PROACTIVE FIRE TRENDS

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● Art lovers get high standards at The Esplanade

New Purpose-Built Arts Centre Features Unique Architecture & Fire-Rated Ducts

This story, all Esplanade images courtesy of The Image Bank, www.esplanade.com

DUCTWORK SPECIALS

Man-made skylines everywhere are based to some extent on the philosophy of perpetual change – kaleidoscopes of shapes and colours, form and function. The latest addition of visual interest to the palette of Singapore's downtown canvas has made an extremely pointed impression, in more ways than one!

Affectionately known by some locals as "The Big Durian", from the middle distance The Esplanade can look remarkably like upturned half shells of Southeast Asia's legendary King Of Fruits, shimmering in the tropical sun.

Up close and personal, however, Singapore's new purpose-built art centre morphs effortlessly into what it actually is an ultramodern, second-to-none structure designed and dedicated solely to the multidisciplinary world of creative arts.

Promoting Local & International Arts

The Esplanade, Theatres On The Bay – its full, official name – was opened to considerable fanfare and global recognition in mid-October 2002.

It began as dream in the 1980s and groundbreaking eventually occurred in August 1996. The substructure was completed in 1998. Above ground superstructure components quickly followed. Topping-off was recorded in February 2001.

The Esplanade opened its doors with a sumptuous Gala Premiere night and a special three-week long opening festival showcasing a programme of popular, classical, traditional and contemporary theatre, music and dance. Some 1,300 artists from 22 countries were invited to perform in 70 paying shows and several hundred free community events.

The launch of The Esplanade gave it international spotlight billing at stage centre of the increasingly globalised artistic village. Its attractions and capabilities will continue to play a central role in Singapore's dynamic, strategically important business, hospitality and tourism industries.

Exceptionally High Building Code & Safety Standards

The spiked domes and interconnected structures of The Esplanade dominate six hectares of prime waterfront real estate on Marina Bay, within sight of the glass and steel towers of the prosperous city state's central business district.

In the immediate neighbourhood are some 5,000 world class hotel rooms, two major convention centres, a thousand varied shops of every persuasion, 300 restaurants and 150 bars and 7,500 car parking spaces. A number of historically important sites are also located nearby.

Singapore's built environment is based on high professional and safety standards. The modern city state is well known for its pursuit of excellence and achievement in many fields of enterprise. It is envied around the world for its stability, cleanliness, security and safety.

The Esplanade is definitely no exception. It is purpose-built to meet and exceed international safety, aesthetic and performance needs for artiste and audience alike.

Big Aspirations But User-Friendly Human Scale

The official name of Singapore's new home of the arts follows that of nearby Esplanade Park, historically linked to leisure and recreational activities. The area today still evokes a lingering air of nostalgia and romance.

A similar, user-friendly intimacy and human scale also pervades the interior of The Esplanade.

Controlled ambient light and pleasingly variable dimensions establish a quiet oasis of cool. The intelligent use of many natural materials enhance an atmosphere of measured calm in the heart of a bustling equatorial metropolis – perfect counterpoint to the technical complexities required of numerous, highly diversified performances within! *Continued on page 2*

Point of View

THE IMPORTANCE OF CONFIDENCE

It seems to me that one of the most important resources for many of us right now is probably one of the most difficult to quantify. It is an abstract commodity at best. It is also extremely fragile. At times it can be extremely illusive and, once fleetingly broken, exceptionally difficult to recapture.

Without it, we can find it sometimes impossible to function. With it, almost anything is possible.

What is this apparent paradox? Confidence. No more, no less.

To illustrate, take a quick hard look at what has happened to the world around us lately. The first natural consequence to the unexpected is to look inward, to protect. This in turn encourages introspection, uncertainty as much for individuals as for groups. As we have seen, the sudden appearance of a previously unknown virus can have amazing, detrimental results. Fear alone can bring entire industries, not to mention countries, to their collective knees.

While it would be unwise to downplaying the significance of recent events, I believe we should continue to build on our strengths. At Promat we have superior products and services. Our company's role as an industry leader is recognised worldwide. Wherever possible we provide holistic solutions that look beyond the immediate problem, into tomorrow. This will continue and, with confidence, hopefully expand.

In this 11th issue of PFT, we examine ducts in order to examine the critically important matter of fire-rated ducts, ducts and more ducts under the microscope of professional detail. Fire rated ducts are an integral link in the much longer chain of wider safety concerns for all involved in improving the built environment. PFT is based on this strategy and will continue to review other interrelated subjects in the months ahead.

Our cover story takes a look at the superb new arts centre in Singapore – The Esplanade, Theatres On The Bay – and the role that some Promat fire-rated ducts play in the design and built-in safety features of that technically complex building.

In our Science and Research department we offer an analysis of the fire resistance requirements of ductwork as outlined in AS 1668.1:1998, often a benchmark for other regulatory framework. There's also takes a look at Fire Inside & Outside Ductwork from Mr. Rick Fox, Promat Australia's Technical Manager.

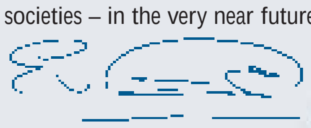
The centrespread Industry Review features a summary of incorporating adequate safeguards into performance-based fire engineering design solutions. In the opinion of the author, Mr. Roger Marchant, it is always better "to err on the side of caution".

Our colleague from Singapore, Mr. Lai Boon Keong, weighs in with a brief but learned article on circuit integrity of cables in fire.

Last but by no means least, Mr. Ray Porter, PIAP's Research & Development Manager provides an overview of the new PROMASTOP® AirChoke®. I am extremely proud and happy to announce that this advanced product is a worldwide first for Promat.

As we move ahead it is equally important to acknowledge that if it is possible to help improve regulatory environment we function within, we should do so. We have the experience, the means and a wealth of proven test results. This will automatically inspire confidence in others which, in turn, is ultimately good for us.

The more confidence we can project from our ourselves, in our products and services, the more we will see it grow in others. In these uncertain times I am convinced that this strategy will produce better dividends for all us – as individuals, as a company and as interdependent societies – in the very near future.



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The Promat International Asia Pacific Network spans the region with innovative proactive fire protection products, systems and solutions: Australia, China, Hong Kong, India, Malaysia and Singapore, with distributors in Brunei, Indonesia, Japan, New Zealand, Philippines, South Korea, Taiwan and Thailand.

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New Purpose-Built Arts Centre Features Unique Architecture & Fire-Rated Ducts

Continued from cover

The Best Of The East & The West

The Esplanade has been built to accommodate the creative and theatrical traditions of both East and West. It incorporates visible connections to the architectural languages of both artistic hemispheres.

The Concert Hall has a seating capacity for some 1,600 concert goers. Its superb acoustics were designed by the world's foremost acoustician, Russell Johnson. It also houses a Klais pipe organ with 4,740 pipes and 61 stops!

The separate 2000-seat Performance Theatre is an adaption of the traditional horseshoe shape, designed for flexibility and the presentation of traditional Asian and Western performing arts. Advanced multi-media presentations can also be accommodated. Several smaller recital studios provide ideal space for intimate chamber music and solo recitals. Numerous galleries and function rooms add to the centre's functionality.

In fact, The Esplanade seamlessly integrates an exceptional collection of entertainment and lifestyle outlets within one complex. These include a library, galleries, restaurants and other stylish retail outlets within its precincts.

Silent Guards Ensure The Show Goes On With Optimum Safety

The Esplanade is a unique architectural structure with a unique mission. Not surprisingly, it incorporates some unique, world-class fire protection solutions. Promat's VICUCLAD® vermiculite board, for example, was used to satisfy both design specifications and building code regulations.

A non-fire rated air-conditioning duct, connected to a VICUCLAD® fire-rated air plenum was required to provide 2 hours fire protection to the plenum without sacrificing integrity where the non-fire rated duct meets the plenum.

A fire damper therefore had to be installed at the plenum and air-conditioning duct interface.

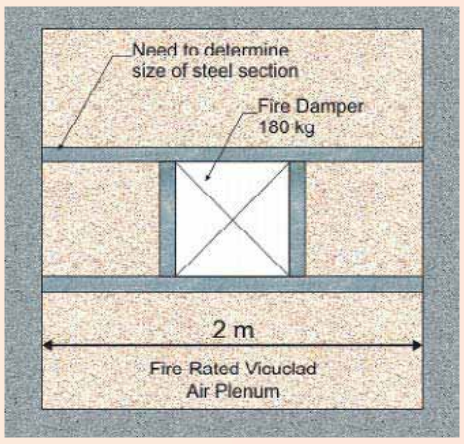
A separate supporting structure was designed to take the weight of the damper, estimated at approximately 180kg, as well as form the framework for the fire protection cladding.

VICUCLAD® fire-rated duct system was chosen for its proven performance and ease of on-site installation at a congested location.

Technical Details For VICUCLAD® Fire-Rated Duct System

It is imperative that fire dampers be supported securely within a frame. The framework's high demand function provides secure support for the fire damper while not deflecting too much in fire condition that it dislodges the fire protection material fixed to it.

The size of the steel section requires that actual on-site support be calculated well before installation.



Loading Conditions

1) Assuming the proposed steel sections to be simple laterally restrained support beams.

2) The weight of 2m x 2m x 40mm thick VICUCLAD® is 65kg and the weight of 2m x 2m x 50mm thick 60kg/m³ mineral wool is 12kg.

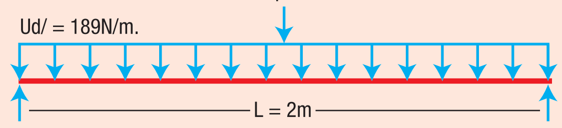
   Although the weight of the boards and mineral wool are assumed to be independently supported and, as such, imposes no load on the proposed steel sections, it is normally used as a dead-load.

   The total weight is 65 + 12 kg = 77kg, divided over two steel sections, i.e, 38.5kg each.

   Total dead-load is therefore 38.5 x 9.81 = 378N/2m = 189N/m.

3) The loading imposed by the fire damper is conservatively assumed to be a imposed point load, divided over two steel sections, i.e. 180kg/2 = 90kg. Imposed point load is therefore 90kg x 9.81 = 883N.

   The loading diagram is therefore as:



Scenario 1 – Complying with BS 5950: Part 1

Assume steel sections to be totally enclosed within the VICUCLAD® boards, and as such, wholly protected from the fire.

1) Design Bending Moment and Shear Force

   The structure is symmetrical, the central bending moment, M, is
   M = (WL/4) + (WL2/8) = 441.5 + 94.5 = 536Nm = 0.536kNm

2) Initial Section Selection

   Assuming design strength of steel(py) = 275N/mm²

   Sx > M/(py) = (0.536 x 106)/275 = 1949mm³

Scenario 2 – Complying with BS 5950: Part 8

Assuming that steel channels are grade 43 and 50 complying with BS 4360, and the temperature will reach 800°C. Steel strength at ambient temperature is 275N/mm², from BS 5950 : Part 8: 1990, for a strain of 0.5%, the strength reduction factor is 0.071.

Initial Section Selection

Assuming design strength of steel(py) = 0.071 x 275= 19.5 N/mm²

Sx > M/(py) = (0.536 x 106)/19.5 = 27487mm3

Deflection Check

A Grade 43 50 x 30 x 2.5mm thick standard rectangular hollow channel:
Sx = 4812mm³ I x = 12.03cm⁴ E = 20500N/mm³

Deflection = (5wL4/384EI) + (wL3/48EI) = 0.798mm + 2.984mm = 3.782mm

The recommended deflection for members carrying plaster or brittle finish material is span/360, i.e. 2000/360 = 5.55mm.

Using 50mm x 30mm x 2.5mm thick RHS is therefore acceptable, as deflection is span/528. The recommended steel section is therefore 50mm x 30mm x 2.5mm or larger. PFT

● Understanding the criteria in applications of non-fire and fire rated ductwork

Fire Resistance Requirements of Ductwork to AS 1668.1: 1998

by **Jennifer Yii** / *Fire Engineer Consultant*, Promat International (Asia Pacific) Ltd.

Australian Standard AS 1668.1:1998 sets out the minimum requirements for the design, construction, installation and commissioning of mechanical ventilation and air conditioning systems for fire and smoke control in multi-compartment buildings, to cope with a single fire event. It has defined five specific methods of smoke control in order to restrict the spread of smoke into the areas within the building via:

a) Fire-isolated exits, ramps and passageways.
b) Principal evacuation routes (e.g. public corridors) leading to a safe place (where practicable).
c) Adjacent fire/smoke compartments via principal connecting paths such as stairs, lift and service shafts, air conditioning ducts, ventilation ducts and ceiling plenums.
d) Throughout the building via minor paths such as structural joints, gaps, cracks and building services penetrations.

These smoke control systems include air purge systems, zone pressurisation systems, fire-isolated exit pressurisation systems, lift shaft pressurisation systems and kitchen hood exhaust systems.

However, this standard is not intended to apply to Class 1 (single dwelling) or Class 10 (non-habitable dwelling), as defined in Building Code of Australia, 1996, or to large single compartments in any type of building utilising smoke exhaust from the hot layer.

Application Of AS 1668.1: 1998 With Respect To Subducts

Role & Objectives of Subducts

Subducts, points of entry into a return or smoke-spill shaft, are part of the ductwork component that forms the air-handling systems and pressurisation systems. They are mainly used in smoke-spill or smoke exhaust systems to prevent the smoke from infiltrating into other compartments. Apart from that, subducts are also in use in the protection of openings associated with smoke-spill where fire dampers are not permitted to be installed, in order to maintain the integrity of fire separation between compartments.

Description of a Subduct

In accordance with AS 1668.1:1998, subducts used in smoke-spill systems are required to be manufactured from steel of 2 mm thickness or constructed of material that has a fusion temperature of not less than 1000°C, whereas, subducts used in minor exhaust systems shall be manufactured from galvanised steel in accordance with the duct construction and installation requirements of AS 4254 from the same material as the sheet metal riser.

Subducts in smoke-spill systems are to be fixed directly to the fire-resisting structure such that clearance between the subduct and the penetration shall be sufficient to allow expansion without imposing forces that will distort the subduct or impair the FRL of the structure. In contrary to that, subducts in minor exhaust systems shall be installed directly into a sheet metal riser constructed in accordance with AS 4254 and fixed to the riser which shall be enclosed in a shaft, which may contain water supply, soil and waste services.

These subducts are required to have an outlet projection facing downstream to the direction of smoke-spill airflow not less than 500mm long.

Typical Applications of Subducts

MINOR EXHAUST SYSTEMS

Minor exhaust systems such as toilet exhaust and incinerator exhaust relatively small quantity of air from each compartment. These systems protected by subducts shall operate during the fire mode.

SMOKE-SPILL SYSTEMS

Smoke-spill systems can be separated into the air-purge system and the zone pressurisation systems. Although both of these systems have a supply air duct and a return or smoke-spill duct, the use of subducts is in the smoke-spill duct. The main difference between the air-purge system and the zone pressurisation system is that the former system affects the entire air space, whereas the latter has better control between the fire affected spaces and the non-fire affected spaces.

In an air-purge system, the smoke-spill air is discharged directly to the atmosphere via ducts or via dampers in each compartment, while outdoor air is supplied to all compartments via the supply air duct at a rate less than the smoke-spill air. Thus, these systems are not effective in preventing the spread of smoke through lift shafts, exits, service shafts, structural joints or gaps and cracks in the structure. As for a zone pressurisation system, it has features as follows:

a) Smoke-spill air from the fire affected compartment is discharged directly to atmosphere.
b) Return air or relief air from non-fire affected compartment is controlled.
c) Uncontaminated air is supplied or made up to all non-fire affected compartment at a rate such that a positive pressure is maintained in non-fire affected compartments with respected to the fire affected compartments.

Limits of Application of Subducts

a) Due to possible exposure to high temperatures, subducts made of steel may expand such that if there is inadequate clearance between the subduct and the penetration, the expansion may distort the subduct and adversely affect the integrity of the structure, which in turn impairs the fire resistance of the system.
b) Subducts that are connected to heavy ductwork may be susceptible to damage by deformation or collapse of the ductwork.
c) The presence of subducts in the return shaft may increase airflow resistance.
d) Although minor exhaust systems comprise a leakage path between fire compartments and no limitation to the number of systems, the leakage has to be considered in the pressure differential requirement to provide a minimum of 20 Pa.
e) The forces due to stack and wind effects may affect the pressure differences of the natural convective forces since the successful use of subducts is dependent upon the buoyancy and momentum of the smoke to prevent entry into the compartment. Smoke or fire dampers may be necessary to prevent backflow.

Fire Resistance Ductwork Requirements to AS 1668.1: 1998

General Requirements of Ductwork

EARLY FIRE HAZARD PROPERTIES

The materials used in the construction of the ductwork, such as the duct liners, insulation and flexible ductwork, are required to comply to AS 4254:1995 "Ductwork for Air Handling Systems in Buildings", so that the smoke developed index is not larger than 3, the spread of flame index is not larger than 0, and are tested to UL 181 burning test.

COMBUSTIBILITY & TEMPERATURE OF FUSION

The materials employed in ductwork, especially in applications associated with ducts above fire dampers in floor openings, ductwork in smoke-spill systems, and ductwork in kitchen hood systems are required to be non-combustible and have a fusion temperature of not less than 1000°C. In addition to that, the insulation material and the flexible connections shall have a fusion temperature of not less than 500°C.

FIRE RESISTANCE

Fire resistance performances are generally required for ductwork forming part of a smoke-spill system, with a fire resistance level (FRL) of not less than the construction separating different fire compartments. However, the required FRL on the duct can be waived if the duct is enclosed in a construction with the essential fire resistance.

When the ductwork links more than one fire compartment and is outside any fire resisting enclosure, the required FRL shall be assessed to fire outside duct for structural adequacy and integrity, and to fire inside duct for structural adequacy, integrity and insulation. In addition, the prototype duct, which is tested in accordance with AS 1530.4 "Fire Resistance Test of Elements of Building Construction" should not deform to the extent that its cross-sectional area is reduced by more than 15%.

As for fire resisting shafts which are to function as smoke-spill shafts, the smoke-spill air is allowed not to be ducted, provided that the shafts are dedicated and containing no other building services, including supply air systems. However, if ducts are provided, then they must be fire rated and comply with the FRL requirement mentioned above.

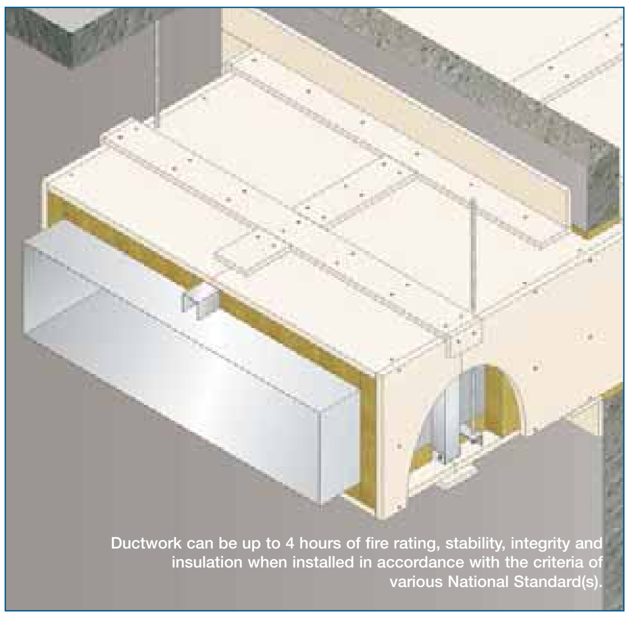
DUCT INSTALLATION

The installation of ducts and components associated with systems shall be such that during a fire, the operation of ducts will not reduce the fire resistance of the construction through which the duct passes.

Applications of Non-Fire Resistant Ductwork

Apart from the application of fire resistant ductwork (which will be discussed in details in the following section), AS 1668.1 also describes a number of applications in which the fire resisting requirements may be waived or are not required, as follows:

a) As mentioned earlier, ducts provided within the fire-resisting shaft are required to have an FRL of not less than the construction separating the different fire compartments, unless the ducts are enclosed in a construction having the required fire resistance.
b) Generally, ductwork connecting openings in two or more fire resisting floors is required to be contained in a fire rated shaft. However, the requirement of the shaft can be waived, if fire dampers with the required FRL with respect to integrity and insulation are installed at each floor level. Furthermore, as fire dampers used in this manner are likely to be associated with supply or exhaust systems not forming part of a smoke control system, the equivalent ductwork in this layout can be non-fire rated.
c) Minor exhaust systems exhaust air having openings, which may be protected by fire dampers or subducts, from a fire compartment not exceeding $0.1m^2$ into a separate shaft or duct within a shaft. However, where closure of the fire dampers will impair the operation of the system or in a kitchen exhaust duct where the build-up of grease would inhibit the action of the damper, then subducts are to be used. These subducts are to be manufactured from galvanised steel from the same material as the sheet metal riser that is enclosed in a shaft. If there is only one exhaust opening ($\leq 0.1m^2$) into the shaft from each floor, then the sheet metal riser may be omitted.
d) A separate riser is required for non-fire protected kitchen exhaust ducts from separate fire compartments (and of cross-sectional area $\geq 0.1m^2$) since fire dampers are not allowed to be installed on openings to kitchen exhaust ductwork due to the presence of grease build-up.



Ductwork can be up to 4 hours of fire rating, stability, integrity and insulation when installed in accordance with the criteria of various National Standard(s).

e) Generally, air-handling systems, such as exhaust systems (minor and major), supply air systems (minor and major) and car park ventilation systems, which do not form part of the smoke control system, are required to be shut down. Therefore, ductwork in these applications does not require special protection, but automatically close air-control dampers on receipt of a fire alarm are to be installed at all fire compartment penetrations in order to maintain the FRL between fire compartments.

Applications of Fire Resistant Ductwork

Fire resistant ductwork that is used as part of a smoke control system can be found in various applications, such as follows:

a) Air purge system
b) Zone pressurisation system
c) Fire-isolated exit pressurisation system
Any shaft used for the protection of ductwork shall contain no other services except those permitted by the building regulations to be installed within fire-isolated exits, and relief ducts or vents passing through compartments other than the compartment being served shall be enclosed in construction having an FRL not less than that required for the construction separating the compartments.
d) Kitchen hood exhaust systems
Ducts from separate fire compartments could share a common riser shaft provided that an FRL of -/-/30 is maintained between the ducts, but if the cross-sectional area of the ducts exceeds $0.1m^2$, then a separate riser shaft is required. For kitchen exhaust, which forms part of a smoke control system, the ducts are required to be fire rated in accordance with the requirements for a smoke-spill system.

Conclusions

AS 1668.1 states that when the ductwork is part of a smoke control system and is required to carry hot products of combustion through fire rated compartments, it must satisfy the fire resistant requirements in accordance with the smoke-spill system. For fire inside the duct, the FRL is assessed for structural adequacy, integrity and insulation, while for fire outside the duct, the FRL is only assessed for structural adequacy and integrity. In either case, the FRL requirements of the ductwork must be determined by a test in accordance with AS 1530: Part 4 and its cross-sectional area must not reduce from deformation by more than 15%. If the ductwork is enclosed within a construction (shaft) having the required fire resistance, then the fire resistance requirements may be waived.

Summary of Ductwork Requirements to AS 1668.1:1998

APPLICATION	REQUIREMENT
All ductwork material	Fire performance requirements of AS 4254
Ducts used: - above fire damper in floor openings - in smoke-spill systems - kitchen hood exhaust	Combustibility and fusion temperature requirements
Ductwork in smoke-spill systems connecting more than 1 compartment	Fire resistance
Ductwork for fire-isolated exit pressurisation	Fire resistance or FR shaft

For more information on this subject, please refer to Warrington Fire Research (Aust) Pty Ltd's reports 'WFRA 20631A: "Application of AS 1668.1: 1998 with respect to Subducts" and 'WFRA 20631B: "Overview of Fire Resistant Ductwork Requirements Under AS 1668.1:1998". Or contact us via Enquiries Form on page 7 for these reports. PFT

- Incorporating adequate safeguards into performance based fire engineering design solutions

BCA Alternative Solutions:

Many Australian fire brigade officers processing alternative solutions (performance-based designs) often confide they feel uneasy about the design methods employed. Some fire safety engineers and building surveyors are also expressing concern about fire engineering design trends. It would seem that many engineers, who call themselves fire engineers, need more knowledge in applied fire safety science, if they are to achieve an acceptable standard of practice. This article:

- Overviews the fundamental concept of performance based fire engineering design.
- Queries the apparent shopping methods used by some designers to select the best equations or computer program which coincidentally achieve the most cost effective solution.
- Discusses the use of limited ad-hoc fire test data as the fire growth model for a design.
- Questions the use of carbon monoxide toxicity levels as a description of smoke tenability, to which escaping occupants will be exposed.
- Challenges the concept that once the building occupants are safely out of the building, the design is complete.
- Looks at the "*fait accompli*" design proposal, which may appear late in the building approval process and the relevant authority has had no previous conceptual involvement.
- Begs designers to include safety factors and undertake a meaningful sensitivity analysis (something foreign to most fire engineers).
- Expresses concern about the dramatic deviations made from the traditional sprinkler codes, without further adequate testing to substantiate such change.

Introduction

This article draws upon a previous paper by the author presented in Sweden[1]. Whilst the author fully supports performance based fire engineering design, it is conditional that adequate safeguards be incorporated into the solution. Concern is being expressed within the fire protection industry, that the quality of many Australian designs is unsatisfactory.

Is the passion for cost saving undermining the fire safety needs of our community?

A brochure for a Society of Fire Safety Seminar[2] warns: "Fire engineers are regarded by some as an unnecessary expense or a non-required consultant, by others as the answer to all their problems. Increasingly perhaps fire safety engineers are being seen as charlatans whose aim is to reduce costs by reducing fire safety."

Dr Bill Porteous, Chief Executive of the New Zealand Building Industry Authority states: "As long as buildings are commodities built for immediate sale on completion, there will be strong incentives for investors to push the minimum mandatory requirements for safe and sanitary buildings to the lowest level possible."[3]

Alternative solutions, which push the cost saving envelope too far, have the potential for disaster. In the words of Dr Bill Porteous: "The construction industry builds prototypes which are also the final product. This means the construction process is highly prone to accidental errors."

Some Fire Engineering Fundamentals

Whilst an alternative solution lies outside the prescriptive regulations, it should be demonstrated (to the satisfaction of the relevant authority) to have a performance as good as, or better than that achieved by the deemed to satisfy provisions. There are two principal types of performance based fire engineering design. Designs that model the physical effects of a fire and those that look at the probabilities of the outcomes of a fire. The latter probabilistic design is rarely done and needs supporting statistics, which are often difficult to find. This overview will deal with the former and more prevalent design methodology.

The usual fire engineering design is scenario based and predicts what physically happens to a building and its occupants if a fire occurs. A time line is used as the basis of analysis. Designs often follow the path below:

1. A fire starts and grows.
2. The building progressively fills with heat and smoke.
3. The occupants progressively evacuate before being adversely affected by the fire and smoke.
4. The fire brigade arrives and does its job before structural collapse occurs.
5. The fire must not spread to adjoining property.

Computer programs are often used to predict fire, smoke and people movement (both occupant egress and fire brigade intervention). Many designs use simple hand calculations based on empirically derived equations. It has been said that some designers use witchcraft.

It is claimed that fire engineering is now at a stage where structural engineering was when it started out. In those early days, a structural engineer Thomas Bouch designed the predecessor to the Firth of Forth Railway Bridge in Scotland. His bridge collapsed when a train went across it and about 170 people died. It is from this unfortunate incident that the term "botch up" arose.

Fire safety design has a structural design paradigm:

LOAD = Smoke + Heat + CO + Other Toxic Gasses etc.

STRENGTH = Auto suppression + Detection + Manual suppression + Fire Brigade etc.

RELIABILITY = Reliability of all systems (more sensitive than simply the reliability of steel).

SAFETY FACTORS = Includes importance factor (e.g. fire resistance levels higher for different building classes).

ACCEPTABLE DESIGN = Strength > Load.

We therefore need to recognise the current limitations of fire engineering designs; we do not want any "botched" jobs.

A fire-engineered design should address the following:

1. Different fires in different parts of the building.
2. How these affect occupant escape, structural collapse, fire brigade operations and fire spread to adjoining property.
3. Incorporate appropriate safety margins.
4. Incorporate a sensitivity analysis (see if any single aspect of the design e.g. travel distance has a pronounced influence on the result).

Typical outcomes claimed when using a fire engineering approach are:

5. Longer distance of travel to an exit.
6. Reduced structural fire resistance.
7. Fewer fire protection systems.
8. Smaller system capacities.

These outcomes are only valid if items 1~4 inclusive have been correctly addressed.

A fundamental performance based design concept is that concerned with occupant escape. The Available Safe Evacuation Time (ASET) must be greater than the Required Safe Evacuation Time (RSET). Simplistically, ASET is the time taken to fill the compartment with smoke; RSET is the time taken for occupants to escape from the compartment. Unfortunately, this concept can result in substantial cost savings if the designer argues a small fire, an extraordinary high resistance to toxic gases and all occupants sprint to the exits like Olympic athletes.

The designer should test the robustness of the solution by considering different fire types in each of a number of locations within the building (this takes both design and approval time – a compromise will usually be necessary). The designer will usually select a growing fire, however a fixed fire of the maximum reasonable size may be employed (a fixed fire is the basis of smoke developed in Fig 2.1 of BCA Specification E 2.2b).

If a growing fire is used, how big does it grow to? What is the appropriate growth rate? Where do we find reference information about appropriate rates of fire growth? With a few exceptions,[4] such information is generally scarce.

The design fire is probably the most difficult aspect to adequately define. Often designers do not appreciate that the design fire is not a likely fire. Generally, the real fire will never match the design fire. The design fire must be sufficient to cater for all reasonably likely fires. It would appear that there is very limited expertise in this area. Unless adequate safety factors are used, the design fire, being the input to the design has the potential for a "garbage in = garbage out" result. A Botched Job.

Likely fire behaviour in a compartment is an important part of the design analysis. An unrestrained fire in a compartment may pass through a number of stages:

1. An incipient stage, the fire has just started, often there is no visible flame (e.g.. smouldering). Smoke detectors are advantageous at this point.
2. A growing or free-burning stage – some U.S. gurus define the transition from incipient to growing as being when the flame height exceeds 10 inches (250 mm).
3. The fire growth stage. It is at this moment that fire sprinklers are of greatest benefit.
4. The rate of growth is initially governed by the available fuel surface. This is the surface which flames can contact. In warehouses, high piles of combustible containers offer a very large fuel surface. This is why vertical spread of flame is so rapid in such buildings.
5. This type of burning is known as a fuel controlled fire, i.e. the fire size is determined by how much combustible surface is available to burn.
6. As the fire size increases, the fire consumes more and more oxygen. The oxygen level in the compartment / room will likely decrease, unless there are large openings in the bounding construction. In a small room, this will markedly influence the rate of fire growth.
7. If the compartment remains intact and there are no openings, then the oxygen will be depleted and the fire will go out.
8. If the compartment has a large volume, or air can enter the compartment through open doors or suchlike, including windows broken by heat from the fire, then fire growth will continue.
9. Building fires generally have an inefficient combustion process. Inefficient combustion produces smoke – the unburnt particles of combustion. Generally the more inefficient the combustion process, the darker the smoke produced. Smoke will be hot, contain toxic gasses, such as carbon monoxide (CO) and due to buoyancy will rise to the underside of a roof or ceiling.
10. As the fire continues, the layer of hot smoke will descend, becoming more toxic and hotter, as the fire pumps more energy into it.
11. The deep hot toxic smoke layer will radiate heat down to the floor and other contents in the room.
12. The radiation eventually becomes so intense that the non-involved contents in the room start to thermally decompose (pyrolysis) producing fuel vapour (gassing).
13. Soon they will all reach (spontaneous) ignition temperature. The temperature at which they will auto ignite.
14. If there is enough oxygen in the room to support combustion (open door, window etc) flashover will occur. This is the simultaneous ignition of all combustible contents.
15. The heat release rate of the fire will then be determined by the amount of oxygen available, this will depend upon the size of the openings allowing air into the compartment.
16. This is called a fully involved (post flashover) ventilation controlled compartment fire. These fires release enormous amounts of heat energy, which can cause breakage of windows, and structural collapse.
17. If no fire brigade intervention occurs, the fire will continue to burn at a maximum heat release rate, determined by the available ventilation, until the fuel source is depleted below that of ventilation dependence.
18. The fire will then enter the decay phase.
19. The fire will eventually burn out through lack of fuel.

Against the above unrestrained fire growth scenario, the designer should check the effects of fire detection or fire suppression and occupant warning systems. The designer should then check that occupants have evacuated before the onset of untenable conditions. Usually much earlier in an un-sprinklered building. The effects of fire brigade intervention, which includes search and rescue and fire suppression also needs to be checked.

As part of a sensitivity analysis, I have not seen any design that has gone up to or beyond flashover. I have seen one design that purported to check aspects of fire spread from one building to another. It seems that fire engineers prefer to sit in the comfort zone of small fires, which stop growing once the occupants have left the building. Designers should as a minimum check what happens if a component of the fire safety system fails (e.g. Sprinklers turned off for service or the Fire Brigade arrives 10 minutes late).

Designers should be able to answer questions put by the regulatory authority such as:

- What happens if this or that fails?
- What is the likelihood (probability) of such failure?
- Can you justify this?
- What statistics have you used to back your design assumptions?
- Where did you get your information (is it a reputable source)?

Which Equation or Computer Program should be used?

Why are we using a Brazilian fire test for resistance of steel to fire, a Russian equation to calculate the heat release rate for a car park fire and population density from research into shopping centers in the Outer Hebrides? Why use an equation in a British CIBSE publication instead of one in the FCRC Fire engineering Guidelines? Why use Yardstick and not the CFAST computer program? Whilst some of these examples may be an exaggeration, it does appear that designers shop around for their design tools.

We suspect that some designers use different equations and computer programs according to desired outcome. Project managers have said they will select different fire engineers, depending upon whether there is an egress problem or a fire load problem. We are told this is because one designer gives more economical solutions for a particular type of problem.

We need to carefully consider how appropriate are the tools the fire engineer has selected. If we have doubts, then the tools may need to be changed, or additional safety factors may be necessary.

Single Ad-hoc Fire Test Results used as a basis of design

Design fire heat release rate curves are often proposed, using experimental data from a single fire test. Invariably, no safety factor is proposed. Bench scale experiments were undertaken in South Australia to see how repeatable were the results of burning mixed combustibles.

Sixty fires were lit in the same identical fire load configuration. 30 were lit at one end, 30 were lit at the other end. Two data sets resulted; each with thirty tests (tests 1a~30a and 1b~30b). Statistical distributions within each array group and for the whole population were then analysed.

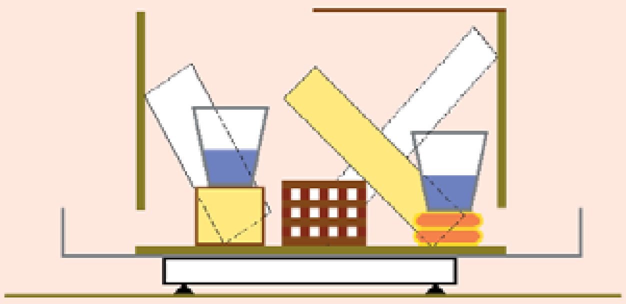


Figure 1: Mixed combustibles in a tray on a load cell.

Critical events, determined by where the fire burnt, were engineered into the experiment by adding 2 paper cups of methylated spirit. Each cup was supported by combustible material. In the tests, fire destroyed or partially destroyed the supports, either leaving spirit in the cup, or spilling the contents, which burnt wholly within or sometimes partially outside the compartment. The rate of mass loss due to the burning of the materials was recorded by placing the whole assembly on a load cell. Figure 1 diagrammatically shows the test configuration.

The rate of mass loss over time is shown in Figures 2 and 3 for tests 3a and 10b respectively. These two figures show the minimum and maximum time of occurrence of peak mass loss rate (i.e. when the burning was most intense) for all 60 tests. Not only did the time of peak heat release rate vary widely, the intensity of this release also varied. If the principles of scale can be applied to these small fires, the conclusions reached by the experimenter[5] will also likely apply to full-scale fires.

BE CAUTIOUS!

by **Roger Marchant**

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Manager, Department of Mechanical Engineering, Adelaide Fire Safety Research Unit, University of Adelaide

This article is published with the author's permission. Taken from the original presentation at The Australian Institution of Building Surveyors Conference, Naracoorte South Australia, year 2002.

"*For this experimental configuration of mixed combustibles, it was concluded that it is not possible to predict with any accuracy a representative fire growth rate by igniting a single configuration. The ignition point varies the fire growth history. Different ignition locations may result in different heat release rates, for the same fire loading. In addition, the location of initial ignition which would result in the maximum heat release rate may be unknown.*"

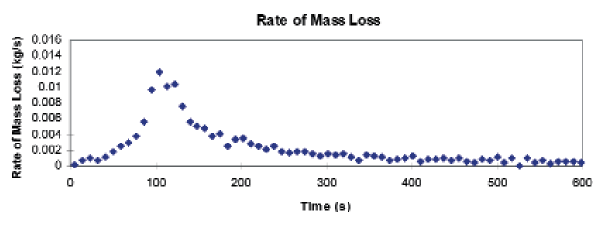

Figure 2: Mass Loss History (Test 3a)

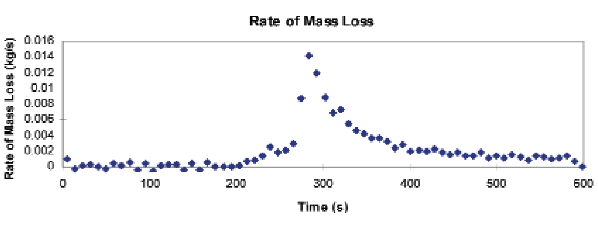

Figure 3: Mass Loss History (Test 10b)

When using limited fire test data, the designer must incorporate adequate safety factors. If our tests are any indication, we should ask that the heat release rate of the design fire be 30% more than the test and peak at a time 50% that of the test.

Carbon Monoxide Toxicity Limits

A design, based upon a theoretical fire, producing a theoretical volume of smoke, containing a theoretical concentration of carbon monoxide (CO), to which archetype people will predictably react, stretches the imagination. Unfortunately this is what some fire engineering designs propose. The accuracy of the computer programs used and the lack of knowledge about the synergy of toxic species within smoke are issues of concern. We should resist designs where, the design principle is that escaping occupants are in the smoke layer.

In designs that supposedly demonstrate acceptable conditions for occupant escape, occupants will be exposed to high carbon monoxide concentrations. The calculated concentrations and exposure time are generally derived from crude equations.

The occupants often travel at a rapid rate of 1.0~1.3 m/s towards the nearest exit (this reduces exposure time). What safety factors address the accuracy and limitations of the software used or the assumptions made?

None! Provided that the calculated ASET is greater than the calculated RSET (to within seconds) the design is supposed to meet the BCA requirements.

Submissions have been received quoting "tenable" carbon monoxide levels ranging from absolute levels of 4500 ppm to time weighted levels of 45,000 ppm.min. Absolute levels of CO are sometimes specified where no egress time has been calculated. Apparently 3200 ppm produces headache, dizziness and nausea after 5 minutes and unconsciousness after 30 minutes. This is for healthy adults, not the general public.

The 45000 ppm.min. "*as found in the literature*",[6] and used in some Australian designs, produces a curve which lies beneath the LC_{50} CO exposure v time curve which, defines levels for a 50% fatality rate for rats. However, the 45000 ppm.min curve lies above another curve found in the literature, the loss of consciousness in primates (chimpanzees). Humans are closely related to chimpanzees, how are homo sapiens going to escape if the design levels produce unconsciousness in these primates?

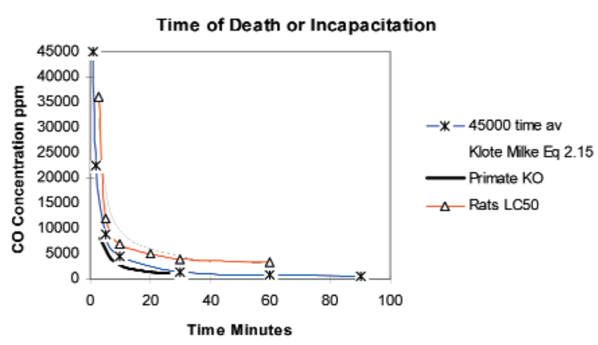

Figure 4: Comparison of CO dose with time.

Figure 4 shows the LC50 curve for rodents, which aligns well with equation 2.15 in Klote and Milke[7]. Beneath these curves lies the time averaged 45000 ppm.min, as quoted in the literature.

Figure 5 shows that a time averaged CO exposure of 27000 ppm.min matches the curve for loss of consciousness in primates. A suggested time averaged exposure of 15000 ppm.min as a basis for design is also plotted.

It would seem that in Australia we are specifying unsafe design CO exposure levels for humans, too close to the rodent LC_{50} curve. No allowance is made for the other toxic gases in the smoke. These gases include acrolein, which inflames the mucus membranes and disorientate occupants due to coughing and eyes streaming. Oxygen depletion, CO_2 and stress will further increase inhalation rates hence the rate of CO absorption. Hydrogen Cyanide at low concentrations has a quick knockdown, allowing the unconscious victim to succumb to the CO.

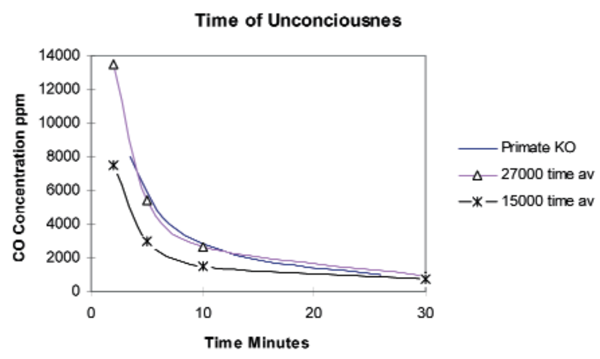

Figure 5: Suggested based exposure level.

If, despite these concerns, smoke toxicity is still to be incorporated in a design, then the designer MUST INCLUDE AMPLE SAFETY FACTORS.

Once building occupants are safely out of the building, is the design complete?

The BCA intends that fire engineered solutions primarily protect life and the adjoining properties from a fire in the proposed building. Ridiculous requirements to protect the new building from the effects of fire in an uncontrolled neighbouring property are not discussed in this paper. Typical objectives of the BCA include fire brigade intervention such as:

"*A building must have elements which will, to the degree necessary, maintain structural stability during a fire appropriate to:*

a) the function or use of the building; and
b) the fire load; and
c) the potential fire intensity; and
d) the fire hazard; and
e) the height of the building; and
f) its proximity to other property; and
g) any active fire safety systems installed in the building; and
h) the size of any fire compartment; and
i) fire brigade intervention; and
j) other elements they support."

Sub clause (i) recognises a cornerstone of building legislation, often taken for granted – fire brigade intervention. Most fire-engineered designs depend upon the unquantified and assumed effectiveness of fire brigade intervention to achieve the design objectives.

Many designers do not check that the building construction, or fire brigade intervention, will prevent fire spread to other properties. Once the occupants have evacuated, the design is often considered complete. It is essential that designers look at post egress fire conditions. Fire must not spread to adjoining property. A design is unacceptable to prevent fire spread if it requires resources beyond the capability of the fire brigade, or if fire brigade is so depleted it is unable to protect other properties which are important to the community (e.g. Hospitals, nursing homes).

The Fire Engineering Guidelines[8] (FEG), a document produced by the Fire Code Reform Centre for the Australian Building Codes Board[9] (ABCB) contains a simple fire brigade intervention procedure. The Australian Fire Authorities Council AFAC and the Fire Code Reform Centre (FCRC) agreed that a more refined methodology was needed[10] to replace that in the FEG. And so the Fire Brigade Intervention Model (FBIM)[11] was produced.

The FBIM, which has been extensively described,[12,13,14,15] is an event-based methodology. For a fire engineering design, the FBIM:

1. Quantifies fire brigade responses from time of notification through to control and extinguishment.
2. Establishes a structured framework to determine and measure fire brigade activities on a time line basis.
3. Interacts with other engineered sub-systems modelling such events as fire growth, smoke-spread and occupant evacuation.

The FBIM Has been primarily developed for use in a building fire safety engineering analysis, to effectively incorporate the functional role of a fire brigade into the building design process.

The FBIM design manual contains 16 flow charts, detailing the extent and order of core brigade activities undertaken at a fire scene. Supporting data is provided detailing the time taken to complete each of these activities. The manual outlines fundamental fire engineering principles and gives a worked example. Supporting training material is being produced for fire engineers to better understand fire brigade equipment and management procedures employed at a fire scene[16]. A FBIM computer program should be released early 2001.

Application of the FBIM

The fire engineering design operates external to the FBIM, in accordance with the agreed Fire Engineering Design Brief (FEDB). The size of the fire, occupant evacuation and the effects of brigade intervention strategies must be examined from time to time as the design scenario progresses. This may show that changes in intervention strategy are necessary (e.g. a change from an offensive to a defensive strategy).

This iterative review process reflects the usual decision making procedure of an Officer in Charge (OIC) at a fire scene (fire ground). The FEG flow charts, which interact with the "fire ground" status, are shown in Figure 6.

The flow charts shown in the following Figure 7, each describe basic actions of a fire brigade at a fire scene. The heavy line shows the flow path, which meets the requirements of the BCA. This does not include protection of the property, its contents or the environment. The FBIM can be used for such purposes using CHARTS 13, 14 and 16 should the building owner so wish.

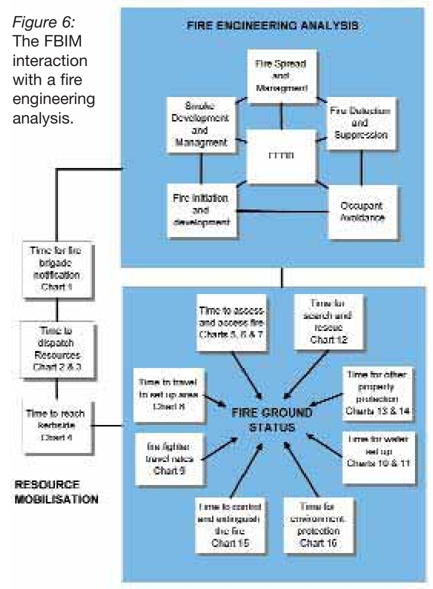

Figure 6: The FBIM interaction with a fire engineering analysis.

A supporting database for use with the flow charts has been derived from Australian fire brigade statistics and special exercises. In the FBIM manual, data is presented in tables and graphical form, showing the statistical population, standard deviation, maximum, minimum, mean values and distribution curves.

The FBIM quantifies the effectiveness of the local fire brigade. This should form an integral part of any performance-based design.

Other Disturbing Trends

The most important part of the FEG is probably the Fire Engineering Design Brief (FEDB). This is a team meeting, where all players involved in a project (e.g. architect, structural engineer, building services engineer, project manager, fire engineer) sit down with the council, or building certifier and the fire brigade. A consensus is reached regarding design principles and methods to be used and how this will be presented for approval. Once all parties have agreed, all players understand the process. No surprise, a smooth approval passage the anticipated outcome.

So much for fantasy. Time after time we are presented with a "*fait accompli*". Final design documentation is tendered with little detail of the input parameters or equations used.

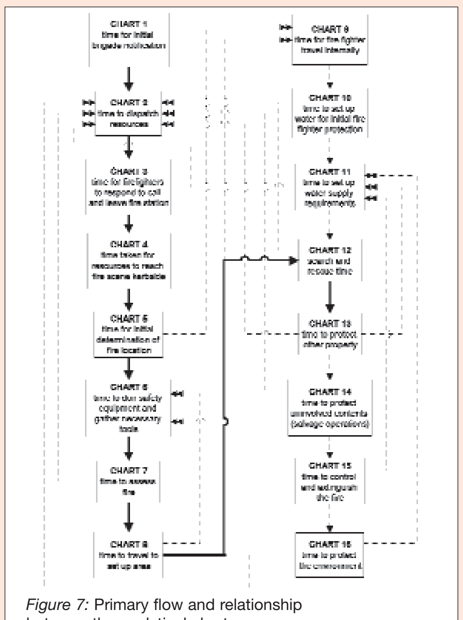

Figure 7: Primary flow and relationship between the analytical charts

Some sprinkler system designs deviate dramatically from the requirements of AS 2118 and Factory Mutual requirements. Using guesswork, sprinkler density of discharge, allowable storage height and area of operation, have been changed. It appears that building applications have been approved without adequate substantiation of the assumptions made.

Deviations from prescriptive standards, which are based upon laboratory tests, should only be entertained if further testing substantiates such change. A current concern is the installation of solid shelving in large high piled Class 6 buildings, which rely solely upon ceiling sprinklers. This is forbidden by the prescriptive standards because the solid shelving prevents pre wetting of combustibles on the lower shelves. This promotes lateral fire spread , which can overrun the operation of the sprinklers. It is understood that this was the contributing factor for a substantial fire loss which occurred recently in London, UK.[17]

Conclusion

Fire safety engineers need to be more thorough in their approach to fire safety design. They need to be more conservative and incorporate adequate safety factors. They generally need more education and exposure to the fundamental aspect of structural fires. Only when fire safety engineers have a greater understanding of fire behaviour, its interactions with building occupants, the environment and the modus operandi and capabilities of the attending fire brigade, will sensible effective designs be produced.

If you wish to obtain a copy of the author's reference lists 1~17 for exact sources, please contact us via Enquiries Form on page 7 . PFT

This article, all figures courtesy of Department of Mechanical Engineering, Adelaide Fire Safety Research Unit, University of Adelaide.

● A closer look at the fire safety of Mechanial & Electrical cables

Circuit Integrity of Cables in Fire

by **Lai Boon Keong** / *Technical Advisor*, Promat Building System Pte. Ltd.

Certain electrical systems and services are required to remain functional in the event of fire for a specified period of time to ensure a full set of fire safety measures in a building. Almost all active fire protection systems require electricity to operate, and may include:

- Electrically operated fire alarms.
- Emergency escape route lightings.
- Electrically operated extinguishing systems.
- Heat and smoke extraction ventilation systems.
- Fire service elevators.
- Water mains to sprinkler systems.
- Fire roller shutter doors.

The above systems are all installed with one ultimate goal – FIRE SAFETY! What if the system does not survive long enough during a fire to operate as required? Has the system met its mission effectiveness goal?

As an example, let us consider the fire alarm system. Typically, a fire alarm system will detect a fire, notify building occupants, and alert fire personnel. However, if cabling for the system has no circuit integrity, it will cause the alarm system to cease operation before it performs its expected function. Moreover, the fire may also quickly damage the wiring inside the conduit which will, in turn, silence the audible signal. As a result, building occupants will not evacuate as they might think that there is a system malfunction. By the time occupants realise an actual fire has caused the alarm, it may then be too late to take the necessary action. This, in fact, has happened before with the inevitable, tragic loss of life and property damage!

Generally, the M & E consultant is responsible for deciding which electrical system and equipment is required to continue to function in a fire. However, due to the nature of training undergone by them and the product knowledge training they are given, the M & E consultants will almost always automatically consider the use of fire resistant cable. But how reliable are these cables?

Fire Resistant Cables: Are They Reliable?

Some manufacturers claim that their fire resistant cables can last for three hours in a fire. But how is this fire resistance measured? This is one big question the specifier should bear in mind.

BS 6387: 1994 "Specification for performance requirements for cables required to maintain circuit integrity under fire conditions" is often used when considering the suitability of cables for used in protected circuits. Circuit integrity is measured by applying a current along a 1000mm length of cable where the cable is supported 200mm from each end, i.e. 600mm centres between supports, and the cable is subjected to heat from an elongated Bunsen burner. The flame temperature ranges between 650°C and 950°C depending on the selected test category. The cable must maintain circuit integrity throughout the heating period of up to 3 hours depending on the test category.

Another well known standard for testing circuit integrity of cables is IEC 60331 (originally IEC 331) "Test for electric cables under fire conditions – Circuit integrity". The test set-up is similar to the one in BS 6387, except that the flame temperature is lower, i.e. between 750°C and 800°C.

There are also other national standards such as AS/NZS 1660.5.5: 1998 (Australia & New Zealand) and SS CP 299: Part 1: 1998 (Singapore) which are also used to measure circuit integrity of cables. AS/NZS 1660.5.5 is very similar to IEC 60331 while SS CP 299 is deemed to replicate BS 6387.

Unfortunately, these standards only test single cables, without any support system exposed to a gas flame. Whilst such tests may be adequate for small cables carefully secured directly to a fire resisting wall or floor, it is arguable they are not suitable to assess the fire performance of larger cables or bunches of cables exposed to a fully developed fire on all sides, particularly if they are supported on a suspended cable tray which may be passing through compartment walls or floors.

Also, the test rig limits the size of cables tested to 21mm diameter. It has to be said that the test methods employed do not ensure a significant section of cable is exposed to all four sides by fire, it is not representative of a real fire in any shape or form as the heat applied during the test is somehow localised to a small area. If these cables were to be exposed to a fully developed fire as the one employed in the ISO 834 time-temperature curve, the cables would have lost their circuit integrity within the first few minutes into the test.

The only fire resistance test standard for circuit integrity of cables, which simulates a real fire scenario, is the German standard DIN 4102: Part 12 "Fire behaviour of building materials and building components – Circuit integrity maintenance of electric cable systems; requirements and testing."

DIN 4102: Part 12

DIN 4102: Part 12 assesses the ability of enclosure systems in maintaining the function of a cable system, for a period of time when exposed to a fully developed external fire. The tested enclosure system protects a wide range of different cable types. Current is passed through the cables throughout the test. As well as the requirement to maintain the fire integrity of the enclosure system, and any penetrations through walls or floors, the standard requires that the cables continue to function for the duration of the heating period and the temperature rise on the cable jacket does not exceed 150°C. The protected cable system will be exposed to a fully developed fire according to the ISO 834 time-temperature curve.

In consideration of fire performance to the standard, cable ducting is one of the best solutions and has been tested successfully. The well established board systems are the only system which currently can fulfil the requirements.

ISO 834 Time-Temperature Curve

ISO 834 or Standard Cellulosic time-temperature curve is used in standards throughout the world, including BS 476, AS 1530, DIN 4102, ASTM, and the new European Norm (EN). It is a model of a ventilated controlled natural fire, i.e. fires in a normal building.

It is impossible for any method to simulate exactly a real fire situation. This is because the rate at which a fire develops, the temperature reached, is greatly governed by the nature and size of the fuel load, the oxygen available to feed the fire and the shape and size of the compartment. However, research has shown that the peak temperature in a typical post-flashover room fire is fairly regularly found to be 900°C~1150°C. This is for a fully-furnished room arrangement that might be found in a typical office. The time-temperature curve for the standard ISO 834 reaches 945°C at 60 minutes, 1049°C at 120 minutes and 1153°C at 240 minutes. It is therefore obvious why the standard ISO 834 fire curve is accepted worldwide. Besides, experience has shown that elements which did not fail the appropriate criteria given for the relevant fire rating are rarely the cause of catastrophic failure in a real fire.

Conclusion

At the end of the day the message of this article should be that critical electrical cables require reliable protection to ensure life safety and property protection. The reliability of the protection system does depend on the nature of the testing standard to which the system has been subjected. There are many cables related fire-testing standards available internationally. The specifier should be aware of this and must be able to distinguish between the requirements within the various standards. There are also other fire-related cable standards such as IEC 60332 (originally IEC 332) that deal only with the combustion or flame propagation of cables and not with the continued functionality of cables although they are heavily promoted as fire resisting cables. The assumption that these cables can maintain circuit integrity in fire conditions is a dangerous fallacy. PFT

● Fire rating of extract and supply air ducts to AS 1530.4 and AS 1668.1: 1998 (with notes on BS 476: Part 24)

Fire Outside & Inside Ductwork

by **Rick Fox** / *Technical Manager*, Promat Australia Pty. Ltd.

The test method specifies the appropriate performance criteria for stability, integrity and insulation for two basic duct situations:
a) Fire outside the duct (external exposure)
b) Fire inside the duct (internal exposure)

Internal Fire Source

This is applicable to all extract ducts passing through more than one compartment, including kitchen extract ducts.

For internal fire testing, AS 1530: Part 4 has the specimen protruding not less than 2000mm from the furnace and 100mm inside the furnace. Hot gases are allowed to vent out of this duct from the furnace by natural means and the temperature inside this duct must be no lower than 250°K below the furnace temperature. BS 476: Part 24 requires the duct (Duct B) to protrude 2500mm from the furnace wall and 3000mm into the furnace. An opening is created in the duct inside the furnace through which the hot gases from the furnace are drawn, by means of an externally mounted fan at a rate of 3m/sec (measured at ambient temperature). It is generally considered that the BS test method is more onerous than the AS method. The heating conditions of the furnace are the same for both test standards.

The failure criteria for both BS 476: Part 24 and AS1530.4 are the same for internal fire conditions. For internal fire source AS1668.1 Cl. 3.7.2, requires the duct to achieve Structural Adequacy, Integrity and Insulation when tested in accordance with AS1530.4 for ducts passing through more than one compartment.

When ducts are in isolated positions, clear of combustible materials, it is quite common for insulation criteria to be waived (integrity only ducts).

External Fire Source

Extract Ducts

This is applicable to all extract ducts passing through more than one compartment (smoke, and kitchen exhaust and return air where dampers are not fitted).

AS 1668.1 Cl. 3.7.2 requires the duct to achieve Structural Adequacy and Integrity only when tested in accordance with AS1530.4.

Supply Air Ducts

These ducts supply air to fire isolated escape routes where they pass through more than one compartment.

For external fire, AS 1668.1 Cl 9.4.3 requires the duct to achieve Stability, Integrity and Insulation when the duct is supplying air to fire isolated exit routes. This is called up in Section 9 which states that the ductwork supplying air to the exits must maintain the same fire rating as the exit itself (internal fire source is not applicable to this type of duct) when tested in accordance with AS 1530.4.

The failure criteria for Structural Adequacy (Stability) and Integrity for AS 1530.4 and BS 476: Part 24 are similar.

However for Insulation criteria. AS1530.4 Cl. 9.6.3.1 test method allows 2 methods for the measurement of this temperature:
1) inside the furnace on the inside, unexposed face of the duct and outside the furnace on the duct face and the penetration seal, OR
2) the temperature criteria in method 1 can to be waived if the designer can prove the temperature of air delivered does not reach unacceptable levels.

It is this second insulation criteria that is generally considered to be relevant for life safety in the situation that these ducts are located.

The purpose of this type of air supply duct is to maintain air supply to the exits in a fire situation. Therefore the air inside the duct must continue to flow to pressurise the exit in a fire situation. The exact temperature of delivered air is not given in either AS 1530: Part 4 or AS 1668: Part 1.

The air flow can be between 1 and 10 metres per second depending upon the design of the system, an average would be 5m/sec.

For brief summary of testing requirements of Australian and British Standards for duct testing see Appendix 1.

BS 476: Part 24 has no requirement to monitor the temperature inside the duct, inside the furnace as required by AS 1530: Part 4. However the temperature of air delivered, can be calculated. The measurement of the surface temperature duct inside the furnace under BS 476: Part 24, is only mandatory for ducts to be used as kitchen extract systems. Contact us via Enquiries Form on opposite page for Appendix 2 on this information.

Appendix 1 — *AS = Australian Standard; BS = British Standard.*

1) *Length of duct*

1.1 Internal Fire: Inside furnace	1.1 Internal Fire: Outside furnace	2.2 External Fire: Inside furnace	2.2 External Fire: Outside furnace
AS: 100mm	AS: 2000mm	AS: 2000mm	AS: 100mm
BS: 3000mm	BS: 2500mm	BS: 3000mm	BS: 2500mm

2) *Joints in duct*
AS: To incorporate intended method of jointing.
BS: Two inside furnace and one outside.

3) *Restraint*
AS: No requirements.
BS: Full restraint is to be produced in the specimen at points 2000mm from the outside of the furnace.

4) *Pressure within duct*
AS: No requirements. *BS: Under pressure of 300Pa (external fire).*

5) *Air flow through duct*
AS: No fan attached. *BS: Fan attached air flow 3m/sec drawing hot gases through the duct (internal fire)*

6) *Pressure within furnace*
AS: 8pa per m. *BS: 10+/- 2Pa.*

7) *Furnace temperature*
AS: I.S.O. 834 1975 *BS: I.S.O. 834 1975*

8) *Surface thermocouples*
AS: Thermocouples on the duct wall, in groups of not less than two at not less than three sections within the duct at specified positions.
BS: On the part of the duct which projects away from the furnace at positions of 50mm and 1000mm away from the furnace wall exposed to the laboratory.

9) *Criteria of failure*
9.1 Structural Adequacy/Stability
AS: Structural Adequacy: Collapse of duct such that it cannot fulfil its intended function.
BS: Same as AS.
9.2 Integrity
AS: Deemed to be lost when hot gases can pass into the duct.
BS: When cracks, holes or other openings are formed in the part of the duct which projects on the outside of the furnace. The cotton wool pad test can be included.
9.3 Insulation
AS: Any thermocouple attached to the unexposed face of the duct will not rise by more than 180'C above the initial temperature, OR
In the case of air supply, the temperature of delivered air does not reach an unacceptable level.
BS: Any thermocouple attached to the unexposed face part of the duct which exceeds a temperature rise of 180°C or 140°C average. PFT

封面内容

● 进艺术爱好者的天堂——新加坡 Esplanade 艺术中心

新建经典艺术中心采用独特的耐火风管系统

现代都市中的天际线都是摩天大楼，变幻的色彩、外形、功能，构成了都市的一道风景线。新加坡这个绮丽多姿的动感之都最近又有了全新的亮点增加，必定会在多方位冲击你的视觉效果。这是因为，新加坡建成了一个外形独具优美，超现代的世界级综合艺术文化中心。

深远影响当地和国际的艺术氛围

海湾 Esplanade 大剧院，是这个艺术中心的官方全名，是在 2002 年 10 月中旬才正式对外启用的。早在 20 世纪 80 年代就有了建设这个剧院的设想，在 1996 年的 8 月终于破土动工，其地下结构于 1998 年完工，然后宏伟的地上结构也紧跟其后，在 2001 年 5 月终于实现结构封顶。

Esplanade 艺术中心的揭幕是以一个长达 3 周的艺术节开始的，其中包含了流行的、经典的；传统的和现代的，有音乐也有舞蹈；有来自 22 个国家的 1300 名艺术家被邀请来参加此次盛会，包括 70 场收费演出和数百场免费的社区演出活动。

由于 Esplanade 艺术中心的启用，新加坡在国际性文化艺术界的形象开始备受瞩目，同时基于它的艺术内涵、吸引力，也必将为新加坡在贸易、旅游等行业注入生机和活力。

采用高等级的建筑法令和安全规范

Esplanade 艺术中心是一个巨大的穹顶建筑群，位于 Marina 海湾处的滨水地区，占地 6 公顷，在繁华的城市中央商务区，可以很清楚的看到它。与它紧紧相邻的是有 5000 套客房的世界级豪华酒店，两座大型会议中心，一千多间风格各异的店铺，300 多间餐馆和 150 家酒吧，以及 7500 个停车位，一些著名的历史遗迹也分布在其周围。

新加坡的优良建筑环境取决于其高等级的职业化和安全规范，这个现代的城市之国以其在许多领域追求完美和卓越而著称，因其国家的稳定、美丽洁净，安全而享誉世界。

Esplanade 艺术中心也不例外，它的性能化设计和建造，不但满足而且超越了许多国际现行的安全、美学、性能要求，为人们带来美的安全的建筑。

以人为本的建筑

新加坡的这个艺术之殿的官方名字来源于临近的 Esplanade 公园，历史上是一个休闲和娱乐活动的场所，直到今天，提起这个名字，就会给人怀旧和浪漫的感觉。

同样的，以人为本的精神也贯穿了建造和设计 Esplanade 艺术中心的全过程。

东西方融合的最佳典范

Esplanade 艺术中心的建造同时吸取了东、西方的创造性和戏剧性的传统，它将建筑和艺术的语言有机的统一起来，以平球的视觉效果生动出现。

这个独立的 2000 座的舞台剧场沿用了传统的马靴型平面形状，在设计上提供了很大的灵活性，既可以用于亚洲和西方传统艺术的表演场合，也可以用于现代多媒体技术的演出场合。另外，还有多个小型的音乐工作室，是进行室内音乐会和独奏会的理想场所，众多的画廊和功能房间也极大的增添了艺术中心的功能多样性。

事实上，这个经典建筑大胆的、史无前例的将文化艺术和休闲生活的设施集为一身，并且成功作到了天衣无缝的融合，其中将包括图书馆，饭店和其他风格各异的零售店铺。

幕后的建筑安全防范使得这个经典建筑的舞台演出永不落幕

Esplanade 艺术中心作为一个经典的现代建筑，同样也承载着非同寻常的使命，毫无疑问，它所提供的防火措施，技术和质量也应当是世界一流的，例如，保全公司的 VICUCLAD® 蛭石型防火板的应用，就很好的满足了设计规格和政府建筑规范。

在一段非耐火的普通空调通风管道穿越防火分区时，要求包覆具有 2 小时防火完整性的保全 VICUCLAD® 防火板，以保证防火安全。

因此在耐火管道与空调风管相连接处，应当安装一个防火阀，为了承受重达 180kg 的防火阀，单独设置了一个独立的支承构架，同时也作为防火保护层的支承体系。

保全 VICUCLAD® 防火风管系统由于其出色的防火性能和灵活安装的简捷性，得到了建筑师和业主的认可并在艺术中心的工程中得到大量采用。

Esplanade image courtesy of The Image Bank, www.esplanade.com

● 进行耐火与非耐火风管选用时，对有关国际规范条文的理解

作者 [illegible]
[illegible]

澳洲标准 AS 1688.1: 1998 对风管耐火性能的要求

澳洲标准 AS 1688.1: 1998 [illegible]

[illegible] WFRA 20631A 和 WFRA 20631B [illegible] Enquiries Form [illegible] PFT

Enquiries Form

My Name: ____________________

Designation: ____________________

Company: ____________________

Nature of Business: ____________________

Address: ____________________

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Postcode: __________ Country: __________

Business Tel: __________ Fax: __________

Business URL: *http://www.* __________ Email: __________

I would like to receive:

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- ☐ Promat Asia Pacific Handbook 2002
- ☐ reports of WFRA 20631A/20631B for the article “Fire Resistance Requirements of Ductwork to AS 1668.1: 1998”
- ☐ reference list for the article “BCA Alternative Solutions: Be Cautious!”
- ☐ Appendix 2 for the article “Fire Inside & Outside the Ductwork”
- ☐ more information of PROMASTOP® AirChoke® fire damper
- ☐ *others (please specify)* ____________________

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On value scale of 1-5, I would rate this issue a ______ for my reference.

FAX NOW

Select your nearest Promat office behind this form

This Enquiries Form refers to ProActive Fire Trends Newsletter Volume 6, Number 1 - First Half, 2003

NEW PRODUCT FOR DUCTWORK FIRE PROTECTION

● Introducing PROMASTOP® AirChoke®

by Ray Porter/R & D Manager,
Promat International (Asia Pacific) Ltd.

Unique Externally Mounted Fire Damper

PROMASTOP® AirChoke® fire dampers incorporates an intumescent material designed to maintain integrity and insulation of the fire-rated element through which ducts pass.

In the event of a fire the PROMASTOP® AirChoke® fire damper rapidly closes off the duct.

This intumescent compound continues to expand throughout the fire and forms a non combustible char which stops the fire passing into adjoining fire compartments.

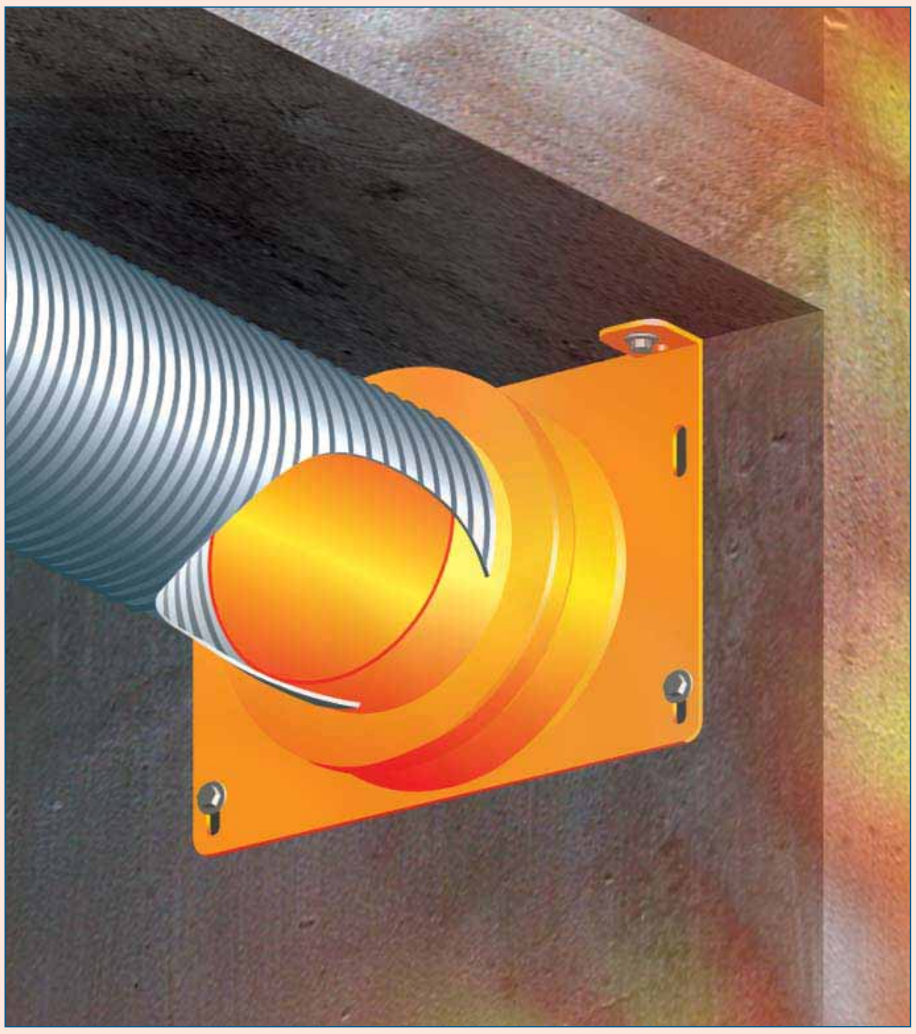
AS 1682: Part 1 Fire Damper including
BS 1042: Part 1 Air Leakage test

Rate of flow at maximum air pressure differential 2L/sec (maximum allowable is 195L/sec).

NOTE: At the time of issue tests have not been carried out on pipes greater than 160mm.

Feature Advantages

- Slotted fixing tabs for slab.
- Powder coated orange, will not corrode easily.
- Truncated uPVC spigots for 150mm duct.
- No disruption to air-flow.
- Externally mounted type fire damper.
- Large rectangular flange plate.
- Low profile only 220mm high.
- Complete closure in less than 2 minutes.
- Complies with BCA require-ments tested in accordance with AS 1530: Part 4, AS 1682: Part 1, AS 1668: Part 1 and BS 1042: Part 1.
- Minimal inspection, no activation or cleaning required.



Drawing above: Installation with 2-hours fire rating, integrity and insulation in accordance with the National Standards listed in this article.

Tested Applications

This fire damper complies with the following Australian Standards and as such complies with the requirements of the BCA.

AS 1530: Part 4: 1997
FRL -/120/120.

AS 1668: Part 1
Fire & Smoke Control
in multi-compartment buildings

Closure in 26 secs (maximum allowable 120 secs).

Packaging

PROMASTOP® AirChoke® fire dampers are packaged in individual boxes.

Installation

Fix the damper to the wall through all four fixing slots on the base plate with 6mm x 25mm masonry anchors (for brick or masonry walls) or with s-point screws that are long enough to attach to the framing of walls (for timber framed walls ensure the screws penetrate at least 32mm into the timber).

For drywall partitions and shafts the opening through which the duct passes must be trimmed with the wall framing and be lined with a single layer of 16mm plasterboard.

The annular gap between the duct and a solid wall must be no more than 10mm.

Attach the duct to each end of the damper "sleeve" and secure into position.

PROMASTOP® AirChoke® is a unique fire stopping product because:

- It is believed to be the first externally mounted fire damper in the world.
- It can accommodate up to 160mm diameter duct.
- It leaves air ducts clear of obstructions
- It is easy to install and can be pre-mounted or post-mounted in position.
- It does not require expensive internal monitoring cameras.
- It does not require any maintenance. PFT