Why Group Numbers?

White Paper

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Who should read this paper: This paper will be of interest to building surveyors, fire safety engineers, architects and other building designers, builders, fire services and building regulators.

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Introduction

Project 2 of the Fire Code Reform Centre[1] focused on interior finish (aka lining) materials and exterior cladding. For interior finish it identified a means to categorise the fire performance characteristics of lining materials and identified the factors that control fire performance. The outcome of this work was a Deemed-to-Satisfy (DtS) building code classification scheme (refer BCA Specification C1.10) using Group Numbers based on fire testing. The relevance of this research is as important today as it was twenty years ago. The most hazardous interior lining products such as low-density fibre board and some foam plastics have been eliminated from use in many buildings thanks to our modern building regulations. But new materials and systems are in constant development, and potential risks must always be addressed.

This paper discusses the DtS approach to managing the risk of lining materials in the building code using the concept of Group Numbers.

Building fire spread

Buildings can be viewed as enclosed spaces separated by barriers. Fire spread occurs within a space and between spaces.[2] The barriers prevent fire spread between spaces and is often specified in terms of a Fire Resistance Level (FRL).[3] External fire spread may occur via the façade (external wall) or from external opening to external opening. Fire spread within a space (enclosed by fire rated construction) is a function of the type, size and location of fuel packages (combustible contents) and combustible wall, floor and ceiling linings.

The National Construction Code's BCA[4] controls the fire safety risk of a building's components by limiting their use or limiting their combustibility. For internal wall and ceiling lining materials, this involves the exposed surface components (system) of the wall or ceiling. For these the BCA has Performance Requirements which must be met to achieve the safety goal. These are

- CP2 — Spread of fire
- CP3 — Spread of fire and smoke in health and residential care buildings

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[1] Custer, Richard and Ashe, Brian "Results and Lessons Learned from the Fire Code Reform Centre" Proceedings of the 4th International Conference on Performance-Based Codes and Fire Safety Design Methods. Melbourne 2002.

[2] Fitzgerald, Robert W. and Meacham, Brian J. Fire Performance Analysis for Buildings, Second Edition. John Wiley & Sons Ltd. 2017.

[3] Barnett, J and Akritidis, A. Why You Shouldn't Use FRLs. Paper in progress.

[4] NCC 2019 Guide to BCA Volume One – Amendment 1. Australian Building Codes Board. 2019.

- CP4 — Safe conditions for evacuation

Compliance can be achieved through a Performance Solution and/or a DtS Solution. In general for wall and ceiling linings, the DtS provisions of the BCA control lining flammability characteristic classifications using **Group Numbers**.

What are Group Numbers?

From BCA Schedule 3, Definitions: "**Group Number** means the number of one of 4 groups of materials used in the regulation of *fire hazard properties* applied to materials used as a finish, surface, lining, or attachment to a wall or ceiling".

From BCA Schedule 3, Definitions: "**Fire Hazard Properties** means the following properties of a material or assembly that indicate how they behave under specific fire test conditions…"

Because the BCA is a performance-based building code, compliance with the code is achieved by meeting the Performance Requirements. Compliance can be achieved through a Performance Solution and/or a DtS Solution. The Performance Solution is a building-specific design solution, although there are standard methodologies that might be used to develop one. A DtS Solution is like the prescriptive requirements of a traditional, non-performance-based building code, as it uses a carefully specified approach/design methodology and set of requirements. From BCA A2.3[5] the DtS Solution is "deemed" to have met the Performance Requirements.

The use of Group Numbers is ONLY a DtS Solution requirement. However, a Group Number may be of value in the development of a Performance Solution. This is because one means of demonstrating that a Performance Solution meets the Performance Requirements is to show that the Performance Solution is at least as safe as the DtS Solution.

History of the development of Group Numbers

In order to develop an understanding of the inter-relationship between wall and ceiling linings under specific fire test conditions, Group numbers and their performance in real fires, it is useful to review the history and development of standard tests and the Group number concept.

In the 1990s as the performance-based code was being developed in Australia, it became clear that there was a need to identify appropriate DtS provisions for wall and ceiling lining materials based on their fire performance. The reason for this was explained by Dowling[6]:

[5] National Construction Code 2019 Volume One Amendment 1; Australian Building Codes Board; 01 July 2020.
[6] Dowling, V. and Blackmore, J. "Fire Performance of Wall and Ceiling Linings, Final Report, Project 2, Stage A". Fire Code Reform Centre Ltd; prepared by CSIRO; July 1998.

In the event of fire, lining materials must not significantly decrease the safety of occupants

- In the presence of an ignition source, linings might significantly reduce the time to untenable conditions; and
- In the presence of an ignition source, linings might significantly contribute to flame spread

Ranking lining materials and categorizing them was not a new concept for building codes in Australia. The first amalgamated code (combining the state building regulations into an amalgamated document) was published in 1988[7]. Wall and ceiling lining limitations derived from individual state building regulations were specified in Specification C1.10. Unlike today's Building Code, the 1988 BCA was a traditional building regulation based on prescriptive requirements to achieve compliance. It had the notable feature of being an amalgamation of existing state and territory building regulations along with some Performance Objectives, Requirements and DtS provisions. It was the natural precursor to our modern performance-based building code.

Instead of today's Group numbers, Specification C1.10 in the 1988 BCA required compliance with Early Fire Hazard Indices. These indices were based on the results of AS 1530.3[8] testing. Tested materials had an index of 1 to 9 for each of three factors: Flammability, Smoke-Developed and Spread-of-Flame. This approach was based on historic or traditional fire safety provisions where linings were cellulosic based. At the time there was little recognition in Australia that certain plastics exhibited "good" early fire hazard indices, even though they were much more hazardous than their cellulosic alternatives.

As stated by Gardner[9], AS 1530.3 is a small-scale test, comparable to the widely used and studied American test ASTM E84[10]. AS 1530.3 was developed in Australia in the early 1950s[11]. Like it's American counterpart it was developed for evaluating the fire hazard of cellulosic-based or behaving wall lining products such as solid timber panelling, plywood panelling, and thick wallpaper. However, in the 1960s[12] it was recognized that small scale tests like ASTM E84 (and its Australian counterpart AS 1530.3) were not appropriate for certain plastic products; particularly plastics that melt and drip or for certain laminated linings with non-

[7] Building Code of Australia; Australian Building Codes Board; December 1988.
[8] AS 1530.3 - Methods for fire tests on building materials, components and structures Part 3: Test for early fire hazard properties of materials; Standards Australia; 1982.
[9] Gardner, W.D and Thomson, C.R. Flame Spread Properties of Forest Products – Comparison and Validation of Australian and North American Flame Spread Test methods – Technical Paper No. 36; Forestry Commission of New South Wales, Sydney; 1987.
[10] ASTM E84 - Standard Test Method for Surface Burning Characteristics of Building Materials; American Society for Testing and Materials; 6 March 2020
[11] Lynch, J and LaRose, T. Determining the radiation and temperature characteristics of the early fire hazard test. WPI MQP; Conducted at CSIRO Highett, VIC. Advised by Dr. J. Barnett; January 2000.
[12] Lathrop, J. "Old Test, Test, Why NFPA 286 testing is preferred for plastics that melt and drip". NFPA Journal; National Fire Protection Association; July 3, 2014.

homogeneous cross sections. By that time the larger scale tests ISO 9705[13] and ASTM E2257[14] were developed. We've referenced the current versions of these standards for reader convenience. These large-scale tests provided a high level of confidence because the problems of testing plastics in the small-scale tests are properly accounted for; large-scale tests were more representative of the "real world". However, interpreting the results and developing a simple means to incorporate the results into building regulations still needed to be developed.

In the 1990s and early 2000s, the Australian Building Codes Board sponsored a series of research projects to support the development of the new performance-based building code. Much of this work was done by the Australian Fire Code Reform Centre. One of the research projects was to determine a way forward for the classification and control of wall and ceiling lining materials. The key relevant findings of Dowling's[15] report were:

- Change from the Fire Hazard Indices approach to a hazard Group number approach
- Change from an ad hoc small-scale Australian test standard, AS 1530.3, to ISO 9705, an internationally recognized large-scale test standard with test component linings applied to three walls and the ceiling.
- Identification of some small-scale test approaches that could be used for certain materials and wall and ceiling systems to predict large-scale test performance. An outcome of this work was the determination that AS 1530.3 was inappropriate for use as a small-scale test substitute for the large-scale test ISO 9705. This was confirmed later at CSIRO when Lynch found no reasonable relationship between the heat exposure from AS 1530.3 and large-scale fire behavior.[16]
- Justification of the use of the Group number approach instead of the fire indices methodology based on an evaluation of international best practice.

The result of this research was that Dowling took the European approach discussed by Kokkala and proposed the same methodology be used in Australia.[17,18] Dowling's Group Number approach was to assign a numerical ranking to a wall or ceiling lining, based on the time to reach "Flashover" in an ISO 9705 test room. This test room is 3.6 m long, 2.4 m wide and 2.4 m high with a 2 m high by 0.8 m wide doorway opening on one wall. The test uses the concept

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[13] ISO 9705: Fire tests - Full-scale room test for surface products; Standards Australia; 16 May 2003 (reconfirmed 2016).

[14] ASTM 2257 Standard Test Method for Room Fire Test of Wall and Ceiling Materials and Assemblies; American Society for Testing and Materials; 2019.

[15] Dowling, V. and Blackmore, J. "Fire Performance of Wall and Ceiling Linings, Final Report, Project 2, Stage A". Fire Code Reform Centre Ltd; prepared by CSIRO; July 1998.

[16] Lynch, J and LaRose, T. Determining the radiation and temperature characteristics of the early fire hazard test. WPI MQP; Conducted at CSIRO Highett, VIC. Advised by Dr. J. Barnett; January 2000.

[17] Dowling, V. and Blackmore, J. "Fire Performance of Wall and Ceiling Linings, Final Report, Project 2, Stage A". Fire Code Reform Centre Ltd; prepared by CSIRO; July 1998.

[18] Kokkala, M. A., Thomas, P. H. and Karlsson, B. (1993), "Rate of heat release and ignitability indices for surface linings"; Fire Materials; 17: 209-216.

of flashover as occurs in an actual room fire. Flashover in a room fire marks the transition from a single burning object to full room involvement where virtually all combustible contents in a room are burning and the room becomes uninhabitable. It is marked by a rapid rise in room temperature of over 500 °C, a heat flux to the floor of over 20 kW/m^2 and heat release rate of 1000 kW. Wall and ceiling linings, particularly combustible ones, have a significant impact on the length of time to reach flashover.

In the test, the test room is lined with the wall and ceiling lining system being evaluated and a gas burner is ignited in the corner of the room opposite an open doorway. The burner operates at 100 kW for the first ten minutes of the test and then is increased to 300 kW for the duration.

Group Numbers are assigned to wall and ceiling lining materials based on time to reach flashover in the room test (using the heat release rate criteria) as follows:

- Group 1 – Flashover takes more than twenty minutes
- Group 2 – Flashover takes between ten and twenty minutes
- Group 3 – Flashover takes between two and ten minutes
- Group 4 – Flashover happens within two minutes

A 100 kW fire is equivalent to a large waste basket fire. In the case of a Group 4 material, the resultant burner/lining fire is enough to make the test room flashover in two minutes or less. This contrasts with a Group 1 material whose presence does not result in flashover during the test's twenty-minute duration.

Change from the Fire Hazard Indices approach to a hazard Group number approach

The Group number is a building code requirement under the DtS provisions of the BCA. In today's building code, linings are divided into four basic categories dependent on building classification (which is related to its use). This encompasses all building uses except for single family homes, small sheds, carports and associated structures (which are addressed in a different document.[19] A wall or ceiling lining with a Group number of 1 may be used within any location in a building. Whereas a product with a Group number of 4 cannot be used within a building. The minimum Group number requirement is listed in BCA Specification C1.10, Clause 4, Table 3. An excerpt of which is in Table 1.

Table 1 - Excerpt of NCC Table 4, Spec. C1.10, Clause 4

Class of building	Fire-isolated exits and	Public corridors	Specific areas	Other areas

[19] National Construction Code Volume Two Amendment 1; Australian Building Codes Board; 01 July 2019.

	fire control rooms			
Class 2 or 3, Unsprinklered. Excluding accommodation for the aged, people with disabilities, and children	Walls: 1 Ceilings: 1	Walls: 1, 2 Ceilings: 1, 2	Walls: 1, 2, 3 Ceilings: 1, 2, 3	Walls: 1, 2, 3 Ceilings: 1, 2, 3

Table 1 illustrates that for Class 2 and Class 3 buildings, which are principally multi-unit residential and hotel accommodations, the maximum Group Number allowed for a wall or ceiling lining used in "Fire-isolated exits and fire control rooms" is 1, but for "other areas" 3. This is typical for how the BCA regulates the fire properties of wall and ceiling linings as a function of occupancy (building classification) and use of the space. In the case of fire-isolated exits for example, the most stringent Group number (Group number of 1) is specified, as the only fuel expected to be in the space are the wall and ceiling linings, and the space is critical as a fire in the space may impede egress. Therefore, it is important to minimize the fuel load of the space's lining materials.

As per Dowling[20], the reason for switching from the Fire Hazard indices to the Group number concept was that the uncertainties in material fire safety behavior are strongly depended on many factors, not just those measured in the tests. These include compartment size and shape (for example, corridor versus room), area of coverage by the lining, proximity to other burning objects, etc. These factors can affect how a lining burns (flame spread, smoke produced, heat generated). For example, the larger the area covered by the lining, the more lining in the space and the greater the lining fire.

Therefore, one of the major challenges in developing a ranking scheme is accounting for the accuracy of the ranking when extrapolating behavior from a standard test to material behavior in a real building fire. If there are ten increments (categories) going from safe to unsafe, there is an implied increase in precision compared to using four increments. Dowling showed that this additional precision was not warranted, and based on expert judgment, recommended four increments or Groups; A through D which when codified in the BCA became Group numbers 1 to 4.

Change from an ad hoc small-scale Australian test standard (AS 1530.3) to an internationally recognized large-scale test standard (ISO 9705)

AS 1530.3 was developed in the 1950s in Australia and was suitable for the wall lining materials of the time. As previously stated, the AS 1530.3 test is not suitable for many modern linings comprised of plastic or certain laminated products. The fundamental reason is based

[20] Dowling, V. and Blackmore, J. "Fire Performance of Wall and Ceiling Linings, Final Report, Project 2, Stage A". Fire Code Reform Centre Ltd; prepared by CSIRO; July 1998.

on combustion physics. Understanding how modern plastic materials burn can provide an insight as to why a new test methodology was needed.

For a plastic (polymer) or any solid combustible fuel to ignite, it typically goes through a complex chemical reaction. For simplicity and for this discussion we can consider the following steps:

- The fuel is heated by an external source to the point where it starts to volatilize (combustible vapors are generated). In the case of a plastic, this occurs as the molecular bonds start to break.
- A stream of volatiles come off the surface of the fuel; sometimes this occurs whilst the fuel begins to char, sometimes after the fuel melts and forms a liquid which is converted to a combustible gas.
- The volatiles mix with the surrounding air. The oxygen in the air then combines with the volatiles.
- When the mixture (oxygen and volatiles) reach what is referred to as the lower flammability limit, the mixture ignites.
- The resulting flame starts to heat other parts of the fuel that haven't yet ignited, causing that portion of the fuel to volatilize faster and eventually ignite.

The key parameters in this scenario are the a) heating of the fuel, b) the external heat source, c) breaking of the bonds, and d) the lower flammable limit. Items c) and d) are functions of the fuel's chemistry and are controlled by the manufacturer. Items a) and b) are a function of the fuel's arrangement and the heat flux to the fuel. These are the items that are impacted by the size, color and shape, arrangement and configuration of the test sample, and the size of test (small or large). For example, in evaluating the use of a test standard, its useful to note that the AS1530.3 test is small compared to the much larger ISO 9705 test.

The fuel's arrangement includes any barriers between the fuel and the heat source, and the thickness of the fuel. Barriers include foil, metal sheet, paper or the like. The thickness of the fuel only matters if it is very thin, or so thick that when the front part of the fuel is hot during the initial part of the fire, the back surface is not; this is called a thermally thick fuel. Otherwise, the fuel is called thermally thin.

- Barrier: barriers can affect the fuel's heating by absorbing the heat, reflecting or transmitting the heat. The thicker the barrier and the lower its conductivity and the greater its specific heat, the more effective it is in preventing the heat from reaching the fuel. This is similar to how a cloth potholder insulates you from a heated skillet on a stove. Likewise, the color of the barrier impacts how well the barrier reflects the heat, similar to a silver faced glove you use on a BBQ. Therefore, a silver or white barrier typically reflects more heat than a black barrier.
- Barriers can also keep a fuel that is melting from flowing away from the heat source, or if there is no barrier or if the barrier melts, then the fuel, if it is the type

that melts, can flow away from the fire. Some plastics melt and flow (called thermoplastics), some char and remain in place (called thermosetting plastics).

- Whether the fuel is thermally thick or thermally thin is also an important consideration. A thermally thin object exposed to a fire is approximately uniform in temperature whereas a thermally thick object is hotter at the fire exposed edge than the non-exposed edge. If it is thermally thin, then the back-surface substrate of the fuel can absorb heat slowing down the temperature increase of the fuel (this depends on the thermal properties of the substrate). If a fuel is thermally thick, the substrate has little or no impact during the early fire growth.

Because of these various issues, in the 1960s and 1970s the international fire research community developed large-scale tests that were better at mimicking (reproducing and predicting) wall and ceiling lining performance in real fires as compared to small-scale test fires and heating sources. However, for this to be effective, the large-scale tests have to reproduce as closely as possible the real-world use of the linings. This can be viewed from two perspectives, first the configuration of the lining and second the heat exposure from the room fire.

Configuration of the lining: Some of the key factors are lining thickness, barrier thickness and colour, lining fastening: for a room test it's important that the lining stay in place during the test similarly to what will occur in a real fire, otherwise if it prematurely falls to the ground, it will no longer burn in the same manner as if it remains on the ceiling or wall.

Room fire exposure (Group Numbers): in the case of the ISO 9705 test the fire exposure mimics a waste basket fire followed by a small chair fire in a corner configuration in a "standard room". But real fires occur in rooms with different geometries than the standard room and involve different fuel sources. The test was developed to account for these differences by requiring that the wall and ceiling lining be installed on the walls and ceiling of the test room so that the test burner, which is installed in a corner, away from the room's opening, will be a severe exposure representative of the most credible fire exposure for a variety of different room sizes and configurations. The important concept is that if one uses the ISO 9705 test to determine a Group number, the test must be conducted as specified, with all components of the lining assembly such as fasteners and joint treatments as close to that as used in the actual building installation.

Room fire exposure (Performance Solution): The use of the standard test configuration is different from using the test to evaluate behavior for use in a Performance Solution written by a fire safety engineer. In that case the engineer might require data from a wall lining only test, a ceiling lining only test, or some other unusual configuration. This is explicit in Appendix G of ISO 9705:[21]

[21] ISO 9705: Fire tests - Full-scale room test for surface products; Standards Australia; 16 May 2003 (reconfirmed 2016).

G.2 Alternative specimen configuration

Other possibilities are to test the product covering only the walls and having standard ceiling materials, or to test the product covering only the ceiling and having standard wall materials.

The standard should then be chosen in accordance with 11 .4.

It is also possible to test combinations of different wall and ceiling wall products in order to evaluate specific scenarios.

But these altered test configurations cannot be used to determine Group Numbers.

Use of small-scale tests to predict large-scale test behavior

Once it became clear that it was important to use large-scale tests to predict real fire performance, it also became clear that this was a very costly enterprise. The international research focus then switched to finding a means to take data from a small-scale test and use a simulation model to predict large-scale test behavior. Unfortunately, no universally acceptable approach to do so has been developed.

Instead, AS 5637.1[22] identifies when a small-scale test is an acceptable alternative to the large-scale test:

5.3.2 *Unsuitable materials*

The empirical correlations shall not be used for products or assemblies—

(a) with profiled facings not allowed by AS/NZS 3837;
(b) that contain materials that melt or shrink away from a flame;
(c) with joints or openings; and
(d) with a reflective surface.

5.3.3 *Suitable materials*

Materials for which the correlation is permitted include—

(a) painted or unpainted paper-faced gypsum plasterboard;
(b) solid timber and wood products such as particleboard;
(c) rigid non-thermoplastic foams such as polyurethane

The important thing is that small scale test results, although useful, may be misleading when directly applied to a full-scale fire exposure.

[22] AS 5637.1 - Determination of fire hazard properties; Standards Australia; 24 August 2015.

Conclusion

This paper discusses the history and evolution of the BCA's method of minimising the adverse impact (and contribution) of internal wall and ceiling lining materials to fire and smoke growth during the incipient phase of a fire.

The paper also explores the role and purpose of group numbers derived by 'large scale' testing to ISO 9705 and how both the testing results and the group numbers can be used in considering DtS compliance and/or a performance design pathway.

There is scope for future work to incorporate a more cost-effective alternative to large scale testing whilst still delivering the outcomes required for proper and safe design of internal lining materials in buildings.