THE PERFORMANCE OF UNIT ENTRY DOORS WHEN EXPOSED TO SIMULATED SPRINKLER CONTROLLED FIRES

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ABSTRACT

This paper examines the interaction of sprinklers and unit entry doors for hotel apartments. Full scale testing was conducted to quantify the smoke leakage performance of typical unit entry doors during simulated sprinkler controlled fire conditions. Test results showed that for a typical tight fitting unit entry door without any smoke gaskets or seals, excessive smoke leakage into adjoining exit corridors will result where no additional mechanical smoke control systems are employed.

1.0 INTRODUCTION

The contribution of fire and smoke doors to an effective fire safety strategy is recognised by most prescriptive codes and standards throughout the world. The increasing international trend towards the use of performance based codes and fire safety engineering design principles has resulted in the need for the performance data which takes into account the interaction between different fire safety sub systems. An important interaction is that of active fire protection and passive fire protection safety sub systems. A specific and topical example is that of sprinklers with fire and smoke doors.

This paper is looks at the interaction of sprinklers and unit entry doors for hotel apartments and office buildings. Full scale testing was conducted to quantify the smoke leakage performance of typical unit entry doors during simulated sprinkler controlled fire conditions.

Important results reported in this paper demonstrate that in a sprinkler controlled apartment or office fire, a tight fitting unit entry door without any smoke gaskets or seals will allow considerable smoke leakage into the adjoining exit corridors. The application of this test data is of great importance to both fire engineering design and prescriptive regulatory approaches to fire safety.

2.0 OBJECTIVE

The objective of this research project was to quantify the smoke leakage through unit entry doors in hotel apartments and office buildings when exposed to simulated sprinkler controlled fires.

3.0 METHODOLOGY

The project consisted of a number of separate but related tasks :

- Recent literature was reviewed to determine appropriate simulated test conditions for a sprinkler controlled hotel or office building fire compartment.
- A series of full scale experimental tests were conducted to quantify the leakage through typical unit entry doors for the above simulated test conditions.
- Recommendations are made for the application of the test results to prescribed Australian regulatory approaches to fire safety.

4.0 LITERATURE REVIEW

4.1 SPRINKLER CONTROLLED FIRES

There is no disputing the fact that the operation of sprinklers limit the fire growth rate, and minimise the fire size, room temperature, radiant heat, buoyancy pressures, gas concentrations, and, production and spread of smoke.

There are many variables that effect the production and spread of smoke and some of these include:

(a) the type of fire; flaming, smouldering, shielded or unshielded,

(b) the fuel load and configuration of fuel sources,

(c) the ventilation conditions,

(d) external effects such as smoke control systems, stack effects and wind,

(e) the geometry of the fire compartment,

(f) and of course the sprinkler design itself.

4.2 FACTORS EFFECTING SMOKE LEKAGE THROUGH CLOSED DOORS

The key variables which effect the leakage through closed doors for a given door construction are:

(a) Door clearances and gaps

For smoke to pass around the perimeter of a closed door, firstly there needs to be some clearances and gaps around or under the door. In order for a door to function in everyday use, that is to open and close, there is a requirement to have operational clearances and gaps. These clearances and gaps under the right conditions will result in surprisingly large volumes of smoke leakage.

(b) Pressure differential across the door

The buoyancy forces of the fire will cause a pressure differential across the door which will push the smoke out of the room of fire origin through any clearances or gaps around the perimeter or under the door.

External forces such as wind, stack effects and mechanical smoke control systems can also have a big impact on smoke movement into or out of a room of fire origin.

(c.) Temperature of the smoke

The temperature of the smoke will not only change the density of the air and effect the leakage characteristics, but may distort the door or degrade any seals or even the door itself, resulting in additional leakage.

(d) Gas species concentrations

Although this does not have a big impact on the leakage characteristics, if the species concentrations of gases in the fire are known, they can be used to predict the species concentration of gases that will pass around the perimeter of the door for a given total leakage volume rate. This is useful data for fire safety engineering analyses.

4.3 FIRE TEST DATA FOR LEAKAGE RATES THROUGH DOORS

There is also very little published data relating to the leakage of smoke through doors during sprinkler controlled fire conditions,

There is however some excellent research data published for non sprinklered or fully developed fire scenarios, Cooper (1980), Berhining (1981), Ahonen and Loikkanen (1984), Stroup and Madrzykowski (1991), and Young & England (1999).

4.4 FIRE TEST DATA FOR SPRINKLER CONTROLLED FIRE CONDITIONS

There has been a great deal of research data published over many years relating to for full scale fire tests incorporating sprinklers. There is an abundance of data available for unshielded fire scenarios but not a great deal for shielded fire scenarios.

Shielded fires are those where the sprinkler discharge cannot directly impinge on the fire as it is shielded by an obstruction such as a table or chair for example.

There is only limited data that looks at shielded fires and also gives the temperature profiles, buoyancy pressure profiles and species gas concentrations. For the data that has been published, the data is specific and limited to the enclosure geometry tested and relates to the specific design and type of sprinkler incorporated in the test series.

Lougheed and Mawhinney (1996) did some interesting work showing the probability of shielded fires. Based on the results of this work it is appropriate to consider shielded sprinkler controlled fires as a reasonable sprinkler controlled fire scenario.

Two of the more recent and detailed published research papers, Mawhinney and Tamura (1994), and Lougheed (1997) have been chosen to qualify both the temperature and buoyancy pressures typical for a shielded sprinkler controlled fire. These papers also have individual species gas concentrations which could be used for subsequent fire safety engineering calculations for individual species leakage based on the overall leakage rates from any testing.

Mawhinney and Tamura (1994), tested standard response pendant type sprinklers with shielded fires and varied the sprinkler discharge density, whilst Lougheed (1997) tested fast response pendant type sprinklers with shielded fires for a standard discharge density.

The Test data from Mawhinney and Tamura (1994) showed that the temperature in the upper portion of the test rooms were in the order of 200 °C, whilst the test data from and Lougheed (1997) showed a temperature of around 100 °C.

Both the test data from Mawhinney and Tamura (1994) and Lougheed (1997) showed the buoyancy pressure differential from the fire alone to be no greater than 12.5Pa.

Based on the work of Mawhinney and Tamura (1994) and Lougheed (1997) the following test conditions were chosen for the basis of an experimental test program:

(a) Temperature

Ambient and 200 °C, to allow some interpolation of results if necessary.

(b) Pressures

Pressure differential of 12.5 Pa.

Other pressure differentials were included to gather data at higher pressures to allow for possible external influences such as wind, stack effects and mechanical smoke control systems.

5.0 EXPERIMENTAL TEST PROGRAM

A research test program was conducted at Intertek Testing Services, Middleton laboratory, in Wisconsin, USA.

The testing involved ambient smoke and medium (200 °C) smoke leakage tests on typical Australian manufactured unit entry doors. These doors included both fire rated doors complying with AS/NZS 1905/1 and tight fitting solid core doors complying with AS2688. These doors were fitted in assemblies with both steel and timber door jambs. Evaluations were then conducted using (a) no sealing system and (b) proprietary ambient / medium temperature smoke seals

5.1 TEST APPARATUS

The testing apparatus was an elevated temperature smoke test rig as specified in UL1784/1 (Air leakage tests of door assemblies). (See Figure 1 and 2).

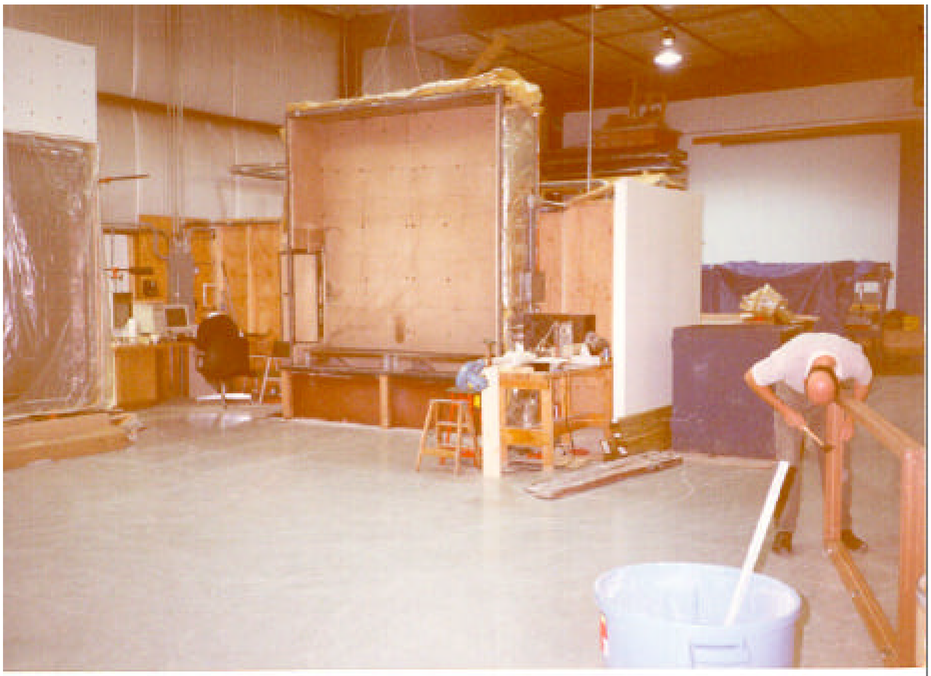

Figure 1 – Smoke leakage testing apparatus (ITS Middleton, WI, USA)

Figure 2 – Tight fitting solid core door ready for a smoke leakage test

5.2 TEST PROCEDURE

The testing procedure was based on that of UL1784/1 and used an air leakage chamber, which essentially is a well sealed box with an opening on the front of it, large enough to accommodate the test sample.

Tests were conducted at both ambient and medium temperature (200 degrees Celsius after 30 minutes exposure) at pressure differentials of 12.5, 25, 50 & 75 Pascal respectively. Tests incorporated solid core doors complying with AS2688, and fire doors complying with AS1905/1. All doors were tight fitting with a maximum of 3mm perimeter (top and side) clearances and a maximum of 6mm threshold (bottom of door) clearance. Data was obtained for doors without any seals and identical doors incorporating proprietary ambient / medium temperature smoke seals.

5.3 RESULTS

Tables 1 and 2 show a summary of some relevant actual leakage rates for ambient and medium temperature respectively, as measured during the test program.

AMBIENT TEMPERATURE LEAKAGE DATA

	DOOR WITHOUT SEALS	DOOR WITH SMOKE SEALS
Door construction	AS2688 solid core door	AS2688 solid core door
Temperature	Ambient	Ambient
Door orientation	Inswing	Inswing
Seal configuration		
perimeter (top & sides)	No Seals - tight fitting door	Lorient Batwing
theshold (bottom)	No Seals - tight fitting door	Lorient RP8
Pressure differential [Pa]	**total leakage [m3/hr]**	**total leakage [m3/hr]**
12.5	144.82	7.07
25	213.74	10.97
50	>340	15.74
75	>340	22.64

Table 1 – Ambient temperature leakage test results

ELEVATED TEMPERATURE LEAKAGE DATA

	DOOR WITHOUT SEALS		DOOR WITH SMOKE SEALS	
Door construction	AS2688 solid core door		AS2688 solid core door	
Temperature	Elevated (200 deg C)		Elevated (200 deg C)	
Door orientation	Inswing		Inswing	
Seal configuration				
perimeter (top & sides)	No Seals - tight fitting door		Lorient Batwing	
theshold (bottom)	No Seals - tight fitting door		Lorient RP8	
Pressure differential [Pa]	**total leakage [m3/hr]**		**total leakage [m3/hr]**	
12.5	172.20	*	5.10	*
25	214.84	*	8.31	*
50	254.28	*	12.43	*
75	307.69	*	16.52	*

* (leakage rates at 200 degrees Celsius, not adjusted to STP)

Table 2 – Elevated temperature leakage test results

Some interesting observations came out of the smoke leakage testing at the medium temperature exposure of 200 °C after 30 minutes :

(a) The door leaves manufactured using standard, one part water based PVA adhesives experienced major delamination (see Figure 3).

(b) The solid core door leaves complying with AS2688 in both a steel and timber door frame deflected quite noticeably due to the medium temperature exposure. To ensure acceptable smoke leakage, door seals that can accommodate this amount of deflection need to be incorporated.

Figure 3 – Delamination of a solid core door after exposure to elevated smoke leakage testing at 200 degrees Celsius for 30 minutes

6.0 DISCUSSION

6.1 GENERAL

The test results presented in the paper provide data for smoke leakage rates through doors without seals and for one specific and proprietary seal configuration.

Results for both ambient and medium temperature testing at 200 °C for 30 minutes have been presented for different pressure differentials.

The test demonstrated clearly the important role played by smoke seals on restricting the spread of products of combustion through closed doors during sprinkler controlled fires. The use of tight fitting doors in sprinkler controlled fire scenarios has been shown to be unsatisfactory.

The fire safety engineer or regulator needs to take into consideration external influences that might increase the pressure differential across the unit entry door such as wind and stack effects and therefore may need to consider pressures greater than 12.5 Pa created by the buoyancy pressure of the fire alone.

The performance of smoke seals is dependent upon the seal design and installation and the results presented in this paper cannot be applied to generic seal configurations.

There is a great deal more testing that has been conducted that is not reported in this paper and there is also a great deal more that needs to be conducted to adequately cover this important and topical subject matter.

6.2 CURRENT AUSTRALIAN REGULATORY REQUIREMENTS FOR DOORS

The current Building Code of Australia (BCA) deemed to satisfy provisions for both fire doors and smoke doors are given in Specification C3.4

Fire Doors

Fire Doors are required to comply with AS1905/1, which in turn requires testing to AS1530/4 to determine the Fire Resistance Level (FRL). During AS1530/4 testing, there is no measurement of smoke leakage, and excessive gaps approaching 150mm long x 6mm wide are permitted before integrity failure is deemed to have occurred.

A common misconception is that a typical Australian fire door complying with AS1905/1, and with no additional smoke seals, is an adequate smoke door.
In actual fact, this is not the case. In terms of smoke leakage, such a door is no different to a tight fitting solid core door and allows excessive quantities of smoke leakage under typical fire conditions. Refer to results provided in Tables 1 & 2.

Smoke Doors

The following are abstracts from Specification C3.4 (BCA96) :

General requirements
“Smoke doors must be constructed so that smoke will not pass from one side of the doorway to another”

This clause is an absolute statement and is not practical. In order for a door to be operational, that is open and close for everyday use, some smoke leakage will result, even for doors with good smoke seals fitted.

A better general requirement might ask for smoke door assemblies (inclusive of smoke seals) whose smoke leakage rates ensure tenable conditions prevail whilst occupants are escaping in case of fire. In some cases smoke doors may also need to be fire doors, in which case these would be termed fire and smoke doors.

The construction deemed to satisfy
“The door leaves are capable of resisting smoke at 200 degrees Celsius for 30 minutes”

This gives us some information regarding the conditions of the smoke and the duration, but does not give us any documented test protocol against which to test, nor does it quantify acceptable smoke leakage levels.

“The door leaves are fitted with smoke seals”

There is no definition or performance criteria associated with the reference to smoke seals and therefore it is not clear whether they in fact need to be capable of resisting smoke at 200 °C for 30 minutes as per the door leaves.

As doors will open and close in everyday service,

There should also be some requirements for the durability of both the doors and the smoke seals. A documented testing and third party approval or certification process that qualifies the long term durability and reliability of the smoke door assembly would suffice. A note regarding the ease of operation is also important, to ensure that properly designed smoke seals systems are employed to ensure doors fitted with smoke seals can be easily opened and closed.

7.0 CONCLUSIONS

(a) There is little published data available for the smoke leakage characteristics of different door configurations during sprinkler controlled fires.

(b) Shielded sprinkler controlled fires can result in temperatures in the order of 200 °C and buoyancy pressure approaching 12.5Pa.

(c) External effects such as winds and stacks effect can increase the pressure differential across unit entry doors during fires and pressures greater than the 12.5Pa buoyancy pressure generated in shielded sprinkler controlled fires may be necessary to consider.

(d) Tightly fitting doors without appropriately designed smoke seals produce excessive amounts of smoke leakage during simulated sprinkler controlled fire testing.

(e) The use of tight fitting doors in sprinkler controlled fire scenarios has been shown to be unsatisfactory.

(f) The testing demonstrated clearly the important role played by smoke seals on restricting the spread of products of combustion through closed doors during sprinkler controlled fires.

(g) One proprietary design of ambient / medium smoke seals resulted in large reduction in smoke leakage through doors in simulated sprinkler controlled fire testing.

(h) The performance of smoke seals is dependent upon the seal design and installation and the results presented in this paper cannot be applied to generic seal configurations.

(i) Australian Building Code Specification C3.4 should be updated to include AS/NZS1530/7 testing protocol and acceptable leakage data rates for buildings with and without sprinklers.

8.0 REFERENCES

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