GRENFELL TOWER INQUIRY – PHASE 1

CLOSING SUBMISSIONS FOR AAP-SAS

[*In this document, references to the reports of the Inquiry experts are to their most recent "Supplementary" reports, unless otherwise stated. No discourtesy is intended by the use of surnames. Page references to their evidence in the transcripts are to the PDF versions.*]

Introduction

1. The Grenfell Tower Inquiry is, in many respects, making history. In part, this is no doubt because of the scale of the tragedy which is being investigated, the number of persons affected and involved, and the complexity of some of the issues. In addition, it is also because of the conscious effort which has been made to enable the survivors, residents and other local people to play their full part – an effort which we, for our part, unreservedly support, and which has already achieved what was described by one of the BSR advocates as representing the "gold standard".
2. Without detracting from the above, however, we submit that the Inquiry will wish to observe the most scrupulous standards of fairness towards all other parties, and we suggest that the more sensitive the position of any particular party, the more crucial it is that such a standard of fairness be achieved. In practice, this means, above all, two things:
   i. That evidence given to the Inquiry, even by experts instructed by the Inquiry itself, should not be accepted uncritically but should be subjected to appropriate interrogation, and where necessary, challenge and contradiction; and
   ii. That conclusions to be drawn by the Inquiry at any stage should not be adverse to the interests of any particular party unless founded on an incontrovertible evidential basis, and after appropriate scrutiny and testing of that evidence.
3. With reference to (i) above, we observe that although we submitted two substantial schedules of questions for the Inquiry experts, those questions have been pursued only in part. We highlight below some of the key issues in relation to which questions which we raised have not yet been pursued.
4. In relation to (ii) above, we observe that, on many occasions, the Inquiry experts have expressly stated that their views are provisional and/or that further work needs to be done before a conclusion on a particular point can be reached, and we submit that the Inquiry itself will not wish to reach a conclusion in such circumstances when its own experts have not yet done so. Again, we highlight below some of the areas where uncertainty remains.
5. To the extent that the Inquiry intends to make preliminary findings at the close of Phase 1, we would emphasise the following key points, all of which are fully supported by the evidence that has been introduced to date.
6. *First*, this kind of ACM cladding panel has been in widespread use for many years in the United Kingdom and abroad, and only now is Government taking steps to control its use, and even now only in a limited range of circumstances, i.e. above a certain height.. The recent position statement by MHCLG

noted that advice has been given to owners of 457 high rise buildings relating to the use of ACM cladding.

7. *Second*, it is important to emphasise that, as Professor Torero has observed, there have been many other cases of fires in residential buildings (including high-rise buildings) involving ACM PE where there has been no loss of life. It was only the use of ACM PE *in combination* with the other materials used in the refurbishment at Grenfell, together with the configuration of those materials, and the other fire safety features (or lack thereof) present in the building, that created the conditions for the catastrophe.

8. *Third*, the evidence now makes clear that, if the rehabilitation of the interior windows surrounds or external envelope of the building had been carried out in a different way, it would have been possible for the firefighters to extinguish the fire in Flat 16 before the fire even reached that cladding system. The use of products with no fire rating in the internal window surrounds ensured, as Lane observed, that any interior fire near the window would penetrate rapidly into the cladding system. And the use of a PIR insulation on the exterior, which catches fire quickly owing to a low thermal inertia, ensured that the cladding system would ignite rapidly, rather than the fire being extinguished within the flat.

9. *Fourth*, the evidence establishes that, if certain internal features of the building had been differently designed and constructed, then the fire would have penetrated the building much less rapidly, and thus all, or at least much, of the tragic loss of life would have been spared. For instance, had the refurbishment used fire-rated window surrounds and non-combustible window infill panels, re-entry of heat and flames and toxic gases from the exterior façade to additional flats would have been significantly slowed.

10. *Fifth*, the external spread of the flame was substantially exacerbated by combining ACM PE with combustible PIR insulation, without any horizontal bands of non-combustible material to limit spread. The PIR insulation ensured that fire would rapidly spread to new portions of the building and then ignite the ACM PE. The absence of any breaks in the continuity of combustible materials ensured the fire had a clear path to spread across the entire façade.

11. It is in relation to these points, among others, that fairness demands the caution and careful scrutiny which we have ventured to identify above.

<u>Factual Findings At This Stage Would Be Premature</u>

12. We respectfully request that the Inquiry exercise caution before making any findings—even preliminary findings—that might prejudice the interests of participants in the Inquiry. As the evidence of the experts demonstrates, the evidence to date is simply too provisional for any firm conclusions to be fairly drawn.

13. One factor rendering much, if not all, of the Phase 1 expert evidence open to continuing question is that, whilst on the one hand we know that police forensic experts were the first on the scene, that they removed a great deal of material including substantial portions of the building structure, and have subjected all this to extensive analysis, so far as we are aware none of the results of that analysis have been made available to the Inquiry, and certainly not disclosed to core participants. We would

respectfully suggest that, in such circumstances, hardly any of the Phase 1 expert evidence can be safely relied on for the purposes of drawing a wholly firm conclusion.

14. In general, we submit that the points which we have made above are consistent with the general law relating to the fair conduct of inquiries. We attach to these submissions a note on the Salmon Principles / Maxwellisation / Warning Letters, which we hope will be of assistance both now and going forward, and invite close attention to the principles set out.

15. We respectfully submit that one area where fairness demands that the Inquiry should proceed with particular care is in relation to the proper <u>scope</u> of any findings to be made at the conclusion of Phase 1. We remind the Inquiry that in his statement at the Procedural Hearing on 11th December 2017, counsel made clear that "the aim is that Phase 1 is a purely fact-finding exercise", and he identified the relevant issues. This statement was followed through in his description of the scope of the Phase 1 expert evidence. (He also stressed that, during oral evidence, the evidence of the experts would be thoroughly tested.)

16. In his response, following that hearing, the Chairman stated that Phase 1 would concentrate on what happened on the night of 14th June 2017, and would seek to establish where and how the fire occurred, how it spread so rapidly, and how the interior of the building became progressively affected. He did stress the need for a degree of flexibility in relation to scope.

17. At the Procedural Hearing in March 2018, it was said that Lane might express a <u>preliminary</u> view about certain aspects of compliance, but would not investigate how any instances of non-compliance came about, being matters that would be dealt with in Phase 2. For his part, the Chairman acknowledged that some aspects of section 8 of the list of issues would be addressed in Phase 1. As regards section 4 in the list of issues, however, at no stage has it been suggested that Phase 1 would go beyond section 4(b), dealing factually with the design, manufacture, composition and method of fixing of the cladding.

18. In his statement to the Inquiry on 4th June 2018, counsel to the Inquiry repeated that the focus of Phase 1 would be on the events of the night of 14th June 2017, and in particular, the state of the building at the time of the fire.

19. In our submission, the expert evidence called by the Inquiry did, in certain respects, trespass outside scope as so defined, even allowing for the need for flexibility. In particular, the so-called "Supplementary Report" of Lane, which (as with Torero and Bisby) was in fact not a report supplementary to her earlier report, but a replacement of it, which was roughly twice the length of the earlier report, including appendices, and the full text of which was received by core participants some 8 working days before the commencement of the oral expert evidence, contains a number of elements, such as Appendix O, which clearly go well beyond any interpretation of the scope of Phase 1. It was troubling that certain questions were posed to Lane relating to this Appendix, particularly as to the BBA certificate, which clearly could have no bearing in relation to Phase 1 issues. It is respectfully submitted that all issues relating to compliance in relation to the cladding system, as well as sub-issues such as test results and certificates, are and must be matters for Phase 2, and that it would be wholly inappropriate

for the Inquiry to draw any conclusions, even provisional, in relation to these matters. This submission is supported by a reference to the Inquiry's letter to Core Participants dated 30 July 2018, in which it was expressly stated that Lane's Appendix F and various compliance matters dealt with by Torero would be for Phase 2.

Phase 1 Evidence

20. We now propose to review the evidence given in Phase 1, with particular reference to the expert evidence and to a number of convenient topics under which this can be discussed. We do so without prejudice to the submission made above to the effect that it is premature for the Inquiry to reach any, or any firm, conclusions at this stage.
21. We have identified 5 main headings which we suggest are relevant for present purposes. Those headings are as follows:
    i. Geometry of Grenfell Tower
    ii. Ignition of cladding materials
    iii. Fire spread
    iv. Stay put/evacuation
    v. Regulatory scheme
22. In order to frame the submissions which we make below, we also attach hereto (and for the avoidance of doubt, as part of our 50-page allocation) a schedule entitled "Summary of Materials / Elements Relevant to Fire Spread Routes and Progression". This schedule lists the many significant contributory factors which, on the evidence of the Inquiry experts themselves, played a part in the spread of the fire. The schedule is cross-referenced in detail to the Phase 1 evidence. This schedule was provided to the Inquiry team together with the above-mentioned schedules of questions to be put to the experts, and together with an invitation to the experts to review it in advance of their oral evidence. We also requested that the matters contained within the schedule be addressed during questioning of the Inquiry experts. We submit that, if and to the extent that the matters in the schedule were not addressed during questioning of the Inquiry experts, then in relation to those matters, the Inquiry should at this stage draw no firm conclusion adverse to our interests.
23. We further submit that where an issue has been raised in our schedules of questions, but not pursued, or not pursued fully, with one or more of the Inquiry's witnesses, it must of course also follow that no firm conclusion or finding ought to be made in relation to that issue which is in any way adverse to the interests of AAP SAS.

Geometry of Grenfell Tower

24. The ACM PE panelling was but one of the many combustible components placed on the exterior façade of Grenfell Tower during the recent refurbishment. Any investigation of the causes and consequences of the fire must, therefore, start with a detailed and precise analysis of the structure of the building and of the component materials, insofar as such an analysis is still possible.

25. A list of the key components of the post-rehabilitation external envelope appears at para 4.7.6 of the report of Lane:

"*4.7.6 The key components installed were:*

a) Aluminium windows supplied by Metal Technology Ltd;

b) Insulating core panels as infill between windows, formed of combustible Styrofoam supplied by Panel Systems Ltd;

c) Window fan inserts specified as the combustible Kingspan TP10 insulation;

d) 100mm thick Celotex RS5100 combustible PIR insulation board applied to columns;

e) 80mm thick Celotex RS5080 combustible PIR insulation board (two layers) applied to the spandrels between floors;

f) Kingspan K15 combustible phenolic foam insulation (two layers) applied to the spandrels between floors;

g) Arconic Reynobond 55 PE Cassette system (smoked silver metallic);

h) Arconic Reynobond 55 PE Cassette system (pure white);

i) EPDM damp proof course between the new windows and the existing concrete structure;

j) Vertical cavity barriers on the columns;

Horizontal cavity barriers."

In addition, it is relevant to mention (as identified in Bisby's initial presentation) the materials contained in the interior window surround, including uPVC window board, the timber baton and the timber window board.

26. Lane's repeated use of the expression "the rainscreen cladding system" (see for example the heading to her section 2.9) is a potentially misleading misnomer. It is of course true that in the case of Grenfell Tower the external envelope of the building comprised a large number of components, capable of being described as a system. The main purpose of the changes that were made to the exterior of the building was to enable it to be comprehensively insulated. The ACM PE rainscreen cladding, which screened the insulation from rain, i.e. provided the rainscreen, was but one component in this broader cladding system.

27. We submit that the fire performance of ACM PE at Grenfell Tower cannot be judged in isolation. Whether a cladding product can appropriately be used in a particular building requires assessment of the overall building architecture and the specific combination of other materials and safety features present within the building.

28. We reiterate now some facts relating to ACM PE:

i. ACM PE panels have been available on the market for more than 15 years, and have been supplied by a range of different suppliers within the UK;

ii. ACM PE panels have been widely specified and installed on various buildings, and it has frequently been used at height;

iii. ACM PE panels, once supplied, need to be fabricated into a desired size and shape, and then fixed to the building by an appropriate method;

iv. One would not expect the supplier of the panels to be involved in the design of the cladding system, in the decision whether – and if so, which – panels to utilise, or in the method of fabrication and fixing;

v. Those concerned in the design, construction or rehabilitation of a building using such panels would inevitably be professionally qualified, and could be expected, for example, to know and/or to receive advice to the effect that a polyethylene core would not be of limited combustibility.

29. Any informed purchaser would have been aware that the core of the ACM PE cladding panels was combustible. Bisby at his paragraph 431 acknowledges that PE materials are known to be highly combustible, something which in his oral evidence he confirmed, pg. 20ff. Consequently, a responsible specifier would have taken into account the combustible nature of ACM PE when selecting the combination of materials to use on the external façade.

<u>Ignition of Cladding Materials</u>

30. The expert evidence to date makes clear that it was the insulation, and not the ACM PE, that triggered the initial combustion within the exterior cladding system. This supports the conclusion that, had the ACM PE been paired with a non-combustible insulation, ignition of the façade may have been sufficiently delayed so that the interior fire could have been extinguished before it took hold in the cladding system. It also demonstrates that the insulation would be a critical factor in the speed with which the flame spread across the façade.

31. Issues relating to ignition came into focus initially during the course of Bisby's presentation (Relativity references: LBY00000189; LBY00000190; LBY00000191) in which he contrasted the qualities of the insulation and the ACM PE. The insulation ignites quickly and, in the presence of a source of heat or flame (e.g. other burning materials) may continue to burn and release heat energy. The ACM PE ignites much more slowly, but once ignited, may contribute to the spread of flame. See his report at paras 360ff, where he explains that the insulation comprises polyisocyanurate (PIR), a synthetic thermoset polymer produced as a rigid foam. PIR has low thermal inertia and therefore tends to have a comparatively low time to ignition. Moreover, PIR will support rapid flame spread, in the sense that it may accelerate flame spread on adjacent materials by preventing the loss of energy from the system i.e. by insulating the cavity in which it is fixed, reducing energy loss and thus accelerating flame spread.

32. Materials with high thermal inertia are slower to heat than those with a low thermal inertia. This means that the low thermal inertia materials will pyrolyse and release combustible gases before a high thermal inertia material, under the same conditions. The low thermal inertia material will be the first to ignite when exposed to the same flame. It is notable that, of all the combustible materials in the façade cladding system, the PE has the highest thermal inertia (Bisby Table 3 at paragraph 435) and PIR, phenolic foam and polyurethane foam have the lowest, by a factor of over 7 times (Bisby Tables 5, 6 and

7 at paragraphs 440, 443 and 446). In his oral evidence Bisby added that *the key message to take away is that there's an order of magnitude difference in the thermal inertia of PE / PIR. We do not focus on the actual values, but focus on the competitive nature of the values.* He also confirmed that the *aluminium skin on the Celotex is much, much thinner than is the case for the ACM, so I would expect it to heat up more quickly and therefore to be removed more quickly* (pg. 24).

33. The PIR is therefore in any event likely to have ignited before the ACM, with an associated high peak heat release rate. This will have aided the heating of the internal face of the ACM and led to it melting and possibly running out of the bottom of the fold in the cassette and being ignited by the flames on the PIR foam. Once ignited, the ACM PE will have contributed to the overall heat release and increased the rapidity of the flame spread. This will have been assisted by the fresh uncharred face of the insulation burning up the inside of the cavity. It is also to be noted that the PIR insulation material covered the building to the same extent as the ACM PE.

34. We ask the Inquiry to take note also of the fuel load posed by the PVC and not just that of the PIR. See for example, Table 1 at para 208 of Purser's Report where the approximate mass of combustible fuels per 1 bedroom flat was: (i) PIR 66.3 kg; (ii) PE 35.3 kg; (iii) Polystyrene (PS) 2.9 kg; (iv) PVC 78.8 kg. At para 209 Purser states: "*... the flat contents provide the largest combustible fire load, but the PIR insulation and LD PE in the cladding also provide large fire loads of smaller but comparable magnitude. The PS presents a relatively minor component, but the PVC around the inside of the windows of each flat also provide a large fire load, significant in comparison with the cladding, insulation and contents...*". Para 210 emphasises, for the purposes of sources of toxic smoke and ingress into the flats and the interior of the tower as a whole, the order in which these materials become involved in the fire, running left to right in his table, so starting with the PIR. As a general point in relation to the toxicity of materials and the impact upon residents, Table 5 of Purser (para 248) shows time to asphyxia by PIR of 23 minutes (or only 2 minutes where there is a lack of ventilation) and by ACM PE at 160 minutes.

35. Bisby's figures of heat release rate for PE and PIR (figure 2 and para 4.10.1) show the early high release rate for low thermal inertia materials (PIR), which then drops, and the contrasting low heat release rate for high thermal inertia materials (PE) which then increases and remains high. If one considers the combination of the two curves, the total heat release rate will remain high from the initial ignition of the PIR until the PE is consumed. In the context of the tower, the heating at any one location will originate with the PIR, and will then be contributed to by the PE, while the panels remain attached and the PE does not fall away in liquid form.

36. In his evidence, Bisby expressed matters as follows: "*The surface temperature of the PIR will rise very quickly when exposed to an external heat flux. That hot PIR surface will radiate back at the ACM panel...If there were no such insulation, or no such combustible insulation, the vertical spread of the fire would have been slower in its initial stages* (pgs. 174-175)...*We have work underway at the University of Edinburgh to try to look at the respective influence of these two issues* (pg. 176)."

37. Lane, in oral evidence, stated: "*…I think in a system with a combustible layer on the inside and a combustible layer on the outside, even before flaming combustion can happen, when you have a heat source, those materials are breaking down, they are producing gases, they are getting ready, if you will, to produce the perfect mix for flaming combustion…The Celotex or any insulation in the cavity, in the system, contributes pyrolysis gases to the system, and the system needs that to create that perfect mix for flaming combustion…Having pyrolysing material on the left, the insulation, and the ACM on the right, I think it's creating a highly effective system…The gases which (the insulation) produces in the pyrolysis process is all part of that combustion system, and the flaming combustion that we see…I think it's very important* (pgs. 98-99)."

38. There was a passage at para. 640 of Bisby's initial report which has been removed from his later report and which states with reference to a video starting at approximately 01.16 *"during the duration of this 26 second video, there is no discernible progression of upward vertical fire spread (i.e., fire growth has not been clearly identified)"*. This paragraph identifies a critical point in that, during the initial stages, the fire appeared to be static or progressing unseen. Then there was some initial resistance to fire spread, or more probably, in the light of the witness evidence, it was advancing unseen behind the cladding, and the development of the fire unseen in the cavity strongly suggests that the PIR insulation was playing a significant role in the spread of the fire.

39. The evidence of firefighters, especially Brown and Batterbee, confirm that the insulation rather than the ACM PE was the first material to ignite. In particular, firefighter Brown gave clear evidence that the fire could be seen within the cavity behind the ACM PE panels travelling up the building. In the course of his recorded interview LFB00003105 at pgs 33 – 37 he describes seeing flames behind or underneath the panels within the columns on either side of the window. In his written statement MET00005251 he gives a similar account and on pg 3 states "*the fire was traveling in an upwards direction behind the cladding…..it was easy to see the material behind [the cladding] was alight and travelling in an upwards direction. However the vast majority of the cladding remained in place and any attempts to extinguish simply bounced off*". The "*material behind*" was plainly the insulation. In his witness statement dated 7th February 2018 MET00010867 he states on pg 11 that he could see the fire behind the panels "*creeping up these vertical sections*" and he adds that "*in order for us to have fought the fire effectively we needed to rip off the cladding and fight the fire underneath*". Finally, in his oral evidence given on 29th June 2018 he explained once again that when he directed water towards the columns it had no effect as the water just bounced off (transcript pdf version pg 34). He confirms again that he could see the fire alight underneath the cladding (pg 37). He refers to a small split in the cladding through which he attempted to direct the hose but without success (pg 38). He confirms that behind the cladding there was a "*noticeable bigger flame travelling in an upwards direction*".

40. Similar evidence was also given by firefighters Cornelius and Loft (Cornelius witness statement MET00012663 at pg 5 – 6, and Loft witness statement MET00007518 at pg 3 and transcript of Loft evidence on 5 September 2018 at pg 130 pdf version).

41. Assuming that as FF Brown describes, flames penetrated into the semi-enclosed space containing the insulation behind the cladding, those flames would not mix with the open atmosphere, and the heat losses would be significantly less than if they had. This, coupled with the lower ignition temperature of the PIR insulation (305°C) would lead to more rapid ignition of the insulation, and the rapid heating of both the ACM and more insulation. Flame growth rates under these circumstances are likely to be rapid.

42. The evidence makes clear that the insulation was a crucial factor in the early spread of the flame. The comparatively low thermal inertia of the PIR, and the thinner protective aluminium skin, meant that the insulation would pyrolyse and ignite far more quickly than the ACM PE.

43. We would add, at this stage, that it is important to focus on smoke/toxin ingress, as well as flame spread/impingement Purser comments (at Para 256 of his Report): "*...When PIR and aluminium foil-faced PIR foam are tested in other configurations and conditions the results can differ somewhat. For the BRE ISO room tests, and later room-corridor tests, aluminium-faced PIR boards were cut into strips to form cribs. In this form the PIR ignited rapidly using a small alcohol ignition source and burned vigorously ... When tested in this way PIR not only burned vigorously, but produced high yields of smoke, CO and HCN during under-ventilated flaming ... In other tests of a PIR panelled room, in the ISO 13784-1 test, with the standard burner and with an additional room fuel contents load in the form of a wood crib, considerable involvement of the PIR panels was obtained and high concentrations of HCN were involved.*" and at Para 259: "*... on a preliminary basis I consider that any fire burning of PIR inside the cavity behind the spandrel and particularly behind the column ACM, is likely to have become rapidly under ventilated, producing higher yields of smoke and toxic gases penetrating into the flat above ...*".

Fire Spread – Compartmentation

44. All the experts agree upon the vital importance of compartmentation. See for example Lane's report at para 2.8.22 of her original report where she lists the "*layers of safety forming the basis of fire safety guidance in high residential buildings*", identifying the first such layer as "*the high degree of compartmentation, around each flat, enclosing every service riser, enclosing the stairs and enclosing the lobbies*". Equally, Torero at line 155 states that "*compartmentalisation is a required part of the Building Regulations, and it is a critical feature of the design of high-rise buildings*".

45. Therefore we seek to establish, through the experts, those features of the construction of the refurbished building which rendered the compartmentation of Flat 16 to be grossly vulnerable. The key factor here was that the window construction was massively altered during the course of the refurbishment, such that the windows and window surrounds were a stimulus to the spread of the fire. See Lane at para 2.18.17 where she says that the "*flat of fire origin was no longer in a separate fire-rated box i.e. the compartmentation required in the building was breached by the ability of the fire to spread on the external wall to that compartmented flat*". She also opines at para 2.18.9 in her original report that "*in the event of any fire starting near a window, there was a disproportionately high probability of fire spread into the rainscreen cladding system*". Bisby, in his original report at para 582ff, considers that the

route of fire spread from inside the kitchen of flat 16 to the external cladding was due to parts of the internal window surround (and external cladding system) being penetrated by the fire, thus allowing fire spread directly into the back of the cladding cavity from within the room of origin. This occurred by penetration of the uPVC window boards, of the thermal insulation to the back face of the uPVC window boards and of the EPDM rubber membrane. All these items would, by their nature, be quickly penetrated and would degrade quickly when exposed to flames or hot gases. It was in this way that the flames and hot gas from the fire in the room of origin would have had a route to impinge upon – and potentially ignite – the combustible materials present within the external cladding cavity, including the EPDM weatherproofing membrane and the PIR insulation. All the above points were considered by Bisby in his first report to be the most likely analysis "*by a considerable margin*".

46. Another vital point is that there was a range of internal features within the building, which, as Lane explained on the second day of her oral evidence, significantly prejudiced compartmentation. We make no further submission with regard to these, though they are relevant to our argument.

47. In support of the above propositions, we rely on the evidence of Lane as to the components of the window surrounds, much of which itself was "plastic" in nature. See her report at paras 9.7.1-9.7.5:

"*9.7.1 In my opinion, once any localised fire occurred near a flat window — regardless of how that fire started — the majority of the construction materials around the window had no potential fire resisting performance. Therefore, no part of the construction had to ability to substantially prevent fire spread from inside the building into the external rainscreen cavity.*

9.7.2 This is because of:

a) the presence of combustible materials, enclosing the windows;

b) the presence of combustible materials closing the cavity between the old and new window infill panels;

c) the majority of new external wall materials, except the window glazing and the aluminium window frames, support the combustion process;

d) the windows were not enclosed with fire resisting cavity barriers around their perimeter...

9.7.3 As a result, it is my opinion that the interface between the window and (a) the column rain screen cladding system and (b) the lateral rain screen cladding system above the window, was the primary cause of the early stages of fire spread from the interior of Flat 16 into the rainscreen cladding system.

9.7.4 I have explained the heating effect through the reveal, caused by the internal fire in the corner of the kitchen in flat 16, and how it spread out through the reveal and into the column cavity. The type of materials and the way in which they were arranged around the window provided no means to limit the spread of fire and smoke from the relatively small kitchen fire to the column cavity...

9.7.6 In my opinion, due to the arrangement of the window within the overall cladding system, once a fire inside a flat within Grenfell Tower was close to the window... there was a real likelihood that fire would penetrate the rainscreen cladding system."

48. We also rely on the oral evidence of Torero as follows: *The uPVC has a particularity, which is that it loses its mechanical strength at very low temperatures, so effectively can actually fall off, so this is the reason why I thought it was important to focus on the uPVC* (pg. 51).

    It is right that uPVC would have reached temperatures, with a total loss of mechanical strength, in approximately 5-11 minutes (pg. 56).

    The smoke, even though its temperature is very low, is capable...to mechanically fail the uPVC so it opens a direct path for any flame to actually impinge on any of the combustible materials on the inside (pg. 57).

    And Lane confirmed: *it remains my position that once there was a localised fire near the window, the majority of materials around the window had no potential fire-resisting performance, therefore, no part of the construction had the ability to prevent fire spread from inside the building to the external wall cavity. Once there was a fire in a flat anywhere near a window, there was a very high likelihood that it would break out of the flat and into the cladding* (pg. 50).

49. The evidence of the BSRs is relevant in this regard, which contains repeated references to the poor construction of the windows, and the gaps and draughts which were created.

50. The deficiencies in the window surrounds are critical, because the nature of fire spread would be different depending whether it spread from the kitchen via the window opening or owing to failure of compartmentation in the window surrounds. If the fire had spread through the open window beneath the extractor fan, then the hot gases and potentially flames would have fed out into the open atmosphere outside the apartment. The gases would have then mixed with the external air and been significantly cooled in the process. [See the oral evidence of Torero at pg. 68, cited below.] The gases and flame would however have impinged on the underside of the ACM panel above the window and not directly onto or into the ACM on the columns. As the flame impingement would have been the outside face of the ACM, there would have been no directly exposed PE edges on the panel. The insulation behind the panel would have been mostly protected by the panel. Ignition of both the PE and insulation would have been delayed. It is likely that full scale testing would have been required to quantify the extent of the delay to ignition of the PE and insulation in these circumstances.

51. We submit, however, that it is now clear that the fire spread through the window <u>surrounds</u>, rather than through the fan panel, the fan or the window, and this allowed the flames to feed directly into the cavity and establish there. The EPDM, followed by the insulation, would presumably have been the first item to ignite with rapid initial heat release and subsequent flame extension in the cavity. It is likely that the initial ignition of the insulation went unnoticed, as it would have been in the cavity of the column and out of sight of fire-fighters.

52. The fire spread and development would therefore have been much more severe via the window surrounds rather than via the open window, the fan, the fan panel or glazing failure. The fire would have been initially out of sight, it would have had significant flame extension in the cavity, it would have had more readily combustible material such as insulation, and it was more difficult to extinguish as there was little opportunity to get water to the seat of the fire in the cavity. Should the fire have spread through rather than around the window, its development would have been in clear view, the panels would have been slower to ignite, the insulation would have been partially protected, the initial fire would have been in a spandrel panel rather than in a column, there would not have been any clear continuous vertical spread route in the early stages, and water could successfully have been applied externally.

53. Bisby discusses these issues by formulating and commenting upon different hypotheses, and expressing what he conceded were very provisional preferences as between those hypotheses. Bisby's hypothesis B1 is essentially the impingement of flaming and hot gases through an open window, whether that be through the extract panel or via the extract fan itself, and then subsequent ignition of the external ACM panels immediately above the kitchen window. His hypothesis B2 is the ignition by flame of the exposed flammable materials in the window surround, and the external cladding system being penetrated by fire, allowing flames to spread into the back of the cladding cavity.

54. Torero said that: *It remains my view that the smoke itself is not going to be hot enough for the smoke that's venting through the window opening to ignite the cladding. I have calculated that direct ignition via direct flame or plume impingement through the window would require a fire of around 830kW to ignite the ACM through the window* (pg. 62).

From a physical perspective, a path that ignites from the inside is a more probable cause of ignition, because the temperatures are always going to be higher inside than outside (pg. 63).

The moment the flame exits the compartment, there is going to be fresh air, and that's going to cool the temperatures of the flame, so it's always going to be the case that the spill flame is going to be colder than the interior compartment. It cannot be the opposite (pg. 68).

To ignite the polyethylene, that has a specific temperature that you need to attain. and not only that, but the polyethylene is a thin film in between two aluminium plates which have very high thermal conductivity, so they take a lot of energy away from the polyethylene. So normally this type of material is actually quite difficult to ignite. What happens is that the heat you apply goes away through the aluminium, and the polyethylene tends to melt instead of igniting, so it requires a significant amount of heat to be able to ignite... (pgs. 70-71)

I have concluded that the most likely route of ignition of the façade is by exposed flammable materials in the window surrounds (pg. 73).

I do not discount what the visual evidence might show, because you can have a random sequence of ignitions that can lead to an external ignition. Anything outside the compartment is going to be colder and further, unless you find the path of ignition that brings you there, and that you can only tell by a detailed analysis of images (pg. 74).

55. *All the materials (in the window surrounds) will have ignition temperatures that are lower than the flame can provide* (pg. 74).

You wouldn't see the fire if it's come around the inside, because it would have gone inside the column and been burning there before we actually see it visually on the outside (pg. 90).

56. *After viewing the video images, the question here will be: does the flame have enough heat to be able to ignite the cassette?...It is not about having a flame, it is having a flame that is sufficiently strong to provide heat fluxes to be able to ignite the cassette* (pg. 92).

57. Bisby claimed that a *fire of 830kW is not necessary in order to have flames coming out of the window.* He said: *I think if you had a fire of 300kW that was sufficiently close to the window, you could have flames going out of the window* (pgs. 108-109)(Note that he stopped short of saying that the flames would actually ignite the cladding).

He added: *I have changed my view about the exit route because additional evidence has come to light. At the stage that I submitted my initial Phase 1 Report…the visual evidence that we had from outside the compartment of origin didn't show any significant external flaming prior to obvious escalation of the cladding fire…* (pg. 112).

It is possible that flames venting out from that window could have ignited the ACM panels…The new video also shows evidence of melted, dripping and burning polyethylene on the spandrel cassettes immediately below the window of Flat 16, which would indicate significant exposure of the spandrel cassette above the window, which would tend to support an idea or a hypothesis that the flame venting the window and heating the spandrel panel directly above the window could have been a mechanism by which the cladding fire gets going (pg. 113).

58. We submit that, on these issues, Bisby's latest evidence simply cannot be relied upon. We are wholly unclear as to what the new evidence is that led to Bisby's new opinion and whether that evidence was materially different to the evidence which he considered when preparing his initial report. In particular, the photographs in Bisby's first report on pgs. 104-105 appear to be indistinguishable from those in his second report on pgs. 118-119 and have the same Relativity number. He was also quite wrong in denying (if he did deny) Torero's (persuasive) view that in excess of 800kW would be needed not merely to reach and exit the window, but to reach and set alight the ACM PE cladding, which Bisby himself concedes is difficult to ignite. In any event, his position on these matters is wholly undermined by the emphatic conclusion expressed in his first report, which was to the effect that what he now calls "Hypothesis B1" i.e. that the cladding itself was the first to ignite as a result of flame spread through an open window, could be "easily disproved". It is of course significant that both Torero and Lane agree with his initial and clear conclusion.

59. Ultimately he said: *I would say that fire spread through the uPVC is ahead by a nose* (pg. 135).

60. He added: *We see flames impinging on the ACM in the footage so we do know it's happened…the question is whether or not the time at which it happens, which is admittedly 2 to 3 minutes after we suspect that we see involvement of the ACM cladding, gives us enough confidence of that as the primary*

candidate for ignition of the cladding, or whether that is a secondary effect that happens after the cladding has already ignited from within…The takeaway for me yesterday from Professor Torero's testimony with respect to all these issues was that inside the compartment you have a hot layer 2 to 300 degrees Celsius, and is, as a consequence of venting, now somewhat cooler than inside the compartment, and the same with the flames, you have the flames venting from the compartment impinging on the cladding, however, again somewhat less than inside the compartment. So, if we agree that the uPVC window framing boards absolutely are absent, then I agree with Professor Torero that the most likely candidate is the hypothesis where the ignition happens via the side of the window through the uPVC (pgs. 144-145).

61. In Lane's view: *By the time we see flames on the exterior…we've had that localised heating condition going on in that corner for several minutes, and I think that it's more probable therefore that the heat transfer and the fire condition there has entered the column cavity within minutes of the first minute we see the flame on the outside…I don't think it happens later, I think it's been going on…everything's been getting ready, and after a few minutes the heat is transferring into that cavity all along…you're straight into the cavity into the column and heating any material in behind the panel there, so the panel itself and the insulation…I can see the flame reaches the glass and the extractor fan, and then becomes an external flame, but I think in the time period it's taking for us to finally see that, this internal heating is going on in this complex corner that we have…I think by the time we see that external flame front, there has been a lot going on for the 10 – even longer – you know, in a fire sense, 10 or so minutes, and that type of heating with those materials in a localised sense is a substantial event* (pgs. 159ff).

62. *It remains my view that once the fire is near the window – or indeed, anywhere in the flat, if allowed to develop and cause heating of the window components – spread to the exterior is practically inevitable <u>if the fire isn't interfered with</u>. Once the fire was within the cladding, there was nothing to impede the spread of fire and smoke around the building* (pg. 164).

63. It is submitted that hypothesis B2 is overwhelmingly to be preferred.

64. Once the fire broke out from the flat, as it did from around the window, we suggest that it ignited the insulation and cladding system. The geometry of the insulation is such that it surrounds the window frame, whilst the rainscreen cladding lies outside the line of the window (Bisby, Figures 14 and 17, Lane, Figure 9.37 in her original report). As such the initial external fire is almost certainly to have been in the insulation. If the small section of insulation beside the membrane (indicated in Bisby, Figure 17) was not installed then the fire is likely to have ignited the insulation in the spandrel panel above the window (Bisby Figure 40). While there are some areas of exposed PE in and around the cladding system cavity, the higher thermal inertia and ignition temperature of the PE in comparison to the PIR, make it highly unlikely that the PE was the first material in the cladding system to ignite. Further, the exposed end of the main insulation along the line of the column seems to present a greater exposed area to any flames penetrating the window jamb, than does the ACM (Bisby Figure 39, Lane, Figures 8.22 and 8.37)

and it is implausible to suggest that the ACM would ignite more readily than the insulation as Bisby suggests.

65. In his report Bisby suggests that it is not currently possible to confirm which of the combustible materials within the building envelope and external cladding system was the first to be ignited and sustain flaming (Bisby paragraph 1221). However, as we have noted above, a) the insulation lies in the path of flame spread from the kitchen to the ACM, and b) the PE is less readily ignited than the PIR of the insulation.

66. The fire-fighter evidence cited above also supports the view that the external fire was initiated in the cavity. This is from the visual evidence of the firefighters. The evidence of O'Hanlon was that the fire was "*roaring like a gas main*" indicating a fire in a cavity with an intense rush of air producing the roaring sound (O'Hanlon witness statement MET000080592 at pg. 5). This is not a sound that can be generated without high air velocities. A fire in an extended vertical cavity will draw air in, much as a solid fuel stove will draw air and eject it up a chimney. The cavities were in effect acting as a chimney drawing the air in and retaining the heat up to the point that the ACM began to fall away. FF Brown's statement of the cladding panels splitting and being pushed out is also evidence of this process.

67. We further submit that, as suggested in our proposed lines of questioning to Inquiry counsel, but not pursued by them:

> "*...if the windows and the window opening had not been constructed as they were, but had been constructed in such a way as to provide appropriate protection, then the spread of the fire would have been interrupted and/or the pace of spread would have been delayed. In consequence, the fire service might well have been able to extinguish the fire within the compartment of origin...*"

68. We further submit that the spread of the fire would have been at least somewhat delayed if (a) in Flat 16 there had been more robust <u>internal</u> compartmentation, and (b) the <u>other</u> apartments, apart from Flat 16, had been constructed so as to achieve the necessary compartmentation. In that event, one would have had a situation akin to those cases identified by Torero at his line 2275ff, in which, as a result of the maintenance of compartmentation, the casualties were either limited or non-existent. Torero stated in his oral evidence that: *Some very large international fires, with comparable fire spread, have not resulted in penetration of smoke and flames into the lobby or stairs* (pg. 177). *In principle, in those cases, compartmentation is a very robust way of giving a very significant amount of time for people to enter the stairs, and be safe in the stair, for an even longer period of time* (pg. 179).

69. We also wish to make some comments on the evidence given by the senior officers of the London Fire Brigade, Cotton, Roe and O'Loughlin. (O'Loughlin pp 51-2, 54, 182, 196-7; Roe pp 154-5, 176-9, 211-212, 230-234; Cotton pp 30, 72, 127-8.) We suggest that the central point emerging strongly from their evidence was that they all assumed in advance of the fire, and moreover considered that they were entitled to assume, that the regulatory system would ensure that compartmentation would be maintained, making it unlikely that a fire in a particular apartment would penetrate to the external envelope. They stressed also that they had assumed, and were entitled to assume, that a fire affecting the external

envelope would not be expected to penetrate back into the building and spread internally, again, in breach of compartmentation. They, however, clearly believed that, in the case of Grenfell Tower, breach of compartmentation, both externally and internally, had occurred, and that this was not only unforeseeable, but indeed was a bigger issue that the fire spread in the external envelope.

70. We suggest that if the fire service were entitled to make, or did reasonably make, such assumptions, then it would follow that the supplier of a component part of the external envelope would surely be able to make similar assumptions, particularly if that supplier was not thereafter involved in any refurbishment/construction work.

<u>Fire Spread – Continuation</u>

71. As Bisby acknowledges at para. 20 of his report, it is not currently possible to quantify the respective contributions as regards the spread of the fire. One cannot therefore properly conclude what materials or construction elements are primary or secondary factors in the spread of the fire. To do otherwise would be to advance an opinion before all the evidence has been properly evaluated.

72. We suggest, however, that the insulation contributed significantly to the rapidity and extent of the fire spread. Without the insulation contributing to the initial heating and subsequent heat loading, it is likely that the flame propagation in the cavity behind the PE would have been slower in the initial stages. However once there was sufficient heat in the cavity from the burning insulation then any PE which escaped would have contributed to the development of the fire. This is likely to be the stage at which flames developed up the side of the window and droplets began to fall from the ACM.

73. As Torero explained: *When you compare the amount of mass that you have of PIR, compared to other combustible materials like polyethylene or the EPDM, the mass of PIR is more significant, therefore it has a propensity to remain burning for a fairly long period of time relative to the other materials*(pg. 123)...*I believe it would be helpful and practicable to work out what remained after the fire, comparing the ACM and other components, such as PIR. In many ways, the interactions between those two materials are relatively unknown, and it will be very important to be able to establish if one can burn without the other, and to what extent that can happen, and all those details can only be done with a very detailed and general survey of the remnants of the insulation* (pg. 129).

<u>Fire Spread – White Panels</u>

74. We should also not overlook the role played by the white polystyrene panels. Bisby, when he wrote his initial report, may have been unaware that the white panels were in fact extruded polystyrene (XPS), which has a higher heat release rate than EPS (in his supplementary report, Bisby acknowledges that the white panels were XPS, but reproduces Figure 56 which shows the material as EPS). The window infill panels at Level 4 and above are the white panels fitted laterally between the windows. They are fitted in a different configuration to the grey ACM panels and are different to the white panels at Level 3.

75. In oral evidence, Bisby added: *I would expect XPS to melt before PE as a consequence of its thermal inertia. As to whether XPS is an appropriate material to use on a high rise building, that's a question I*

would want to answer in the context of the overall fire safety strategy for the building. It's conceivable it could be used by someone who takes adequate account of its response to fire (pg. 37).

76. We suggest that the infill panels are likely to have contributed significantly to the total heat release. Additionally, their heat release is likely to have been distributed to the façade and into the flats in roughly equal measure as they were not backed by insulation. Moreover, the core of the infill panels is some 25mm thick, compared with 3mm for the PE.

77. The infill panels do not appear to have played a role in the spread of the fire from Flat 16, but given their fire properties and installation they are likely to have a played a significant role in the spread of the fire up the façade and back into other apartments. The XPS of the infill panels has similar ignition temperatures and heating capacity to the PE, although with a higher melting temperature of 230°C, compared to the PE melting temperature of 130°C. The low density of the XPS means that it is likely to have a lower thermal inertia than the PE, however it is notable that Bisby suggests that thermal inertia is not applicable to XPS as it melts. This is in contradiction to his assessment of PE, as it melts at lower temperature than XPS yet is given a thermal inertia value. We suggest that the XPS, being of low density and an insulation product is likely to have a low effective thermal inertia and will be prone to ignition before the PE.

78. The infill panels are fitted to the aluminium window frame assemblies in the same way as the glazing units are fitted. They act as a barrier to fire ingress to the apartments, yet as they have aluminium faces and flammable cores, they will provide a route for fire spread. As flames impinge on the outer aluminium face of the infill panel, the XPS will melt, and with any distortion of the aluminium face will be ignited by the external flames. The XPS may form a pool at the base of the panels and begin to burn there or may burn on the surface of the inner aluminium face. The inner aluminium face of the panel will also heat and distort and the flames are then free to enter the apartment. We note that insulation foam, both phenolic and polyurethane, is fitted on the inside of the panels, but there is no further protection to prevent the fire spreading into the apartments.

79. We note that the infill panel therefore provides the only fire protection between the outside and inside of the building where it is fitted. As such, it may assist external fire spread, but also allows ready internal/external fire spread. The high heat release rates in comparison to the other materials would appear to make it a likely route for fire spread as it will readily ignite through its outer aluminium face, and heat the opposite aluminium face. Ignition of the XPS core will result in the rapid heating of the internal face, and the possible ignition of any combustible materials against the internal face. These would appear to include insulation, uPVC window jambs and possibly Purlboard. It is of note that although Bisby considers the construction around the window panes, spandrel and columns (Figures 15 to 19), he does not address the geometry of the infill panels.

80. The panels also provide a mechanism for external vertical spread from one spandrel panel to the next. Once the flames impinging on the external surface of the panel have ignited the XPS core, the flames

from the core are likely to impinge on the underside of the ACM and insulation in the spandrel panel above and the fire will spread up the façade.

81. We suggested in our questions (though the point was not pursued in any detail) that the role of the infill panels in assisting vertical spread can be readily observed in the initial spread of the fire from Flat 16 up the façade (Bisby Figures 96, 97 and 98). Although the dominant vertical spread is up the columns, there is some simultaneous lateral and vertical spread across the façade. It is highly unlikely that this vertical spread is from one ACM spandrel panel to the next. There are no external exposed PE edges to generate flames that might directly ignite the next spandrel panel and the vertical spread appears to be "*stepwise*" with lateral movement then vertical (Lane Figures 9.25 and 9.26).

82. The spread up the façade, in line of the infill panels and away from the columns, recorded by Lane, suggests that the contribution of the infill panels is likely to have been significant in terms of vertical fire spread. Even if the cladding on the columns had not been present there is an alternative vertical fire spread mechanism that would have spread the fire up the building. Coupled with the lateral spread through the spandrel panels (with no vertical cavity barriers) the infill panels would have contributed to the complete spread of the fire across the facade. Bisby considers the aluminium window infill panels in terms of lateral spread (Bisby para 1147ff). He considers that although the infill panels comprised a smaller area than the ACM panels, it is likely that they played an as yet unquantified role in later fire spread. This is in contrast to Lane who clearly considers that the infill panel provides a mechanism of horizontal and vertical spread, and provides photographic evidence in support of this position (Figures 9.25 and 9.26). She also considers that the infill panels contributed to fire transfer back in to the apartments (Figure 9.27). These appear to be fire spread routes that are overlooked by Bisby.

<u>Fire Spread – Other Factors</u>

83. The spread of the fire up the external façade is dependent on there being sufficient continuous combustible material on the façade with insufficient passive fire protection to prevent the spread. The fire spread is likely to require a combination of factors to allow continuous heat transfer, either by conduction, convection or radiation. A break in one or all of these may have restricted the fire spread on the façade.

84. We suggested in our questions (though the point was not pursued in any detail) that the Inquiry experts make no mention of conductive heat loads, either in reference to the infill panels or, importantly, to fires in the spandrel cavities. The windows are mounted over the spandrel panels, outside the line of the original façade and within the line of the combustible PIR insulation. The angle bracket supporting the window installation is backed by a cavity surrounded by combustible material. The external surface of the bracket is against the exposed edge of the rainscreen cladding insulation. Any fire in the cavity will attack the insulation, and flames are visible in the images along the lower edge of the windows (Lane, Figure 9.23, 9.24 amongst others). The flames within the cavity and on the insulation will impinge on the underside of the bracket supporting the windows. The combustible insulation in the cavity will be exposed to high conductive heat loads through the thin metal bracket of the window and is likely to lead

to direct ignition of the combustible materials (insulation, timber and uPVC) that form the window sill. Survivors report window sills beginning to emit smoke and char.

85. A heavy concrete parapet existed around the edges of the crown of the building. The outside face of the parapet was fitted with vertical aluminium fixing rails to support ACM louvres on the face of the building. The edge of the roof was capped with aluminium “coping” over insulation, below which ACM panels, matching those of the spandrels were fitted (Lane Figure 10.47). The majority of the ACM louvres had come away from the parapet, but some remained with little or no fire damage (Lane Figure 10.40). The insulation beneath the aluminium coping had deep charring and the aluminium above it had melted. It is notable that sections of the outer face of the aluminium coping, which would have projected over the ACM panels below, had not melted.

86. As regards the architectural crown itself, Lane notes that there were both insulation and ACM panels wrapped over the top of Level 23 and that these materials were continuous around the top of the building (Lane Figures 10.40 10.46 and 10.47). In contrast, the ACM fins attached to the balustrades were not backed with combustible insulation and were not continuous. She suggests that it is therefore unclear what role these ACM fins played in the lateral spread of fire (Lane 10.8.21). The fact that some of these fins survived the fire suggests that they were not a dominant transfer mechanism. Aerial photographs suggest that around 10% of the louvres remained after the fire (MET00004431, 4539, 4545). The absence of combustible insulation behind them suggests that a fire on the ACM panels is not self-sustaining without the heat retention of a backing insulation.

87. The issues relating to the crown to which we refer above were squarely raised for consideration by the experts in the questions we put forward, but regrettably did not feature in their oral evidence. As regards Torero, the only relevant question (at pg. 152) was to invite his comment on the suggestion that the lateral fire spread “might have more to do with the presence of combustible insulation at the top of the building” rather than the ACM. This question wholly failed to make clear the lines of reasoning expressed above. In the evidence of Bisby, the matter was not pursued at all. As to Lane, the only question put to her was to the effect that it had been suggested that some of the aluminium coping had melted immediately above the insulation, but not on the edge and that that “might be significant”. Lane was asked if she had a view about that and unsurprisingly said she did not (at pg. 95). Again the points we raised were not really explored at all, let alone with the rigour which had been foreshadowed.

88. It is to be noted that Bisby produces what he entitles a “video still” (Relativity reference LBYS0000006_0001) which is in fact a still from a thermal imaging camera. It is Bisby’s Figure 142. It shows undamaged ACM louvres and he has annotated the image “section of uninvolved architectural crown”. He shows similar visual evidence in Figure 139. We submit that this is clear evidence that the ACM panels at the top of the crown are not driving the lateral spread, and that the fire is spreading via the ACM panels beneath which are backed by PIR insulation. This demonstrates that it was the PIR insulation which was significant in driving the spread of the fire.

89. At pg. 98 in his oral evidence, Bisby mistakenly asserts that the insulation terminates above the level of the windows. The error in this assertion can be demonstrated by reference to Lane's Figures 10.40 and 10.47, which shows the insulation spreading horizontally onto the crown.

90. It is also notable that the insulation at the crown was overlaid at the roof by solid aluminium sheeting not ACM, and therefore the insulation was providing the direct heating to the aluminium sheet with sufficient intensity to melt it locally at the inner edge. Although there are likely to have been severe fires on the façade, the outer edge of the aluminium sheets was not damaged in some sections. This lends weight to the proposal that the insulation played a large part in providing highly localised heat loading, while the ACM did less so.

91. Lane considers that fire spread around the architectural crown of the building contributed to lateral fire spread but that it was not the only mechanism for this type of fire spread (Lane 10.8.11 in her original report). She notes that some of the ACM panels on the crown survived the fire in contrast to the ACM spandrel and column panels (Lane, Figure 10.40). This is at odds with Bisby who appears to suggest that the crown was the dominant mechanism for lateral spread (Bisby para 1140ff) despite providing evidence of lateral spread below the crown (Bisby Figures 125, 126, 139 and 142). Bisby therefore relies on vertical downwards spread via the columns to support the full development of the fire. Lane provides clear evidence of lateral spread away from the seat of the fire in the early stages (Lane, Figure 10.39 in her original report).

92. As stated by Bisby at paras. 1121 and 1123, the role of the PE as a factor in promoting horizontal fire spread has not been quantified. As also stated by Bisby at para. 1123, the significance of the PE as a factor in promoting horizontal fire spread is unknown. It cannot therefore be properly concluded that the PE was the dominant factor in promoting horizontal fire spread.

93. In relation to the downward spread of the fire, we note that the downward spread was initiated by falling burning droplets, other burning debris or liquid PE but we suggest that it was the burning insulation which primarily sustained the fire. It appears that burning falling PE in the cavity landed on the cavity barriers and continued to burn there. There are soot deposition marks at the horizontal panel joints where the cavity barriers were located (Photograph MET00004453) at levels below extensive fire damage. At these lower levels, however, the most severe damage patterns to the ACM cladding is in the centre of the panels, suggesting that the primary fire loading is from burning insulation and not the exposed PE at the edges of the panels. Bisby's Figures 115 to 118 of his Supplementary Report show extensive areas where the central section of the ACM panels on the columns have been consumed, yet at the apex of the columns where the fixing rail is located and where the majority of the exposed PE exists, the ACM remains intact. The fire damage to the ACM panels is central to the panels and there is no evidence to suggest that the downwards propagation was via the fixing rails.

<u>Fire Spread – Re-entry</u>

94. Double glazed window units are resistant to fire attack and it is by no means certain that they will fail during a fire. Further, it is clear from the evidence provided by Bisby and Lane that the fire spread into

apartments was first via the window surrounds and not via glass failure. As such the spread of the flames from the façade into the tower was more rapid and widespread than it would have been if the window surrounds had been constructed from suitable materials and had suitable fire cavity barriers.

95. Lane stated: *The weaknesses in the window arrangement that I have identified could also have accelerated the rate at which the fire could break back in once it spread up the exterior…Because of the voids around the window, and how those voids then connected into the larger cavities and all the materials in those two parts – the small cavities and the much larger main cavities – yes, there is an easy route either above on the spandrels above the window; on the columns beside the window; and also on the insulation core panel side of the windows also, where the Aluglaze panels were installed. So, it's about materials and just that interconnectedness of all the cavities* (pg. 58).

96. Clearly fire spread and ingress of toxic gases into the building is as important as the fire spreading out and across the building, particularly to the residents in the building. Bisby suggests that routes of possible fire ingress include, open windows, extractor fan units, pre-existing gaps in the window framing, failure of window framing and thermal fatigue of the glazing (Bisby Section 7.3). He says that the "EPS filler" i.e. the XPS has a low melting temperature and is likely to melt, drip and run. Lane considers however that the XPS panels also provide a significant route for fire ingress as they form part of the path by which the fire may pass into the building.

97. We suggest that it is difficult to decouple the contribution of the cladding system heat loads from those of the apartment contents. We note that the window header rails in most apartments had melted during the fire while the window footer rails had not. We suggest that this reflects the severity of the flames spread from, rather than into the apartments, and this flame spread has contributed significantly to the overall rapidity of the fire spread on the façade. It should be noted that once the fire entered an apartment, and ignited the contents, the fuel load within the apartment in the vicinity of the breached window aperture would be greatly increased and would contribute to the external heat loading and fire spread.

<u>Fire Spread - Conclusions</u>

98. The tragedy at Grenfell Tower shows the awful consequences which can arise when combustible materials are used in a particular combination and configured in a particular manner, when compartmentation is significantly compromised by refurbishment works and when there is a lack of any or any sufficient protective measures, such as sprinklers. However, it does not show that the ACM PE cladding itself would necessarily have been a source of danger. Under the applicable regulatory regime there was no prohibition on the use of this material, and it has been widely used. Whether it could be appropriately used, and if so to what extent and in what manner, would have been a matter for assessment, taking into account all the features of the building, including its component materials and including the extent of active and passive fire prevention measures. Given that the objective of the regime is the protection of human life, it is relevant to notice that other factors such as compartmentation will be of equal or greater importance.

99. We suggest that it is likely that, if there were sections where the continuous ACM PE rainscreen was interrupted, either by non-PE panels or different design features, such that continuity of the PE was broken, the fire would have been slowed and/or interrupted. However, the combustible insulation and the non-existent/ineffective cavity barriers would have allowed the fire to propagate in any event. It is also possible that had the infill panels not been combustible, there would not have been vertical spread between the spandrels, as there would have been neither combustible insulation nor combustible panels in the window line. If a non-combustible band had also been present on the columns, it is likely that fire spread would have been dramatically slowed and possibly prevented.

Stay Put / Evacuation

100. It is clear that, based on the firefighters' evidence, the Inquiry will be pressed very strongly to conclude that the decision to advise residents to leave was taken far too late, and that if it had been taken earlier, then the residents' lives could have been saved. We do not, for our part, seek to make submissions upon this topic at this stage.

Regulatory Scheme

101. As suggested in para 19 above, we respectfully suggest that it is premature at this stage to draw conclusions relating to compliance. Without prejudice to that general contention, and for the assistance of the inquiry, the key points which we seek to reiterate under this heading are the following:

102. The Building Regulations have been made *inter alia* for the purposes of securing the health and safety of persons in and about a building.

103. Regulation B4, in requiring that the external walls of a building shall adequately resist the spread of fire over the walls, must mean "adequately to achieve that objective", i.e. adequately to ensure a reasonable standard of health and safety in all the circumstances, and to ensure that occupants can exit or be evacuated from the building safely in the event of fire. NB Torero line 819ff as to the ambiguity of this provision.

104. Despite conceding that there is ambiguity, Torero opines that the Regulations require that there should be no fire spread whatsoever (Torero lines 238 – 244). Such an interpretation cannot be reconciled with the wording of the legislation and would clearly be unworkable in practice, since a building, whether traditional or modern, might well have cladding or other features that include combustible elements, though safety would not in any way be compromised. If a fire does not ignite external materials readily, or spread rapidly, then there is the ability to extinguish it or escape from it.

105. Approved Document B, though it provides guidance in common building situations, is not in itself mandatory and does not mandate any particular way of achieving compliance.

106. Approved Document B, taken together with other guidance, offers (in relation to buildings over 18m in height) a number of different routes to compliance, including:

i. The linear route, applying, as appropriate, paragraphs 12.6 and 12.7;

ii. The route which entails reliance upon full scale test date from the British Standards (The BRE have proposed that each test will take an average of 8 days to complete, from construction of the test sample to the removal of the materials post-testing.);

iii. The route identified at (ii) above, but incorporating reliance on a desktop study;

iv. A holistic fire engineering assessment, which would take into account all the features of the building (see paragraph 9 above). See Torero line 1781, where he makes clear that holistic system testing, provided it is carried out by a highly proficient professional, is in fact preferable to some form of comprehensive testing methodology.

These 4 routes are recognised in the Government Consultation paper, dated April 2018, and see also Approved Document B, Volume 2, paragraphs 0.30-0.32. Note that Lane makes clear that she has <u>not</u> considered industry guidance for the purposes of her initial report (para 2.7.8), another reason why no conclusions on compliance can presently be drawn.

107. From the above follow four important consequential points, namely:

i. That route (i) above would have been obviously inapplicable owing to the use of inter alia combustible insulation;

ii. That routes (ii)-(iv) require analysis of the precise configuration of the materials to be used on the building, rather than of any particular component in isolation;

iii. That the manufacturer/supplier of ACM cladding panels cannot, by itself, make any assessment as to the degree of compliance of the cladding system as a whole;

iv. In any event, such manufacturer/supplier would be entitled to assume that the cladding would not be used unless compliance by an appropriate route, such as the holistic fire engineering route, could be achieved.

108. Both Torero and Lane agreed that the DCLG tests provide the Inquiry with little, if any assistance. Thus, Torero said "*I place very little significance on the results of the DCLG tests* (pg. 127)*"* and Lane commented "*I don't take anything from those tests, because I don't consider them to be relevant because they're so far away from the kind of construction detailing that people like me have to worry about in our profession* (pg. 99)*."*

109. With regard to the BBA certificate, we have already mentioned that we consider this to be well outside the proper scope of Phase 1 (see paragraph 19 above). We submit that it would be wholly inappropriate for the Inquiry to express any conclusions whatsoever in relation to the BBA certificate at this stage.

110. We were surprised to hear questions put to Lane as to the "validity" of the certificate, and we sensed that Lane herself was troubled by the form of some of the questions on this topic. In particular, no questions were asked about the most crucial paragraph in the certificate, namely paragraph 6.5, which reads as follows: "*for resistance to fire, the performance of a wall incorporating the product can only be determined by tests from a suitably accredited laboratory and is not covered by this certificate*". No

proper analysis of the certificate, its relevance or "validity" can possibly be undertaken without paying regard to this provision.

111. We also point out that Lane herself expressly concedes (see for example paragraph O1.1.15 in Appendix O) that "*I have not seen any evidence that it (the certificate) was provided in the context of any building control approval or compliance regarding fire safety*" at Grenfell Tower. On this basis alone, any conclusion about the role of the BBA certificate at this stage would be premature.

<u>Conclusion</u>

112. We fully acknowledge the weight and difficulty of the task facing the Inquiry team. Phase 1 has been an extremely useful exercise in introducing everyone to the complexities of the subject and in enabling us all to familiarise ourselves with the huge amount of detail involved. We continue, however, to submit that any conclusions at this stage must at best be provisional, and subject entirely to review during Phase 2 when the Inquiry experts and others should be free to submit or re-submit evidence so far as relevant in relation to Phase 1 topics. We will also be making submissions in Phase 2 as to the procedural safeguards necessary to remedy what we have identified above as procedural difficulties encountered in Phase 1. This must be a task of the Inquiry for Phase 2.

113. We also submit that the admittedly incomplete expert and scientific evidence introduced to date establishes that it was a confluence of unfortunate circumstances, and not the mere presence of ACM PE, which created the conditions for the Grenfell Tower fire. In particular, the failure of compartmentation, the choice to pair ACM PE with a combustible insulation with a low thermal inertia, the configuration of the materials, the absence of horizontal bands of non-combustible material along the exterior facade, the use of XPS window infill panels, and the lack of other safety features such as sprinklers, were all crucial factors in allowing the fire to spread beyond Flat 16 and rapidly to engulf the building.

NOTE ON SALMON PRINCIPLES/MAXWELLISATION/WARNING LETTERS

1. There are three aspects to this Note - Salmon principles, Maxwellisation procedures and "warning letters" under the Inquiry Rules 2006 – all which have a common theme, the duty to be fair.

Salmon principles

2. The Report of the Royal Commission on Tribunals of Inquiry (Cmnd 3121, 1966), chaired by Lord Justice Salmon, was concerned to ensure that people should have an opportunity to meaningfully respond before adverse findings were made against them.
3. The Report identified six principles which became known as the Salmon principles. These principles were as follows:
   i. Before any person becomes involved in an inquiry, the tribunal must be satisfied that there are circumstances which affect them and which the tribunal proposes to investigate.
   ii. Before any person who is involved in an inquiry is called as a witness, they should be informed of any allegations made against them and the substance of the evidence in support of them.
   iii. They should be given an adequate opportunity to prepare their case and of being assisted by legal advisers.
   iv. They should have the opportunity of being examined by their own solicitor or counsel and of stating their case in public at the inquiry.
   v. Any material witnesses they wish to call at the inquiry should, if reasonably practicable, be heard.
   vi. They should have the opportunity of testing by cross-examination conducted by their own solicitor or counsel any evidence may affect them.
4. On this latter aspect, if, contrary to the Salmon principles, a core participant is not permitted to cross-examine witnesses then it must follow that there is a heightened duty on counsel to an inquiry to rigorously test and challenge any such evidence.
5. In the light of the second Salmon principle, it is established practice that "Salmon letters" should be sent to such a person informing that person of any criticisms or allegations made against them and the substance of the evidence in support of them. The "Inquiries Guidance" issued by the Cabinet Office states that these letters should be "sent out before public hearings or evidence sessions commence".

Maxwellisation procedures

6. Salmon letters are separate and distinct from a Representation process. The former concerns fair notice provided before the evidence begins. The latter concerns the opportunity to make further representations after the evidence has been heard and at the stage where provisional adverse findings have been formulated. The "Inquiries Guidance" issued by the Cabinet Office refers to such a process, referred to in that document as "Maxwellisation procedures", as being "now standard practice".
7. The Representation process has evolved from the cases in the 1970s involving Robert Maxwell and his conduct in relation to the Pergamon Press. An illustration of the Representation process is to be found in

the BCCI Inquiry chaired by Lord Bingham whose statement of proposed procedure was to the effect that provisional findings of fact would be disclosed to the subjects of them and anybody upon whom a finding might be thought to reflect unfavourably would be given a full opportunity to challenge criticisms and to rebut adverse findings of fact before any final conclusion was reached.

8. The procedure recommended in the "Inquiries Guidance" is as follows:
   - Once an inquiry has prepared a first draft of their report they normally write to the witness setting out the intended criticisms with notice of the evidence on which they are based giving a fixed period to respond;
   - Where an inquiry considers it appropriate, representations made by a witness in response to proposed criticism may be included in the report either wholly or in part;
   - Witnesses must formally undertake to treat draft passages of a report issued to them in confidence; and
   - An inquiry is not obliged to give a witness more than one opportunity to respond to evidence or to possible criticisms nor are they required to enter into prolonged correspondence with the witnesses about the terms of criticisms or the text of their report. Further views may be sought from witnesses in respect of revised criticisms.
9. Two further points should also be noted:
   i. In this context, criticism means circumstances where a person's interests (including in that term reputation) may be adversely affected by a finding (see, for example, *Mahon v Air New Zealand Ltd* [1984] AC 808 at 820H).
   ii. The duty to be fair requires that both natural and legal persons be provided with the opportunity to make representations. The interests of legal persons can plainly be adversely affected by findings made in public reports.

<u>Inquiry Rules 2006</u>

10. The Inquiry Rules 2006 cannot be interpreted so as to dilute this common law position.
11. First, subordinate legislation brought into force by a Minister, as opposed to primary legislation enacted by Parliament, cannot extinguish the common law.
12. Secondly, in any event, it is well established that legislation is enacted against the back cloth of the common law and the common law is not extinguished unless the legislation has made this clear by express statutory words or by necessary implication.
13. Thirdly, requirements of fairness cannot be eroded based on whether the inquiry is statutory or non-statutory. The same common law duty to be fair applies to both forms.
14. Fourthly, properly interpreted, the Inquiry Rules 2006 actually supplement and enhance the common law position as reflected in Salmon letters and Maxwellisation.
15. The Inquiry Rules 2006, rules 13 – 15, set out a statutory code in relation to "Warning letters". Those provisions read, in so far as is material, in the following way:

"13 –

(1) The chairman may send a warning letter to any person –

(a) he considers may be, or who has been, subject to criticism in the inquiry proceedings; or

(b) about whom criticism may be inferred from evidence that has been given during inquiry proceedings; or

(c) who may be subject to criticism in the report, or any interim report.

……………

(3) The inquiry panel must not include any explicit or significant criticism of a person in the report or in any interim report, unless –

(a) the chairman has sent that person a warning letter; and

(b) the person has been given a reasonable opportunity to respond to that warning letter.

……………..

15 –

(1) Subject to paragraphs (3) and (4), the warning letter must –

(a) state what the criticism or proposed criticism is;

(b) contain a statement of the facts that the chairman considers substantiate the criticism or proposed criticism; and

(c) refer to any evidence which supports those facts.

(2) The chairman may provide copies of the evidence referred to with the warning letter, if he considers it appropriate to do so.

(3) Where the warning letter is sent to a person under rules 13(1)(b) –

(a) the requirements of paragraph 1 do not apply, but

(b) subject to paragraph (4), the letter must refer to the evidence from which criticism could be inferred.

………………..

16. It can be seen that Salmon letters are statutorily provided for by reference to rule 13. Whilst rule 13, through the use of the word "may", provides the chairman with a discretion, any discretion must be exercised in accordance with the common law position and the common law duty to be fair. Therefore, if it was proposed that evidence was to be heard which might reflect adversely on a core participant then Salmon letters or "Warning letters" should have been sent to those to be affected.

17. As to Maxwellisation, a number of points may usefully be noted at this stage:

i. First, there is a statutory prohibition on criticising a person in a report if that person has not been afforded a reasonable opportunity to respond to that proposed criticism. Put another way, and having regard to the meaning of criticism in this context, if it is proposed to include a finding in a report which may adversely affect a person's interest in a significant way then the chairman must provide notice of that and afford the person a reasonable opportunity to respond before producing any report or interim report.

ii. Secondly, the content of the "warning letter" is now provided for expressly by legislation and codifies what fair notice is in this context. Rule 15 requires that written notice is given of the criticism or proposed criticism together with a statement of facts which is considered to substantiate that criticism or proposed criticism, and the warning letter must also contain reference to any evidence which is said to support those facts.

Summary of materials/elements relevant to fire spread routes and progression

NB. The references in this schedule are to the presentations of the Inquiry experts and the initial reports which they prepared. For ease of reference, where a figure has a new number in the experts' "supplementary reports" this has also been included in brackets as SR followed by the number.

Stage 1	**Spread from the Apartment of Origin**		
Number	**Material / Construction Element**	**Details, location and expert commentary (Bisby Figures 14, 15, 17, 37, 38, 39, 41, 42, Pres pg 74, 75, Lane Figure 9.16, Pres pg 266)**	**Interacts With Material**
1.1.	uPVC window jambs/reveals and sills (glued into place) (Bisby Figure 135 (SR/163), Pres pg 63, 73, 113, 114, Lane Figure 8.18, 9.17 Pres pg 250, 251, 263, 264, 265)	New material - part of the refurbishment. The uPVC has no fire resistant properties and would be expected to fail at an early stage of fire development within the apartment potentially forming a direct route to the combustible materials within the external wall build up. Further, the use of glue rather than mechanical fixings means any integrity would be subject to the performance of the glue and early failure of the glue would cause the boards to move away from the substrate allowing passage of smoke and flame from the interior of the building into the cavity in the external wall build-up. The main route of fire spread from Flat 16 to the cladding system and back into the apartments would be via the uPVC window jambs/reveals. The uPVC window sills would be a route of fire spread (albeit of lesser magnitude).	The melting and drooping of the uPVC allowed fire in the kitchen to ignite the following materials: 1.2 Expanding Foam 1.3 Timber battens 1.4 Insulation board
1.2	Expanding foam	New material - part of the refurbishment.	The expanding foam was combustible and filled

	(also referred to as "Polyurethane joint filler" Lane Figure 8.28 (SR/8.29), 8.38 (SR/8.40), 9.10, Pres pg 229, 256)	Used as a joint filler to partly fill gaps associated with the installation throughout the rain screen system. Combustible material.	many of the gaps around the windows frame and between the materials below. Ignition of the expanding foam would have contributed to the ignition of these materials: 1.1 UPVC jambs/reveals 1.3 Timber battens 1.4 Insulation board 1.7 EPDM
1.3	Timber battens lining the window sills, jambs and heads (Bisby Figures 37, 38, 39, Pres pg 56, 67, Lane Pres pg 253, 254)	Part of the original construction. The timber elements could aid fire spread from the apartment of origin. The timber frames would be part of various likely routes of fire spread from the apartment (including alongside the insulation as the main route from the uPVC window jambs/reveals).	The timber was combustible and supported the uPVC around the windows. It would contribute to the heat load from the fire spreading around the window to the following materials. 1.1 UPVC jambs/reveals 1.2 Expanding Foam 1.4 Insulation board
1.4	Celotex and Kingspan PIR foam insulation board TB4000 in the cavities behind the new uPVC window reveals (Bisby Pres pg 62, Lane Figures 8.13, 8.17 and 11.11, Pres pg 258)	New material - part of the refurbishment. Combustible material. This was likely to become involved in fire growth at an early stage and form a fire spread route. This material was relevant to all potential routes of fire spread from the apartment	The Insulation board in the cavities would act in a similar way to the expanding foam (1.2) and timber battens (1.3) and promote fire spread through the EPDM (1.7) and to the external PIR insulation (1.8).
1.5	Cavity (voids) between the window frame and the structural opening (Lane Figure 8.15, Pres pg 246, 256 and Bisby Figure 132 (SR/160))	New element - created by the refurbishment. This cavity provided a direct route from the interior of the apartment to the external wall build up and the combustible materials contained therein.	The cavities around the window allowed the spread of heat and flames to the external PIR insulation (1.8). Had suitable barriers been present in the void, this fire spread via this route would have been stopped or significantly slowed

		No cavity barriers in place.	
1.6	Extract fan panel - although the core material was specified as Kingspan TP10, XPS was contained within Aluglaze panels (Lane Figure 8.23, 8.69 (SR/8.72), 8.70 (SR/8.73))	New material - part of the refurbishment. Combustible material. This would aid in the growth and spread of fire.	The extract panel may have assisted in spreading the fire to the fan housing and the ACM PE (1.9) and PIR Insulation (1.8),
1.7	Damp proof membrane (EPDM) (Bisby Figures 40, 137 (SR/165), Pres pg 71, 117 Lane Figure 9.10, Pres: pg 226)	New material - part of the refurbishment. Used as a weatherproof seal and bonded to the face of the window frame and the concrete column to close the gap created by the alteration of the windows. Specific product/thickness unknown but commercially available in 1-3mm (which generally fits with what was seen at GT). This was part of the main routes of fire spread both out of the original apartment and back into apartments. Combustible material.	The EPDM was a barrier between the external elements and the apartment, and was combustible. As such it needed to burn away to allow the fire to spread to the PIR insulation (1.8). The combustible window surrounds (1.2, 1.3, 1.4) would have caused flames to impact the EPDM and then spread to the PIR insulation (1.8) (Lane Figure 8.22, 9.37)
1.8	Celotex RS5100 PIR insulation (Bisby Pres pg 59, 60, 69, 72, 103, 104, Lane Pres: pg 228, 229)	New material - part of the refurbishment. Combustible material that would contribute to fire growth and development within the cavity in the external wall build-up. Exposed edges confirmed. The column insulation edges would be the initial route of fire spread from the original apartment into the column ACM PE and	The fire spreading through the EPDM (1.7) would have initially attacked the PIR insulation and then spread to the ACM PE (1.9).

		would also aid fire growth and spread up the columns.	
1.9	ACM PE (Bisby Pres pg 60, 70 Lane Pres pg 232, 233)	New material - part of the refurbishment. The PE ACM would aid the fire spread and growth. See 2.5 below in relation to the implications of the fixing of such panels.	Once the ACM PE ignited the heat from the burning ACM would contribute to the burning rate of the PIR insulation (1.8) and vice versa Any flames extending from the infill panel (1.6) will heat the external ACM PE, helping to liquefy and ignite it.

Stage 2	Spread Upwards (and Downwards) on the Façade		
Number	**Material / Construction Element**	**Details, location and expert commentary (Bisby Figures 16, 18, 22, 25, 70 (SR/73), 71 (SR/71), Pres pg 82 Lane Figure 5.2)**	**Interacts With Material**
COLUMNS			
2.1	Celotex RS5100 PIR insulation (Bisby Pres pg 89, Lane Pres pg 229, 24	New material - part of the refurbishment. Combustible material that would contribute to fire growth and development within the cavity in the external wall build-up. Exposed edges confirmed. The column insulation edges would be the initial route of fire spread from the original apartment into the column ACM PE and would also aid fire growth and spread up the columns.	Once the PIR insulation ignited the heat from it would be trapped in the cavity and it would ignite the ACM PE (5.2). Flames and heat would rapidly spread up the cavity (2.3) Downwards spread is likely to have been initiated by molten burning PE (2.2) falling inside the cavity and igniting the PIR insulation. (Bisby Figures 102 to 105)
2.2	ACM PE (Bisby Press pg 89, Lane Pres pg 232, 233)	New material - part of the refurbishment. The PE ACM would aid the fire spread and growth. See 2.5 below in relation to the implications of the fixing of such panels.	Once the ACM PE was heated by the PIR insulation (2.1), it would have begun to liquefy and burn. The PE may pool at the base of the panel and either burn there or runout the sides of the panels and burn externally (Bisby Figure 19). The molten PE may have also fallen down the cavity to ignite the PIR insulation (2.1) lower down. Any flames within the cavity (2.4) would have added to the heat from the PIR and the fire would spread up the cavity.
2.3	Cavity created between the original column and the outer "biscuit" (Lane Figure 9.9, 9.10	Original element – created an additional cavity for fire spread adjacent to the window void by the refurbishment. This may have originally been an external feature but with the	The burning PIR insulation (2.1) might allow some heat to spread up this cavity, but it is unclear that this would generate any significant heat loading to insulation, or to other combustible

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	Pres pg 240, 256)	relocation of the windows outwards it now represents a potential route for fire spread vertically from one apartment to another. No cavity barriers in place.	materials.
2.4	Ventilated cavity of 139mm depth between the inside of the ACM panels and outer face of the combustible insulation (Bisby Figure 23)	New element - created by the refurbishment. The presence of combustible materials in that cavity would have propensity to extend the length of flames significantly. Flame extension in a cavity lined with non-combustible material may be 5-10X free flame length. When lined with combustible material this extension would be greater still. Vertical cavity barriers not provided on all columns.	The fire spread unrestricted up this cavity fuelled by the PIR insulation (2.1) and the ACM PE (2.2). The limited heat loss from the cavity to the surroundings accelerated the combustion of both the PIR insulation and the ACM PE. Hot gases and flames were able to pass up the vertical fixing rails (2.5).
2.5	Vertical fixing rails (Bisby Figure 22, 23, Pres pg 90, Lane Figure 10.28 (SR/10.29))	New element - created by the refurbishment. The continuous vertical fixing rails create a number of routes of vertical fire spread up (and down) the columns and to the column/spandrel junction. Recent Kingspan testing suggests the size of the gaps between the panels may be significant in terms of the system's fire performance	The continuous fixing rails assisted in both conductive and convective heat transfer up the cavity by providing a clear route for flame spread up the edges of the ACM PE (2.2) and flames from the PIR insulation (2.1) to bypass the cavity barriers. The fixing rails also provided rapid conduction of heat. (Bisby Figures 22, 85)

2.6	Pre-cast biscuit cavities formed by the application of the rain screen cavity insulation (Bisby Figure 18, Lane Figures 8.33 (SR/8.35), 8.34 (SR/8.36))	New element - created by the refurbishment. There is no cavity barrier or fire stopping which would therefore allow extended flame spread and rapid fire growth and development.	The burning insulation would generate some heat and flames that may spread up this cavity, Flames spreading via this route would assist in the preheating of the PIR insulation (2.1) leading to its more rapid ignition.
2.7	Cabling in cavity at columns (Lane BLAR00000018_0100)	There were large looms of cabling (primarily co-ax) running up some of the columns. It was observed on a site visit that there was spalling to a column from one group of cables. The looms appeared continuous up the building. There is no mention of the cablings or associated fire stopping in the PI Expert reports It is noted that much cabling is not fire rated and communications cabling frequently has no flammability rating, or flammability tests are for ignition and lateral flame spread. Typically PVC insulation is used.	The cable insulation is combustible, and the cables ran up the cavity adjacent to the columns (2.4), There is likely to be rapid fire spread up the cable looms as the PIR insulation (2.1) burns. The heat from these flames will feed back into the ACM PE (2.2) and PIR insulation and promote more rapid fire spread
2.8	Cavity Barriers (Lane Figures 8.42 (SR/8.44), 8.45 (SR/8.48), 8.47 (SR/8.50), 10.21 (SR/10.22), 10.22 (SR/10.23), Pres pg 242)	Ineffective cavity barriers – Penetrated by fixing rails, cabling and Installed upside down.	The ineffective cavity barriers would have allowed the flames to extend up the cavity (2.4) and along the fixing rails (2.5) heating and igniting the ACM PE (2.2), PIR insulation (2.1) and cabling (2.7) in the cavity.

SPANDRELS Bisby Pres pg 82			
2.9	Vertical fixing rails (Bisby Figures 14, 21, 25, 26, Lane Figure 8.59b (SR/8.62b), 10.28 (SR/10.29), Lane Pres pg 235, 236)	New element - created by the refurbishment. As the fixing rail is the joint between the column and the spandrel, it is the first item in this chain The continuous vertical fixing rails create a number of routes of vertical fire spread up (and down) the columns and to the column/spandrel junction. Recent Kingspan testing suggests the size of the gaps between the panels may be significant in terms of the system's fire performance	The fixing rails and the gaps between them at the ACM PE (2.11), housed vertical exposed PE edges of the ACM. Flames would have spread first from the PIR insulation (2.10) to the PE and then travelled vertically up the fixing rail to the underside of the ACM PE external window sill. None of the cavity barriers (2.13) would have prevented this fire spread route.
2.10	Kingspan K15 PIR/Celotex RS5000 (Lane Pres pg 229, 230, 239)	New materials - part of the refurbishment. Both are combustible materials with exposed edges. This was one of the routes of fire spread from one floor to the next.	The PIR insulation will spread the fire to the ACM PE (2.11) and vice versa. As the PIR chars it will allow the flames to spread behind the fixing rails (2.9) and spread vertically in the spandrel to the underside of the external window sill. (Lane Figure 10.27 (SR/10.28))
2.11	ACM PE (Lane Pres pg 232, 233)	New material - part of the refurbishment. This was one of the routes of fire spread from one floor to the next. See comments on the fixing mechanism in 2.5 and 3.1 also apply to the ACM spandrel panels.	The ACM PE and PIR insulation (2.10) spread the fire vertically. Flames along the top edge of the spandrels (Lane Figure 5.2, 10.2, 10.3) show the vertical spread in the cavity. These flames are then able to impinge on the lower edges of the window frames and infill panels (2.12).
2.12	Aluglaze white infill window panels (Lane Figures 9.26, 10.29 (SR/10.30), 10.32 (SR/10.34), 10.35	New material - part of the refurbishment. Styrofoam is combustible. This would aid fire spread within the external build up and into	The Aluglaze panels may be ignited by the PIR insulation (2.10) and/or ACM PE (2.11) burning at the top of the spandrel panels. The Aluglaze panels in the window frames had expanding foam (2.13) above and below them

	(SR/10.37) Pres pg 237)	apartments. XPS is likely to have contributed around 15% of the fire load of the cladding.	around the window frames themselves. Flames from the expanding foam or the Aluglaze will impinge on each other. Once the XPS core of the Aluglaze ignited the fire would have spread vertically to the expanding foam at the top of the window frame and the ACM PE at spandrel panel above.(Lane Figures 10.29 (SR/10.30), 10.32 (SR/10.34) and 10.35 (SR/10.37))
2.13	Expanding foam (Bisby Figure 24, Lane Figures 8.28 (SR/8.29), 8.38 (SR/8.40), 9.10 Pres pg 229)	New material - part of the refurbishment. Used as a joint filler to partly fill gaps associated with the installation throughout the rain screen system. Combustible material.	The expanding foam was combustible and filled many of the gaps around the window frames and between the support rails. Ignition of the expanding foam would have contributed to the ignition of the ACM PE panel above (2.11).

Stage 3	**Spread Across the Façade**		
Number	**Material / Construction Element**	**Details, location and expert commentary (Bisby Figure 119, Lane Figures 5.11 (SR/5.12), 5.12 (SR/5.13), 5.13 (SR/5.14), 10.27 (SR/10.28), 10.39)**	**Interacts With Material**
SPANDRELS			
3.1	Vertical fixing rails (Bisby Figures 14, 21, 25, 26, Lane Figure 8.59b (SR/8.62b), 10.28 (SR/10.29) Pres pg 235, 236)	New element - created by the refurbishment. As the fixing rail is the joint between the column and the spandrel, it is the first item in this chain The continuous vertical fixing rails create a number of routes of vertical fire spread up (and down) the columns and to the column/spandrel junction. Recent Kingspan testing suggests the size of the gaps between the panels may be significant in terms of the system's fire performance	The fixing rails and the gaps between them at the ACM PE (3.3), house vertical exposed PE edges of the ACM. Flames spread first from the PIR insulation (3.2) to the PE and then transferred laterally to the next ACM panel, and ignited the PIR insulation. There were no cavity barriers (3.4) to prevent lateral spread. (Bisby Figure 91 (SR/97) shows early lateral spread)
3.2	Kingspan K15 PIR/Celotex RS5000 (Lane Pres pg 229, 230, 239)	New materials - part of the refurbishment. Both are combustible materials with exposed edges. This is one of the routes of fire spread from one floor to the next.	The PIR insulation will spread the fire to the ACM PE (3.3) and vice versa. As the PIR chars it will allow the flames to spread behind the fixing rails (3.1) and spread laterally across the spandrel in the absence of cavity barriers (3.4)
3.3	ACM PE (Lane Pres pg 232, 233)	New material - part of the refurbishment. This is one of the routes of fire spread from one floor to the next. See comments on the fixing mechanism in 2.5 and 3.1 also apply to the ACM spandrel panels.	The ACM and PIR insulation (3.2) spread the fire laterally. Flames along the top edge of the spandrels (Lane Figure 9.23a (SR/9.24a), 9.25) show the lateral spread in the cavity. These flames are then able to impinge on the lower edges of the window frames and infill panels (3.5).

3.4	Cavity barriers in columns/spandrels (Lane Figures 8.42 (SR/8.44), 8.45 (SR/8.48), 8.47 (SR/8.50), 10.21 (SR/22), 10.22 (SR/10.23) Pres pg 243)	New elements/materials - created by the refurbishment. Multiple issues with the Siderise Open State cavity barriers that were in place: - Vertical cavity barriers not provided on all columns. - Vertical cavity barriers were actually horizontal cavity barriers rotated into the vertical position. - Horizontal cavity barriers were fitted above the line of the compartment floors and below the window cill. - Both vertical and horizontal cavity barriers were not fitted in accordance with manufacturer's recommendations - eg fitted upside down, cut around continuous vertical fixing rail and "rough cut" leading to an imperfect fit with the column or spandrel as well as a poor fit where joining other cavity barriers. - Open state cavity barriers by design take time to close the cavity so in the initial period there is a fully connected column cavity in any event.	The horizontal cavity barriers are penetrated by the vertical fixing rails (3.1) allowing vertical flame spread in the spandrel. Additionally there were no vertical cavity barriers in the spandrels to prevent lateral spread in them. (Lane Figure 8.45)
INFILL PANELS			
3.5	Aluglaze white infill window panels (Lane 9.17 (SR/9.13), Pres pg 237, 260)	New material - part of the refurbishment. Styrofoam is combustible. This would aid fire spread within the external build up and into apartments. XPS is likely to have contributed around 15% of the fire load of the cladding.	The Aluglaze panels may be ignited by the PIR insulation (3.2) and/or ACM PE (3.3) burning at the top of the spandrel panels. The Aluglaze panels in the window frames have expanding foam (3.6) above and below them around the window frames themselves. Flames from the expanding foam and the Aluglaze will impinge on each other. Once the XPS core of the Aluglaze ignites the fire will spread to the cavity (3.8) between the

			apartment and the infill panels and ignite the insulation board (3.7) (Lane Figure 8.19)
3.6	Expanding foam (Bisby Figure 24, Lane Figures 8.28 (SR/8.29), 8.38 (SR/8.40), 9.10 Pres pg 229)	New material - part of the refurbishment. Located around the window frames, including the top and the bottom, hence involvement with the spread to and from the spandrel panels Used as a joint filler to partly fill gaps associated with the installation throughout the rain screen system. Combustible material.	The expanding foam at the head and foot of the windows and the infill panels (3.5) will assist lateral spread although it exists in only small quantities. It may provide some additional heating between the ACM PE (3.3), the PIR insulation (3,2) and the infill panels
3.7	Insulation board (possibly Celotex TB4000 PIR) (Lane Pres pg 258, 260)	New material - part of the refurbishment. Insulation in places between the new and old infill window panels. Combustible material	The insulation board is likely to contribute fire spread from the infill panels (3,5) to the apartment as it backs onto the infill panels. It is unlikely to play a significant role in lateral transfer.
3.8	Cavity formed between the new and old infill panels located between the window sets (Lane Figure 8.19, 9.7 (SR/9.4) Pres pg 260)	No cavity barrier present.	As for the insulation board (3.7), the cavity between the new and original infill panels (3.5) are unlikely to contribute to lateral fire spread beyond the transfer of the fire from the panel to the apartments.

Stage 4	Spread Back into Apartments		
Number	**Material / Construction Element**	**Details, location and expert commentary (Bisby Figures 14, 15, 17, 37, 38, 39, 41, 42 Lane Figure 9.16 Press pg 266)**	**Interacts With Material**
4.1	Kingspan K15 PIR/Celotex RS5000 (Bisby Pres pg 59, 60, 69, 72, 103 Lane Pres pg 229, 230, 239, 260)	New materials - part of the refurbishment. Both are combustible materials with exposed edges. This is one of the routes of fire spread from one floor to the next.	The fire spread up the columns via the PIR and ACM PE (4.2) will impact the EPDM (4.8) and then into the cavity voids (4.7), and into the apartment. Flames in the insulation below the windows will heat the window support rails (4.4) and ignite insulation boards (4.10) and timber battens (4.9) in the void. Fire spread into the apartments is also likely from laterally spreading flames via the window support rails (4.4) to the infill panels (4.5). The expanding foam (4.6), and timber battens (4.9) will ignite in the void. (Lane Figure 9.22)
4.2	ACM PE (Bisby Pres pg 60, 70 Lane Pres pg 232, 233)	New material - part of the refurbishment. This is one of the routes of fire spread from one floor to the next.	The expanding foam (4.6) around the window frames (4.3) will ignite from burning ACM PE below the windows. The flames are also likely to ignite the Aluglaze panels (4.5) providing a further transfer mechanism of the fire to the battens (4.9), expanding foam (4.6) in the void and to the Purlboard (4.11) at the window heads.

4.3	Aluminium window frames	New material - part of the refurbishment. Aluminium has a relatively low melting point and the coefficient of expansion would likely give rise to the potential for joints to open in the construction separating the interior of the apartment with the rear of the cladding system at a relatively early stage in the fire development in the apartment.	Although the window frames are not combustible, they are highly conductive and have a low melting point. Burning PIR (4.1) and ACM PE (4.2) will heat the window frames and ignite the expanding foam (4.6) which was used to fill gaps around the frames
4.4	Aluminium window support rails	New material - part of the refurbishment. One route of spread to and from window frames and associated insulation and timber to the column insulation edges	Although the window support rails are not combustible, they are highly conductive and have a low melting point. Burning PIR (4.1) will heat the window frames and ignite the expanding foam (4.6) which was used to fill gaps around the rails and frames. Heat from burning PIR (4.1) will have conducted through the lower rail and ignite the insulation board (4.10) fitted in the void behind it.
4.5	Aluglaze white infill window panels (Bisby Figure 44)	New material - part of the refurbishment. Styrofoam is combustible. This would aid fire spread within the external build up and into apartments. XPS is likely to have contributed around 15% of the fire load of the cladding.	The white infill panels will be heated via the conductive window frames (4.3) and the burning expanding foam used to seal the frames (4.6). The infill panels will also have been directly heated by burning PE (4.2), either in the panel below the infill panels or by falling PE that came to rest on the ACM PE window sills. The burning XPS core of the infill panels would have ignited the combustible material behind I including the timber battens (4.9), the insulation board (4.10) and the Purlboard (4.11) (Lane Figure 9.27, 10.30 (SR/10.31))
4.6	Expanding foam (Bisby Figure 24, Lane Figures 8.28 (SR/2.9), 8.38 (SR/8.40), 9.10,)	New material - part of the refurbishment. Used as a joint filler to partly fill gaps associated with the installation throughout the rain screen system. Combustible	The expanding foam, while small component of the window construction was in close proximity to all other components and would have contributed to the overall fire spread and heat loadings in the

		material.	following materials: 4.1 PIR Insulation 4.2 ACM PE 4.3 Window frames 4.4 Window support rails 4.5 Aluglaze infill panels 4.9 Timber Battens 4.10 Insulation board 4.11 Purlboard
4.7	Cavity (voids) between the window frame and the structural opening (Lane Figure 8.15, Bisby Figure 132 (SR/160))	New element - created by the refurbishment. This cavity provided a direct route from the interior of the apartment to the external wall build up and the combustible materials contained therein. No cavity barriers in place.	The voids around the window were between the PIR insulation (4.1) and the combustible materials framing the window. Flames burning in the insulation would have spread to the expanding foam (4.6), the EPDM (4.8), the timber battens (4.9), the insulation board (4.10) and the Purlboard (4.11)
4.8	Damp proof membrane (EPDM) (Bisby Figures 40, 137 (SR/165), Pres pg 71, 116, 117 Lane Figure 9.10, 9.12, Pres. Pg 225)	New material - part of the refurbishment. Used as a weatherproof seal and bonded to the face of the window frame and the concrete column to close the gap created by the alteration of the windows. Specific product/thickness unknown but commercially available in 1-3mm (which generally fits with what was seen at GT). This was part of the main routes of fire spread both out of the original apartment and back into apartments. Combustible material.	The EPDM was the present to provide a vapour barrier between the outside and the inside of the apartment. As such flames outside the EDPM in the PIR insulation (4.1) would have ignited the EPDM (Lane Figure 8.22) allowing the fire to reach the combustible expanding foam (4.6), (Bisby Figure 136) Cavity voids (4.7), Timber battens (4.9), Insulation board (4.10) and Purlboard (4.11) in the void (4.7)

4.9	Timber battens lining the window sills, jambs and heads (Bisby Figures 37, 38, 39 Pres pg 56, 67 Lane Pres pg 253, 254)	Part of the original construction. The timber elements could aid fire spread from the apartment of origin. The timber frames were part of various likely routes of fire spread from the apartment (including alongside the insulation as the main route from the uPVC window jambs/reveals).	The timber was combustible and supported the uPVC around the windows (4.10). It would contribute to the heat load from the fire spreading to the expanding Foam (4.6) and Purlboard (4.11) in around the window.
4.10	Celotex and Kingspan PIR foam insulation board TB4000 in the cavities behind the new uPVC window reveals (Bisby Pres pg 62, Lane Figures 8.13, 8.17 and 11.11 Pres pg 258)	New material - part of the refurbishment. Combustible material. This was likely to become involved in fire growth at an early stage and form a fire spread route. This material was relevant to all potential routes of fire spread from the apartment	The Insulation board in the cavities would have contributed to fire spread in similar way to the expanding foam (4.6), timber battens (4.9) and to the Purlboard (4.11)
4.11	Purlboard polyurethane foam insulation (Bisby Figure 49, Pres pg 57, 109 Lane Figure 8.5, Pres pg 249)	Part of the original construction. 20mm thick product consisting of 12mm combustible polyurethane foam insulation bonded to the rear of a 8mm thick plasterboard layer. 350mm wide strip fitted to close the gap between the window head reveal and the concrete soffit above. It lines the ceiling adjacent to the full perimeter of the external wall in each flat. Such combustible materials on the internal construction of the window details/the celling are likely to have been involved in the early stages of the fire growth and development in the apartment and may have led to the spread of fire in the initial stage from the apartment to the external wall. This material would contribute to a route of spread from the apartment but would not be the main route.	The Purlboard would have assisted fire spread into the apartments having been ignited by flames developing in the materials in the void (4.7) around the window or behind the infill panels (4.5). Those materials contributing to the ignition of the Purlboard were the expanding foam (4.6), the EPDM (4.8), the timber battens (4.9) and the insulation board (4.10)

4.12	uPVC window jambs/reveals and sills (glued into place) (Bisby Figure 135 (SR/163), Pres pg 63, 73, 113, 114, Lane Figure 8.18, 9.17 (SR/9.13) Pres pg 250, 251, 263, 264, 265)	New material - part of the refurbishment. The main route of fire spread from Flat 16 to the cladding system and back into the apartments was via the uPVC window jambs/reveals and the uPVC window sills to also be a route of fire spread (albeit of lesser magnitude).	The fire created by the burning expanding foam (4.6), timber battens (4.9) and insulation board (4.10) in the void around the window would have caused the uPVC window jambs and sill to melt and droop, and allowed flame to enter the apartment

APARTMENT CONTENTS			
	NUMEROUS DIFFERENT MATERIAL TYPES	All will contribute to the overall fire load on the building by flaring from breached window apertures (Lane Figure 5.19)	
	Soft Furnishings	Curtains, blinds, sofa's, armchairs, bedding etc – contributes significantly to the fire load in the apartment and to the building exterior when vented through the windows	
	Solid Furnishings	Tables, hard chairs, bookshelves, cupboards, baskets etc As for Soft furnishings	
	Electrical Appliances - Plastics	Stereos, computers, DVDs, CDs etc Contribute to fire load but less than furnishings, owing to higher ignition temperatures and thermal inertia.	
	Paper	Newspapers, boxes, magazines, books etc Contributes to fire load to a smaller extent, as solid paper blocks (books etc) tend to char	
	Gas supplies	Boilers, stoves/oven – pipe/meter leakage/rupture Potentially high, sustained and inextinguishable fire load if supply is not isolated. Pipe work and meters in apartment protected, and appear unlikely to fail in the first hour. Nature of isolation process slow due to restricted access. No realistic chance of isolation in the first 6 hours of the fire.	

Stage 5	Spread Across the Architectural Crown		
Number	**Material / Construction Element**	**Details, location and expert commentary**	**Interacts With Material**
5.1	Kingspan K15 PIR/Celotex RS5000 (Lane Pres pg 229, 230)	New material - part of the refurbishment. – also under bituminous roofing Combustible material that would contribute to fire growth and development within the cavity at the roof wall build-up. Exposed edges confirmed.	The PIR insulation was fitted up to and over the edge of the roof line. Fire in the cladding system (PIR 5.1) and ACM PE (5.2) spread the fire to the crown igniting the ACM PE louvres (5.6) and the insulation and bituminous roof covering (5.4). A lack of effective cavity barriers allowed the fire to spread around the top of the columns.
5.2	ACM PE (Bisby Pres pg 99)	New material - part of the refurbishment, used as both cladding and architectural louvres at the crown. This would be a route but not the primary route of lateral fire spread.	The ACM PE rain screen was fitted up to the roofline but did not extend over the edge of the roof. It was continuous in a line above the windows but below roof level (lane figure 10.46). Fire in the cladding system (PIR 5.1) and ACM PE (5.2) spread the fire to the crown igniting the ACM PE louvres (5.6) and the insulation and bituminous roof covering (5.4). A lack of effective cavity barriers allowed the fire to spread around the top of the columns.
5.3	Cavity barrier at head of rainscreen	No cavity barrier present (Lane Pres pg 247)	
5.4	Bituminous roofing (Lane Figure 5.37 (SR/5.39), 5.41 (SR/5.43) and most probably shown in Figure 10.37a (SR/10.39a))	New element over insulation. Also pre-existing back to plant room and on top of plant room Appears to have interacted with insulation, cabling and timber edging on the original roofing inside the parapet.	The bituminous roof covering has burnt away around the edge of the roof, melting the aluminium cladding (5.7), and contributing to the ignition of the ACM PE louvres (5.6) and, in parts, burning away the timber edging (5.5) and underlying PIR (5.1) insulation.

5.5	Timber edge under bituminous roofing	Burnt away with roofing material inside the parapet.	The timber edging at the inner edge of the new bituminous roofing (5.4) has been fire damaged by the combustion of the bituminous roofing.
5.6	ACM PE LOUVRES (Bisby Press pg 99, Lane Figures 10.38 (SR/10.40), 10.44 (SR/10.47), 10.46 (SR/10.49))	New material - part of the refurbishment to original concrete parapet. Contributes to lateral spread – unclear extent.	The ACM PE lay inside the line of the external cladding (5.1 and 5.2) and over the solid aluminium cap (5.7). The louvres appeared to have been ignited from the fire spread via the insulation (5.1) and ACM PE (5.2) at the columns. Molten PE had dropped onto the aluminium cap (5.7) below. Areas of the louvres remained unburnt after the fire, suggesting that external flame impingement was required to keep them burning
5.7	Aluminium Cap (Lane Figure 10.44 (SR/10.47))	New material as a cap at the outer edge of the roof. Fitted over PIR insulation and directly under the ACM PE louvres	Aluminium had melted away at the inner edge over the bituminous roof covering (5.4). The Aluminium appears to have been melted by the PIR insulation (5.1) and/or the bituminous roof covering (5.4) burning beneath it.