Water Conservation and Sustainable Use in Fire Protection Systems.

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Abstract:

While environmentalists, government planners and industry work to develop solutions to our current water shortage, the way the fire industry utilises water for fire systems is about to change forever; the days of unlimited water usage are now over.

This paper provides closure to the Fire Australia'05 water use proposals and details practical solutions for the conservation and sustainable use of water in fire systems. It remains to encourage building owners & occupants, together with fire industry service providers, to make the necessary changes now permitted in Australian standards.

The Fire Protection Association of Australia is committed to continuing its leadership role in facilitating change, promoting awareness and encouraging State and Federal government to provide the necessary recognition and incentives to building owners and those in the industry who promote change.

1) Introduction

2003 – 2005 – 2007

The process of fire system water conservation started in 2003 with the 'clean sheet' rewrite of the new maintenance standard for automatic sprinkler systems, where it was agreed that procedures on how to conduct each test would be specified rather than leave it up to an individual's interpretation. This provided the opportunity to consider the water use aspects of each new procedure as well the ability of the procedure to achieve its reliability goal.

During this process it also became apparent that the design standards did not sufficiently relate to their companion maintenance standard, which could prevent fire systems being tested in the definitive mode envisaged by the new maintenance standards. More importantly, it was revealed, that no requirements or options existed for the sustainable water use (reuse) in the design standards for either, sprinkler systems, fire pumpsets or fire hydrants. Independently of this a number of water supply authorities had decided to implement water supply pressure management programs of which the fire system standards community had only basic engineering detail.

In 2005 a number of sustainable water use options were proposed at the Adelaide Fire Australia conference[1] and now in 2007 we can reveal the work is almost complete. This paper provides detailed practical solutions for the conservation and sustainable use of water in fire systems. It remains to encourage building owners & occupants, together with fire industry service providers, to make the necessary changes now permitted in Australian standards.

2) Fire System Maintenance

As discussed in Fire Australia 2005 paper, the AS1851-2005 maintenance standard[2] now has the potential to reduce annual water usage from fire system testing by 75%, as the summary in *Table 1 – New AS 1851 Water Savings* shows. These figures are based on the testing procedures now specified in the standard and on the assumption that the option of moving from weekly to monthly test frequency is adopted for sprinklers and fire pumps.

However since AS1851-2005 was published it is acknowledged the perceived cost of upgrading some sprinkler control valve assemblies and older fire pump-sets has been prohibitive, limiting to move to monthly testing. Importantly though, the higher than expected costs have been due more to the lack of detail provided in the maintenance standard to specify acceptable upgrade methods, than the actual scope of the upgrade required. For monthly testing to be adopted it was not intended that these older systems be upgraded in line with the latest design standards but rather their reliability improved for the change in testing frequency. A correction has been proposed for inclusion into AS1851-2005 Amendment 3, due for publication this year. It is also possible that the one-off upgrade costs for monthly testing of existing systems could be off-set by lower life cycle costs that result from fewer breakdowns and emergency call-outs that come with better maintenance and reliability.

It should be born in mind that frequency of maintenance is not the only factor leading to system reliability. The increased reliability provided by AS1851-2005 is due more to the prescribed procedures for conducting each activity as well as the pass/fail benchmarks set for many tests and together with the required documentation of records & reports, AS1851-2005 provides an underlying ISO 9001 QA approach to fire system maintenance.

It is also important to note that the standard was written with both new and existing fire systems in mind. It is accepted that the existing stock of systems vary in design and may not have the functionality or all of the facilities of a new system as their design is based on older standards, making it impractical in some cases to conduct some tests as specified or to complete them at all.

Finally, it is understood that saving water at the expense of reliability of a life safety system is unacceptable. The standard aims to achieve both. With the adoption of monthly verses weekly testing, twelve site visits are required compared to fifty two, helping to off-set water usage as well as the costs for two significant new tests. Namely, the system interface test, where the functionality of the interconnection between the building's various fire systems is established and secondly the annual system survey, where, by the use of a check list, the system's conformance to the applicable design standard is reviewed including the ability of the system to meet its performance goals

Type of System Water Supply	Current weekly test water usage	New AS1851 water usage	Annual water savings
Town Main – Ordinary Hazard	**58 kl**	**15 kl**	**74%**
Electric pump - Ordinary Hazard	**105 kl**	**26 kl**	**75%**
Diesel & electric pump - Ordinary Hazard	**423 kl**	**103 kl**	**76%**
Diesel & electric pump – High Hazard	**890 kl**	**215 kl**	**76%**
Hydrant System with electric pump	**94 kl**	**22 kl**	**77%**

Table 1 – AS 1851 Annual Usage Water Savings

AS1851-2005 Amendment 3:

Following publication of AS1851 and the subsequent review of the companion design standards, further water saving initiatives have been proposed by the FPAA for inclusion into amendment 3 of AS1851-2005, due for publication this year:-

Frugal Water Supply Testing

The two activities that consume the greatest amount of water are the now annual pump load test, followed by the water supply flow test. The idea of permitting these two tests to be conducted simultaneously necessitated the development of a set procedure, consistent with the remainder of the document where it was agreed to modify each of these procedures to limit their water use but still achieve their reliability goals.

Previously, the load test required a diesel pump to run under continuous maximum water flow (load) conditions for 30 minutes, during this time observations and readings where taken. The revised diesel pump load test now requires the pump to run:-

- 10 min. at shut-off (zero flow) for pump to attain normal operating temperature.
- 10 min. at the most hydraulically favourable duty flow, while recording results.
- Reduce flow to the most hydraulically unfavourable duty point
- Further reduce the flow until shut-off (zero flow) is achieved and continue to run the pumpset and record results until total run time has reached 30 minutes.

Previously, the water supply flow test required multiple flow and pressure readings to be taken, starting at pump shut-off or standing pressure to just past maximum flow conditions, *see fig 1 Previous Flow Test* (red dots). The procedure was then reversed, taking confirmation & usually more accurate readings back down to shut-off (blue dots). The revised water supply flow test now only requires three readings need to be taken, *see fig 2 Proposed Flow Test*:-

- 1) The pressure at pump shut-off or standing pressure (zero flow).
- 2) The pressure at the most hydraulically favourable duty point flow.
- 3) The pressure at the most hydraulically unfavourable duty point flow.

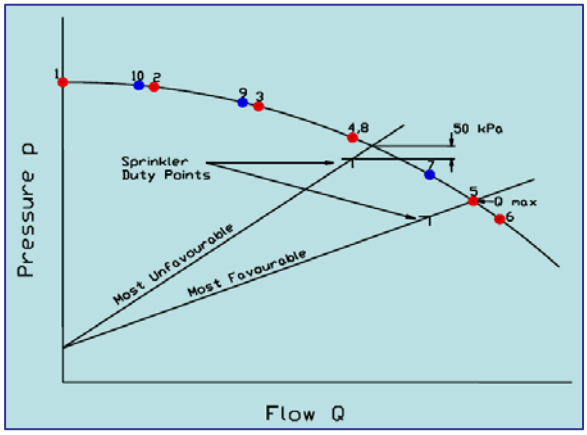

Fig 1 Previous Flow Test

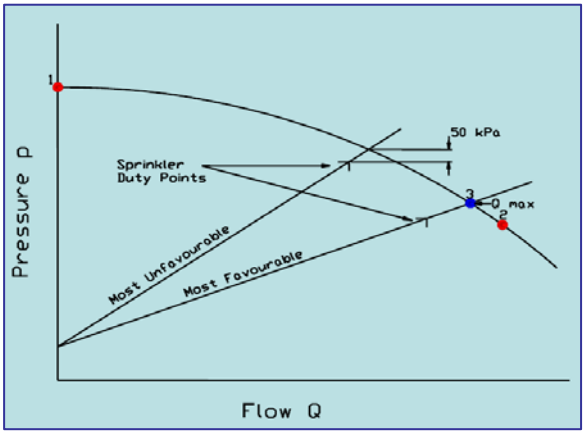

Fig 2 Proposed Flow Test

Monthly Testing Upgrade

As discussed earlier, the scope and acceptable methods for upgrading existing sprinkler systems and fire pumpsets for a move to monthly testing are now to be specified in AS1851 and include:-

- Acceptable construction of the enclosed locked cabinet for sprinkler valve.
- Substitution of valve monitoring by properly constructed enclosure.
- Removal of the inconsistency of pump alarms to be repeated at the CIE (if fitted)
- Specification for a single pump starting battery & its biennial replacement.
- Guidance for the provision of a fire pumpset diesel fuel tank level switch.

Hydrant Flow Testing

Hydrant system flow testing is traditionally conducted at the most remote hydrant landing valve(s), therefore unlike the sprinkler system standard, the hydrant standard does not specify a fixed 'annubar' flow test device, making it impractical to install tank return lines or reticulate pipework to the building's re-cycle tank. Although not mandated in the maintenance standard, one concept that has been successfully trialled is to collect fire hose flow meter output into mobile (on wheels) water tank(s) and then transfer the test water into a truck or trailer for transport to a re-use facility such as the local council where it can be added to the water supply for garden maintenance use. The concept of catch & cart, *see fig 3 Catch & Cart*, does cost more and requires set-up costs as well as support from local council however the extra effort is consistent with our current times.

Fig 3 Current Method vs Catch & Cart

3) Design & Installation Standards.

The final goal of the water saving strategy is the development of permanent, sustainable, water reuse options. These options require the installation of water re-cycling facilities but have the potential to take water usage savings from the creditable 75% with the water conservation measures in AS1851-2005, up to a potential of over 90%, ie less than 10% of the original amount of water we have consumed in system maintenance testing to date.

Since water saving designs do not aid (or hinder) fire protection performance, inclusion of these concepts into the relevant design standard is intended for new installations and then only as an option, (whether new or existing systems) ; it would up to the regulator to encourage their use. Similarly the water reuse options have been drafted to permit their retrospective installation if system design and building space permit.

AS2118-2006 Automatic Fire Sprinkler Systems:

Publication in late December 2006 of the significantly revised AS2118 sprinkler standard resulted in a completely new Section 4 Water Supplies, where the insurance concept of grades of supply was replaced by a benchmark single reliable town main supply and acceptable alternative supplies with a similar reliability. This provided the opportunity to include a number of water re-use options however there was insufficient time to extend committee drafting process to include a section (the full range of options) on sustainable water use. AS2118-2006 now includes:-

Tank return line & Remote annubar

Clause 4.3.4.1 *Pump suction tank water supply,* now requires that waste water from the water supply flow test device, pump pressure relief and circulation relief facilities be piped back to the water supply tank except where hydraulically precluded due to tank elevation. This single requirement has the greatest impact on water re-use, presents little added cost and is suitable for retrofit however it does require a tank ~~to~~ be installed.

Where return lines from the flow test device might be excessive in length, potentially causing inaccurate flow measurement from return line back-pressure, Clause 4.4 *proving of water supplies* now permits the flow measuring device to be installed at any point on the system downstream hydraulic calculation datum point, usually adjacent to the tank and downstream of the pump, *see fig 4 Tank Return Lines & Remote Annubar.*

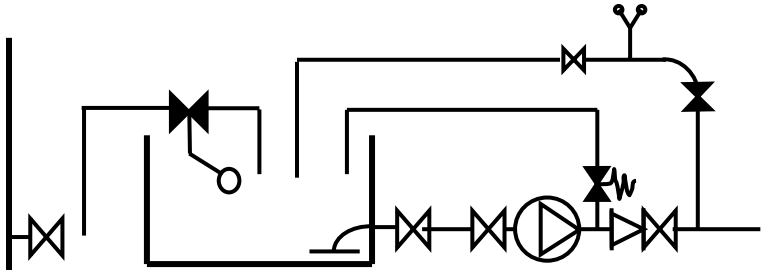

Fig 4 Tank Return Lines & Remote Annubar

Reduced Capacity Water Supply Tank.

To help reduce the cost of a water supply tank and thus encourage their use AS2118-2006, clauses 9.3.2, 10.3.2 for Light & Ordinary Hazards respectively, now permit the tank capacity to be reduced by up to 2/3rd for buildings under 25m in effective height verses the previous 1/3rd, subject to the provision of an automatic infill sufficient to make up the reduction in tank capacity within the system operating time. For buildings over 25m in height where dual water supplies are specified tanks can still be reduced by 1/3rd capacity but without the need for automatic infill. There has been no change to tank capacity reduction for High Hazard systems (remaining at 1/3rd) however the previous requirement for provision of dual water supplies for High Hazard systems has been removed.

Flexible Droppers.

AS2118 now acknowledges the use of flexible tube assemblies in clause 7.6 and when used to feed below ceiling sprinklers they can preclude the need to drain down a sprinkler system when undertaking tenancy remodelling, as sprinklers can be relocated with-in the radius of the flexible dropper while charged with water assuming the system has been de-pressurised. A small point maybe but when a high rise office building or shopping centre sprinkler system is being drained most weeks due to high levels of tenancy change it can make a difference.

AS2118-2006 proposed amendment 1:

Amendment 1 of AS2118-2006 is due out early in 2008 and will include options for sustainable water re-use:-

Recycle Tank

Water supplies drawing from town main and boosted by a pump consume water that would normally be sent to waste when conducting monthly (or weekly) pump run testing and annual pump load testing. The recommendation of a Recycle Tank and recirculating pipework & valves, *see figure 5*, will enable test water to be reused during pump testing by isolating town main and recirculating water to the tank. On completion of the test, the town main supply must be restored. Note also that the annual flow test cannot be combined with the pump load test as town main is isolated to recycle test water.

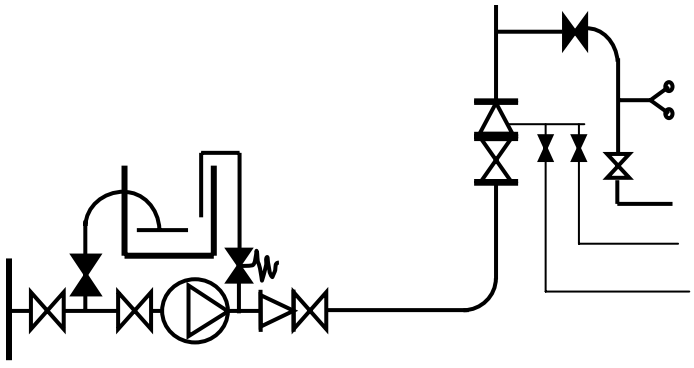

Fig 5 Recycle Tank

Pump Re-circulating Loop

Permitted in NFPA 13 and NZ4541 sprinkler standards where water supplies draw from town main and are boosted by a pump, *see fig 6,* annual pump load test water can be continually re-circulated, although the duty point load on the pump is not recreated. A re-circulating loop for the system pressure relief valve, which will often open during monthly (weekly) pump run test, has not been included until pump trials have been successfully completed. Note as with the recycle tank, the annual flow test cannot be combined with the pump load test as town main is effectively isolated by the water supply check valve.

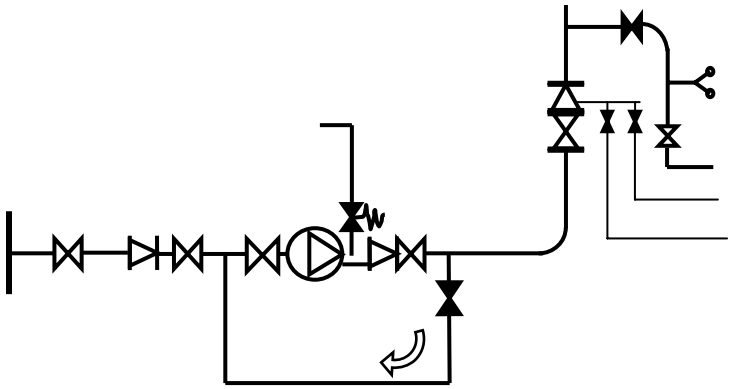

Fig 6 Pump Re-Circulating Loop

Minimum Capacity Break Tank

The inclusion of a Minimum Capacity Break Tank is aimed to help continue to lower the cost of a water supply tank for all Hazard classes including High Hazard. A Break Tank will permit tank capacity to be reduced to an absolute minimum where town main is able to meet the automatic infill demand for remaining tank capacity. Tank design however may require tanks baffles to eliminate turbulence and potential pump cavitation, while duplication of automatic infill and provision of testing facilities is necessary due to the potential single point failure of the infill valve.

Water Quality

AS2118-2006 now acknowledges the use of non-potable water however in doing so Clause 4.3.1.3 requires consideration be given to compatibility of components, health, environmental and system maintenance requirements. Where the water supply source is classed as non-drinkable (but not grey water), such as re-cycled water or filtered rain water, then it is proposed that no additional safeguards should be required, thus facilitating the use of a building's re-cycled or rainwater supply.

Building Non-drinkable Tanks.

Although most likely to be a commentary only in the standard, when the water supply is direct from town main without pumps or from a gravity tank, the most significant water usage is for the annual water supply flow test. A recommendation to reticulate the flow test facility outlet to a building's non-drinkable supply tank or grey water re-cycle tank

could assist in the overall water efficiency. Alternatively, as flow test water from a potable supply should be classed as non-drinking water when discharged, reticulation to landscape garden supply tank would be equally suitable.

Sprinkler System Zoning.

Similarly to the use of flexible droppers, the recommendation to zone a sprinkler system into discrete use areas via monitored sectional valves not only assists with system reliability by limited the amount of protection 'off-line' at any one time, zoning will also assist in limiting drain down waist water in high change occupancies such as shopping centres and high rise offices

AS2941-2007 Fire Protection Pumpsets:

Variable Speed Control

One of the most significant contributions to water use is the monthly (weekly) pump run test where town main pressures, normally greater than the minimum provided by the water supply authority, combine with pump shut-off head and result in system over-pressure relief valve opening to waste. This valve is sized for approximately 1/3rd of pump duty flow however variable speed pumps now to be permitted in AS2941-2007, clause 8.2.6 for electric motor driven pumps and clause 9.3.9 for diesel engine driven pumps, will limit pump pressures to 110% of duty head.

4) Water Supply Pressure Manage Programs

Water supply pressure management has demonstrated considerable savings can be achieved in both town main network water loss and water usage [3], however water supply authorities have said little about the impact on fire safety systems.

Minimising network water losses is about delivering a stable town main pressure and this can also have a very positive impact on fire system pump selection and the resultant pump testing water wastage. At the same time, reducing network water usage is about lowering town main pressures and it can be shown that existing fire systems should be able to cope with the lower pressure if the water supply authority is able to consider current fire system design standards when choosing a minimum pressure.

As a reliability measure AS2118 requires system design to be based on town main flow and pressure characteristics that can be maintained for at least 95% of the time and if not available the minimum water supply data shall apply. The potential for town main pressure fluctuations over a 24hr period are demonstrated in *Figure 7 Pressure Management for Stable Town Main* and Yarra Valley Water define "95% of the time" to be the minimum pressure on a dry summers day [4].

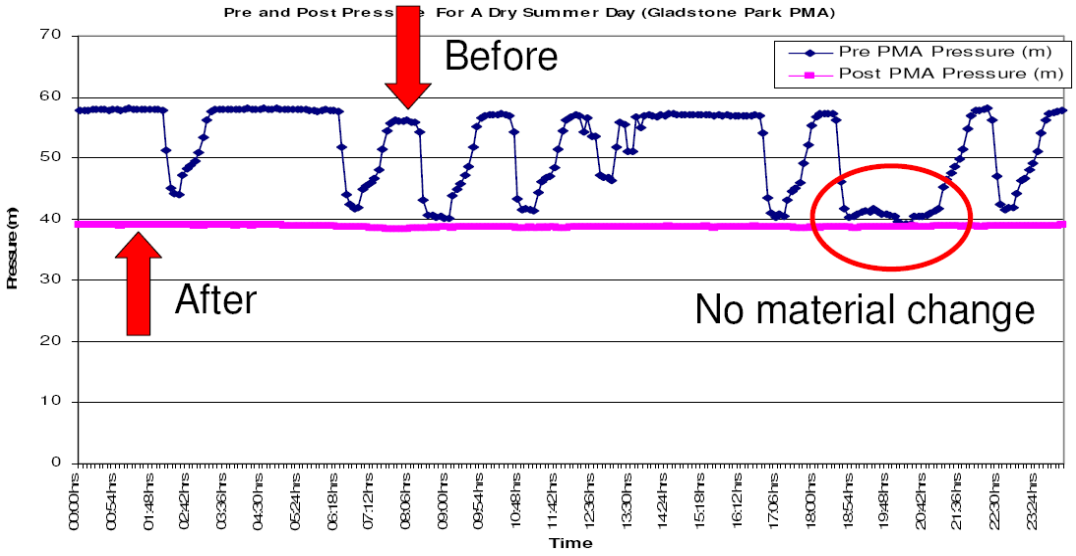

Fig 7 Pressure Management for Stable Town Main

In this case it is possible, during certain times of the day, that a sprinkler system fire pump being tested for peak performance as part of the maintenance regime will provide almost 200 kPa greater pressure than required, resulting in the system pressure relief valve opening to protect the sprinkler pipework from failure and dumping a considerable amount of water to waste unless water recycling facilities are installed.

Importantly though, note in this case that the stable post pressure manage curve aligns with dry summer day minimum pressure, thus pressure management aligns perfectly with the AS2118 sprinkler system standard “95%” design requirement, with no system modification required and no future excess water loss during fire pump testing.

This simple point of compromise between the fire industry and water supply authorities would allow pressure management programs to proceed with much less impact on existing fire systems and the building occupant safety they provide.

However pressure management can be also about limitations in flow as well as stable lower pressures. The reduced hydraulic capacity of a pressure management area can result in a reduced amount of water being available at time of fire. Pressure management often involves the creation of small volume, finite pressure zones, of a sufficient size to be responsive to a limited number of pressure management valve arrangements, which could be as little as two or three, as indicated in *Fig 8 Town Main Network Diagram* [5]. This can result in the pressure zone’s maximum flow limitations being more easily reached and a loss in the previous ‘infinite’ grided town main network.

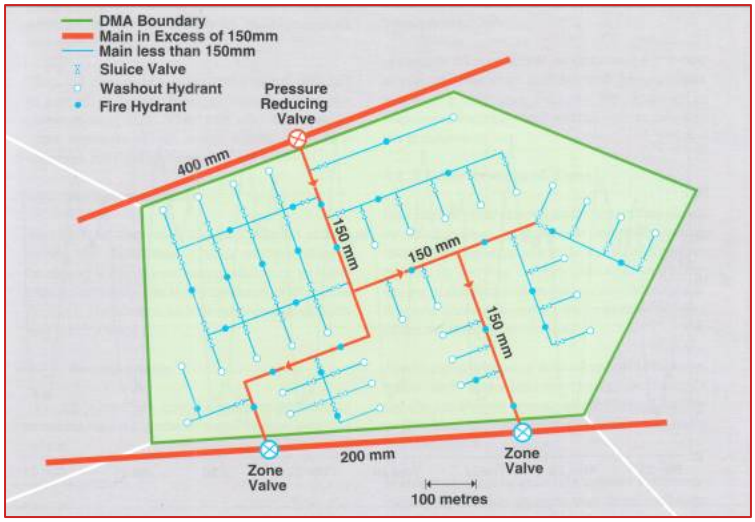

Fig 8 Town Main Network Diagram

Water supply authorities in the UK do not permit fire systems in certain areas to draw directly from town main where booster pumps are required to meet fire system flows, necessitating the use of costly water supply tanks and fire pumps. Clearly there is a need for fire system design standards to incorporate pressure management programs into their design criteria but in such a way as to ensure water supply is both effective and cost efficient as well as incorporating sustainable water reuse concepts.

It can be seen in *Figure 9 Pressure Management Reduced Hydraulic Capacity* that the pressure zone valve arrangements are not able to react sufficiently to dampen the impact peak demand resulting in continued fluctuating town main pressures during the 2100hr peak draw-off period. Importantly, the post pressure manage curve is also well below the previous dry summer day minimum pressure and this will affect the fire system as its water supply was most likely designed to the AS2118 “95%” requirement.

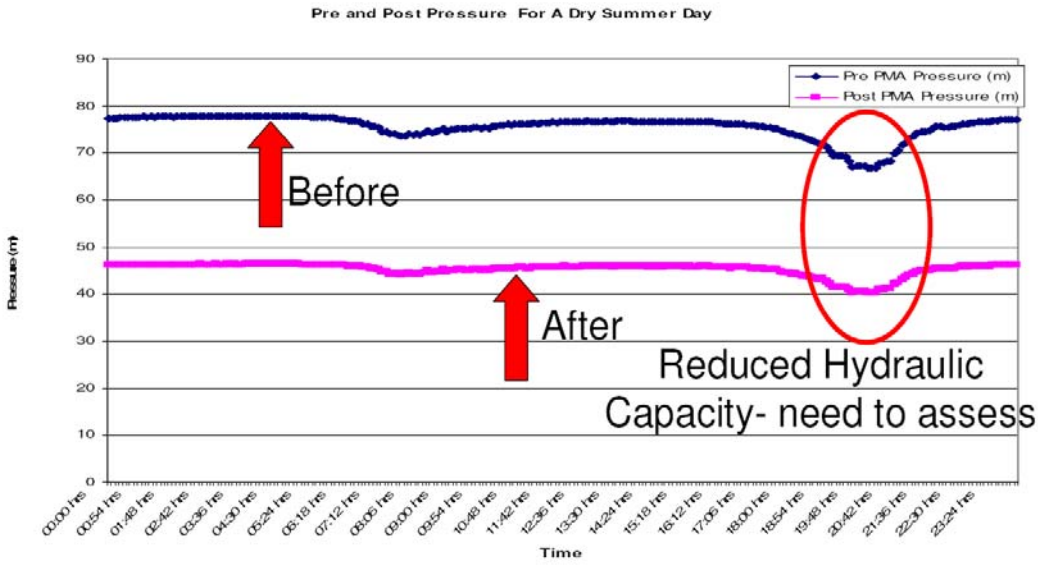

Fig 9 Pressure Management Reduced Hydraulic Capacity

Harry Marryatt in a “Fire a century of sprinkler protection” notes that it is a rare event for a fire in a sprinklered building to require maximum flow demand where all sprinklers in the design area are flowing simultaneously. Only 2.34% of sprinkler fire operations required between 11 to 25 sprinklers to operate and a further 0.96% more than 25 [6].

Even more unlikely is a fire where town main is required to supply maximum sprinkler demand with the fire brigade drawing maximum hydrant demand; however without a sprinkler system protecting the building and occupants, brigade flows could easily exceed this combined figure. The possible impact of low pressures on other water users in the pressure management zone should not form part of the fire system or water supply authority’s design requirements as this would be a temporary and extreme fire event.

This should not be the case however when conducting fire system maintenance. For example fire pump maintenance testing of a High Hazard sprinkler system water supply, drawing direct from town main, could have regular, monthly (or weekly), impact on other town main users. An ESFR high hazard sprinkler system drawing from town main will often have one or two booster pumps, each capable of supplying over 6,000 litres/min. It is understandable that water supply authorities may wish to limit the maximum draw-off from smaller pressure management zones as well as require water storage tanks to effectively recycle pump test water rather than letting the water be reticulated to waste.

The impact of High Hazard fire sprinkler system maintenance on town main supplies can be gauged by analysis of Wormald sprinkler maintenance data [7] in *Fig 10 Sprinkler System Water Supplies,* which indicate that over 75% of sprinkler water supplies draw from town main and since approximately 25% of systems are high hazard, it concludes that 19% of future sprinklers systems would be candidates for water recycling capability.

Sydney Metro Area	Town’s main supply	TM & Booster Pumps	TM plus Pumps & Tanks	Pumps & Tanks
Northern Region	30 %	35%	35%	0 %
Southern Region	45%	25%	15%	15%
CBD Region	15%	35%	45%	5%
Sydney Metro Average	30 %	30 %	35 %	5 %

Fig 10 Sprinkler System Water Supplies

Although not directly related to water savings, sprinkler system false alarms to the NSW fire brigade, resulting from evening pressure surges in a fluctuating town main, are captured in the AIRS Incident Reporting System at 3.01% [8] of annual NSWFB false alarms. This represents almost $ 1 million of the brigade’s $32 million annual cost of false alarms [9] and a stable town main under pressure management could do a lot to reduce these false alarms.

It is also interesting to observe the move in timing of Yarra Valley Water peak water demand from 1800hrs to 2300hrs due to evening water restrictions [4]. Harry Marryatt [10]

details in *Fig 11* that calls to the fire brigade peak at 1800hr just when town main water pressure was at its lowest. However with garden watering postponed until later in the evening water pressures at peak brigade call time have been restored.

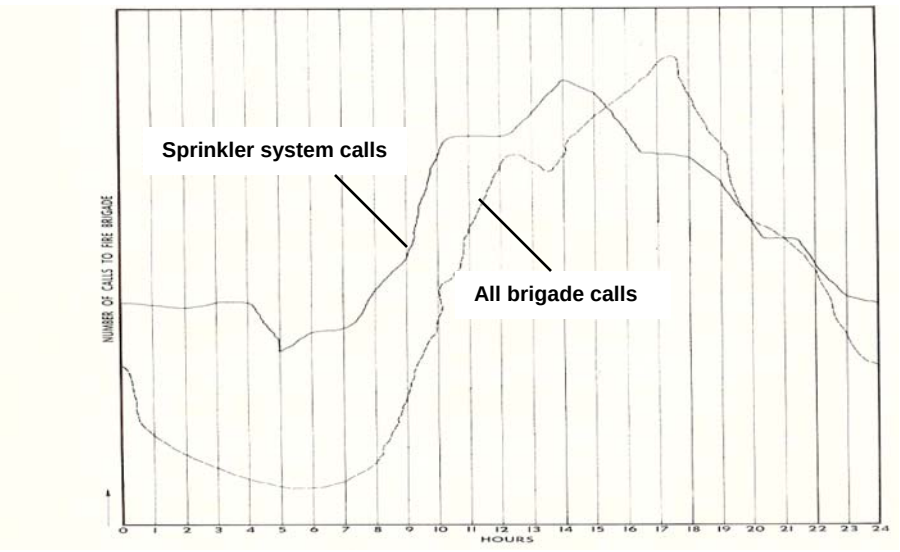

Fig 11 Fire brigade calls

5) Goals

In summary then, building owner or occupier action plans for the conservation and sustainable use of water in fire systems may include the following:-

Water conservation action plan:

Existing buildings:

1) Transition to AS1851-2005, using the monthly testing option, carrying out the sprinkler system & diesel pumpset reliability upgrade where necessary

2) Adopt the use of wire-braided flexible “droppers” in accordance with AS2118-2006 when carrying out future sprinkler tenancy alterations.

3) Where possible, sub-divide the sprinkler system into floor or area zones using monitored sectional valves as permitted in AS2118.

New buildings:

4) Ensure the sprinkler system and pumpsets are to be designed and commissioned in accordance with AS2118-2006 & AS2941-2007 respectively.

5) Ensure that the building occupancy certification for fire system maintenance specifies the use of AS1851-2005.

Sustainable water use action plan:

Storage tank & pump water supply:

1) Install a tank return line from the system pressure relief valve in accordance with AS2118-2006 for monthly pump run & annual pump load tests.

2) Install remote annubar flow test assembly with tank return lines from the annubar outlet in accordance with AS2118-2006 for the annual water supply flow tests.

3) Consider the use of a 1/3rd capacity water supply tank for Light & Ordinary Hazard systems in accordance with AS2118-2006, when sufficient infill water is available from town main but pressure management limits the full quantity of water being draw-off or water conservation is a priority.

4) Consider the use of a minimum capacity break tank for all Hazard class of systems in accordance with AS2118-2006 (amend 1), when sufficient infill water is available from town main but pressure management limits the full quantity of water draw-off or water conservation is a priority.

5) Consider a water storage tank utilising infill from filtered rainwater or recycled grey water non-drinkable water supply now permitted in AS2118-2006; assuming the reliability of the supply meets the requirements of Section 4.

6) Adopt the use of a temporary on-site water tank to capture and reuse water from the 12-year preventative maintenance water supply tank inspection and clean.

Pump boosted town main water supply:

7) Install a variable speed pump in accordance with AS2941-2007 for monthly pump run test or;

8) Review the pump design for shut-off head when redesigning water supply as part of a pressure reduction program.

9) Install a testing recycle tank in accordance with AS2118-2006 (amend 1) for the annual pump load and water supply flow tests.

Town main water supply (pump boosted or otherwise):

10) In the case of a Hydrant system, adopt a “capture and cart” reuse method for the annual water supply flow test and five yearly hydrant booster test or;

11) In the case of a Sprinkler system, reticulate from the annubar outlet to the building’s on-site grey water treatment storage tank for the annual pump load and water supply flow tests or;

12) In either case, provide drainage system to divide water to a surge tank for immediate reuse of via landscape watering sub-surface reticulation system.

References

1 Roger Thomas, Water Supply Restrictions 2005. Implications for Fire Protection Systems and Fire Fighting.

2 AS1851-2005 Maintenance of Fire Protection Systems and Equipment.

3 Water Pressure Management Program, Sydney Water briefing of FPAA Oct 2006.

4 Yarra Valley Water Pressure Management strategy to PCA November 2006.

5 Extract from UK Fire Service Manual, Vol 1, London 2001.

6 H.W.Marryatt 1988, “Fire – A Century of Automatic Sprinkler Protection”, page 307.

7 Wormald sprinkler system maintenance data for the Sydney metropolitan area.

8 FPAA ongoing review of NSWFB Incident Reporting Systems (AIRS)

9 Supt W. Isemonger NSWFB, False Alarm Reduction – The Facts. July 2006

10 H.W.Marryatt 1988, “Fire – A Century of Automatic Sprinkler Protection”, page 96.