<u>Fire and Rescue NSW (FRNSW): Fire research report- Smoke Alarms in Homes: Stage2</u>

Final review report (21 June 2017)

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<u>The final review report on the document, entitled: Fire and Rescue NSW (FRNSW): Fire research report- Smoke Alarms in Homes: Stage 2, prepared by the Centre for Environmental safety and Risk Engineering (CERSARE), Victoria University, Melbourne, Australia</u>

1. Introduction:

The current document constitutes the final report on the document produced by the Fire and Rescue New South Wales (FRNSW), entitled: Fire and Rescue NSW (FRNSW): Fire research report- Smoke Alarms in Homes: Stage2 , especially, pertaining to its scientific robustness, in general, and regarding the methodology, results and analyses sections, in particular. It is relevant to note here that the report from FRNSW, is second in the series (i.e. centred on the Stage 2 of the project), and the pervious one (in relation Stage 1) needs to be treated as the relevant fore-runner to the Stage 2 documentation. I may be also to noted that we have already submitted a preliminary assessment report to the FRNSW, as an interim one, on 5 June 2017 (Joseph, 2017). In our interim report we have detailed the general background and context of a boarder study, commissioned by the Australian Building Codes Board (ABCB), on the efficacies of different types of smoke detectors in a residential setting in altering the occupants before tenability limits of major toxic effluents from domestic fires are reached. Primarily for the sake of continuity, we have retained some relevant portions of our initial assessment report here as well, but the essence of the current exercise is to scrutinize, in detail, the *scientific robustness of experimental methodology, and the validity and wider applicability* of the main conclusions drawn from the data in hand.

The Stage 1 report, produced in 2014 by the FRNSW, sought to assess the differences in performance between photoelectric, ionisation and dual-sensor smoke alarms, if any, in their responses to smouldering and flaming fires residential dwellings. The key focus of this research was assessing whether smoke alarms provided adequate notification to allow occupants to exit a dwelling before tenability limits for temperature and toxic gases were reached. *The research identified that ionisation alarms were inferior to photoelectric and dual alarms in most of the fire scenarios, and that the smoke alarms that were in use failed to provide sufficient notification for safe egress when located only in the Hallways, as required under current legislation.*

In response to the report, in 2015, ABCB commissioned a critical review of the FRNSW research and other existing literature by the Centre for Environmental and Risk Engineering (CESARE), Victoria University, Melbourne (Novozhilov et al., 2015). *The review identified that the FRNSW smoke alarm research was based on too few tests, did not consider an adequate range of fire* *scenarios, and that the ignition methods were not representative of real scenarios.* Based on this critical review, the FRNSW conducted several further tests (27 in total and to include: 10 smouldering fires, 13 flaming fires and four nuisance tests- each scenario was also repeated three times; see Table 2 on page 28). A proper rationale for exclusion of few tests (as originally suggested; Table 1 on page 27) and inclusion of some others (see for example entries 7 a and 7b in Table 2 on page 28) is also provided. In the following sections, an overall assessment regarding the scientific validity and rigour of both the experimental protocol, collation of data, and the ensuing analyses are given.

2. Methodology:

Burn unit and furnishings- whilst a proper rationale for choosing the particular burn unit, its dimensions, or layout, and the construction elements and associated contents (see Appendix A on page 182) of the unit are not given, the diagrammatic scheme pertaining to the unit is clear and well narrated (Figure 1 on page 26). It is also not clear why the investigators used this set-up, or whether they are guided by any specific regulatory frame work, or regarding the need to comply with known Australian/Newland standard. However, the report does refer to a similar test scenario as previously reported *internally* (Engelman, 2015).

Test scenarios- as mentioned before, the guiding principles behind the number and nature of the test scenarios (27 in total) is well articulated in the report and are clearly given in the associated (Table 2; page 28; see also, Novozhilov *et al.*, 2015).

Fire ignition and extinguishment- essentially, three types of pilots are narrated in this section- a soldering iron in combination with a pure cotton batting, a single-lit-cigarette and a butane barbecue lighter- the former two set-ups as the initiating source for smouldering fires, and the latter one as the corresponding source for flaming fires. It should be noted here that such pilots might not bear actual resemblances, in terms of the nature, or duration, or intensity, to those that are often stipulated in common standard test protocols. Therefore, in the absence of explicit literature precedents justifying the use of the pilots, they can only be assumed to be somewhat bespoke for the test scenarios described in the report. Furthermore, one needs also to taken for granted an acceptable degree of reproducibility/repeatability of these pilots.

In the above context, the investigators also make an implicit assumption, in the case of lit-cigarette, that the situation is similar to a case reported in the literature (Babrausks, 2003) as to its incident power and temperature profile. However, the inference that amount of energy transferred from a soldering iron (set at 350°C at ~72% power for 6 minutes with ~20% of its surface area in contact with the batting material) is comparable to that from a lit cigarette (kept smouldering for 12 minutes) can be only considered as a gross approximation. Here again, the assumption that the energy outputs of the two pilots, one originating from smouldering combustion of cellulosic material and other from the Ohmic heating of a resistive heating element, merely from qualitative observations (i.e. visual observations of damage done of a basal substrate) need to be considered as somewhat misleading.

Smoke alarms- the nature of all the smoke alarms, their relative positional dispositions and the conformance with the current and relevant standards (i.e. AS 3986- 1993 and ABCB- part 3.7.2.2; see ABCB, 2016) are properly articulated in the report. Furthermore, the signals emanating from these devises (a total 476) were tested for their directional dependence and sensitivity at the CSIRO laboratories, in Victoria, according to AS 3786- 2014- all the alarms, except one (P111), used in the present study were found to meet the required standards (the links to corresponding test reports are given in the report- Appendix C on page 185).

Instrumentation- the type, spatial deployment and other operating parameters pertaining to the thermocouples, infrared digital video cameras, the portable digital camera, and gas analysers/probes are given in the report. In addition, a list of gases analysed through FTIR spectroscopic method and the associated tenability limits are provided in Appendix B. Here as the investigators do not furnish any details regarding the calibration technique(s) used for each gaseous species, nor the quantitative nature of the test results, one has to assume that the results are reliable in terms both their accuracy and precision, especially, in the absence of corroborative validity through better measurements such using a Gas Chromatography (with a capillary tube column)/Mass Spectrometry (GC/MS) unit (see for example, Xe and Pan, 2001). It should be also noted that in order to standardise various readings and data acquired, the relevant parameters pertaining to the prevailing ambient conditions, as appropriate, are also monitored and stated.

It is highly relevant to note that smoke detectors and the gas analysers work on entirely different principles, and hence their detection sensitivities and ranges are bound to vary. Therefore, one should ideally attach an adequate level of uncertainty with the recommended concentration limits (given in ppm) in Appendix B on page 183- at least from the perspective of giving tolerance limits of measurements for each gaseous species (Novozhilov, *et al.,* 2015 and the relevant references therein; NFP, 2002). Furthermore, one also need to take into account of actual dose (generally expressed as the product of concentration of a particular species and the time of exposure) and need to factor this in into an appropriate expression to calculate the Fractional Effective Dose (FED; see for example, Hartzell *et al.,* 1988). In addition, ideally, one should duly consider the exponential mode of inhalation (i.e. stemming from hyperventilation owing to other irritant species, such as lower aliphatic aldehydes, phenols, etc.- just to mention few species given in appendix B) by the victims, especially, in the initial stages of enclosure fires where lack of oxygen (anoxia) should be also commonplace (Bruce et al., 2005; Bunce and Remillard, 2003). However, in the FRNSW Stage 2 report, the above factors are not gauged owing to obvious reasons such: sheer complexity of actual fire scenarios to be replicated in controlled experiments; direct physiological effects of the toxic products of combustions on humans cannot be directly extrapolated from limited known experimental studies involving; etc.

Data analyses- Microsoft Excel was the primary tool employed to process the data in hand, and the calculations relating to the tenability limits were performed using a previously reported method (Englesman, 2015; Appendix B). Here again, as the cited reference being an *internal* report, the actual formulae used, or the ensuing calculations (FECs/FEDs), are presumably not available in the public domain to be assessed with regard to their reliability and/or mathematical consistency. However, the ensuing statistical analyses were conducted through, established methods, using the common SPSS software with the associated significant level set at 0.05.

Study limitations- the various constraints, and the inability to acquire certain additional parameters are clearly given in this section of the report. Whilst the repeatability of the tests are evident in the experimental regime of the programme, the claim that these tests are representative of typical fires occurring in the residential units of in NSW cannot be ascertained upto an acceptable level of confidence. Therefore, these should be taken into consideration whilst one considers the wider applicability of, or lack thereof, the study as reported.

3. Results:

A comprehensive account of each test scenario, with photographs as appropriate, is given (30 in total), which also includes tables detailing the smoke alarm activation times (recorded in triplicate), tenability limits (as indicated by Fractional Effective Concentrations/Fractional Effective Doses- also given in triplicate), Available Safe Egression Times (ASETs), associated ambient conditions, and graphical representations of activation times (according to the type and location, except in the case of the ‘nuisance’ tests). This section of the report need to be considered as a very systematically narrated part, and does contain the most relevant set of information, such as the materials/contents involved, the nature and contact time/extent of exposure of the pilot employed, visual monitoring of the scenario, etc. In addition, comments on the degree of repeatability and the influence of the ambient conditions, if any, are also provided.

Generally, it was found that the irritant gases contributing to escape impairment and incapacitation included, acrolein, formaldehyde, phenol, nitrogen dioxide and sulphur dioxide, as measured along various locations. It is also evident that the main variable factor, apart from the nature of combustion (smouldering versus flaming, at least in part dictated by the nature of the pilot) was the ventilation factor of the point of initiation, i.e. the bedroom, lounge room, kitchen, laundry/bathroom, hallway, etc. (with doors opened versus door closed).

4. Analysis and discussion: In this section, a previously reported non-dimensional analysis technique (Milarick *et al.,* 2008), where the main test-specific variables, such as fire type and intensity, and fire development and smoke spread are eliminated, is provided. Following on from this, routine statistical variables and features (mean, standard deviation, p, χ^2, etc.) are depicted for the different types of scenarios, such as: smouldering, flaming and nuisance alarm cases. The smoke alarm activations, and the difference in activation times between different alarm types, along with the relevant statistical analyses and interpretations are provided under separate headings, such for: smouldering and flaming test scenarios. In addition, a detailed analysis where a non-activation of alarm is implicated and the nuisance tests cases are also given. The final part of this section provides the results relating to the tenability limits are given.

5. Conclusions and recommendations:

This adequately captures the primary outcomes of the experimental protocol of the study followed by few recommendations by FRNSW. Given the comprehensive nature of the present study, along with the systematic analyses of the wealth empirical information collated, it can be said with a fair degree of confidence that the main conclusions drawn are quite valid the data in hand. This feature also aptly supports relevance and significance of the recommendations made in the report with a view to improving the fire safety in residential settings.

6. References:

The list of references provided can be considered as adequate, and often gives complementary information justifying the salient features of the study.

7. Appendices:

This section includes a total of three relevant appendices.

Concluding remarks: Given the wide variability, scarcity of a stipulated and harmonious standard test protocol relevant to the study, and other associated complicated features (such as nature and layout of the test rig, materials used for its construction and the associated contents, ventilation factors, temperature profiles, nature and composition of the combustible volatiles, the prevailing ambient atmospheric condition, and the nature, intensity, and duration of the pilot, etc.) for enclosure fires, it is often difficult fully justify the employment of the particular experimental set-up/measurements given in the report. However, the experimental part, and collation and analyses of the data, can be considered as scientifically robust. The main conclusions drawn from the study are also quite valid the data in hand. In short, the experimental protocol is systematically carried out, and the associated report is comprehensive and definitely of a standard that can be deemed to have contributed reliable and original knowledge in the subject area. It may be also noted here that the statistical treatment of the data is scientifically robust where the various aspects of its significance is properly numerated, where appropriate. Over all, we have found the work to be fundamentally sound and devoid of any serious drawbacks.

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