OPERATION NORTHLEIGH

GRENFELL TOWER
BUILDING MANAGEMENT SYSTEM

REVIEW FOR METROPOLITAN POLICE

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REVISION HISTORY

Revision	Date	Description	Authored	Verified
000	20/04/2018	First Issue	Kevin Harnett	Harry Lees
001	26/04/2018	2nd Issue post WSP review	Kevin Harnett	Harry Lees
002	16/05/2018	Amended with BRE comments	Kevin Harnett	Harry Lees

PREFACE

PURPOSE OF THIS DOCUMENT

This document is the final report detailing the findings of a review of the Building Management System (BMS) at Grenfell Tower, London.

It has been written following various site surveys and subsequent examinations of the BMS equipment retrieved from the site.

GLOSSARY OF TERMS

AOV	Automatic Opening Vent. Part of the Smoke Extract system and located in the lift lobbies on each residential floor, consisting of motorised dampers linked to, and controlled by, the fire and smoke extract system. Four per floor. The BMS had no direct control of the AOVs.
BMS	Building Management System (see page 9 for an outline of this particular system).
Hard-wired	Interlocks between devices or items of plant which rely solely on electrical cabling and not any form of software controlled microprocessor. These are considered the most reliable and safe method of achieving safety related interlocking (such as fire, gas shutdown, emergency stop etc.).
IQF	A type of file used in older Trend Outstations before the invention of SET.
MCC	Motor Control Centre. Usually a wall mounted or floor standing steel cubicle containing controls and switchgear relating to mechanical plant such as boilers, fans and pumps.
O&M Manual	Operating and Maintenance instruction manual usually containing all relevant technical advice on design, procurement, operation, and maintenance of the plant and associated systems.
Outstation	A microprocessor-based control device which provides the facility to accurately control plant such as boilers, pumps, fans, lights and security systems in response to changing conditions such as time, temperature and light levels.
SET	System Engineering Tool. A software application provided by Trend Control Systems by which software for their BMS hardware can be designed, managed (uploads/downloads), edited and documented.

CONTENTS

INTRODUCTION

Following the serious fire at Grenfell Tower on 14th June 2017, as part of their criminal investigation, the Metropolitan Police asked WSP to review the Building Management System (BMS) in order to determine whether it played any part in the catastrophic events. Due to the technical nature of the type of equipment that forms a BMS, WSP employed the expertise of Accurro Ltd to assist them with the technical and specialist parts of the review.

PERSONNEL AND ROLES INVOLVED

WSP (Building Services Consultants)

Andrew Bickerdyke	Project Director
Paul Sheridan	Associate

Accurro Ltd (Controls and Building Management Systems Consultants)

Chris Smith	Director and office-based Project Lead
Harry Lees	Director and Project Assistant
Kevin Harnett	Site Project Lead and author of this report
Gordon Lester	Site Project Assistant
Matt Gee	Software Specialist

OVERVIEW

Due to the technical nature of Building Services and the wide range of disciplines across which services are spread, a large number of specialists are involved in the investigation. At our initial meeting on 16 January 2018, the Metropolitan Police asked us to limit our review to the following areas:

- BMS operation and logging/alarm logs
- Cabling, disconnections, overrides and isolations
- BMS Design
- Smoke Extract System (BMS links only)
- Fire Alarm (BMS links only)
- Gas Safety/Shutdown

It is understandable that there are a number of overlaps between disciplines and, following subsequent meetings, it became obvious that specialists in other fields were investigating all but the top three items above. This report is therefore limited to those topics, and where overlaps to the other disciplines exist, we have detailed the limit to which the BMS was involved.

Due to the technical nature of Building Management Systems, this means that parts of this report also have technical content.

EXCLUSIONS

We have specifically excluded any detailed references to the following items because they do not fall within our remit, nor are they within our field of expertise.

- Fire alarm
- Automatic Opening Vents (AOVs)
- Lifts
- External Cladding
- Windows
- Structural

DOCUMENTS RECEIVED

The following documentation was issued to us by the Metropolitan Police:

1.0 Mechanical O&M Manual.pdf - received 18/01/2018
Test Sheets (6 documents) - received 26/01/2018
Strategy Drawings (2 Trend SET documents) – received 26/01/2018
Drawings (2 documents Basement and Roof panels) – received 26/01/2018
Data sheets (Manufacturer's mechanical equipment standard data) – received 26/01/2018
Grenfell Tower Des Ops Issue 3 – received 26/01/2018

See Page 14 for observations made during our review of this documentation.

BMS AT GRENFELL TOWER

The term Building Management System (BMS) is a loose term often linked with the manufacturers of controls equipment, and not necessarily with the specific function or usage of the equipment on a particular project. In the case of Grenfell Tower, the BMS (manufactured, but not installed, by Trend Control Systems Ltd) was predominantly a heating and hot water boiler control system (located in the basement), with some additional cold water storage tank monitoring and limited ventilation control (located at roof level). It appears that the overall system was installed in two phases. The original first phase, for which no documentation has been received, related to the old boiler system. Documentation suggests that the system may have been partially redundant at the time of the incident although this could not be verified. The date of the original installation isn't known but at this time, the system consisted of a single outstation.

The second, more recent phase, is documented as being certified on 15/01/2016, and controlled the new boilers and associated equipment feeding heating and hot water to the flats. At this time, an additional outstation was added at basement level. The Trend SET files show minor subsequent modifications being undertaken later, the last being on 15/03/2016. This was confirmed from the software retrieved from the basement outstation.

In addition to the basement boiler room, a further BMS outstation was located on the roof and provided monitoring for cold water storage tanks and limited normal ventilation control via the AOV/Smoke Extract system. The system appears to have had no local supervisory PC (usually Trend 963) although locally installed modems suggest it may have been accessible from a remote location for monitoring purposes only. It can be determined by the alarm addresses set in the BMS Outstations however, that no data were sent to any remote location. For local interrogation, alarm monitoring, or adjustment of system variables such as temperature set points, a Trend IQView8 was provided on the facia of the basement control panel.

System Outstations

Basement IQ250 Outstation L000O11 (original boiler control system)
Basement IQ3Xcite Outstation L000O50 (refurbishment boiler control system)
Roof IQ3Xcite Outstation L000O56 (refurbishment CWS tank monitoring and ventilation)

Apart from one digital output to the ventilation system sent via the BMS network from the basement, the roof outstation was for monitoring purposes only and can therefore be excluded from any building control influence.

RECORD OF BMS SURVEY WORK

Numerous surveys were undertaken, both on site at Grenfell Tower, and later at the Lambeth Forensic Laboratory. A full log of these surveys and their objectives can be found in Appendix 10 on Page 22. The surveys resulted in the information given in this report. Whilst there were obvious signs of water damage to the BMS equipment in the basement, and heat damage to the BMS equipment on the roof, this did not prevent us significantly from obtaining sufficient information about the system.

Basement BMS Outstations

Basement IQ250 Outstation L000O11 (original boiler control system)
See Appendix 7 on Page 19 for photographic evidence.

Although the basement partially filled with water from firefighting during the incident to a depth of approximately 700mm, this outstation was mounted above the waterline and was therefore undamaged.

However, it was only possible to extract a Trend IQF file from the device and although there was no documentation against which to compare the device, it is believed that it was largely redundant as it controlled the original boiler system which was later superseded.

Basement IQ3Xcite Outstation L000O50 (refurbishment boiler control system)
See Appendix 8 on Page 20 for photographic evidence.

This outstation was mounted at the bottom of the new MCC and was therefore completely immersed by water for a period of time (unknown). However, after a careful cleaning and drying out process, the Outstation powered up successfully and its data was successfully retrieved. Where relevant, those findings are detailed later.

Roof BMS Outstation

Roof IQ3Xcite Outstation L000O56 (refurbishment CWS tank monitoring and ventilation)
See Appendix 9 on Page xx for photographic evidence.

Apart from one digital output to the ventilation system sent via the BMS network from the basement, this outstation was for monitoring purposes only and had no control functions. It can therefore be excluded.

BMS LINK TO THE VENTILATION SYSTEM

The documents state that the smoke extract system had a dual function in addition to operation during a fire alarm, it being used for normal lift lobby ventilation to limit high space temperatures (i.e. environmental control only). This was confirmed from the surveys and software retrieved from the system.

The BMS monitored the space temperatures of lift lobbies on floors Ground, 5th, 10th 15th and 20th, and if the average temperature was greater than 25°C between the hours of 09:00 and 20:00, a single hard-wired "RUN" signal was sent to the Smoke Extract System to open all the AOVs and run the fans for ventilation. It is assumed that the ventilation run signal would have been overridden by the Smoke Extract system in the event of a fire, although there is nothing in the BMS documentation to confirm that.

As this single link was the only connection between the two systems, we have not considered it further.

BMS LINK TO THE AOVs

There was no direct link shown in the documentation between the BMS and the AOVs except that when signalled to run for lobby temperature limiting ventilation, the Smoke Extract system would have opened the AOVs and started the fans. This was confirmed from the surveys and software retrieved from the system.

As this single link is the only connection between the two systems, and should have been overridden in fire mode, we have not considered it further.

BMS LINK TO THE LIFTS

There was no link shown in the documentation between the BMS and the Lifts. This was confirmed from the surveys and software retrieved from the system.

BMS LINKS TO THE FIRE SYSTEM

The documents show the BMS having a hard-wired link (i.e. not software dependent) with the Fire System in order to shut down boiler plant in the event of a fire. The signal should have also shut down the gas supply into the boiler room by means of the gas solenoid valve. This is standard practice.

However, the fire alarm shut down facility on the new MCC panel (terminals 10/11) was found to be linked out (see Appendix 1 photo). No fire alarm interface was evident and it looked as if there had never been an interface installed or connected.

The fire alarm shut down facility on the old original MCC was identified by tracing the gas valve interlock from the new MCC (terminals 12/13 - see Appendix 1 photo) to the original MCC terminals 112/113 (see Appendix 2 photo). In turn, this allowed us to identify the electrical connections to the gas solenoid valve and the associated safety circuit within the old MCC (for which no drawings or documentation have been found so far). It was established that the fire alarm shut down facility on the old panel was also linked out (terminals 200/201) and had probably never been fitted (see Appendix 3 photo). No fire alarm interface or associated cabling could be found.

It was confirmed that the safety circuits, including emergency stop buttons at entrances and thermal links above the new boilers, would probably have been operable. The gas solenoid valve could only have been closed by operation of one of these devices, or by power failure caused by water ingress during the fire incident. The control transformer secondary control circuit fuse was found to be blown. This could have been the reason the valve eventually closed. See also Page 13 Alarm Logs and Appendix 6.

The gas solenoid valve status in the new MCC (terminals 14/15) was connected to the 230VAC supply to the gas valve so would not have given a positive positional feedback, but would have indicated whether the valve was powered. Further interrogation of the BMS outstation software (SET) confirmed that there was no software interlock between the Fire System and BMS that would have shut the gas valve.

The direct interconnections between the BMS and Fire Alarm system (terminals 234-243 inclusive) were identified and found to be connected. These were software dependent. The signal entitled "FA-CP Fire Alarm Active" was configured in software to shut down the boilers but could not have closed the gas valve (see Appendix 5 – SET drawing excerpt). However, this point did not appear in the alarms log (see Appendix 6 on Page 18) so may not have operated at the time of the fire. This cannot be determined.

Note: The gas solenoid valve referred to above, supplied gas to the basement boilers only. It did not connect to any of the flats.

However, the BMS Contractor's commissioning sheets show the BMS points relating to the fire system link and also basement gas safety detection highlighted in "red" (the rest being highlighted in green) which might suggest one of the following:

1. The signals were not connected at the time of commissioning.
2. The signals were connected but not commissioned.
3. The signals were connected and commissioned by the BMS engineer but not possible to prove from the Fire System side for some reason.
4. The signals were commissioned at a later date after the certification was issued/completed.

5. Some other reason not listed above.

Subsequent investigation of the outstation software in the SET file showed at least one of the links being operational around the time of the fire (FP-CP Critical Fault). See Alarms Log on Page 18. Note that this alarm is a panel fault, not a fire alarm (assuming they were correctly configured).

The roof BMS panel was inspected and the fire alarm shutdown facility (terminals 10/11 – see Appendix 4 photo) were found to be linked out with no fire system interface evident. This should have been present in order to stop the normal ventilation software, but as the "vent run" signal was sent via the BMS network to the Basement MCC, the fire alarm shut down could have been provided in the basement had it been fitted (which it was not).

BMS SOFTWARE / SET

Of the three Trend outstations installed on site encompassed by the BMS, the primary outstation was new Outstation 50 located in the most recent basement MCC panel. This controlled the new boiler plant, and the environmental ventilation control link to the AOVs and smoke extract fans for lift lobby temperature limiting only.

Although this outstation was submerged in fire-fighting water for a period of time during and after the fire, it was removed from site, dried out, and revived to a state where it powered up and could be interrogated with some success. The SET file was extracted and the alarm log was possible to view whilst connected to the outstation via a PC. Unfortunately, it's internal timeclock had not retained real time (see also Alarm Logs below).

A paper copy of the SET file from the original O & M Manual was issued by the Metropolitan Police. This was compared to the version extracted from the outstation removed from site, and the software, to all intents and purposes, was confirmed as being the same. This means that all statements made in this report related to documentation, correlate to the working software version in the outstation.

As the outstation was predominantly a boiler control system, and five floors below the fire, its influence on events was insignificant.

ALARM LOGS

Whilst connected to Outstation 50 (primary basement boiler controller) after it had been retrieved from site and revived, it was possible to read the alarm logs. Each alarm contains a date and time stamp, a label of the alarm, and relevant alarm data such as temperature or input status. Although there were in excess of 300 historical alarms recorded, only the last few were of any relevance. Unfortunately, it would appear from the time stamps, that the internal time clock had not been properly set because the last alarm was at 06:27 on 15/06/2017 (i.e. 24 hours after the fire was at its height). This is clearly not possible so any alarm log information is of little use.

An extract of the alarm logs is shown in Appendix 6. The only fire alarm system related log is "FA-CP Critical Fault". This is not a fire alarm. It is a panel fault which may have been sent as

the system was about to fail (assuming it was working properly at all). Note: the point entitled "FA-CP Fire Alarm Active" was never sent which raises doubt as to whether the system was properly operational. Even if it was, its only action would have been to shut down the boilers and associated pumps (not the gas valve).

DESIGN AND WORKMANSHIP

Whilst it is difficult to give precise details of design and workmanship standards, the entire project had an air of poor design and implementation standards, shortcuts or oversights.

An example of this is the failure to directly link the BMS and mechanical plant to the fire alarm system via a hard-wired interlock. Whilst the BMS Contractor had left provision for the interlock within their MCC panel, it had never been installed.

OTHER OBSERVATIONS / AREAS OF CONCERN

In the course of our investigation, although not directly within our scope, we feel we have a responsibility to highlight anything which raised concern. Other experts are bound to have raised these issues, but the following were the most notable:

1. Page 7 of the O&M (Smoke Control Ventilation) states that new fans were installed as part of the smoke extract system. Were these, and the overall system, properly commissioned and were they regularly tested?
2. Page 7 of the O&M (Smoke Control) states that "it is not viable to adapt the existing building to comply with current standards". Was this agreed and approved by the Professional Team/District Surveyor?
3. It would be normal for damper actuators on AOVs to spring to a fail-safe position in the event of a fire alarm (probably closed in this situation in order to prevent spread of fire and/or smoke between floors). The actuators fitted (Belimo BLE24) have no springs.
4. Pages 810 to 913 of the O&M outline the operation of the Smoke Extract System. However, the document reads more like a specification of what should be installed, rather than an account of what was installed. Was the system installed, commissioned and certified in line with the document, and was it regularly tested? The description of operation also describes how the system should be operated by the Fire Brigade. Was there any report of this being possible?
5. During our site visits, it was mentioned that there is a total of 3 gas main supplies into the building. Our report only refers to the one supply feeding the boilers only. Its manual isolation valve was situated at least 5 meters from floor level in the basement and totally inaccessible without special access equipment. Did the other two gas supplies exhibit similar problems?
6. For all buildings containing a certain number of occupants (say 10?), whether that be flats, domestic, commercial, industrial, or a hotel, we feel there should be enforced legislation that ensures that emergency gas shut-off solenoid valves are fitted and linked to the fire alarm system. This should include all buildings regardless of whether they are old, new, existing, or refurbished.

7. It was noted that new gas main pipework had been installed throughout the building to each flat. However, none of the pipes had been fire-stopped where they pass through floors and/or walls.

8. Both lift cars were stuck on the 10th Floor. It is normal practice for lifts to be linked to the Fire Alarm system, and to ground in the event of an alarm. It would appear that this didn't happen either because they weren't linked, or because the link didn't operate (or the Fire System didn't operate).

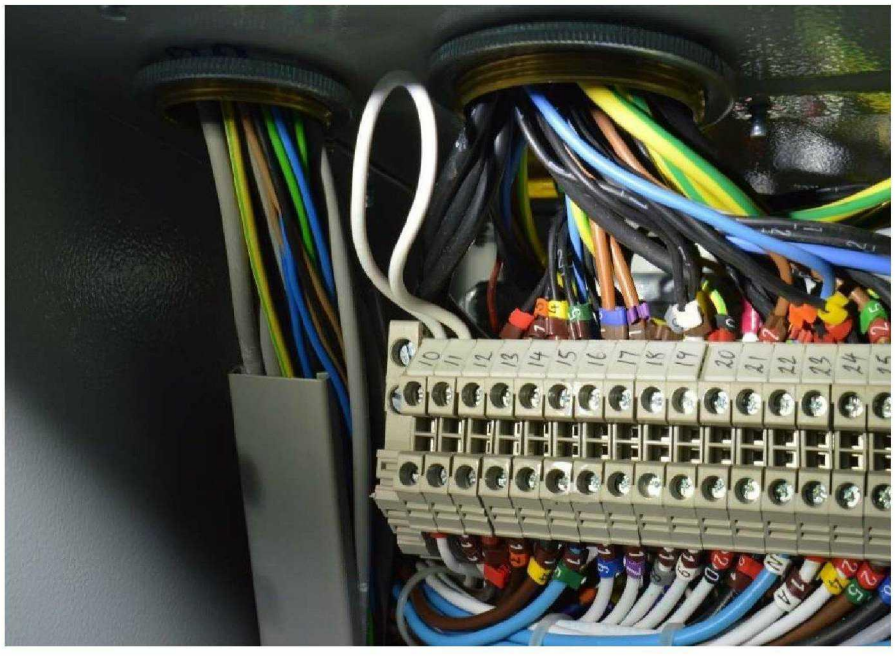
9. It was noted that the one and only staircase in the building was extremely narrow and, by today's standards, inadequate to be classed as a means of emergency escape for hundreds of people.

CONCLUSION

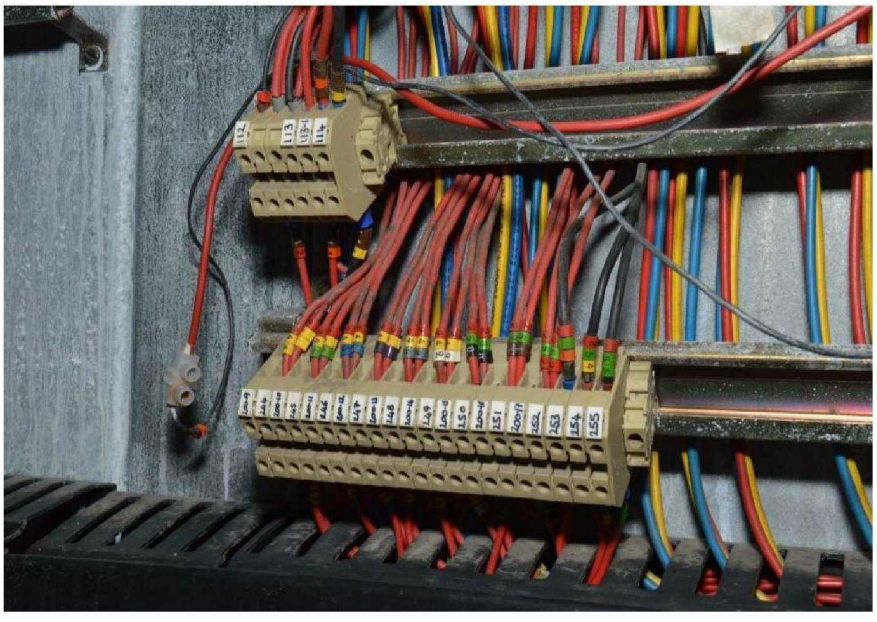
As stated previously, whilst there were numerous design and implementation issues with the BMS and associated plant, the system was essentially a boiler control system. As such, it is our opinion that none of our findings would have been responsible for, or even linked to, or have exacerbated the incident, the fire, or the loss of life.

APPENDICES

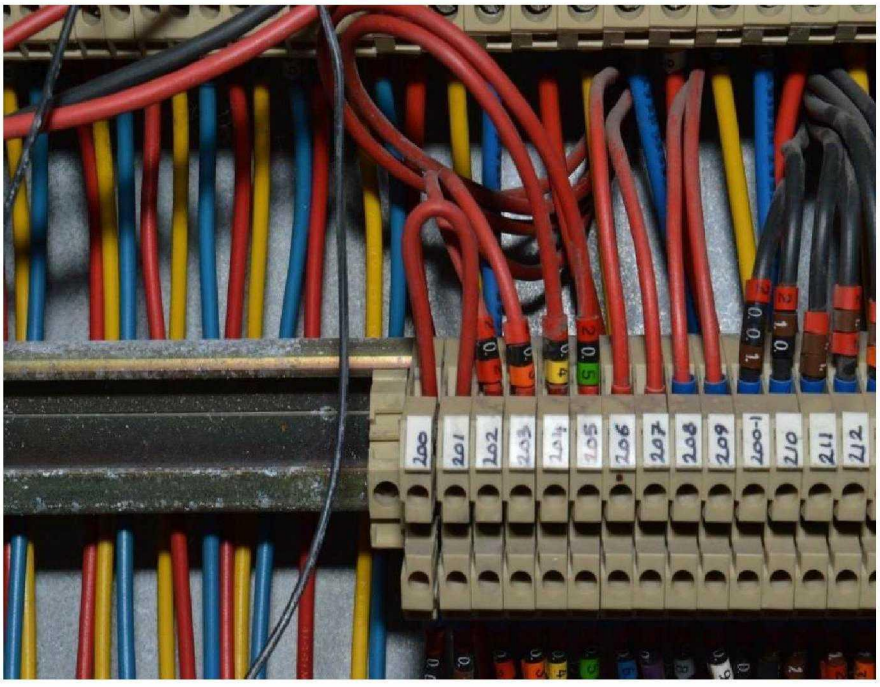
Appendix 1 – Refers to Page 12



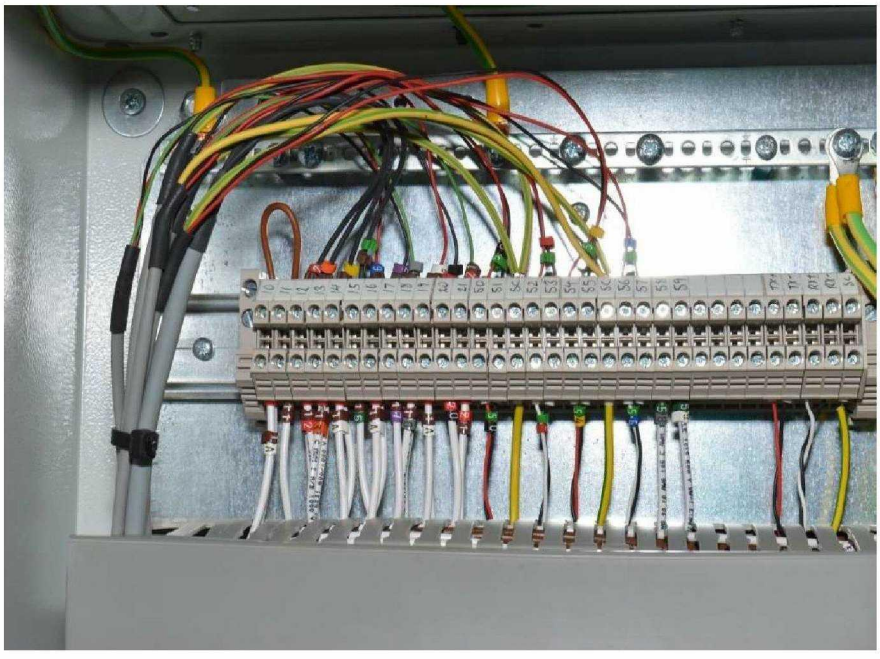
Appendix 2 – Refers to Page 12



Appendix 3 - Refers to Page 12

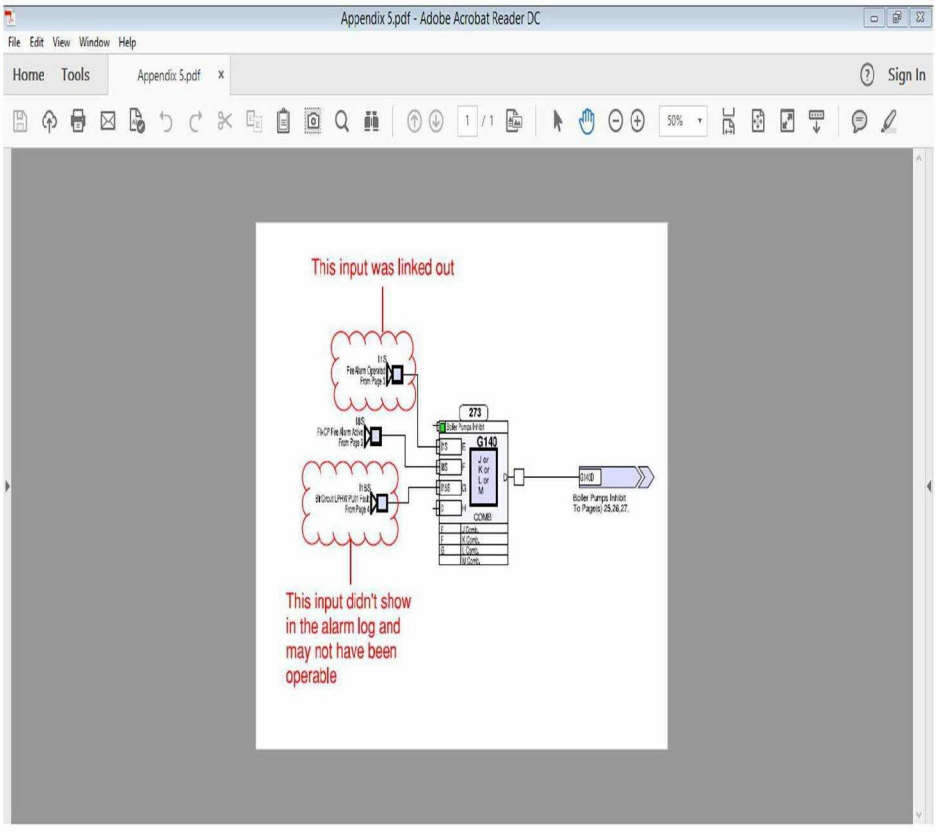


Appendix 4 - Refers to Page 13



Appendix 5 – refers to Page 12

SET excerpt



Appendix 6 – Refers to Page 13

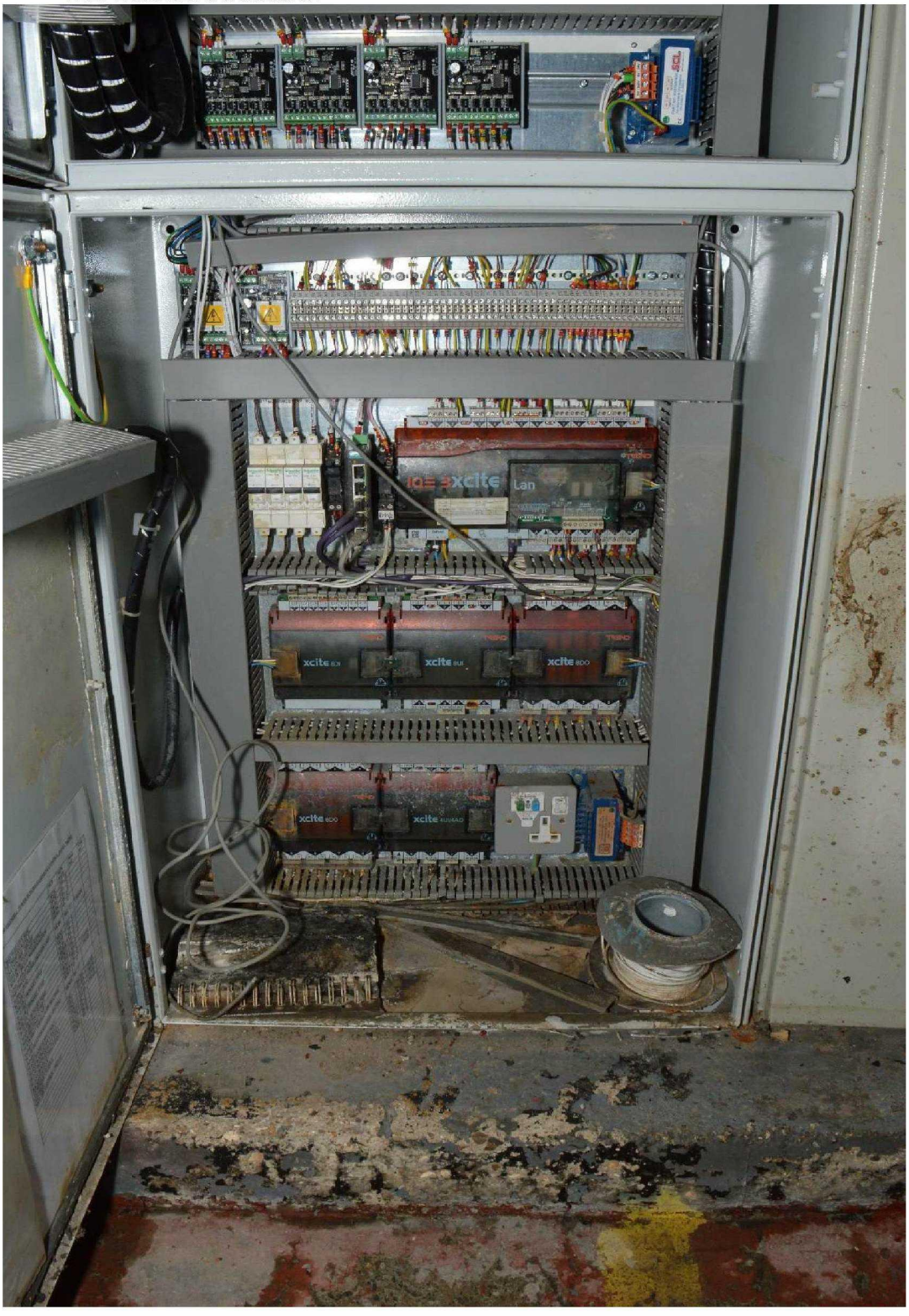
Alarm Log - Note the time stamps suggest the Outstation time clock was incorrect

Trend Ref	Date	Time	Label	Alarm	Value	Notes
V296	14/06/2017	13:29:29	Gas Valve	Alarm clear	Not Closed	
V32	14/06/2017	13:39:23	Gas Valve	Alarm	Closed	
V29	14/06/2017	13:40:30	Gas Valve	Alarm clear	Not Closed	
V19	15/06/2017	05:24:34	Fire Alarm-Control Panel	Critical Fault	Alarm	This is a panel fault, not a fire alarm
V10	15/06/2017	06:07:08	5th Floor Space Temperature	Out of limits	57.99°C	
V9	15/06/2017	06:27:08	5th Floor Space Temperature	Out of limits cleared	43.57°C	
V8	15/06/2017	06:27:10	5th Floor Space Temperature	Out of limits	76.29°C	

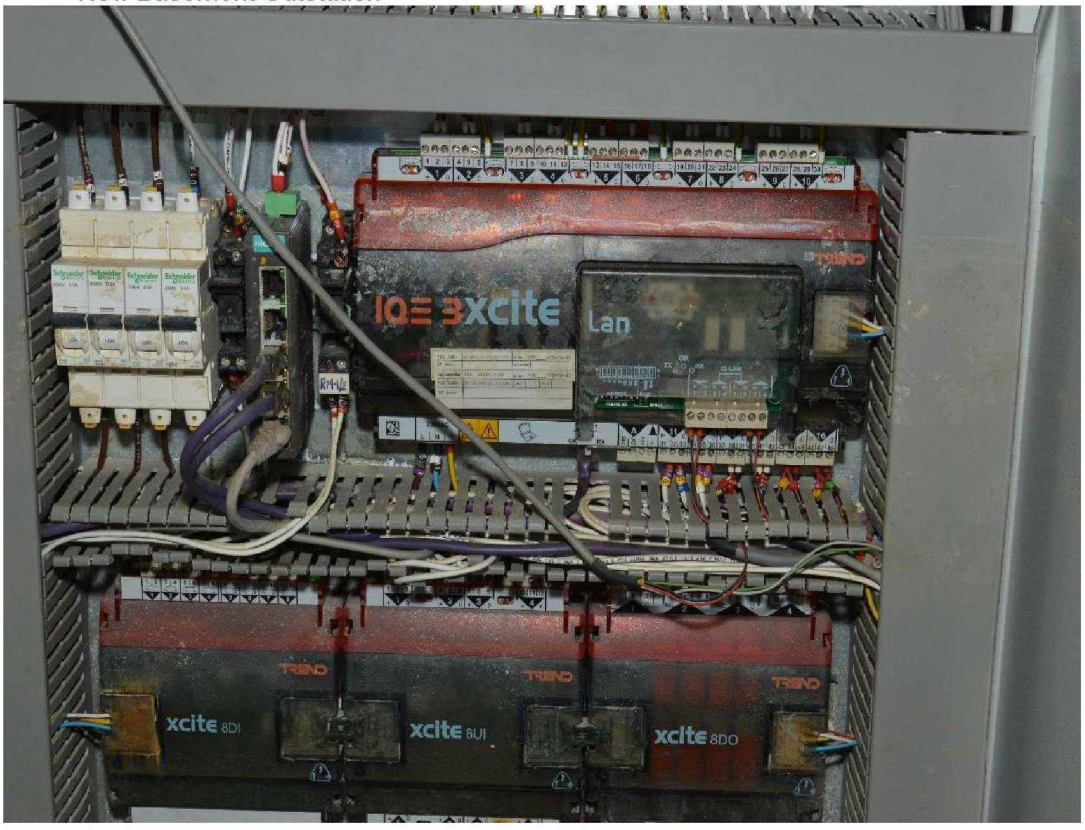
Appendix 7 – Refers to Page 10.
Original Basement IQ250 Outstation

Redundant boiler system MCC housing IQ250 outstation

Appendix 8 – Refers to Page 10.
New Basement Outstation



Appendix 8 continued
New Basement Outstation



Appendix 9 – Refers to Page 10
Roof Outstation

Appendix 10 – Survey Log – Refers to Page 10.

Date	Task	Where	Comment
20/12/2017	Initial pre-order Grenfell site visit.	Grenfell	
16/01/2018	Site introduction and initial survey. Verbal scope briefing provided by Met Police.	Grenfell	Initial visit to site, mask fitting and introduction meeting. Tour of building main core, basement plant room and roof plant room.
18/01/2018	Initial Mechanical O&M documentation received (see Documents Received - Report Page 8)	Office	Internal report only - summarised in this report.
22/01/2018	Review of Mechanical O&M documentation	Office	Internal report only - summarised in this report.
26/01/2018	Further site documentation received (see Documents Received - Report Page 8)		Internal report only - summarised in this report.
29/01/2018	Meeting at WSP	Holborn Office	Discussed initial findings from Mechanical O&M review. Agreed a way forward to confirm the scope of works covered by third parties and ourselves.
31/01/2018	Review of further site documentation (see Documents Received - Report Page 8)	Office	Internal report only - summarised in this report.
02/02/2018	Site survey and removal of BMS hardware	Grenfell	The two basement and one roof controllers were photographed and then removed to the site portacabins. Basement panel safety circuits traced and confirmed. Any cable links noted and photographed. See Appendix 7 for photographs of controllers.
05/02/2018	Inspection and cleaning of IQ3Xcite controller.	Grenfell	Met with Rob Jones of the MET Police. The controller was physically dismantled by removing it from its plastic case and dismantling the three circuit boards. Each board was brushed down to remove any debris and then brushed with a wet brush to remove any stubborn debris. Distilled water was used for this process. The boards were then dabbed dry with paper towels and then placed in a sealed plastic box that contained two 500g bags of Silica Gel.

(cont.)

Date	Task	Where	Comment
06/02/2018	Outstation Strategy Extraction	Grenfell	To extract the control strategies from the Roof Plant Room IQ3xcite and the Basement Plant Room IQ250. Met with Rob Jones (MET Police Senior Digital Forensic Specialist) **Roof IQ3xcite controller.** The control strategy was saved and viewed. The only points of interest were the space temperature sensors. There were time stamped alarms in the alarm log. The first relevant alarm on the day was a High temperature alarm on the 20th floor. The time stamp on this alarm was "01:38:20 14/06/17 when the temperature reading was shown at 74.44DegC. **Basement IQ250 controller.** Only a strategy IQF file was extracted. We were unable to obtain a strategy SCAN file, so unable to view the alarm log via the system view in the Trend SET software. Points of interest. Digital Input 1 - "Gas valve open" Digital Inputs 8 -10 Boilers 1-3 "Boiler Gas booster fail" Digital Input 31 "Fire Alarm" (linked out) All controllers were later removed to Lambeth Forensic Laboratory for safe storage.
08/02/2018	Controller File download, checks and reviews.	Office	Strategy extractions from the Basement IQ250 and the Roof IQ3xcite reviewed.
28/03/2018	Outstation Strategy Extraction	Lambeth	**Basement IQ3Xcite controller.** The control strategy was saved and viewed. The alarm logs were inspected and recorded where relevant.
17/04/2018	Re-check of Basement Controller alarm log	Lambeth	The alarm log of the Basement IQ3Xcite controller was reviewed once again to try and ascertain the amount of time shift on the time stamps. No better data found.
20/04/2018	Final report (Rev 0)	Office	Internal report and peer checking.
26/04/2018	Final report (Rev 0)	Office	Issue of final report (Rev 0)
17/05/2018	Amend Final Report (Rev 1)	Office	Issue of amended report (Rev 1)

END OF DOCUMENT