, full and part-time;
- 76 communication centre staff positions.

The total cost associated with fire management in New Zealand is estimated to be about $1.0 billion dollars per annum, or about 0.79% of total Gross Domestic Product. The largest cost components are fire protection measures in buildings (particularly commercial buildings); the cost of public fire emergency services; fire damage to property (particularly dwellings) and injury costs as a consequence of fire events (NZFSC, 2005). It is noted that the fire protection costs component related to reticulated water supply is estimated as $5.8 M/annum in depreciated capital costs for new works. This estimation is very low and excludes the depreciation cost embodied in the existing capital stock of reticulated supply network.

1.2 FIRE SERVICE KEY OBJECTIVES, OPERATIONS AND RESPONSE

The NZFSC provides, on behalf of the Government, a range of fire risk reduction, fire safety and emergency response services to the community. The principle role of the NZFS is to reduce the incidence of fire and its consequences for people, property, the community and the environment. This is achieved through setting and meeting strategic objectives that are linked to a high standard of service using the following key performance indicators (NZFSC, 2008):

- Avoidable residential fire fatalities;

- Fire injuries to the public;
- Fires in structures;
- Hectares lost to wildfire;
- Emergency Response time (Currently 7 minutes response to 90% of all calls).

The NZFS is required by Section 27A of the Fire Service Act 1975 to develop operational procedures. Each urban fire district is divided into zones and specific turnout procedures have been specified for each of the various incidents that may occur in that zone.

In addition to the predetermined response to an incident, the Chief Fire Officer of a Fire District is required to develop risk plans for specific buildings so as to provide fire fighting information to the responding units. The type of buildings that are required to have risk plans include the following:

- Boarding houses, hotels and other licensed apartments;
- Motels and apartment buildings;
- Rest houses;
- Hospitals and psychiatric care institutions;
- Prisons and places of lawful restraint;
- Public assembly;
- LPG/CNG installations;
- Special risk industrial and commercial premises.

It is unclear if the NZFS is required to coordinate with the relevant water authority in the development of these risk plans; however, it is something that is worth considering in the future for the ultimate benefits of both parties and to improve the fire safety of the wider communities.

1.3 LEGAL FRAMEWORK

There are several pieces of legislation that governs the provision and operation of fire fighting in New Zealand including:

- Local Government Act 1974;
- Resource Management Act;
- Fire Service Act 1975;
- Building Act 1991.

The legal obligation to supply fire-fighting water within urban New Zealand is implicitly required under the Local Government Act 1974. Councils have a statutory obligation (under section 647 of the Local Government Act 1974 (LGA74)) to install fire hydrants in the "main pipes" of the waterworks, at the most convenient places for extinguishing fires and keep them charged and in good working conditions as approved by the NZFSC. The councils also have a general function under the Resource Management Act 1991 (RMA) to avoid or mitigate natural hazards, including fire. In order to discharge this obligation, the Councils have included provisions in the subdivision section of their District Plans in terms of the installation and location of fire hydrants. These provisions reflect and/or refer to the NZ Fire Service Code of Practice for Fire Fighting Water Supplies in terms of hydrants locations and spacing but without referring to specific flow or volume requirements. The flow, storage and volume requirements were left for the New Zealand Fire Service to assess and advise the local authorities as per Section 30 of the Fire Service Act 1975.

It is also worth noting that many water utilities have adopted a policy where they do not guarantee an un-interrupted water supply and hence are not liable for any compensation arising from deficiencies in their water supply operation.

Overall, there is no direct legislation that requires water utilities and/or councils to provide fire fighting water supply, but where reticulated water mains are provided, fire hydrants must be installed, kept charged with water at all times and kept in good working order. Councils and water utilities could be liable in negligence for failure to perform its obligations to keep charged with water the pipes in which the fire hydrants are fixed as demonstrated in recent law cases such as MacEachern v Pukekohe Borough [1965] and MacEachern v Pukekohe Borough (No 2) [1965].

1.4 FIRE GROWTH AND FIRE INTERVENTION

It is important to have an appreciation of both fire behavior and fire fighting principles in order to make informative decisions regarding the provision of fire fighting water supplies. The vast majority of fires follow a typical pattern of distinct stages, although the timescales, rates and magnitudes vary widely.

Fires start when an ignition source containing enough energy heats up a fuel to its piloted or auto-ignition temperature. Once started, a fire is easily described as a self-sustaining "heat engine". A fire is the combustion of vaporised fuel, which when burnt produces heat, which in turn converts more fuel into vapour, thus continuing the combustion cycle. The speed with which a fire grows will then depend on the fuel that is burning, geometry, and how much air can get to the fire. If there is an open window or door, fresh air to feed the fire can flow in, and smoky gases will flow out. Usually the hot smoky gases will form a layer in the ceiling and there will be a clearer layer of cool air near the floor. This air is drawn into or entrained in the smoke plume that rises from the fire. As the fire grows the smoky layer descends closer to the floor and becomes hotter and blacker.

As the fire continues to develop, the temperatures rise and all the exposed surfaces are heated by radiation from the flames, hot surfaces and the upper layer of smoke and hot gases. Once the temperature in the upper layers reaches approximately 600^0 C, all the exposed combustible surfaces ignite and burn fiercely. This transition is called "flashover". Generally flashover can occur within 3-5 minutes of a fire starting and it is noted that the NZFS average response time is 7 minutes, which means fire fighters are most likely arriving to the fire scene after flashovers and thus are usually confronted with fully developed fires that require very large quantities of water.

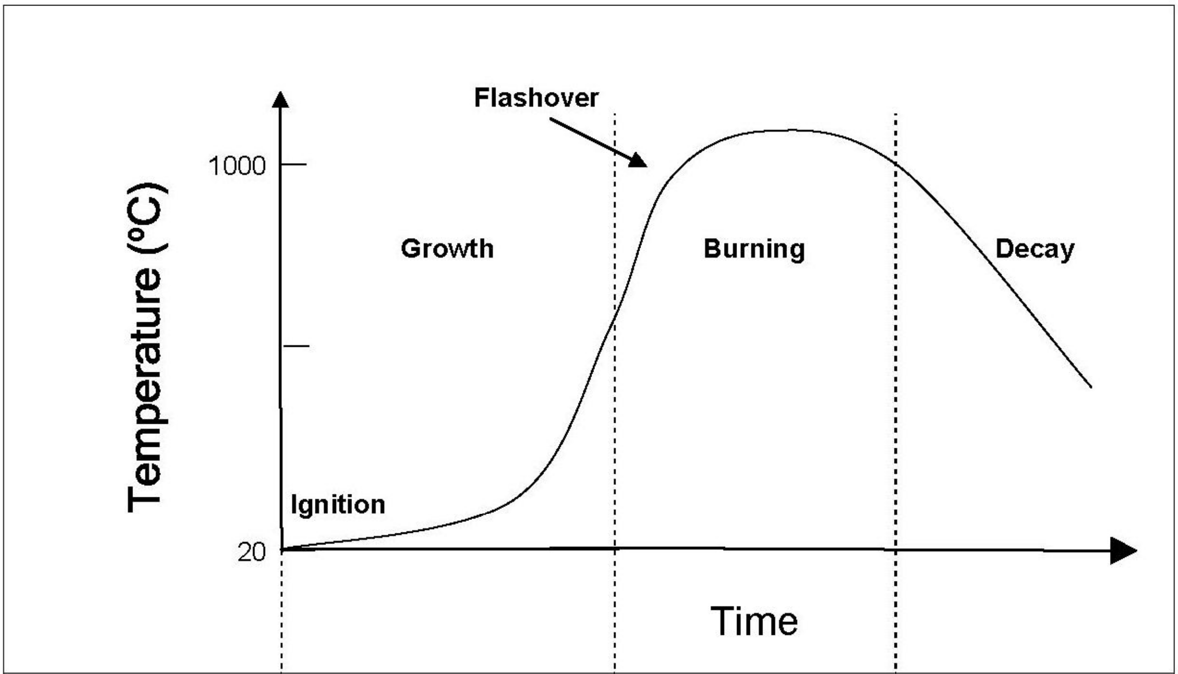
Once flashover has occurred, the fire is in the burning stage (fully developed), which is characterized by very high heat release rate, and high temperature. The rate of burning is governed by the availability of oxygen (ventilation controlled).

After a period of fully developed burning, the fire intensity decreases as the fuel is consumed and the fire is said to be in the "decay" stage. The transition to this stage is often defined as the time when 80% of the fuel is consumed. Once the available fuel is consumed, the fire then goes out.

Fire growth is stopped by either the introduction of firecells to limit spread of fire, intervention by the Fire Service or the activation of an automatic suppression system. The smaller the fire, the less water is required. Hand held extinguishers or hose reels can extinguish a very small fire. Sprinklers are designed to extinguish a larger fire in the growth stage, but they are ineffective after flashover.

Typical stages of development for fires (or fire behavior) are shown in Figure 1 below (Buchanan, 1994).

Figure 1: Typical Stages of Fire Development



Stage	Growth	Burning	Decay
Fire behaviour	Fuel-controlled	Ventilation-controlled	Fuel-controlled
Human behaviour	Escape	Death	
Control	Extinguish by hand, sprinklers or Fire Service, Smoke control	External smoke and flame	
Fire Service Tactic	Offensive	Defensive	

The NZFS usually consider employment of one of two operational tactics when attempting to control a fire (Davis, 2000). These are:

- Defensive;
- Offensive

A defensive tactic is employed if the fire has reached such a size that it cannot be tackled by the available resources. This requires the fire fighters containing the fire so that it can burn itself out without affecting the neighbouring property. The protection of adjacent property (exposure) is achieved by projecting water onto the exposed surfaces so as to keep them cool and hence below their ignition point. In this tactic, the addition of water to the fire achieves little impact and is usually detrimental due to the high quantities of contaminated runoff water. Research in the USA concluded that fire departments have only a 50% chance of preventing total compartment or building loss once the fire size reaches 86m2 (Fowler, 2002).

Offensive tactics are considered when the fire fighters are able to get the water on the seat of the fire and thus extinguishing a pre-flashover fire or a small fire after flashover.

1.5 EXTINGUISHING PROPERTIES OF WATER

Water has the highest heat-absorbing capacity of any of the common substances. Water's ability to absorb great quantities of heat makes it a very important firefighting tool in addition to its ability to expand into steam when heated above 100°C.

Water can be used to smother fire by converting the water into steam. Once water has absorbed sufficient heat to convert it from a liquid to steam, it expands as a vapour. The volume of steam produced at 100°C is approximately 1,600 times the original liquid volume. The volume continues to increase as the temperature increases beyond 100°C. Fire fighters can use this high expansion property of water to fill a room with steam that replaces the air. In addition, the water itself absorbs heat. Thus at the same time a fire can be smothered and cooled by the combined process of steam production and heat absorption. Fire will only be effectively suppressed by water application if the rate of cooling through water application exceeds the rate of heat output of the fire. Water is also used for other aspects of fire fighting operations such as the protection of exposures, protection of fire brigade personnel and damping down smoldering material (Davis, 2000).

It is most likely that water will continue to be used as the primary substance for extinguishing fires; however, the rate of its use will be reduced dramatically in the near future.

2 NEW ZEALAND FIRE SERVICE OPERATION

Every emergency incident attended by the New Zealand Fire Service or the Rural Fire Authorities is recorded and a form summarising the important features of the incident is completed. The information is then processed and the data is used in research projects directed at fire safety improvements to building standards and codes and community safety programmes. A summary of the data is also published in electronic format on the NZFS website at www.fire.org.nz/facts_stats.

Some of the relevant statistics regarding the emergency incidents attended by the NZFS in the 2006/2007 year are summarised below:

- During the year, the NZFS responded to 73,075 emergency incidents, of which only 35% of incidents were fire related emergencies, reflecting the fact that most of the NZFS operations are for non-fire activities, even though the service is totally funded by the Fire Service Levy;
- During the same year, the NZFS responded to 25,488 fire incidents, 27 % of these fires were residential, 22% for outdoor areas, 7% industrial and 5% commercial properties;
- Highest percentage of fires occurred on Saturdays at dinner time (17:00-17:59) reflecting the fact that most fires do not occur during peak demand condition of the potable water network contrary to common assumptions;
- There were a total 34 fire related fatalities during the year, of which 55% of these fatalities occurred during residential fires;
- High percentages of residential fires start in the kitchen area (33%) followed by the lounge area (12%);
- Almost 30% of fires were extinguished by High Pressure Delivery hose (HPD), 5% by Automatic/Manual Building Systems, 5% by NZFS Portable Pumps and 1 % by using Foams or special additives.

Unfortunately there are no accurate records of water use during fire incidents available. However, a recent research paper from the University of Canterbury reported that 94% of fires were extinguished by less than 10 L/sec (Davis, 2000) reflecting the positive impact of utilising the HPD technology, especially for extinguishing residential fires.

3 FIRE FIGHTING WATER REQUIREMENTS

Generally, water supply systems should be designed and installed not only to provide sufficient water for domestic, commercial, and industrial demands but also to provide the water that may be needed to fight fires. But although the actual amount of water used in a year for fire fighting is small, the rate of use is large. In many cases the domestic demand is not critical and the supply for fire fighting purposes will generally determine the pipe sizes required, which are ultimately much bigger than what would be required for potable water use. In addition to unnecessary extra construction and maintenance costs, oversized pipes cause water resident times to be unnecessarily long and this is known to be an important contributor to water quality degradation in distribution systems. In particular, extended reaction time causes greater loss of disinfectant residual promoting microbial re-growth, survival of pathogens and biologically derived taste and odour.

In 1911, a formula for determining the required fire flow in downtown districts was developed, representing the fire-flow estimate as a function of the population. This formula was adopted for many years for an average estimation of fire fighting demands in many countries. However, with the development of urban communities across the world, the population growth in downtown districts was not becoming the effective parameter. Shopping centres, large apartment complexes, and industrial parks were springing up in different locations across any city and each was a major fire-fighting problem in itself.

Various methods were then developed to estimate fire fighting water requirements in relation to a building parameter, either the floor area or compartment volume. Some of these methods rely on scientific principles, while others are based predominantly on empirical evidence. Some of the methods consider a large number of factors, while others are based simply on the floor area or volume of the firecell in question. Some of the methods are useful only for small floor areas.

3.1 WORLD PRACTICES

Fire is a complex set of dynamic interacting processes that are inadequately understood. Unwanted fires occur in unconfined geometries with heterogeneous mixes of fuel, uncontrolled air supply and uncertain ignition events. Fires are characterised by a multiplicity of time and length scales, and the complexity of the phenomena that control fire dynamics renders accurate and scientific analysis and calculation. Thus, there are not many methods for determining water supplies for fire fighting purposes. Some of the methods allow for flow and storage, some for only flow, some only for suppression, and others have an allowance for both exposure and suppression. The Iowa University method is based on fire engineering calculation, while the rest are based on statistical and/or empirical data. However, all of the methods have different assumptions and this makes direct comparison of these methods somewhat difficult.

Overall there are approximately eight worldwide recognised methods including:

- Insurance Service Office (ISO) Method- USA;
- Iowa State University Method- USA;
- Illinois Institute of technology Method-USA;
- Ontario Building Code Method- Canada;
- Grimwood Method-UK;
- Sardqvist Method- UK;
- National Research Council of Canada (NRCC) Method;
- National Fire Protection Association (NFPA) Method- USA.

These methods have been reviewed on behalf of the New Zealand Society of Fire Protection Engineers and sufficient details are provided for each method in the SEPE NZ-TP 2007/1 (Barnett, 2007).

Overall, there are large differences between the results for both flow and storage between all the methods and direct comparison between their results is difficult.

3.2 NEW ZEALAND METHODS

In New Zealand, the current New Zealand Code of Practice for Fire Fighting Water Supplies (2008) provides two alternative methods for estimating fire demands to various fire risk classifications. The first method is known as the NZS PAS 4509:2008 Tabular Method and is basically an estimation based on the considered opinion of the National Commander of the New Zealand Fire Service. This method is widely used by most of the water utilities in New Zealand and comprises two tables. Table 1 sets out estimated flow rates for firecell areas ranging from 0 to 2800 m2. Table 2 sets out the required storage volumes based on estimated times of flow ranging from 20 to 180 minutes. Information is not available as to how the values for flow and storage in the Tables were derived. However, it is interesting to note that the values in these tables are similar to the values stipulated in previous fire codes including 1965, 1992 and 2003 and as shown in Table 1 below.

Table 1: CoP Fire Fighting Water Supply Classification and Flow Rates

1965 Code	1992 Code	2003 Code	2008 Code
A- 2500 gpm (187.5 L/sec)	A- 200 L/sec	W7- 200 L/sec	FW6- 200 L/sec
B- 2500 gpm (187.5 L/sec)	B- 200 L/sec	W6- 150 L/sec	FW5- 150 L/sec
C- 1250 gpm (93.8 L/sec)	C- 100 L/sec	W5- 100 L/sec	FW4- 100 L/sec
D- 600 gpm (45 L/sec)	D-50 L/sec	W4- 50 L/sec	FW3- 50 L/sec
E- 600 gpm (45 L/sec)	E-25 L/sec	W3- 25 L/sec	FW2- 25 L/sec
F- 300 gpm (22.5 L/sec)		W1/W2- 12.5 L/sec	FW1- 7.5 L/sec

The main difference in the 2003 and 2008 CoP from the 1992 NZFS CoP, is changing the fire risk classifications from geographical base system into building risk base and reducing the required fire flow rates for commercial buildings and/or residential properties that are fitted with approved fire sprinkler systems.

It also noted that there was some inconsistency in terms of the application of the required flow rates. The 1965 and the 1992 CoPs stated that the flow rates should not be additional to the domestic water use. However, the 2003 CoP stipulated that these rates should be added to the peak demand of the potable water network, while the 2008 CoP required that two thirds of the annual peak consumer demand should be used consecutively with the fire flow from the hydrants. No explanation was provided to justify these requirements; however, it is common practice to design the water supply systems for the greater of the following scenarios:

- Peak Hour Demand;
- Maximum Day demand plus Fire Flow.

Obviously, it possible for fires to occur during peak hour demand, but since this simultaneous occurrence is more unlikely than for a fire to occur sometime during the maximum day demand, this is not usually considered to be an appropriate criterion for design of the water system (Mays, 1999).

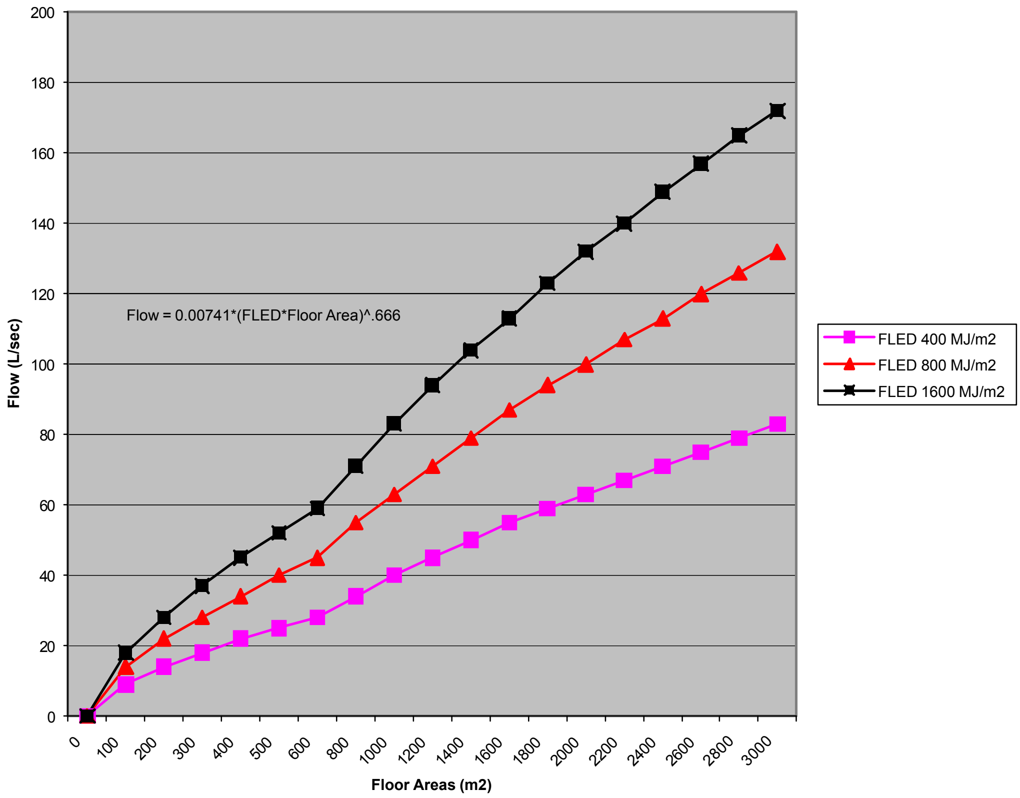
The second alternative is known as the NZS PAS 4509:2008 Calculation Method and detailed in Appendices H and J and it is of very limited use by water utilities and the fire service compared to the Tabular Method.

The flow calculation method is based on a fire engineering approach on which the amount of water used for suppression is sufficient to absorb the energy of the fire when the water is turned to steam at 100 °C. A value of Qmax is determined as being the smaller of the calculated values for either Qvent (ventilation controlled) or Qfuel (fuel surface controlled) fire. The smaller result may then be reduced further by a series of factors. This method is based partially on fire engineering and partially on arbitrary fire intensity values, which are higher than those, which would be derived from specific fire engineering calculations (Barnett, 2007).

The New Zealand Society of Fire Protection Engineers has considered that NZFS Tabular Method (Tables 1 and 2) will create huge additional costs to the public in the form of larger than necessary water mains and reservoirs (45 South, 1998) and has therefore produced a guidance document, known as the SFPE (NZ) Technical Publication TP 2004/1 – "Calculation Methods for Water Flows Used for Fire Fighting Purposes" followed by the development of the SFPE (NZ) Technical Publication TP 2005/2- "Water Storage for Fire Fighting Purposes". The SFPE TP Method is based on fire engineering calculations involving a study of over 500 building geometries ranging from 100 to 2000 m2 in area and depends on the quantity of fuel defined in the form of Fire Load Energy Density (FLED), measured in MJ/m2 of floor area (Barnett, 2007).

Fire fighting flow rates, per floor areas, calculated using the SEPE TP 2004/1 Method are plotted in Figure 2 below (Barnett, 2004).

Figure 2: Fire fighting flow rates calculated using TP2004/1 Method



A third method is also available in the Zealand Fire Engineering Design Guide (FEDG) (Buchanan, 1994). The FEDG method is based on the premise that the required flow rate of water F is that which when heated to only 100 °C will be sufficient to absorb the energy of the fire. However, the formula given in the FEDG applies only to small firecells (Barnett, 2007).

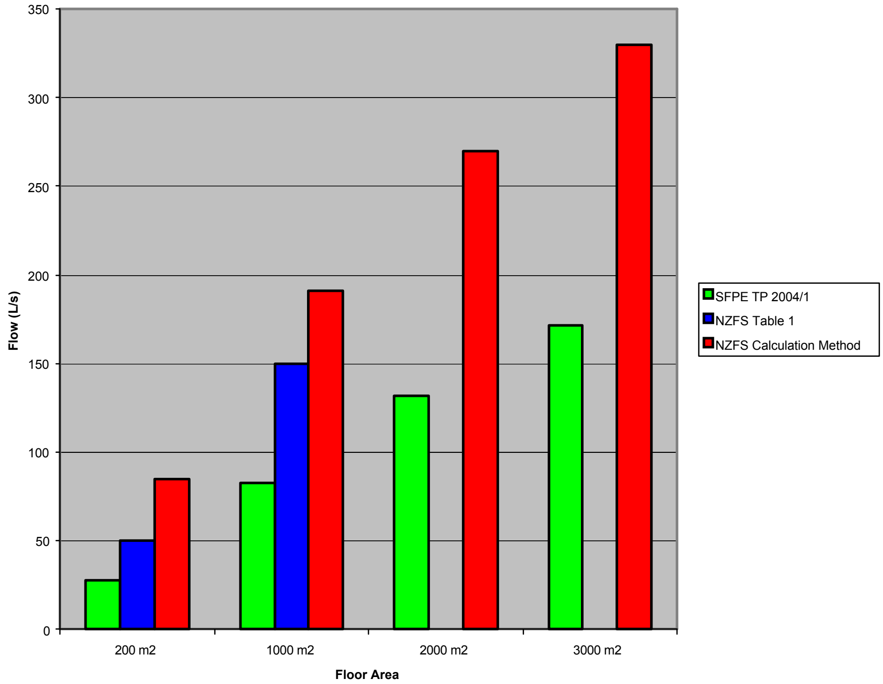
Municipal water supplies are also graded for fire fighting adequacy by the Insurance Council of New Zealand (ICNZ). These grading are then used to establish different insurance premiums for different grades. However, the methodology employed by the ICNZ is unpublished, but it was reported that it is most likely to be based on the USA Insurance Standards Office (ISO) method (Davis, 2000).

Currently no accurate records are kept of water use during a fire incident and the recording of water consumption will only be possible by the introduction of measuring and recording devices on individual appliances. The NZFS have installed several flow measuring devices on their new appliances and hopefully this information would provide valuable information on the water used during a fire, such as the operation and use of peak water flows, total water used and the time it takes to physically intervene in a fire's growth.

Figure 3 below compares flow rates, for different floor areas, as calculated using the NZPAS 4509 methods (Table 1 & Calculation) against the SFPE TP method assuming a Fire Load Energy Density (FLED) of 1200 MJ/m^2. Overall, the flow rates calculated using the SFPE TP method are significantly lower than the NZS 4509 methods.

The NZFS plans to revisit its CoP every five years and it is prudent for the water authorities to work with the NZFS and come up with better methods for estimating fire fighting water supplies that are more aligned to their planning needs.

Figure 3: Fire Flow Comparison



4 PLANNING FOR FIRE FIGHTING

Traditionally, most of the councils in New Zealand have opted to categorise fire fighting water supplies in accordance with the Town Planning designation for their different areas by using the District Scheme, which were established in accordance with the requirements of the Town and Country Planning Act 1977.

The District Scheme subdivided the urban area into zones where similar type of development would take place. These districts were then used as the basis to match geographical areas with a water quantity based on the 1992 version of the NZFS Code of Practice (CoP) for fire fighting water.

A given geographical area will allow a certain type of development and would thus require certain water supply flow rates. Fire fighting water supplies can then be matched to the designated classification of the District Plan. All service providers, i.e water utilities, were able to plan their future service developments (i.e networks) based on the future district schemes.

However, this approach does not take into consideration the potential large variations in a buildings fire risk that can occur within any given zone and also does not specifically allow analysing the effect of a proposed development with respect to fire impact as required under the Resource Management Act. The councils have also included provisions in the subdivision section of their District Plans in terms of the installation and location of fire hydrants but without referring to specific flow or volume requirements. To compensate for this deficiency, councils usually request that the NZFS comment on the suitability of a water supply in an existing area for any proposed new development with respect to the available fire fighting water supply and for access by fire fighters to undertake rescue and suppression operations as per Section 30 of the Fire Service Act 1975.

However, the new 2003 and 2008 CoPs have changed the basis for determining fire fighting water requirements from purely geographical area base into building "fire risk" base. This approach provides a valid and more scientific methodology to equate "fire risk" to fire fighting water usage and allows engineers to design specific pipes servicing existing deficient buildings as a better alternative to designing networks of pipes to service total areas, which were considered to be deficient under the 1992 CoP. However, it creates a planning problem for the water utilities in terms of determining the required fire fighting capacity for their future networks. Most of these utilities design their network for 50-100 years life horizon and thus their engineers and/or network planners need to estimate the fire fighting water requirements, in terms of flow rates and storage for the same time horizon, as fire fighting water requirements usually dominate the sizing of the water supply networks. Added to the complexity of the planning problem is the fact that within the next 50-100 years, there will be many future innovations in fire safety systems, technologies, and building design that ultimately will reduce the "fire risk" in future buildings and thus reduce the fire fighting water requirements.

In addition, the provision of fire fighting water is closely linked to the response and tactics employed by the fire service and thus will be influenced by the introduction and application of new technology, which will ultimately require less water. Unfortunately what is available in the existing CoPs and/or the SFPE TP calculation methods is of little use for water engineers, who require calculation methods based purely on land area and/or characteristics rather than building specifics.

It is very important to appreciate that having more water available does not necessarily reduce, better control or eliminate fire risks. A review of large fires indicates that the use of large quantities of water has minimum change to the outcome of the fire. Most of these fires occurred in buildings with a large floor area, single fire cell and single storey, with minimum or no fire protection systems. It was also noted that almost 94% of fires were extinguished by less than 10 l/sec (Davis, 2000). This situation was also recognised in UK and USA and a new planning approach was introduced for all new buildings by capping the maximum allowable floor areas for non-sprinkler buildings. For example, municipal planners in Plano, Texas require all buildings, having floor areas over 558m2, to be provided with sprinkler protection (Fowler, 2002).

Another planning approach that could be considered by the water authorities is to limit the amount of water available for fire fighting purposes based on the availability of future water resources, network capacity and capital funding. This should be implemented after extensive consultation with the Fire Service and the community.

5 ADVANCEMENT IN FIRE FIGHTING TECHNOLOGY

At an increasing rate, the NZFS is learning to put to use existing technologies and is anticipating the integration of new innovative technologies, such as tactical decision aids, training simulators, and improved protective clothing. For existing technologies, it is critical that performance be measured and evaluated in a scientifically sound method and that the technology be successfully transferred to the fire service through comprehensive training programs. This is very important for the NZFS, where almost 80% of the fire fighters are volunteers, to insure that the above science and technology can be successfully transferred in a usable form to the fire service.

In New Zealand, the use of High-Pressure Delivery hose (HPD) has reduced water usage since its introduction in the mid to late seventies. This is reflected by the fact that more than 30% of the 2006-2007 structural fires in New Zealand were extinguished by the HPD and almost 94% of fires were extinguished with less than 10 L/sec. These devices deliver water at a pressure greater than 2000 kpa and a flow less than 3.5 L/sec and provide a fine water spray or stream projected at high velocity and thus enabling the rapid uptake of heat from the fire. In addition, the NZFS have also introduced the new fire fighting technologies described below. However, the impact of the implementation of these new technologies, especially in terms of reducing water usage, is not yet reflected in the current flow rates stipulated in the 2008 CoP.

5.1 COMPRESSED AIR FOAM (CAF)

The NZFS has introduced Compressed Air Foam systems (CAF) with all new first response vehicles (Davis, 2000). The CAF system was added to the existing high pressure delivery (HPD) hoses. The introduction of CAF must be considered one of the most significant recent advances in fire fighting with the following key benefits.

- 35%-50% reduction in water consumption;
- Foam adheres to fuel and reduces the likelihood of re-ignition and this further reduces the quantity of water used;
- Reduction in pressure drop through hose;

- Maintain visibility due to reduction in steam;
- Reduce flare ups;
- Ability to apply from outside the building, which will improve the safety of the fire fighters and allows a greater reach.

The foam is produced by the injection of foam concentrate into the water stream. Compressed air is then introduced into the plumbing. The foam reduces the surface tension of the water in the hose and hence lowers the pressure resistance of the hose to the passage of the water/foam. This means the mixture may be pumped further.

CAF is termed a class “A” foam and is used at lower concentrations than other foams. These concentrations vary between 0.1 and 1.0 %. CAF breaks down the surface tension of water, which allows the foam to penetrate vegetation and stick to vertical surfaces. Because it adheres to the fuel surface it wets the fuel for a longer time and because of its bulk, brings more water into direct contact with the fuel. The foam blanket shields the fuel from impinging radiation and excludes the oxygen from the fuel.

The main disadvantage of CAF is the inability to produce a dispersed wide pattern spray so as to protect fire fighters against the effects of radiation from the fire. To overcome this problem research is being conducted into prototype tips that are capable of producing a water shield as well as foam.

5.2 WATER ADDITIVES

The most recent appliances being introduced into the NZFS have the provision for the injection of water additives (Davis, 2000). The introduction of surfactant chemicals (wet ability agents) into the water stream reduces the high surface tension of water. This makes it easier to pump the water as it reduces the friction loss and improves the water penetration and hence improves the water’s extinguishing characteristics.

Thickening agents are also introduced to improve the water streams adhesion to vertical surfaces, again with the aim of enhancing the residence time of the water and hence improving its extinguishing capability. This additive has long been used in rural fire fighting to pre-wet fuel in front of a fire front.

5.3 OTHER TECHNOLOGIES

In addition to the technology advancements described above that have been implemented in New Zealand, there are other emerging fire fighting technologies that have been widely implemented in different parts of the world with reported success. These technologies focus on improving the capabilities of the fire fighters with the potential of optimising water application. Some of these technologies include:

5.3.1 THERMAL IMAGING CAMERAS (TIC)

Thermal imaging cameras operate by using the infrared part of the electromagnetic spectrum to detect differences in heat and allow fire fighters to navigate around inside smoke filled buildings faster. These devices can distinguish human bodies against a cooler background or the seat of a fire though visibly obscured. This enables fire fighters to conduct search and rescue operations and locate the seats of fire faster. These cameras can also be used to locate hot spots that are invisible to the human eye.

5.3.2 POSITIVE PRESSURE VENTILATION

Positive Pressure Ventilation is a procedure where fire fighters can utilise mechanical fans to pressurise a structure so as to clear smoke and flames away from an advancing fire fighting team. Positive Pressure Ventilation fans introduce an induced air stream into the building with the aim of clearing smoke and heat away from the intended entry point and pushing the products of combustion out through an external vent. This allows fire fighters to advance in a cool stream of air, unhindered by heat and visibility problems, onto the fire and reach the seats of fires.

5.3.3 ROBOTS

Robots are ideal in the time between marginal tenability conditions and structural collapse. They are suitable for deployment in large single story industrial buildings and vehicle tunnels. The main task of these units so far has been in reconnaissance, but some are fitted with hoses such that they can optimise the application of the water to the seat of the fire.

6 CONCLUSIONS

Provision of the fire fighting requirement comes with a noticeable cost to every water utility and there is much anecdotal evidence indicating that 30% of the capital cost of water supply infrastructure is attributed to the provision of fire fighting capability (NZFSC, 2005). The fact that a very large proportion of fires in New Zealand are extinguished with less than 10 L/sec of water demonstrates the success of implementing the HPD technology in fire fighting. Having more water available does not necessarily reduce, better control or eliminate fire risks. More efforts should be focused on improving fire protection systems, fire fighting access and response time rather than building oversized public water systems.

A large proportion of structure fires in New Zealand are residential and the same applies to fire fatalities. Recent research suggests that 'installing domestic sprinkler systems in 10% of existing dwellings each year, in addition to all new dwellings, could save about 550 lives and $1.8 billion worth of property damage over a 30-year period (Rahmanian, 1995). Most of these fires start in the kitchen areas, and maybe designing an extension to the ordinary house plumbing system and adding a special domestic sprinkler unit to the kitchen area could be a very cost effective solution to these fires.

In New Zealand, the use of the High-Pressure Delivery (HPD) has reduced water usage within the last 30 years. In addition, the NZFS has successfully introduced Compressed Air Foam systems (CAF) with all new first response vehicles. This new technology has the potential to reduce water requirements by a minimum of 35%. However, the impact of the implementation of these new technologies, especially in terms of reducing water usage, is not yet reflected in the current flow rates as stipulated in the 2008 CoP, which essentially are similar to the ones stipulated in the 1965 CoP.

The NZFS have installed several flow measuring devices on their new appliances and hopefully this information will provide valuable information on the water used during fires. Water utilities should encourage and work more closely with the NZFS to utilise this information to the benefit of both parties.

From a planning perspective, what is available in the existing CoPs is of little use for water engineers, who require calculation methods based purely on land area and/or characteristics rather than building specifics. However, a new planning approach could be introduced by capping the maximum allowable floor areas for non-sprinkler buildings and thus reducing the fire fighting water requirements. This needs to be further discussed with the NZFS to explore this planning approach and to agree on an affordable and optimised use of fire fighting water with the aim of reducing the capital cost of future water networks.

Overall, the current prescriptive NZFS CoP and the existing planning practices fail to recognise innovation in fire safety systems, fire fighting technologies, and innovative building design in terms of required water usage during fires. To ensure fire safety in a sustainable, cost-effective manner and to reduce fire losses among our communities, it is essential that we have a forward looking vision and explore science-based tools and practices to enable the development of the next generation of planning standards and fire codes that address the fire problem more efficiently.

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