

Report on Fire in Atrium Buildings Problems and Control

including a case study on the
Pan Pacific Hotel Auckland

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ABSTRACT

Atrium buildings are now becoming a common feature in New Zealand with this new structural form being applied to hotels, office blocks and hospitals. Being a new form of structure, there has been little study or experience of how these buildings perform in the event of fire.

In an effort to investigate just how safe atrium buildings are, this report will outline problems specifically associated with atria. The fire protection and safety systems employed which can most effectively be used to protect property and save lives. By the use of case studies, typical fire control measures installed in atrium buildings are described, with a report on how these were installed in the Pan Pacific Hotel, Auckland, together with a brief description of recent incidents of atrium building fires.

It should be made clear, how recent studies have led to the establishment and subsequent development of design guidelines and codes for fire safety in atrium buildings.

A.

*See later report.
Just what we need!*

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1.0 INTRODUCTION

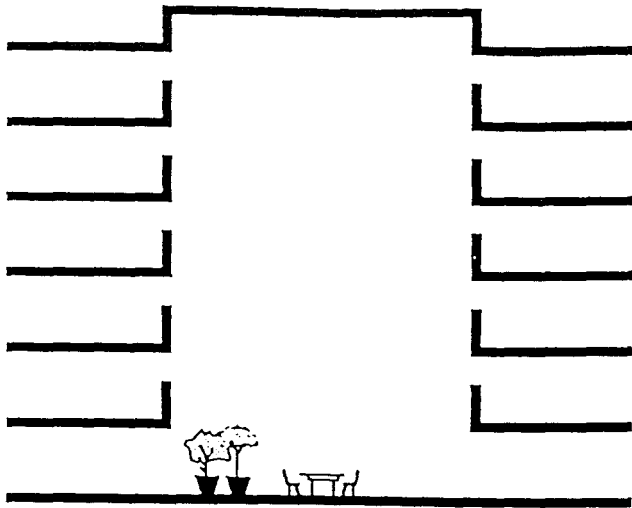
An atrium within a building is a large space which connects openings in floors, and which is wholly or partially enclosed at the top by a floor or roof. The essential difference between an atrium and a traditional inner courtyard or mall is that an atrium is greater than two storeys high, roofed over and smoke from a fire cannot readily escape to the outside atmosphere.

Atrium buildings are a recent type of building structure, with many having been built overseas. They have become popular because they allow light into lower levels of buildings, creating an outside atmosphere which is protected from the extremes of climate. Therefore atriums can contribute to visual appeal and achieve economies in the use of heat and light as well as providing recreational space and an air of spaciousness.

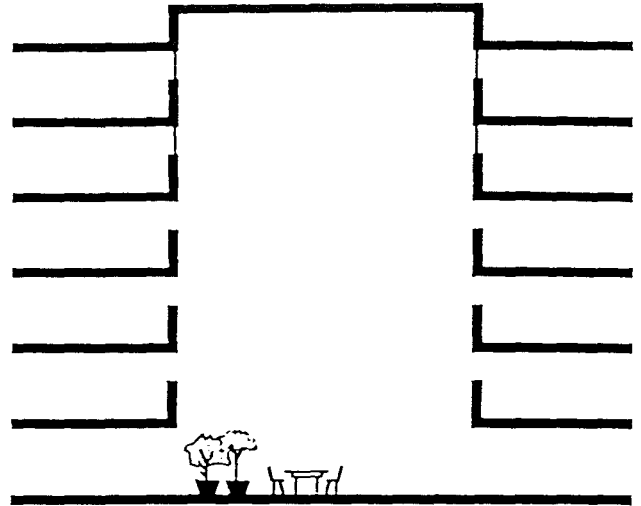
There are four main types of atrium and different fire safety problems and solutions may evolve from each,(fig 1.1):

- a) The fully open atrium is where the building has all its upper levels open to the atrium shaft.
- b) The partially open atrium is where the building has some of its lower levels open to the shaft and the remainder closed off.
- c) The closed atrium is where the atrium shaft is separated from the remainder of the building by ordinary (non-fire resistant) construction. The atrium floor may be used for recreation, restaurants or as a hotel lobby.
- d) The sterile tube atrium has an atrium shaft separated from the remainder of the building by fire resistant construction, with the atrium floor being used only for circulation and containing no combustible material.

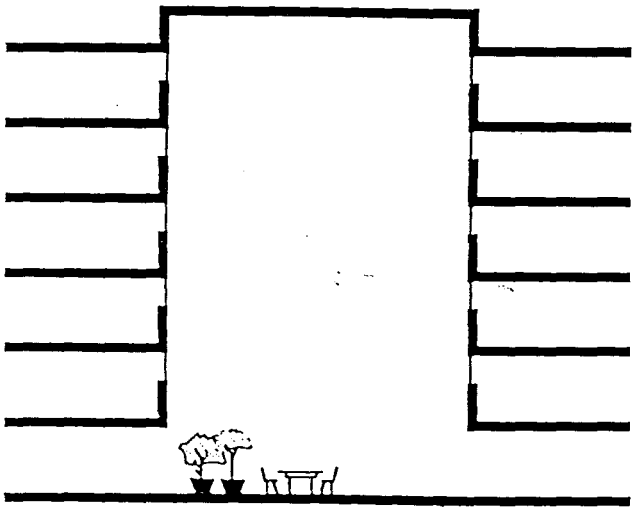
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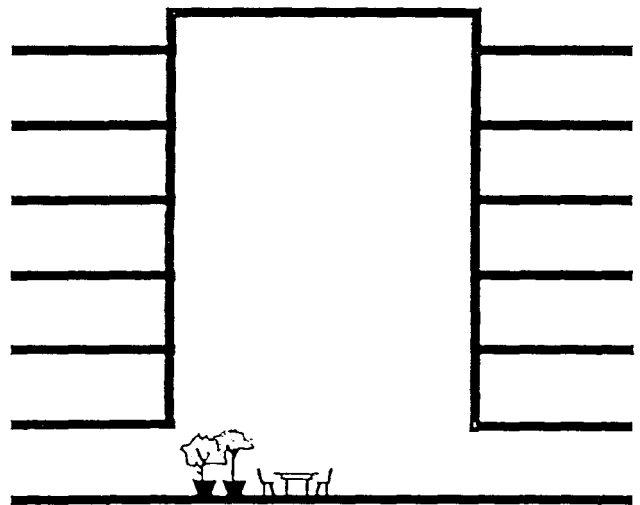
(a) Fully Open



(b) Partially Open



(c) Closed



(d) Sterile Tube

Fig 1.1 Types of Atrium⁽⁶⁾

2.0 FIRE SAFETY PROBLEMS IN ATRIUM BUILDINGS

The existence of a large shaft extending through a number of floors is a departure from the traditional fire protection principal of compartmentalisation, for restricting the spread of smoke and fire. As far as fire is concerned, an atrium shaft is likened to a massive chimney.

Standard requirements for protected shafts and compartmentalisation are intended to limit smoke and fire spread to the floor of origin, but fire occurring at the atrium floor level is likely to fill the atrium with smoke, and fire spread floor by floor is just as possible inside an atrium shaft as it is up the external facade of a building.

Another major problem is egress through the atrium space. Visibility in a smoke logged atrium decreases rapidly and causes loss of orientation. Coupled with this is the tendency for people to escape from the building the same way they came in, because of their unfamiliarity with the exits. This causes delays in evacuation and prolongs their exposure to toxic smoke. ✓

By far the most dangerous aspect of fire in atrium buildings is that of smoke control. It is well known that it is generally not fire, but smoke which is the main cause of death.

There are general principles or control measures which have to be applied to atrium buildings to establish fire safety effectiveness;

If possible, smoke from a fire should be confined to the floor of origin by extraction on that floor.

If smoke is allowed to spread into the atrium, it must be recognised that the smoke level will descend in the atrium for several floors unless high extraction rates are used.

Sprinklers should be installed throughout to prevent the growth of fire. ✓

Smoke control must be by mechanical extraction as natural smoke venting is only effective for very low atrium spaces. ✓

No part of the escape path, in event of fire, should be in or open to the atrium, since it is likely that substantial smoke logging can occur within it. Open balconies, stairs and escalators in an atrium space are regarded as hazardous areas, unless special measures are taken. ✓

In the fire protection design of atrium buildings, fire and smoke control systems are specifically designed with the above principles in mind.

The design of fire control systems can be broken down into two main categories;

- i. Passive control systems, which are functional at all times, and are built-in features of the atrium building, and
- ii. Active control systems, which detect and fight fires directly when they occur.

Active and passive smoke control systems are provided in the atrium space principally to increase the time available for evacuation, by preventing or delaying smoke and fire from spreading to the escape routes, and at the same time directing as much of it away to the outside of the building as possible. ✓

3.0 PASSIVE FIRE AND SMOKE CONTROL IN ATRIUM BUILDINGS

3.1 Fire Spread.

In a conventional, compartmented building it is assumed that a fire will be contained within the floor of origin. It is evident for atrium buildings, that fire spread may occur up the sides of the atrium shaft, and that the problems confronted are similar to those for an external facade. Controlling the spread of fire in atrium building is a lesser problem than the hazard to life safety caused by spread of smoke. ✓

3.2 Smoke Spread

Fires can rapidly generate a large volume of hot smoke which will rise and spread outwards, and at the same time become diluted with many times its volume of cold air. A fire occurring in lower floors can fill much of the atrium volume with smoke in a time scale well within that needed for escape by the occupants of a tall building. ✓

It is unwise to rely on dilution of smoke by mixing within the atrium shaft. Cold air will be entrained by the hot gas as it rises in the atrium shaft, reducing its density and hence its buoyancy. At some height it will cease to rise by its own buoyancy but still spread sideways. This loss of buoyancy will tend to cause stagnation of the smoke mass which will be forced upwards by the smoke pressure below. Therefore there is an upper limit of about four storeys for the height within which natural venting from the top of the shaft will be effective. ✓

It is also essential that a smoke reservoir be created at the top of the atrium shaft, otherwise as soon as the smoke reaches the top of the shaft it will begin to spread sideways into the uppermost floor space. This reservoir should be of the order of one storey in height. ✓

Where the atrium is fully open, fire occurring on any floor will result in smoke spreading into the shaft. If the fire originates from the atrium floor it is likely that the rising smoke will bypass some of the lower floor levels and spread laterally into the upper floors. The partially open atrium shaft has an improved level of safety, for those occupants situated on the enclosed floors.

Smoke stop doors within areas adjacent to the atrium will prevent smoke spread to and from adjacent areas.

3.3 Fire Resistant Linings.

Generally the building materials used within the atrium and in adjacent areas have good fire resistant properties, and the level of fire resistance is usually in compliance with code requirements.

If glazing is installed to permit viewing, and entry of light, the glass may shatter after being exposed for some time to hot gases on one side. This will permit the entry of smoke into the adjacent floor spaces.

4.0 ACTIVE FIRE AND SMOKE CONTROL IN ATRIUM BUILDINGS

4.1 Escape Routes and evacuation

Building codes include provisions for safe escape routes for occupants within which they are protected from the effects of fire during their travel to a safe place. As described previously what happens when a fire occurs in an atrium building, it is evident that occupants will be at risk from rapid spread of smoke.

Since they may be situated away from the fire source, it is essential that alarm systems are installed which provide occupants with an adequate escape time before smoke reaches them. This alarm must be audible, and in some cases visual, to all occupants. It has been found in overseas studies that sprinkler system alarms are too slow to ensure safe escape, so smoke detectors are specified in addition to these.

Some atrium buildings have stairs and escalators situated within the atrium space, but these create problems because in the event of a fire in the atrium, smoke logging occurs, and occupants may become trapped while evacuating. Therefore in atrium buildings, it has been found necessary to provide two or more means of escape. Most codes require two separate protected stairwells remote from the atrium shaft. Open escape balconies can sometimes be found within the atrium space and are normally protected by the HVAC (Heating, Ventilation and Air Conditioning) systems, which provides pressurisation or uses fresh air deflectors to keep encroaching smoke away from the escape path.

4.2 Smoke Extraction

As previously mentioned natural venting at the top of an atrium shaft is ineffective in the extraction of smoke during a fire. Because of the large volume of smoke and hot gases, mechanical extraction is the preferred option for smoke removal.

No smoke extraction system at the top of the shaft will perform as designed, unless adequate quantities of fresh inlet air are supplied at the base of the atrium shaft. It is recommended that the quantity should be equal to or greater than the design smoke extraction rate.

With a fully mechanical system, care should be taken in locating the outlets from fresh air fans, because if an upward jet impinges on the base of a buoyant smoke layer, the resultant mixing could cause a disturbance of the smoke layer leading to downward mixing and poorer visibility at lower levels. Smoke extraction through the top of the atrium shaft is also affected by external wind flow. The roof geometry and surrounding land or cityscape may cause wind effects to oppose the escape of smoke. A solution to this is to divide the vent or fan size between leeward and windward sides of the smoke reservoir. One development is to install the full vent area on each side of the reservoir with direct wind sensors ensuring that only downwind vents open in the event of fire. ✓

4.3 Sprinklers, Drenchers and Deluge Systems

These active forms of fire protection are important in controlling the developing fire, keeping it small, and ensuring that the quantity of smoke generated is at a level where it can be handled by the extraction systems.

All areas should be covered by sprinklers. Sprinklers installed at the top of the atrium shaft are ineffective because there is a delay in response time as the hot gases rise and accumulate in the atrium reservoir. On activation, water cooling the rising gases decreases smoke buoyancy. ✓

On the atrium floor level, sprinklers can be located around the perimeter, but are only effective against fire directly below them.

For fire out of range of the perimeter sprinklers, deluge systems or sprinklers with long throw heads, can be installed around the lower floor levels, these discharge large volumes of water. ✓

Wherever a floor is open to the atrium shaft, there is a danger of a slow response for sprinkler heads because of the time it may take to accumulate enough hot gas to activate them. Smoke baffles should be installed to trap smoke and immerse the heads so that they will activate sooner in the event of fire. Smoke baffles on the other hand may encourage lateral spread of smoke. (Fig 4.1)

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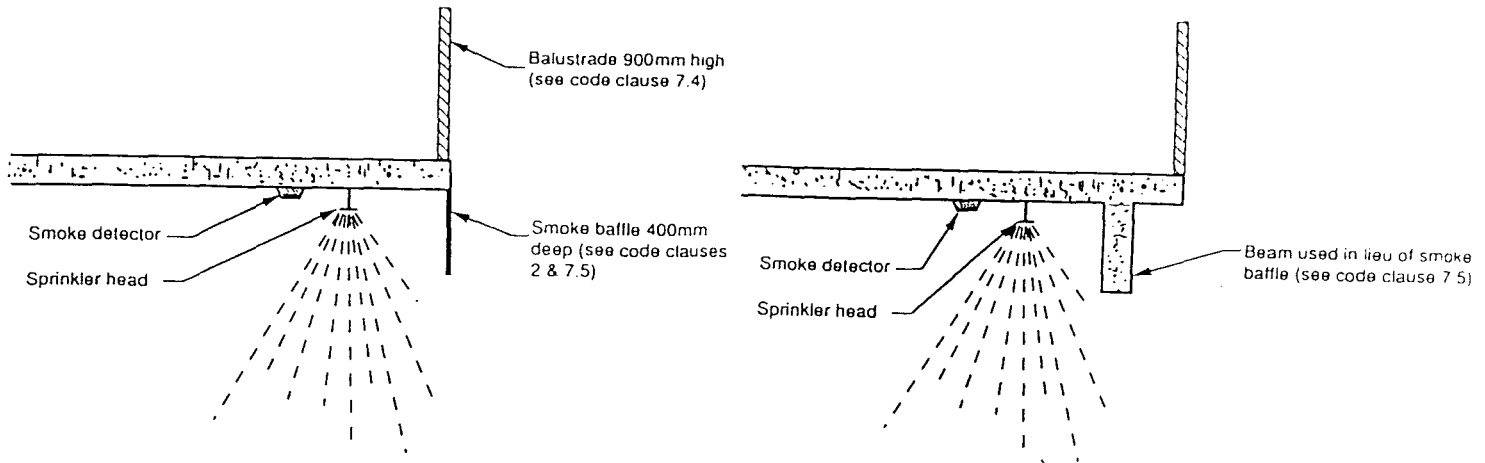


Fig 4.1 Detail of Smoke Baffle or Floor Edge at Atrium Shaft.⁽⁶⁾

Another form of sprinkler which can be installed is the external wall drencher which is generally used to protect glazing between floors in the event of fire, by directing spray upon the glazed surface.

4.4 Pressurisation

Pressurisation of shafts and escape routes are important smoke control measures. The pressurisation system uses the building's HVAC system and maintains higher pressures in safe areas like balconies and protected exit ways so that air flow is always directed outwards. This prevents smoke from collecting in these areas and hindering evacuation.

When the fire occurs, fresh air flows into balconies and the atrium shaft, which become pressurised. Smoke flowing from the fire floor is prevented from encroachment onto the other floors.

Using pressurisation with selective controls placed on air handling equipment, in fire mode, the fire floor can be placed on extract (to the exterior) and the remainder of the floor is pressurised avoiding filling the atrium.

5.0 CODE ESTABLISHMENT

As atrium buildings are a fairly recent form of structure in New Zealand, there have been no previous codes or standards on which to base fire protection requirements, except for the conventional building codes. They also present unique problems, and there has been a need for the establishment of codes and fire prevention standards.

New Zealand guidelines for the design and standards of performance of fire safety features in atrium buildings are set out in NZS4238:1991, "Code of Practice for Fire Safety in Atrium Buildings". The key aim being public safety. ✓

Assessments need to be made and various factors have to be considered in the design of atrium structures;

The activities which will take place in the atrium.

Justification for the selection of smoke control and extract systems.

Adequacy and efficiency of the smoke extraction system chosen.

The duration for which the smoke control system will be able to keep the building occupied with all exit signs visible.

The ventilation in the atrium space and the efficiency of the fresh air inlets and smoke extraction outlets in maintaining the required air circulation in the shaft.

The adequacy of evacuation routes and strategies for the early evacuation of occupants.

The reliability of smoke and thermal detection devices used.

During the planning and design stage, agreement must be reached between the engineer and the approving authority, and fire service, as to the suitability of the proposed smoke control systems to be used in the building.

In some cases smoke testing is carried out in the atrium to determine smoke extraction system effectiveness. Smoke testing is a method of assessing the effectiveness of the smoke control system. Commercially available chemical smoke in heated (hot), or unheated (cold) forms are used.

There are two main phases involved. The first is the testing of individual components in the smoke control system to ensure that they perform to specification. This includes smoke detector and alarm responses, pressurisation systems, automatic door closers and trigger mechanisms for emergency power supplies from back up diesel generators. The second phase is a full simulation of the worst possible fire in the atrium space to gauge the effectiveness of all the components working together. Response times of detectors, efficiency of the smoke extractors, pressurisation and duration for which exit signs remain visible are all monitored.

Reproduction of smoke that is cold, non toxic, chemically inert and clean is difficult in the quantities required to simulate a real fire. Only when a real fire occurs can the effectiveness of any system be evaluated.

It should be emphasised that atrium buildings throw up problems which are different for every case. Every building design must be analyzed in its own right, and any attempt to apply a generalised building code may not necessarily produce a safe building.

6.0 INCIDENTS IN ATRIA BUILDINGS: CASE SUMMARIZATIONS

As atria buildings are a fairly new form of structure, there have been few documented fire incidents worldwide. A study of the few which have occurred have shown that any smoke control system must be designed to cater for very large volumes of smoke.

6.1 Atlanta Regency Hyatt Hotel

Feb?

This was a small incident where burning curtains on an upper gallery in the atrium were extinguished by the fire brigade without any smoke logging or evacuation. Sprinklers have dealt with undeveloped fires in hotel rooms also without problems.

6.2 Regency Hyatt O'Hare Hotel, Chicago

Feb

The Regency Hyatt O'Hare Hotel is an atrium structure where four bedroom towers open up onto the atrium which contain a lift and off which shops, a restaurant and nightclub open to the bottom level.

This was a major fire which was started deliberately in the nightclub at lobby level, below one side of the bedroom courts. The club was unoccupied and a large fire developed as sprinklers were not installed in the area. The atrium was filled with smoke down to bedroom level, directly above the lobby, and the automatic extract system was inoperative as it had been disconnected for maintenance. Neither the recirculation based system nor summertime cross-ventilation system under the skylight were operational.

There were protected stairs in the core of the bedroom towers, but some guests got into difficulty by trying to reach the atrium lifts. Guests were all evacuated and no one was hurt although there was extensive smoke logging. ✓

6.3 International Monetary Fund Building, Washington D.C. rel.

This is a 13 storey atrium office building with its floor space almost entirely subdivided into cellular offices with glass walls to the atrium. A small fire broke out in one 14m office on the 10th floor one evening and broke a window to the atrium, filling it with smoke. Smoke detectors operated and released six spring loaded panels in the roof glazing to vent the smoke. Only two of these panels opened due to corroded springs or slides and the remaining four were opened manually at a later stage.

Smoke quickly filled the 30x43m² atrium space and spread downwards reaching the floor of the atrium. The atrium HVAC system which included smoke purging facilities had been switched off and the fire service did not know how to operate it in the building engineer's absence. Sprinklers under the plastic glazed roof never reached operating temperature, but even if they had they would only have cooled and mixed the smoke in the atrium. The smoke was finally cleared using portable smoke ejection fans placed on the atrium floor, as all venting proved ineffective. very messy

The above three incidents highlight three main features;

- Small fires in atrium buildings will generate very large quantities of smoke.

- Natural venting proves inefficient in tall atrium buildings, as the smoke is cool and loses buoyancy.

- Smoke control should be by mechanical extraction and must be operational at all times.

7.0 CASE STUDY OF THE PAN PACIFIC HOTEL AUCKLAND

7.1 Introduction

The Pan Pacific Hotel is the first fully open atrium building in New Zealand and was originally designed as a closed atrium structure.

The problems associated with atrium buildings have been outlined in previous parts of this report, and it is hoped that this case study outlines the way in which these obstacles were overcome.

The Pan Pacific Hotel is situated opposite the Aotea Centre in downtown Auckland and is separated in to buildings, the hotel and car park. The car park consists of 12 levels of car parking, a banquet hall, private dinning areas and associated kitchen, with a tennis court on the roof. The hotel is a fourteen level V shaped building with eleven floors of accommodation, two levels of restaurants, bars, concierge, etc and one level of offices, staff facilities and plant rooms.

During construction, ideas incorporated into the design had to get council and fire service permission, many of these were tested during full scale smoke tests carried out while the building was under construction. These involved producing a mock up of a corridor section and igniting smoke bombs while different configurations of linear deflectors, handrails, fans and air quantises were trailed. Final configurations had to get council and fire service permission before installation could begin and further conditions were imposed that a full scale smoke test be carried out prior to hotel opening.

The main concern and reason for these tests was clogging up of the corridors with smoke from lower floors, hindering escape to egress stairs for guests, and making fire fighting duties difficult. ✓

7.2 Standard Fire protection Systems.

The first line of defence for fire is the sprinkler, riser fire hose reel and fire resisting construction employed throughout.

Most measures taken in this respect don't differ from that found in normal high rise construction. Sprinklers are installed in all rooms, corridors, concealed spaces, as well as in the hollow roof beams and long throw sprinklers surround the level 3 atrium perimeter

Internal division between floors was treated as for external floor division, requiring the handrail to be made into a (solid) fire resisting wall instead of the glass one originally specified. Doors opening on to the atrium corridors were required to have a 2 hour FRR (fire resistance rating) together with walls separating the atrium (fig 7.1) from other areas.

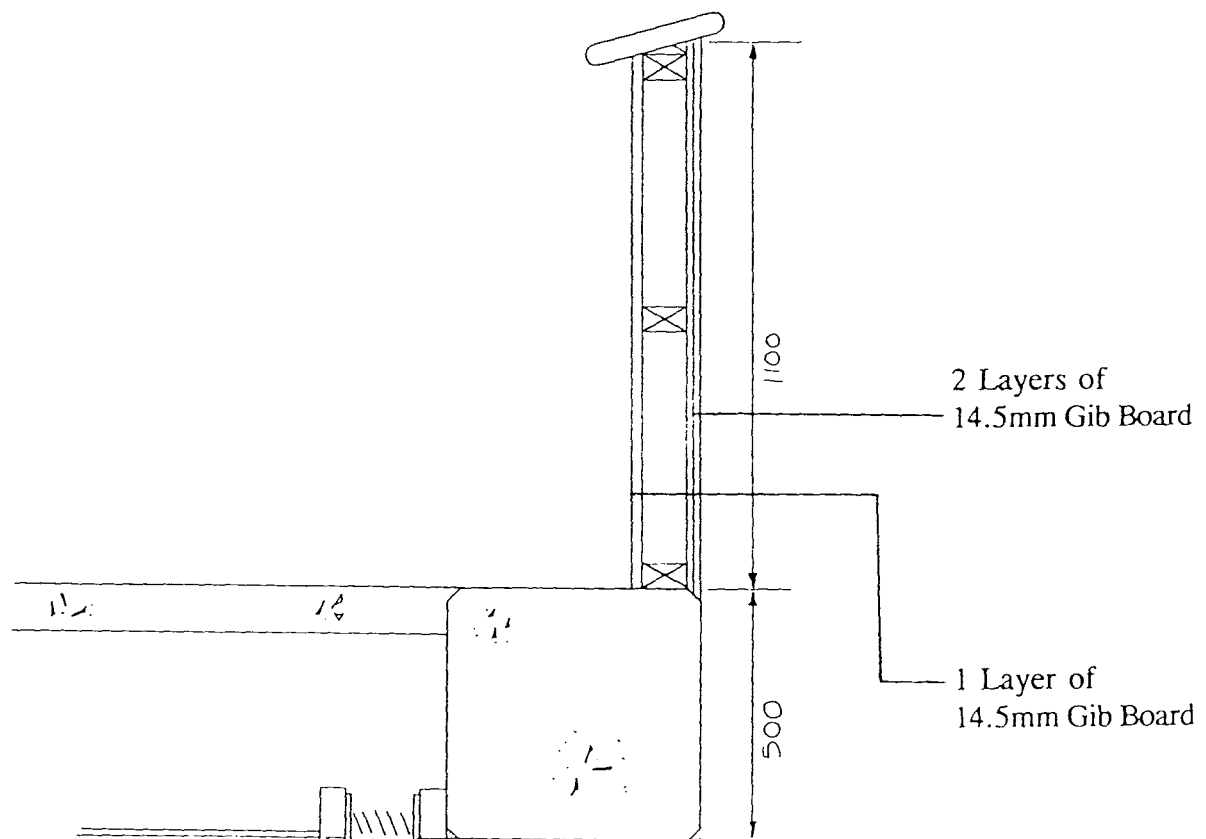


Fig 7.1 Inter Floor Separation

Fire hose reels are installed on every floor open to the atrium, these are situated to cover all corridors within the atrium area. Operation of these is monitored in the security room and water is supplied by one of two pumps situated in the main plant room.(fig 7.2)

Dry risers are installed in all egress stairs servicing the atrium with connection points situated adjacent the pump house mimic panel and on Vincent St.(fig 7.2)

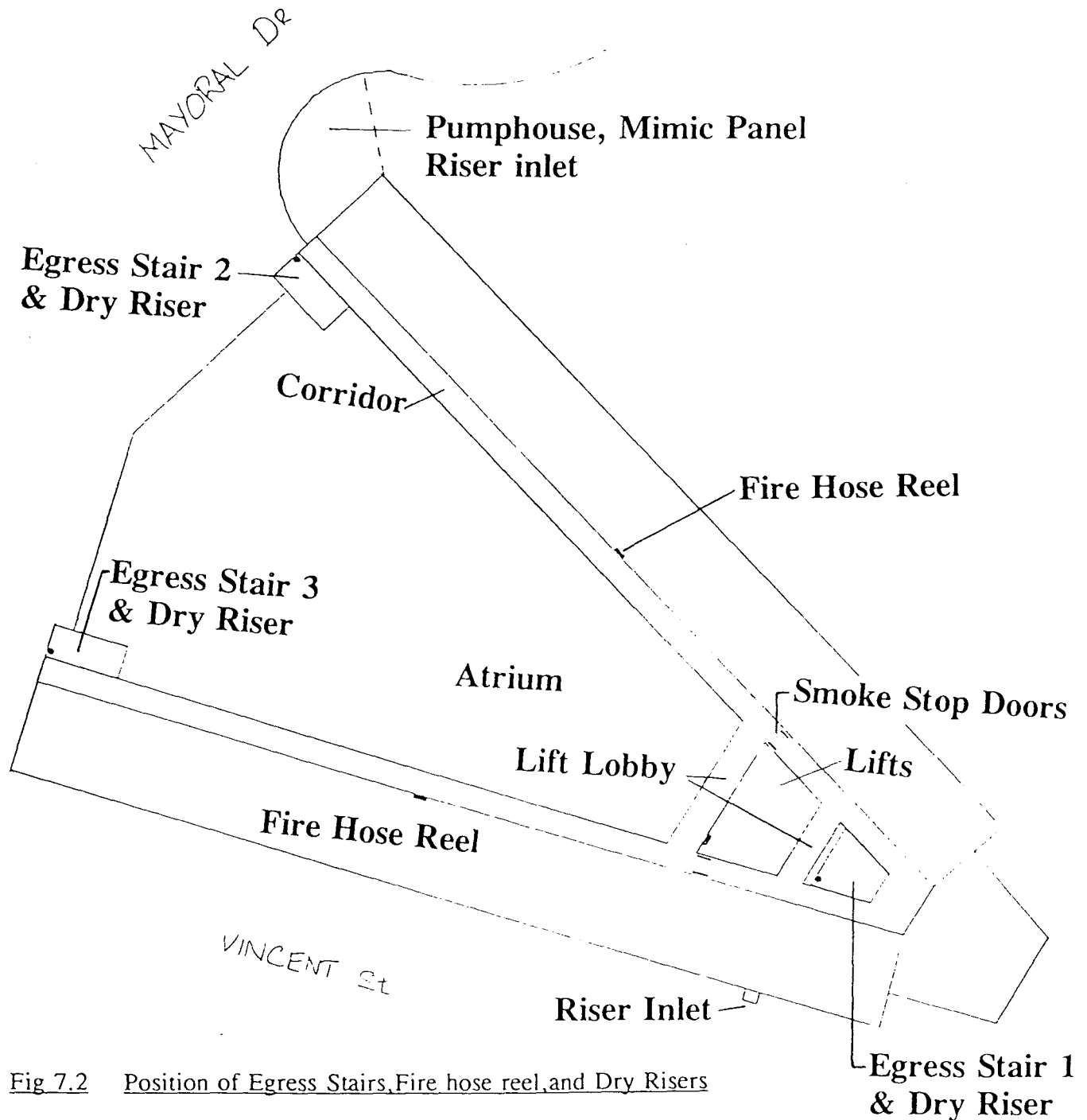


Fig 7.2 Position of Egress Stairs, Fire hose reel, and Dry Risers

7.3 Fire Detection

There is a two fold fire detection system installed in the Pan Pacific Hotel, firstly infra red detectors, there are two of these installed angled at 45° from level 3 into the Atrium foyer these are designed to detect heat haze, as a result little combustible material is allowed in the atrium floor area.

The second detection system is for smoke, there is a series of seven pairs of linear detectors that cross the atrium at level four. These are an interrupted beam type detector which detect smoke rising in the atrium.

On activation of one of the detectors either infra red or linear the security room is informed that a detector has been activated, security is then given a limited time (16 minutes) to determine the problem and remedy the fault. Failure to remedy the problem within the time limit will result in activation of the emergency evacuation system

Activation of both systems simultaneously will result in the emergency evacuation system being activated.

7.4 Emergency Evacuation System

Activation of the emergency evacuation system may be by the smoke, flame detection system, sprinkler system operation by means of a flow switch on the sprinkler pumps or manual activation in the security room. On activation of this system sirens sound in the public areas, while in hotel rooms televisions are switched on via an infra red remote control placed in the ceiling cornice. An emergency evacuation message is played on the television and through a loud speaker situated in the bathroom. This is designed to wake up any occupants that may be sleeping.

Activation of the emergency evacuation system will result in an automatic call to the Fire Service and the emergency evacuation system will continue until the Fire service has given the all clear.

On activation of the emergency evacuation system the atrium smoke control system comes into operation.

7.5 Atrium Smoke Control System.

Activation of the emergency evacuation system results in the automatic operation of the atrium smoke control system. This begins a series of measures that stop smoke entering the atrium, extracts any smoke that does enter the atrium, and prevents smoke that may enter the atrium from entering corridors further up the building.

Lobby level smoke extraction system.

On activation of the atrium smoke control system a smoke extraction system operates on lobby level. In case of a fire this is to prevent smoke from other areas detached of the atrium entering the atrium. This involves smoke flaps surrounding the atrium dropping by means of hydraulics revealing ducting connected to a smoke extraction system. This is designed to extract smoke flowing along the ceiling and prevent it entering the atrium.

Smoke Extract Fans

In normal use these control build up of heat in the upper atrium, while under emergency evacuation system conditions these fans "wind up" to extract 100 m³/s through fans situated at each end of the five hollow beams that support the roof glazing. This results in an air change in the atrium every ten minutes. These are designed to keep the atrium clear of smoke in the event of fire.

Corridor Air Curtain.

Every pair of rooms is serviced by a utilities duct which in normal use is pressurized by a fan at the top of each duct providing fresh air to corridors via a scoop at each of the accommodation levels controlling heat build up . Under atrium smoke control system use, the fans operate at full speed and air from linear deflectors surrounding the atrium form an air curtain which provides fresh air and stops smoke from entering the corridor by deflecting air onto the handrail which is shaped to provide a swirling action into the corridor and deflect smoke into the atrium space, away from the corridor. (fig 7.3)

This handrail configuration is also useful in preventing objects falling into the atrium.

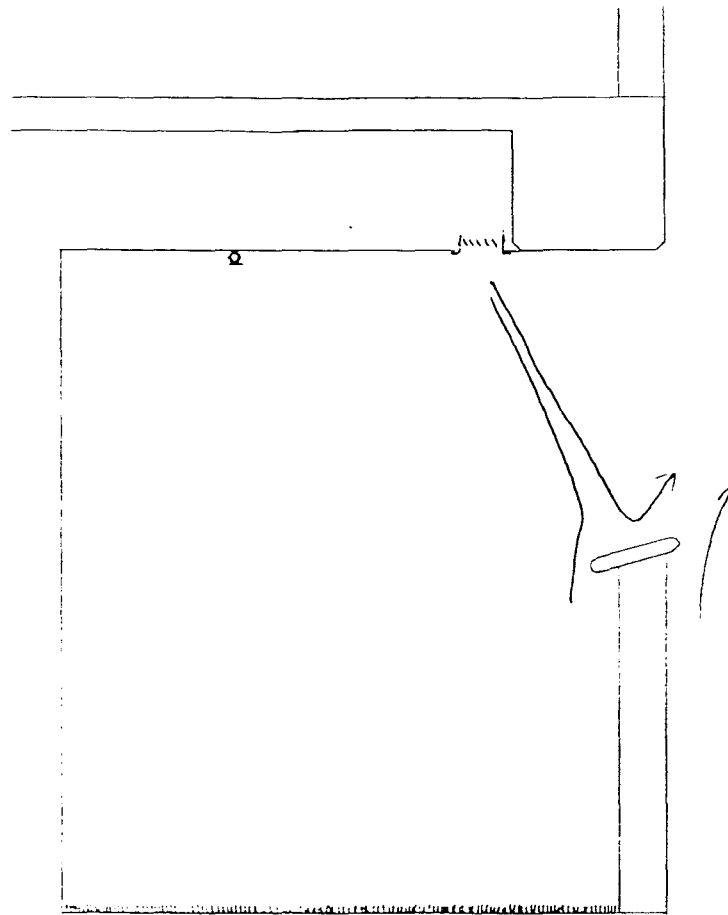


Fig 7.3 Linear Deflector Handrail Detail

7.6 Auxiliary Systems.

On operation of the emergency evacuation system, the long throw sprinklers surrounding the atrium at Level 3 operate. These are a deluge system and are intended to cover the entire open atrium area.

On the underside of the hollow roof beams normal sprinklers with a temperature rating of about 100°C are installed, these are to cool smoke and stop overheating of the fans, in the event of a large fire.

Smoke stop doors on the accommodation levels separating the atrium from other areas are held open by magnetic clamps and are released on activation of the emergency evacuation system.

Opening of utility ducts for maintenance activates an alarm in the security room, as operation of the emergency evacuation system while a duct was open would cause loss of integrity of the system.

Supply air fans operate to replenish air being extracted by the atrium smoke extract fans. These discharge onto level 1 so as not to disrupt the smoke flaps on the level below.

Every component of the emergency evacuation system is monitored by computer in the security room which is manned 24 hours with any unusual operation sending an alarm. Equipment is also monitored for normal status operation on a regular basis.

✓

8.0 CONCLUSION

From the consideration of fire safety in atrium buildings, it is possible to make the following conclusions;

An atrium is an acceptable way of creating a pleasant internal environment in a building, and protecting it from the extremes of climate. ✓

There is a need to pay added attention to life safety during a fire than for a normal compartmented building. ✓

The first consideration when designing an atrium building is the provision of adequate means of escape to a place of safety. Keeping egress corridors clear of smoke. ✓

As smoke control is a major concern, smoke detectors are essential for providing adequate early warning of smoke and for actuating the smoke extraction system. ✓

Mechanical smoke extraction systems are essential and must be operational at all times. ✓

The installation of automatic sprinklers is an essential means of controlling fire growth, and to ensure that the quantity of smoke is capable of being handled by the smoke extraction system. ✓

Calculation for the design of a smoke extraction system should take into account the behaviour of hot buoyant gases. ✓

Atrium is to be compartmentalised from other areas of the building, to stop smoke from entering other areas of the building from the atrium, or to keep smoke out of the atrium. ✓

Fire resistant construction to be used to keep fire growth minimised ✓

Codes and guidelines have been established for fire protection in atrium buildings, but safety evaluation and smoke testing should be carried out on structures before commissioning. ✓

Therefore for a new form of structure such as atrium buildings, we find that new forms of fire and smoke control have been developed, and design guidelines and codes established, for the protection of property and public safety. ✓

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