IN THE GRENFELL TOWER PUBLIC INQUIRY

THE INQUIRY RULES 2006, RULE 9

SECOND WITNESS STATEMENT OF HUGH MAHONEY

I, **HUGH MAHONEY**, will say as follows:

1. My name is Hugh Mahoney. I made my first witness statement to the Inquiry on 28th September 2018 {**PSB00001329**}. In that statement, I provided information about the involvement of PSB UK Limited ("**PSB**") in the design of the smoke control system installed in Grenfell Tower ("**the System**"). At the time of making my first statement I had access to PSB's documents only. Since then, I have been able to refer to more documents made available by the Grenfell Tower Inquiry ("**the Inquiry**").

2. As I stated at paragraph 6 of my first statement, I left PSB in February 2016 to work for a competitor firm: Colt Smoke Control, a division of Colt International Limited ("**Colt**"). I retired from work in December 2020.

3. I have been asked whether there is anything in my first statement that I wish to correct or any matter that I should want to clarify, or whether there is any further information I should want to provide to the Inquiry.

4. I think it may assist the Inquiry if I were to set out in more detail my relevant experience and professional background, particularly as relates to research and guidance relevant to smoke control systems. I shall also look to explain the approach that I took to the design of the System and the type of smoke control system that I designed. I shall address these two matters in this statement.

Experience and Professional Background

5. As I said in paragraph 11 of my first statement, I began working in the smoke control industry in around 1983. NuAire Limited had invented a fan that would work at very high temperatures (834°c), described as a 'smoke clearance fan'. This was an exciting time in the development of smoke control with the publication of Fire Papers 7 and 10 (both funded by Colt) in the late 1970s and Butcher and Parnell's *"Smoke Control in Fire Safety Design"* in 1979. These documents were the first to consider how smoke control systems might be used in fire safety design.

6. I was asked to sell the fan to the market, with other colleagues, because we were the only people working at a sufficiently senior level who understood the underlying physics. The product sold well, and Colt saw an opening in the market for smoke control systems. There were (and remain) a relatively small number of companies operating in the UK smoke control industry who are specialists. PSB is one of those companies.

7. As I explained in paragraph 14 of my first statement, I have always been interested in the regulation and guidance concerning smoke control systems. Over the course of my career, I have been involved in the work of various industry and professional bodies in seeking and providing greater clarification of such regulation and guidance.

8. I explain a little more about my involvement with industry and professional bodies below.

The Smoke Control Association and the SCA Guide

9. The Smoke Control Association ("**the SCA**") was established in 1987. It is part of the Federation of Environmental Trade Associations (FETA). It was originally called the Smoke Ventilation Association. The SCA has members from a range of organisations which are involved in the manufacture, design, supply and fitting of smoke control systems and equipment. The organisation is run via several committees, each of which carries out a specific function.

10. I first joined the SCA in around 1992, when I was employed by NuAire. At the time I joined, there was a Plenary Committee which was mainly attended by company executives of member companies. The individuals on the Plenary Committee were responsible for discussing commercially sensitive issues such as the state of the industry,

promotional matters, etc. There was also a Technical Committee which was responsible for discussing technical matters such as products, product standards, test standards, etc.

11. I was Chairman of the SCA between 1998 and 2000. After that I continued to have an active role and in the late 2000s, I put together a proposal for the SCA to prepare a guide which would deal with the topic of smoke control in apartment buildings, including flats and maisonettes.

12. The idea was to provide individuals and companies with consolidated information about how to design effective smoke control systems. I was asked to chair a working group to produce the guide. I recall that there was a lot of interest from members of the SCA and volunteers came forward to form the working group. In addition, members put forward names of organisations they thought would want to take an active role in preparing the document. The SCA Secretary then wrote inviting these organisations to ask them if they wanted to send representatives to be part of the working group. It was my role to co-ordinate the work of the working group.

13. The original guide was called *"Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes)"* ("**the SCA Guide**") and was issued in November 2010.

14. Until the SCA Guide was published, practical guidance in relation to the design of smoke control systems was sparse; what little there was, was spread across several publications. The aim of the SCA Guide was to bring the guidance from industry, professional and government organisations together in one place to assist individuals and companies involved in the design of smoke control systems to be installed in apartment buildings. The Guide also provided details and gave recommendations not previously covered in other standards or codes of practice. As we explained in the Introduction to the SCA Guide, whilst there were some prescriptive methods of providing smoke control, these methods could not always be implemented, and it had become necessary to develop performance based solutions to improve conditions within common escape routes.

15. The SCA Guide was revised in June 2012 (Revision 1) {**LFB00059241**} to reflect changes in best practice and the publication of BS 9991:2011 *"Fire Safety in the design, management and use of residential buildings. Code of practice."* {**CTAR00000040**}. I

was also a member of the working group involved in the revision of this revised SCA Guide in 2012.

16. The SCA Guide was further revised in October 2015 (Revision 2) {**RBK00001778**}. I was also an active member of the working group responsible for the revision at that time. I have been shown 29 documents disclosed to the Inquiry by RBKC and JS Wright which relate to this revision process. There are a number of working drafts of the document, agendas for meetings of the working group, and correspondence between various parties about the proposed revisions.

17. I left the SCA when I began my employment with Colt in March 2016. By that time, I had been an active member of the SCA for 24 years.

The British Standards Institute

18. As I explained in paragraph 14 of my first statement, I was an independent member of the BSI's FSH25 Committee for Smoke Control Systems from around 1994 to 2014. The Committee was responsible for reviewing any documents, information, etc which was or could be related to smoke control systems.

19. The Committee also:

    a. Prepared codes of practice such as converting some of the SCA Guides into British Standard 'speak' and issuing British Standards Codes of Practice;

    b. Had members on all CEN (European Committee for Standardization) working groups producing harmonised European Standards (BSEN);

    c. Had members on many other British Standards Committees;

    d. Reviewed and discussed topical matters associated with the industry; and

    e. Gave impartial advice if requested.

20. I was co-opted, as an independent member, onto FSH25 due to my knowledge and understanding of a type of smoke control system known as Pressure Differential Systems (discussed further below).

21. I was then proposed and accepted by the members of FSH25 to be the Committee's representative on CEN/TC191/SC1/WG6 (Working Group 6), the European group

responsible for drawing up BS EN 12101-6:2005 *"Smoke and heat control systems. Specification for pressure differential systems. Kits"* {**BSI00000132**}. At that time, the UK did not have a principal expert on that Working Group and so I was asked by the BSI to take the position of Principal Expert for the UK on the Working Group.

22. I was also a member of the FSH25 working group which drew up the code of practice for car park ventilation systems, BS7346-7:2013 *"Components for smoke and heat control systems. Code of practice on functional recommendations and calculation methods for smoke and heat control systems for covered car parks."* {**LABC0008415**}.

Chartered Institution of Building Services Engineers ("CIBSE")

23. I was the author of the section on Pressure Differential Systems in the first edition of the *"CIBSE Guide E: Fire Engineering"*. I worked on the document alone between 1995 and 1996. The document was published in 1997.

The Smoke Control System at Grenfell Tower ("the System")

The Initial Design Proposals

24. As I said at paragraph 16 of my first statement, my first involvement in the Grenfell Tower project occurred towards the end of April (or perhaps the beginning of May) 2014.

25. PSB did not determine the initial design concept of the System. Grenfell Tower was a pre-existing building which already had a pre-existing smoke control system in place (albeit that it was not fully functioning when I became involved in the project). I explain my understanding of how the pre-existing system was designed to operate at paragraphs 17 to 20 of my first statement.

26. As I state at paragraphs 21 to 23 of my first statement, prior to my involvement in the project, Max Fordham had proposed a 'push-pull' smoke control system as part of the refurbishment project.

27. The push-pull system proposed by Max Fordham is a type of smoke control system usually employed when the travel distance in the escape corridor leading to the stairwell is greater than that specified in the ADB or BS 9991. Such systems are designed to provide smoke dilution on the escape route, reducing the levels of smoke toxicity and visibility to acceptable levels. This is achieved by introducing clean fresh air through a

mechanical inlet air shaft at low level local to the stair door within the corridor. An extract shaft is located at the furthest end of the corridor extracting diluted air/smoke at a volumetric rate equal to the fresh air inlet.

28. I knew from experience that there would be a number of problems with the proposed use of a push-pull system in Grenfell Tower.

29. As well as the issues raised in paragraph 23 of my first statement, I was also aware that the lobby layout at Grenfell Tower was not a typical corridor arrangement. The two shafts were located on either side of the lobby, but there were additional areas coming off the main lobby area which provided access to the flats in each corner of the tower. One shaft had a grille at low level (the south side) and the other had a grille at high level (the north side). The location of the door from the lobby to the stair was also an issue as it was not positioned at the end of a corridor. I recognised that the specific orientation of the lobby and the position of the shafts and door to the stair in Grenfell Tower meant that it would not be possible to adequately mitigate the risk that smoke would enter the stair using a push-pull system. Given the size of the lobby and the position of the shafts there would also be dead spot areas in the lobby where there would be no air flow and therefore no mixing of air and smoke to create dilution.

30. I am aware that Fergus MacGregor of PSB, with whom Max Fordham had been dealing, provided a quotation for work to the smoke control system at Grenfell Tower which was based on a push-pull system {**PSB00000814**}. In the quotation, Fergus MacGregor stated that the exhaust flow rate of the system would have been 4.0m³/s; this would have resulted in an air velocity, in a standard corridor of around 1.0m/s, but not a lobby arrangement such as at Grenfell. However, for the reasons stated, I thought there would be problems with this proposed system type and considered that the approach to the design needed to be reconsidered.

My Design Approach

31. The design of smoke control systems in high rise buildings is based on a number of set assumptions which informed my approach to the design of the System. These can be summarised as: a single flat fire location, a single floor of operation, and a focus on protecting the stair. I also approached the design on the basis that it would be mechanical, would operate automatically, and would include a manual override. These are explained

in my first statement, but I think it important to remember the limits of these assumptions on the design of smoke control systems.

32. As I said at paragraph 24 of my first statement: *"[t]he design I developed was for a depressurisation system, in other words a system which achieved smoke control using depressurisation principles achieved by mechanical extraction. Depressurisation systems are one of the most common types of smoke control system used in buildings in the UK."*

33. In the SCA Guide the word 'depressurisation' was defined to include "*smoke control using pressure differentials where the air pressure in the fire zone or adjacent spaces is reduced below that in the protected zone*" (*4.5 Terms and Definitions, in the First Edition and Revision 1, 1.5 Terms and Definitions in Revision 2*). Those with a background in smoke control would know the different types of system to which this term and definition can be applied.

34. A mechanical extract 'depressurisation' system principally works by extracting air and smoke from the lobby so that, when the door between the lobby and the stairwell is opened, an airflow is created from the stair to the lobby which would limit smoke ingress into the stair.

35. To prevent too much force from being generated on the stairwell door by the operation of the fans, such systems monitor the difference in pressure between the lobby and the stairwell. The fans operate at a lower speed with the stairwell door closed (a pressure differential being in place) and respond quickly to run at an increased speed when the door is opened (the pressure differential no longer being in place).

36. Mechanical extract systems which create a depressurised adjacent space (in this case the lobby) resulting in an induced air flow across the open door to the stair can be referred to as 'depressurisation' systems; indeed, that is a common way to describe them in the industry. These types of system should not however be confused with *"Pressure Differential Systems"* which are designed to comply with all of the requirements of BS EN 12101-6:2005 *"Smoke and heat control systems. Specification for pressure differential systems. Kits"*.

37. In contrast with the mechanical extract 'depressurisation' system I designed at Grenfell Tower, the types of Pressure Differential Systems referenced in BS EN 12101-6 are either:

    a. Positive Pressure Differential Systems which pump air *into the protected space.* In the case of Grenfell Tower, the protected space was the stairwell. I discussed at paragraph 32(4) of my first statement the impracticability of a installing a positive Pressure Differential System at Grenfell Tower, as it would have meant cutting large holes through the concrete slab to accommodate supply ducts to the stair, lobby and lift shaft, and accommodation air release paths.

    b. Depressurisation systems *which extract air direct from the fire zone.* In the case of Grenfell Tower, the fire zone was the fire flat. Such a system would have been inherently impractical at Grenfell Tower as it would have required large holes to have been cut in the concrete slab to accommodate new supply and smoke extract ducts from each flat.

38. In my experience, the classes of Pressure Differential System set out in BS EN 12101-6 are not commonly used in residential developments in the UK.

39. A decision had been made before PSB were instructed on the project to make use of the existing shafts (i.e., it would not be possible to make the shafts any bigger or to install new shafts on the exterior of the tower). I was therefore asked to design a system which re-used the existing shafts and did not require any material changes to the building. Later in the project it was also a requirement that the existing shafts were extended to serve the floors where the new accommodation was located.

40. It follows that I did not design a Pressure Differential System, which are designed to comply with all the requirements of BS EN 12101-6.

41. My design reflected a more common type of mechanical extract 'depressurisation' system. A performance-based building appropriate solution widely adopted as a type of smoke control system and which were often referred to within the industry as 'depressurisation' systems and is commonly called the ColtShaft mechanical shaft system.

Applicable Research and Guidance

42. Mechanical extract 'depressurisation' systems like the System were first introduced in the UK in the early 2000s by companies such as Colt.

43. Such systems were studied in BRE reports "*Smoke Shafts Protecting Fire Fighting Shafts, Their Performance and Design*" (2002) and "*BD2410 Smoke Ventilation of Common Access Areas of Flats and Maisonettes Final Factual Report*" (2005) {**CTAR00000050**}; the latter of which looked at several different types of smoke control system and the way in which they acted to protect the stairwell and common lobby.

44. I have looked at BD2410 again and the following conclusions are relevant:

> "*i. Natural smoke venting into vertical smoke shafts, in the absence of adverse wind or building stack effects, can protect the stair very well, albeit at the expense of generally leaving the corridor / lobby smoke filled if exposed for more than a short duration.*
>
> *ii. External window vents did, on average, provide some improvement to conditions inside the vented corridor / lobby compared to smoke shafts, but at the expense of less effective protection to the stair.*
>
> *iii. Suitably designed mechanical ventilation systems can provide protection to the stair that is, in principal, resilient to adverse wind and building stack effect pressures. This can be achieved by either depressurising the corridor / lobby relative to the adjoining stair (extracting air/smoke from the corridor / lobby) or by directly pressurising the stair with air/smoke relief from the corridor / lobby. Tenable conditions inside the adjoining corridor / lobby are not in general maintained if exposed to smoke for a more than a short duration. However, by a judicial choice of extraction rate, a depressurised corridor scheme may be able to prevent smoke migration into the stair while at the same time maintaining some degree of smoke stratification in the corridor."*

45. The revised ADB 2006 edition, which followed the publication of BD2410, included as main changes to the means of escape guidance, commentary on the role of a smoke control system to protect the stair to minimise the possibility of serious contamination of

the firefighting stairwell (although it was recognised that some smoke contamination of the stairwell was possible).

46. At the time I became involved in the refurbishment project at Grenfell Tower, ADB 2013 referred to natural ventilation systems, mechanical ventilation systems and Pressure Differential Systems. However, it did not incorporate any guidance on mechanical ventilation systems other than its reference to BS EN 12101-6 in respect of Pressure Differential Systems. Of course, ADB recognised that other codes or guidance may be available which might be of greater assistance to the designers of smoke control systems.

47. Mechanical extract 'depressurisation' systems which create a depressurised space resulting in an induced air flow across the open door to the stair (flowing from the stairwell into the lobby) and, perhaps more importantly, a set of agreed performance criteria for such systems, are not and have never been addressed in their entirety in any one British Standard.

48. However, although it did not itself set out agreed performance criteria for mechanical smoke ventilation systems, BS 9991 did at least refer the reader on to the SCA Guide in that regard, stating at Annex E as follows:

> *"NOTE There are numerous different types of fan assisted system including a mechanical extract/natural inlet and a mechanical extract/mechanical inlet system. Further information on these can be found in the Smoke Control Association publication, "Guidance on smoke control to common escape routes in apartment buildings (flats and maisonettes)."*

49. In fact, it was precisely because there was no formal guidance on how these types of systems should be designed that I became involved in the production of the SCA Guide, as the Chairman of the working group.

50. Revision 1 of the SCA Guide, published in June 2012, was the then current version at the outset of the refurbishment project at Grenfell Tower. Revision 2 was published in October 2015 while the refurbishment works were still going on.

51. The SCA Guide 2012 contains a section entitled *"System Types" (Section 6)*, a subsection of which deals with *"Mechanical (Powered) smoke ventilation" (Section 6.4)*. Two specific types of mechanical extract system are described; the first is a *"Mechanical*

Extract, Natural Inlet" system (*Section 6.4.2*) and the second is a *"Mechanical Extract, Mechanical Inlet"* system (*Section 6.4.3*).

52. The System was similar to, but not the same as, the *"Mechanical Extract, Natural Inlet"* system detailed in the SCA Guide 2012.

53. The *"Mechanical Extract, Natural Inlet"* description in the 2012 Guide states that:

> *"6.4.2 Mechanical Extract, Natural Inlet*
>
> *The purpose of a mechanical extraction system is to assist in the ventilation of common access spaces. The system comprises mechanical extraction shaft(s) serving one or more common spaces on all, or some, of the floor levels. The mechanical extraction ventilation shaft(s) should discharge directly to the outside."*

54. Two figures in the 2012 Guide (*Figures 6.4.2a and 6.4.2b*) then show indicative layouts for such systems. One shows the natural inlet of air via a shaft and the other shows the natural inlet of air via a vent directly to the outside off the common access space. Neither of these layouts matched the situation at Grenfell Tower. Replacement air at Grenfell Tower was to be drawn either from around the door and the leakages in the lobby (door closed) or through the door via the permanently open vent at the top of the stair (door open).

55. The SCA Guide 2015 changed the description of the *"Mechanical Extract, Natural Inlet"* system type. The description in the 2015 Guide states that:

> *"6.4.2 Mechanical Extract, Natural Inlet*
>
> *The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, of the floor levels supplemented by the provision of natural inlet air provided by automatically opening vents or permanent vent to the outside (either directly or by way of a shaft, stairway or duct)."*

56. The two figures showing the indicative layouts remained the same, but this change of wording in the SCA Guide 2015 acknowledged a type of system which allows for natural inlet air to be provided by way of a stairway, as was the case with the System.

57. I knew from experience that a mechanical extract system of the *"Mechanical Extract, Natural Inlet"* type, which created a depressurised space resulting in an induced air flow across the open door to the stair (flowing from the stairwell into the lobby), would afford the stair in Grenfell Tower the best form of protection available.

58. *"Mechanical Extract, Natural Inlet"* type smoke control systems were (and remain) commonly used in the industry.

59. An example of this type of system, which works in the same way to that which I designed for Grenfell Tower (using extraction through shafts to create a depressurised space resulting in an induced air flow across the open door to the stair), as referenced above this is commonly referred to, in the Building Services Industry, as the ColtShaft mechanical shaft system.

60. Information about ColtShaft including how it was developed, how it works and the testing it was subject to is publicly available, as it was at the time of my involvement in the Grenfell Tower project. ColtShaft is a Local Authority Building Control ("LABC") Registered System with a certificate first issued in November 2010:

https://www.coltinfo.co.uk/colt-product-library/mechanical-ventilators-hvac-products/coltshaft.html

Performance Criteria

61. Once I had settled on the design basis of the System, I needed to determine and state the performance criteria of the System.

62. There is no comprehensive guidance available as to generic performance criteria for systems of this type, even in the SCA Guide.

63. However, BS EN 12101-6 sets out guidance in relation to certain performance criteria relevant to Pressure Differential Systems which I felt were appropriate for the System. I explain why below.

64. In BS EN 12101-6, the stair in a residential building is protected by either raising the stair pressure so it is higher than the accommodation areas (the fire zone) or

depressurising the fire zone. In the case of the System, on the other hand, protection of the stair is achieved by extracting (de-pressurising) air from the lobby.

65. BS EN 12101-6 states that when the stair door is open a velocity of air flowing through the open stair/lobby door should be either 0.75m/s for a Class A system (Means of Escape for Residential Buildings) or 2.0m/s for a Class B system (All Building Types for Firefighting).

66. Whilst the System did not operate in the same way as a Class B Pressure Differential System, the airflow it was designed to generate across the open door was similar to that aspect of the required performance criteria of a Class B Pressure Differential System. It is for this reason that I felt that it was appropriate to adopt the figure of 2.0m/s from BS EN 12101-6 for the System.

67. I know from my experience in designing smoke control systems that 2.0m/s velocity through an open door is the airflow required to enable smoke to be kept out of the stair.

68. As I set out in my initial Technical Proposal {**PSB00001233**}, as a matter of physics, to obtain a velocity of 2.0 m/s across an open door with an area of 1.6m^2, you would need to produce a volumetric flow of 3.2 m^3/s.

69. However, at the early design stage, when deciding upon the volumetric flow that the System must produce in order to create a velocity of 2.0 m/s across the open lobby door, I also needed to account for air leakages elsewhere in the building. There is no single standard which provides definitive guidance on how to do this. However, BS EN 12101-6 states that, when calculating the necessary volumetric flow, 50% must be added to the rate to account for unidentified fabric losses and closed motorised ventilator leakage. From my experience, I considered this to be appropriate guidance to apply in respect of the design of the System. As such, in the Technical Proposal I said that the overall volumetric flow to be generated by the System should be 4.8 m^3/s (i.e. 3.2m^3/s x 1.5).

70. I have been shown the flow readings taken by Granville Partlow, PSB's Commissioning Engineer from the System in April 2016 which demonstrate that the System did in fact achieve ~~a~~ minimum velocity of 2.0 m/s across all the open lobby doors.

71. In addition, because the System involved creating a depressurised space (the lobby), it was necessary to ensure that anyone attempting to evacuate the fire zone was able to open

the door to the stair. Paragraph 5.3.2.1.2 of the SCA Guide 2012 *"Performance Criteria"* states:

> *"Pressure differences between the corridor/lobby and adjacent stairs and accommodation should not cause door opening forces to exceed 100N at the door handle. This is unlikely to be exceeded if pressure differentials across the door are limited to 60Pa."*

72. I designed the System to use pressure sensors which were set at around -25Pa in the lobby areas to ensure that the fans would be working at a rate which would mean that the door opening force would not exceed 100N. Each floor was addressed individually, and the pressure sensors were required to be set specifically to allow for the leakages in each individual floor lobby.

73. These were the two principal performance criteria that I determined to be appropriate for the System.

Conclusion

74. For the reasons outlined above, I believe the basis of my design and the performance criteria I specified for the System were sufficient to meet the requirements of the Building Regulations. Both the basis of my design and the performance criteria were agreed with the approving authority.

75. Within the constraints of the building and given the requirements of the design brief presented to me, I was satisfied that the design of the System was the most effective type of smoke control system that could reasonably be installed at Grenfell Tower.

76. I understand that this statement will form part of the evidence before the Inquiry and will be published on the Inquiry's website.

STATEMENT OF TRUTH

I believe the facts stated in this statement are true.

Hugh Mahoney ....

Dated 26th March 2021 ....