Grenfell Tower

Smoke Ventilation Analysis

Rev A

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MAX FORDHAM

GRENFELL TOWER – SMOKE VENTILATION ANALYSIS

1 Summary

This report has been prepared in order to compare the design performance of the existing smoke extract ventilation system in Grenfell Tower with the design performance of the new system proposed as part of the refurbishment works.

It has been found that the proposed upgrade to the system should result in a considerable performance increase:

Existing System 1.1 – 1.2 m^3/s

Proposed System 5.0 m^3/s

Note: *Please note that this report should be read in conjunction with attached Max Fordham drawing U[14]01_200 (rev T2) 'Core Services Smoke Ventilation Schematic'.*

2 Existing System

The existing smoke extract system in Grenfell Tower consists of the following elements:

- 2x natural ventilation supply shafts of 0.24 m^2 area each, with 2x low level smoke dampers of 0.18 m2 area each. These serve floors 1-20 (residential floors only). Inlet at Walkway +1 level.
- 2x natural ventilation extract shafts of 0.24 m^2 area each, with 2x high level smoke dampers of 0.18 m2 area each. These serve floors 1-20 (residential floors only). Outlet at roof level.
- Manual fireman's override switch located in dry riser inlet cupboard on ground floor allowing control of mechanical supply and extract run and standby fans. Supply fans located at Walkway +1 level, extract fans located in roof top plant room.

The existing system operates in the following manner on detection of smoke within a communal lobby:

- Actuators open supply and extract dampers on fire floor upon receiving signal from smoke detector outstation. All dampers on other floors remain in closed position.
- Smoke is cleared by the stack effect in the extract shaft caused by the pressure differential arising from the temperature difference between the hot smoke and cooler external air temperature.
- Make-up air is drawn through the low level supply shaft.
- The supply and extract fans do not operate unless the manual override switch is operated by the fire brigade upon their arrival. This switch opens smoke dampers local to both fan sets and activates the fans to enable mechanical ventilation to aid smoke removal. This switch is located on the ground floor adjacent to the dry riser inlet breaching valve and controls the fans only.

The existing shaft dimensions are considerably less than those demanded for a natural smoke extract system in a new building by Approved Document B:

	Existing System	Approved Document B
Vent between lobby and shaft free area (m^2)	0.36	1.00
Shaft free area (m^2)	0.48	1.50

Table 1 - Comparison of Existing Free Area with Approved Document B

3 Proposed System

The proposed new smoke extract system will provide automated mechanical smoke ventilation in the event of a fire, as well as providing general ventilation to the communal lobbies in day to day use.

The system is constrained by the existing shaft dimensions. For this reason an automated mechanical system has been chosen in order to protect the escape route through the lobby to a higher standard than currently provided by the natural ventilation based system.

The proposed system will consist of the following elements:

- Retention of existing supply and extract shafts, and openings between the shaft and lift lobbies.
- New automated motored smoke dampers for supply and extract shafts.
- New smoke detectors and associated control outstations.
- New uprated 600 mm diameter supply and extract fans for smoke clearance sized to provide a balanced flow rate of 5 m^3/s.
- New general ventilation supply and extract fans separated from the smoke shafts in the event of a fire by new smoke dampers.

The proposed system will operate in the following manner on detection of smoke within a communal lobby:

- General supply and extract fans switched off, motored smoke dampers local to these close.
- Motored smoke dampers on supply and extract shafts on fire floor fully open.
- Smoke dampers on all other floors motor closed.
- Smoke clearance supply and extract fans operate autonomously to maintain safety of the escape route.
- Fireman's override switches will be provided within each lobby to control the fans on/off and the local smoke dampers open/closed.

4 Performance Comparison of Existing System versus Proposed System

The system currently installed in Grenfell Tower is by default a natural ventilation system. It can be overridden by the fire brigade to provide mechanical assistance if required but this involves a manual intervention.

Natural Ventilation Mode
Natural ventilation based smoke clearance systems depend on the stack effect caused in the extract shaft due to the pressure differential arising from the temperature difference between the hot smoke and cooler external air temperature. The flow rate achieved depends on the following factors;

- The height of the stack; i.e. the distance from the lobby extract vent to the roof top vent.
- The temperature of the external air.
- The temperature of the extracted air; i.e. smoke in the case of a fire.
- The cross sectional area of the shaft.

These factors can be used to calculate the flow rate as follows;

$$Q = CA\sqrt{2gh\,\frac{T_i - T_o}{T_i}}$$

Where;

Q	Flow rate	m^3/s
C	Discharge coefficient	0.61 *(based on a sharp edged rectangular opening)*
A	Flow area (shaft area)	0.48 m^2
g	Gravitational acceleration	9.81 m s^{-2}
h	Stack height (shaft length)	5.0 m
T_i	Internal temperature	473.15 K *or* 353.15 K
T_o	Outside temperature	301.15 K

For the purposes of this comparison the worst case condition is to be considered. This would be where the temperature differential between the smoke to be extracted and the external air is at its lowest and the height of the stack is the shortest possible distance. In this case, this occurs when the fire is at the highest floor during a summer's day of 28 °C.

Two smoke layer conditions are to be considered; the first is a high temperature layer of 200 °C, the maximum allowable temperature above an escape route. The second is perhaps the more typical case of a lower temperature smoke layer of 80 °C associated with the dispersal of smoke from a fire in an adjacent space.

The results are;

Q = 1.75 m^3/s @ 200 °C *(473.15 K)*

Q = 1.11 m^3/s @ 80 °C *(353.15 K)*

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Manual Override Mode

Although this is not the default mode of operation upon detecting a fire, a comparison between the existing mechanical system and the proposed automated system will ensure that smoke clearance conducted by the fire brigade is not impaired.

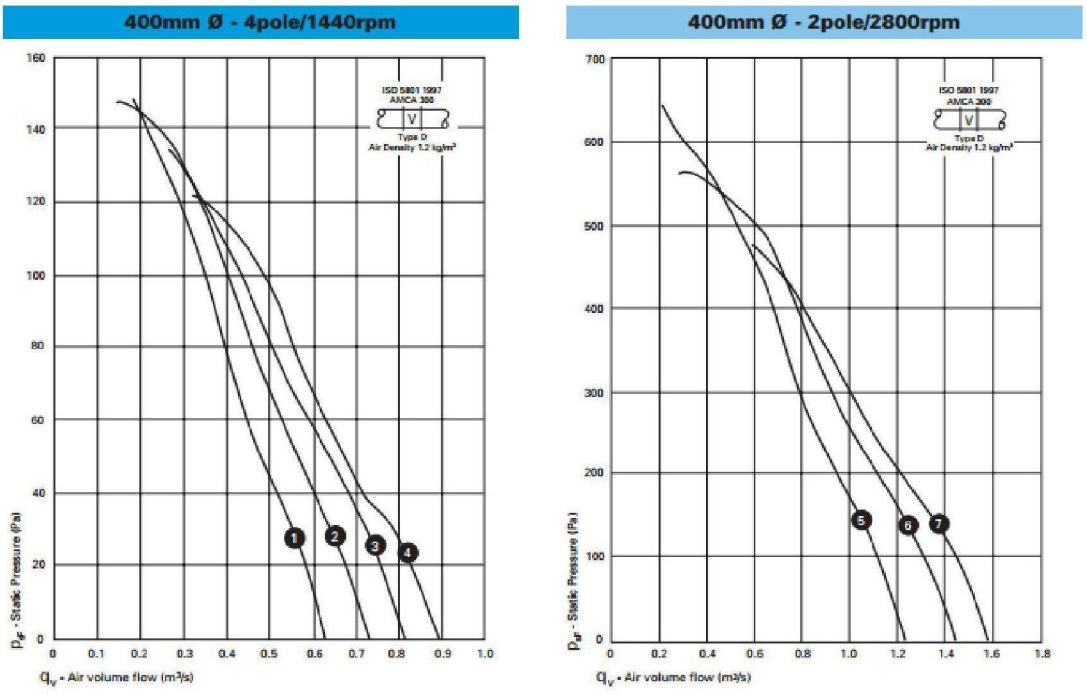
The mechanical smoke ventilation as it is installed currently is a balanced 'push-pull' system. This means that an extract fan operates to remove smoke from the fire floor with make-up fresh air provided at the same rate of flow by a mechanical supply fan. This principle is to be retained but automated in the proposed new system.

The existing bifurcated extract fans (run and standby) were supplied by Victoria Fans Limited in 1993. Although no data of their duty was available from the manufacturer, they were able to provide the following specifications of the units:

Diameter:	400 mm
Blade Pitch:	8 °
Motor:	0.55 kW
Motor Speed:	2850 rpm

This data is sufficient to allow comparison with fans of a similar specification to ascertain the flow rate at the calculated pressure drop of the extract shaft. For this purpose the fan curve data is to be taken from curve 5 of the following extract from Nuaire's catalogue on the following page:

Bifurcated Axial Flow - 400mm ø



General							Electrical/Motor						Noise/Sound In-duct sound power levels dB re 1pW inlet Octave band mid frequency Hz						
Curve No	Unit Code	Blade Angle	Speed RPM	Unit kg	A.V. Set	Motor frame size	1 Phase (230V-50Hz) Motor kW	flc amps	sc amps	3 Phase (400V-50Hz) Motor kW	flc amps	sc amps	125	250	500	1k	2k	4k	8k
400mm Ø - 4pole/1440rpm																			
1	AXB40M-411A*	20°	1410	28	NAV2	LS71L	0.37	2.9	11.6	-	-	-	85	79	76	74	68	60	50
2	AXB40M-421A*	25°	1410	28	NAV2	LS71L	0.37	2.9	11.6	-	-	-	85	81	75	75	70	61	52
3	AXB40M-431A*	30°	1410	28	NAV2	LS71L	0.37	2.9	11.6	-	-	-	85	81	77	76	71	64	55
4	AXB40F-431A*	35°	1410	28	NAV2	LS71L	0.37	2.9	11.6	-	-	-	85	83	78	76	71	63	56
400mm Ø - 2 pole/2800rpm																			
5	AXB40M-21A*	20°	2700	31	NAV2	LS80L	1.1	7.5	35	1.1	2.5	14	86	90	92	94	87	79	72
6	AXB40M-22A*	25°	2700	31	NAV2	LS80L	1.1	7.5	35	1.1	2.5	14	87	96	93	93	87	80	74
7	AXB40M-23A*	30°	2700	31	NAV2	LS80L	1.1	7.5	35	1.1	2.5	14	90	95	94	94	88	81	75

Figure 1 - Nuaire Comparable Fan Curves - http://www.nuaire.info/catalogue/Axial-AXB.pdf

The worst case condition to be calculated in this case would be a fire on the lowest residential floor as this would be the index run for the system, i.e. would incur the largest pressure drop.

For the purposes of this comparison it can be modelled simplistically as a smoke damper in the lobby, a 90 ° bend into the shaft, a 60 m length of smoke extract shaft and a smoke damper prior to the extract fan. The following pressure drops have been applied to these components:

Lobby smoke damper:	10 Pa
90 ° bend:	8.3 Pa
Extract shaft:	0.3 Pa/m
Fan smoke damper:	7.88 Pa

This gives a total pressure drop in the system of **44.2 Pa**.

When the total pressure drop calculated previously is applied to the relevant comparison fan curve, curve 5, it can be seen that:

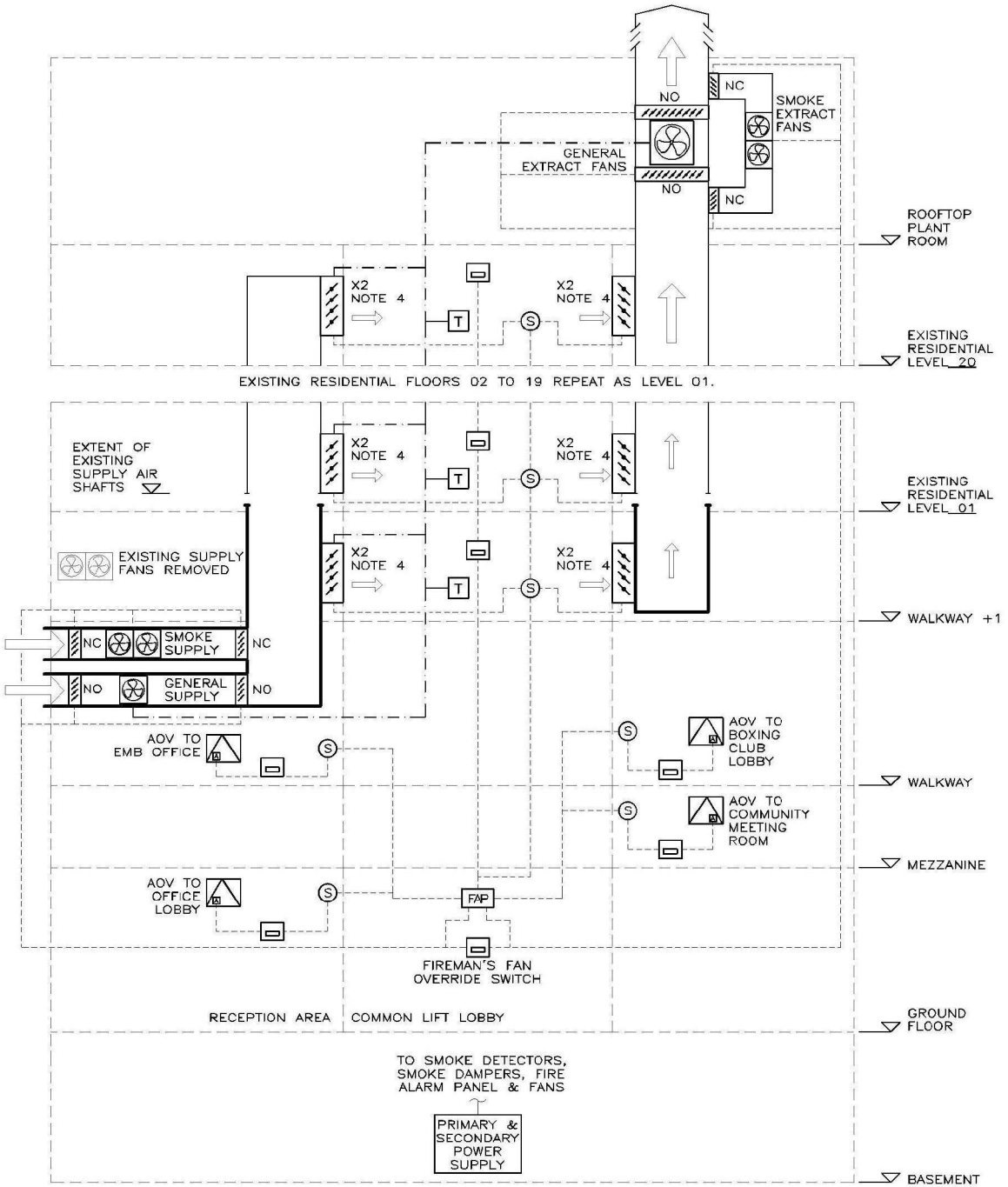
Q = 1.2 m^3/s @44.2 Pa

5 Performance Comparison Results

Method	Flow Rate – Worst Case (m^3/s)
Existing Natural Ventilation	1.1
Existing Mechanical Ventilation (manual override)	1.2
Proposed Mechanical Ventilation (automated)	5.0

Table 2 - Performance Comparison of Existing and New Systems

From the table above it can clearly be seen that the performance of the smoke ventilation system in Grenfell Tower will be considerably improved as part of the refurbishment works. The fans will be sized in order to provide a minimum of 5 m^3/s flow rate at the furthest point from the fans. This is line with current best practice for balanced 'push-pull' type smoke ventilation systems, with the figure arising from a 3.5 m^3/s flow rate through an open door to prevent smoke ingress from the lobby to the escape stair during escape plus an additional 1.5 m^3/s allowance for leakage from the builder's work shafts and remaining dampers.



KEY

- DIRECTION OF AIR/SMOKE FLOW
- EXISTING DUCT
- NEW DUCT
- SMOKE EXTRACT CONTROL LINE
- VENTILATION CONTROL LINE
- NEW AUTOMATIC OPENING VENT (AOV) 0.4 m² FREE AREA
- NEW SMOKE DAMPER
- NO — NEW SMOKE DAMPER (NORMALLY OPEN)
- NC — NEW SMOKE DAMPER (NORMALLY CLOSED)
- FAP — FIRE ALARM PANEL
- FIREMAN'S OVERRIDE SWITCH
- S — SMOKE DETECTOR
- NEW/EXISTING FAN REUSED
- EXISTING FAN REMOVED
- A — WINDOW ACTUATOR
- T — TEMPERATURE SENSOR FOR GENERAL COOLING CONTROL

NOTES:

1. DO NOT SCALE FROM THIS DRAWING
2. READ IN CONJUNCTION WITH THE MF TENDER DOCUMENTATION.
3. READ IN CONJUNCTION WITH THE T(90)01 SERIES COMBINED MECHANICAL LAYOUTS.
4. ONLY HALF THE DAMPERS & DUCTS SHOWN FOR CLARITY, EACH FLOOR HAS TWO SUPPLY AND TWO EXTRACT DUCTS SERVICING EACH LOBBY. EACH MOTORISED DAMPER IS TO BE NORMALLY OPEN, WITH ALL DAMPERS EXCEPT THOSE ON THE FIRE FLOOR CLOSING IN THE EVENT OF A FIRE.
5. EXISTING SMOKE EXTRACT SYSTEM SUPPLY AIR FANS LOCATED IN CEILING VOID OF WALKWAY+1. THESE FANS WILL BE REMOVED. PROPOSAL IS TO INSTALL NEW FANS IN LOCATION SHOWN ON T(90)01_102.

rev	date	description	eng
T2	20/11/13	STAGE E TENDER ISSUE	MJS
T1	01/11/13	STAGE E TENDER ISSUE	MJS

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architect
STUDIO E LLP

job title
GRENFELL TOWER REGENERATION

project leader	date	scale (at A3)
DC	NOV' 2013	NTS

drawing title
CORE SERVICES SMOKE VENTILATION SCHEMATIC

job no	dwg no	rev
4614	U(14)01_200T2	