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## 27th September 2017

**Sir Martin Moore-Bick,**

**Grenfell Tower Inquiry,
Royal Courts of Justice,
Strand,
LONDON WC2A 2LL.**

Dear Sir Martin,

**A proposition as to why the fire took hold and burned so rapidly in the Grenfell Tower incident: the combined roles of the inner and outer claddings, water and heat.**

Following studies I have recently carried out on behalf of BBC South’s “Inside Out” investigative programme to be screened on Monday 2 October, I feel I need to make you aware of a combination of circumstances regarding the Grenfell Tower catastrophic fire that seems to have been overlooked.

It has been stated that both claddings passed fire retardant tests before installation and it is reasonable to presume that these materials would not have been knowingly sold on any other grounds. Yet, the fire in the Grenfell Tower spread very rapidly, apparently by means of the external cladding. Furthermore, when such claddings were subsequently removed from other buildings, all were found to fail fire retardant tests when both claddings were examined in combination.

Why should this be so?

Several factors have been proposed to explain the rapid spread of the fire (*inter alia*, presence of polyethylene in the outer cladding and a chimney effect) and these may very well have some influence on the end result. However, none of the hypotheses thus far has considered the effect of the presence of water on the flammability of the external cladding bearing in mind that the external aluminium cladding appears to have totally disappeared from the fire-affected areas of the exterior of the Grenfell Tower.

Polyisocyanurate foam acts as an insulator due to the minute pockets of air trapped within its structure. However, these pockets can absorb moisture, either from general humidity or ingress of rain, over a period of time. The external aluminium-polyethylene cladding provides mechanical protection, gives a cosmetic appearance and some, but not total, protection from the environment. In the case of a building fire, the weathered polyisocyanurate foam will become hot and liberate the absorbed water as steam before it starts to burn itself. If this steam impinges on hot aluminium at temperatures around or above 300 oC – a temperature readily attained in a building fire – it will react violently with the aluminium, generating large quantities of heat and large volumes of hydrogen that will, in turn, burn producing more heat and more steam. This can then continue to fuel the violent reaction of the aluminium. Once the aluminium layer has been breached, the inner polyethylene lining will also catch fire, generating further heat and more steam and, when the polyisocyanurate foam eventually catches fire and decomposes, it too will produce steam. At this point a runaway sequence of steam reacting with increasingly hot aluminium can begin and the fire will accelerate out of control.

It is counter-intuitive that water should exacerbate the situation and, of course when the fire brigade hosed the building, the fire was quenched. This is because, in that case, that amount of water was such that its cooling properties overwhelmed the fire. However, production of steam from the wet inner cladding as the building fire built up in intensity could occur at such a rate that it would feed the fire rather than quenching it. Moreover, as steam, it would not absorb heat of vaporization (the energy required to go from a liquid to a gas at its boiling point), a significant factor when water quenches a fire.

When provided with both types of cladding materials by BBC South’s “Inside Out” team, I was able to demonstrate that a block of the polyisocyanurate foam could be made to absorb up to its own weight of water, and readily absorbed almost 10% of its weight by merely soaking in cold water overnight. I was also able to demonstrate that heating panels of the outer cladding with a blow-torch caused the paint surface to burn off and the aluminium to glow red hot, but aluminium is a very good conductor of heat and the heat was largely conducted away from the heated area. However, when a fine spray of water was applied to the hot aluminium, a violent reaction occurred producing flames, destroying the aluminium surface exposing the polyethylene inner layer and causing it to burn. On one occasion, the reaction was so violent that it burned right through the cladding, consuming both sides of aluminium coating and the polyethylene within.

In conclusion, it is my firm belief that the presence of water absorbed by the polyisocyanurate foam, over a lengthy period of exposure to the elements, played a significant role in accelerating the Grenfell fire by causing the aluminium in the outer cladding to react violently at relatively low temperatures, generating heat and hydrogen, the latter then burning violently to produce more heat and steam. This would then allow the polyethylene inner layer to be exposed over a large surface area, in turn burning to produce more heat and more steam, setting up a feedback loop and causing a runaway fire.

This would also explain why weathered cladding subsequently removed from other buildings has consistently failed fire retardant testing. Ingress of water into the inner cladding could have been significant in other similarly fabricated high-rise building fires and even in fires that have occurred on warships with aluminium superstructures such as SS Belknap (1975) and HMS Amazon (1977) – despite a UK Defence White Paper and a Ministry of Defence Working Party review of ship design (1982) finding that ‘Where the balance is in favour, aluminium should be used in warships or elsewhere.’ In these inquiries, it would seem that the affect of sea spray on hot aluminium was not taken into account.

I am at the disposal of the Inquiry Committee should you require further information.

Yours sincerely.

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Professor Laurence Harwood

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**Addendum - background information**

The Grenfell Tower was clad in a combination of a thick layer of polyisocyanurate foam to act as insulation and an outer layer of aluminium-polyethylene composite; the latter to provide mechanical protection, to prevent significant water ingress and to provide a cosmetic finish.

Polyisocyanurate foam, also referred to as PIR, polyiso, or ISO, is a [thermoset](https://en.wikipedia.org/wiki/Thermosetting_polymer) plastic used as rigid thermal insulation. Its chemistry is similar to [polyurethane](https://en.wikipedia.org/wiki/Polyurethane) (PUR) except that the proportion of [methylene diphenyl diisocyanate](https://en.wikipedia.org/wiki/Methylene_diphenyl_diisocyanate) (MDI) is higher and a [polyester](https://en.wikipedia.org/wiki/Polyester)-derived polyol is used in the reaction instead of a [polyether](https://en.wikipedia.org/wiki/Polyether) [polyol](https://en.wikipedia.org/wiki/Polyol). Catalysts and additives used in PIR formulations also differ from those used in PUR. Dibondaluminium composite panelsfeature two thin (*ca.* 0.5 mm) sheetsof aluminium enclosing a polyethylene core (*ca.* 1 mm).

Aluminium is an extremely light, soft, non-magnetic, ductile metal with very good thermal and electrical conductivity. Aluminium makes up about 8% of the Earth’s crust by mass and is the most abundant metal in the crust. Yet, aluminium metal is so chemically reactive that it is not found naturally as the free metal, but is found in over 270 different minerals, most notably the aluminosilicates (clays). The [ore](https://en.wikipedia.org/wiki/Ore) now used for commercial aluminium production is bauxite.

Oersted was reputedly the first to isolate impure aluminium in 1825, but Wohler is usually credited with isolating the pure metal in 1827. However, it was not until Hall in the United States and Heroult in France separately produced metallic aluminium by electrolysis of molten cryolite in 1886, that aluminium became readily available. Prior to that date, aluminium was more expensive than gold and reputedly Napolean III ate off aluminium plates; whereas his guests ate off gold plates.

Although chemically highly reactive and extremely energetic, aluminium is able to resist [corrosion](https://en.wikipedia.org/wiki/Corrosion) through a phenomenon termed “passivation”. Pure aluminium rapidly forms a thin, coherent and impermeable oxidized surface layer on contact with the atmosphere. Although so thin as to be invisible (and so the aluminium retains its metallic lustre) this creates a physical barrier to any further reaction under most conditions. Therefore, although aluminium is *thermodynamically* *unstable*, it is *kinetically* *stable*. In other words, although it should not exist as the free metal under environmental conditions, there is an energy barrier preventing it reacting due to the protective oxidized layer surrounding it. If this layer is broken, the natural reactivity of aluminium can express itself.

Bulk aluminium does not readily burn in dry air. When the temperature exceeds its melting point (660 oC), the aluminium melts, but does not burn. Com­bus­tion of bulk alu­minium in air does not occur at tem­per­a­tures be­low about 1850 °C. Such extreme temperatures are not likely to be attained in a building fire.

However, aluminium reacts violently (*exothermically*) with [water](https://en.wikipedia.org/wiki/Water), particularly at temperatures above about 280 °C, to produce hydrogen, aluminium hydroxide and heat; for example:

2 Al + 6 H2O (g) → 2 Al(OH)3 + 3 H2  (g) – 852 kJ

This reaction has been considered as a possible means for the production of hydrogen as a fuel for large vessels (US Department of Energy, feasibility document, 2008).

The hydrogen produced will then immediately ignite, producing even more heat and water as steam:

 2 H2 (g) + O2 (g) → 2 H2O (g) – 572 kJ

The water can then re-enter the cycle. Furthermore, any water produced, as steam, by burning organic material, such as the polyethylene inner layer or the polyisocyanurate foam, would also contribute to the cycle, reacting with more aluminium and causing a runaway fire. The aluminium acts as a fuel.