# Technical Note

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# Victoria House

| Job Number: 100555 | Date: 28 March 2023 | Client: Oxford Victoria House Limited |
|---|---|---|
| Prepared By: CW | Approved By: SG | |

## 1. Introduction

1.1. Planning permission (ref. 2022/3480/P), recently approved in November 2022, granted permission for new roof level plant (including fume stacks and replacement of a diesel generator) to support lab enabled space at levels 1 to 9 of the building. Condition 7 of the permission required approval of an air quality assessment (AQA), which has been submitted to the Council and is currently pending determination.

1.2. This technical note has been prepared to respond to comments made by the council on the AQA, submitted to discharge condition 7.

## 2. Air Quality

2.1. The following comments have been made in respect to the AQA.

Comment 1:

> *"Figure 3.3 indicates that the fume cupboard flues are quite close to air inlets RC, RG and RH and the prevailing wind direction from 2 flues are towards inlet RD. Relocation of these inlets is recommended or further details including the distance and cross-sectional diagrams of the exhausts / flues and inlets (to show location and relative heights) are required to ensure that there is no recirculation of emissions.*

2.2. We understand that a detailed wind tunnel survey was carried out to obtain accurate concentration estimates at building air intakes and other sensitive locations due to emissions from the proposed laboratory extract sources located on the Victoria House. The CCP (2022) *Final Air Quality Report. Victoria House* report[1], which was appended to the KJ Tait's MEP report, has now been updated and is appended to this TN. The CPP (2023)[2] report concluded that all of proposed inlets modelled will meet the ASHRAW criterion (as outlined on page 3). Standard 62.1 of ASHRAW:

> *"specifies minimum ventilation rates and other measures intended to provide indoor air quality (IAQ) that's acceptable to human occupants and that minimizes adverse health effects. The standard provides procedures and methods for meeting minimum ventilation and IAQ requirements to engineers, design professionals, owners, and jurisdictional authorities where model codes have been adopted."*

[1] CPP, 2022. *Final Air Quality Report. Victoria House. London, England. CPP Project 16452.*
[2] CPP, 2023. *Final Air Quality Report. Victoria House. London, England. CPP Project 16452.*

2.3. It is, however, noted that the CCP report summaries that the ASHRAE criterion is not met at some rooftop air intakes for less than 1% of wind conditions; this is typically considered an acceptable risk of exceedance.

2.4. On this basis, the air inlets modelled in line with drawing no. KJT-ZZ-R-DR-M-5701 meet the ASHRAW criterion *"to provide indoor air quality (IAQ) that's acceptable to human occupants and that minimizes adverse health effects."*

Comment 2:

> *"Filtration should be installed to air inlets A and C as a minimum. Details of filtration to be installed are required."*

2.5. We understand that the client will be providing filtration at these proposed air inlets, as outlined in drawing no. 21593-CWA-VH-ZZ-DR-A-3000, in the form of the AAC Nitrosorb Swiftpack System[3]. This System uses carbon filter technology to deliver a high efficiency and sustainable range of standard and customised $NO_x$ filter units.

2.6. The Swiftpack solution is suitable for indoor air projects in new build and retrofit schemes and is designed for use with all types of MVHRs.

[3] AAC Eurovent. AAC Nitrosorb® Swiftpack. Accessible at: https://www.aaceurovent.co.uk/product/aac-nitrosorb-swiftpack-system/

# Appendices

# AIR QUALITY REPORT

**CPP PROJECT 16452**
**24 MARCH 20233**

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## EXECUTIVE SUMMARY

This report documents the wind-tunnel study conducted by CPP, Inc. on behalf of Oxford Victoria House Limited for the Victoria House, located in London, England, which is currently planned to be converted from office space to laboratory research space. The objective of the study was to obtain accurate concentration estimates at building air intakes and other sensitive locations due to emissions from the proposed laboratory extract sources located on the Victoria House. The laboratory extract sources are understood discharge an even mix of air from laboratory research spaces and office areas. As such, they may periodically emit chemicals or other contaminants that may enter nearby buildings through air intakes, or be present at other sensitive locations, and impact staff or the general public. If adverse impacts were found, mitigation measures were evaluated.

To meet the objectives of the study, a 1:240 scale model of Victoria House and nearby surroundings within a 415 m radius was constructed and placed in CPP's boundary-layer wind tunnel. Concentration measurements were obtained in the wind tunnel to define the impact of emissions from roof level laboratory extract sources at building air intake and other sensitive locations. Additional analysis for a proposed rooftop standby diesel generator was conducted using CPP's enhanced version of the ASHRAE Handbook model (ASHRAE, 2019).

The conclusions are summarized below and discussion for the proposed extracts are presented Table ES-1.

**Conclusions**

- Laboratory extracts are expected to meet the recommended ASHRAE criterion during full flow operation (3.6 $m^3/s$ at 20.8 m/s) .
- A screening level assessment that does not take into account local site conditions was conducted for a typical 700 kW generator. Estimates indicate that health limits would be met at distances greater than 4.4 m from the flue, while odors were estimated to extend up to 187 m downwind from the flue.
    - It is understood that an oxidizing extract filter will be added to the generator; assuming an 80% reduction of odor, the extent of odors would be reduced to a to 37.5 m radius.

**Table ES-1**
**Summary of Results for Laboratory Extracts on Bloomsbury Square Fume Extracts**

| Source Description | Stack Base Height (m) description | Design Description | Volume Flow Rate and Efflux Velocity $m^3/s$ (m/s) | Stack Height Above Base (m) | ASHRAE[1] Design criterion met/not met (exceeded) as follows: |
|---|---|---|---|---|---|
| **Bloomsbury Square Fume Extracts** *EF-N1 & EF-N2 and EF-S1 & EF-S2* | 35.5 Main Roof | Initial Proposed | 6.4 (16.1) | 4.0 | met[2] |
| | | Updated Proposed | 3.9 (20.8) | 4.0 | met[2] |
| **Discussion** Both the initial and updated proposed designs meet the recommended ASHRAE criterion at all intakes evaluated. | | | | | |

[1] ASHRAE recommended performance criterion for laboratory fume hood extract. See Section 2.5.1.

[2] ASHRAE criterion is not met at some rooftop air intakes for less than 1% of wind conditions, which is typically considered an acceptable risk of exceedance.

## TABLE OF CONTENTS

## 1. INTRODUCTION

This report documents the wind-tunnel study conducted by CPP, Inc. on behalf of Oxford Victoria House Limited for the Victoria House, located in London, England, which is currently planned to be converted from office space to laboratory research space. The objective of the study was to obtain accurate concentration estimates at building air intakes and other sensitive locations due to emissions from the proposed laboratory extract sources located on the Victoria House. The laboratory extract sources are understood discharge an even mix of air from laboratory research spaces and office areas. As such, they may periodically emit chemicals or other contaminants that may enter nearby buildings through air intakes, or be present at other sensitive locations, and impact staff or the general public. If adverse impacts were found, mitigation measures were evaluated.

To meet the objectives of the study, a 1:240 scale model of Victoria House and nearby surroundings within a 415 m radius was constructed and placed in CPP's boundary-layer wind tunnel. Concentration measurement tests were conducted for a variety of meteorological conditions and source/receptor combinations. The concentration measurements were converted to full-scale normalized concentrations ($C/m$). Additional analysis for a proposed rooftop standby diesel generator was conducted using a simplified ASHRAE separation distance procedure (ASHRAE, 2019). The results provide estimated separation distances required to meet the recommended odour and health criteria (i.e., a design concentration). The design concentration was specified such that health and odour effects due to any expected chemical release would be minimal at sensitive locations.

Included in this report are a description of various site-specific issues, a discussion of the experimental methods, and the results of the study. The conclusions are summarized in an executive summary, which is located at the beginning of the report.

## 2. PROJECT SPECIFIC INFORMATION

### 2.1. DESCRIPTION OF SITE

The existing Victoria House is located in London, England. Figure 1 presents a detailed view of the area modelled on the turntable. Figure 2 is a close-up plan view of Victoria House showing source and surrounding receptor locations. Photographs of the model in the wind tunnel are shown in Figure 3. All testing was carried out in CPP's closed-circuit wind tunnel shown in Figure 4.

It was determined that a target surface roughness length of 0.7 m was appropriate for use in the wind-tunnel modelling based on aerial photos and previous experience in the area.

### 2.2. EXTRACT SOURCES

Victoria House is planned to be equipped with laboratory extract stacks located on the roof. The laboratory extracts will discharge an even mix of air from laboratory research and office areas. In addition, three (3) existing standby diesel generators will be replaced with a single unit with an estimated capacity of 700 kW. Note, it is understood that there are existing boilers and cooling towers with extract discharged at the roof level. Based on our experience, air quality impacts from these extracts will be the same as existing conditions. New air intakes are expected to see similar impacts as existing air intakes

Extract discharges were simulated by installing stacks constructed of brass tubes at the appropriate locations. Trips were installed within the stacks as required to ensure that the stack flow was fully turbulent upon exit. The stacks were supplied with a tracer gas (ethane) and inert gas (nitrogen) mixture with a density similar to room temperature air. Precision mass flow controllers were used to monitor and regulate the discharge momentum.

An updated design of the laboratory extracts was evaluated using a numerical analysis informed by previously collected wind tunnel data, see “Simulated Runs” in Table 4.

All of the extract locations are shown in Figure 2. The full-scale extract parameters for each source are listed in Table 1.

### 2.3. RECEPTOR LOCATIONS

The emissions from the extract sources described above have the potential for causing health or odour problems at sensitive locations such as air intakes, plazas, entrances, and nearby buildings. The various receptor locations where concentrations were measured during the study are identified in Figure 2. Table 2 provides a list of abbreviated receptor identifications and their approximate elevations. Proposed intakes on the central penthouse structure at both Level 8 (receptor 46) and Level 9 (receptor 45) were initially evaluated during this wind tunnel study. Following review of the results and subsequent discussion, these intake locations were discounted as a viable strategy and are not reflected in the above-mentioned recommendations. An alternate location along the north façade of the penthouse structure was considered at Level 9 (receptor 47). Based on CPP’s experience and further review of the initial results, air quality impacts from the laboratory extracts to this location are expected to meet the recommended ASHRAE criterion.

The receptor locations were evaluated by installing a small diameter brass tube at the specified location. This brass tube was then connected to the analysis instrumentation to determine the amount of tracer gas present at the receptor location.

It should be noted that not all receptors were sampled for each source. Only those receptors of most interest or those likely to give the highest concentration for a particular source were evaluated.

### 2.4. METEOROLOGY

The meteorological information of primary interest for this evaluation is the wind speed frequency distribution. This information is used to specify a reasonable upper limit wind speed to be used for testing. This information is also used in conjunction with the wind-tunnel measured concentrations to determine the percent time a certain concentration is predicted to be exceeded.

Figure 5 shows the wind speed and direction distribution, in the form of a wind rose, at the Heathrow Airport anemometer. The anemometer is located approximately 22 kilometers west of Victoria House. The data was collected during the period from 2005 to 2022. The wind rose indicates that the most frequent winds are from the south-southwest through west. The strongest winds, greater than 16 m/s (35.8 mph), occur primarily from the west-southwest through west.

Figure 6 shows the cumulative frequency distribution of wind speed at the Heathrow Airport anemometer. The wind speed distribution was used to determine the wind speed at the anemometer that is exceeded 1% of the time (i.e., the 1% wind speed). The figure shows that the 1% wind speed is approximately 12.3 m/s (27.5 mph) at the anemometer. The likelihood of specific wind conditions at the project site was considered in the wind tunnel testing and subsequent analysis.

### 2.5. CONCENTRATION DESIGN CRITERIA

Developing concentration acceptance criteria can be as important as predicting extract concentrations. Concentration predictions from wind tunnels or numerical methods by themselves are not useful for examining source designs unless some maximum acceptable concentration, or design criterion, is specified. This criterion will vary with source type and each source type may have a criterion that varies depending upon such things as emission type, emission quantity, and number of units emitting.

An air quality "acceptability question" can be written:

$$C_{max} < C_{health/odour} \; ? \qquad \text{Equation 1}$$

where $C_{max}$ is the maximum concentration expected at a sensitive location (air intakes, operable windows, pedestrian areas), $C_{health}$ is the health limit concentration and $C_{odour}$ is the odour threshold concentration of any emitted chemical. When a large number of potential chemicals are emitted from a pollutant source, a variety of mass emission rates, health limits, and odour thresholds need to be examined. It then becomes operationally simpler to recast the acceptability question by normalizing (dividing) Equation 1 by the mass emission rate, $m$:

$$\left(\frac{C}{m}\right)_{max} < \left(\frac{C}{m}\right)_{health\,/\,odor} \; ? \qquad \text{Equation 2}$$

The left side of Equation 2 $(C/m)_{max}$, is only dependent on external factors such as stack design, receptor location, and atmospheric conditions. The right side of the equation is related to the emissions and is defined as the ratio of the health limit, or odour threshold, to the emission rate. Therefore, a highly toxic chemical with a low emission rate may be of less concern than a less toxic chemical emitted at a very high emission rate. Three types of information are needed to develop normalized health limits and odour thresholds:

1. a list of the toxic or odourous substances that may be emitted,

2. the health limits and odour thresholds for each emitted substance, and
3. the maximum potential emission rate for each substance.

It should be noted that the normalized concentration design criteria discussed below are derived from occupational exposure limits, odour thresholds and estimated mass emission rates. The occupational exposure limits are based on a mixture of guidelines, recommendations, and regulatory limits from the ACGIH, OSHA or NIOSH. The limits provided by ACGIH and NIOSH were developed as guidelines to assist in the control of health hazards, and are not intended for use as legal standards. The limits provided by OSHA are regulatory limits on the amount or concentration of an airborne substance that may be present in the workplace.

The mass emission rates for the laboratory extracts are based on an assumed accidental release scenario. Therefore, no safety factor has been applied per ANSI/ASSP Laboratory Ventilation Standard Z9.5-2022 (Z9.5-2022). The odour thresholds were obtained from published information with no safety factor applied. CPP recommends that the user employ an Industrial Hygienist to review both the design criteria development procedure described in this report and the user's anticipated laboratory procedures to determine the appropriateness of the established design criteria, discussed below. CPP further recommends that this document be reviewed each time the user experiences either a program change or a change in laboratory procedures. Failure to do so may nullify the recommendations presented in this report. A detailed explanation of the calculation is presented in an internal CPP document "CPP Simulation and Analysis Techniques for Air Quality Assessments" (September 2018). This document is available on request.

The following paragraphs discuss the specific design criteria used in this study as well as potential mitigation measures. The sources of concern for this evaluation and the design criterion for each source type are summarized in Table 3. The table also summarizes the basis from which each design criterion was developed.

### 2.5.1. LABORATORY EXTRACT

Design criteria specific for the chemicals used in a laboratory facility can be developed using chemical-specific information. However, Z9.5-2022 states "toxic and hazardous substances may be used at some point during the lifetime of the facility." This implies that one needs to assume that the chemical utilization will change over time and specifying the criteria based on current chemical utilization may not be appropriate.

No proposed chemical inventory was provided for this project. Therefore, the normalized health limit ($HL/m$) and normalized odour threshold ($OT/m$) design criteria were set at 400 $\mu g/m^3$ per g/s, which corresponds to the ASHRAE example criterion discussed in Chapter 16 of the 2019 ASHRAE Handbook HVAC Applications (ASHRAE, 2019). This criterion assumes a 7.5 L/s chemical emission rate (i.e., due to a liquid spill or lecture bottle fracture) and a concentration of 3 mg/kg or less at an intake. Chapter 16 (ASHRAE, 2019) includes the following disclaimers regarding this criterion: 1) laboratories using extremely hazardous substances should conduct a chemical specific analysis based on published health limits; 2) a more lenient limit may be justified for laboratories with low levels of chemical usage; and 3) project specific requirements must be developed in consultation with the safety officer.

The ASHRAE criterion may be put into perspective by considering the "as installed" chemical hood containment requirements outlined in Z9.5-2022 (i.e., a concentration at a mannequin outside the chemical hood of 0.10 ppm or less for "as installed" with a 4 L/m accidental release in the hood as measured using the ANSI/ASHRAE 110-2016 test method). The "as installed" requirement is equivalent to a design criterion of 1500 μg/m³ per g/s. Hence, the criterion for a mannequin (i.e., worker outside the chemical hood) is 1.9 to 3.8 times less restrictive than that for the air intake or other outdoor locations. This seems reasonable (i.e., that the air intake has more strict criteria) since the worker at the chemical hood can shut the hood or walk away to avoid adverse exposure. Also, the ANSI/ASHRAE 110-2016 test is not necessarily a "worst-case" exposure scenario for the worker.

For reference purposes, CPP has provided the following information in Table 6 for chemicals with published occupational exposure values (SEPA, 2010; ACGIH, 2018a and 2018b), workplace environmental exposure levels (TERA, 2019), and odour thresholds (Ruth, 1986; SEPA, 2010; AIHA, 2019):

- the normalized health limit and odour threshold associated with a 1 L spill or 1-minute lecture bottle release; and
- the limiting value (i.e., lowest value of the normalized health limit or odour threshold) associated with a 1 L spill or 1-minute lecture bottle release; and
- the maximum allowable fume hood volume (liquid) or release rate (gas) for each of the criteria discussed above.

The facility owner should review the table to determine whether they will be using chemicals in a manner that could create a problem. Also, a detailed hazard assessment should be carried as outlined in Z9.5-2022, which states:

"The first step in a hazard assessment is to identify what chemicals can be released including normally uncharacterized by-products. After characterizing the inherent hazard potential (largely based on physical properties, toxicity, and routes of entry), the next step is to ascertain at least qualitatively, the release "picture". At what points within the control zone will chemicals be evolved and at what release rate? Will the chemical release have velocity? How has the maximum credible accidental release been accounted for? Finally, how many employees are/could be exposed and what means are available for emergency response?"

### 2.5.2. COMBUSTION SOURCES

**Standby Diesel Generator.** The normalized health limit (*HL*/*m*) design criteria for the diesel emergency generator were based on information obtained from the U.S. Environmental Protection Agency (EPA, 1996a) and the U.S. Code of Federal Regulations (CFR, 2002). The normalized odour threshold (*OT*/*m*) design criteria were based on a 20% objection level to an exhaust dilution of 1:2000 (Vanderheyden, 1994). These filters typically reduce unburned hydrocarbons (the odourous exhaust components), by about 80%. If these filters are installed, the 1:2000 dilution requirement stated above is reduced to a 1:400 dilution requirement. The normalized concentration design criteria (*HL*/*m* and *OT*/*m*) for the diesel emergency generator are listed in Table 2. Normalized criteria for a single unit are computed in Table 7.

# 3. NUMERICAL MODELLING METHODOLOGY

## 3.1. CONCENTRATION PREDICTIONS

Numerically predicted exhaust concentrations were calculated using CPP's simplified ASHRAE procedure for calculating exhaust/intake separation distances (Petersen, 2016), as described in the following section. The predicted concentrations are used to estimate the area of impact from the proposed diesel standby generators. In order to quantify results for specific source/receptor combinations, additional analysis using a detailed numerical model or wind tunnel testing is required. A summary of the estimated separation distances required to meet health and odor criteria are summarized in Table 5.

## 3.2. SIMPLIFIED ASHRAE SEPERATION DISTANCE PROCEDURE

The simplified separation distance procedure is a variation of the separation distance equations and tables from ASHRAE Standard 62.1 (ANSI/ASHRAE, 2019). The simplification procedure was developed by CPP, through ASHRAE sponsored research (Petersen, 2016). In the development of the new procedure, several case-studies were compared against the current Standard 62.1 concentration predications. Modifications to Standard 62.1 equations were made to better-predict dilution versus distance, with a higher frequency of producing conservative dilution estimates (i.e., not over-predicting dilution). The exhaust stack operating parameters listed in Table 1 were used. The exhaust stack distance and height above/below the receptor location are used as inputs, along with several other factors, including turbulence, wind speed, and stack orientation (capped/un-capped).

# 4. RESULTS

## 4.1. CONCENTRATION MEASUREMENTS

Normalized concentrations (*C/m*) due to emissions from the various sources were measured and evaluated following CPP's standard data collection procedures, which are available upon request. A compilation of the maximum steady-state *C/m* values for each source/receptor combination tested is presented in Table 4. The conclusions derived from these results are presented in the tables included in the Executive Summary at the front of this report. *C/m* values versus wind speed and wind direction for each test are archived at CPP and available upon request.

In addition to presenting the maximum measured steady-state normalized concentration for each source/receptor combination evaluated, the table also indicates the percent time that the design criterion may be exceeded, if applicable. The percent time exceeded is calculated by determining the wind conditions that are predicted to result in an exceedance of the design criteria. The summation of the frequency that these wind conditions are expected to occur is then the percent time exceeded presented in Table 4. This value does not take into consideration the probability of the emission event associated with the specified design criteria. Therefore, to determine the probability of exceeding (i.e., not meeting) the design criteria, the value listed in Table 4 should be multiplied by the frequency of occurrence of the emission event. For example, if an laboratory extract is expected to operate for 8,760 hours per year, and the percent time exceeded for the ASHRAE criterion indicated in Table 4 is 10.0%, wind conditions that could result in an exceedance of the criterion are expected to be present at the specified receptor location 87.6 hours per year (8,760 hours/yr x 0.10).

## REFERENCES

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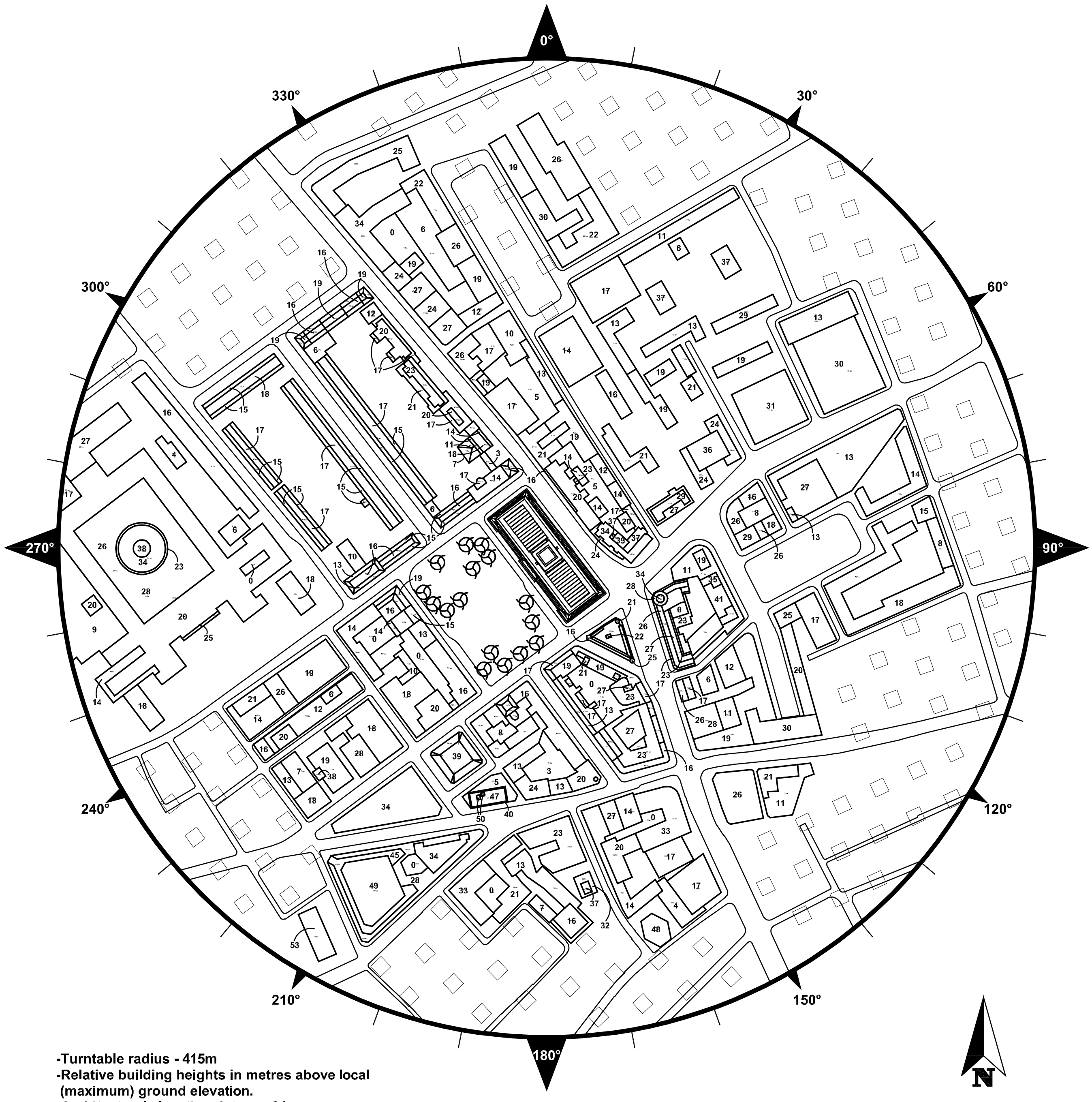
## FIGURES




-Turntable radius - 415m
-Relative building heights in metres above local (maximum) ground elevation.
-Architectural elevation datum = 24

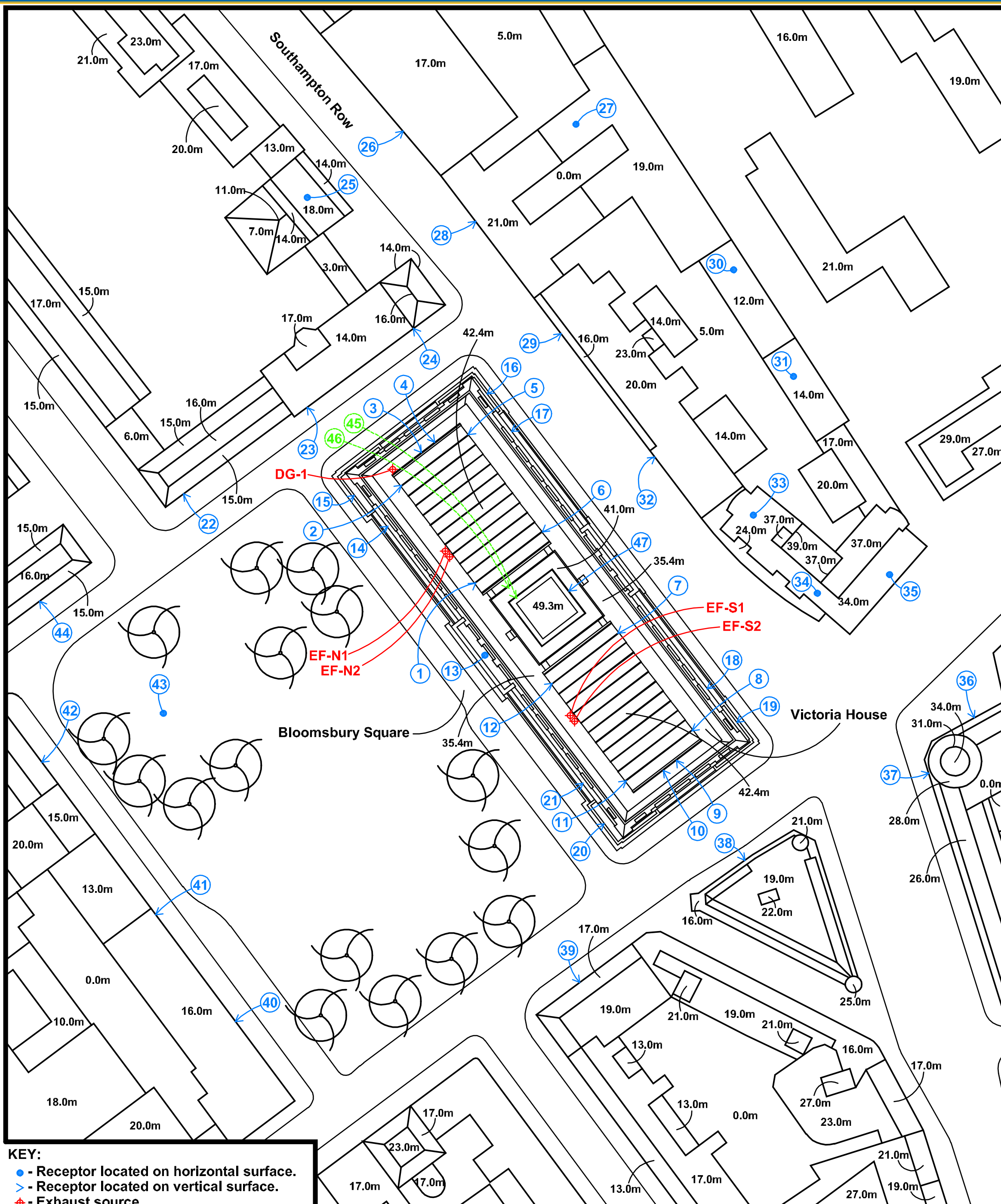
**CONFIGURATION A**

0m 100m 200m
50m 150m

**TREES:**
- 24 Deciduous Trees

**NOTE:**
All Building Heights are in Metres.

***Figure 1:*** *Plan vie of the area modelled on the turntable with building heights*




KEY:
- ● - Receptor located on horizontal surface.
- > - Receptor located on vertical surface.
- ⌖ - Exhaust source.
- > - Receptor No Longer in Design

TREES:

- 24.0m Deciduous Trees

0m 20m 40m
10m 30m

N

**CONFIGURATION A**
**RECEPTORS 1-47**

- -Receptors 1-12 located at el. 37.0m
- -Receptor 13 located at el. 29.0m
- -Receptors 14-21 located at el. 16.0m
- -Receptors 22, 30, 44 located at el. 13.5m
- -Receptors 23-24 located at el. 12.5m
- -Receptor 25 located at el. 18.0m
- -Receptors 26, 31 located at el. 15.5m
- -Receptor 27 located at el. 20.5m
- -Receptor 28 located at el. 19.5m
- -Receptors 29, 40-42 located at el. 14.5m
- -Receptor 32 located at el. 18.5m
- -Receptors 33-35 located at el. 35.5m
- -Receptors 36-37 located at el. 20.00m
- -Receptor 38 located at el. 13.0m
- -Receptor 39 located at el. 14.0m
- -Receptor 43 located at el. 1.5m
- -Receptors 45,47 located at el. 45.0m
- -Receptor 46 located at el. 39.5m

***Figure 2:*** *Close up of Victoria House with building tier heights and source and receptor locations*

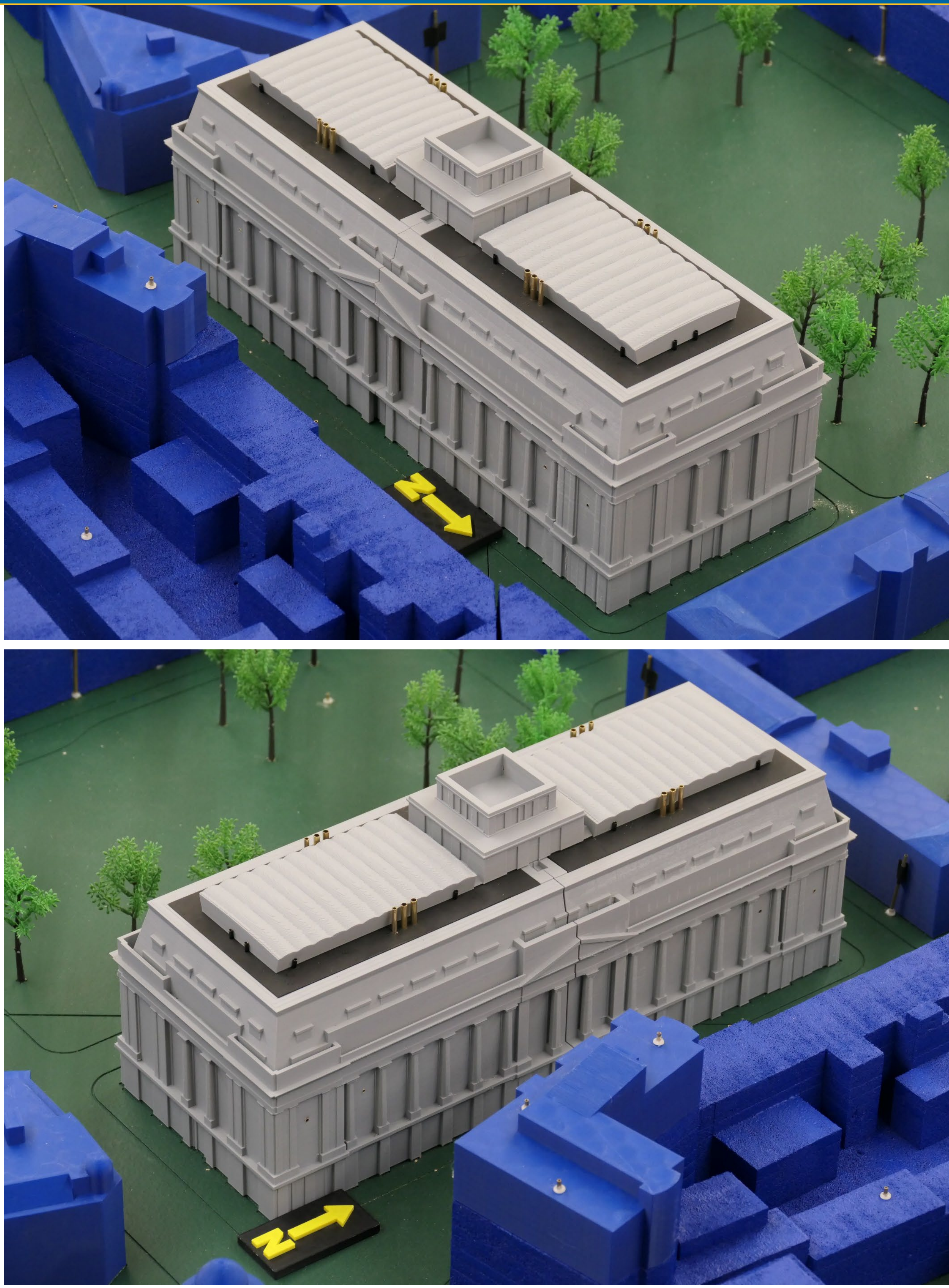



*Figure 3:* *Photographs of the model in the wind tunnel: View from the northeast (top); View from the southeast (bottom).*

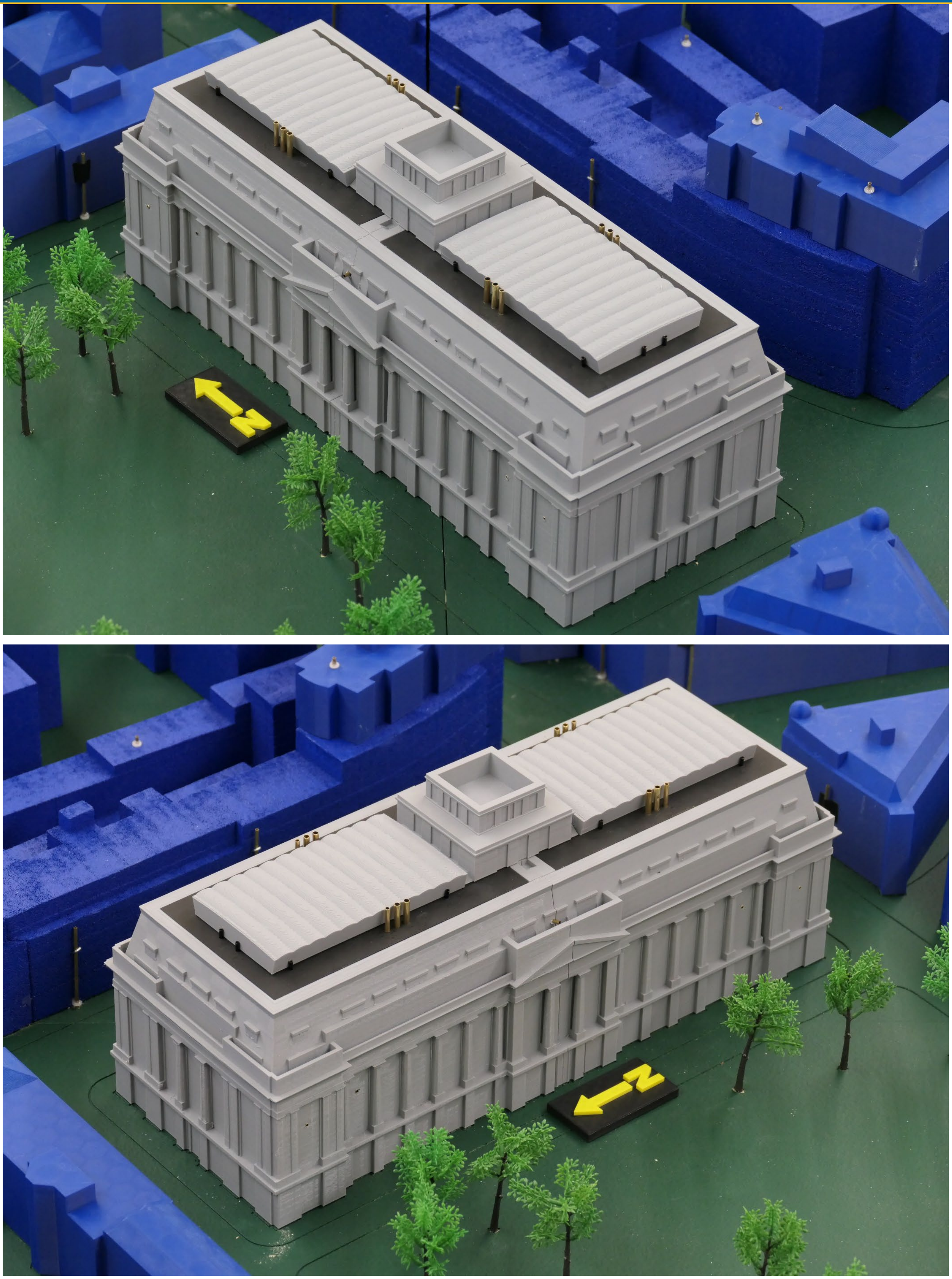


***Figure 3:*** *Photographs of the model in the wind tunnel: View from the southwest (top); View from the northwest (bottom).*

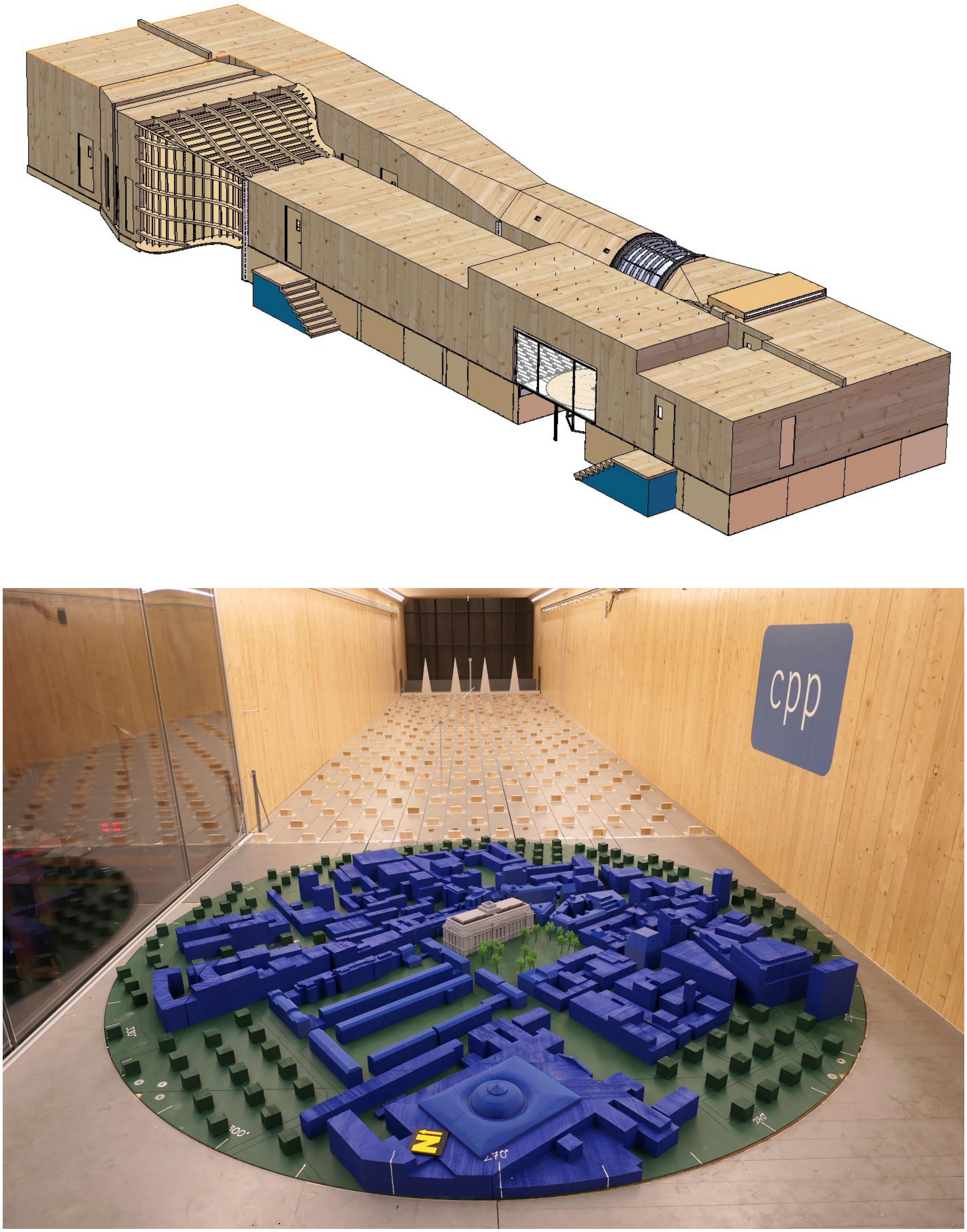



***Figure 4:*** *Rendering of the wind tunnel used for testing and photograph of the wind-tunnel configuration. Note spires and trip at entrance to test section, and roughness elements on approach fetch to develop a turbulent boundary-layer flow.*

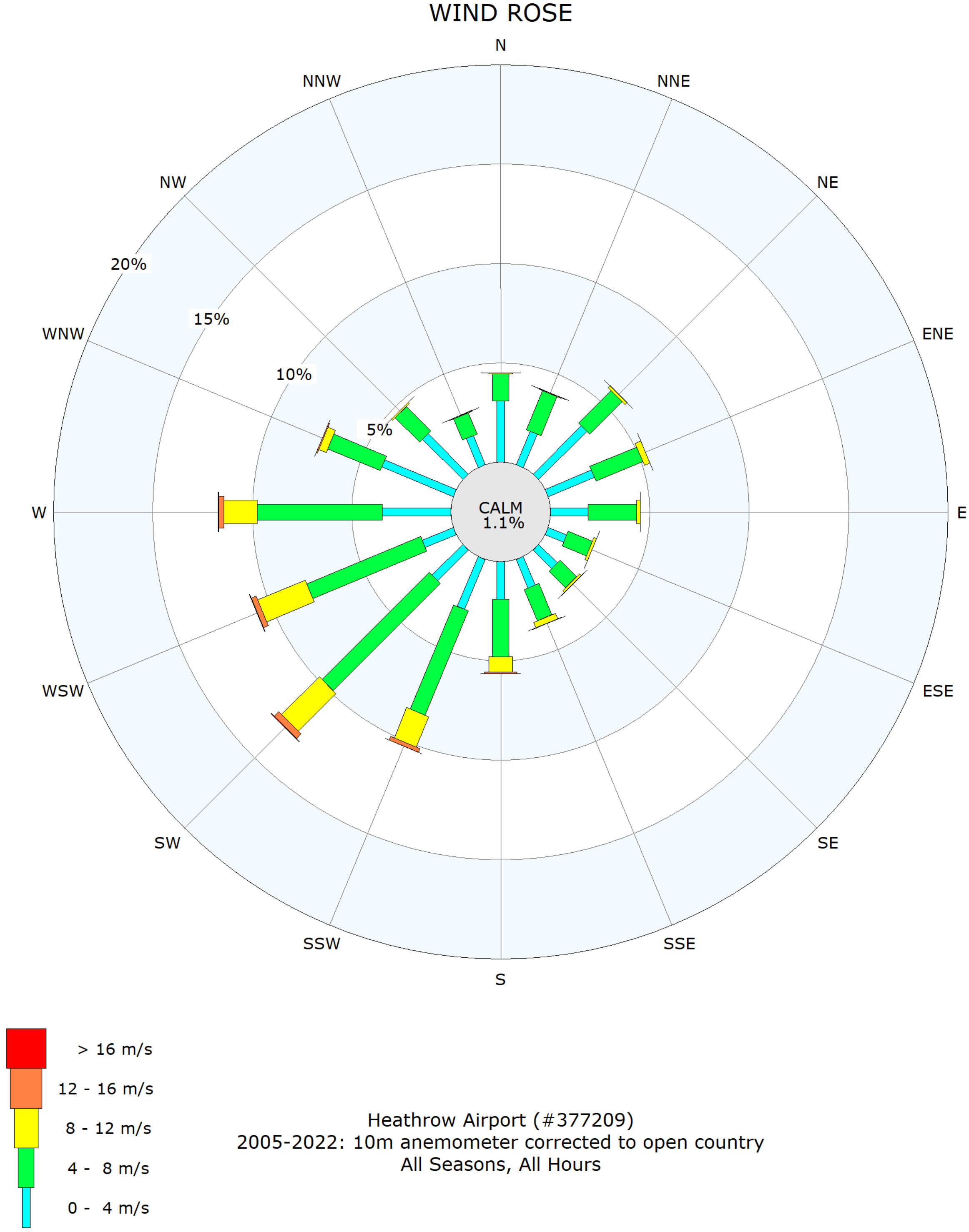
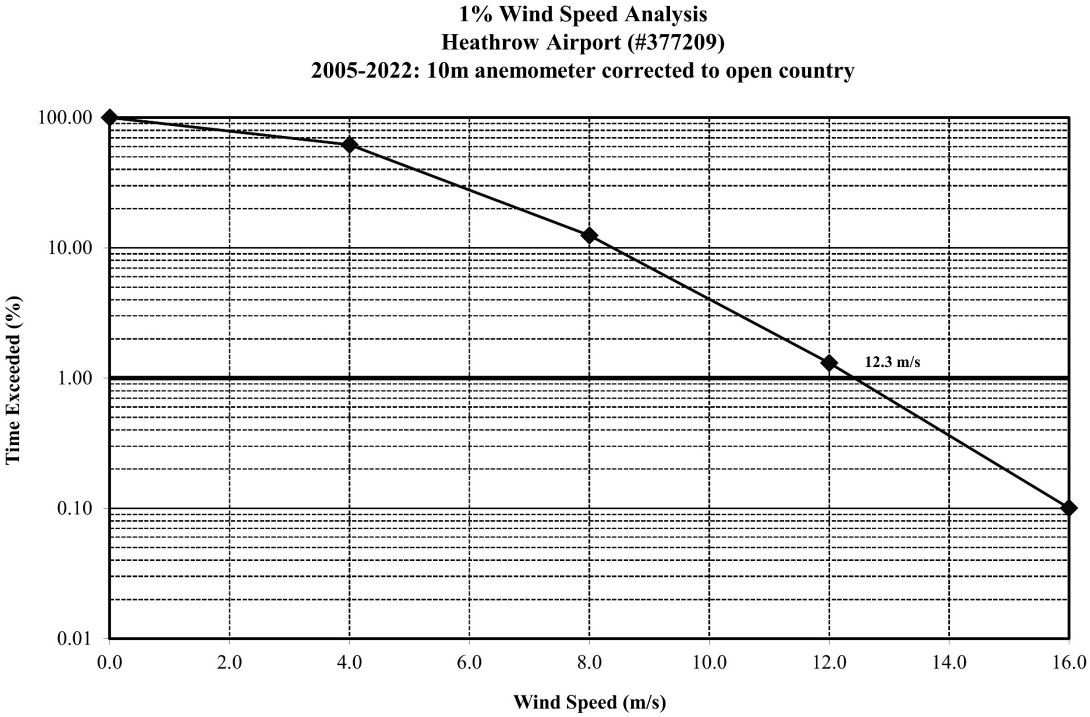



***Figure 5:*** *Wind rose for the Heathrow Airport anemometer*




**Joint Probability Distribution of Wind Speed and Wind Direction at the Heathrow Airport (#377209) Anemometer**

| **Category:**<br>**Maximum Wind Speed (m/s):** | **1**<br>**4.0** | **2**<br>**8.0** | **3**<br>**12.0** | **4**<br>**16.0** | **5**<br>**>16** | **Totals by Direction (%)** |
|---|---|---|---|---|---|---|
| N | 3.097 | 1.349 | 0.041 | 0.000 | 0.000 | **4.487** |
| NNE | 1.814 | 2.136 | 0.034 | 0.000 | 0.000 | **3.983** |
| NE | 3.428 | 2.331 | 0.123 | 0.002 | 0.000 | **5.884** |
| ENE | 2.515 | 2.554 | 0.300 | 0.003 | 0.000 | **5.372** |
| E | 1.888 | 2.456 | 0.188 | 0.003 | 0.000 | **4.535** |
| ESE | 1.004 | 1.330 | 0.135 | 0.001 | 0.000 | **2.469** |
| SE | 1.332 | 1.167 | 0.131 | 0.000 | 0.000 | **2.629** |
| SSE | 1.555 | 1.707 | 0.300 | 0.011 | 0.000 | **3.573** |
| S | 1.898 | 2.873 | 0.786 | 0.081 | 0.006 | **5.644** |
| SSW | 2.721 | 5.683 | 1.664 | 0.187 | 0.010 | **10.264** |
| SW | 2.187 | 7.630 | 2.682 | 0.330 | 0.023 | **12.851** |
| WSW | 1.696 | 6.208 | 2.582 | 0.272 | 0.029 | **10.787** |
| W | 3.464 | 6.291 | 1.668 | 0.272 | 0.030 | **11.726** |
| WNW | 3.891 | 2.872 | 0.406 | 0.047 | 0.003 | **7.219** |
| NW | 2.864 | 1.746 | 0.080 | 0.001 | 0.000 | **4.690** |
| NNW | 1.586 | 1.153 | 0.035 | 0.000 | 0.000 | **2.773** |
| Calm | 1.110 | | | | | |
| **Totals by Category (%):** | **38.048** | **49.485** | **11.153** | **1.210** | **0.101** | **100** |
| **Time Exceeded (%):** | **61.949** | **12.463** | **1.310** | **0.100** | **0.000** | |

***Figure 6:*** *Percent time indicated wind speed is exceeded at the Heathrow Airport anemometer*

# TABLES

## Table 1: Full-Scale Extract and Modelling Information

| Source Description | Source ID | Initial Height Above Base (m) | Exit Diameter (m) | Exit Temp. (K) | Mass Flow (kg/s) | Volume Flow Rate ($m^3/s$) | Exit Velocity (m/s) | Source Orientation | Base Height Above Grade (m) | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| **Bloomsbury Square Fume Extracts** | | | | | | | | | | |
| Bloomsbury North Fume Stack 1 | EF-N1 | 4.00 | 0.71 | 298.2 | 7.70 | 6.40 | 16.10 | Vertical | 35.5 | Main Roof |
| Bloomsbury North Fume Stack 2 | EF-N2 | 4.00 | 0.71 | 298.2 | 7.70 | 6.40 | 16.10 | Vertical | 35.5 | Main Roof |
| Bloomsbury South Fume Stack 1 | EF-S1 | 4.00 | 0.71 | 298.2 | 7.70 | 6.40 | 16.10 | Vertical | 35.5 | Main Roof |
| Bloomsbury South Fume Stack 2 | EF-S2 | 4.00 | 0.71 | 298.2 | 7.70 | 6.40 | 16.10 | Vertical | 35.5 | Main Roof |
| **Updated Fume Extract Design** | | | | | | | | | | |
| Bloomsbury North Fume Stack 1 | EF-N1-2 | 4.00 | 0.47 | 298.2 | 4.33 | 3.60 | 20.77 | Vertical | 35.5 | Main Roof |
| Bloomsbury North Fume Stack 2 | EF-N2-2 | 4.00 | 0.47 | 298.2 | 4.33 | 3.60 | 20.77 | Vertical | 35.5 | Main Roof |
| Bloomsbury South Fume Stack 1 | EF-S1-2 | 4.00 | 0.47 | 298.2 | 4.33 | 3.60 | 20.77 | Vertical | 35.5 | Main Roof |
| Bloomsbury South Fume Stack 2 | EF-S2-2 | 4.00 | 0.47 | 298.2 | 4.33 | 3.60 | 20.77 | Vertical | 35.5 | Main Roof |
| **Equipment Sources** | | | | | | | | | | |
| 700 kW Standby Diesel Generator | DG-1 | 4.00 | 0.30 | 714.3 | 1.39 | 2.77 | 37.93 | Vertical | 35.5 | Main Roof |

**Site Parameters:**

| | | |
|---|---|---|
| Scale Reduction: | 240 | |
| Grade Elevation (m): | 24 | 78 ft msl |
| Typical Building Height (m): | 40 | |
| Ambient Temperature ($^o$K): | 298 | Assumed Equal to Indoor Temperature |
| Anemometer Height (m): | 10 | Heathrow Airport |
| Anemometer Surface Roughness (m): | 0.03 | Heathrow Airport |
| Site Anemometer Height (m): | 10 | |
| Site Surface Roughness (m): | 0.70 | |
| 1 Percent Wind Speed (m/s): | 12.3 | Heathrow Airport (Period of Record: 2005 to 2022) |

**Table 2: Receptor Identifications**

| Receptor Number | | Receptor Identification | Receptor Elevation (m) |
|---|---|---|---|
| 1 | - | North Roof SW Intake | 37 |
| 2 | - | North Roof NW Intake | 37 |
| 3 | - | North Roof N Intake 1 | 37 |
| 4 | - | North Roof N Intake 2 | 37 |
| 5 | - | North Roof NE Intake | 37 |
| 6 | - | North Roof SE Intake | 37 |
| 7 | - | South Roof NE Intake | 37 |
| 8 | - | South Roof SE Intake | 37 |
| 9 | - | South Roof S Intake 1 | 37 |
| 10 | - | South Roof S Intake 2 | 37 |
| 11 | - | South Roof SW Intake | 37 |
| 12 | - | South Roof NW Intake | 37 |
| 13 | - | Ammenity Terrace Pedestrian | 29 |
| 14 | - | NW Façade Intake 1 | 16 |
| 15 | - | NW Façade Intake 2 | 16 |
| 16 | - | NE Façade Intake 1 | 16 |
| 17 | - | NE Façade Intake 2 | 16 |
| 18 | - | SE Façade Intake 1 | 16 |
| 19 | - | SE Façade Intake 2 | 16 |
| 20 | - | SW Façade Intake 1 | 16 |
| 21 | - | SW Façade Intake 2 | 16 |
| 22 | - | Bloomsbury Square Building 1 | 13.5 |
| 23 | - | Bloomsbury Place Building 1 | 12.5 |
| 24 | - | Bloomsbury Place Building 2 | 12.5 |
| 25 | - | South Hampton Building 1 | 18 |
| 26 | - | South Hampton Building 2 | 15.5 |
| 27 | - | Old Gloucester Building 1 | 20.5 |
| 28 | - | South Hampton Building 3 | 19.5 |
| 29 | - | South Hampton Building 4 | 14.5 |
| 30 | - | Old Gloucester Building 2 | 13.5 |

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**Table 2: Receptor Identifications**

| Receptor Number | | Receptor Identification | Receptor Elevation (m) |
|---|---|---|---|
| 31 | - | Old Gloucester Building 3 | 15.5 |
| 32 | - | South Hampton Building 5 | 18.5 |
| 33 | - | NYX Hotel Terrace 1 | 35.5 |
| 34 | - | NYX Hotel Terrace 2 | 35.5 |
| 35 | - | NYX Hotel Terrace 3 | 35.5 |
| 36 | - | Theobalds Building 1 | 20 |
| 37 | - | Theobalds Building 2 | 20 |
| 38 | - | Theobalds Building 3 | 13 |
| 39 | - | Theobalds Building 4 | 14 |
| 40 | - | Bloomsbury Square Building 2 | 14.5 |
| 41 | - | Bloomsbury Square Building 3 | 14.5 |
| 42 | - | Bloomsbury Square Building 4 | 14.5 |
| 43 | - | Bloomsbury Square Park | 1.5 |
| 44 | - | Bloomsbury Square Building 5 | 13.5 |
| 45 | - | Level 9 N Intake (Removed) | 44 |
| 46 | - | Level 8 N Intake (Removed) | 39.5 |
| 47 | - | Level 8 and 9 Intake | 44 |

**Table 3: Summary of Normalized Concentration Criteria**

| Source Type | Design Criteria Type | ($\mu g/m^3$) / (g/s) | Basis for Design Criteria[1] |
|---|---|---|---|
| **Victoria House** | | | |
| Laboratory Fume Extracts | Health/Odor | 400 | ASHRAE (2019) example criterion for an accidental spill in a fume hood |
| **Equipment Sources** | | | |
| 700 kW Standby Diesel Generator | Health (ACGIH) | 4,580 | Health limit associated with NO2 emissions |
| | Health (OSHA) | 36,161 | Health limit associated with NO2 emissions |
| | Odour (Standard) | 181 | 1:2000 odor dilution threshold for diesel exhaust |
| | Odour (Filtered) | 903 | 1:400 odor dilution threshold for filtered diesel exhaust |

Note:
1) See Section 2 for detailed discussion.

## Table 4: Test Plan, Normalized Concentration Results and Percent Time the Design Criteria may be Exceeded for Each Source/Receptor Combination Evaluated in the Wind Tunnel

| Run # | Source ID | Stack Height Above Base (m) | Receptor Identification | Wind Direction (Deg.) | Wind Speed (m/s) | (1) Max Normalized WT-Measured Concentration (μg/m³)/(g/s) | (2) Design Criteria (μg/m³)/(g/s) | (3) Design Criteria Achieved? | (4) Approximate Percent Time Design Criteria May Be Exceeded |
|---|---|---|---|---|---|---|---|---|---|
| **Bloomsbury Square Fume Extracts** | | | | | | | | | |
| **Bloomsbury North Fume Stack 1** | | | | | | | | | |
| Source Base Height: 35.5 m (Main Roof) | | | | | | | | | |
| (6.4 m³/s @ 16.1 m/s) | | | | | | | ASHRAE | | |
| 101 | EF-N1 | 4.0 | 2 - North Roof NW Intake | 120 | 12.3 | 673 | 400 | No | 0.2% |
| 102 | EF-N1 | 4.0 | 3 - North Roof N Intake 1 | 170 | 14.1 | 154 | 400 | Yes | - |
| 103 | EF-N1 | 4.0 | 5 - North Roof NE Intake | 200 | 12.3 | 203 | 400 | Yes | - |
| 104 | EF-N1 | 4.0 | 6 - North Roof SE Intake | 270 | 16.2 | 184 | 400 | Yes | - |
| 175 | EF-N1 | 4.0 | 7 - South Roof NE Intake | 300 | 12.3 | 227 | 400 | Yes | - |
| 106 | EF-N1 | 4.0 | 8 - South Roof SE Intake | 300 | 9.3 | 297 | 400 | Yes | - |
| ~~107~~ | ~~EF-N1~~ | ~~4.0~~ | ~~45 - Level 9 N Intake (Removed)~~ | ~~310~~ | ~~9.3~~ | ~~1,141~~ | ~~400~~ | ~~No~~ | ~~1.8%~~ |
| 108 | EF-N1 | 4.0 | 10 - South Roof S Intake 2 | 320 | 9.3 | 150 | 400 | Yes | - |
| 109 | EF-N1 | 4.0 | 11 - South Roof SW Intake | 330 | 12.3 | 385 | 400 | Yes | - |
| 110 | EF-N1 | 4.0 | 12 - South Roof NW Intake | 320 | 14.1 | 499 | 400 | No | 0.1% |
| 111 | EF-N1 | 4.0 | 15 - NW Façade Intake 2 | 30 | 12.3 | 39 | 400 | Yes | - |
| 112 | EF-N1 | 4.0 | 16 - NE Façade Intake 1 | 210 | 16.2 | 1 | 400 | Yes | - |
| 113 | EF-N1 | 4.0 | 23 - Bloomsbury Place Building 1 | 110 | 21.4 | 4 | 400 | Yes | - |
| 114 | EF-N1 | 4.0 | 43 - Bloomsbury Square Park | 50 | 5.3 | 41 | 400 | Yes | - |
| ~~115~~ | ~~EF-N1~~ | ~~4.0~~ | ~~46 - Level 8 N Intake (Removed)~~ | ~~305~~ | ~~16.2~~ | ~~982~~ | ~~400~~ | ~~No~~ | ~~1.0%~~ |
| 116 | EF-N1 | 4.0 | 1 - North Roof SW Intake | 320 | 16.2 | 282 | 400 | Yes | - |
| **Location Sensitvity Testing** | | | | | | | | | |
| (6.4 m³/s @ 16.1 m/s) | | | | | | | | | |
| 141 | EF-N2 | 4.0 | 2 - North Roof NW Intake | 120 | 12.3 | 644 | 400 | No | 0.4% |
| 142 | EF-N2 | 4.0 | 12 - South Roof NW Intake | 320 | 12.3 | 464 | 400 | No | 0.0% |
| ~~143~~ | ~~EF-N2~~ | ~~4.0~~ | ~~45 - Level 9 N Intake (Removed)~~ | ~~310~~ | ~~12.3~~ | ~~1,148~~ | ~~400~~ | ~~No~~ | ~~2.1%~~ |
| **Simulated Runs - Desktop Evaluation of Updated Design** | | | | | | | | | |
| (3.6 m³/s @ 20.77 m/s) | | | | | | | | | |
| 101B | EF-N1-2 | 4.0 | 2 - North Roof NW Intake | 120 | 12.3 | 673 | 400 | No | 0.2% |
| 141B | EF-N2-2 | 4.0 | 2 - North Roof NW Intake | 120 | 12.3 | 644 | 400 | No | 0.4% |

**Table 4: Test Plan, Normalized Concentration Results and Percent Time the Design Criteria may be Exceeded for Each Source/Receptor Combination Evaluated in the Wind Tunnel**

| Run # | Source ID | Stack Height Above Base (m) | Receptor Identification | Wind Direction (Deg.) | Wind Speed (m/s) | (1) Max Normalized WT-Measured Concentration (µg/m³)/(g/s) | (2) Design Criteria (µg/m³)/(g/s) | (3) Design Criteria Achieved? | (4) Approximate Percent Time Design Criteria May Be Exceeded |
|---|---|---|---|---|---|---|---|---|---|
| **Bloomsbury Square Fume Extracts** | | | | | | | | | |
| **Bloomsbury South Fume Stack 1** | | | | | | | | | |
| Source Base Height: 35.5 m (Main Roof) | | | | | | | | | |
| (6.4 m³/s @ 16.1 m/s) | | | | | | | ASHRAE | | |
| 201 | EF-S1 | 4.0 | 1 - North Roof SW Intake | 150 | 14.1 | 489 | 400 | No | 0.0% |
| 202 | EF-S1 | 4.0 | 2 - North Roof NW Intake | 140 | 7.0 | 420 | 400 | No | 0.2% |
| 203 | EF-S1 | 4.0 | 11 - South Roof SW Intake | 350 | 12.3 | 601 | 400 | No | 0.3% |
| 204 | EF-S1 | 4.0 | 12 - South Roof NW Intake | 10 | 14.1 | 417 | 400 | No | 0.0% |
| 205 | EF-S1 | 4.0 | 34 - NYX Hotel Terrace 2 | 240 | 7.0 | 272 | 400 | Yes | - |
| ~~206~~ | ~~EF-S1~~ | ~~4.0~~ | ~~45 - Level 9 N Intake (Removed)~~ | ~~160~~ | ~~7.0~~ | ~~597~~ | ~~400~~ | ~~No~~ | ~~1.5%~~ |
| ~~207~~ | ~~EF-S1~~ | ~~4.0~~ | ~~46 - Level 8 N Intake (Removed)~~ | ~~160~~ | ~~12.3~~ | ~~526~~ | ~~400~~ | ~~No~~ | ~~1.0%~~ |
| 208 | EF-S1 | 4.0 | 8 - South Roof SE Intake | 260 | 12.3 | 226 | 400 | Yes | - |
| 209 | EF-S1 | 4.0 | 9 - South Roof S Intake 1 | 300 | 12.3 | 146 | 400 | Yes | - |
| **Simulated Runs - Desktop Evaluation of Updated Design** | | | | | | | | | |
| (3.6 m³/s @ 20.77 m/s) | | | | | | | | | |
| 203B | EF-S1-2 | 4.0 | 11 - South Roof SW Intake | 350 | 12.3 | 601 | 400 | No | 0.3% |

Notes:

1) The maximum normalized concentration (*C/m*) measured in the wind tunnel for the specific source/receptor pair.
2) The maximum acceptable *C/m* for each specific source, based on criteria discussed in Section 2.
3) "Yes" if (1) < (2) or "No" if (1) > (2).
4) Approximate percentage of time for which the prescribed emission scenario may produce concentrations greater than (2), based on a curve fit to all data collected for the specific source/receptor pair and the local wind frequency distribution.

**Table 5: Predicted Normalized Concentrations as a Function of String Line Distance for the Proposed Generator**

| Run # | Source ID | Description of Air Quality Impact Scenario Evaluated | Volume Flow Rate $Q_e$ ($m^3/s$) | Exit Diameter $d_e$ (m) | Exit Velocity $V_e$ (m/s) | String Line Distance S (m) | PREDICTED MAX Concentration C/m ($(\mu g/m^3)/(g/s)$) |
|---|---|---|---|---|---|---|---|
| **700 kW Standby Diesel Generator** | | | | | | | |
| (5862 cfm @ 7464 fpm) | | | | | | | |
| 901 | DG-1 | Seperation distance to meet Health (ACGIH/OSHA) | 2.77 | 0.30 | 37.93 | 4.4 | 4,580.0 |
| 902 | DG-1 | Seperation distance to meet Odor (Standard) | 2.77 | 0.30 | 37.93 | 187 | 181 |
| 903 | DG-1 | Seperation Distance to meet Odor (Filtered) | 2.77 | 0.30 | 37.93 | 37.5 | 903.0 |

## Table 6: Chemical Fume Hood Normalized Health Limits and Odour Thresholds in Order of Toxicity and Volatility

| | | 1 min Lecture Bottle Release / 1 Liter Spill Health Limit (µg/m³)/(g/s) | | 1 min Lecture Bottle Release / 1 Liter Spill Odor Threshold (µg/m³)/(g/s) | | Limiting Value Per 1 Liter Spill or 1 min Release | Max Volume (mL) for Liquid Max Release Rate (g/s) for Gas ASHRAE | |
|---|---|---|---|---|---|---|---|---|
| *Substance* | CAS# | Gas | Liquid | Gas | Liquid | (µg/m³)/(g/s) | gas (g/s) | liquid (mL) |
| Arsine | 7784-42-1 | 0.3 | | 3888.4 | | 0.3 | 0.005 | - |
| Methyl mercaptan | 74-93-1 | 264.3 | | 0.3 | | 0.3 | 0.003 | - |
| Ethyl mercaptan | 75-08-1 | | 437.2 | | 0.3 | 0.3 | - | 0.7 |
| Ethyl acrylate | 140-88-5 | | 193981.8 | | 3.1 | 3.1 | - | 7.8 |
| Nickel carbonyl (as Ni) | 13463-39-3 | | 3.6 | | 360.5 | 3.6 | - | 9.0 |
| Perchloromethyl mercaptan | 594-42-3 | | 1741.8 | | 5.7 | 5.7 | - | 14.3 |
| Sulfur pentafluoride | 5714-22-7 | | 6.5 | | | 6.5 | - | 16.2 |
| Chromyl chloride | 14977-61-8 | | 6.9 | | | 6.9 | - | 17.2 |
| Chlorine trifluoride | 7790-91-2 | 10.0 | | | | 10.0 | 0.95 | - |
| Butyl mercaptan | 109-79-5 | | 5263.3 | | 10.8 | 10.8 | - | 26.9 |
| Osmium tetroxide | 20816-12-0 | | 15.5 | | | 15.5 | - | 38.8 |
| Picric acid | 88-89-1 | | | | 20.1 | 20.1 | - | 50.4 |
| Pentaborane | 19624-22-7 | | 21.9 | | 1828.7 | 21.9 | - | 54.9 |
| Hydrogen sulfide | 7783-06-4 | 3964.8 | | 22.1 | | 22.1 | 0.21 | - |
| Carbon disulfide | 75-15-0 | | 12253.0 | | 25.8 | 25.8 | - | 65 |
| Acetic anhydride | 108-24-7 | | 452071.9 | | 27.3 | 27.3 | | |
| Chlorine | 7782-50-5 | 191.6 | | 30.6 | | 30.6 | 0.58 | - |
| Acetaldehyde | 75-07-0 | 3737845.4 | 12758.3 | 10017.4 | 34.1 | 34.1 | 0.001 | 85.3 |
| Hydrogen selenide | 7783-07-5 | 126.9 | | 36.6 | | 36.6 | 0.35 | - |
| Chloromethyl ether(bis-) | 542-88-1 | | 37.7 | | | 37.7 | - | 94.3 |
| Hydrogen fluoride | 7664-39-3 | 607.9 | 1396.8 | | 40.5 | 40.5 | 0.38 | 101 |
| Isopropylamine | 75-31-0 | | 8149.5 | | 49.1 | 49.1 | - | 123 |
| Isopropyl ether | 108-20-3 | | 986753.6 | | 53.8 | 53.8 | - | 135 |
| Methyl isocyanate | 624-83-9 | | 65.5 | | | 65.5 | - | 164 |
| Diethylamine | 109-89-7 | | 29597.6 | | 104.0 | 104.0 | - | 260 |
| Cresol (all isomers) | 1319-77-3 | | 2559512.3 | | 105.5 | 105.5 | - | 264 |
| Phosgene | 75-44-5 | 105.7 | | 373.8 | | 105.7 | 2.0 | - |
| Amyl acetate(sec-) | 626-38-0 | | 19750987.8 | | 108.4 | 108.4 | - | 271 |
| Tungsten hexafluoride | 7783-82-6 | 132.2 | 409.0 | | | 132.2 | 25.0 | 1,022 |
| Dimethylhydrazine(1,1-) | 57-14-7 | | 146.8 | | 22079.3 | 146.8 | - | 367 |
| Butyl acetate(n-) | 123-86-4 | | 5031407.0 | | 165.8 | 165.8 | | |
| Diborane | 19287-45-7 | 240.3 | | 2265.5 | | 240.3 | 0.75 | - |
| Phosphine | 7803-51-2 | 264.3 | | 685.7 | | 264.3 | 2.5 | - |
| Ethylamine | 75-04-7 | 16560.0 | | 287.2 | | 287.2 | 1.2 | - |
| Nitrogen dioxide | 10102-44-0 | 297.5 | | 739.2 | | 297.5 | 4.5 | - |
| Methyl hydrazine | 60-34-4 | | 320.4 | | 12139.2 | 320.4 | - | 801 |
| Benzyl mercaptan | 100-53-8 | | | | 320.7 | 320.7 | - | 802 |
| Bromine pentafluoride | 7789-30-2 | | 335.7 | | | 335.7 | - | 839 |
| Tetramethyl lead (as Pb) | 75-74-1 | | 337.8 | | | 337.8 | - | 845 |
| Butadiene | 106-99-0 | 4652.0 | | 350.2 | | 350.2 | 2.5 | - |
| Butylamine | 109-73-9 | | 23069.0 | | 367.6 | 367.6 | - | 919 |
| Bromine | 7726-95-6 | | 436.6 | | 953.5 | 436.6 | | |
| Dimethylamine | 124-40-3 | 9118.9 | | 479.8 | | 479.8 | | |
| Ethyl ether | 60-29-7 | | 430364.0 | | 487.9 | 487.9 | | |
| Acrolein | 107-02-8 | | 540.7 | | 968.9 | 540.7 | | |
| Acetic acid | 64-19-7 | | 516651.6 | | 548.1 | 548.1 | | |
| Triethylamine | 121-44-8 | | 34967.1 | | 558.2 | 558.2 | | |
| Methyl styrene(alpha-) | 98-83-9 | | 18743772.3 | | 565.2 | 565.2 | | |
| Morpholine | 110-91-8 | | 1854740.4 | | 690.8 | 690.8 | | |
| Diisopropylamine | 108-18-9 | | 78187.2 | | 699.7 | 699.7 | | |
| Tetranitromethane | 509-14-8 | | 706.5 | | | 706.5 | | |
| Mesityl oxide | 141-79-7 | | 1044501.9 | | 711.7 | 711.7 | | |
| Methyl methracrylate | 80-62-6 | | 2835791.4 | | 800.7 | 800.7 | | |
| Fluorine | 7782-41-4 | 819.4 | | 1585.9 | | 819.4 | | |
| Hydrogen bromide | 10035-10-6 | 1308.4 | 53793.6 | 881.1 | 36224.8 | 881.1 | | |
| Sulfur dioxide | 7446-09-5 | 1718.1 | | 933.6 | | 933.6 | | |
| Nitric oxide | 10102-43-9 | 129285.6 | | 944.2 | | 944.2 | | |
| Hydrogen chloride | 7647-01-0 | 1850.2 | 4440.7 | | 944.3 | 944.3 | | |
| Methylene chloride | 75-09-2 | | 162165.3 | | 981.8 | 981.8 | | |
| Boron trifluoride | 7637-07-2 | 986.8 | | 1585.9 | | 986.8 | | |
| Germane tetrahydride | 7785-65-2 | 1080.0 | | | | 1,080.0 | | |
| Ethyl alcohol | 64-17-5 | | 25364403.4 | | 1138.7 | 1,138.7 | | |
| Hydrazine | 302-01-2 | | 1153.9 | | 139411.6 | 1,153.9 | | |
| Ethylene oxide | 75-21-8 | 1321.6 | | 199823.8 | | 1,321.6 | | |
| Dibromo-3-chloropropane(1,2-) | 96-12-8 | | 1420.4 | | 8158.6 | 1,420.4 | | |
| Propyl acetate(n-) | 109-60-4 | | 2348473.6 | | 1695.5 | 1,695.5 | | |
| Tributyl phosphate | 126-73-8 | | 1801.5 | | | 1,801.5 | | |
| Xylidine | 1300-73-8 | | 571244.3 | | 1828.0 | 1,828.0 | | |
| Phosphorus trichloride | 7719-12-2 | | 1881.2 | | | 1,881.2 | | |
| Butyl alcohol(n-) | 71-36-3 | | 3114476.3 | | 1883.9 | 1,883.9 | | |
| Iron carbonyl | 13463-40-6 | | 1883.9 | | | 1,883.9 | | |
| Fluroxene | 406-90-6 | | 1985.8 | | | 1,985.8 | | |
| Chloroprene(beta-) | 126-99-8 | | 1997.4 | | | 1,997.4 | | |
| Methylamine | 74-89-5 | 6696.0 | | 2102.6 | | 2,102.6 | | |
| Cumene | 98-82-8 | | 11289536.2 | | 2411.4 | 2,411.4 | | |
| Dichloropropane (-1,2) | 78-87-5 | | 1037501.0 | | 2449.1 | 2,449.1 | | |

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## Table 6: Chemical Fume Hood Normalized Health Limits and Odour Thresholds in Order of Toxicity and Volatility

| | | 1 min Lecture Bottle Release / 1 Liter Spill — Health Limit (µg/m³)/(g/s) | | Odor Threshold (µg/m³)/(g/s) | | Limiting Value Per 1 Liter Spill or 1 min Release | Max Volume (mL) for Liquid Max Release Rate (g/s) for Gas ASHRAE | |
|---|---|---|---|---|---|---|---|---|
| *Substance* | CAS# | Gas | Liquid | Gas | Liquid | (µg/m³)/(g/s) | gas (g/s) | liquid (mL) |
| Allyl chloride | 107-05-1 | | 2454.3 | | 4206.5 | 2,454.3 | | |
| Methyl (n-amyl) ketone | 110-43-0 | | 18834454.7 | | 2532.8 | 2,532.8 | | |
| Halothane | 151-67-7 | | 2635.8 | | | 2,635.8 | | |
| Toluene | 108-88-3 | | 2806478.0 | | 3014.3 | 3,014.3 | | |
| Ethyl acetate | 141-78-6 | | 5947095.3 | | 3106.0 | 3,106.0 | | |
| Enflurane | 13838-16-9 | | 3293.8 | | | 3,293.8 | | |
| Xylenes (o-,m-,p-isomers) | 1330-20-7 | | 6287488.4 | | 3349.2 | 3,349.2 | | |
| Chloroacetaldehyde | 107-20-0 | | 3527.9 | | 3527.9 | 3,527.9 | | |
| Ethylenimine | 151-56-4 | | 3534.0 | | 5354.6 | 3,534.0 | | |
| Styrene, monomer | 100-42-5 | | 7530337.5 | | 3767.9 | 3,767.9 | | |
| Nitrogen trifluoride | 7783-54-2 | 3832.6 | | | | 3,832.6 | | |
| Hydrogen cyanide | 74-90-8 | 29610.5 | | 3915.8 | | 3,915.8 | | |
| Thionyl chloride | 7719-09-7 | | 3959.5 | | | 3,959.5 | | |
| Ethylene dibromide | 106-93-4 | | 4094.1 | | 314424.5 | 4,094.1 | | |
| Nitric acid | 7697-37-2 | | 30526.8 | | 4180.1 | 4,180.1 | | |
| Chloroform | 67-66-3 | | 4725.8 | | 452145.7 | 4,725.8 | | |
| Methyl iodide | 74-88-4 | | 4879.1 | | | 4,879.1 | | |
| Benzene | 71-43-2 | | 5043.1 | | 43456.2 | 5,043.1 | | |
| Ethylmorpholine(n-) | 100-74-3 | | 921528.1 | | 5337.8 | 5,337.8 | | |
| Methyl chloride | 74-87-3 | 54713.7 | | 5550.7 | | 5,550.7 | | |
| Chloropicrin | 76-06-2 | | 5643.2 | | 18204.3 | 5,643.2 | | |
| Phenyl ether (vapor) | 101-84-8 | | 37966601.1 | | 5651.8 | 5,651.8 | | |
| Phosphorus oxychloride | 10025-87-3 | | 6249.0 | | | 6,249.0 | | |
| Methyl bromide | 74-83-9 | 7048.5 | | 49840.1 | | 7,048.5 | | |
| Boron tribromide | 10294-33-4 | | 7056.9 | | | 7,056.9 | | |
| Cyclohexanone | 108-94-1 | | 5640310.3 | | 7159.0 | 7,159.0 | | |
| Acrylonitrile | 107-13-1 | | 45032.8 | | 7263.4 | 7,263.4 | | |
| Formic acid | 64-18-6 | | 108940.9 | | 7478.1 | 7,478.1 | | |
| Acetone cyanohydrin | 75-86-5 | | 7612.4 | | | 7,612.4 | | |
| Cyanogen | 460-19-5 | 7929.5 | | | | 7,929.5 | | |
| Propyl alcohol(n-) | 71-23-8 | | 4490946.1 | | 7930.5 | 7,930.5 | | |
| Carbon tetrachloride | 56-23-5 | | 8310.7 | | 168519.5 | 8,310.7 | | |
| Ammonia | 7664-41-7 | 8458.1 | | | 78402.4 | 8,458.1 | | |
| Tetrachloroethane(1,1,2,2-) | 79-34-5 | | 126456.3 | | 8791.7 | 8,791.7 | | |
| Trichloroethylene | 79-01-6 | | 650450.4 | | 8835.0 | 8,835.0 | | |
| Trimethylamine | 75-50-3 | 9515.4 | | | | 9,515.4 | | |
| Acetylene | 74-86-2 | 39781.2 | | 9731.1 | | 9,731.1 | | |
| Allyl alcohol | 107-18-6 | | 88789.5 | | 10417.1 | 10,417.1 | | |
| Dichloroethylene(1,2-) | 540-59-0 | | 1015984.0 | | 11039.8 | 11,039.8 | | |
| Ethylene dichloride | 107-06-2 | | 11655.7 | | 153070.2 | 11,655.7 | | |
| Silane | 7803-62-5 | 11880.0 | | | | 11,880.0 | | |
| Amyl acetate(n-) | 628-63-7 | | 22333809.3 | | 12283.3 | 12,283.3 | | |
| Pyridine | 110-86-1 | | 262584.6 | | 12434.0 | 12,434.0 | | |
| Dioxane | 123-91-1 | | 13007.4 | | 101083.1 | 13,007.4 | | |
| Sulfur monochloride | 10025-67-9 | | 13018.0 | | | 13,018.0 | | |
| Nitrobenzene | 98-95-3 | | 1124854.7 | | 13941.2 | 13,941.2 | | |
| Ethyl bromide | 74-96-4 | | 13974.0 | | 188437.2 | 13,974.0 | | |
| Benzyl chloride | 100-44-7 | | 364585.6 | | 15448.3 | 15,448.3 | | |
| Butyl alcohol(sec-) | 78-92-2 | | 2361811.2 | | 15699.5 | 15,699.5 | | |
| Chloroacetone | 78-95-5 | | 15801.3 | | | 15,801.3 | | |
| Vinyl acetate | 108-05-4 | | 17890.1 | | | 17,890.1 | | |
| Methyl cellosolve | 109-86-4 | | 18195.7 | | 150715.2 | 18,195.7 | | |
| Pentyl mercaptan | 110-66-7 | | 18420.2 | | | 18,420.2 | | |
| Methoxyflurane | 76-38-0 | | 18882.2 | | | 18,882.2 | | |
| Propylenimine | 75-55-8 | | 20353.0 | | | 20,353.0 | | |
| Dichloromonofluoromethane | 75-43-4 | 21145.4 | | | | 21,145.4 | | |
| Furfural | 98-01-1 | | 2276607.7 | | 21853.7 | 21,853.7 | | |
| Methylacrylonitrile | 126-98-7 | | 22776.0 | | | 22,776.0 | | |
| Acrylic acid | 79-10-7 | | 26387.9 | | | 26,387.9 | | |
| Glutaraldehyde | 111-30-8 | | 28404.0 | | | 28,404.0 | | |
| Phenyl mercaptan | 108-98-5 | | 29971.8 | | | 29,971.8 | | |
| Formaldehyde (Formalin) | 50-00-0 | | 113852.8 | | 30143.0 | 30,143.0 | | |
| Dichoropropene(1,3-) | 542-75-6 | | 32077.9 | | | 32,077.9 | | |
| Tetraethyl lead (as Pb) | 78-00-2 | | 32102.7 | | | 32,102.7 | | |
| Dichloroethylene(1,1-) | 75-35-4 | | 33866.1 | | | 33,866.1 | | |
| Propargyl alcohol | 107-19-7 | | 34105.8 | | | 34,105.8 | | |
| Methyl acrylate | 96-33-3 | | 34639.1 | | 115463.5 | 34,639.1 | | |
| Diisobutyl ketone | 108-83-8 | | 14109694.0 | | 35938.2 | 35,938.2 | | |
| Nitrous oxide | 10024-97-2 | 36475.8 | | | | 36,475.8 | | |
| Isopropyl acetate | 108-21-4 | | 2774295.8 | | 36781.7 | 36,781.7 | | |
| Propylene oxide | 75-56-9 | | 51415.0 | | 38102.2 | 38,102.2 | | |
| Chlorobenzene | 108-90-7 | | 942806.8 | | 40818.7 | 40,818.7 | | |
| Pentane(n-) | 109-66-0 | | 575358.5 | | 44977.8 | 44,977.8 | | |
| Phenylhydrazine | 100-63-0 | | 51237.6 | | | 51,237.6 | | |
| Dichlorobenzene(o-) | 95-50-1 | | 18839403.8 | | 52750.3 | 52,750.3 | | |
| Hexyl acetate(sec-) | 108-84-9 | | 18885130.5 | | 57258.9 | 57,258.9 | | |

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## Table 6: Chemical Fume Hood Normalized Health Limits and Odour Thresholds in Order of Toxicity and Volatility

| | | 1 min Lecture Bottle Release / 1 Liter Spill Health Limit (µg/m³)/(g/s) | | Odor Threshold (µg/m³)/(g/s) | | Limiting Value Per 1 Liter Spill or 1 min Release | Max Volume (mL) for Liquid Max Release Rate (g/s) for Gas ASHRAE | |
|---|---|---|---|---|---|---|---|---|
| *Substance* | CAS# | Gas | Liquid | Gas | Liquid | (µg/m³)/(g/s) | gas (g/s) | liquid (mL) |
| Methyl cellosolve acetate | 110-49-6 | | 58623.9 | | 62170.0 | 58,623.9 | | |
| Cyclohexanol | 108-93-0 | | 55277292.6 | | 60286.1 | 60,286.1 | | |
| Ethylene chlorohydrin | 107-07-3 | | 68804.8 | | | 68,804.8 | | |
| Acetone | 67-64-1 | | 1421616.4 | | 87822.8 | 87,822.8 | | |
| Tetrahydrofuran | 109-99-9 | | 712921.0 | | 88488.1 | 88,488.1 | | |
| Sulfuric acid | 7664-93-9 | | 282303.0 | | 94101.0 | 94,101.0 | | |
| Diacetone alcohol | 123-42-2 | | 56722494.1 | | 101732.8 | 101,732.8 | | |
| Chlorodiphenyl (42% chlorine) | 53469-21-9 | | 107340.8 | | | 107,340.8 | | |
| Diethylaminoethanol(2-) | 100-37-8 | | 108021.2 | | | 108,021.2 | | |
| Bromoform | 75-25-2 | | 109548.7 | | 38707224.4 | 109,548.7 | | |
| Crotonaldehyde | 4170-30-3 | | 118518.9 | | | 118,518.9 | | |
| Methyl formate | 107-31-3 | | 118748.9 | | 1583143.2 | 118,748.9 | | |
| Ethylene glycol dinitrate | 628-96-6 | | 121384.7 | | | 121,384.7 | | |
| Benzoyl chloride | 98-88-4 | | 122558.9 | | | 122,558.9 | | |
| Ethoxyethanol(2-) | 110-80-5 | | 138315.9 | | | 138,315.9 | | |
| Vinyl chloride | 75-01-4 | 166292.6 | | | | 166,292.6 | | |
| Epichlorohydrin | 106-89-8 | | 175030.2 | | 485521.1 | 175,030.2 | | |
| Isophorone | 78-59-1 | | 4675771.0 | | 178974.3 | 178,974.3 | | |
| Methyl (tert-) butyl ether | 1634-04-4 | | 188822.2 | | | 188,822.2 | | |
| Propiolactone(beta-) | 57-57-8 | | 192052.2 | | | 192,052.2 | | |
| Butyl alcohol(tert-) | 75-65-0 | | 1334775.6 | | 192879.6 | 192,879.6 | | |
| Propionitrile | 107-12-0 | | 193133.2 | | | 193,133.2 | | |
| Ethyl chloride | 75-00-3 | 209339.2 | | | | 209,339.2 | | |
| Cyclopentadiene | 542-92-7 | | 215964.0 | | | 215,964.0 | | |
| Hydrogen peroxide | 7722-84-1 | | 228067.6 | | | 228,067.6 | | |
| Carbon monoxide | 630-08-0 | 238655.8 | | | | 238,655.8 | | |
| Dichloroethane(1,1-) | 75-34-3 | | 486498.4 | | 243401.2 | 243,401.2 | | |
| Chloropentafluoroethane (Freon 115) | 76-15-3 | 250572.7 | | | | 250,572.7 | | |
| Dichloro-1-nitro-ethane(1,1-) | 594-72-9 | | 256603.4 | | | 256,603.4 | | |
| Hexanone(2-) | 591-78-6 | | 276386.5 | | | 276,386.5 | | |
| Ethoxyethyl acetate(2-) | 111-15-9 | | 282804.8 | | | 282,804.8 | | |
| Acetonitrile | 75-05-8 | | 310756.3 | | 5987317.4 | 310,756.3 | | |
| Cyclohexane | 110-82-7 | | 3456874.0 | | 322192.3 | 322,192.3 | | |
| Nitropropane(1-) | 108-03-2 | | 3496707.5 | | 333928.4 | 333,928.4 | | |
| Butyronitrile (n-) | 109-74-0 | | 339121.9 | | | 339,121.9 | | |
| Methyl aniline | 100-61-8 | | 345095.6 | | | 345,095.6 | | |
| Methyl aniline | 100-61-8 | | 345095.6 | | | 345,095.6 | | |
| Ethylenediamine | 107-15-3 | | 1047266.8 | | 369441.0 | 369,441.0 | | |
| Chloro-1-nitropropane(1-) | 600-25-9 | | 373434.8 | | | 373,434.8 | | |
| Hexane(n-) | 110-54-3 | | 376962.9 | | | 376,962.9 | | |
| Methyl acetate | 79-20-9 | | 545123.4 | | 392033.8 | 392,033.8 | | |
| Methyl alcohol | 67-56-1 | | 1015906.5 | | 409552.3 | 409,552.3 | | |
| Dibutyl phosphate | 107-66-4 | | 439167.8 | | | 439,167.8 | | |
| Isopropyl alcohol | 67-63-0 | | 5701786.0 | | 490966.3 | 490,966.3 | | |
| Trichloroethane(1,1,2-) | 79-00-5 | | 491685.7 | | | 491,685.7 | | |
| Propionic acid | 79-09-4 | | 539492.0 | | | 539,492.0 | | |
| Ethyl formate | 109-94-4 | | 560605.7 | | | 560,605.7 | | |
| Isoamyl alcohol | 123-51-3 | | 1682089.6 | | 608843.9 | 608,843.9 | | |
| Methyl isobutyl carbinol | 108-11-2 | | 4967925.0 | | 614098.1 | 614,098.1 | | |
| Butyl glycidl ether(n-) | 2426-08-6 | | 709009.8 | | | 709,009.8 | | |
| Toluene-2,4-diisocyanate | 584-84-9 | | 741896.2 | | 39223103.4 | 741,896.2 | | |
| Phenol | 108-95-2 | | | | 753576.2 | 753,576.2 | | |
| Ethyl benzene | 100-41-4 | | 4719962.5 | | 756237.1 | 756,237.1 | | |
| Cyclohexylamine | 108-91-8 | | 799247.4 | | | 799,247.4 | | |
| Nitromethane | 75-52-5 | | 810712.0 | | 1351186.7 | 810,712.0 | | |
| Propyl nitrate(n-) | 627-13-4 | | 829539.2 | | 1024724.9 | 829,539.2 | | |
| Nitropropane(2-) | 79-46-9 | | 860728.0 | | 1069470.7 | 860,728.0 | | |
| Chlorobromomethane | 74-97-5 | | 1404492.8 | | 936328.6 | 936,328.6 | | |
| Nicotine | 54-11-5 | | 1067121.0 | | | 1,067,121.0 | | |
| Dimethyl sulfate | 77-78-1 | | 1098093.7 | | | 1,098,093.7 | | |
| Anisidine (o-,p-isomers) | 29191-52-4 | | 1123941.7 | | | 1,123,941.7 | | |
| Trichloropropane(1,2,3-) | 96-18-4 | | 1127296.8 | | | 1,127,296.8 | | |
| Valeraldehyde (n-) | 110-62-3 | | 1260714.0 | | | 1,260,714.0 | | |
| Tetrachloroethylene | 127-18-4 | | 2724214.1 | | 1264931.4 | 1,264,931.4 | | |
| Butyl acrylate (n-) | 141-32-2 | | 1304542.1 | | | 1,304,542.1 | | |
| Methyl chloroform | 71-55-6 | | 1314804.0 | | 1469473.5 | 1,314,804.0 | | |
| Ethyl silicate | 78-10-4 | | 11300929.0 | | 1356437.1 | 1,356,437.1 | | |
| Butoxyethanol | 111-76-2 | | 1408165.6 | | | 1,408,165.6 | | |
| Butoxyethanol | 111-76-2 | | 1408165.6 | | | 1,408,165.6 | | |
| Chlorodiphenyl (54% chlorine) | 11097-69-1 | | 1415844.8 | | | 1,415,844.8 | | |
| Aniline | 62-53-3 | | 3767880.8 | | 1507152.3 | 1,507,152.3 | | |
| Difluorodibromomethane | 75-61-6 | 1544400.0 | | | | 1,544,400.0 | | |
| Butanone(2-) | 78-93-3 | | 1595926.5 | | | 1,595,926.5 | | |
| Trichloro-1,2,2,-trifluoroethane(1,1,2-) | 76-13-1 | | 1641997.1 | | | 1,641,997.1 | | |
| Hexone | 108-10-1 | | 1727415.4 | | | 1,727,415.4 | | |
| Allyl glycidyl ether | 106-92-3 | | 1778360.5 | | 1778360.5 | 1,778,360.5 | | |

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## Table 6: Chemical Fume Hood Normalized Health Limits and Odour Thresholds in Order of Toxicity and Volatility

| | | 1 min Lecture Bottle Release / 1 Liter Spill Health Limit (µg/m³)/(g/s) | | Odor Threshold (µg/m³)/(g/s) | | Limiting Value Per 1 Liter Spill or 1 min Release | Max Volume (mL) for Liquid Max Release Rate (g/s) for Gas ASHRAE | |
|---|---|---|---|---|---|---|---|---|
| *Substance* | CAS# | Gas | Liquid | Gas | Liquid | (µg/m³)/(g/s) | gas (g/s) | liquid (mL) |
| Toluidine(m-) | 108-44-1 | | 1894484.8 | | | 1,894,484.8 | | |
| Isopropyl glycidyl ether | 4016-14-2 | | 2118487.2 | | 12710923.0 | 2,118,487.2 | | |
| Cyclohexene | 110-83-8 | | 2126738.4 | | | 2,126,738.4 | | |
| Heptane(n-) | 142-82-5 | | 4145796.9 | | 2166531.4 | 2,166,531.4 | | |
| Diglycidyl ether | 2238-07-5 | | 2205808.3 | | 19694717.2 | 2,205,808.3 | | |
| Nitrotoluene, m-isomer | 99-08-1 | | 2221977.8 | | | 2,221,977.8 | | |
| Nitrotoluene, o-isomer | 88-72-2 | | 2221977.8 | | | 2,221,977.8 | | |
| Nitrotoluene, p-isomer | #N/A | | 2221977.8 | | | 2,221,977.8 | | |
| Propane | 74-98-6 | 2283700.4 | | 3404339.6 | | 2,283,700.4 | | |
| Trichlorobenzene(1,2,4-) | 120-82-1 | | 2358828.7 | | | 2,358,828.7 | | |
| Glycidol | 556-52-5 | | 2533107.4 | | | 2,533,107.4 | | |
| Dichlorodifluoromethane | 75-71-8 | 2616740.1 | | | | 2,616,740.1 | | |
| Cyclopentane | 287-92-3 | | 2654330.2 | | | 2,654,330.2 | | |
| Butyltoluene(p-tert-) | 98-51-1 | | 10671004.2 | | 2667751.0 | 2,667,751.0 | | |
| Dimethylformamide | 68-12-2 | | 2841373.8 | | 9471246.1 | 2,841,373.8 | | |
| Ethanolamine | 141-43-5 | | 5665696.3 | | 2848872.7 | 2,848,872.7 | | |
| Furfuryl alcohol | 98-00-0 | | 5646059.9 | | 3014304.6 | 3,014,304.6 | | |
| Bromotrifluoromethane | 75-63-8 | 3018171.8 | | | | 3,018,171.8 | | |
| Methylal | 109-87-5 | | 3418594.5 | | | 3,418,594.5 | | |
| Phosdrin | 7786-34-7 | | 3705699.0 | | | 3,705,699.0 | | |
| Dimethylaniline | 121-69-7 | | 3808295.3 | | | 3,808,295.3 | | |
| Mercury vapor | 7439-97-6 | | 3834873.7 | | | 3,834,873.7 | | |
| Indene | 95-13-6 | | 4297333.0 | | | 4,297,333.0 | | |
| Butyl acetate(tert-) | 540-88-5 | | 4354102.2 | | | 4,354,102.2 | | |
| Methylcyclohexane | 108-87-2 | | 10493600.6 | | 4372333.6 | 4,372,333.6 | | |
| Pyrethrum | 8003-34-7 | | 4381949.9 | | | 4,381,949.9 | | |
| Methacrylic acid | 79-41-4 | | 4508313.1 | | | 4,508,313.1 | | |
| Sulfur hexafluoride | 2552-62-4 | 4733920.7 | | | | 4,733,920.7 | | |
| Nitroethane | 79-24-3 | | 7075594.7 | | 4763158.2 | 4,763,158.2 | | |
| Ethyl amyl ketone | 541-85-5 | | 5113934.8 | | | 5,113,934.8 | | |
| Dichloroethylether | 111-44-4 | | 5348809.7 | | 40660928.1 | 5,348,809.7 | | |
| Dimethyl acetamide | 127-19-5 | | 5564221.2 | | 8605675.6 | 5,564,221.2 | | |
| Octane | 111-65-9 | | 14146049.7 | | 5651821.1 | 5,651,821.1 | | |
| Dipropyl ketone | 123-19-3 | | 5660249.3 | | | 5,660,249.3 | | |
| Pentanone(2-) | 107-87-9 | | 5903587.6 | | | 5,903,587.6 | | |
| Isobutyl alcohol | 78-83-1 | | 6228952.7 | | | 6,228,952.7 | | |
| Hexylene glycol | 107-41-5 | | 6713476.7 | | | 6,713,476.7 | | |
| Kerosene | 8008-20-6 | | 6923480.9 | | | 6,923,480.9 | | |
| Toluidine(o-) | 95-53-4 | | 7577939.3 | | | 7,577,939.3 | | |
| Phorate | 298-02-2 | | 8453578.6 | | | 8,453,578.6 | | |
| Diethyl ketone | 96-22-0 | | 8461272.1 | | | 8,461,272.1 | | |
| Dichlorvos | 62-73-7 | | 9398390.4 | | | 9,398,390.4 | | |
| Phosphoric acid | 7664-38-2 | | 9419701.9 | | | 9,419,701.9 | | |
| Butyl acetate(sec-) | 105-46-4 | | 9433888.2 | | | 9,433,888.2 | | |
| Tetraethyl pyrophosphate | 107-49-3 | | 9549628.8 | | | 9,549,628.8 | | |
| Formamide | 75-12-7 | | 10257008.7 | | | 10,257,008.7 | | |
| Chlorotoluene(o-) | 95-49-8 | | 10483768.8 | | | 10,483,768.8 | | |
| Ethylene glycol | 107-21-1 | | 10635147.3 | | | 10,635,147.3 | | |
| Turpentine | 8006-64-2 | | 22643855.2 | | 10751210.0 | 10,751,210.0 | | |
| Dichlorotetrafluorethane | 76-14-2 | 12582000.0 | | | | 12,582,000.0 | | |
| Isobutyl acetate | 110-19-0 | | 12833143.5 | | | 12,833,143.5 | | |
| Fluorotrichloromethane | 75-69-4 | 13440000.0 | | | | 13,440,000.0 | | |
| Nitroglycerin | 55-63-0 | | 13549549.2 | | | 13,549,549.2 | | |
| Ethyl butyl ketone | 106-35-4 | | 13943963.3 | | | 13,943,963.3 | | |
| Phenyl ether-bi-phenyl mix (vapor) | 8004-13-5 | | 14597700.7 | | | 14,597,700.7 | | |
| Vinyl toluene | 25013-15-4 | | 37721841.7 | | 18743772.3 | 18,743,772.3 | | |
| Naphtha (coal tar) | 8030-30-6 | | 20141035.3 | | | 20,141,035.3 | | |
| Di-sec octyl phthalate | 117-81-7 | | 23639712.8 | | | 23,639,712.8 | | |
| Triethanolamine | 102-71-6 | | 26552179.8 | | | 26,552,179.8 | | |
| Isoamyl acetate | 123-92-2 | | 27917261.7 | | | 27,917,261.7 | | |
| Methylcyclohexanone(o-) | 583-60-8 | | 28302762.1 | | | 28,302,762.1 | | |
| Methylcyclohexanol | 25639-42-3 | | 28372934.0 | | 94980619.4 | 28,372,934.0 | | |
| Dichrotophos | 141-66-2 | | 29212999.5 | | | 29,212,999.5 | | |
| Sulfotep | 3689-24-5 | | 33727832.9 | | | 33,727,832.9 | | |
| Phenyl glycidyl ether | 122-60-1 | | 36900631.0 | | | 36,900,631.0 | | |
| Dibutylphthalate | 84-74-2 | | 49755522.0 | | | 49,755,522.0 | | |
| Acetylene tetrabromide | 79-27-6 | | 56076790.6 | | | 56,076,790.6 | | |
| Disulfoton | 298-04-4 | | 56151507.6 | | | 56,151,507.6 | | |
| Acetophenone | 98-86-2 | | 56541760.6 | | | 56,541,760.6 | | |
| Stoddard solvent | 8052-41-3 | | 57695674.1 | | | 57,695,674.1 | | |
| Diazinon | 333-41-5 | | 65070309.1 | | | 65,070,309.1 | | |
| Dimethylphthalate | 131-11-3 | | 71302583.9 | | | 71,302,583.9 | | |
| Dibrom | 300-76-5 | | 109031195.2 | | | 109,031,195.2 | | |
| Parathion | 56-38-2 | | 118837639.8 | | 377111443.5 | 118,837,639.8 | | |
| Dipropylene glycol methyl ether | 34590-94-8 | | 140151435.1 | | 174799550.8 | 140,151,435.1 | | |
| Triorthocresyl phosphate | 78-30-8 | | 375867583.7 | | | 375,867,583.7 | | |

**Table 6: Chemical Fume Hood Normalized Health Limits and Odour Thresholds in Order of Toxicity and Volatility**

| | | 1 min Lecture Bottle Release / 1 Liter Spill Health Limit (μg/m³)/(g/s) | | Odor Threshold (μg/m³)/(g/s) | | Limiting Value Per 1 Liter Spill or 1 min Release | Max Volume (mL) for Liquid Max Release Rate (g/s) for Gas ASHRAE | |
|---|---|---|---|---|---|---|---|---|
| *Substance* | CAS# | Gas | Liquid | Gas | Liquid | (μg/m³)/(g/s) | gas (g/s) | liquid (mL) |
| Fenthion | 55-38-9 | | 569248172.0 | | | 569,248,172.0 | | |
| Chlorinated diphenyl oxide | 55720-99-5 | | 612318112.0 | | | 612,318,112.0 | | |
| Thioglycolic acid | 68-11-1 | | 1142637454.6 | | | 1,142,637,454.6 | | |
| Malathion | 121-75-5 | | 20954845316.1 | | 9429680392.2 | 9,429,680,392.2 | | |
| Ethion | 563-12-2 | | 19231891367.9 | | | 19,231,891,367.9 | | |

NOTE: See CPP internal document "Simulation and Analysis Techniques for Air Quality Assessments," April 2010 for a description on how an HL is computed from the OEL.

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## Table 7: Normalized Health Limits and Odour Thresholds Listed for Combustion Source

***Health Limits and Odor Thresholds***

| | Health (µg/m³) TWA | Health (µg/m³) STEL | Odor (µg/m³) |
|---|---|---|---|
| Diesel Exhaust (dilution): | | | 2,000 |
| CO - ACGIH[(1)] | | 229,000 | #N/A |
| NO - NIOSH[(1)] | 30,000 | 90,000 | 657 |
| $NO_2$ - NIOSH[(1)] | | 1,800 | 4,472 |
| $NO_2$ - ACGIH[(1)] | 380 | 1,140 | 4,472 |
| $NO_2$ - OSHA[(1)] | | 9,000 | 4,472 |
| $SO_2$ - ACGIH[(1)] | | 13,000 | 3,832 |
| $PM_{10}$ (Inhalable) OSHA[(1)] | 15,000 | 45,000 | #N/A |
| $PM_{2.5}$ (Respirable) OSHA[(1)] | 5,000 | 15,000 | #N/A |

| ***Emissions Data*** | | 700kW Diesel Generator Tier 2 (2) |
|---|---|---|
| *Input Data:* | Energy Input (MMBTU / hr): | |
| | % sulfur in fuel: | 0.05 |
| | Number of vehicles: | |
| | Vehicle speed (mph): | |
| | Length of road (miles): | |
| *Output Data:* | ated Engine Power Output (kW): | 700.00 |
| | Mass Emission Rate (g/s): | 1,391.30 |
| | Mass Emission Rate (lb/hr): | 11,042.28 |
| | Volume Flow ($m^3$/s): | 2.77 |
| *Emission Factors:* | CO (g/kWhr-DG): | 3.50 |
| | $NO_x$ (g/kWhr-DG): | 6.40 |
| | $SO_2$ (g/kWhr-DG): | 0.25 |
| | $PM_{10}$ (g/kWhr-DG): | 0.200 |
| | $PM_{2.5}$ (g/kWhr-DG): | 0.200 |
| *Emission Rates:* | $NO_2/NO_x$ ambient ratio: | 0.20 |
| | CO (g/s): | 0.68 |
| | $NO_x$ (g/s): | 1.24 |
| | NO (g/s): | 1.12 |
| | $NO_2$ (g/s): | 0.25 |
| | $SO_2$ (g/s): | 0.05 |
| | $PM_{10}$ (g/s): | 0.04 |
| | $PM_{2.5}$ (g/s): | 0.04 |

***Normalized Health Limits and Odor Thresholds***

| | | |
|---|---|---|
| **Health Limits** | CO (µg/m³)/(g/s): | 336,490 |
| | NO (µg/m³)/(g/s): | 80,357 |
| | NIOSH - $NO_2$ (µg/m³)/(g/s): | 7,232 |
| | ACGIH - $NO_2$ (µg/m³)/(g/s): | 4,580 |
| | OSHA - $NO_2$ (µg/m³)/(g/s): | 36,161 |
| | ACGIH - $SO_2$ (µg/m³)/(g/s): | 271,777 |
| | OSHA - $PM_{10}$ (µg/m³)/(g/s): | 1,157,143 |
| | OSHA - $PM_{2.5}$ (µg/m³)/(g/s): | 385,714 |
| | **Health Design Criteria (µg/m³)/(g/s):** | **4,580** |
| | **OSHA Health Design Criteria (µg/m³)/(g/s):** | **36,161** |
| **Odor Thresholds** | Combined Exhaust (µg/m³)/(g/s): | 181 |
| | CO (µg/m³)/(g/s): | #N/A |
| | NO (µg/m³)/(g/s): | 587 |
| | $NO_2$ (µg/m³)/(g/s): | 17,968 |
| | $SO_2$ (µg/m³)/(g/s): | 80,111 |
| | $PM_{10}$ (µg/m³)/(g/s): | #N/A |
| | $PM_{2.5}$ (µg/m³)/(g/s): | #N/A |
| | **Odor Design Criteria (µg/m³)/(g/s):** | **181** |

**Notes:**

1) Only applies to Health Limits, Odor Thresholds are referenced in report text.

2) Emission factors for all except $SO_x$ from CFR Title 40, Part 89, Table 1 (CFR, 2002).
$SO_x$ emission factor from AP 42 Table 3.4-1 (EPA, 1996).