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AN ANALYSIS OF DOMESTIC SPRINKLER SYSTEMS FOR USE IN NEW ZEALAND

BY

F. RAHMANIAN

Supervised by

Dr Andrew H Buchanan

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School of Engineering
University of Canterbury
Private Bag 4800
Christchurch, New Zealand

Phone 643 366-7001
Fax 643 364-2758

ABSTRACT

This report evaluates the economics of domestic sprinkler systems in New Zealand. It includes a literature search, review and comparison of sprinkler codes around the world, costs and benefits of a domestic sprinkler system, and case studies for two single dwellings in Christchurch, followed by three cost-benefit scenarios.

The study concludes that domestic sprinkler systems have tremendous potential for saving life and property.

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NOTATION

A_o	Recurring annual sum to be paid over a period of N years
C	A constant for the type of pipe
F	Future sum of money to be paid in the n^{th} year
FL	Friction loss (kPa/m)
h	Difference in height between sprinklers junction and datums (m)
i	Interest (discount) rate
K	Loss factor listed with the approval for the particular size and type of valve
N	Expected lifetime of the system (year)
P	Pressure loss or gain due to head (kPa)
Q	Discharge from sprinkler (l/min)
R	A constant for the particular type and size of pipe
SPW	Single present worth ($)
UPW	Modified uniform present worth ($)

CHAPTER 1

INTRODUCTION

1.1 Objective

The objective of this study is to undertake an analysis of the potential for domestic sprinkler systems to be used in order to reduce life loss and property damage from fires in New Zealand.

1.2 Scope

This study deals with domestic sprinkler systems in New Zealand for protection against fire hazards in domestic dwellings such as single family homes, townhouses or small apartment buildings. At present, sprinkler systems are not often installed in this type of building.

1.3 Definitions

For the purpose of this report the following definitions apply:

Domestic sprinkler system - A sprinkler system that is used in domestic dwellings such as single family homes, town houses or small apartment buildings.

Residential sprinkler systems - A sprinkler system that is used in large residential occupancies such as rest homes, motels, etc. This system is quite common at the present time.

1.4 Method

The method of carrying out this study was to:

- Undertake a literature survey, of national and overseas studies;
- Review New Zealand and overseas codes;
- Examine the cost of installing domestic sprinkler systems in two typical houses;
- Investigate the potential benefits (life and property protection);
- Consider the following scenarios:

1- Costs and benefits of sprinkler systems for the owner of a single house

2- Costs and benefits of sprinkler systems for new dwellings for a period of 30 years

3- Costs and benefits of sprinkler systems for 10% of existing dwellings and all new dwellings each year.

1.5 Background

The automatic sprinkler system was introduced in New Zealand more than 100 years ago. Since then it has been adopted widely by commercial and industrial occupancies, but not by the domestic residencies. It is the most effective means of fire protection for both life and property that is available today. It's function is to detect and control fires in buildings. Many communities in the United States have experienced that sprinkler systems can save lives and property. The system is simple and consists of a water supply, control valves, alarms, pipes and sprinkler heads that are mounted on pipes at ceiling level. The important parts of a typical sprinkler system are shown in Figure 1.1.

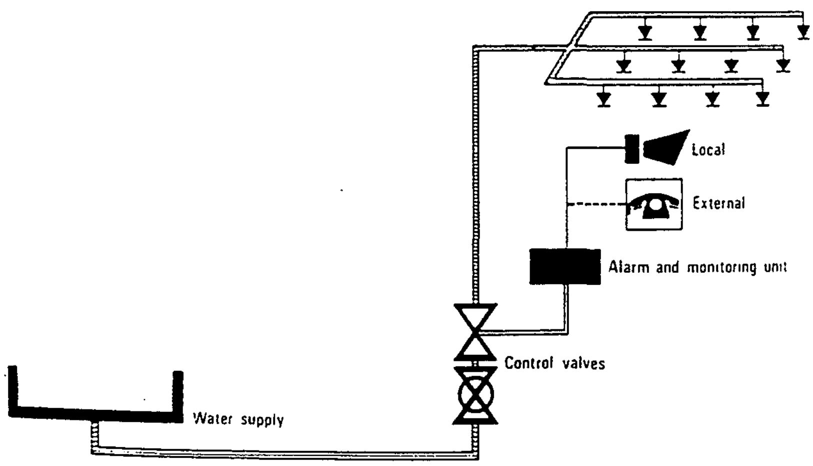


Figure 1.1 - Automatic sprinkler system (Nash 1991)

New Zealand continues to experience death, injuries and property losses as a result of fires. These losses are in spite of the fact that New Zealand has an excellent Fire Service and adequate building code requirements. The number of fire related deaths which occurred between 1986 and 1992 are shown in Figure 1.2.

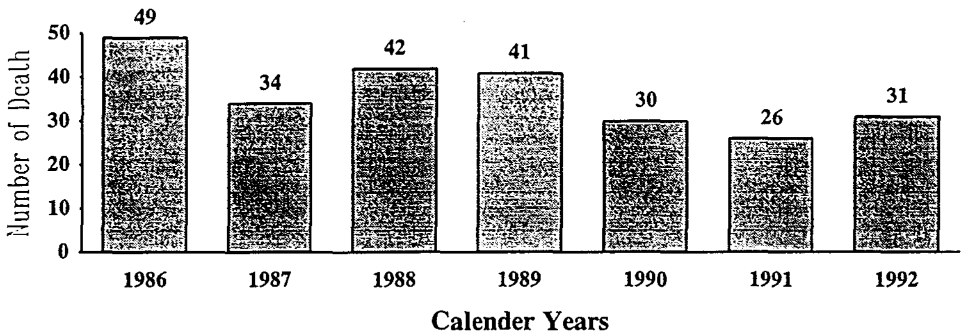


Figure 1.2 - New Zealand's fire death statistic(Emergency Incident Statistics 1992)

A large proportion of these deaths occurred in residential dwellings. Narayanan (1994) has arranged the NZ Fire Service data for fire related deaths and injuries in different building types from 1986 to 1993. Part of this information is reproduced in Table 1.1, showing deaths and injuries in building fires attended by the NZ Fire Service. Table 1.1 does not include other fire related deaths and injuries, such as vehicle fires.

Table 1.1 - Fire related deaths and injuries

Occupancies	No. of Deaths	No. of Injuries
Domestic dwellings	142	1286
Apartments	22	159
Offices	1	35
Schools	0	77
Rest homes	12	29
Hospitals	1	24
Hotels	7	16
Total	**185**	**0**

Table 1.1 shows that approximately 77 per cent of all fire deaths and 79 per cent of injuries occur in domestic dwellings. Only about 50 per cent of all fires in New Zealand occur in homes, where people feel safe and protected, yet most of the fire fatalities occur in these occupancies.

New Zealand fire death rates compare well with several other countries of similar social and economic background. Figure 1.3 compares the number of deaths per million population for selected countries for 1990. This is based on Cropp (1991).

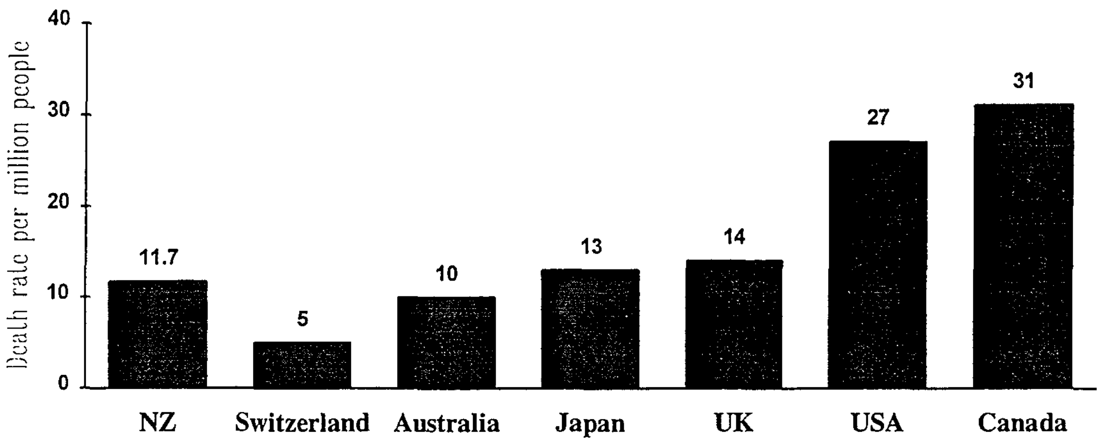


Figure 1.3 - Fire death in various countries

CHAPTER 2

LITERATURE SURVEY

2.1 *Introduction*

This chapter will look at other investigations that have been undertaken in the area of domestic or residential sprinkler systems. There are many elements involving domestic sprinkler systems, and questions that one might ask can be categorised as follow:

- How serious are the fires in dwellings ?
- What are the current preventive methods ?
- What are the alternatives ?
- How much do they cost ?
- What are the disadvantages ?
- What are the advantages and benefits ?
- Do they need maintenance ?

After considering the major studies, the above questions will be answered in subsequent sections of this chapter.

Note: Exchange rates of $US 0.61 = $NZ 1.00 is used in this report, and figures are rounded up to the closest whole digit.

2.2 *Major Studies*

There are many references to residential sprinkler systems in the international literature, mostly in the US. Five studies from three different countries which are more detailed than others will be briefly considered in this section. These are the Melinek study (1993) in the United Kingdom, the Strategos study (1989) in New Zealand, the Ruegg & Fuller study (1984) and the Cote study (1984a, 1984b, 1983a, 1983b) in the United States.

2.2.1 Melinek study

S J Melinek of the Building Research Establishment, Fire Research Station, Borehamwood, Hertfordshire, UK has published a study under the title of ***Potential Value of Sprinklers in Reducing Fire Casualties.*** This paper is part of a research study for developing quantitative fire engineering methods for assessment of fire risk. In this paper no distinction is made between dwellings and other buildings. Techniques that have been used in this paper include:

- Sprinkler reliability
- Sprinkler effectiveness
- The number of sprinkler heads opening
- The area damaged by fire
- Scenario techniques
- Simulation
- Case studies
- Comparison of fires in sprinklered and unsprinklered buildings
- Comparison of fires in which sprinklers work with fires in sprinklered buildings in which the sprinklers do not work.

The paper mentions that sprinklers in all buildings could reduce the number of fatal fire casualties by half, and the number of non-fatal fire casualties by about twenty percent. It states that most fire deaths occur in residential dwellings. Hence many lives could be saved by the universal installation of sprinklers in dwellings, very few of which are currently sprinklered. It also concludes that despite the fact of the substantial reduction in life risk, sprinklers in dwellings may, at current prices, be uneconomic compared with the cost of safety measures in other fields. It is suggested that installation of domestic sprinklers in living and dining rooms might be more cost effective than full protection.

2.2.2 Strategos study

Strategos Consulting Ltd and M & M Protection Consultants prepared a report entitled ***Fire Sprinkler Technology: Costs and Benefits*** for the New Zealand Fire Service Commission which was published in 1989. The authors analysed the overall national and community costs and benefits of sprinklers and related technology. The potential offered by sprinklers for a lower expenditure on the New Zealand Fire Service was also studied.

Methodology that was used by this study group include:

- Literature search
- North American study components
- New Zealand study component
- Fire incidents attended

The study concludes that automatic sprinklers do not produce a net economic benefit and no general recommendation for extending mandatory use of sprinklers can be made. Also the study group concluded that the issue of Fire Service costs and potential for saving cannot be looked at solely in relation to sprinklers or in isolation from funding issues. So it recommended that no attempt be made to cut Fire Service costs purely through mandatory sprinkler systems.

2.2.3 Ruegg and Fuller study

R T Ruegg and S K Fuller from the Operation Research Division of the Center for Applied Mathematics of the National Bureau of Standard, Gaithersburg, MD, USA prepared a report with the title of ***A Benefit-Cost Model of Residential Fire Sprinkler Systems*** for the Fire Safety Technology Division of the Center for Fire Research of the same organisation in 1984.

The aim of this study is to develop and illustrate a methodology for evaluating the cost-effectiveness of fast response automatic sprinkler systems in new single family dwellings. The focus is on modelling the investment decision as it affects the individual homeowner.

The methodology used by this study includes:

- The decision process
- Model of homeowner's investment decision

Nine hypothetical cases were considered from which the study group made the following conclusions:

- Code changes which allow the use of plastic pipe have improved the cost effectiveness of residential sprinkler systems;
- Sprinkler systems might be more cost effective for high risk occupancies than other risk conditions;
- Sprinkler systems are more attractive to people who are part of a community of sprinkler users who receive some saving through local government or the home builder;
- People who live in localities with a "water standby fee" or who use commercial sprinkler systems are unlikely to have a cost effective sprinkler system;
- Sprinkler systems are more cost effective for conditions where additional protection is required, for example, when occupants are not able to respond to the alarm.

2.2.4 Cote Studies

A E Cote is assistant Vice President of the NFPA. He has published the following papers on residential sprinkler systems:

1- ***Field tests and evaluation of residential sprinkler systems*** (Cote 1983a, 1984a, 1984b);

A series of full-scale residential sprinkler fire tests were conducted in a two-story residence in Loos Angeles, CA, and in a mobile home in Charlotte, NC. The aim of the tests was to determine the effectiveness of quick response sprinklers in controlling residential home fires before untenable conditions occur.

The tests resulted in the following conclusions:

- In flaming-started fires, the critical limits for tenability were not exceeded when sprinkler systems controlled the fire;
- In the smouldering-started fires, the critical limits were not exceeded when the transition to flaming occurred and sprinkler system controlled the fires;
- In one smouldering-started fire, the transition to flaming never occurred and critical limits were exceeded;
- In all other tests in which sprinklers were not able to control the fires, the critical limits were exceeded.

2- ***Update on residential sprinkler protection*** (Cote 1983b).

This paper discusses the need for residential sprinklers, the barriers and incentives to the more widespread use of residential sprinklers.

The paper concluded the following:

- The residential sprinkler system is very effective in reducing the loss of life and property damage from fire in dwellings.
- With improvement in technology, the incentives for the use of residential sprinklers are beginning to outweigh the barriers against their use.

2.3 Fire in Domestic Dwellings

New Zealand and overseas studies show that more than half of the fires occur at residential dwellings. A study conducted by BRANZ (Narayanan 1994) indicated that fires which occur in homes account for about 50% of fires in New Zealand, and cause about 77% of fire deaths each year. These figures are higher in the United States; National Fire Protection Association (NFPA) figures show that 75% of all building fires occur in homes (Anon, 1994). Teague (1988) and Cote (1983 b) report that 80% of Americans who died from fire died in their homes. Fire is the second most frequent cause of accidental death in United States homes. Well over a billion dollars of residential property loss results each year from residential fires Ruegg & Fuller (1984).

These trends are similar in the United Kingdom. Craig (1989) notes that every year more than 700 people lose their lives in domestic fire tragedies in the UK. This is about 75 percent of the annual total death toll from fire.

2.4 Fast Response Sprinkler Heads

Automatic sprinkler systems have heat-sensitive sprinkler heads that operate to release water when activated by high temperatures. A "standard" sprinkler head, as used in the industry for many years, will typically operate a few minutes after a fire begins to grow. In recent years "fast response" sprinkler heads have been developed which will operate much sooner than standard heads. Some fast response sprinkler heads have been developed specifically for residential use, designed to provide wide water coverage with spray high up on the walls when operating with limited water supplies. New and improved heads are continually being developed. A typical fast response sprinkler head is shown in Figure 2.1.

Young (1992), reports that the potential for the use of sprinklers in life safety application was recognised in New Zealand in the early 1940s where hospitals were protected by standard sprinklers. Work in the USA in the 1960s led to the development of fast response sprinklers, and residential sprinkler systems using fast response sprinkler heads are now commonplace in much of North America, Australia and New Zealand.

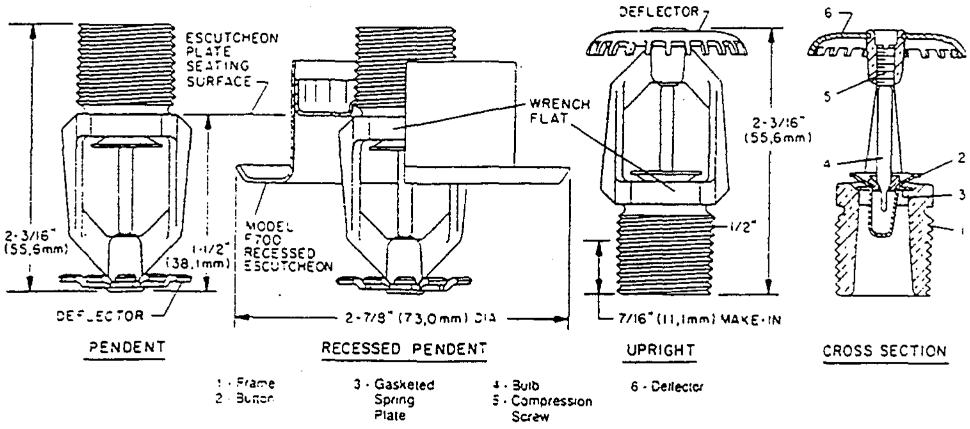


Figure 2.1 - Fast response sprinkler head

The first Underwriter Laboratory listing for a residential sprinkler was granted in June 1981. The sprinkler had a nominal K-factor (loss factor due to valves and sprinkler head) of 2.8, a maximum coverage of 3.65 by 3.65 m and a rapid thermal response. The thermal sensitivity of a sprinkler is measured by its RTI, Response Time Index. Listed residential sprinklers have RTI values of about 40 to 100 $ft^{1/2}$ $sec^{1/2}$. This is five to ten times faster than standard sprinklers (Pounder 1989).

Recently in New Zealand Collier (1994) has tested the operation of sprinkler system in a low cost three bedroom dwelling. His experiments showed that fast response sprinklers with an RTI of 31 and an activation temperature of 68 °C, activated 62 seconds after ignition. Sprinklers were effective in extinguishing the fire.

2.5 Costs of Domestic Sprinkler Systems

Unit costs of sprinkler systems vary from one country to another. This is mostly because of the requirements of different codes of practice or standards in each country. Almost all the sprinkler installers charge on the basis of either per square metre of sprinkler coverage or per number of sprinkler heads used in a building. In both cases as the job gets bigger the cost will decrease (per square metre of floor area or per sprinkler head). Different contractors quote differently. However the cost of sprinkler system for a new house is less than that of an existing house. That is because installation in an existing house is more time consuming than in a new house.

The following references from US literature give some indication of sprinkler costs in that country, with conversions to New Zealand dollars.

Carini (1994) observed that the wholesale costs of residential sprinkler systems to builders generally range from \$US 1.00 to \$US 2.50 per square foot (\$NZ 18 to \$NZ 44 per square metre) of sprinkler coverage. The article cited the National Association of Home Builders (NAHB) Center's findings and analysis which indicated that the cost of residential sprinkler system could be reduced to \$US 0.5 per square foot (\$NZ 9 per square metre) of sprinkler coverage.

In new construction it costs about \$US 2,000 (\$NZ 3300) to install a full sprinkler system in a 1,000 square foot (92.6 metre square) house. ie about \$NZ 35 per square metre. Retrofitting a system to an existing house of the same size costs about \$US 3,000 (\$NZ 4,900). ie: about \$NZ 53 per square metre (Anon, 1994).

Teague (1988) estimates that a residential sprinkler system in a new house costs about \$US 1.00 per square foot (\$NZ 18 per square metre). And a residential sprinkler system in an existing structure is at least three to five times more expensive.

Table 2.1 shows installation costs of sprinklers for four types of residential dwellings in Montgomery County in Maryland, USA. These costs were produced by Operation Life Safety (Anon, 1988).

Table 2.1 - Installation cost of sprinkler system in residential dwellings in Montgomery County, MD, USA

Type of Dwelling	Area (m^2)	Cost	
		\$US / ft^2	\$NZ / m^2
Garden apartment (348 units)	78	0.93	16.5
3 Stories back to back townhouse	150	1.00	18
3 Stories townhouse	200	0.92	16
Single family-detached	250	1.17	21

As it can be seen only American literatures have been used in this section, the reason as far as this study is concerned is because no independent study from another country on this matter has been published yet. Note that even in US the cost of installation varies.

2.6 Causes of The High Cost of Domestic Sprinkler System

Many people ask why the installation of domestic sprinklers is so expensive. The Carini (1994) study shows that a central cause of high cost is the fact that many complex technical and regulatory requirements that were designed for sprinkler installation in commercial, industrial, and technical facilities have been transferred into the field of residential sprinklers. These include special certification of installers; municipal approval of specific, detailed plans; and exclusion from fire sprinkler installation of plumbers who normally install water and gas piping in homes. As the supply of sprinkler installers increase the cost of installation will decline.

The writer also mentions the fact that typically residential sprinkler systems are installed separately from the home's regular water supply by the installers. This results in duplicated effort and physical plant, which create non-value-added cost.

More details are provided in chapter 3 of this report.

2.7 Can Smoke Detectors Substitute for a Sprinkler System

The first alternative to sprinkler systems that come to one's mind is the smoke detector. They are reasonably cheap, and are able to warn the occupant of a possible fire in its early stages. As Buettner (1980) states, smoke detection with an early warning system is the most effective life safety system that can be provided. Occupants can die from smoke and gas produced at temperatures that are too low to activate sprinklers.
But the question is could they really replace a sprinkler system?

Craig (1990) and Budnick (1984) write that smoke detectors can provide adequate time to escape in many cases. But if you are unfortunate enough to be disabled or infirm due to illness or old age, a smoke alarm have little or no benefit. The use of smoke detectors has decreased the number of residential fire fatalities, but detection alone is not sufficient. It cannot save life if the occupants of the building are incapacitated due to age, disabilities or other factors (Oleszkiewicz 1986).

In addition to the obvious fact that sprinklers will control or extinguish a fire, another advantage of sprinklers over domestic smoke detectors is much greater reliability of operation because sprinklers do not rely on batteries for operation.

PLC (1992) reports that in comparing sprinkler system performance to other fire protection measures, there are no other systems or combination of systems which are as effective in reducing both life and property fire losses in buildings.

Anderson (1988) states that smoke detectors and sprinklers can reduce the loss of life by around 98 percent, an increase of some 48 percent over smoke detectors alone.

2.8 Plumbers Installing Sprinkler Systems

One of the ways that could possibly reduce the installation cost of a sprinkler system is to increase the number of people who are allowed to install sprinkler systems. Therefore competition between these people could result in a lower installation costs. Carini (1994) points out that plumbers who normally install water and gas piping in homes must be allowed to install sprinkler systems. If this take place, tougher inspections and control must be put in place to ensure the reliability of the system.

Cote (1983b) states that a mechanism for reviewing the plans and inspecting the sprinkler installation will have to be established to ensure that the sprinkler systems are properly designed and installed before delegating the sprinkler installation to the residential plumber.

2.9 Sprinkler Systems with Plastic Pipe

Another way that could reduce the costs of a sprinkler system may be to use plastic pipe instead of other piping systems. Cote, (1983 b) states that one way to reduce the cost of sprinkler systems, especially retrofit, is to use lightweight plastic pipes. The potential savings appear to be more in the US than in New Zealand.

Plastic pipes are not very common and generally steel pipe is being used for sprinkler systems in New Zealand. Both system have some advantages and disadvantages. Notarianni & Jackson (1994) report that steel and copper fire sprinkler piping have higher mechanical strength and much higher melting points than CPVC and PB pipe. They are less susceptible to damage from dropping or stepping on the pipe, UV exposure, heat, or damage from other work ongoing near the pipe, and also require fewer hangers. CPVC and PB plastic sprinkler pipes, on the other hand are lighter weight and more easily routed around objects in the field, making installation procedures easier. A disadvantage is the wait time for curving of the CPVC joints before water can be put on. Plastic pipes are not susceptible to corrosion and scale build-up as is steel pipe in some circumstances. Economics is an important factor, and the prices for different piping systems vary depending on different factors, including installer experience, size of sprinklered area, available material supply, and local code.

2.10 Sprinkler Acceptance by Users

What is the optimal cost of a sprinkler system ? There can be as many answers to this question as the number of people who answer it. Cote, (1983 b) indicates that a study performed by Yurkonis on user acceptance of domestic sprinkler concepts gave the following results; 50 percent of the people interviewed said that they would not install sprinklers in their homes. 10 percent were afraid of accidental discharge, 10 percent reject the system due to its appearance and 30 percent did not see any need for it. 20 percent said they would install a sprinkler system if it cost $US 0.20 per square foot ($NZ 3.50 per square metre), and 30 percent would install a sprinkler system if there was no cost involved.

2.11 Water Damage Due to Sprinkler Operation

There is a misconception amongst some people (mostly insurers) that water damage from a sprinkler system is more than the property loss in the event of fire.

Two types of water damage by sprinkler systems are considered here. The first is water damage caused by accidental discharge and the second is water damage as a result of sprinkler heads operating in a fire.

2.11.1 Accidental discharge of sprinkler system

Marryatt (1988), uses the NFPA Handbook, 13th Edition, (pages 16-141), and states that according to records of sprinkler leakage loss in the United States, it has been estimated that the chance that a sprinkler may open accidentally because it is defective is less than one in a million each year.

An insurance survey in the US indicates that accidental activation occurs in only one out of 16 million sprinkler heads (Anon, 1994).

2.11.2 Water damage due to sprinkler operation in a fire

Marryatt, (1988) gives the following facts and figures. In fires in Australia and New Zealand involving sprinkler systems, 65% required one head operating, a further 16% of fires required two heads operating. A total of 93% of fires required six heads or fewer in operation and 96% of fires required ten heads or fewer in operation.
He arrives at an estimate of total amount of water discharge in a fire from a sprinkler head under average conditions in Australia and New Zealand. Under the water supply pressure conditions in the majority of systems, it is expected that the discharge per sprinkler head will be of the order of 130-180 l/min. Assuming that the sprinkler system is located two miles from the fire brigade, which will result in a 9 minute response time (by the time the fire service locate the fire), the total discharge from one sprinkler head would be of the order of 1200-1600 litres. On the other hand in the absence of fire sprinklers, even if an alarm is installed which normally gives about two minutes earlier detection time than sprinkler heads, and considering two to three minutes for connection of hoses, still it will usually take 10 minutes or more before the fire service can attack the fire. Remembering that fire growth is exponential, the fire damage and the quantity of water required for extinguishment increases steeply for each minute of delay. The water applied through one standard hose nozzle is at a rate

of about 700 l/min. The greater the delay in attacking the fire with a hose stream the more critical will be the ratio between the growth of the fire and the quantity of water required to extinguish it. So if there is no sprinkler in a building the amount of damage incurred by fire and water will be very much greater than in a sprinklered building.

Marryatt (1988) quotes from the Executive Summary of United States Department of Energy Report issued in June 1982 that both the frequency of losses and the mean dollar loss from sprinkler incidents is about half of that from other water systems on the basis of actual experience.

Bakke (1994) compares two identical living rooms in Egremont, Massachusets, one with a sprinkler system designed according to NFPA 13D and the other without a sprinkler system. Given a response time of 8 to 9 minutes, it took the firefighters 75 minutes and 15,000 to 20,000 gallons (56000 to 74000 litres) of water to suppress the fire after extensive fire damage in the unsprinklered living room. On the other hand the sprinkler was activated 30 seconds after ignition and the fire was extinguished in another 30 seconds. It resulted in a total water use of 180 gallons (50 litres) and minimal fire damage in the sprinklered living room.

2.12 Incentives For Installing Sprinkler Systems

The value of residential sprinkler systems in saving life and property is more recognised in the United States than any other country around the world. There are some incentives that encourage the use of domestic sprinkler systems.

2.12.1 Insurance discount

The majority of insurance companies around the world are reluctant to give a discount on premium for homes that have sprinkler systems. This is basically because domestic sprinkler systems are very few in number, and incidents that show they save life and property are isolated. However some insurance companies recognise the domestic sprinkler system's potential in saving life and property by giving some discount on their premium. For example AllState insurance in US give a 10 percent discount on a homeowner policy if the home is sprinklered (Teague, 1988).

Ronny (1985) writes that the Sentry Insurance company in Phenix, Arizona, offers up to a 50 percent discount on premium for homes with sprinkler systems. With a 50 percent discount in a home with a $400 a year premium, it would not be very long before the initial cost of the system is returned to the owner.

Cote (1983b) writes that an ad-hoc committee from the insurance industry sponsored a number of test fires in Los Angeles and concluded that residential sprinklers have the potential for reducing homeowners' claim payment expenses. As a result, the Insurance Services Office (ISO) Personal Lines Committee recommended that a 15 percent reduction in premium be given for installation of a Residential Sprinkler System installed in accordance with NFPA 13D.

Smeby (1993) states that many insurance companies will deduct as much as 15% from the homeowner policy premium for single family residences with sprinklers and smoke detectors. A $100,000 house would gets a reduction of $7.50 a month on its premium. With a 7.5% fixed interest rate, after 30 years this amounts to $1,072. The average residential sprinkler system costs between $1500 and $2000. This means the actual price is between $428 and $928 or only $2.97 to $6.48 more per month.

2.12.2 Property tax (Rate) reduction

The state of Alaska passed legislation in 1981 that provides 2 percent of the assessed value of any structure would be exempt from taxation if the structure is protected with a fire protection system(Cote, 1983b).

2.12.3 Lower mortgage rate

Cote (1983b) mentions a number of legislative suggestions that have been made to encourage the installation of automatic sprinklers in residences. One of these is that low interest loans be made available to those homeowners or builders who wish to install residential sprinkler systems in new or existing housing.

2.12.3 Trade-offs in building code requirements

Cote (1983b) states that many "authorities having jurisdiction" are considering building code trade-offs as an incentive to the installation of residential sprinklers. Cobb County, Georgia, USA, amended its Buildings and construction code to include tradeoffs for multifamily structures equipped with residential sprinkler systems. These trade-offs include:

- Substitution of 1/2-inch gypsum wallboard and 5/8-inch plywood in place of 5/8-inch fire rated gypsum wallboard and 3/4-inch plywood in 1-hour floor/ceiling assemblies.

- Substitution of 1/2-inch gypsum wallboard in place of 5/8-inch fire rated gypsum wallboard in 1-hour rated tenant separation walls.

- Firestops in attics required at every 3,000 ft^2 (278 m^2) instead of at every tenant unit.

- Maximum travel distance for one exit extended from 20 ft. (6 m) to 35 ft. (10.7m)

- Four-hour firewall separation extended from 6,000 ft^2 (555 m^2) to 10,000 ft^2 (926 m^2)

Buettner (1980) concludes that tradeoffs in the form of reduced fire ratings and other reduction in building quality are not in the public interest. Sprinkler systems are not 100 percent reliable. Hence if they are the only life safety features in a building and do not operate in a fire, the results can be devastating. Safe design should always consider the possibility of sprinkler failure.

Smeby (1993) writes "The sprinklered residences were safer, so they could be built closer together, and the builder could make more money off a parcel of land.

2.13 Care and Maintenance

Even though sprinkler systems are durable, they do require continuous inspections and maintenance.

Nash & Young (1991) refer to a NFPA study and write that 44 percent of unsatisfactory performances of sprinkler systems were directly attributed to inadequate maintenance.

Marryatt (1988) notes in his book that a practice of vital importance was the introduction of automatic alarms to fire brigades. It soon became apparent that false alarms could become a serious problem unless automatic sprinkler systems were maintained in first class working order at all times.

Maryatt has demonstrated that the reliability and performance of sprinkler systems in Australia and New Zealand is excellent, better than in any other part of the world. Reasons for an excellent record of sprinkler performance in New Zealand include the following:

- Stop valve secured against tempering or inadvertent closure
- Direct signal to the Fire Service if pressure drops
- Regular maintenance inspection
- Total building coverage
- Pressurisation of the pipe network system which has the benefits of:
  - Alarm sounding on drop in pressure
  - Distribution of fire spray at high pressure from first head operating.

CHAPTER 3

REVIEW OF CODES

3.1 Introduction

This chapter will briefly outline the code requirements for sprinkler systems in different countries. These are codes in the United States of America, United Kingdom, Australia and New Zealand. A comparison of these codes will be made to the New Zealand standard for residential sprinkler system.

3.2 New Zealand Standards

There are two standards for sprinkler systems in New Zealand, one for residential, one for all others.

3.2.1 NZS 4541:1987 Automatic fire sprinkler systems (Incorporating amendments 1&2)

This is a New Zealand standard that provides rules by which a sprinkler system for commercial, industrial and large residential occupancies may be designed, installed and maintained. It uses conventional, spray, retraced deflector, sidewall and large droplet types of sprinkler heads with a temperature rating from 57 °C to 260 °C for various hazard classes. As stated in the foreword its function is to provide a system which could control the fire in the designed area before levels of toxic products of combustion become life threatening. There is no mention of property protection.

This document is originally based on the Rules of the Fire Offices Committee 29th Edition of UK. It uses American, Australian and some other British and New Zealand standards as its references.

The third amendment of this standard is expected to be published by the end of 1994. There are numerous minor amendments to the existing code but the main issues addressed are: Seismic protection, Residential sprinkler heads, Flammable liquid storage, Pumps, Frier hoods, Evidence of approval to be displayed, Staircases, Water supplies, and Ordinary hazard; substantial changes to part 8.

However the existing code (including amendments no. 1 & no. 2) will be considered here. It consists of twelve parts plus nine appendices, summarised briefly below:

Part 1 Miscellaneous and General Information - Covers general information and definitions.

Part 2 Basic Rules of Design - Defines the basic rules of design and establishes the classes of fire hazard. There are three broad classes of fire hazard;

a) Extra light hazard (ELH): Non-industrial occupancies where the amount and combustibility of the contents is low. This itself is broken into two main groups of educational and residential (boarding houses, hospitals, hotels, motels, prisons, residential clubs and youth hostels).

b) Ordinary hazard (OH): Commercial and industrial occupancies involving the handling, processing and storage of mainly ordinary combustible materials unlikely to develop intensely burning fire in the initial stages. This is further divided into four subgroups, Group 1, 2, 3 and 3 Special.

c) Extra high hazard (EHH): Commercial and industrial occupancies having high fire loads. This is subdivided into EHH-process risk and EHH-high piling of goods.

In order to easily identify any type of occupancy according to the above categories, a representative list of occupancies is included in this part.

Part 3 - Type of System - This part gives the type of sprinkler systems which are covered by this standard. There are two main group of sprinkler systems;

a) Conventional sprinkler systems (individual head operates in response to heat)
b) Deluge system (discharge from a number of heads simultaneously)

Note that deluge systems are only used occasionally in special high risk occupancies.

The conventional sprinkler system itself is divided into wet pipe system, dry pipe system, pre-action system, anti-freeze system, tail end anti-freeze system, alternate wet and dry pipe system, wet pipe or alternate wet and dry pipe system incorporating tail end dry pipe systems, and wet pipe system incorporating tail end alternate systems.

Part 4 System Components - This section covers the system components and explains about the sprinkler types, temperature ratings, orifice sizes and their required performance. It also covers the pipe work, valves, pressure gauges, alarm devices and storage height limitation signs.

Part 5 Location of Sprinklers - This section covers the location of sprinklers and includes topics such as the maximum spacing between sprinklers considering any obstructions, clear space below sprinklers, special requirements for spacing and location of sidewall sprinklers, conditions requiring special consideration, obstruction below sprinklers and external sprinklers. There are small sections on sprinkler installation in film and television production studios, theatres and music halls, cupboard and wardrobes and skylight shafts. All parts of each building must be protected with sprinklers.

Part 6 Water Supply - This section deals with the water supply requirements. The following topics are discussed in this section: flow and pressure requirements, classes of water supply, storage tank capacity and refilling, town mains, boosted town mains, supplemented town mains, pumped supplies, elevation tanks, pressure tanks, brigade inlet connections and proving of water supplies.

Parts 7-9 Extra Light Hazard, Ordinary Hazard and Extra High Hazard system design data - These are the titles of each part respectively. Water supplies, sprinkler type and spacing, area of operation, number of heads operating, pipework and other special requirements are discussed separately in each part.

Part 10 Fully Hydraulically Calculated Design - This gives the design requirements and the way in which area of operation, design flow and pressure are determined. Also it outline the methods of calculation and documentation.

Part 11 Precautions to be Taken when an Installation is Rendered Inoperative - This part gives precautionary procedures that should be followed by contractors.

Part 12 Routine Testing, Maintenance and Surveying - This section gives procedures that should be followed weekly, monthly, quarterly, yearly and four yearly for routine tests and maintenance.

Materials which are covered in appendices are testing of territorial local authority water mains, orifice plates, minimum criteria for embankment supported membrane pillow tanks, sprinkler system storage declaration, aerosols background and example of classification, aerosol warning signs, evaluation of contractors, certificate of approval of contractor and some explanatory information about the large droplet sprinklers.

3.2.2 NZS 4515: 1990 Residential Fire Sprinkler Systems

The requirements of this standard are similar to those of NZS 4541, except it requires different types of sprinkler heads, number of heads operating, control valve sets, and design flows and pressures. This standard is based upon residential sprinkler heads which will operate earlier than conventional types in the typical pattern of fire development. It has the stated intention to maintain a high standard of reliability of fire sprinkler systems in New Zealand. A residential sprinkler system that complies with this standard should control the fire so that the conditions throughout the building are survivable for at least 20 minutes after ignition. It contains many details and assumes that all systems will be designed, installed and maintained by approved contractors.

The first amendment of this standard is expected to be published by the end of 1995. There are number of amendments which maintain alignment with NZS 4541. There are also other amendments from which the main changes are: the response time for sprinklers in roof, ceiling and under floor spaces, the alarm connection and the use of CPVC pipes. However the existing code (NZS 4515: 1990) will be considered here.

Only systems in buildings used as residences can be designed according to this standard. The limitations are:

a) - The sum of the area of all the floors does not exceed 500 m^2

b) - Not more than two stories high.

These limits can be increased to 2000 m^2 and four stories high respectively, if the sprinkler system has a water supply which will provide at least 60 minutes flow at the design flow and pressure, and the system is fitted with a fire sprinkler inlet and a fire brigade alarm to ensure rapid arrival of the Fire Service to ensure rapid evacuation, search and rescue.

Sprinkler systems which exceed these limits should be designed according to NZS 4541: 1987 Automatic Fire Sprinkler Systems.

This standard permits the use of chlorinated PVC and polybutylene pipe which has been tested and listed for fire sprinkler use by either Underwriters' Laboratories or Factory Mutual.

Each requirement in this document is dependent on compliance with other requirements for technical validity. So in order to comply with this standard, a system should conform to all requirements of this document.

The standard consist of eight sections and seven appendices. References are made to American, British, German and other New Zealand standards. The contents of each section are briefly summarised below:

Section 1 General Requirements - This section covers scope and application of this standard, definitions, compliance, approval of contractors, seismic resistance, workmanship, welding or other hot work and documentation.
Section 2 General Design Requirements - This section gives details on extent of protection, type of system, provision of hand operated fire fighting appliances and materials with a high spread of flame index.

Section 3 System Components - This section discusses and specifies the maximum operating pressure for a sprinkler system, type of sprinkler head to be used, sprinkler head guards, stock of replacement sprinkler heads, allowable pipes and jointing options, installation control valves and other items that shall be located within the same enclosure, required alarm types, Fire Brigade alarm connection, pressure reducing valve and automatic pressure relief valve.

Section 4 Location of Sprinklers - This section specifies the location of internal and external sprinklers throughout the building.

Section 5 Determination of Water Supply Requirements - This section defines the methods for calculation of the design flow and design pressure in different parts of a building.

Section 6 Water Supply - This section sets out the water supply requirements which include town mains, storage tank, pumped supplies, elevated tanks, fire sprinkler inlet and water supply characteristics.

Section 7 Hydraulic Calculations - This section sets out a hydraulic calculation method that determines the compliance of the sprinkler system with the demand requirements of section 5.

Section 8 Testing, Maintenance and Survey Inspection - This section covers the weekly, monthly and periodic tests and maintenance of sprinkler systems, record keeping of all inspections and tests and precautions when a system is impaired.

The following materials are given in appendices A - G;

A- Residential sprinkler system certificate of compliance

B- Residential sprinkler system extension of certificate of compliance

C- Testing of territorial local authority water mains

D- Guidelines for evaluation of contractors by authority having jurisdiction

E- Certificate of approval of contractor

F- Technical requirements for routine system testing of pumps

G- Application for approval of residential sprinkler system to NZS 4515: 1987

3.3 American Standards

There are three standards for sprinkler system in the United States, two for residential, and one for all others.

3.3.1 NFPA 13 - 1991 Standard for the installation of sprinkler systems

This is an American standard produced by National Fire Protection Association (NFPA) in the United States. It provides rules for design and installation of automatic sprinkler systems for commercial, industrial and large residential (more than 4 stories) occ-upancies. As stated the purpose of this standard is to provide a reasonable degree of protection for life and property from fire through standardisation of design, installation, sound engineering principles, test data and field experience.

It consists of ten chapters and three appendices. The contents of each chapter are summarised here:

Chapter 1 General Information - This chapter covers the scope, purpose, retroactivity clause, definitions, abbreviations and level of protection.

Chapter 2 System Components and Hardware - This chapter set outs requirements for use of sprinkler system components. It contains some general information followed by information on sprinklers, pipe and tube, fittings, jointing of pipe and fittings, hangers, valves, fire department connections and water flow alarms.

Chapter 3 System Requirements - This chapter defines the requirements for wet pipe, dry pipe, pre-action and deluge, combined dry and pre-action, and anti freeze systems. It also covers requirements for automatic sprinkler systems with nonfire protection connections, outside sprinklers for protection against exposure fires, sprinkler system in cold storage rooms, and commercial-type cooking equipment and ventilation.

Chapter 4 Installation Requirements - This chapter includes basic requirements for spacing, location, and position of sprinklers, protection area limitations, use of sprinklers, sprinkler spacing and location, piping installation and system attachments.

Chapter 5 Design Approaches - This chapter contains general information, occupancy and hazard classification, and special design approaches.

It classifies the occupancies into four classes: Light (low) hazard, Ordinary (moderate) hazard, Extra (high) hazard and special occupancy hazard. Light hazard is where the amount of combustible materials are of minor quantity. Ordinary hazard is where the amount of combustibles and flammables are presented in greater quantity than light hazard. Ordinary hazard is subdivided into two groups, group 1 and group 2. Extra hazard is where the total amount of combustibles and flammables present, in storage, production use, and/or finished product is over and above those expected for ordinary hazard.

Chapter 6 Plans and Calculations - This chapter set outs the requirements for working plans, hydraulic calculation forms, water supply information, hydraulic calculation procedures, and pipe schedules.

Chapter 7 Water Supplies - This chapter requires that all sprinkler systems shall have at least one automatic water supply and specifies the types of water sources for sprinkler systems.

Chapter 8 System Acceptance - This chapter covers the requirements for approval of sprinkler systems, instruction and circulating closed loop-systems.

Chapter 9 System Maintenance - This chapter specifies the requirements for maintenance, replacement of sprinklers, obstruction in piping and testing of anti freeze systems.

Chapter 10 Referenced Publication - This chapter is a list of American publications that were used by this standard.

Appendices - appendices are not part of the requirements of this standard, but are included for information purposes only.

3.3.2 NFPA 13D - 1991 Standard for the installation of sprinkler systems in one and two family dwellings and mobile homes

This is an American standard for the installation of sprinkler systems in one and two family dwellings and mobile homes produced by the National Fire Protection Association (NFPA). It has five chapters and two appendices.

Chapter 1 General Information - This chapter covers general information such as scope and purpose of this standard, definitions, maintenance, devices, materials, design, and installation and units of measurement.

Chapter 2 Water Supply - This chapter includes general provisions, water supply sources, multipurpose piping systems and mobile home water supply.

Chapter 3 System Components - This chapter sets out the requirements for valve and drain arrangements, pressure gauges, piping types; properties and supports, sprinklers types, painting and ornamental finishes and alarm systems.

Chapter 4 System Design - This chapter specifies the design criteria, position of sprinklers, allowable system types, pipe sizing, piping configurations and location of sprinklers.

Chapter 5 Referenced Publication - This chapter is a list of documents that are referred to in this standard and are part of its requirements. All of these documents are American publications.

Appendices are not part of the requirements of the code, but are included for information purposes only.

3.3.3 NFPA 13R - 1991 Standard for the installation of sprinkler systems in residential occupancies up to and including four stories in height

This is an American standard for the installation of sprinkler systems in residential occupancies up to and including four stories in height. This standard is intended to provide life safety and property protection for low rise, multifamily dwellings. It can be regarded as an amendment to the NFPA 13D standard. It has slightly more details on working plan, acceptance tests and systems design than the NFPA 13D document. It consist of three chapters and two appendices.

Chapter 1 General information - This chapter is similar to chapter one of NFPA 13D with some more details and explanations. It includes scope and purpose of this standard, definitions, units of measurement, piping and system types.

Chapter 2 Working plans, Design, Installation, Acceptance tests, and Maintenance - This chapter has seven main sections and gives requirements for approval of the working plan and its characteristics, approval of sprinkler systems and finally acceptance tests and flushing of underground connections in the first section. It follows with design and installation, water supply, system components, system design, location of sprinklers and maintenance.

Chapter 3 Referenced Publications - This chapter is a list of documents that are referred to in this standard and are considered as part of its requirements. All of these documents are American publications.

Appendices are not part of the requirements of this document, but are included for information purposes only.

3.4 British Standards

There are two documents regarding sprinkler systems in the United Kingdom, TB 14 for residential and BS 5306: Part 2 for all others.

3.4.1 BS 5306: Part 2: 1990 Fire extinguishing installation and equipment on premises. Specification for sprinkler systems

This is a British standard for installation of sprinkler systems. It must be used in conjunction with the 'Rules for automatic sprinkler installations' issued by the Loss Prevention Council (LPC) of UK. This standard specifies requirements and gives recommendations for design, installation and maintenance of fire sprinkler systems in buildings and industrial plant. It states that sprinkler systems in addition to property protection may serve for the protection of life, but additional requirements may be necessary for systems specifically intended for life safety protection. The requirements of this document are very much the same as NZS 4541:1987. It can be regarded as the British document on which NZS 4541:1987 was based.

This standard consists of seven sections and three appendices. Each section is divided into several sub-sections covering detailed requirements and information. They can be summarised as follow:

Section 1 General - This section covers introduction, scope and definitions.

Section 2 Planning - This section set outs the initial consideration when considering a sprinkler systems, extent of sprinkler protection, classification of occupancies and fire hazards, selection of installation types; size and design, and hazard to personnel.

It classifies the occupancies and fire hazard into three categories, Light hazard, Ordinary hazard and Extra high hazard.

Non-industrial occupancies such as hospitals, hotels, institutions, libraries, nursing homes, office buildings, prison, school and colleges etc. where the amount and combustibility of the contents are low are classified as light hazard occupancies.

The Ordinary hazard is further divided into four groups, group I to group III Special.

Commercial and industrial occupancies having abnormal fire loads are classified as high hazard and are sub-classified as process high hazard, high-piled storage hazard, potable spirit storage hazards and oil and flammable liquid hazard.

Wet pipe, alternate (wet and dry pipe), dry pipe, pre-action, and recycling sprinkler systems are permitted by this standard. Also wet pipe and alternate systems may include tail-end alternate, Tail-end dry pipe, and deluge systems.

Section 3 Contract Arrangements - This section specifies the requirements for contract drawings/information documents, work on site, commissioning and acceptance tests, extension and alteration of sprinkler systems.

Section 4 Water Supplies - This section covers some general information such as reliability and quality of water supplies, and connections supplying water for other services. It follows by detailed requirements on types of water supply, design density and assumed area of maximum operation for fully hydraulically calculated installations, water supply pressure-flow characteristics and velocity, water storage capacity, town mains, elevated private reservoirs, gravity tanks, suction and booster pumps, pressure tanks, hydraulic calculation and pipe sizing table, and pressure flow tests on water supplies.

Section 5 - Components and Installation Design - This section includes the requirements for valves, pipe and pipe fittings, pipework supports, pipework in cold storage warehouses, pipe sizing and sprinkler array design, sprinkler; multiple control and sprayer design characteristics and uses, sprinkler spacing, arrangement and location, alarm and alarm devices, and pressure gauges.

Section 6 Signs, Notices, Information and Colour coding - Requirements for block plan, signs and notices, marking and colour coding are in this section.

Section 7 Upkeep of the System - This section gives the requirements for inspection and maintenance of sprinkler systems. It includes general arrangement, actions following sprinkler operation, user's programme of inspection and checking, service and maintenance schedules.

Materials covered in appendices A-C respectively are water supply pressure test, orifice plate design and precautions when carrying out hot work.

3.4.2 Technical Bulletin 14: 1990 Sprinkler systems for dwelling houses, flats and transportable homes

This document is one of a series of Loss Prevention Council (LPC) technical bulletins for sprinkler systems. It is the first publication in the UK that specifies the requirements for the installation of sprinkler systems in dwelling houses, flats and mobile homes.
The bulletin, together with British Standard 5306:part 2:1990, form the LPC Rules for automatic sprinkler installation in domestic homes.

The bulletin has its limitations and does not apply where more than two dwellings have a common water supply connection to a town main or water storage tank.

It is the stated intention of this specification to reduce the likelihood of death and serious injury, and fire damage to property in the event of fire.

There are eleven sections in this bulletin. The content of each section is briefly out lined below:
Section 1 and 2, Introduction and Scope respectively.

Section 3 General - This section introduces the components of a domestic and mobile home sprinkler system, gives a typical sprinkler installation layout and specifies the precautionary requirements.

Section 4 Definitions - This section defines the technical words.

Section 5 Consultation - This section gives a list of organisations that must be consulted at an early stage of consideration of a sprinkler system.

Section 6 Components - This section covers the requirements for different components of a sprinkler system such as pipe, fittings and sprinkler heads.

Section 7 Design Consideration - This section includes materials such as extent of sprinkler protection, installation type, water supply, control and monitoring equipment, pipe work and sprinkler coverage and location.

Section 8 Installation - This section sets out the requirements for the installer, pipe work support and pipe work accessibility.

Section 9 Commissioning - This section defines the requirement for leakage and installation flow testing.

Section 10 Documentation - This section specifies the acceptable way of presentation of all drawings and documents, and information that must be provided for the user.

Section 11 Bibliography - This section is a list of different publications including NFPA13D.

3.5 Australian Standards

There is only one standard for all occupancies in Australia. There is no Australian equivalent of NZS 4515: 1990. However a draft code of practice for one and two family dwelling sprinkler systems was introduced in 1992. It is expected that it will form part of AS 2118. It is totally based on American standard 13D and 13R.

Nevertheless the design, installation and maintenance of domestic sprinkler system in Australia is covered by AS 2118: 1982 under the light hazard category. If a comparison of Australian standards to that of New Zealand has to be made, it should be made to NZS 4541: 1987. Both AS 2118: 1982 and NZS 4541: 1987 are based on the Rules of the Fire Offices' Committee of UK and are very similiar. A detailed comparison of these two documents is beyond the scope of this project.

3.5.1 AS 2118: 1982 SAA code for automatic fire sprinkler system

This is an Australian code for automatic sprinkler systems that provides rules by which a sprinkler system for all types of buildings can be designed, installed and monitored. This document incorporates amendments 1, 2 and 3. Amendment 3 was published in 1989. Unlike America, Britian and New Zealand that have a separate code for domestic sprinkler systems, domestic sprinkler systems are included in this standard as part of light hazard occupancy classification.

It is stated that this document is closely aligned with the Rules of (formerly) the U.K Fire Offices' Committee (FOC) for automatic sprinkler installation, and with other overseas standards, but mentions no names.

It consists of eleven sections in three parts, four appendices and one annex.
Part one consists of section one and two, part two consists of sections three to eight, and part three consists of sections nine to eleven. These are briefly summarised below:

Part 1 Scope, Definitions, Classification and Design data

Section 1 covers scope and definitions.
Section 2 Sets out classification of sprinkler system and design data.

There are three classes of occupancies recognised by this standard, Extra light hazard, Ordinary hazard and Extra high hazard. There is a list of examples for each class.

Extra light hazard occupancies includes occupancies like boarding houses, residential section of clubs, hotels, motels, office, prisons, schools, colleges, hospitals and homes.

Ordinary hazard occupancies are divided into four groups, Group I, II, III and III special.

Extra high hazard occupancies are divided into Extra high hazard process risk and Extra high hazard high piled storage risk. Extra high hazard high piled storage risk is subdivided into four categories, with a list of examples for each category.

There are two types of sprinkler systems permitted by this code;

- Standard sprinkler systems
- Deluge systems

Standard sprinkler systems are divided into wet pipe, alternate wet and dry pipe, wet pipe or alternate wet and dry pipe; incorporating tail-end dry pipe systems, wet pipe incorporating tail-end alternate systems, dry pipe, and pre-action systems.

Part 2 General Requirements

Section 3 Installation - This section sets out requirements for confirmation of class of hazard, information to be provided for approval of sprinkler systems, extent of sprinkler protection, protection against exposure hazards, transmission of alarm signal to fire brigade, local alarm and system monitoring.

Section 4 Water Supplies - This section specifies the acceptable sources of water supply, water supply grades, connections to other services, pressure and flow requirements, pressure limitations, minimum capacity of stored water supplies, pump suction tanks, private water supplies, town mains, pump installation, pump sets, pressure tanks and proving of water supplies.

Section 5 Spacing and Location of Sprinklers - This section covers standard spacing and staggered spacing of sprinklers, minimum distance between sprinklers, location of sprinklers, locations or conditions involving special consideration, obstruction below sprinklers, sprinkler spacing in film and television production, theatres and musical halls, and in cold storage warehouses.

Section 6 Sprinkler, Sprayers and Multiple controls - In this section the following topics are discussed: types of sprinklers, sprayers and multiple controls, sprinkler K factors, orifice and thread size, application of sprinkler types, temperature ratings, colour coding, stock of replacement sprinklers, anti corrosion treatment of sprinkler, sprinkler guards, escutcheon plates, and protection against frost.

Section 7 Pipework - This section sets out the requirements for pipe and pipe fittings specifications, hydraulic test pressure, pipe jointing, embedding of pipework, corrosion protection of pipework, pipework in unsprinklered buildings, protection of pipework against mechanical damage, hazardous processes and explosion hazard, facilities for flushing pipework, prohibited use of pipework, slope of pipes for drainage, low level drainage, pipe sizes, orifices plates, and support of sprinkler pipework.

Section 8 Valves and Ancillary Equipment - This section contain information on installation control valves, stop valves, block plan, location plate, non-return valves, alarm valves, pressure reducing valves, deluge and pre-action valves, alarm devices and pressure gauges.

Part 3 Summaries of Requirements for System

Sections 9-11 - Extra Light, Ordinary and Extra High Hazard class system respectively. These sections contain requirements for each class of occupancy. These requirements are: design data, water supplies, spacing of sprinklers, system components, system drainage and the number of sprinklers controlled by one set of valves.

3.6 Comparison of Codes

3.6.1 Comparison of NZS 4515: 1990 with NFPA 13D

Both of these standards are for residential occupancies and have some similarities, but NZS 4515 is more conservative and has more details of its requirements. There are some differences between these two documents and the main differences are described in Table 3.1:

Table 3.1 - Comparison between NZS 4515: 1990 and NFPA 13D: 1991

NZS 4515: 1990	NFPA 13D: 1991
For residential buildings that have 500 m^2 floor area and a maximum of two stories. These limits can be increased to 2000 m^2 and four stories respectively if the building has fire brigade alarm connection, fire sprinkler inlet and a water supply which will provide at least 60 min. flow at the design pressure.	For one and two family dwellings and mobile homes and does not indicate any height or floor area limitation.
Requires a sprinkler operating alarm and an evacuation alarm (could be sprinkler operating alarm with additional sounders or in a single dwelling could be the sprinkler operating alarm provided it can be heard throughout the building).	Requires local water flow alarms or smoke detectors.
Does not make any assumption on smoke detectors installations.	Assumes that one or more smoke detectors will be installed in the dwelling.
Has detailed requirements on compliance, approval of contractors, seismic resistance, workmanship and documentation.	All responsibilities for compliance and workmanship is left to owner and the authority having jurisdiction.
Requires sprinklers throughout the building with some exceptions in concealed spaces only after certain	Excludes sprinkler in bathroom 5.1 m^2 and less, closets and pantries 2.2 m^2 and less, garages, open attached porches,

requirements have been met. It also requires external sprinklers for protection from adjacent structures or accumulation of combustibles which are not sprinklered.	carports, attics, crawl spaces and other concealed spaces that are not used or intended for living purposes or storage. External sprinklers are not required.
Allows wet pipe and antifreeze type of systems.	Allows dry pipe, wet pipe and antifreeze type of systems.
Requires a minimum flow rate of 100 l/min for a single operating sprinkler head.	Requires a minimum flow rate of 68 1/min for a single operating sprinkler head.
The number of design sprinklers include all sprinklers in a compartment to a maximum of three sprinklers in some compartments.	The number of design sprinklers include all sprinklers within a compartment to a maximum of two sprinklers.
Requires different sprinkler coverage areas for rooms, skylight shafts, basements and garages, external protection, roofs, ceilings and under floor spaces sprinkler heads.	Maximum coverage area for a single sprinkler head of 13.4 m^2 with a maximum distance between sprinklers of 3.7 m on or between pipelines. The maximum distance from a wall or partition is 1.8 m and the minimum distance between sprinklers within a compartment is 2.4 m.
Allows a common supply main to the building, serving both sprinklers and domestic uses. The connection can only be upstream of the domestic water meter.	Allows a common supply main to the building, serving both sprinklers and domestic uses. The connection could be upstream or downstream of domestic water meter.

3.6.2 Comparison of NZS 4515: 1990 with NFPA 13R

Comparisons that were made between NZS 4515: 1990 and NFPA 13D: 1991 in the previous section are also valid here, except in the parts described in Table 3.2.

Table 3.2 - Comparison of NZS 4514: 1990 with NFPA 13R: 1991

NZS 4515: 1990	NFPA 13R: 1991
For residential buildings that have 500 m^2 floor area and a maximum of two stories height. These limits can be increased to 2000 m^2 and four stories height respectively if the building has fire brigade alarm connection, a fire sprinkler inlet and a water supply which will provide at least 60 min. flow at the design pressure.	For low-rise, multifamily dwellings up to and including four stories in height. Does not indicate any floor area limitation.
The number of design sprinklers includes all sprinklers in a compartment to a maximum of three sprinklers.	The number of design sprinklers includes all sprinkler in a compartment to a maximum of four sprinklers.
Allows wet pipe and antifreeze systems.	Allows dry pipe, wet pipe, preaction and antifreeze systems.

There is considerable debate about the need for sprinklers in concealed ceiling spaces. In the USA, there is no requirement for sprinkling ceiling spaces because of possible problems with freezing, on the basis that only 91% of fires start in these spaces. Sprinklering of ceiling spaces in New Zealand has been required considering a less severe winter climate and 15% of reported fires starting in roof spaces (John Fraser, pers. comm.).

3.6.3 Comparison of NZS 4515: 1990 with TB14: 1990: 1

TB14: 1990: 1 is the British code for domestic sprinkler systems and should be used in conjunction with BS 5306: part 2: 1990. This is very similar to NZS 4515: 1990, perhaps this is not surprising since standards for sprinkler systems in New Zealand are largely based on Rules of the Fire Offices' Committee of the United Kingdom. However NZS 4515: 1990 seems to be more comprehensive than its British equivalent. There are some differences between these standards which are tabulated in Table 3.3.

Table 3.3 - Comparison of NZS 4515: 1990 with TB14: 1990: 1

NZS 4515: 1990	BT14: 1990: 1
For residential buildings that have 500 m^2 floor area and a maximum of two stories height. These limits can be increased to 2000 m^2 and four stories height respectively if the building has fire brigade alarm connection, fire sprinkler inlet and a water supply which will provide at least 60 min. flow at the design pressure.	There is no mention of any area limitations.
Multifamily dwellings can have a common water supply connection provided it can supply the required flow and pressure.	Only two dwellings can share a common water supply connection to a town main or water storage tank.
Requires seismic resistance for sprinkler system.	Seismic resistance is not mentioned.
Allows residential, quick response, standard response and drencher sprinkler heads.	Allows only domestic and standard quick response sprinkler heads.

Allows 10 mm and 15 mm sprinkler heads.	Allows only 15 mm sprinkler heads.
Requires sprinkler protection throughout the dwelling except in some concealed spaces after satisfying certain requirements.	Requires sprinkler protection throughout the dwelling with no exception.
Requires sprinkler protection from other structure, or accumulation of combustibles which is not itself sprinklered.	Requires no sprinkler protection from other structure, or other combustibles.
Allows only wet pipe or anti-freeze installation.	Allows only wet pipe installation.
Allows direct connection to a reliable town main, elevated tank and pump supply from the permitted sources as a water supply.	Allows direct town main connection, gravity tank, pressure tank and automatic pump drawing from a stored water supply as a water supply.
Requires to use approved sprinklers. The manufacturer ratings of these sprinklers provide the flow rate for each type of approved sprinkler head.	Requires flow rates of 60 l/min through any single sprinkler and 42 l/min per sprinkler through any two sprinklers operating in a compartment.
Requires a water supply that is capable of supplying simultaneously the design flow and pressure requirements of the sprinkler system and the domestic demand.	Requires an addition of 50 l/min to the above flow rates where the connection serves a sprinkler system and domestic services.
Requires a minimum capacity for the storage tank of the greatest design flow for 20 minutes or 60 minutes if limitations on	Requires a minimum capacity for storage tank of the greatest design flow for 10 minutes.

floor area are exceeded.	
Requires two pressure gauges in the installation control valve sets, one for measuring the mains water supply pressure and the other for measuring the pressure in the sprinkler system.	Requires one pressure gauge in the installation control valve sets for measuring the pressure in the sprinkler system.
Requires the pipework between the town main and the installation valve to be of at least 20 mm diameter.	Requires the pipework between the town main and the installation valve to be of at least 25 mm diameter.
Requires anti-freeze solution for frost protection.	Requires protection against freezing by the manner of its installation, or installation, or insulation and electrical trace-heating.
Refer to the manufacturers' listing for sprinklers spacing and positioning.	Specifies sprinklers spacing and positioning.
Does not require tests for leakage.	All sprinkler installations must be tested for leakage at the commissioning stage over a period of at least 8 hours.

3.7 Summary

There are basically two types of standards available for sprinkler systems in New Zealand, United States, and United Kingdom. One for the residential occupancies and one for other occupancies. In the United States there is a further distinction between sprinkler systems for one and two family homes, and larger residential buildings up to four storeys tall.

The contents of the standards are very similar. However there are some major differences between New Zealand standard NZS 4515 and American standard NFPA 13D for residential sprinkler systems. NFPA 13D does not require sprinkler protection in attics and other concealed spaces, garages, carports and similar structures. Also there is no requirement for protection from neighbouring structures or combustible materials in NFPA 13D. NZS 4515 requires sprinkler protection throughout the buildings.

CHAPTER 4

BENEFITS AND COSTS

4.1 Introduction

This chapter will discuss the benefits and costs of domestic sprinkler systems. Benefit and cost streams associated with domestic sprinkler systems can be divided into the following major groups:

Benefit streams: **Direct benefits**

Indirect benefits

Cost streams: **Direct Costs**

Each group can be further subdivided into subgroups as follows:

Direct benefits:

- Life protection
- Property protection of owner's building
- Property protection of adjacent buildings

Indirect benefits:

- Insurance discount
- Reduction in injuries and medical treatments
- Reduction in size of fire station
- Reduction in fire fighters early retirement through injury
- Reduced rates (property taxes)
- Reduced mortgage rate
- Trade-offs in building code requirements
- Reduced environmental impacts
- Reduction in relocation,
- Reduction in loss of valuable and personal property
- Peace of mind to the owner

Direct costs:

- ♦ Installation
- ♦ Maintenance

Each of these will be discussed in this chapter.

4.2 Background Information

4.2.1 Life and property protection

The benefits of residential sprinklers will be the lives saved, injuries prevented, and property loss reduced.

Since the development of fast response sprinklers, many tests have been performed around the world on their reliability and effectiveness. The tests provided conclusive and well documented data that sprinkler systems are effective in reducing risk to life and property. To be effective sprinklers must be properly designed, installed and maintained. The primary effect of sprinklers is to minimise the likelihood of large fires and to improve life safety.

The principal economic benefits from any residential fire protection strategy result from the potential reductions in losses from fires and from reduction in the underlying probability of fire (USFA 1989). The major categories of economic benefits are:

- Reduced property damage costs
- Reduced property insurance premiums
- Construction variances accompanying sprinkler system
- Increased marketability of units equipped with fire sprinklers.

4.2.2 Fire dynamics

When fires start and burn freely without any fire fighting intervention, three phases of development for fires can be recognised, 1. growth, 2. fully burning and 3. decay. A typical fire development curve is shown in Figure 4.1.

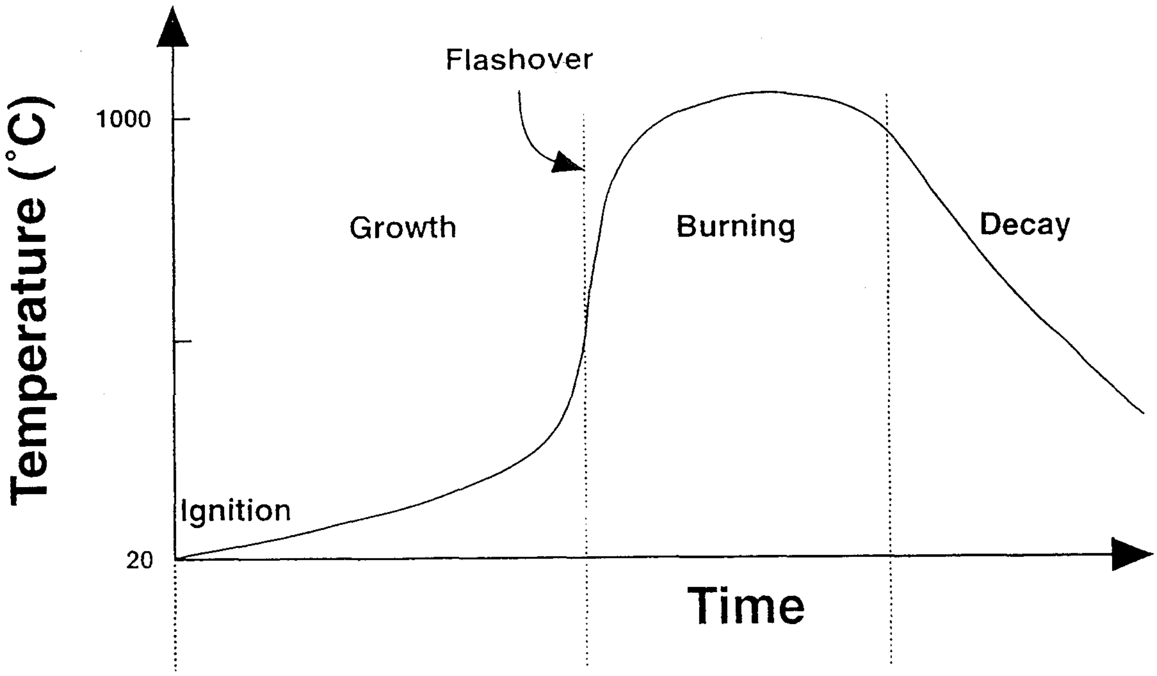


Figure 4.1 - Typical fire development curve (Fire Engineering Design Guide 1994)

Flashover is the transition step from the growth phase to the fully burning phase. In most fires flashover occurs in the first 10 minutes depending on the fuel. When flashover occurs in a compartment nothing can be saved in that compartment, and fire fighters can only try to stop the fire spreading to other areas. The majority of residential home contents are combustible and burn well in a fire, leading to an early flashover. Therefore to be effective in saving life or property the fire must be controlled or suppressed in the early stages of growth, requiring an early detection system. Heat and smoke detectors can detect fires and if somebody could hear the alarm, hopefully they are able to call the fire services. In urban areas the New Zealand Fire Service generally can be at the scene of a fire about eight minutes after receiving the call. In most cases this is too late for saving a life or property. Sprinkler systems fight the fires as soon as they are detected by the sprinkler head. This means that the fire is either suppressed or controlled to a manageable size by the sprinklers before arrival of the fire service. Table 4.1 compares the response time for different detectors.

Table 4.1 - Response time of various detectors *(Fire Engineering Design Guide 1994)*

Type	Response Time (min)	Fire Size
VESDA (Very Early Smoke Detection Apparatus)	1	10-100 W
Smoke detector	1-3	100W-1kW
Heat detector	2-5	5-10 kW
Normal Sprinkler	5-10	10-15 kW
Quick response sprinkler	2-5	5-10 kW

Figure 4.2 shows how fire growth can be restrained in the early stages by a sprinkler system.

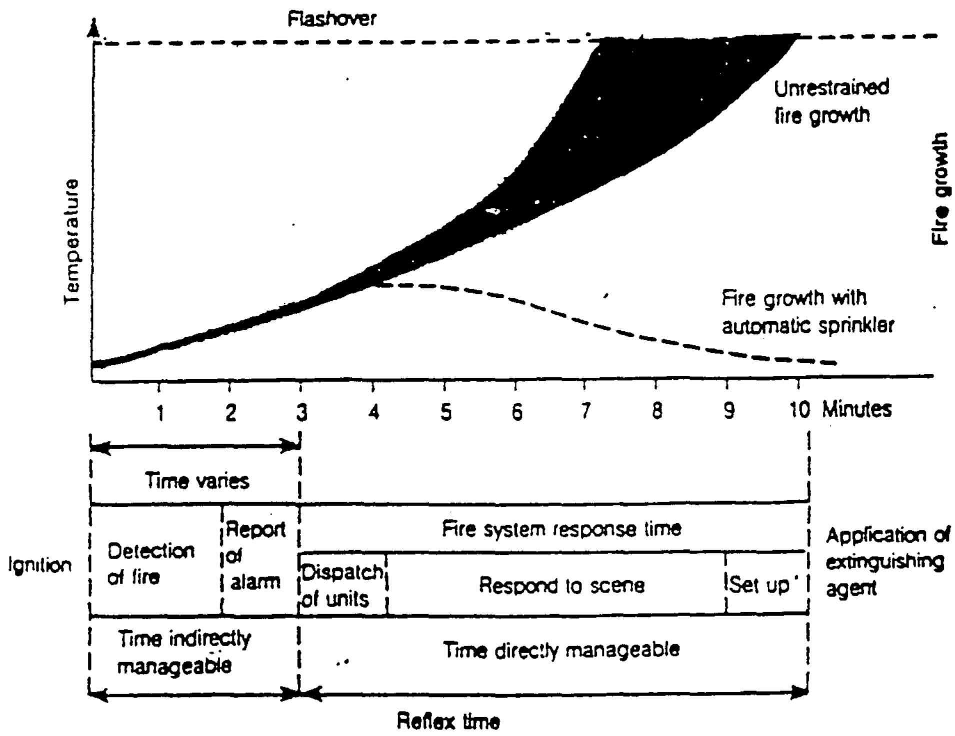


Figure 4.2 - Fire growth vs Reflex time (ILSG 1989)

4.2.3 Tenability limits

Toxic gases in the smoke in high concentrations can kill a human in the matter of a few seconds. Smoke and heat from a fire can be as deadly as the fire itself. As smoke and hot gases travel upward in a plume, they intercept the ceiling forming a ceiling jet.

Ceiling jets move horizontally until they reach the walls (Figure 4.3). From this point on as fire progresses the upper layer thickness will increase and move downwards. This process may take from a few minutes to a few hours depending on fuel, ventilation and nature of the ignition.

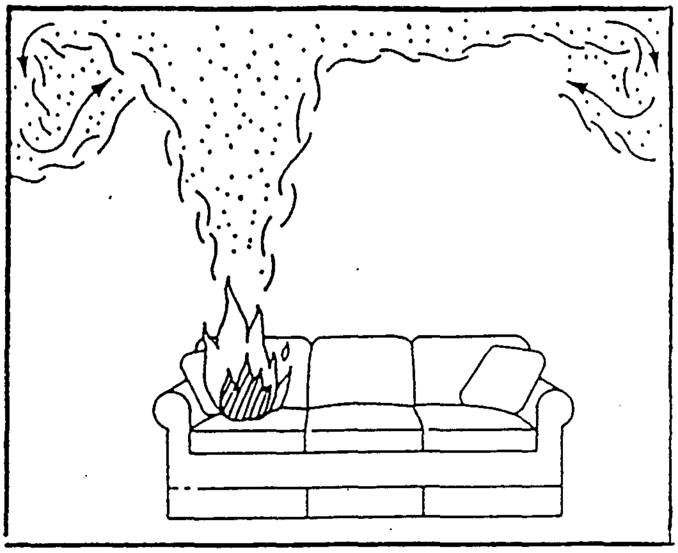


Figure 4.3 - Typical plume and ceiling jet

If there is no alarm or sprinkler system in the house people who, for some reason, can not respond to the situation, may lose their lives. (According to Cropp 1991, about 14% of people killed in fires were children under 5 years of age and 11% people over 75). On the other hand, if the house is equipped with a sprinkler system, hot gases in the ceiling jet or plume will pass over the sprinkler head and activate the head. The fire will be controlled or suppressed, and hence, prevent the increase in the upper layer (hot layer) thickness.

Temperature of 65 °C - 100 °C will cause loss of consciousness and death within a few minutes (Cote 1984a).

The oxygen concentration in the normal air is 21%. A range of 12-15% of oxygen will result in shortness of breath, headache, dizziness and rapid fatigue (Cote 1984a).
The Fire Engineering Design Guide gives the following limits;

Concentration limits for species which lead to incapacitation in about 30 minutes.

CO not > 1400 ppm (small children incapacitated in half the time)

HCN not > 80 ppm

O_2 not < 12%

CO_2 not > 5%

Visibility in the relevant layers should not fall to less than 2 metres.

The radiant flux from the upper layer should not exceed 2.5 kW/m^2. Above this, the tolerance time is less than 20 seconds.

4.2.4 Instances of Sprinkler Failing to Save Lives

Sprinkler systems have saved large numbers of people from death by fire. It is almost impossible to find reports of deaths in sprinklered buildings.

A suspicious fire killed a 49 year old man in a sprinklered dwelling in New Zealand in December 1992, and damaged 100% of the house. The man was in close proximity to the fire, but could not escape as his clothing was alight. The type of material that ignited was reported to be a flammable combustible liquid, which was ignited in more than one place. Some deaths could still occur, even if detectors and sprinkler systems were in use. Fires that start very close to a victim, so that he or she could be described as being intimate with the ignition of the fire, could result in the victim's death, before operation of the sprinkler (PLCL 1992). Sprinkler systems may also fail to save life in an explosion which causes a large number of sprinkler heads to operate simultaneously. According to NZS 4515 a maximum of 3 heads should be operating in a domestic sprinkler system. So, if for some reason more than 3 heads operate, insufficient water may be delivered to each sprinkler head, and as a result, the fire may not be controlled and may finally take over.

Another case to consider is smouldering fires. Fires can smoulder for hours before detection. Even though there may not be sufficient heat to activate the sprinkler or heat detector systems, fires could still produce enough toxic gases to incapacitate or kill a sleeping person, hence the requirement of NFPA 13D for smoke detectors.

4.3 Benefit Streams

When a fire occurs it is a loss for everyone. Firstly it is loss of life and/or property to the owner which may be compensated by insurance companies and/or government. Secondly it is a loss of resources and materials to the nation and the environment.

Benefits that could directly or indirectly result from the installation of a sprinkler system are discussed below.

4.3.1 Direct benefits

4.3.1.1 Life Protection

Life is the ultimate price that one can pay. This is a loss that never could be recovered. The main feature of sprinkler systems is the ability to save life. Sprinklers in dwellings can reduce the number of deaths by 50% or more (Melinek 1993). In average about 35 people lose their lives in fires in New Zealand each year, about half of which are in domestic dwellings. The total number of fires in sprinklered dwellings in New Zealand from 1986 to 1993 (8 years) were 18, which resulted in one death and no injuries (Narayanan 1994).

There is more data collected in the United States than any where else in the world about the life protection of sprinkler systems.

Operation Life Safety, an organisation sponsored by the International Association of Fire Chiefs, is collecting and documenting fire incident data related to the successes reported in residential sprinkler operations. Cobb County, Georgia has recorded 18 residential fires which were successfully controlled by sprinklers. It was estimated that 17 lives would have been lost without the sprinklers (ILSG 1989). It is believed that a combination of sprinklers and Smoke detectors can be more effective than sprinkler alone. Together they reduce the loss of life by 98 % (Anderson 1988).

It is very difficult to put a monetary value to human life. Placing a dollar value on human life raises difficult philosophical, ethical and theoretical issues.

Ruegg & Fuller (1984) consider an approach which is most consistent with economic theory of willingness-to-pay concept. The willingness-to-pay value is computed according to how much a decision maker will invest to reduce his/her risk of death by a certain fraction. Surveys of expressed willingness to pay for small reduction in the risk of death show most values are between $US 250,000 and $US 1,000,000.

Most studies in the US assume a $US 500,000 value for each life saved. The Strategos study (Strategos 1989) assumed the value of a statistical life in New Zealand would be about $800,000. This value will be used in this study.

4.3.1.2 Property Protection

Probably property loss has second place in peoples minds when they are thinking about fire losses. In New Zealand about 50% of fires occur at residential dwellings. It costs millions of dollars to owners and insurance companies to repair or recover these losses.

A comparative study of property losses in sprinklered and unsprinklered dwellings was conducted by the city of Scottsdale, Arizona in 1982. Property saving of 85% were recorded in structures with automatic sprinklers (ILSG 1989).

The loss of residential property as a result of fire cost New Zealand millions of dollars each year. The exact amount of property loss is difficult to obtain. Firstly, because the only available data for property losses are those from insurance companies the majority of which are not willing to submit their information. Secondly not all the properties which are damaged or lost through fires are insured, and finally not all fires are reported. However, as will be discussed in chapter 7 of this paper, property loss due to fires in N.Z is about $74 million per year.

It must be mentioned that only a hand full of dwellings in New Zealand have sprinklers. More widespread use of sprinklers would reduce the large claims.

4.3.2 Indirect benefits

4.3.2.1 Insurance discount

A minority of insurance companies especially in the United State recognise the ability of the domestic sprinkler systems in saving life and property by giving some discount on their premium for those houses that install a reliable sprinkler system. In the United states these discounts vary from 10% to 50%.

The Insurance Council of New Zealand is naturally very supportive of domestic sprinkler systems, and believes that if insurance companies in New Zealand are asked for a reduction on premiums it is very likely that they will give some (Bridge, pers. comm.).

The potential of the sprinkler systems in commercial, industrial and large residential occupancies are recognised by the insurance companies in New Zealand, and buildings with sprinkler systems will get some discount on their premium. The amount of discount is not clear at this time because insurance companies do not have any policy for reduction of premium for sprinklered buildings, and give their possible discount on a case by case basis only.

In New Zealand there is structure insurance and contents insurance. Some insurance companies give 10% discount on insurance premium for houses with sprinkler systems. The premium for an average three bedroom house is about $300-$500 for a combined structure and contents insurance. Assume that the insurance premium for an average three bedroom house is about;

$500.00 for unsprinklered house

then the discounted premium would be:

$\$500 - (\$500 \times 0.1) = \$450.00$ for sprinklered house

This is a $50 dollars saving per year. If the fire component of the premium is 20% of the total premium, or $100.00 per year, then the 10% overall reduction is 50% of the fire component.

4.3.2.2 Reduced injuries and medical treatments

All the arguments about assigning a dollar value to human life are valid for injury, to a lesser extent. It would be impossible to measure the emotional stress experienced by fire victims and their families, or to measure the value of permanent scars left on a victim.

From 1986 to 1993 there were 1,286 injuries in domestic dwellings in New Zealand. These are hidden costs to the nation. Some of these injuries could be prevented by controlling fires with automatic sprinklers. Sprinklers in dwellings can reduce the number of non fatal injuries by 45% (Melinek 1993).

Disfigured and disabled victims of fire are rarely seen in public but, exist in burn centres, rehabilitation centres or behind the closed doors of their homes. Burn injuries require an extensive period of treatment and are one of the most costly injuries to treat. The range of the average charges of initial hospitalisation in USA are $US 16,541 ($NZ 27,000) to $US 132,953 ($NZ 218,000). Burn injuries are compounded by the emotional stress experienced by victims and their families, a burden which frequently leads to family disintegration. A tragedy of these injuries is that children account for 44% of serious burn injuries. Burns related death are the leading cause of accidental death for children (ILSG 1989).

However some kind of value must be adopted to enable the calculation to be performed. Studies in the USA, generally assign a value of $US 20,000 per injury. The Strategos study uses a value of $NZ 40,000 per injury in New Zealand. This value will be used in this report.

4.3.2.3 Reduction in size of fire stations

Some reduction in the fire department size has been achieved in United States, mainly in areas where mandatory sprinkler systems are adopted. Requiring sprinkler systems in new and growing communities will help to reduce the growth of fire department staffing, while providing a high level of fire protection services (ILSG 1989).

According to David Allen of the New Zealand Fire Service, only about 17% of all calls to the Fire Service are related to fires in family dwellings. Even if all the houses were sprinklered, there could not be a major reduction in the size of the Fire Service because of their need to attend other emergencies, many much more demanding than house fires.

4.3.2.4 Reduction in fire fighters early retirement

The exact cost of early retirements due to injuries incurred while fighting fires in New Zealand is not known. But experience in the United States shows that the cost is a substantial burden on public resources (ILSG 1989).

4.3.2.5 Reduced rate (Property tax)

Some states in USA reduce the property tax for dwellings which install sprinkler systems. This is used especially in newly developed communities as an incentive for installing sprinkler systems, to reduce the size of fire service department. Fire services in USA are part of City Council and have the same source of income.

In New Zealand the Fire Service budget is independent of city council budgets, so city councils around the country do not see any reason to reduce property rates.

4.3.2.6 Reduced mortgage rate

Banks in New Zealand require structural insurance by the new home buyers, but do not give any reduction on mortgage rates as an incentive for installation of sprinkler systems that could well protect the structure.
It was suggested (Cote 1983), that reduced interest rates be available to those who wish to install residential sprinkler systems in their new or existing housing.

4.3.2.7 Trade-offs in building code requirements

Some trade-offs in building code requirements are offered by local authorities in the United States to encourage the use of domestic sprinkler systems. One of these trade-offs is that builders and developers are allowed to build structures more closely together if they install sprinkler systems in their houses. Another example would be that the fire rating of a structure can be reduced.

New Zealand building codes do not require fire rating for single family dwellings. Approved Documents that are prepared by the Building Industry Authority, offer an acceptable solution to the performance based New Zealand Building Code. In the Approved Documents the installation of sprinkler systems in commercial buildings can be used to reduce the fire rating of structural members or to obtain other benefits. The Approved Documents have no mention of sprinkler systems in multiple family dwellings up to three stories, but the performance based code would allow the submission of an alternative solution using sprinklers with some reduction in other requirements such as passive fire protection to separating or boundary walls.

4.3.2.8 Reduced environmental impacts

There are about 2200 fires in dwellings each year in New Zealand, the majority of which are large fires. These fires pollute the environment, by either releasing toxic gases into the atmosphere or contaminating the sewerage or stormwater system through run off water from fire extinguishing activities.
At the present time the environmental impact of the domestic fires is not known and may not be very significant, but it is an important issue and should be considered.

The widespread use of fire sprinklers can have important implications in terms of water conservation (less water is required for fire fighting, specially in times of drought) and limiting the release of hazardous substances to the environment by rapidly controlling fires while they are small (Byrne 1994).

Structures or contents which are lost in the fires have to be replaced by new materials which means that more raw materials such as timber, plastic, etc. must be extracted from natural resources.

Fires also have a hinge social impact, including the costs of emergency services other than the Fire Service, which would be reduced if there were fewer serious house fires.

4.3.2.9 Reduction in relocation

After a major fire the occupants must move to either a permanent or temporary location. Costs include temporary loss of earning capacity of the individuals affected. Costs associated with these relocations would be eliminated if sprinklers were installed.

4.3.2.10 Reduction in loss of art work

Sometimes very expensive art work and personal mementos with significant historic and heritage values are lost in the fires. Sprinkler systems with their early detection and suppression abilities reduce or eliminate these losses.

4.4 Cost Stream

4.4.1 Direct costs

4.4.1.1 Installation

This includes the cost of water connection, piping, valves, fittings, sprinkler heads, and other elements of a domestic sprinkler system. These costs incur once, and vary between contractors. As it will be demonstrated in chapter 6 of this study, the cost of a domestic sprinkler system in New Zealand would be about \$40 - \$70 per m^2 of floor area.

4.4.1.2 Maintenance

For a system to be functional and reliable it must be inspected and maintained regularly. This task for the domestic sprinkler systems is not difficult, and most home owners with a mechanical mind and some practical experience can perform it (but one must consider the opportunity cost of the owners' time). NZS 4515 requires some regular tests that can be carried out by either an approved contractor or the owner provided that the owner can show competence to the authority having jurisdiction. There are also some annual tests that must be carried out by an approved contractor. The details and results of all tests plus the name and the signature of the tester must be recorded in a log book which is always kept at the control valve.

These tests may cost about $100 - $300 per year for a residential occupancy, depending on who is undertaking the tests. A value of $100.00 will be used in this study.

4.5 Summary

The main benefits of a domestic sprinkler system are protection of lives, properties and possessions, prevention of injuries, insurance discounts, and reduction in size of fire stations.

The major costs of a domestic sprinkler system are the installation and maintenance costs.

CHAPTER 5

COMPONENT COSTS

5.1 Introduction

This chapter will look at the different components of a domestic sprinkler system that comprise the total prices of the system. The cost of a sprinkler system is a combination of the cost of each component. The New Zealand standard for residential sprinkler NZS 4515, requires more components than required by its American equivalents NFPA 13D and 13R. This results in a more expensive domestic sprinkler system in New Zealand than in United States. The components are discussed in the following order in this chapter:

- Water supply
- Valve set
- Pipes
- Sprinkler heads
- Alarms
- Approval
- Labour costs
- Maintenance

5.2 Water Supply

The main characteristic of sprinkler systems is water. Without it a sprinkler system is of no use. In the design stage of a sprinkler system it is important to make sure that there would be enough water behind the sprinkler heads for a certain period of time during a fire. The required source of water supply is very similar around the world. In New Zealand, NZS 4515 requires at least one of the following water supply sources:

- Town main
- A privately owned elevated reservoir
- A pump supply

Connection to a town main is the most common water supply source for domestic sprinkler systems in New Zealand. At this point in time the water flow rate and pressure in town mains in most cities around the country is sufficient for a domestic sprinkler system. If it is not sufficient it can be boosted by a pump. Houses that are located in rural areas normally use clean water from elevated tanks, or pump water from wells, tanks or open water as their water supply.

5.2.1 Connection to a town main

Connection to a town main (Figure 5.1) seems to be the most reliable and convenient water source for a domestic sprinkler system. However, the cost of connection is not a standard price in most cities in New Zealand. City Councils are responsible for these connections. They bring the required pipe size from the town main up to the premises boundary. Their charges vary from one connection to another. The cost of the connection would increase if the town main is on the opposite side of the road or the terrain is rough to dig. Generally City Councils break down the cost into four different categories;

- Materials
- Plant
- Labour
- Restoration

Material cost increases as the connection size increases. Other categories depend on distance from the town main to the boundary and terrain roughness.

Generally it costs about $500 to $1500 for a town main connection in Christchurch. For example, two jobs (A & B) were priced for a 50 mm town main connection by the Christchurch City Council. They are shown in Table 5.1.

Table 5.1 - Costs break downs for water main connection by Christchurch City Council

	Cost ($), Job A	Cost ($), Job B
Materials	300	200
Plant	50	150
Labour	200	330
Restoration	100	90
Total	750	970

The town main was on the opposite side of the street for Job B, and on the same side of the street, about two metres to the boundary for Job A.

Auckland City Council has a similar approach as Christchurch City Council, but Wellington City Council has a different policy.

The approach that is taken by Wellington City Council for town main connection fees are summarised in Table 5.2.

Table 5.2 - Costs of connection to the town main by Wellington City Council

Connection size	Connection plus 1st metre	Additional cost per metre
32 mm	$705	$100
40 mm	$770	$120
50 mm	$935	$130

However, NZS 4515 allows sprinkler systems to be connected to a domestic water supply system, (Figure 5.2) provided the pipe that supplies the domestic water supply is not less than 20 mm in diameter (15 mm pipe is the usual domestic water supply source), and carries enough water for both sprinkler and domestic systems. This could considerably reduce the cost of connection to a town main.

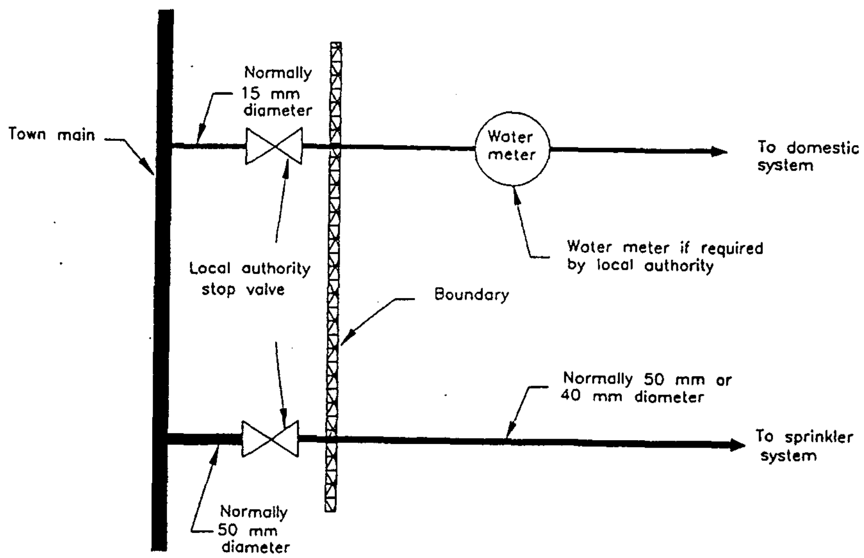


Figure 5.1- A typical town main connection

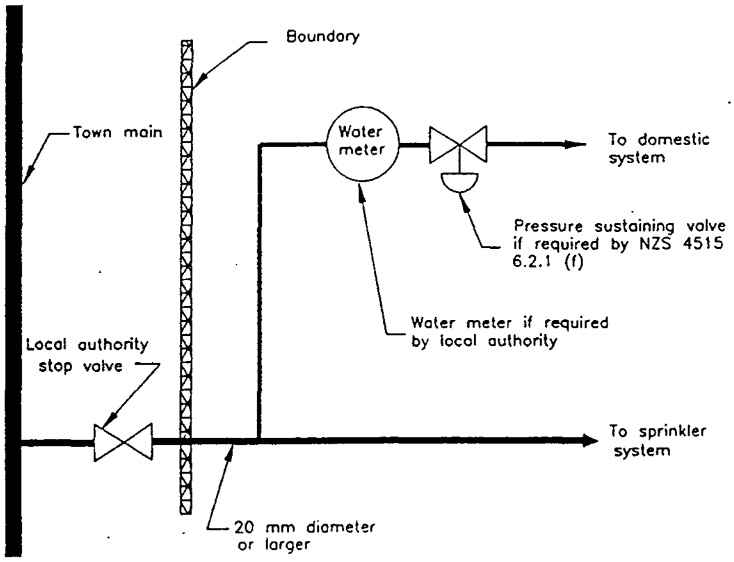


Figure 5.2 - A combined sprinkler and domestic water supply

5.2.2 Elevated tanks

The elevated tank (Figure 5.3) is an alternative to a town main prescribed in NZS 4515 and also other codes around the globe. It is more common in the United States than in New Zealand. This is primarily because of good, and relatively cheap water supply from a town mains in New Zealand. In some areas in New Zealand the high risk of earthquake damage would increase the cost of tanks.

In rural areas where there is no town main this option can be used. In most of these cases the elevated tank is probably already being used for domestic water supply and may well have the capacity to serve the domestic sprinkler system as well.

NZS 4515 specifies the requirements for construction of an elevated tank in New Zealand. The tank should be of non-combustible material. The costs of different types of tanks with 3000 litre capacity are shown in Table 5.3. The cost of a pump for filling the tank, and a possible stand, need to be added to these prices.

Table 5.3 - Prices of water storage tanks

Types of Tank	Cost ($)
Stainless Steel	6,000
Steel (galvanised inside)	1,500
Fibreglass	1,080
Timber	2,000
Concrete	800.0

A six to seven metre steel stand for a tank costs about $800.00.

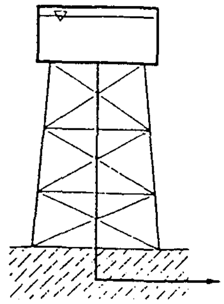


Figure 5.3 - A typical elevated tank

5.2.3 Pumps

A pump by itself cannot be considered as a source for water supply, because it needs to draw water from a town main, a tank (Figure 5.4), a well or open water. If required, it is the most expensive part of the water supply for a domestic sprinkler system. Industrial and multi-storied apartments are most likely to use pumps for boosting a town main or to draw water from a tank. As explained previously, it is not very likely that a pump will be used to provide water for a domestic sprinkler system.

NZS 4515 allows the use of both diesel or electric pumps, which must comply with specific requirements set forth in the code. If the pump is the only source of taking water for the sprinkler system, it should be diesel driven. However, NZS 4515 permits an electric pump to be used for a single family dwelling and a licensed rest home, if the source of water is a town main which due to daily fluctuations in pressure is unable to provide the required pressure. The cost of pumps varies, depending on the pressure and flow rate required and whether the pump is electrical or diesel. Prices of pumps delivering 170 l/min at 400 kPa supplied by B R Homersham Limited. are given in Table 5.2.

Table 5.4 - Pump prices

Type of pump	Price ($)
Diesel	15,450
Electric	5,850

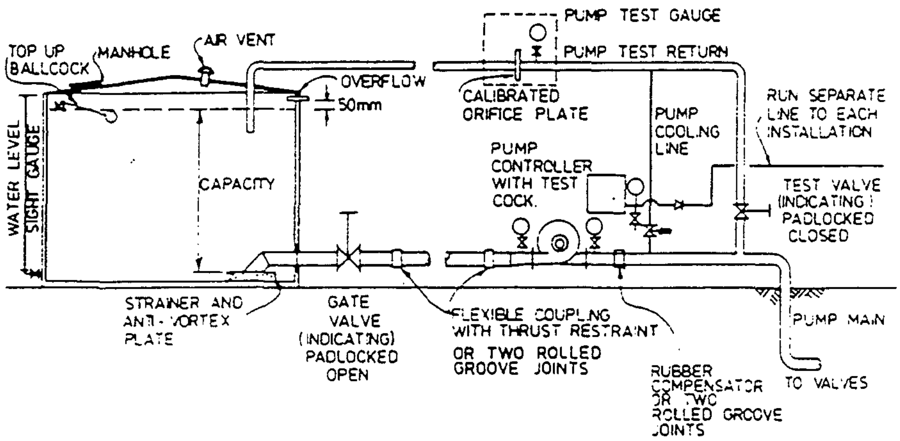


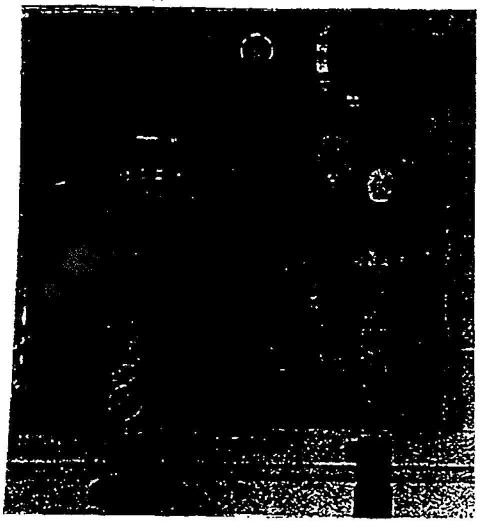
Figure 5.4 - Typical arrangement for pump and tank supply (NZS 4515)

5.3 Valve Set

According to NZS 4515, two types of control valve sets are allowed in residential occupancies in New Zealand. One is used for a residential sprinkler system in a small dwelling up to two stories and/or 500 m^2 in total floor area. This is the simplest and the cheapest allowable valve set (Figure 5.5). It consists of a cabinet, two pressure gauges, a non-return valve, drain and isolating valves, water flow and pressure detectors and related alarm equipment, a drain valve and a flow test connection. The cost of the whole package is about $1,000. Table 5.5 shows the cost of the main components of a simple valve set.

Table 5.5 - The price of simple valve set components

Items	Price	Source
Pressure gauge	$25	Taylors Ltd - Chch
Drain valve (25 mm)	$20	Taylors Ltd - Chch
Isolating valve (40 mm)	$31	Taylors Ltd - Chch
Non-return valve (40 mm)	$64	Taylors Ltd - Chch
Water flow detector	$185	James Hardie of Chch
Pressure detector	$60	James Hardie of Chch
Fibre glass cabinet	$150	James Hardie of Chch



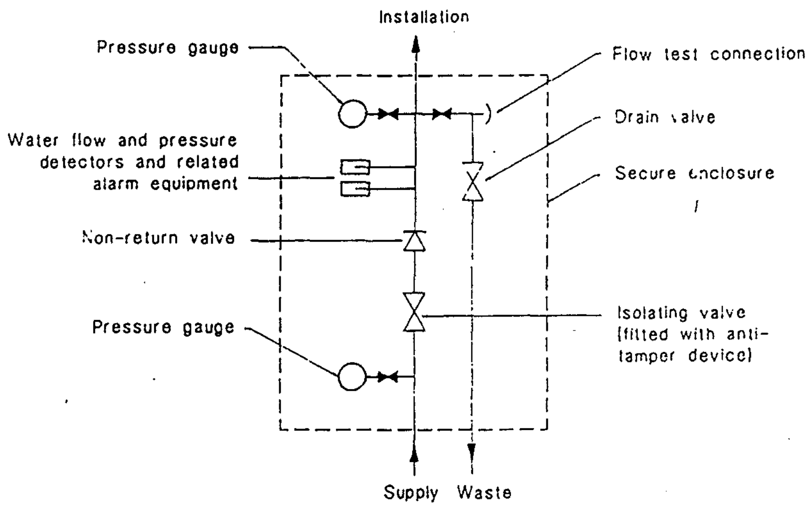


Figure 5.5 - Picture and layout (NZS 4515) of a simple domestic sprinkler control valve set

Another type of control valve set for residential sprinkler systems is used for larger buildings, up to four stories and/or more than 500 m^2 in total floor area. This type of valve set (Figure 5.6) is more expensive than the other type, simply because it requires more components to be built into it. The main difference between this type and the previous type is that this type has a fire sprinkler inlet and a fire brigade alarm connection in addition to the components of the other valve set. Such a control valve set costs about $2,500.

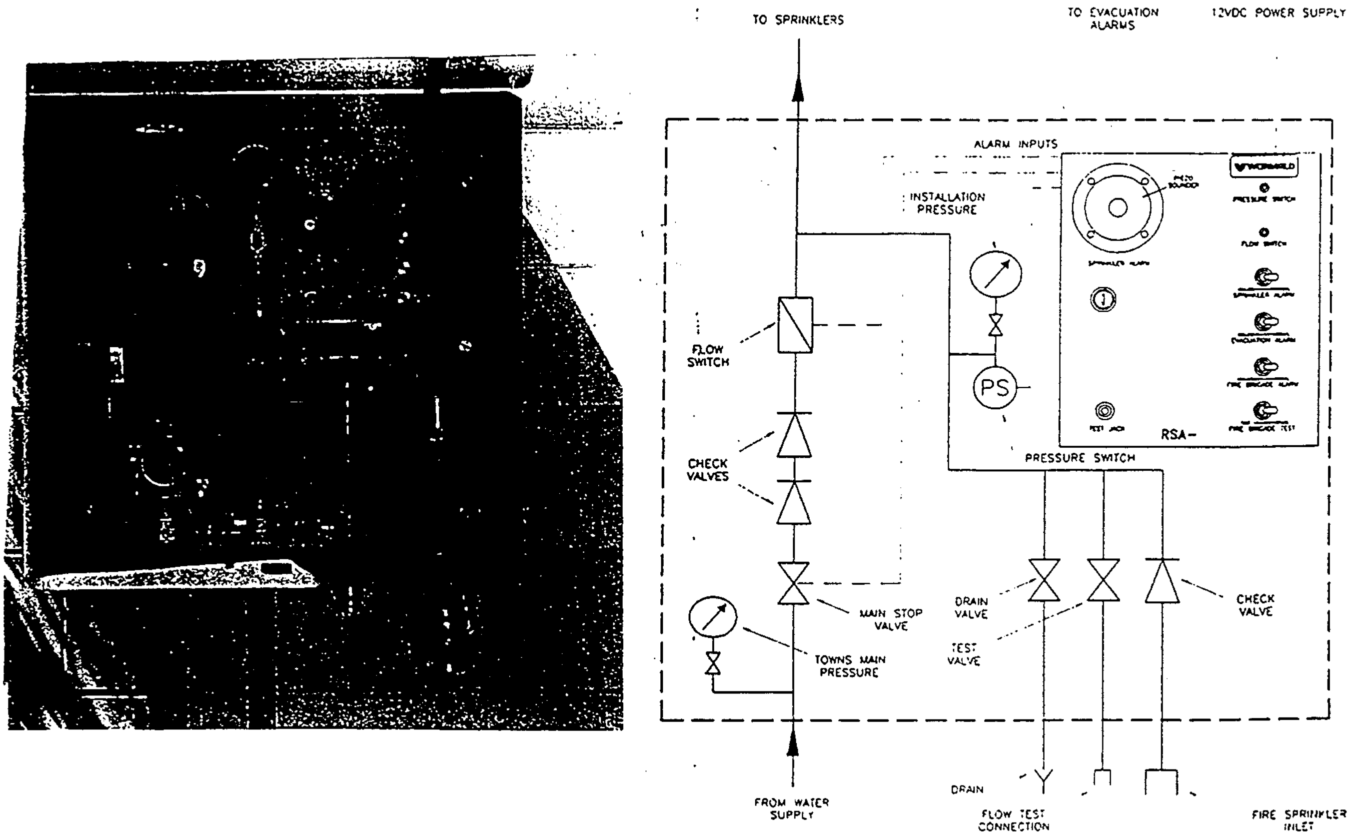


Figure 5.6 - Picture and layout of a typical residential sprinkler control valve set (Wormald Manual)

5.4 Pipes

NZS 4515 allows the use of steel, copper, chlorinated poly vinyl chloride (CPVC), and polybutylene (PB) pipes in residential sprinkler systems.

Note: **All prices for pipes and fittings are directly from the manufacturers price lists and exclude GST and the labour costs of installing. However, contractors get about 25% discount on these prices from manufacturers.**

5.4.1 Steel pipe

Steel pipe is the most common type of pipes used in sprinkler systems in New Zealand. Most steel pipe is pre-primed, and may be painted after installation for appearance or corrosion purposes. The Insurance Council of New Zealand has recently approved the use of FIRELITE pipes in sprinkler systems. This is externally galvanised light weight solid wall pipe, and uses pressfit fittings and victaulic roll grooved coupling systems. Table 5.6 shows prices of black and Firelite steel pipes. The size of the pipes that are shown in this table are those normally used in domestic sprinkler systems.

Table 5.6 - Price of black and Firelite steel pipes

Nominal Size (mm)	Black steel ($/m length)	Firelite ($/ m length)
20	3.49	2.68
25	4.45	3.38
32	5.57	4.24
40	6.37	4.83
50	9.28	6.60

There are numerous fittings for steel pipes. Table 5.7 shows prices for some of these fittings in order to give a general indication of prices. Firelite pipe is cheaper but fittings are more expensive. However, no welding is required for Firelite pipe.

Table 5.7 - Prices of steel fittings

Type	Black Steel ($)	Firelite ($)
Elbows;		
32 × 32	4.42	7.93
32 × 20	5.06	10.10
25 × 25	2.84	5.98

25 × 15	3.13	8.5
Tees;		
32 × 32 × 32	6.00	10.10
25 × 25 × 32	6.95	9.00
25 × 25 × 25	4.11	8.4

5.4.2 Plastic pipes

Chlorinated PVC and Polybutylene (PB) pipes are relatively new in New Zealand. They are smoother than steel pipes and therefore are hydraulically more efficient. These types of pipes require very careful jointing for a good result, thus the experience of the fitters plays an important role for an acceptable standard. Only 15 mm and 20 mm PB pipes are manufactured in New Zealand. Larger sizes are not available in New Zealand and must be imported from overseas on a case by case basis. However, CPVC pipes and fittings are imported and are available in this country. Importing of plastic pipes results in a more expensive system in New Zealand than in the United States. Also contractors in the United States are more experienced and familiar with plastic pipes than in New Zealand, and can complete the job much faster which itself can save money. The higher material cost of plastic pipe and fittings is expected to be offset by lower labour costs in installation. Lack of experience with plastic pipes in New Zealand seems to have created a general resentment among contractors toward this system. Many claim that they can do the job with steel pipes much faster and cheaper, but some have had very successful experiences with CPVC pipes in residential sprinkler systems.

The cost of plastic pipes varies, depending on the size. Table 5.8 gives a price list for plastic pipes.

Table 5.8 - Price of plastic pipes

Nominal Size (mm)	CPVC Pipes ($/m length)	PB Pipes ($/ m length)
15	-	2.83
20	4.11	4.80
25	6.29	Not available in NZ
32	9.88	Not available in NZ

40	13.65	Not available in NZ
50	20.44	Not available in NZ

Fittings for plastic pipes are more expensive than steel fittings. Table 5.9 gives prices for some plastic fittings.

Table 5.9 - Price of plastic fittings

Type and size	CPVC ($)	PB ($)
Elbows;		
32 × 32	5.86	Not available in NZ
25 × 25	4.57	Not available in NZ
25 × 15	4.06	Not available in NZ
20 × 20	2.07	3.59
15 × 15	-	3.59
Tees;		
32 × 32 × 32	8.92	Not available in NZ
25 × 25 × 32	8.84	Not available in NZ
25 × 25 × 25	5.68	Not available in NZ
20 × 20 × 20	2.8	4.37
20 × 20 × 15	-	4.66

5.4.3 Copper pipe

Even though NZS 4515 permits the use of copper pipes in residential sprinkler systems, it is not being used by sprinkler contractors in New Zealand. One of the reasons for this is it's high price. Two methods of jointing copper pipe and fittings are allowed in NZS 4515, they are brazing and capillary soldering. Copper pipes are more flexible than steel pipes especially in smaller diameter. Installation of copper tube systems generally requires significant training and instruction (Notarianni & Jackson, 1994). Tables 5.10 and 5.11 give prices for some copper pipes and fittings.

Table 5.10 - Price of copper pipes

Nominal Size (mm)	$/ m length
20	9.9
25	14.2
32	22.15
40	26.43
50	35.2

Table 5.11 - Price of copper fittings

Type And Size (mm)	Cost ($)
Elbows;	
32 × 32	5.94
25 × 25	4.18
Reduced elbows	*Not Available
Tees;	
40 × 40 × 40	25.68
32 × 32 × 32	17.88
25 × 25 × 25	7.38
25 × 25 × 20	11.00
32 × 32 × 25	**~ 20.00

* Are not readily available but are made by individual plumbers as required.

** Are not readily available but can be manufactured to order in large quantities.

5.5 Sprinkler Heads

There are many types of sprinkler heads available today, but NZS 4515 allows only Residential, Quick response, Standard response and Drencher sprinkler heads (see Figure 5.7). Instead of drenchers for exterior exposure, sidewall sprinkler heads are commonly being used in New Zealand. Differences between these heads are in their response time water demand and the spray pattern. Table 5.12 shows the prices of these sprinkler heads.

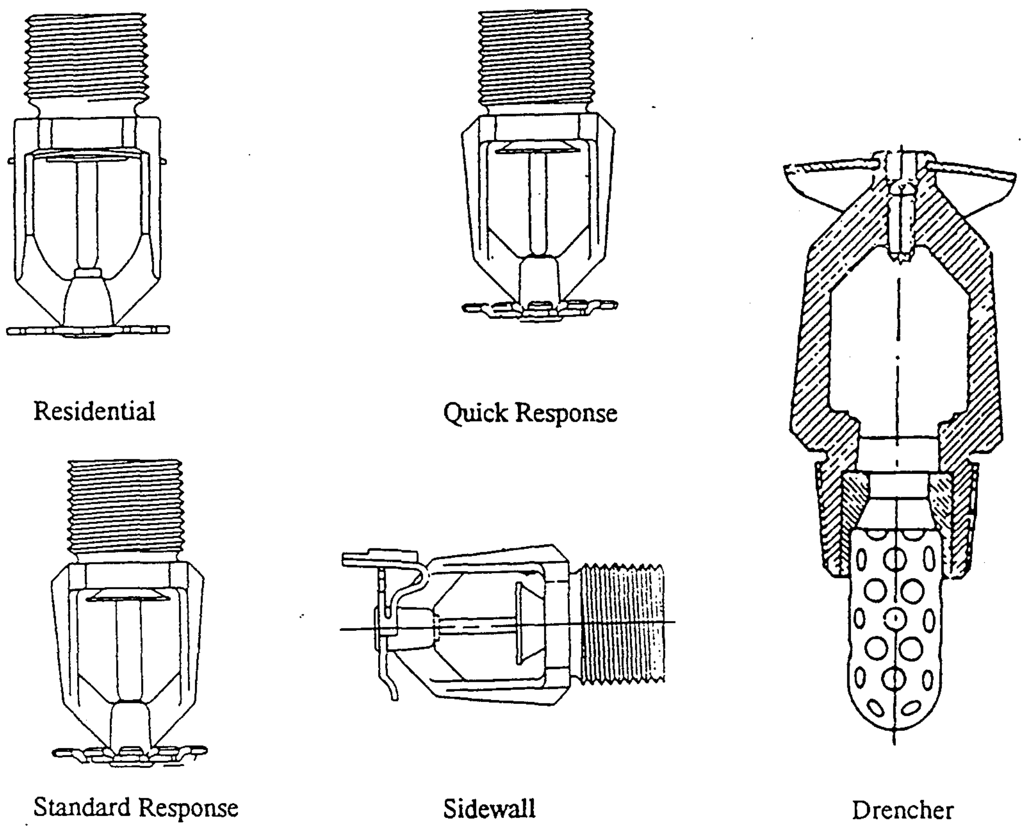


Figure 5.7 - Sprinkler heads (Ansul and Grinnell 1991)

Table 5.12 - Prices of sprinkler heads

Type of Head	Cost ($)	Source
Residential	16	Fire Fighting
Quick Response	17	Pacific
Standard Response	11	Fire Fighting
Drencher	30	Pacific
Side-wall (normally being used instead of drencher)	17	Fire Fighting
		Pacific Wormald
		Fire Fighting
		Pacific

5.6 Alarms

NZS 4515 requires all sprinkler installations to have a sprinkler operating alarm and an evacuation alarm. The sprinkler operating alarm is located on the exterior of the building. In the case of a single family dwelling, an evacuation alarm is not required if the sprinkler operating alarm can be heard clearly throughout the building. For other residential buildings, the sprinkler operating alarm also can replace the evacuation alarm if it incorporates additional sounders. Control valve sets incorporate a flow switch that will activate the alarms when water flows through it due to sprinkler operation. There are different types of alarms and sounders available in the market place. Table 5.13 gives the prices for a few of the most common alarms in New Zealand. Prices are taken from Wormald catalogues.

Table 5.13 - Price of alarms

Type of Alarm	Cost ($) per Sounder
General purpose sounder where medium to high level sound is required	$26
Adjustable electronic sounder	$50
Bell with medium level sound	$75

5.6.1 Fire Brigade alarm

Residential buildings with a total floor area of more than 500 m^2 and/or more than two stories in height require a Fire Brigade alarm connection. NZS 4515 recommend Fire Brigade connection buildings of any size where people can not evacuate without assistance.

There are two types of connection available in New Zealand, both through telephone lines. One which uses the existing telephone line and is available in all cities except Christchurch, is called ATS (Alarm Transporting System). It cost $820 a year plus GST. Another type, which needs a special telephone cable and is available only in Christchurch, costs $668 a year plus GST to the owner and a further $300 that is subsidised by the NZ Fire Service. This is likely to change to ATS in the near future. There is an initial connection fee of $338 associated with both types of connection.

5.7 Approval

To comply with NZS 4515, all sprinkler systems are required to be inspected and approved by the authority having jurisdiction. Insurance Council of New Zealand is the approving authority nominated in the standards for all New Zealand sprinkler systems. The approval and inspection fees are paid by contractors.

5.7.1 Insurance Council of New Zealand

Insurance Council of New Zealand (ICNZ) charge a once-off fee of $60 for approving the design of a domestic sprinkler systems.

5.7.2 Fire Protection Inspection Services

Fire Protection inspection Services Limited (FPIS) is an organisation that carries out sprinkler system inspections on behalf of ICNZ. They charge a minimum fee of $250 for inspection of residential occupancies. They undertake a flow test and check the valves, flow switch, pressure switch, gauges, sprinkler spacing, and brackets, etc. The inspection is only carried out once. for initial approval purposes, except for occassional routine surveys.

5.8 Labour Costs

A major cost to a sprinkler system is the labour cost. It consists of design and installation labour, plus some office work. It all depends on the contractors how much they charge. In industrial buildings a cost of $25 for each under ceiling head and $20 for each concealed head has been suggested by one contractor as an indication of labour costs. For residential sprinklers two hours per head and $35 per hour has been suggested, which would be $70 per head. It was suggested by another contractor that two thirds of the total cost of a residential sprinkler system covers the labour cost. This ratio decreases to one half as the job gets bigger.

5.9 Maintenance

Maintenance is an important and inseparable part of a sprinkler system. NZS 4515 requires some regular tests that can be carried out by either an approved contractor, or the owner, and some annual tests that must be carried out by an approved contractor. As mentioned in a previous chapter a value of $100 will be used in this study.

5.10 Summary

The possible installation costs of a typical domestic sprinkler system, using steel pipes, are summarised in Table 5.14. Design cost, contractors profit and overheads are included in these figures. These figures do not include GST.

Table 5.14 - Summary of domestic sprinkler costs

Materials		Approximate value
Fixed Costs:		
	Town main connection	$1,000
	Valve set	$1,000
	Alarm	$50
	Approval	$310
	Pipes and fittings	$24 per m^2 of floor area
	Labour	$70 per sprinkler head
Continuing Costs:		
	Maintenance	$100 per year
Extra costs (required sometimes):	Elevated tank (cheapest)	$800
	Pump (electric)	$5,850
	Pump (diesel)	$15,450
	Fire Brigade alarm	$820 per year
	Fire Brigade alarm connection	$338

Costs for two typical homes are discussed in the next chapter.

CHAPTER 6

CASE STUDIES

6.1 Introduction

To have a better appreciation of the cost of a domestic sprinkler system, two case studies are considered here. Sprinkler systems for two houses will be designed and installed and associated costs will be calculated. For both houses steel and plastic piping systems will be evaluated. One of these houses is a simple low cost three bedroom house (Figure 6.1 and Figure 6.2) which will be referred to as *House No. 1* in this report, and the other is an up market two storey house (Figures. 6.3, 6.4, and 6.5) which will be referred to as *House No.2*. It is assumed that neighbouring properties are more than three metres away from both buildings and so external sprinklers are not required. According to different contractors the cost of sprinklers for a new house in New Zealand does not differ much from that of an existing house. This is because for retrofitting a sprinkler system in New Zealand, it is common practice that the pipes are exposed, meaning that only some painting is needed for aesthetic purposes and no other extra efforts are involved.

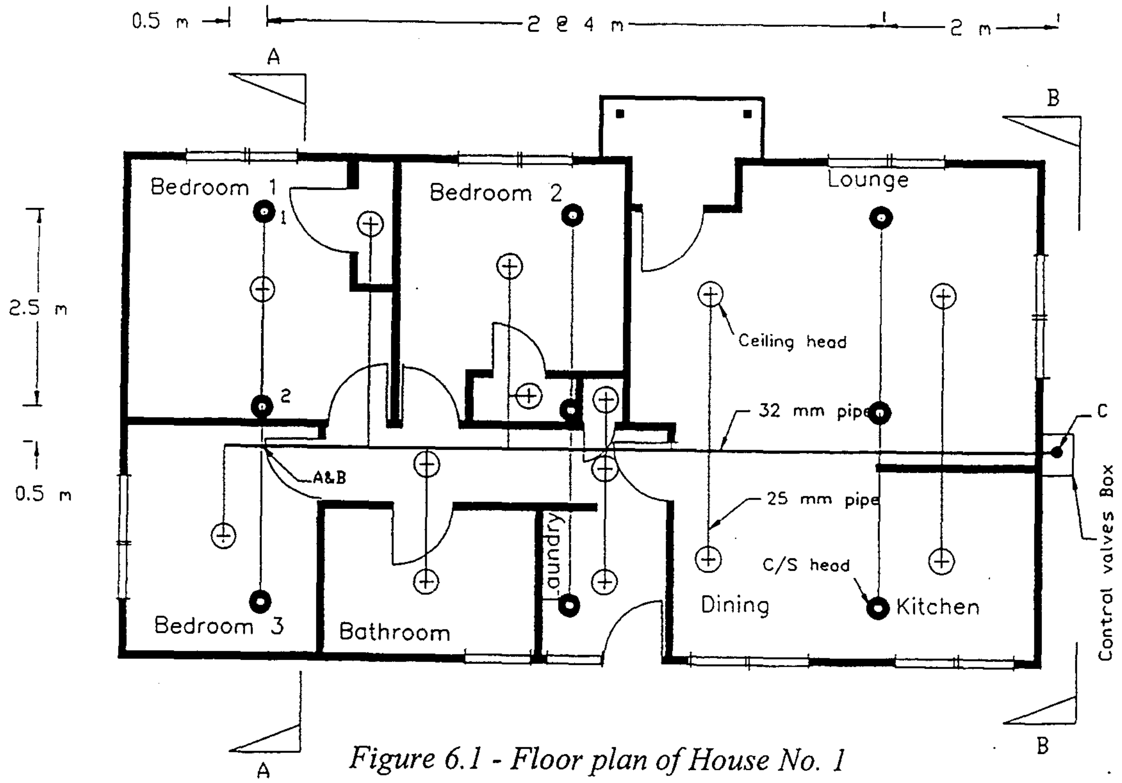
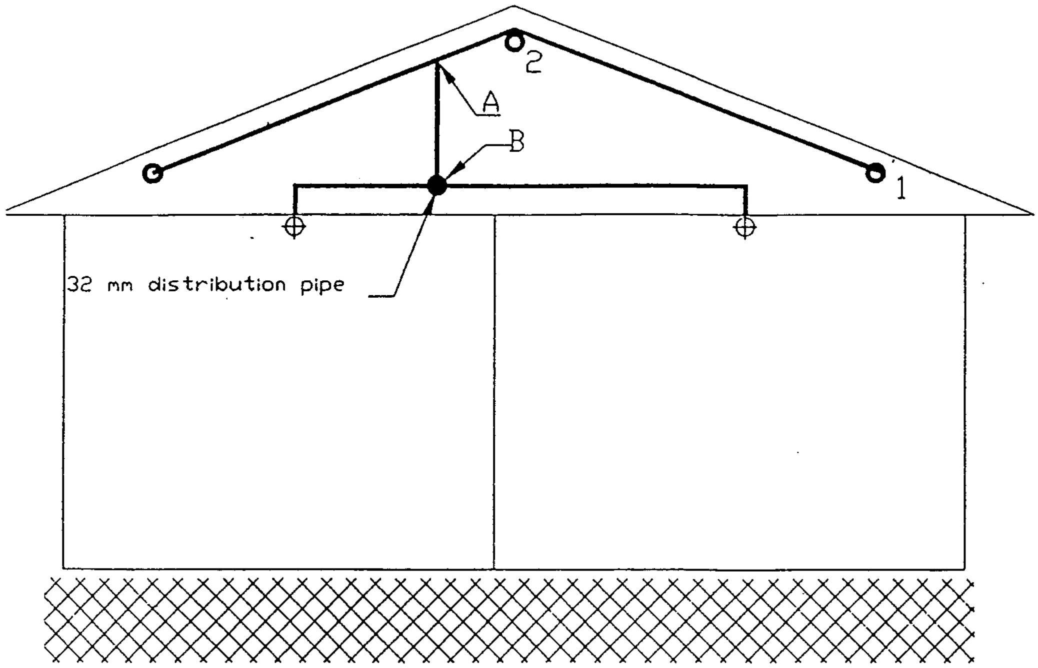
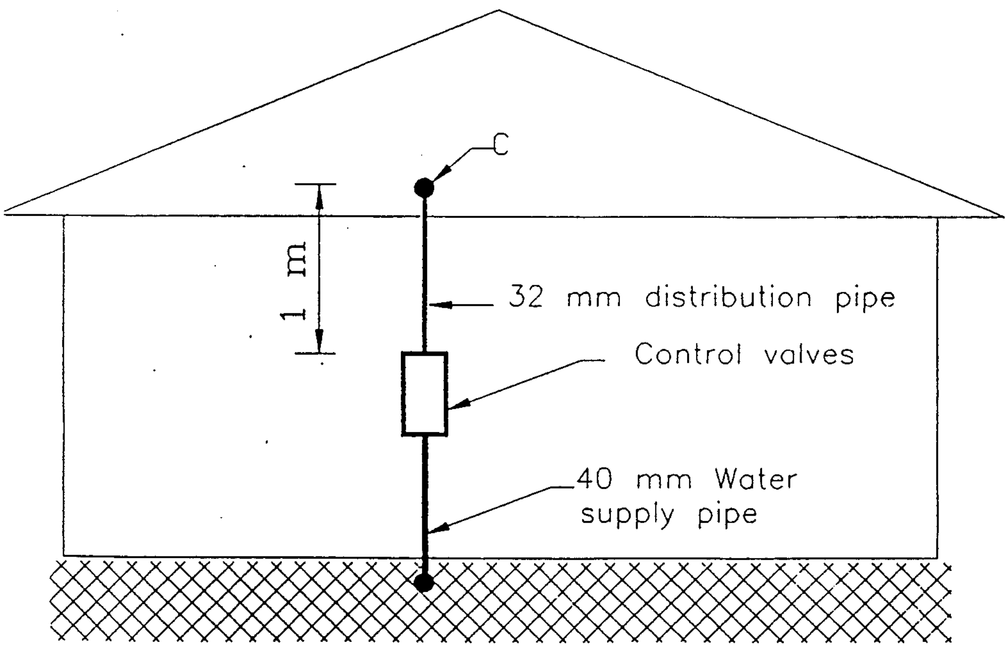


Figure 6.1 - Floor plan of House No. 1



Section A - A



Section B - B

Figure 6.2 - Sections of House No. 1

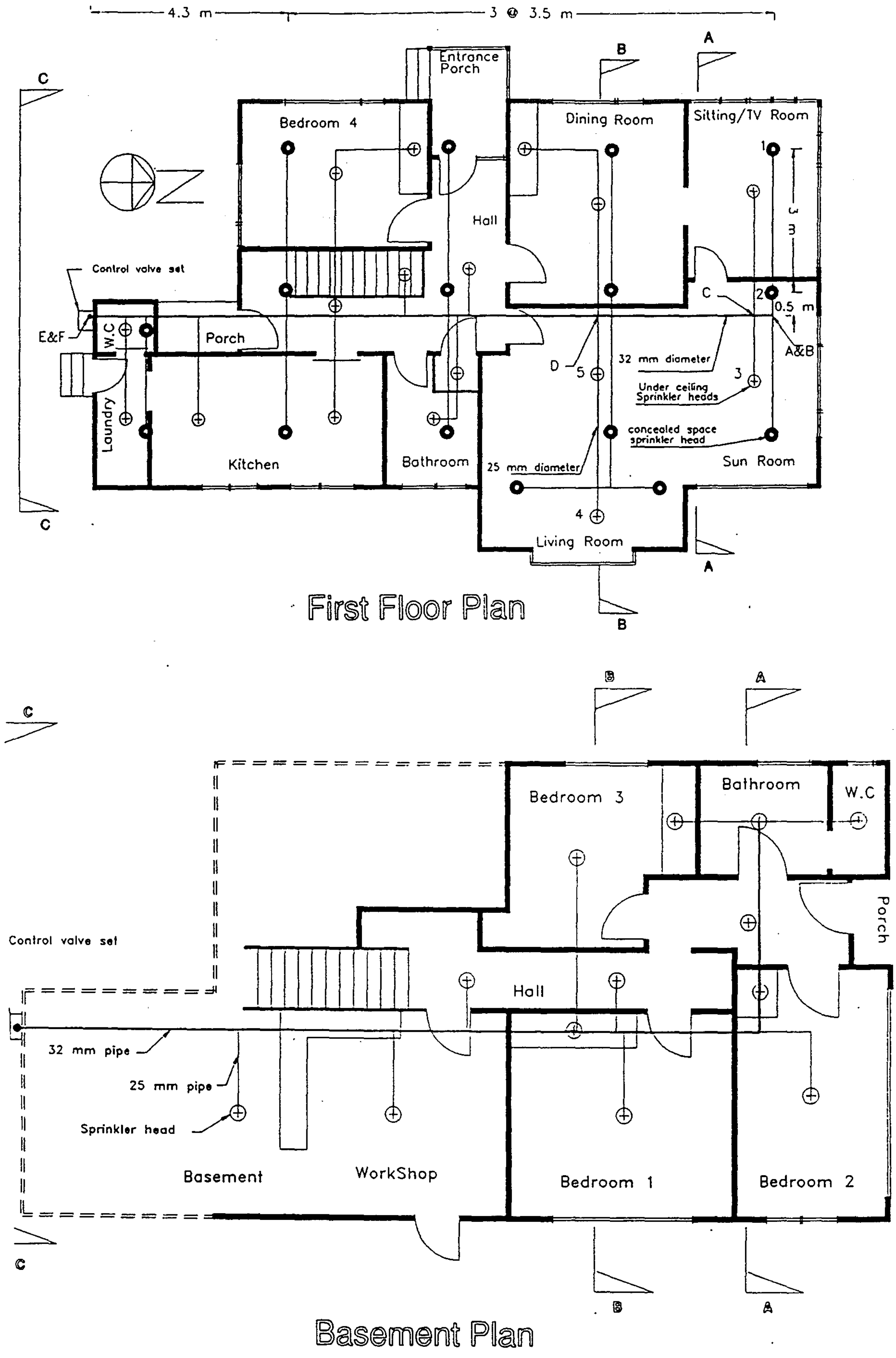


Figure 6.3 - Floor plans of House No. 2

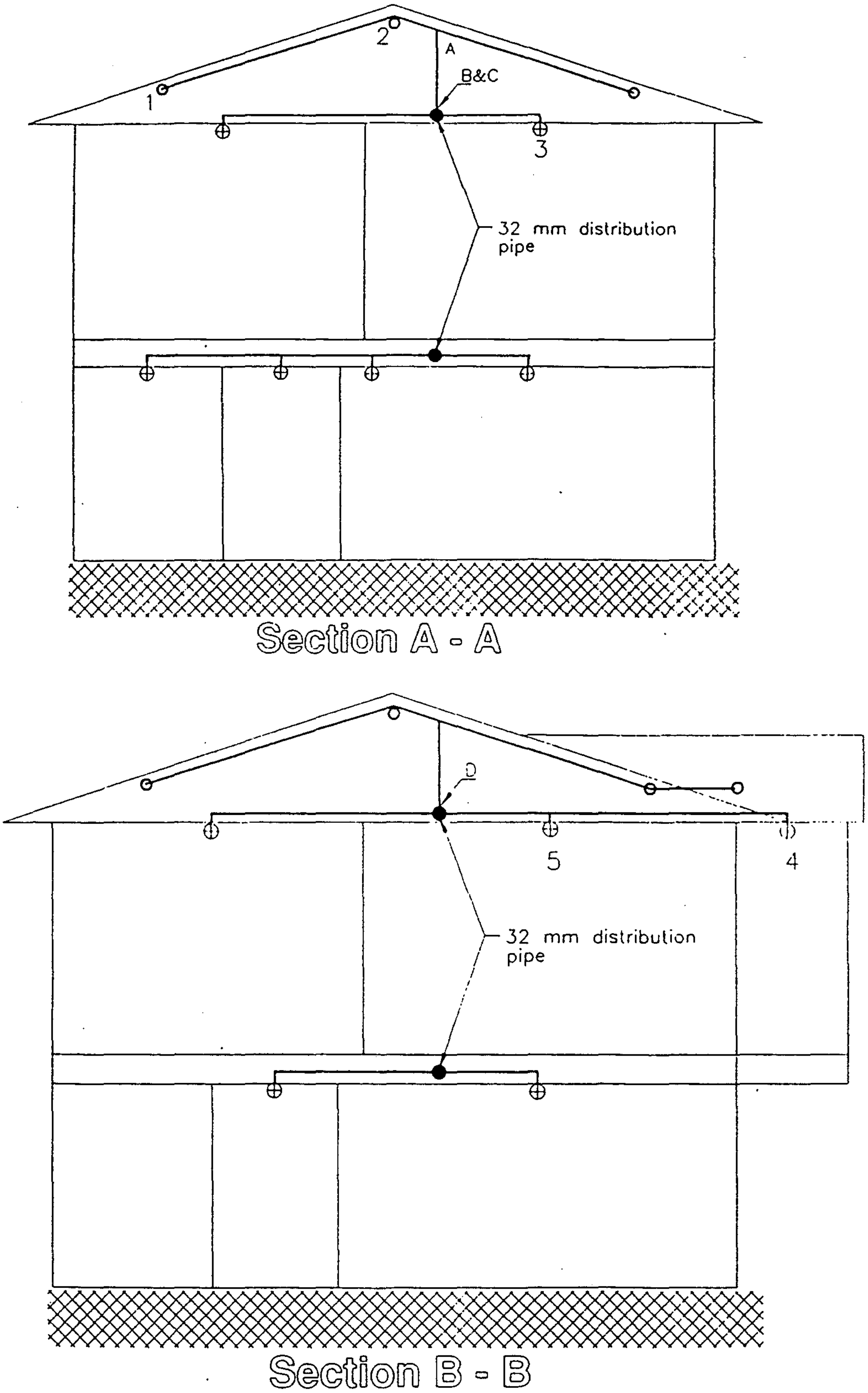


Figure 6.4 - Sections of House No. 2

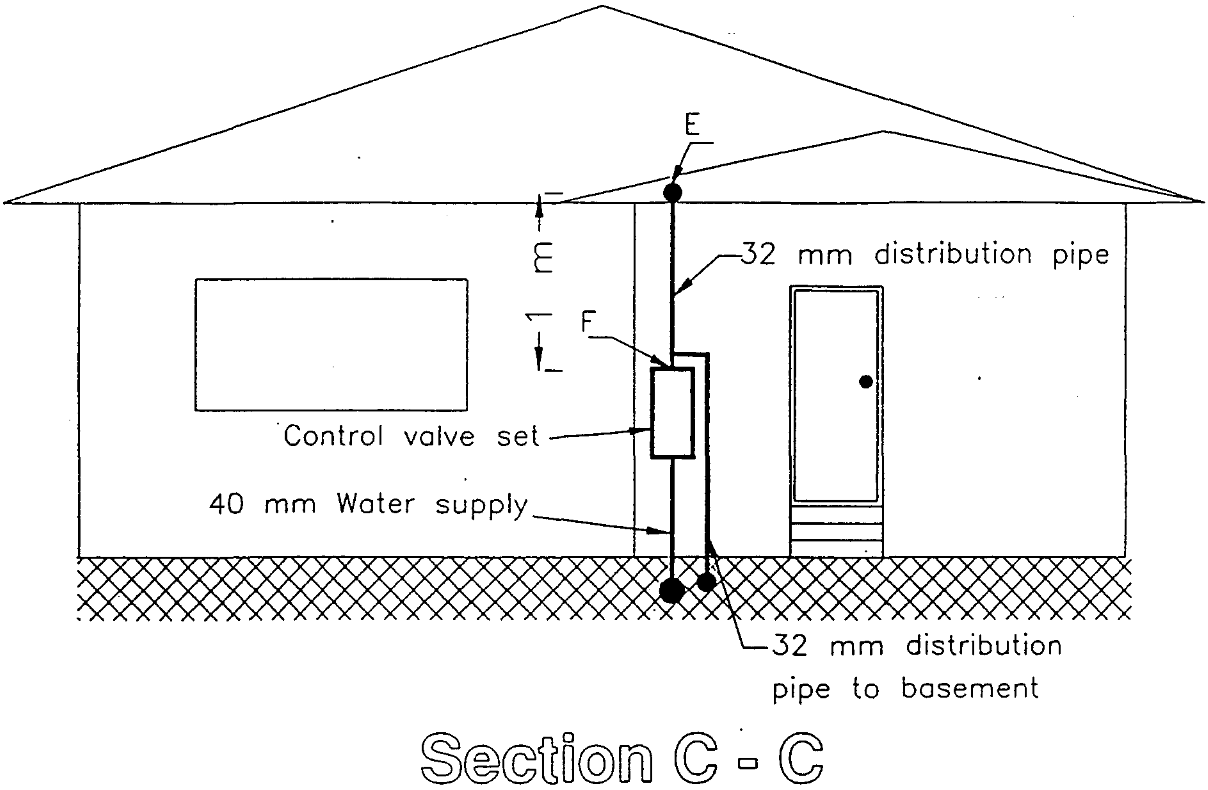


Figure 6.5 - Section of House No. 2

6.2 *Design and Installation Costs*

Hydraulic design for both cases are given in Appendix A. The price of each component of a domestic sprinkler system using both steel and plastic pipe systems are given in Tables 6.1, 6.2, 6.4, and 6.5 for both Houses No. 1 and No. 2. These prices are taken from the manufacturers' price list (see below).

6.2.1 House No. 1 - Material costs

Table 6.1 - Sprinkler System Pricing for House No. 1 (Steel Pipe)

Item No.	Description	Quantity	Unit Rate ($)	Cost ($)
1.	40 mm Pipe to valve set	Assume 5	6.37	31.85
2.	32 mm Pipe	12 m	5.57	66.84
3.	25 mm Pipe	69 m	4.45	307.05
4.	40× 40 Elbow	2	5.69	11.38
5.	50× 40 Bush	1	5.06	5.06
6.	40× 32 Socket	1	4.11	4.11
7.	32 ×32× 25 Tee	6	6.95	41.70
8.	25 ×25× 25 Tee	6	4.11	24.66
9.	32 ×25 Reduced Elbow	1	5.06	5.06
10.	25× 25 Elbow	13	2.84	36.92
11.	25 ×15 Reduced Elbow	6	3.13	18.78
12.	32 Cross	3	11.06	33.18
13.	32×25 Reduced Bushes	6	2.84	17.04
14.	25×15 Socket	16	2.5	40.00
15.	32 mm Clips	5	0.95	4.75
16.	25 mm Clips	25	0.8	20.00
17.	Concealed space head (QR)	9	17	153.00
18.	Residential heads	14	16	224.00
19.	Ceiling plates	14	2.65	37.10
20.	Fittings/fixing/jointing		40	40.00
21.	Domestic valve set	1	1,000	1,000.00
22.	Alarms	2	50	100.00
			Total	**2222.48** ≅ **2222.00**

Prices associated with Items 1 to 14 are taken from Steel & Tube New Zealand's price lists, dated 1/3/93 and 19/4/93, from which contractors get about 25% discount.

Prices associated with Items 15 to 21 are provided by Fire Fighting Pacific (FFP) of Christchurch.

The price associated with Item 22 was taken from Wormald's alarm catalogues.

Table 6.2 - Sprinkler System Pricing for House No. 1 (CPVC Pipe)

Item No.	Description	Quantity	Unit Rate	Cost ($)
1.	40 mm Pipe to valve set	Assume 5 m	13.65	68.25
2.	32 mm Pipe	12 m	9.88	118.56
3.	25 mm Pipe	69 m	6.3	609.96
4.	40× 40 Elbow	2	8.15	16.30
5.	50× 40 Reduced coupling	1	7.44	7.44
6.	40× 32 Reduced coupling	1	5.52	5.52
7.	32 ×32× 25 Tee	6	8.84	53.04
8.	25 ×25× 25 Tee	6	5.65	33.9
9.	32 Cross	3	7.70	23.1
10.	32 ×25 Reduced Coupling	7	3.87	27.09
11.	25× 25 Elbow	13	4.57	59.41
12.	25 ×15 Sprinkler head adaptor	6	5.71	34.26
13.	25 ×15 Fab Drops (adaptor)	16	4.72	75.52
14.	32 mm clips and hangers	5	1.4	7.00
15.	25 mm clips and hangers	25	1.33	33.25
16.	Concealed space head (QR)	9	17	153
17.	Residential heads	14	16	224.00
18.	Ceiling plates	14	2.65	37.1
19.	Sundry Fittings/fixing/jointing		40	40
20.	Domestic valve set	1	1,000	1,000
21.	Alarms	2	50	100
			Total	**2726.43** **≅2726.00**

Prices associated with Items 1 to 15 are taken from Asmuss Plastic System Limited's price lists, dated 1/July/91 (still valid).

Prices associated with Items 16 to 20 are provided by Fire Fighting Pacific (FFP) of Christchurch.

The price associated with Item 22 was taken from Wormald's alarm catalogues.

6.2.2 House No. 1 - Labour costs

According to Graham Horwarth of Fire Fighting Pacific, in Christchurch, the approximate cost of labour for a domestic sprinkler system with steel pipes is equivalent to two hours per sprinkler head at $35 per hour. This rate includes design, installation and all overheads. Since there is no real experience with domestic sprinkler systems with plastic pipes in New Zealand, it will be assumed that labour costs for plastic pipe systems would be the same as a steel pipe system. This may not be exactly true in the United States where they have more experience with plastic pipes and claim that plastic pipe installation is much faster.

There are a total of 23 sprinkler heads in House No. 1.

So

Total labour hours = 23×2 = 46 hours

Total labour costs = 46×35 = $1610.00

6.2.3 Cost of Sprinkler Systems for House No. 1

The total cost of design and installation of domestic sprinkler system for House No. 1 including the town main connection is given in Table 6.3.

Table 6.3 - Costs of domestic sprinkler systems for house No. 1

Description	Steel Pipe	Plastic Pipe
Cost of Materials	$2,222.00	$2,726.00
Cost of Labour	$1,610.00	$1,610.00
*Town main connection (approximate)	$1,000.00	$1,000.00
	$4,832.00	$5,336.00
Total Cost	**≅ $4,800.00**	**≅ $5,300.00**

The value of House No.1 with a floor area of about 72 m^2 would be about $100,000 (including land and construction). Note that the cost of sprinkler systems are about 5%

of the house value, or \$67 and \$74 per m^2 for steel and plastic pipe systems respectively.

According to Section 4.1.2 (d) of NZS 4515, if wardrobes are vented into the rooms with a clear opening of at least 0.02 m^2 at the top of the doors, sprinklers in wardrobes can be omitted which would save about \$200 (being \$140 in labour and about \$60 in materials) in both systems (see Table 6.3.1). This is about 4% of the total cost.

Table 6.3.1 - Cost of sprinkler systems for house No. 1 excluding sprinklers in wardrobes.

Description	Steel Pipe	Plastic Pipe
Costs of Materials	\$2,222- \$60	\$2,726 - \$60
Cost of labour	\$1,610 - \$140	\$1,610 - \$140
*Town main connection (approximate)	\$1,000.00	\$1,000.00
	\$4,532.00	\$5,136.00
Total Cost	**≅ \$4,600.00**	**≅ \$5,100.00**

* Referring to discussion in Chapter 5 of this report, an approximate town main connection fee of \$1,000.00 was chosen.

6.2.4 House No. 2 - Material costs

Pricing for House No. 2 (Table 6.4) is broken into three sections, ie. basement, main floor and roof space (concealed space). This will allow a later comparison to NFPA 13D to be made. NFPA codes do not require sprinkler protection in concealed spaces.

Table 6.4 - Sprinkler System Pricing for House No. 2 (Steel Pipe)

Item No.	Description	Quantity	Unit Rate (\$)	Cost (\$)
	Basement			
1.	40 mm Pipe to valve set	Assume 10 m	6.37	63.70
2.	32 mm Pipe	16 m	5.57	89.12
3.	25 mm Pipe	18 m	4.45	80.10
4.	40× 40 Elbow	2	5.69	11.38
5.	50× 40 Bush	1	5.06	5.06
6.	40× 32 Socket	1	4.11	4.11
7.	32 ×32× 32 Tee	1	6.00	6.00

8.	32 ×32× 25 Tee	8	6.95	55.60
9.	32 ×25× 25 Tee	1	6.95	6.95
10.	25 ×25× 25 Tee	4	4.11	16.44
11.	25×15 Socket	14	2.50	35.00
12.	32 ×32 Elbow	2	4.42	8.84
13.	25× 25 Elbow	11	2.84	31.24
14.	32 mm Clips	5	0.95	4.75
15.	25 mm Clips	20	0.80	16.00
16.	Residential heads	13	16.00	208.00
17.	Ceiling plates	13	2.65	34.45
18.	Alarm	1	50.00	50.00
	Total (BSMT)			**745.39**
	Main Floor			
19.	32 mm Pipe	16 m	5.57	89.12
20.	25 mm Pipe	36 m	4.45	160.20
21.	32 Cross	2	11.06	22.12
22.	32 ×25 Bushes	4	2.84	11.36
23.	25 Cross	1	7.58	7.58
24.	32 ×32× 25 Tee	5	6.95	34.75
25.	25 ×25× 25 Tee	6	4.11	24.66
26.	32 ×25× 25 Tee	1	6.95	6.95
27.	25×15 Socket	19	2.50	47.50
28.	32 ×32 Elbow	1	4.42	4.42
29.	25× 25 Elbow	13	2.84	36.92
30.	32 mm Clips	5	0.95	4.75
31.	25 mm Clips	20	0.80	16.00
32.	Residential heads	17	16.00	272.00
33.	Ceiling plates	17	2.65	45.05
34.	Fittings/fixing/jointing		40.00	40.00
35.	Domestic valve set	1	1,000.00	1,000.00
36.	Alarms	2	50.00	100.00
	Total (MF)			**1923.38**
	Concealed space			
37.	25 mm Pipe	32 m	4.45	142.4
38.	32 ×32× 25 Tee	4	6.95	27.80
39.	25 ×25× 25 Tee	4	4.11	16.44
40.	25 ×25× 15 Tee	6	4.55	27.3
41.	25×15 Elbow	10	3.13	31.30
42.	32 ×25 Elbow	1	5.06	5.06
43.	32 Cross	1	11.06	11.06
44.	32 ×25 Bushes	2	2.84	5.68
45.	25 mm Clips	20	0.80	16.00
46.	Quick Response heads	16	17.00	272.00
	Total (C/S)			**555.04**
				3223.81
			Total	**≅3224.00**

Prices associated with Items 1-15, 19-29, 37-44 are taken from Steel & Tube New Zealand's price lists dated 1/3/93 and 19/4/93, from which contractors get about 25% discount.

Prices associated with Items 14-17, 30-35, 45 and 46 are provided by Fire Fighting Pacific of Christchurch.

The price associated with Item 22 was taken from Wormald's alarm catalogues

Table 6.5 - Sprinkler System Pricing for House No. 2 (CPVC Pipe)

Item No.	Description	Quantity	Unit Rate ($)	Cost ($)
	Basement			
1.	40 mm Pipe to valve set	Assume 10 m	13.65	136.50
2.	32 mm Pipe	16 m	9.88	158.08
3.	25 mm Pipe	18 m	6.30	113.40
4.	40× 40 Elbow	2	8.15	16.30
5.	50× 40 Reduced coupling	1	7.44	7.44
6.	40× 32 Reduced coupling	1	5.52	5.52
7.	32 ×32× 32 Tee	1	8.92	8.92
8.	32 ×32× 25 Tee	8	8.84	70.72
9.	32 ×25×25 Tee	1	8.84	8.84
10.	25 ×25× 25 Tee	4	5.68	22.72
11.	25×15 Fab Drops (adaptor)	14	4.72	66.08
12.	32 ×32 Elbow	2	5.87	11.74
13.	25× 25 Elbow	11	4.57	50.27
14.	32 mm clips and hangers	5	1.40	7.00
15.	25 mm Clips and hangers	20	1.30	26.00
16.	Residential heads	13	16.00	208.00
17.	Ceiling plates	13	2.65	34.45
18.	Alarm	1	50.00	50.00
	Total (BSMT)			**1001.98**
	Main Floor			
19.	32 mm Pipe	16 m	9.88	158.08
20.	25 mm Pipe	36 m	6.30	226.80
21.	32 Cross	2	7.70	15.40
22.	32 ×25 Coupling	4	3.87	15.48
23.	25 Cross	1	5.52	5.52
24.	32 ×32× 25 Tee	5	8.84	44.20
25.	25 ×25× 25 Tee	6	5.68	34.08

26.	32 ×25× 25 Tee	1	8.84	8.84
27.	25×15 Fab Drops (Adaptor)	19	4.72	89.68
28.	32 ×32 Elbow	1	5.86	5.86
29.	25× 25 Elbow	13	4.57	59.41
30.	32 mm clips and hangers	5	1.40	7.00
31.	25 mm clips and hangers	20	1.30	26.00
32.	Residential heads	17	16.00	272.00
33.	Ceiling plates	17	2.65	45.05
34.	Sundry Fittings/fixing/jointing		40.00	40.00
35.	Domestic valve set	1	1,000.00	1,000.00
36.	Alarms	2	100.00	100.00
	Total (MF)			**2153.40**
	Concealed space			
37.	25 mm Pipe	32 m	6.30	201.60
38.	32 ×32× 25 Tee	4	8.84	35.36
39.	25 ×25× 25 Tee	4	5.68	22.72
40.	25 ×25× 15 Tee	6	4.79	28.74
41.	25×15 Sprinkler head adaptor	10	5.71	57.10
42.	25 ×25 Elbow	1	4.57	4.57
43.	32 Cross	1	7.70	7.70
44.	32 ×25 Coupling	3	3.85	11.55
45.	25 mm Clips and hangers	20	1.30	26.00
46.	Quick Response heads	16	17	272.00
	Total (C/S)			**667.34**
			Total	**3822.72** **≅3823.00**

Prices associated with Items 1-15, 19-31, and 37-45 are taken from Asmuss Plastic System Limited's price lists dated 1/July/91 (still valid).

Prices associated with Items 16,17, 32-35, and 46 are provided by Fire Fighting Pacific of Christchurch.

Prices associated with Items 18 and 36 were taken from Wormald's alarm catalogues

6.2.5 House No. 2 - Labour Costs

As explained for House No. 1, a labour cost (including design labour) of two hours per sprinkler head at $35 per hour will be assumed here. Labour costs for House No. 2 are given in Table 6.6.

Table 6.6 - Labour Costs for House No. 2

Location	Number of Heads	Labour (hours)	Labour ($)
Basement	13	26	910.00
Main Floor	17	34	1190.00
Concealed Space	16	32	1120.00
		Total	**3220.00**

6.2.6 Cost of Sprinkler Systems for House No. 2

The total cost of design and installation of a domestic sprinkler system for House No. 2 including the town main connection is given in Table 6.7.

Table 6.7 - Costs of Domestic Sprinkler Systems for House No. 2

Description	Steel Pipe	Plastic Pipe
Costs of Materials	$3,224.00	$3,823.00
Cost of Labour	$3,220.00	$3,220.00
Town main connection (assume)	$1,000.00	$1,000.00
Total costs	$7,444.00 **≅ $7,440.00**	$8,043.00 **≅$8,040.00**

Total floor area of House No. 2 is about 200 m^2 and its market value is in the region of $230,000. Therefore the costs of sprinkler system would be about $37.2 and $40.2 per m^2 for steel and plastic pipe system respectively, or 3% of the house value.

According to Section 4.1.2 (d) of NZS 4515, if wardrobes are vented into the rooms with a clear opening of at least 0.02 m^2 at the top of the doors, sprinklers in wardrobes can be omitted. There are 5 sprinkler heads in wardrobes of House No. 2, which means if omitted a saving of about $500 ($70 on labour and about $30 on materials per sprinkler head) could be achieved. This is about 7% of the total cost. Table 6.7.1 gives the costs of sprinkler systems for house No. 2 adjusted for this change.

Table 6.7.1 - Costs of sprinkler systems for house No. 2 excluding sprinklers in wardrobes

Description	Steel Pipe	Plastic Pipe
Costs of Materials	$3,224 - $150	$3,823 - $150
Cost of Labour	$3,220 - $350	$3,220 - $350
Town main connection (assume)	1,000.00	1,000.00
	$6,944.00	$7,543.00
Total costs	**≅ $6,940.00**	**≅ $7,540.00**

6.2.7 Mortgage for House No. 2

An analysis of mortgage payment for House No. 2 will be considered here to show the feasibility of the sprinkler systems. The analysis is based on a personal inquiry from Trust Bank.

The market value of House No. 2 is in the region of $230,000. A 75% bank mortgage with an interest rate of 11% requires a weekly payment of about $413 for a period of 20 years. A sprinkler system for this house will only increase the payment by about $20 per week.

6.3 Comparison with NFPA Codes

NFPA 13D and 13R do not require sprinkler protection in wardrobes (less than 2 m^3), concealed spaces and bathrooms (5.1 m^2). However NFPA codes assume that one or more smoke detectors are incorporated with the sprinkler system. Conversely smoke detectors are not required by NZS 4515. The cost of a sprinkler system for House No. 2 with steel pipe was calculated to be $7,440. This cost is adjusted to NFPA 13D requirements in Table 6.8.

Requirements for wardrobe and cupboard protection are similar in both NZS 4515 and NFPA 13D, with the exception that NZS 4515 allows sprinklers to be omitted from these spaces if they are vented into the sprinklered area by an opening of at least 0.02 m^2 in the top of the door. The major differences between these two standards in the case of House No. 2 are in concealed spaces and two bathrooms. There is one sprinkler in each bathroom, which if omitted would save about $180 (consisting of $70 labour and $20 material cost per sprinkler).

Table 6.8- Cost adjustment to NFPA 13D requirements for house No. 2

Item	Cost ($)
NZS 4515 system	**7,440.00**
Bathroom	- 180.00
Concealed space (material + labour)	- (555.04 + 1,120)= - 1,675.00
Smoke detector	+ ~ 150.00
Total cost of **NFPA 13D** system	**5,735.00**

Installation under the NFPA system is about 20% cheaper than the NZS 4515 system and in this case the costs comprise 2% of the house value. This is a rough comparison but gives an indication of the savings that could be made on design and installation by omitting the concealed space sprinklers.

What also must be borne in mind is the assumption that no external sprinkler protection is required for the houses. Naturally if external sprinkler protection is required, its cost must be added to the total cost of NZS 4541 system. This would create a larger cost gap between NZS 4541 and NFPA 13D systems, since NFPA 13D does not require external sprinkler protection.

6.4 Summary

Sprinkler systems with plastic pipes are more expensive than those with steel pipes. This could be the result of more expensive materials which must be imported to New Zealand and/or the result of assumption that labour cost of steel pipe systems is the same as plastic pipe systems. American studies claim that both labour and material costs for plastic pipe systems are lower than steel pipe systems. Table 6.9 summarises the costs of sprinkler systems for this case study.

Roughly speaking, a domestic sprinkler system designed according to NFPA 13D is about 20% cheaper than designed by NZS 4515.

A saving of about 4% to 7% can be made on total costs of domestic sprinkler systems if sprinklers in wardrobes were eliminated from NZS 4515 systems.

Table 6.9 - Costs of sprinkler system for house No. 1 and house No. 2

Description	Steel Pipe	Plastic Pipe	% of house value
House No. 1	$4,800.00	$5,300.00	5
House No. 1 (excluding sprinklers in wardrobe)	$4,600.00	$5,100.00	5
House No. 2	$7,440.00	$8,040.00	3
House No. 2 (excluding sprinklers in wardrobe)	$6,940.00	$7,540.00	3
House No. 2 (NFPA 13D system)	$5,735.00	-	2

CHAPTER 7

SCENARIOS

7.1 Introduction

This chapter will compare the costs and benefits of domestic sprinkler system in New Zealand for a range of scenarios. Three scenarios will be considered;

1 - Costs and benefits of sprinkler systems for the owner of a single house

2 - Costs and benefits of sprinkler systems for new dwellings for a period of 30 years

3 - Costs and benefits of sprinkler systems for 10% of existing dwellings and all new dwellings each year.

7.2 Life cycle costing

All cost items will be expressed in 1994 NZ dollars. Assume that there will be no escalation in any cost item during the life time of the sprinkler system. Almost all studies regarding sprinkler system adopt a life time cycle of 30 years for the system, and a discount rate of 6 percent for converting the future costs into present value. These will be used here.

The discounting of future sums of money will be done by the following formulas from Harmathy (1988). The single present worth for single future sum of money is given by:

$$\mathrm{SPW} = \mathrm{F}\left[\frac{1}{(1+i)^n}\right] \qquad \text{(eq. 1)}$$

The modified uniform present worth for annually recurring future sums of money is given by:

$$\mathrm{UPW} = \mathrm{A_0}\left[\frac{1}{i}\left(1-\frac{1}{(1+i)^N}\right)\right] \qquad \text{(eq. 2)}$$

Where

SPW = Single present worth

i = Interest (discount) rate

F = Future sum of money to be paid in the n^{th} year

UPW = Modified uniform present worth

A_0 = Recurring annual sum to be paid over a period of N years

N = Expected lifetime of the system

7.3 Statistics

Building permits for new dwellings in New Zealand are given in Table 7.1. Numbers are permit issued to 31^{st} March in each year.

Table 7.1 - Building permits for new dwellings

Year	Number of Permits
1988	19,886
1989	19,583
1990	22,851
1991	20,820
1992	17,563
1993	17,905
1994	19,361
Average per year	19,710

The total number of dwellings recorded in the 1991 Census was 1,185,700. There were another 54,829 dwellings built from 1992 to 1994. This will give a total number of 1,240,829 dwellings in 1994.

Assume that about 0.5% of houses were demolished since 1991, so the total number of dwellings in 1994 will be:

$$1,240,529 - (1,240,529 \times 0.005) = 1,234,326 \quad \cong 1.234 \text{ million}$$

Generally, new dwellings are less susceptible to fires than old houses, because of higher quality materials and less exposed wood. Since the number of fires in new dwellings is not available, it will be assumed that they behave in the same manner as existing dwellings.

The Insurance Council of New Zealand (ICNZ) has the total cost associated with domestic dwellings each year. These costs are presented in Table 7.2. These figures are only for member companies and do not include non-insured and self-insured dwellings.

Table 7.2 - Total cost of domestic claims to ICNZ members

Year ending	Net Claims Domestic Building (M$)	Net Claims Domestic Contents (M$)
June 94	63.8	130.3
Dec 93	59.1	135.6
Dec 92	62.2	134.0
Dec 91	59.4	132.3
Dec 90	62.9	114.6
Average/year	61.48	129.36
Total/year	≅191.00	

It was roughly estimated by Mr Norman Bridge (pers. comm.) of the ICNZ that about 30-35% of claims are fire related.

Assuming that 35% of above figures are fire related, then the cost of domestic fires per year will be:

$$191 \times 0.35 = \$66.850 \text{ million} \cong \$67 \text{ million}$$

Figures were also obtained from NZI Insurance (Mr. Bob Oldnall, pers. comm.). Property losses from fire for one year (1993/1994) recorded for single family dwelling by NZI insurance (about 28% of the insurance market) is shown in Table 7.3.

Table 7.3 - NZI record for Property loss in New Zealand for one year (1993/1994)

Type of Claims	Structure		Content		
	< $5,000	> $5,000	< $5,000	> $5,000	Total
Cost of Claims (million dollars)	1.875	12.45	1.8	7.2	**22.605**

One reason for high structural loss compared with contents is due to mandatory structure insurance required by banks or other mortgage companies.

The property losses recorded by NZI insurance would give a total fire loss for single family dwellings of

$$\left[\frac{22.605}{0.28}\right] = \$81 \text{ million per year}$$

There is some discrepancies between the NZI and ICNZ figures. An average of these values will be used here. So the average property loss due to domestic fires in New Zealand will be:

$$\left[\frac{67+81}{2}\right] = \$74 \text{ million per year}$$

7.3.1 Probability of fire in dwellings

As discussed earlier in this chapter, the estimated total number of dwellings in 1994 is about 1.234 million. This number has been growing at an average rate of 19,710 dwellings per year for the past few years. Since there is no exact statistics of demolished houses it will be assumed that 1% of new buildings are replacing the demolished dwellings. This will give about 200 dwellings demolished a year. Assuming that growth and demolition rates stay constant for the next 30 years, the total number of dwellings in the year 2024 will be about 1.82 million. Thus the average number of dwellings over the 30 years period can be calculated as follows:

$$\left[\frac{1.234+1.82}{2}\right] = 1.53 \cong 1.5$$

From 1986 to 1993 (8 years) a total of 17,339 fires occurred in New Zealand dwellings, an average of 2,167 fires per year (excluding any fires not attended by NZ Fire Service).

Assuming that this rate stays constant for 30 years, the total number of fires in domestic dwellings over the next 30 year period will be:

$$30 \times 2167 = 65{,}010 \text{ fires}$$

The expected probability of a fire in a dwellings in a 30 year period can be calculated using the following formula:

$$\text{Probability of a fire in a dwelling} = \left[\frac{\textit{Expected number of fires}}{\textit{Total number of dwellings}}\right]$$

$$= \left[\frac{65{,}010}{1{,}500{,}000}\right] = 0.043 \text{ per 30 years}$$

7.4 Cost Streams

The major costs of a domestic sprinkler system can be categorised as follows:

- Cost of design and installation
- Cost of maintenance
- Cost of part replacement

7.4.1 Costs of system design and installation

The cost of design and installation of domestic sprinkler systems varies, depending on the contractors and the size of the dwellings. Two steel pipe systems discussed in chapter 6 of this report cost \$4,800 for the smaller house and about \$7,500 for the larger house. These are the lowest prices that were offered by one contractor.

7.4.2 Cost of maintenance

For a system to be functional and reliable it must be inspected and maintained regularly. As discussed in chapter 4, a value of \$100 will be assumed here. This is a recurring annual sum, and will be discounted at a rate of 6% for 30 years. So the present value cost of maintenance using equation 2, is:

$$UPW = A_o \left[\frac{1}{i}\left(1-\frac{1}{(1+i)^N}\right)\right] = \$100\times\left[\frac{1}{0.06}\left(1-\frac{1}{(1+0.06)^{30}}\right)\right] = \$1376.5 \cong \$1380.00$$

7.4.3 Cost of part replacement

Assumption is made that replacement of parts take place during the regular maintenance service, so there would be no extra labour costs involved with part replacement. The cost of sprinkler heads used in this project are \$16 and \$17. A cost of \$17.00 per sprinkler head will be used in this analysis. Ruegg & Fuller (1984) have chosen an approach that estimates this component of cost. They assume that about half the sprinkler heads need to be replaced during the 30 years period, with the frequency of replacement lower during the earlier years and higher in the later years. Figure 7.1 shows the specific replacement pattern of sprinkler heads assumed in their calculation. This method will give a present value cost of head replacement of \$160.

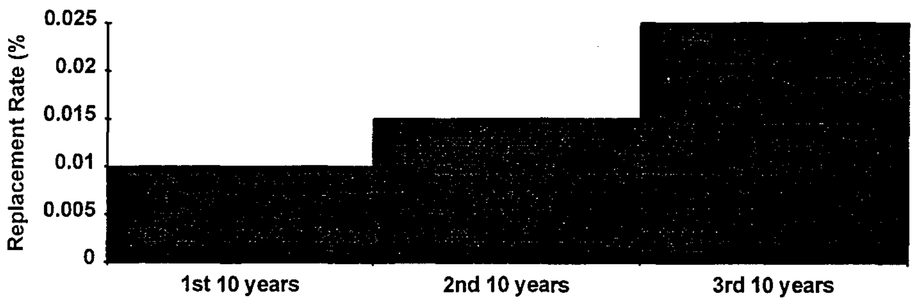


Figure 7.1 - Assumed annual rate of replacement of sprinkler heads during the life of the system. (Ruegg & Fuller 1984)

Sprinkler heads that are being used in New Zealand, according to manufacturers, do not need to be changed during the 30 year period, unless they activate in a fire or are exposed to high temperatures. As calculated previously the probability of a fire in a dwelling over a 30 year life is about 0.043. New Zealand and Australia data show that 65% of fires are controlled by one head and 16% by two heads only. NZS 4515 allows a maximum of three heads to activate in residential occupancies. On the basis of this requirement, assume that in the remaining 19% of fires three heads would activate. So by using these data, the expected number of activated heads in 30 years period per dwelling will be:

$$0.043 \times (0.65 \times 1 + 0.16 \times 2 + 0.19 \times 3) = 0.066 \cong 0.00$$

This would be more likely to happen than the other case, and it will be used in this study.

7.5 Benefit Streams

As it was outlined in chapter 4, there are a number of benefits that could be derived using a domestic sprinkler system. However it is not possible to consider all of them in the cost-benefit analysis. For example at this stage it is not possible to accurately estimate the amount of code trade-offs that the system offers. Even if it was possible to evaluate the amount of code trade-offs, still there is a doubt that a reduction in code requirements may not be in the best interest of the public. So the major benefit of domestic sprinkler system can be categorised as follow:

- Death prevented,
- Injury prevented,
- Property saved,
- Discount on insurance premiums,
- Limiting fire service costs.

7.5.1 Death prevented

As assumed in chapter 4, $NZ 800,000 will be saved for each death avoided by sprinklers.

7.5.2 Probability of death

NZ Fire Services' data for the years 1986-1993 (Narayanan 1994) shows that there were 142 deaths in domestic dwelling over that period. Thus, about 18 people lost their life due to fires in dwellings each year during that period. Even with the number of death fluctuating from year to year, it would be reasonable to expect the same number of death in domestic dwellings for the future (ignoring any significant steps towards the reduction of fires in dwellings).

So for the period of 30 years, the expected number of deaths would be:

$$30 \times 18 = 540 \text{ deaths}$$

Thus the probability of death per person over the 30 year period will be:

$$\left[\frac{540}{3,600,000}\right] = 1.5 \times 10^{-4}$$

This means that an individual New Zealander faces a probability of 0.00015 of experiencing death by domestic fire over the 30 year period.

7.5.3 Injury prevented

As assumed in Chapter 4, $NZ 40,000 will be saved for each injury prevented by sprinklers.

7.5.4 Property loss prevented

As calculated earlier in this chapter about $74 million per year is paid for domestic fire claims in New Zealand by insurance companies. Large number of these claims are for small fires, some of which in fact might be so small that the incident would not be reported to the Fire Service. Since the aim of sprinkler systems is to reduce the number of large claims, only the number of fire incidents reported to the NZ Fire Service will be considered here. There are about 2,167 fires in domestic dwelling reported to the NZ Fire Service each year, so the average fire loss per event will be:

$$\left[\frac{74,000,000}{2167}\right] = \$34,149 \cong \$34000.00$$

7.5.5 Insurance discount

The amount of discount on premiums that an owner would get in the case of sprinklering the premises is not clear. There is no insurance company in New Zealand that has a policy on reduction of insurance premiums for domestic dwellings. However as pointed out in chapter 4, some insurance companies are ready to give some kind of discount on premium for sprinklered dwellings. This varies for each insurance company and each case is considered separately. The possible discount would not be very significant at the present time. The trend may well change in future, when more wide spread use of domestic sprinkler systems has been made, and the potential for domestic sprinkler system is more understood by insurance brokers.

Insurance companies in the United States are giving discounts on premiums from 10% up to 50% for sprinklered dwellings. In New Zealand it is more likely that this figures is in the region of 8% to 20%. To be on the optimistic side a discount rate of 20% will be assumed in this study.

7.5.6 Limiting Fire Service cost

Dwellings with sprinkler systems require fewer fire fighting personnel and resources and response time can be increased. This will result in reduced cost of the Fire Service. In New Zealand expenditure on the Fire Service is about $175 million per year (Strategos 1989). As was mentioned in a Chapter 4 about 17% of this expenditure could be related to fires in dwellings. Hence about $30 million is being spent each year on domestic fires alone. This is probably a very conservative figure. Assume that this would stay the same for the next 30 years, and all of it would be saved if all dwellings have sprinklers. Thus the present value of saving discounted at a rate of 6% can be calculated as follows:

$$\text{Total saving } = \$30\times\left[\frac{1}{0.06}\left(1-\frac{1}{(1+0.06)^{30}}\right)\right] = \$413 \text{ million}$$

$$\text{So the present value of saving per dwelling would be } = \left[\frac{413\ M}{1{,}500{,}000}\right] = \$275$$

7.6 Scenario 1

7.6.1 Costs and benefits of sprinkler systems for owner of a single house

7.6.1.1 Cost of Sprinkler System

In Chapter 6 of this report the design and installation cost of a sprinkler system for House No. 2 with steel pipes were calculated to be about $7,440. This is the present value of the system and will be used in this analysis. It has not been adjusted for the time value of money. This is in accordance with Strategos 1989, and other cost-benefit studies around the world.

7.6.1.2 Cost of Maintenance

As calculated earlier the present value cost of maintenance for a period of 30 years with a discount rate of 6% is \$1,380.

7.6.1.3 Cost of part replacement

As assumed earlier there would not be any cost associated with part replacement.

7.6.2 Summary of costs

The present value of total cost of sprinkler system for House No. 2 is as follow:

Design and	\$7,440.00
installation	\$1380.00
Maintenance	**\$8,820.00**
Total	

7.6.3 Benefits

7.6.3.1 Expected life saved

A value of \$800,000 per life saved is used and assumed it will remain constant over the 30 years period. As assumed previously the average population and number of dwellings in the 30 years period were 3,600,000 and 1,500,000 respectively. This gives an average of 2.4 person per dwelling. So the present value benefit of life saved will be:

$$\$800,000 \times 1.5 \times 10^{-4} \times 2.4 = \$288 \cong \$300 \text{ per dwelling}$$

Where 1.5×10^{-4} is the probability of death over 30 years for a New Zealander.

7.6.3.2 Expected injury prevented

NZ Fire Service data gives a total number of 1286 fire related injuries in domestic dwellings for the period of 1986-1993. About 161 injuries per year.

$$\frac{1286}{8} = 161 \text{ fire injuries per year}$$

Using the same procedure discussed for expected life saved section, the following figures could be calculated.

$$\text{Probability of injury} = \left[\frac{161 \times 30}{3{,}600{,}000}\right] = 1.34 \times 10^{-3}$$

$$\text{Expected injury prevented} = \$40{,}000 \times 1.34 \times 10^{-3} \times 2.4$$

$$= \$128.64 \cong \$130.00 \text{ per dwelling}$$

7.6.3.3 Property saving

Having the probability of fire in dwellings and the average property loss per fire, the expected property loss in dollars can be calculated. In this case the amount of loss is given by:

$$\text{Estimated property loss} = 0.043 \times \$34{,}000 = \$1{,}462 \cong \$1{,}500.00$$

7.6.3.4 Insurance discount

As mentioned previously House No. 2 is an occupied residence in Christchurch. The insurance premium paid by the owner is \$330.00. Hence as assumed earlier in this chapter with a 20% discount the annual saving is:

$$\$330 \times 0.20 = \$66.00$$

The present value of insurance saving for 30 years period at a discount rate of 6%, using equation 2 would be:

$$\text{UPW} = A_0 \left[\frac{1}{i}\left(1 - \frac{1}{(1+i)^N}\right)\right] = \$66 \times \left[\frac{1}{0.06}\left(1 - \frac{1}{(1+0.06)^{30}}\right)\right] = \$908.5 \cong \$910.00$$

7.6.4 Summary of benefits

The present value of the benefit group for a sprinkler system in House No. 2 is:

Death prevented	\$300.00
Injury prevented	\$130.00
Property saved	\$1,500.00

Discount on insurance premium $910.00

Total **$2,840.00**

7.6.5 Summary of costs and benefits

It must be mentioned that when a property is insured the owner would not lose money on property and will be reimbursed by insurance company. So property loss is a loss to insurance companies not to the owner. Some people say that insuring their house is much cheaper than installing a domestic sprinkler system. This can be quite true, when an owner is insuring his/her property for other purposes in New Zealand, the marginal cost of fire insurance is low. On the other hand, if a property is not insured, the owner will not get the insurance discount, and property loss is the loss to owner.

As discussed earlier an insured owner would not save any money on saving property. On the other hand an uninsured owner would not save any money on insurance premiums. The adjusted cost-benefits in owners view only are presented in Table 7.4.

Table 7.4 - Costs and benefits for house No. 2

	Insured		Uninsured	
Items	Costs	Benefits	Costs	Benefits
Design and installation	$7,440.00		$7,440.00	
Maintenance	$1380.00		$1380.00	
Death prevented		$300.00		$300.00
Injury prevented		$130.00		$130.00
Property saved		-		$1,500.00
Discount on insurance premium		$910.00		-
Net cost	**$7,480.00**		**$6,890.00**	

This shows that sprinklers will be more attractive to uninsured person (but it is unlikely that such a person would put in sprinklers).

7.6.5.1 Break even analysis

Note that the gaps between costs and benefits in Table 7.4 are very large and significant changes in all values are required in order to get break even values.
With everything else stays the same the following changes to Table 7.4 need to be made in order to have break even costs and benefits.

Insured case: 18 time increase in the values of death and injuries prevented.

Uninsured case: 17 time increase in the values of death and injuries prevented.

These changes are presented in Table 7.5.

Table 7.5 - Break even costs and benefits for house No. 2

Items	Costs		Benefits	
	Insured	Uninsured	Insured	Uninsured
Design and installation	$7440.00	$7440.00		
Maintenance	$1380.00	$1380.00		
Death prevented			$5520.00	$5,100.00
Injury prevented			$2390.00	$2,200.00
Property saved				$1,500.00
Discount on insurance premium			$910.00	-
Total	$8,820.00	$8,820.00	$8,820.00	$8,820.00

On the other hand, a 85% and 78% reduction on design, installation and maintenance costs of insured and uninsured property respectively also could give break even values. Neither of these break even scenarios are realistic.

7.7 Scenario 2

7.7.1 Costs and benefits of sprinkler systems for new dwellings in 30 years time

Costs and benefits of domestic sprinkler systems to the nation as a whole will be considered here. In this scenario it is assumed that sprinklers are installed in all new dwellings from now on. Some of these dwellings are larger than others, so to have an installation cost for an average dwelling, costs of domestic sprinkler system with steel pipes for House No. 1 and House No. 2 that were discussed in chapter 6 of this report will be used. So an estimate is made of the cost of installation of domestic sprinkler system for an average new dwelling by averaging the costs for House No.1 and House No.2.

$$\left[\frac{\$4,800+\$7,440}{2}\right]=\$6,120.00$$

Costs and benefits of the average domestic dwellings is given in Table 7.6. Except for the design and installation costs, all of the costs and benefits remain the same as house No. 2.

Table 7.6 - Costs and benefits of an average domestic dwelling

Items	Costs	Benefits
Design and installation	$6,120.00	
Maintenance	$1380.00	
Death prevented		$300.00
Injury prevented		$130.00
Property saved (Saved by community)		$1,500.00
Discount on insurance premium (Saved by owner)		$910.00
Fire Service saving		$275.00
Total	$7,500	$3,115
Net cost	**$4,385.00**	

This will give annual costs and benefits as follows:

Costs	$7,500 × 19,710 =	$147.8 million
Benefits	$3,115 × 19,710 =	<u>$61.4 million</u>
Net cost		$86.4 million per year

As calculated earlier, the total number of dwellings in 1994 were about 1.234 million and the average number of new dwellings built were 19,710. If we assume that this stays the same for the next 30 years, and about one percent of this number is being demolished each year, the average number of new dwellings would be about 19,500 per year. Thus the total increase in dwellings over 30 years is:

$$19{,}500 \times 30 = 0.585 \text{ million dwellings}$$

And the total number of dwellings at the end of 30 years would be:

$$1.234 + 0.585 = 1.82 \text{ million dwellings}$$

Hence if we start sprinklering all new dwellings now, in 30 years time about 32% of houses will be equipped with domestic sprinkler systems.

As mentioned before, from 18 fires in sprinklered dwellings in New Zealand in the past few years, one person lost his life. No injury was reported for these fires. This gives the domestic sprinkler system in New Zealand a success rate of 94%. According to Fire Service data there are about 18 deaths per year due to fires in dwellings. If we start installing domestic sprinkler system now, we would progressively save lives. The number of lives saved in 30 years are given in Table 7.7. Note that column A assuming death rate remain constant at 1994 and column B assuming death rate correlates equally with the increase in dwellings.

In Table 7.7 two cases were considered. One was to assume that the present average deaths of 18 per year remains constant during the 30 year period. The number of lives saved then was calculated as follows:

$$\text{Number of lives saved} = \text{ \% of new dwellings} \times 18 \times 0.94$$

For example number of lives saved in the year would be:

$$2024 = 0.32 \times 18 \times 0.94 = 5.4 \cong 5.0 \text{ lives}$$

Another case was to assume that the present average death of 18 per year increase in proportion to the number of dwellings. For example, expected number of deaths in the year 2024 would be:

$$\frac{1.82 \times 18}{1.234} = 26.54 \cong 27 \text{ people}$$

The total number of lives saved in 30 years in both cases is about 18% of expected total number of deaths. This means that if installation of new domestic dwellings started today, 18% of lives that would be lost otherwise, will be saved.

Table 7.7 - Lives saved due to sprinklers in new dwellings

year	New dwellings	Total dwellings ($\times 10^6$)	% of New dwellings	Assumed Present death with no sprinklers A	Sprinklers installed		Expected death with no sprinklers B	Sprinklers installed	
					lives saved	lives lost		Expected lives saved	Expected lives lost
1994		1.234					18		
1995	19710	1.254	2	18	0	18	18	0	18
1996	39420	1.273	3	18	1	17	19	1	18
1997	59130	1.293	5	18	1	17	19	1	18
1998	78840	1.312	6	18	1	17	19	1	18
1999	98550	1.332	7	18	1	17	19	1	18
2000	118260	1.351	9	18	1	17	20	2	18
2001	137970	1.371	10	18	2	16	20	2	18
2002	157680	1.390	11	18	2	16	20	2	18
2003	177390	1.410	13	18	2	16	21	2	18
2004	197100	1.429	14	18	2	16	21	3	18
2005	216810	1.449	15	18	3	15	21	3	18
2006	236520	1.468	16	18	3	15	21	3	18
2007	256230	1.488	17	18	3	15	22	3	18
2008	275940	1.507	18	18	3	15	22	4	18
2009	295650	1.527	19	18	3	15	22	4	18
2010	315360	1.546	20	18	3	15	23	4	18
2011	335070	1.566	21	18	4	14	23	4	18
2012	354780	1.586	22	18	4	14	23	5	18
2013	374490	1.605	23	18	4	14	23	5	18
2014	394200	1.625	24	18	4	14	24	5	18
2015	413910	1.644	25	18	4	14	24	6	18
2016	433620	1.664	26	18	4	14	24	6	18
2017	453330	1.683	27	18	5	13	25	6	18
2018	473040	1.703	28	18	5	13	25	6	18
2019	492750	1.722	29	18	5	13	25	7	18
2020	512460	1.742	29	18	5	13	25	7	18
2021	532170	1.761	30	18	5	13	26	7	19
2022	551880	1.781	31	18	5	13	26	7	19
2023	571590	1.800	32	18	5	13	26	8	19
2024	591300	1.820	32	18	5	13	27	8	19
			Total	**540**	**95**	**445**	**672**	**123**	**549**

The possible amount of property saved by sprinklers for the 30 year period is shown in Table 7.8. Sprinklers do not stop the fires from igniting but minimise their catastrophic effects that might otherwise occur. So some property damage due to fires in sprinklered dwellings must be considered even where sprinklers operate successfully. According to (Narayanan 1994) there are about 2167 fires each year in NZ domestic dwellings. Property saving of 85% by sprinkler systems were recorded in Arizona, USA (ILSG 1989). Note that general sprinkler success rate in the USA is 96.2% compared with 99.8% of NZ. However since there is no actual property saving rate available for New Zealand, the 85% property saving rate will be used here. The same procedures as Table 7.7 were followed in Table 7.8 as well. First it was assumed that the number of fires in dwellings remain constant at 1994, and secondly it was assumed that the number of fires correlate with the increase in number of dwellings. Therefore the number of fires successfully effected by sprinklers in each year would be:

$$\% \text{ of new dwellings} \times 2167 \text{ (or expected fires)} \times 0.998$$

Hence the amount of property saved, assuming that successful sprinkler operation save 85% of the property, would be:

$$\text{No. of fires successfully effected} \times \$34{,}000 \times 0.85$$

Where as calculated before $34,000 is the average property loss per fire.

Table 7.8 shows that between 12000 to 16000 fires will be successfully controlled by sprinklers in dwellings which could save properties worth between $M 350 to $M 459 or roughly about $M 400 over a 30 year period.

Table 7.8 - Property saved by sprinkler systems

year	New dwellings	Total dwellings × 10^6	% New dwellings	Assumed Present No. of fires without sprinklers	sprinkler installed		Expected fires without sprinkles	Sprinkler installed	
					No. of fires effected	$M property saved		No. of fires effected	$ M property saved
1994		1.234		2167	0	0	2167		0
1995	19710	1.254	2	2167	34	0	2201	34	0
1996	39420	1.273	3	2167	66	2	2235	68	2
1997	59130	1.293	5	2167	98	3	2270	102	3
1998	78840	1.312	6	2167	129	4	2304	137	4
1999	98550	1.332	7	2167	158	5	2338	171	5
2000	118260	1.351	9	2167	187	5	2372	205	6
2001	137970	1.371	10	2167	215	6	2407	239	7
2002	157680	1.390	11	2167	243	7	2441	273	8
2003	177390	1.410	13	2167	269	8	2475	307	9
2004	197100	1.429	14	2167	295	9	2509	342	10
2005	216810	1.449	15	2167	320	9	2544	376	11
2006	236520	1.468	16	2167	345	10	2578	410	12
2007	256230	1.488	17	2167	368	11	2612	444	13
2008	275940	1.507	18	2167	392	11	2646	478	14
2009	295650	1.527	19	2167	414	12	2681	512	15
2010	315360	1.546	20	2167	436	13	2715	547	16
2011	335070	1.566	21	2167	458	13	2749	581	17
2012	354780	1.586	22	2167	479	14	2783	615	18
2013	374490	1.605	23	2167	499	14	2817	649	19
2014	394200	1.625	24	2167	519	15	2852	683	20
2015	413910	1.644	25	2167	539	16	2886	717	21
2016	433620	1.664	26	2167	558	16	2920	752	22
2017	453330	1.683	27	2167	576	17	2954	786	23
2018	473040	1.703	28	2167	595	17	2989	820	24
2019	492750	1.722	29	2167	612	18	3023	854	25
2020	512460	1.742	29	2167	630	18	3057	888	26
2021	532170	1.761	30	2167	647	19	3091	922	27
2022	551880	1.781	31	2167	663	19	3126	957	28
2023	571590	1.800	32	2167	680	20	3160	991	29
2024	591300	1.820	32	2167	695	20	3194	1025	30
			Total	**67177**	**12119**	**350**	**83096**	**15887**	**459**

7.8 Scenario 3

7.8.1 Sprinklering 10% of existing dwellings and all new dwellings each year

This scenario is similar to the previous one, except 10% of existing dwellings would be sprinklered each year in addition to all new dwellings. Thus after 10 years all the dwellings in New Zealand would be sprinklered. As shown in Table 7.9 a significant reduction on death could be achieved in ten years time.

Table 7.9 - Sprinklers in 10% of existing and all new dwellings

year	New dwellings	Total dwellings	% sprinklered	No sprinklers	Sprinklers installed		No sprinklers	Sprinklers installed	
				Present death rate	lives saved	lives lost	Expected death	Expected lives saved	expected lives lost
1994		1.234		18			18		
1995	19500	1.254	11	18	2	16	18	2	16
1996	39000	1.273	22	18	4	14	19	4	15
1997	58500	1.293	33	18	6	12	19	6	13
1998	78000	1.312	44	18	7	11	19	8	11
1999	97500	1.332	54	18	9	9	19	10	10
2000	117000	1.351	63	18	11	7	20	12	8
2001	136500	1.371	73	18	12	6	20	14	6
2002	156000	1.390	82	18	14	4	20	15	5
2003	175500	1.410	91	18	15	3	21	17	3
2004	195000	1.429	100	18	17	1	21	19	2
2005	214500	1.449	100	18	17	1	21	20	2
2006	234000	1.468	100	18	17	1	21	20	2
2007	253500	1.488	100	18	17	1	22	20	2
2008	273000	1.507	100	18	17	1	22	20	2
2009	292500	1.527	100	18	17	1	22	21	2
2010	312000	1.546	100	18	17	1	23	21	2
2011	331500	1.566	100	18	17	1	23	21	2
2012	351000	1.585	100	18	17	1	23	21	2
2013	370500	1.605	100	18	17	1	23	22	2
2014	390000	1.624	100	18	17	1	24	22	2
2015	409500	1.644	100	18	17	1	24	22	2
2016	429000	1.663	100	18	17	1	24	23	2
2017	448500	1.683	100	18	17	1	25	23	2
2018	468000	1.702	100	18	17	1	25	23	2
2019	487500	1.722	100	18	17	1	25	23	2
2020	507000	1.741	100	18	17	1	25	24	2
2021	526500	1.761	100	18	17	1	26	24	2
2022	546000	1.780	100	18	17	1	26	24	2
2023	565500	1.800	100	18	17	1	26	24	2
2024	585000	1.819	100	18	17	1	27	25	2
			Total	**558**	**436**	**106**	**690**	**549**	**123**

The same procedure as in the previous scenario has been followed in Table 7.9. In both cases 78% of lives that would otherwise be lost could be saved by sprinkler systems. The important point to note here is the reduction in number of lives lost over a 30 year period.

The amount of property saved in this scenario is given in Table 7.10, where two similar cases as Table 7.8 were considered.

Table 7.10 - Property saved by sprinkler system

year	New dwellings	Total dwellings × 10^6	% New dwellings	Assumed Present No. of fires without sprinklers	sprinkler installed		Expected fires without sprinkles	Sprinkler installed	
					No. of fires affected	$M property saved		No. of fires effected	$M property saved
1994		1.234		2167	2167	0	2167		0
1995	19500	1.254	11	2167	247	7	2201	250	7
1996	39000	1.273	22	2167	486	14	2235	501	14
1997	58500	1.293	33	2167	717	21	2270	751	22
1998	78000	1.312	44	2167	942	27	2304	1002	29
1999	97500	1.332	54	2167	1160	34	2338	1252	36
2000	117000	1.351	63	2167	1372	40	2372	1503	43
2001	136500	1.371	73	2167	1578	46	2407	1753	51
2002	156000	1.390	82	2167	1779	51	2441	2003	58
2003	175500	1.410	91	2167	1973	57	2475	2254	65
2004	195000	1.429	100	2167	2163	63	2509	2504	72
2005	214500	1.449	100	2167	2163	63	2544	2538	73
2006	234000	1.468	100	2167	2163	63	2578	2573	74
2007	253500	1.488	100	2167	2163	63	2612	2607	75
2008	273000	1.507	100	2167	2163	63	2646	2641	76
2009	292500	1.527	100	2167	2163	63	2681	2675	77
2010	312000	1.546	100	2167	2163	63	2715	2709	78
2011	331500	1.566	100	2167	2163	63	2749	2743	79
2012	351000	1.585	100	2167	2163	63	2783	2778	80
2013	370500	1.605	100	2167	2163	63	2817	2812	81
2014	390000	1.624	100	2167	2163	63	2852	2846	82
2015	409500	1.644	100	2167	2163	63	2886	2880	83
2016	429000	1.663	100	2167	2163	63	2920	2914	84
2017	448500	1.683	100	2167	2163	63	2954	2948	85
2018	468000	1.702	100	2167	2163	63	2989	2983	86
2019	487500	1.722	100	2167	2163	63	3023	3017	87
2020	507000	1.741	100	2167	2163	63	3057	3051	88
2021	526500	1.761	100	2167	2163	63	3091	3085	89
2022	546000	1.780	100	2167	2163	63	3126	3119	90
2023	565500	1.800	100	2167	2163	63	3160	3153	91
2024	585000	1.819	100	2167	2163	63	3194	3188	92
			Total	**67177**	**57838**	**1609**	**83096**	**71035**	**2053**

As it can be seen in table 7.10 between 57,000 to 71000 fires in dwellings will be successfully controlled by sprinklers, which would save about $1.8 billion of properties over a 30 year period.

7.8.1.1 Cost and benefits

It was assumed that there would be 19710 new dwellings built each year. This plus 10% of existing dwellings, will give a total number of dwellings that should be sprinklered each year. Therefore

Total no. of dwellings to be sprinklered = 19,710 + (0.1×1,234,326)

=143,142/year

After 10 years all dwellings have installed sprinklers and the number of dwellings to be sprinklered each year will drop to 19,710, ie: only new dwellings.

Thus the costs and benefits of the sprinkler systems are as follows:

First 10 years:

Costs	$7,500 × 143,142 = $1.073 billion /	year
Benefits	$3,115 × 143,142 = $0.446 billion /	year
Net Costs	**$0.627 billion /**	**year**

Subsequent years:

Costs	$7,500 × 19,710 = $0.147 billion /	year
Benefits	$3,115 × 19,710 = $0.061 billion /	year
Net cost	**$0.086 billion /**	**year**

Therefore costs and benefits over a 30 year period will be:

Costs	$1.073 × 10 + $0.148 × 20 = $13.69 billion
Benefits	$0.446 × 10 + $0.061 × 20 = $5.68 billion
Net cost	**$8.01 billion**

Note that this is the cost over a 30 year period, during which we would save about 550 lives (about $14.6 million per life saved). After this period, the costs of sprinkler systems in new dwellings, which was calculated to be about $86 million per year need to be considered. This would result in only one or two deaths per year in domestic fires (about $5 million per life saved).

7.8.1.1.1 Break even analysis

Assuming everything else stays the same, a 58% reduction on design, installation and maintenance costs would yield a break even costs and benefits.

Note from Table 7.6 that even a significant increase in the value of injury prevented or life saved would not alter the total benefit earned, since they only comprise about 4% - 10% of the total benefit. Property saved and insurance discount are more sensitive and can make some significant effect. On the other hand in the cost group the most sensitive category is the cost of design and installation which comprises about 80% of costs.

7.9 Summary

In respect of saving lives, scenarios can be categorised in three groups as follows:

- Sprinklers in all new dwellings and lives saved in a 30 year period.
- Sprinklers in all new plus 10% of existing dwellings per year.

Costs and benefits of four scenarios are summarised in Table 7.11. In the present situation economically the cost of a domestic sprinkler system outweigh its benefits. Some significant changes are required to get a break even value.

Table 7.11 - Summarised costs and benefits

Item	Scenario 1		Scenario 2	Scenario 3
	House No. 2		New Dwellings ($ million)	All New plus 10% of Existing Dwellings ($ billion)
	Insured	Uninsured		
Cost	$8,820	$8,820	$147.8	$13.69
Benefits	$1,340	1,930	$61.4	$5.68
Net Cost	**7,480**	**$6,890**	**$86.4 /year**	**$8.01** (over 30 years)

Sprinkler systems are more attractive to uninsured than insured owners.

Installation of sprinkler systems in all new dwellings from now on would save about 100 lives over a thirty year period. This means about $26 million per life each year. In the same period between 12000 to 16000 fires would be controlled by sprinklers which would save about $M 400 in property losses.

Installation of sprinkler systems in all new, plus 10% of existing dwellings would save about 500 lives over 30 years (about $14.6 million per life saved). Further life saving by domestic sprinkler systems will cost about $5 million per life. About 57000 to 71000 fires would be successfully controlled by sprinklers with a property saving of about $1.8 billion over 30 years.

The calculations in this chapter show that a simplified cost-benefit study cannot be used on its own to justify the installation of domestic sprinkler systems.

However, that does not mean that sprinkler systems cannot or should not be used.

It is clear that widespread installation of domestic sprinkler system gives an enhanced quality of life to building occupiers, including improved life safety, peace of mind, and reduced potential loss of irreplaceable property.

Many more people might decide to make such an investment if they were more aware of the costs and benefits involved.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The following conclusions can be drawn from this study:

- About half of the annual fire fatalities in New Zealand occur in domestic dwellings. This amounts to an average of 18 deaths per year.

- Annual property loss due to domestic fires in New Zealand is about $74 million.

- Domestic sprinkler systems have tremendous potential to reduce life and property loss.

- In New Zealand the installation cost of a NZS 4515 domestic sprinkler system for a typical 200 m^2 house is approximately $37 per m^2 of floor area (about 3% of house value). For a smaller house (72 m^2) the costs increase to $67 per m^2 of floor area (about 5% of house value). These costs are significantly more than the equivalent reported costs in the United States (about $NZ 21- $NZ 44 per m^2 of floor area).

- NZS 4515 is more conservative than any other equivalent standard around the world. This results in higher installation costs for domestic sprinkler systems in New Zealand than in other countries, mainly due to the need for sprinkler heads in concealed spaces.

- Installing domestic sprinkler systems in new dwellings only, could save over 100 lives and $450 million worth of property damage over a 30 year period.

- 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.

- At the present time, the cost of installing a domestic sprinkler systems is greater than the expected value of benefits, but the gap between its costs and benefits become narrower when benefits to the community as a whole are considered.

- A significant reduction in the present design and installation costs of domestic sprinkler systems and a large increase in value of life, injuries, and insurance discount is required in order for the systems to become cost effective.

- Because of the small number of systems being installed, there is not much competition for this type of business. That would change if domestic sprinkler systems became more popular.

- Widespread use of domestic sprinkler systems is not very likely to markedly reduce the costs of operating the New Zealand Fire Service.

8.2 Recommendations

The following recommendations to different organisations could reduce the costs of a domestic sprinkler system and encourage their more widespread use in New Zealand.

8.2.1 City councils

- A major cost of domestic sprinkler systems is the town main connection fees. As an incentive to the owners who install sprinklers, and hence are taking steps toward a safer community, this cost should be abolished or significantly reduced or subsidised.

- A 20 mm or larger pipe should be used for domestic water supplies, instead of 15 mm pipes which are normally used. This will allow a domestic sprinkler system to be connected to the domestic water supply instead of to the town main, resulting in several hundreds of dollars of saving.

8.2.2 Insurance companies

- Insurance companies will significantly benefit from the widespread use of domestic sprinkler systems. So they must officially recognise their potential for reducing property damage by giving a tangible discount on their premium for those who install sprinklers.

8.2.3 Sprinkler industry

- The sprinkler industry sometimes uses a complicated control valve set for domestic dwellings which is required by NZS 4515 for large residential buildings. The more simplified version of this valve set as allowed by NZS 4515 should be used for domestic premises, to reduce the installation costs.

- Instead of a lump sum price for a valve set, its cost could be based on materials used only, with the assembling cost included in overall labour costs of the system.

- The present price of sprinkler installation is very high compared with North America. It must be reduced significantly, to encourage widespread use of the system. More efficient installation practices in a large number of houses should reduce costs.

8.2.4 Insurance Council of New Zealand

- ICNZ as an "authority having jurisdiction" should initiate changes to allow more people (for example plumbers) to be able to install domestic sprinkler systems. This will increase the competition between contractors and drop the installation costs.

8.2.5 Building Industry Authority

- The Approved Documents should be modified to give trade-offs in passive fire protection where sprinkler systems are installed in multi-family dwellings.

8.2.6 Future research

The following topics in relation to domestic sprinkler system could be investigated by future research.

- Numbers of domestic fires which started in roof, cupboards or other concealed spaces, and evaluation of fire risk from combustible materials outside the home.
- Possible trade-offs that could be incorporated in the building code for multifamily dwellings.
- Which types of housing and which socio-economic groups are at greatest risk from fires.
- Environmental impacts of domestic fires.
- Indirect costs of domestic fires, above those paid for by insurance claims.
- More detailed analysis of fire claims in domestic buildings.

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APPENDIX A

HYDRAULIC CALCULATIONS

House No. 1

According to Section 5 of NZS 4515, the number of operating sprinkler heads in this building would be a maximum of two. These could be in either the lounge, kitchen and dining room, or roof. Sprinklers in the roof (heads 1 and 2 in Figure 6.1) are the most remote heads, and hydraulically the most disadvantageous. therefore hydraulic calculations will be based on these two heads and are presented in Chart 5.1. Sample calculations will be given for each different step, so the origin of all the numbers in Chart A.1 can be understood.

15 mm sprinkler heads which have the following specification (Central, 1991) will be used in concealed spaces:

Quick response heads: Flow rate = 47.3 l/min

k = 8.0

Section 7.3.5.1 of NZS 4515 requires that discharge from a sprinkler head to be calculated by the following formula:

$$Q = K\sqrt{P}$$

Where

Q = Discharge from sprinkler (l/min)

P = Pressure at entry to sprinkler orifice (kPa)

Required pressure at point 1 $P_1 = \left(\frac{Q}{K}\right)^2 = \left(\frac{47.3}{8.0}\right)^2 = 35$ kPa

Using medium quality steel pipe with a Hazen/Williams Factor of C = 120, from table 7.2 of NZS 4515, hydraulic equivalent length factors for pipe fittings are given in Table A.1.

Table A.1 - Equivalent length factors

Item	Equivalent Length Factor
Tees into branches	0.06
Elbows	0.03
Bends	0.015

Section 7.3.3.3 of NZS 4515 permits pressure loss in each metre of pipe to be calculated using the following formula:

$$P = R \times Q^{1.85}$$

Where

P = pressure loss per metre of pipe (kPa)

Q = flow rate through pipe (l/min)

R = the appropriate value from table 7.1 of NZS 4515. For this case they are shown in Table A.2.

Table A.2- Value of 'R' for steel pipe

Pipe Nominal Bore	Value of R
25	8.73×10^{-4}
32	2.28×10^{-4}

Pressure loss from point 1 to point 2 $P_{1-2} = 8.73 \times 10^{-4} \times 47.3^{1.85} = 1.1$ kPa/m

Equivalent length of fittings and bends:

Bend at point 2: $0.015 \times 25 = 0.375$ m

Tee at point A : $0.06 \times 25 = 1.5$ m

Elbow at point C: $0.03 \times 32 = 0.96$ m

$\therefore$ Total pressure loss due to pipe and fittings from point 1 to point 2 is

$2.875 \times 1.1 = 3.2$ kPa

Hydraulic calculations for the system is presented in the standard Chart A.1.

Chart A.1 - Hydraulic calculation for house No. 1

Nozzle Type & Location	Flow in l/min	Pipe Size	Fittings & Devices	Pipe Equivalent Length (m)	Friction Loss (kPa/m)	Required Pressure (kPa)	Notes
1	47.3			LGTH. 2.5		35	Two head operating
1-2	47.3	25	bend	FTG. 0.375	1.1	3.2	
				TOT. 2.875			
2	49.4			LGTH. 0.5		38.2	$Q_2 = 8 \times \sqrt{38.2}$
2 - A	97	25	Tee	FTG. 1.5	4.14	8.28	
				TOT. 2			
A	97			LGTH. 0.8		46.48	
A - B	97	25	Tee	FTG. 1.5	4.14	9.5	
				TOT. 2.3			
B	97			LGTH. 9.7		60	
B - C	97	32	Elbow	FTG. 0.96	1.1	12	
				TOT. 10.66			
C	97					72	

Calculation of static pressure head

Section 7.3.2.1 of NZS 4515 specifies that static pressure equivalent of differences in height between sprinklers junctions and datum to be taken as:

$P = h \times 10$

Where

P = pressure loss or gain due to head (kPa)

h = difference in height between sprinklers junctions and datum (m).

For this case datum will be taken at the top of the control valve set, so h = 1.0 m.

$\Rightarrow P = 1 \times 10 = 10$ kPa

Required pressure and flow rate

Total pressure required at the valve set is the combination of static pressure and the pressure that was hydraulically calculated.

$P_{TOT} = 72 + 10 = 82$ kPa

As hydraulically calculated the total flow rate required is 98 l/min.

$\Rightarrow$ $\underline{Q_{TOT} = 97 \text{ l/min at } P_{TOT} = 82 \text{ kPa}}$ At the top of valve set

This is the flow rate and pressure at the top of valve set. According to Mr Horwarth of Fire Fighting Pacific, losses through a 40 mm valve set is not very significant, and normally is less than that of a two metre pipe with the same diameter. However, if these losses are consider the flow rate and pressure will be:

$\underline{\mathbf{Q_{TOT} = 98 \text{ l/min at } P_{TOT} = 83 \text{ kPa}}}$ At the base of valve set

Sprinkler system for House No. 1 has been designed on the plan only and the actual house does not exist. It can be constructed anywhere in New Zealand. It will be assumed that the flow rate and pressure in the town main, just outside the house, is sufficient and satisfies the required flow rate and pressure for the sprinkler system.

House No. 2

Even though this house is a two storey building, it's hydraulic calculation is very similar to House No. 1. According to Section 5.1.1 of NZS 4515, the number of operating sprinkler heads in this building would be a maximum of three heads. These are in the sun room and living room which are connected to each other by an open space (heads 3, 4, and 5, in Figure 6.4 Section B-B). Concealed space sprinklers in the roof (heads 1 and 2 in Figure 6.4- Section A-A) are the most remote heads. Hydraulic calculations for both cases will be considered in order to be able to recognise the most disadvantageous case. Calculations are presented in chart A.2. Sample calculations will be given for each different step, so the origin of all the numbers in chart A.2 can be understood.

15 mm sprinkler heads which have the following specification (Central, 1991) will be used :

Residential heads (for ceiling): Flow rate = 45.42 l/min

k = 6.2

Quick response heads (for concealed space): Flow rate = 47.3 l/min

k = 8.0

Discharge from a sprinkler as required by section 7.3.5.1 of NZS 4515 is calculated by the following formula:

$$Q = K\sqrt{P}$$

Where

Q = Discharge from sprinkler (l/min)

P = Pressure at entry to sprinkler orifice (kPa)

Medium quality steel pipe with a Hazen/Williams Factor of C = 120 will also be used for this case. Hydraulic equivalent length factors for pipe fittings were given in Table A.1.

Pressure loss in each metre of pipe as allowed by Section 7.3.3.3 of NZS 4515 is also calculated using the following formula:

$$P = R \times Q^{1.85}$$

Where; P = pressure loss per metre of pipe (kPa)

Q = flow rate through pipe (l/min)

R = the appropriate value from table 7.1 of NZS 4515. For this case they are shown in Table A.2.

Equivalent length of fittings and bends:

Bend at point 2:	$0.015 \times 25 = 0.375$ m
Tee at point A, C&D:	$0.06 \times 25 = 1.5$ m
Elbow at point B:	$0.03 \times 25 = 0.75$ m
Elbow at point E:	$0.03 \times 32 = 0.96$ m

Concealed space sprinklers

Hydraulic calculations for the system is presented in the standard Chart A.2.

Chart A.2- Hydraulic calculation for house No. 2

Nozzle Type & Location	Flow in l/min	Pipe Size	Fittings & Devices	Pipe Equivalent Length (m)	Friction Loss (kPa/m)	Required Pressure (kPa)	Notes
1	47.3			LGTH. 3.0		35	Two heads operating
1-2	47.3	25	bend	FTG. 0.375	1.1	3.7	
				TOT. 3.375			
2	48.8			LGTH. 0.5		38.7	$Q_2 = 8 \times \sqrt{38.7}$
2 - A	97	25	Tee	FTG. 1.5	4.14	8.28	
				TOT. 2			
A	97			LGTH. 0.8		47	
A - B	97	25	Elbow	FTG. 0.75	4.14	6.4	$FL_{A-B} = 8.73 \times 10^{-4} \times 97^{1.85}$
				TOT. 1.55			
B	97			LGTH. 14.8		63.62	
B - E	97	32	Elbow	FTG. 0.96	1.1	17.38	$FL_{B-E} = 2.28 \times 10^{-4} \times 97^{1.85}$
				TOT. 15.8			
E	97					81	

Sample calculation

Required pressure at point 1 $P_1 = \left(\frac{Q}{K}\right)^2 = \left(\frac{47.3}{8}\right)^2 = 35$ kPa

Friction loss from point 1 to point 2 $FL_{1-2} = 8.73 \times 10^{-4} \times 47.3^{1.85} = 1.1$ kPa/m

$\therefore$ Total pressure loss due to pipe and fittings from point 1 to point 2 is

$3.375 \times 1.1 = 3.7$ kPa

Three sprinklers operating

Hydraulic calculations for the system is presented in the standard Chart A.3.

Chart A.3 - Hydraulic calculation for house No. 2

Nozzle Type & Location	Flow in l/min	Pipe Size	Fittings & Devices	Pipe Equivalent Length (m)	Friction Loss (kPa/m)	Required Pressure (kPa)	Notes
3	45.42			LGTH. 1.4		53.7	Three heads operating
3-C	45.42	25	Tee	FTG. 1.5	1.1	3.2	$FL_{3-C} = 8.73 \times 10^{-4} \times 45.42^{1.85}$
				TOT. 2.9			
C	45.42			LGTH. 3.3		59	
C-D	45.42			FTG.	0.3	0.99	$FL_{C-D} = 2.28 \times 10^{-4} \times 45.42^{1.85}$
				TOT. 3.3			
D						60	
4	45.42			LGTH. 3.0		53.7	
4-5	45.42	25		FTG.	1.02	3.06	$FL_{4-5} = 8.73 \times 10^{-4} \times 45.42^{1.85}$
				TOT. 3.0			
5	46.8			LGTH. 1.2		57	$Q_5 = 6.2 \times \sqrt{57}$
5-D	92	25	Tee	FTG. 1.5	3.7	10	$FL_{5-D} = 8.73 \times 10^{-4} \times 92^{1.85}$
				TOT. 2.7			
D						67	

Pressure required by heads 4 and 5 at point D is greater than of that required by head 3. This will result in a higher flow rate at point C. New flow rate at C is calculated as follows:

$$K_D = \frac{45.42}{\sqrt{60}} = 5.8$$

So the new flow rate at point C is $Q_c = 5.8 \times \sqrt{67} = 48$ l/min

$\therefore \quad Q_{TOT} = Q_C + Q_D = 48 + 92 = 140$ l/min

$P_{C+D} = P_D + PL_{D\text{-}C} = 67 + 0.99 = 67.99 = 68$ kPa

$\Rightarrow \quad P_E = P_{C+D} + PL_{D\text{-}E} = 68 + R_{32} \times Q_{TOT}^{1.85} \times (11 + 0.03 \times 32)$

$= 68 + 2.28 \times 10^{-4} \times 140^{1.85} \times 11.96 = 93.46 \cong 93$ kPa

Sample calculations

Required pressure at points 3 & 4 $P_3 = P_4 = \left(\frac{Q}{K}\right)^2 = \left(\frac{45.42}{6.2}\right)^2 = 53.7$ kPa

Friction loss from point 3 to point C $FL_{3-C} = 8.73 \times 10^{-4} \times 45.42^{1.85} = 1.1$ kPa/m

$\therefore$ Total pressure loss due to pipe and fittings from point 3 to point C is

$2.9 \times 1.1 = 3.2$ kPa

Worst case

Two sprinklers operating in the concealed space requires a flow rate of 97 l/min at 81 kPa at point E. In the case of three sprinklers operating in sun room and living room, they require flow rates of 137 l/min at 93 kPa at point E. So the second case (three sprinklers operating) will govern the design for House No. 2.

Calculation of static pressure head

According to Section 7.3.2.1 of NZS 4515 the static pressure equivalent of differences in height between sprinklers junctions and datum is:

$P = h \times 10$

P and h were defined previously.

For this case datum will also be taken at the top of the control valve set, so h = 1.0 m.

$\Rightarrow P = 1 \times 10 = 10$ kPa

Required pressure and flow rate

Total pressure required at the valve set is the combination of static pressure and the pressure that was hydraulically calculated.

$P_{TOT} = 93 + 10 = 103$ kPa

As it was hydraulically calculated the total flow rate required is 137 L/min.

$\Rightarrow$ <u>$Q_{TOT} = 137$ l/min at $P_{TOT} = 103$ kPa</u> At the top of valve set

Following the discussion for previous case, the losses through valve set increase the required flow rate and pressure to 138 l/min and 105 kPa respectively.

$\Rightarrow$ **<u>$Q_{TOT} = 138$ l/min at $P_{TOT} = 105$ kPa</u>** At the base of valve set

House No. 2 is a house on the Cashmere Hills in Christchurch. According to the New Zealand Fire Service flow test, available flow rate and pressure in the town main just outside the house are well above the required flow rate and pressure. So the town main supply will be sufficient for the sprinkler system and no pump or elevated tank is required.