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BRE/CIBSE NVG Seminar
(27 February 1997)

VENTILATION AND AIR POLLUTION: BUILDINGS LOCATED IN URBAN AND CITY CENTRES

Proceedings

Prepared by:
Dr Vina Kukadia

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SYNOPSIS

Dr Vina Kukadia, Senior Scientist, BRE

The objective of this one-day seminar was to address the issues of design and provision of low-energy ventilation strategies for non-domestic buildings located in urban and city centres where external air and noise pollution may be of prime concern.

Current concerns about energy usage and CO_2 emissions have led to an increasing number of buildings, both new builds and major refurbishments, employing low-energy ventilation strategies such as natural or fan-assisted ventilation. However, optimum ventilation provision also requires that the quality of the indoor air for the occupants is not compromised. As a result, this has created much debate about how this may be achieved in buildings located in areas where external air and noise pollution may be a major issue. This is compounded by a poor understanding of the interaction between indoor air quality and external pollution.

All speakers are at the forefront of the current debate and are actively involved in the areas of low-energy buildings and air pollution; their expertise include policy issues, research, design, construction and commissioning. The programme was prepared to provide a forum to discuss and disseminate current knowledge on low-energy ventilation strategies for urban areas, ingestion into buildings of pollution from traffic and other sources; and air quality monitoring and guidelines. The seminar enabled constructive discussions between speakers and delegates to take place to enable a positive way forward for the future in this area.

This seminar was of much interest and value to those involved in the UK construction industry either through policy, research, design, commissioning or development. It also provided delegates with a unique opportunity and a forum to address and discuss issues relating to low-energy ventilation strategies and ventilation provision in urban and city centres where pollution may be of much concern.

VENTILATION AND AIR POLLUTION:
Buildings located in urban areas and city centres

Venue: Building Research Establishment - 27 February 1997

Programme

9.00 - 9.30 *Coffee and registration*

9.30 - 9.45 Introduction and welcome
David Warriner ***(Assistant Director, Environment Group, BRE)***

9.45 - 10.00 DOE's view: Urban pollution and building ventilation
Dr Les Fothergill ***(Building and Regulation Division, DOE)***

UNDERLYING ISSUES

10.00 - 10.30 Health effects and buildings in urban areas
Prof. Patrick O'Sullivan, ***OBE (Dean of Faculty for the Built Environment University College, London)***

10.30 - 11.00 Air quality in the UK: practical aspects and guidelines
Prof. Roy Harrison ***(Chairman of Quality of the Urban Air Review Group and Professor on Environmental Health, Birmingham University)***

11.00 - 11.30 *Coffee*

RESEARCH ACTIVITIES

11.30 - 11.55 Pollutants and their dispersion in Urban Areas
Dr David Hall ***(Senior Scientist, BRE)***

11.55- 12.20 Air quality in buildings in urban areas
Dr Vina Kukadia (***Senior Scientist, BRE***)

12.20 - 12.45 Location of ventilation inlets to minimise contamination: State-of-the-art review
Steve Irving (***Research Director, Oscar Faber***)

12.45 - 14.00 *Lunch*

14.00 - 14.25 Ventilation and air pollution: Current research at BSRIA
Peter Jackman ***(Director of Research, BSRIA)***

STRATEGIES AND SOLUTIONS

14.25-14.45 Low-energy strategies in urban areas
Chris Twinn ***(Associate Director, Ove Arup & Partners)***

14.45- 15.05 *Tea*

15.05 - 15.30 Case study: Canning Crescent Centre
Ian Logan ***(Partner: MacCormac, Jamieson, Prichard)***
Patrick Bellew ***(Director: Atelier Ten Engineers.)***

15.30 - 15.50 Direct passive cooling in naturally ventilated offices
David Arnold ***(Partner: Troup, Bywaters and Anders)***

15.50 - 16.30 *Discussion and round up*
Dr Martin Liddament ***(Head of Air Infiltration and Ventilation Centre)***

CHAIRMAN'S INTRODUCTION

David Warriner, Research Director, Environment Group, BRE

Today we are faced with a broad range of environmental issues and concerns which can range from local problems to global impacts that have the potential to threaten our entire ecosystem. A key aspect of Sustainable Development will be the provision of healthy, safe and productive working and living places whilst minimising adverse impacts on the global and local environments.

The growing recognition of the potentially serious impacts on health and economic performance of global and local environmental issues has resulted in a series of international initiatives, in particular:

- The Montreal Protocol which addresses the regulation of ozone depleting substances and has set a timescale for the phase out of CFCs and HCFCs.
- The 1992 Earth Summit in Rio de Janeiro which addressed the threat of climate change resulting from emissions of "green house" gases.

Important though these drivers are, we should not overlook the significance of commercial pressures for more environmentally friendly buildings. In the UK it is estimated that we have the potential to reduce our national energy bill by £1 billion per annum, cost effectively through improved management of energy resources. Many developers and clients are now recognising the value of specifying buildings which have a low environmental impact and of gaining recognition for their achievements through assessment schemes such as BREEAM.

There is an obvious link between these policy, commercial and social considerations. Our buildings must provide a healthy indoor environment, one that will offer a productive and efficient workplace responsive to the needs of the individual as well as those of the organisation.

These expectations must be considered against a background of growing concern over the effects of urban pollution and the consequent quality of the internal environment in buildings which are situated in urban areas. It will become increasingly unacceptable and impractical to respond to these concerns by moving development out of our town centres and consuming green field sites. We can already see increasing pressure to redevelop urban areas, to reduce the need for travel between the home and the workplace and to re-establish urban centres with an effective balance between commercial, living and leisure provision.

So it is timely that we should address ourselves to the relation between the external urban environment and the indoor environment where we spend much of our working and leisure time, and in doing so we face some important challenges:

- We need to develop strategies by which we can achieve an acceptable indoor environment without undue energy penalty within polluted urban locations

- We must be able to provide low-energy ventilation solutions which will be taken up by the designers and developers of the buildings which will be constructed in urban areas.

The issues were summed up most effectively in a recent editorial in Building Services Journal ('Talking Shop' by Roderic Bunn, February 1997):

> "Any crusade to improve indoor air quality should embrace sources of pollution, adequate ventilation and filtration, better facilities management and higher quality construction. That demands the close co-operation of many industry partners, not just the air conditioning suppliers as it does at the moment".

The favoured design solution for buildings in noisy and polluted areas has been to seal the envelope and condition the internal environment, and for many projects this will remain the most appropriate approach. Designers will respond to the needs of the market by developing increasingly efficient systems that offer high levels of control and occupant choice. But we are also developing the understanding and design approaches that allow naturally ventilated solutions to be viable options in an increasing number of cases. In this seminar our emphasis will be on developments in this field and I hope that we will see that the range of low energy design options for buildings in polluted urban areas is expanding.

DOE'S VIEW: URBAN POLLUTION AND BUILDING VENTILATION

Les Fothergill - Building Regulations Division, Department of the Environment

Summary

The Department takes an interest in ventilation because of the need to avoid wasting energy through over-ventilation, yet maintain reasonable air quality to protect health.

Several parts of the Department are interested in energy conservation or air quality. The main ones are the Construction Sponsorship Directorate, the Environmental Protection Group, the Health and Safety Executive. The Construction Sponsorship Directorate includes Building Regulations Division, and Construction Innovation and Research Management Division - which is responsible for the Partners in Technology scheme. The Health and Safety Executive has some overlap with Building Regulations on ventilation of commercial buildings, but they also have responsibility for occupational exposure which is beyond the scope of the paper.

The Department's main objectives are broadly to identify pollutants, establish the effects they have on health, determine levels of ventilation necessary to dilute the pollutants sufficiently to produce health and encourage designers to provide ventilation in an energy efficient way. In parallel with this we are keen to reduce levels of pollutants inside and outside buildings in cost effective ways. Outdoor air quality is a particular issue in urban areas.

The paper gives an overview of the relevant work the Department has been doing, or sponsoring, over the last few years.

The results of research are of no use if not implemented, and the Department will continue to rely on people in the ventilation and air pollution community to take account of the latest information to improve this indoor environment in an energy efficient way.

DoE's view: urban pollution and building ventilation

Introduction

1. I would like to begin by explaining why the Department is interested in ventilation. In a well insulated building a substantial part of the energy consumed is used for ventilation, so to conserve energy it is important not to over ventilate. On the other hand as people spend so much of their time in buildings it is essential that we ventilate sufficiently to protect health.

2. So while we are not interested in ventilation per se - we are interested in the effect ventilation has on energy conservation and the health of people in buildings.

3. Our Departmental objectives are broadly to: identify pollutants; establish the effects they have on health, determine levels of ventilation that are necessary to dilute the pollutants sufficiently to protect health, and to encouraging designers to provide ventilation in an energy efficient way. In parallel with this we are keen to reduce levels of pollutants inside and outside buildings in cost effective ways.

4. The Department has several groups with interests in energy or air quality. The main ones are the *Construction Sponsorship Directorate*, the *Environmental Protection Group,* and the *Health and Safety Executive.* Construction Sponsorship includes *Building Regulations Division* and *Construction Innovation and Research Management Division.* The Environmental Protection Group includes divisions with interests in indoor and outdoor air quality, and energy efficiency.

5. The HSE's and Building Regulation's interests overlap with ventilation of commercial buildings in that our resposibility ends when the building is completed and the HSE take over the continuing control, but we have to ensure that the completed building will be able to meet the HSE's requirements. HSE also have responsibility for occupational exposures which are beyond the scope of my talk.

6. I will give you a brief overview of what the Department, and Building Regulations Division in particular, has been doing on the subject over the last few years.

Government work progresses much more slowly than research so I can't give you a *state of the art* paper like the other speakers. I will also talk in fairly general terms because there other speakers giving papers on many of the points that we are concerned with.

Building Regulations

7. I will start with Building Regulations. Our job is to write and maintain Regulations which will ensure reasonable standards of health and safety for people in and around buildings, conserve fuel and power, and provide access for the disabled. To support the Regulations we produce Approved Documents which provide technical guidance on common methods that can be used to satisfy the Regulations. To be effective the Regulations should cover the main factors which affect health and safety and the guidance should be authoritative and robust.

8. To do this we need to know what are the main factors that affect health and safety in buildings? To find out we commissioned BRE to review the available information on safety and health hazards and to put them roughly in rank order of importance. The rankings take account of the severity of the harm, the number of people affected by it, and the reliability of the data.

9. The main factors that affect the health of people in buildings are shown here, and this influences the priority we attach to research in support of our technical guidance.

TABLE from the health report

10. The highest category relates to a risk of death or other extremely severe outcome such as permanent paralysis. The second level relates to severe outcomes such as prolonged loss of consciousness. The third level relates to more moderate outcomes such as regular severe dermatitis. The fourth level relates to outcomes such as occasional severe discomfort.

11. You can see that poor air quality is not a major hazard in commercial buildings. Environmental tobacco smoke is the main offender but that is as much a management problem as a ventilation problem. Carbon monoxide poisoning appears in the second level of risk, but that is a design or a maintenance problem rather than one of ventilation. Ventilation related harms are mainly in the third level with Volatile Organic Compounds (VOCs) probably being the first clear ventilation problem. As sources of VOCs are products like: paints, building materials, and cleaning agents - indoor concentrations are about 10 times higher than outdoors. As there are up to about 300 types found in homes there is much more to be learnt. Particulates are near the bottom in the unclassified section, but there are suspicions that we need to know more about the effects they have on health.

12. For the Approved Documents we monitor the effectiveness of the guidance and update it when there is a need. Currently we choose ventilation rates to limit levels of water vapour in dwellings and carbon dioxide in commercial buildings, on the assumption that if we take care of these, then levels of other pollutants will also be safe. But that is not to say there are no problems now, and I will mention some of them.

13. In 1995 a new edition of Approved Document L: *Conservation of fuel and power* came into force. It was decided to include guidance on how to reduce infiltration of cold air through leakage paths for both domestic and non-domestic buildings. So knowing that we were going to encouraged people to **build tight** we carried out a parallel revision of Part F - Ventilation - to give more guidance on how to complete the cliche and **ventilate right**. The main addition to the Approved Document was guidance on ventilation in non-domestic buildings. This drew heavily on BRE research, but there are a few areas where the guidance is a little light.

14. For example, in car-parks it suggests rather simplistically that designers should predict the level of CO and design the ventilation rates accordingly. We are currently supporting a Partners in Technology research programme to produce a model for doing this.

15. For mechanical ventilation systems the guidance suggests that air inlets should not be sited where they may draw in excessively contaminated air. Even that is not as straightforward as it sounds as you will hear later this morning.

16. No talk is complete without a reference to activity in Europe. Most of you will know that prENV 1752 advocates using additive ventilation rates to dilute pollution due to the occupants and pollution due to the building components. While the draft allows our current practice to continue, there are concerns that in the long term it could lead to higher ventilation rates than are normally considered necessary in the UK. BRE is involved with the work and is monitoring the situation for us. The controversy has not been without benefit as it has focused attention on emissions from materials - which may help us to understand Sick Building Syndrome better.

17. As well as this work we support quite a large ventilation research programme at BRE. Topics include comparing occupant satisfaction in naturally ventilated and air-conditioned offices; the need for humidification in offices; reasons for air leakage in dwellings; prediction of moisture movement within buildings; sizing of windows to provide required ventilation rates; ventilation for control of dust mites; and techniques for improving natural ventilation in urban areas - which you will hear about later. Most of this work is ongoing.

Construction Innovation and Research Management Division

18. Now I will tell you a little about Construction Innovation and Research Management Division. They run the Partners in Technology or PiT programme which is intended to encourage industry to work with research organisations to solve their technical problems and develop or improve performance or products, and in the longer term to help the construction industry improve its international competitiveness. Normally the Department funds up to 50% of the cost of a project and the partners fund the rest.

19. The programme was originally research led, in that each proposal was assessed on its merits, with the Department's policy priorities being one of many factors

considered. Last year some radical changes were made. Five Business Units were set up - each with its own Business Plan for research sponsorship.

TABLE of business unit names and aims

20. The idea is that as we do not have the resources to fund everything, the Department sets out its policy priorities explicitly in each of the Business Plans so that applicants can direct their efforts into areas that are most likely to be funded. These areas are fairly broad, and as the plans were subjected to public consultation, we think they cover all the main areas. The system is evolving and will develop as we gain experience.

21. There are currently several PiT projects on ventilation. Research on ventilation hardware is likely to come under *Technology and performance*, while air quality issues are likely to be under *Safety and Health* or perhaps *Environment* if the emphasis is not directly on health effects.

22. Many of the research topics are relevant to urban areas. I have already mentioned location of air intakes and ventilation of car parks: others include: sound attenuation of passive stack ventilators; and evaluation of HSE guidelines on Sick Building Syndrome.

23. The Division also fully sponsors some research that will be of benefit to the construction community and support Departmental policy. The latest project is to develop guides on natural ventilation of office buildings for use by clients and designers. It has been estimated that natural ventilation is the obvious choice for about 20% of new office buildings, while another 20% are on sites where noise or air pollution make mechanical ventilation necessary. So we are particularly interested in the 60% where there is most scope for energy economy. The purpose of the new guides is to encourage people to seriously consider natural ventilation, and its lower energy costs, instead of assuming that good buildings have to be air conditioned. The guides will address all the main objections to natural ventilation objectively and bring together existing information in one source, so the users will be able to make a well informed

decision. The guides should be available in about 18 months and will probably be in CD-Rom form.

Environmental Protection Group

24. The Environmental Protection Group has a role in both indoor and outdoor air quality.

25. Last year the details of a major study of indoor air quality were published. The study was carried out by BRE in cooperation with researchers from the University of Bristol who were participating in a European wide study of child development. It entailed monitoring the concentration of nitrogen dioxide and various organic compounds and biological particulates in 174 homes over a period of 12 months. The medical implications of exposure to the pollutants were assessed by an international group of experts and published by the Institute for Environment and Health.

26. The general conclusion was that for the five pollutants in the study the levels in homes were low, and the risk to health was small, but nevertheless it would be prudent to reduce exposure even further.

27. The study is continuing and the second phase is addressing carbon monoxide, tobacco smoke, particulates and other allergens.

28. Actions to reduce exposure are set out in the UK National Environmental Health Action Plan (UKNEHAP) which was published last July and is part of a European initiative. The Government will continue to support research and monitoring of indoor air quality and emissions from particular sources, and continue to assess the effects of pollutants on health, particularly for vulnerable groups. Perhaps the most important action will be to provide the public with more information so they can make informed choices.

29. As well as the UKNEHAP, the Government has recently consulted on a proposal

to make the *Environment* the sixth key area in the Health of the Nation programme. This proposal includes indoor air quality and if accepted will support the UKNEHAP by setting targets for disseminating information and reducing exposure levels.

30. Of course the quality of indoor air cannot be considered in isolation from outdoor air. Outdoor air quality is also covered by the UKNEHAP and the *Environment* key area, and last year the Government launched a strategy for improving outdoor air quality.

31. Basically this involves setting health-based standards for each of the main pollutants, and developing or strengthening policies which will make cost-effective progress towards meeting the standards by the year 2005.

32. So to sum up, the Department has a lot of interest in improving the air quality inside and outside buildings in urban areas and the high level of research sponsorship and policy development, is likely to continue for some time. We will continue to rely on people in the ventilation community to take account of the latest information to improve the indoor environment in an energy efficient way.

33. Finally, as this will be the last conference on ventilation held at BRE as an Agency, I would like to thank our colleagues here for the work they have done for the Department over the years, and look forward to working with them in their new role as the Foundation for building research.

DEPARTMENT
OF THE
ENVIRONMENT

L C Fothergill

CONSTRUCTION
SPONSORSHIP
DIRECTORATE
working with our industries

1B

Department of the Environment and
The Welsh Office

The Building Regulations 1991

Ventilation

F

APPROVED DOCUMENT

F1 Means of ventilation

F2 Condensation in roofs

HMSO

1995 Edition

Health hazards: grouped in rank order of risk

Homes	Non-domestic buildings
Highest Risk	
Hygrothermal conditions	
Radon	
House dust mites	
Environmental tobacco smoke	
Carbon monoxide	*Radon*
Second level of risk	
Fungal growth	*Environmental tobacco smoke*
Security and the effects of crime	*Sources of infection other than sanitary accommodation*
Noise	*Carbon monoxide*
Lead	
Third level of risk	
Sanitary accommodation	*House dust mites*
Sources of infection other than sanitary accommodation	*Volatile organic compounds*
Space	*Lighting*
Volatile organic compounds	*Space*
Oxides of nitrogen	*Hygrothermal conditions*
Particulates	*Fungal growth*
Fourth level of risk	
Sulphur dioxide and smoke	*Sanitary accommodation*
Landfill gas	*Noise*
Pesticides	*Oxides of nitrogen*
No clear basis for risk assessment	
	Sulphur dioxide and smoke
	Lead
	Landfill gas
	Particulates
Lighting	*Pesticides*
Electromagnetic fields	*Electromagnetic fields*

The aims of CD's business plans

Work areas	Business plans, their primary aims and work areas				
	Environment	Safety and health	Technology & performance	Construction process	Motivation
Primary aims	*Improve the environmental performance of the construction sector*	*Secure reasonable health, safety & security and provide for the disabled*	*Develop competitiveness by enhancing & applying technical knowledge*	*Develop a competitive UK advantage and improve value for clients*	*Encourage uptake of research & innovation to improve performance*

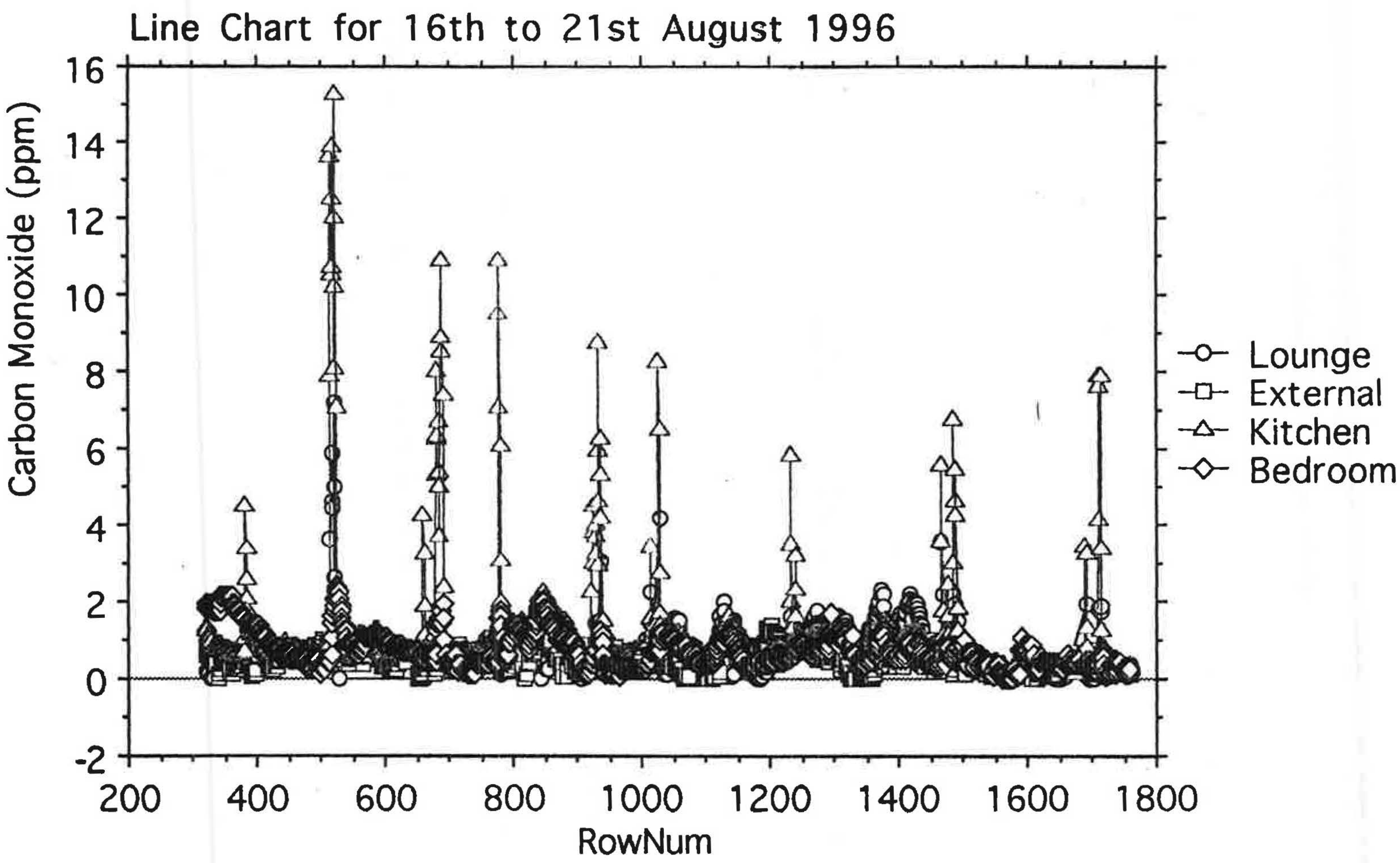
UNDERLYING ISSUES

HEALTH EFFECTS AND BUILDINGS IN URBAN AREAS

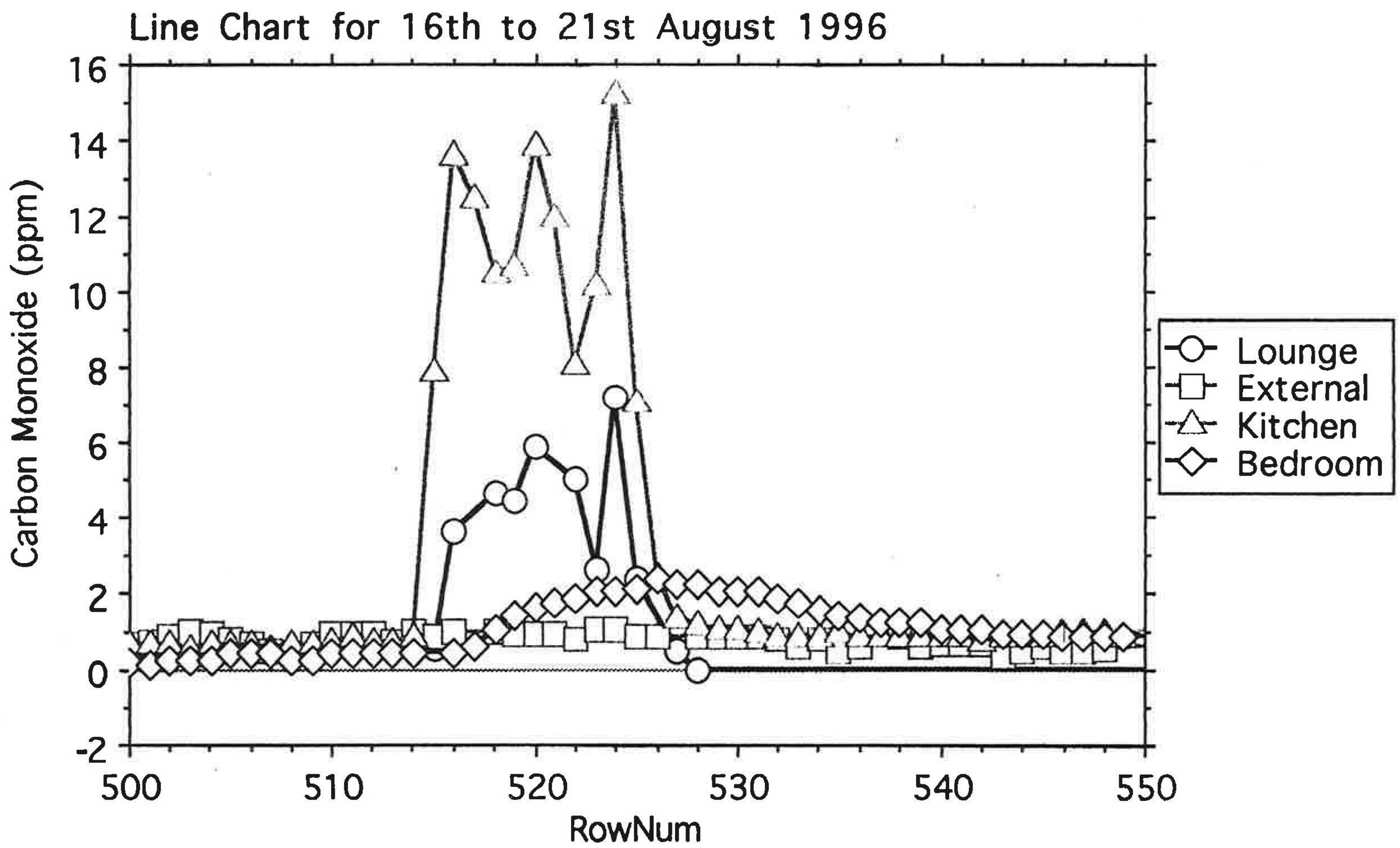
Professor Patrick O'Sullivan OBE - Dean of Faculty for the Built Environment, University College, London

Summary
This paper reviews the underlying issues behind the current ventilation and air pollution debate. These include:

- Is ventilation for human health the same as for comfort?
- How should we be planning for healthy cities?
- Can cities increase their density and still remain healthy?
- Who has the right to pollute 'fresh air'?
- How can we legislate for 'fresh air' when building and planning regulations are separate?
- To what extent can we clean the air in our buildings and therefore ignore external pollution?
- Should we be designing for natural ventilation when in the future we can not control what goes on inside or outside our buildings?
- Are the operational and maintenance costs of natural ventilation lower than air conditioning?
- What are the real advantages of air conditioning and how best does it affect human health?



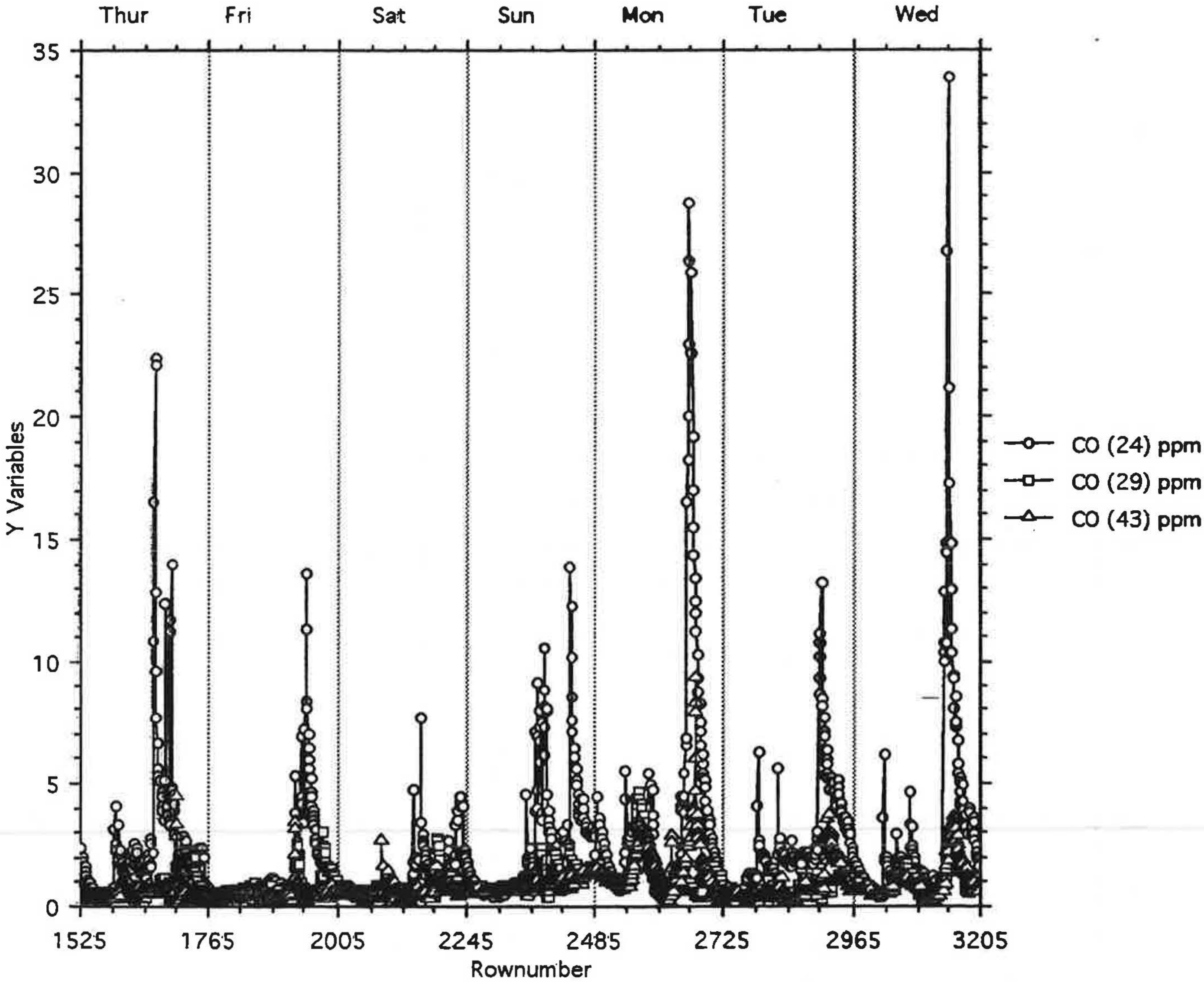
The kitchen receives much more CO than other rooms

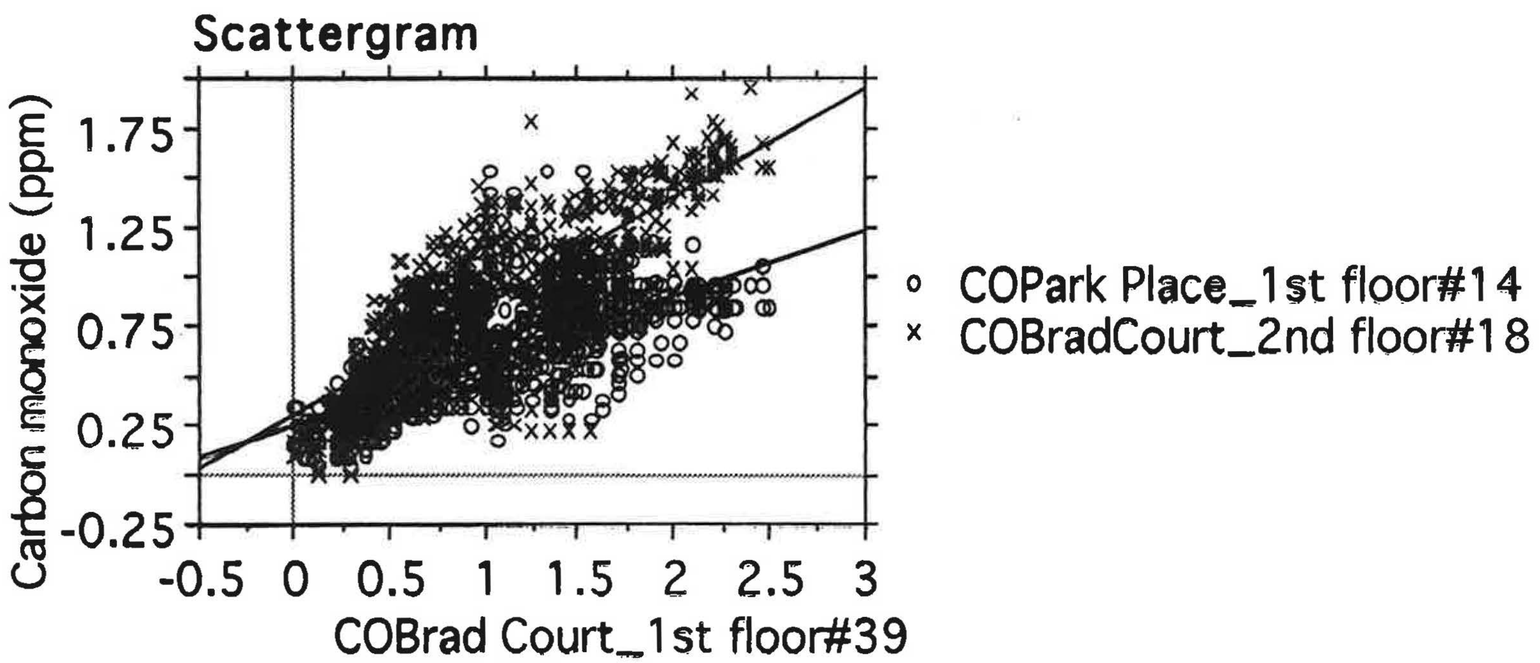


Close up of previous graph: The peak is lower and more delayed in other rooms

Mechanical Ventilation with Heat Recovery

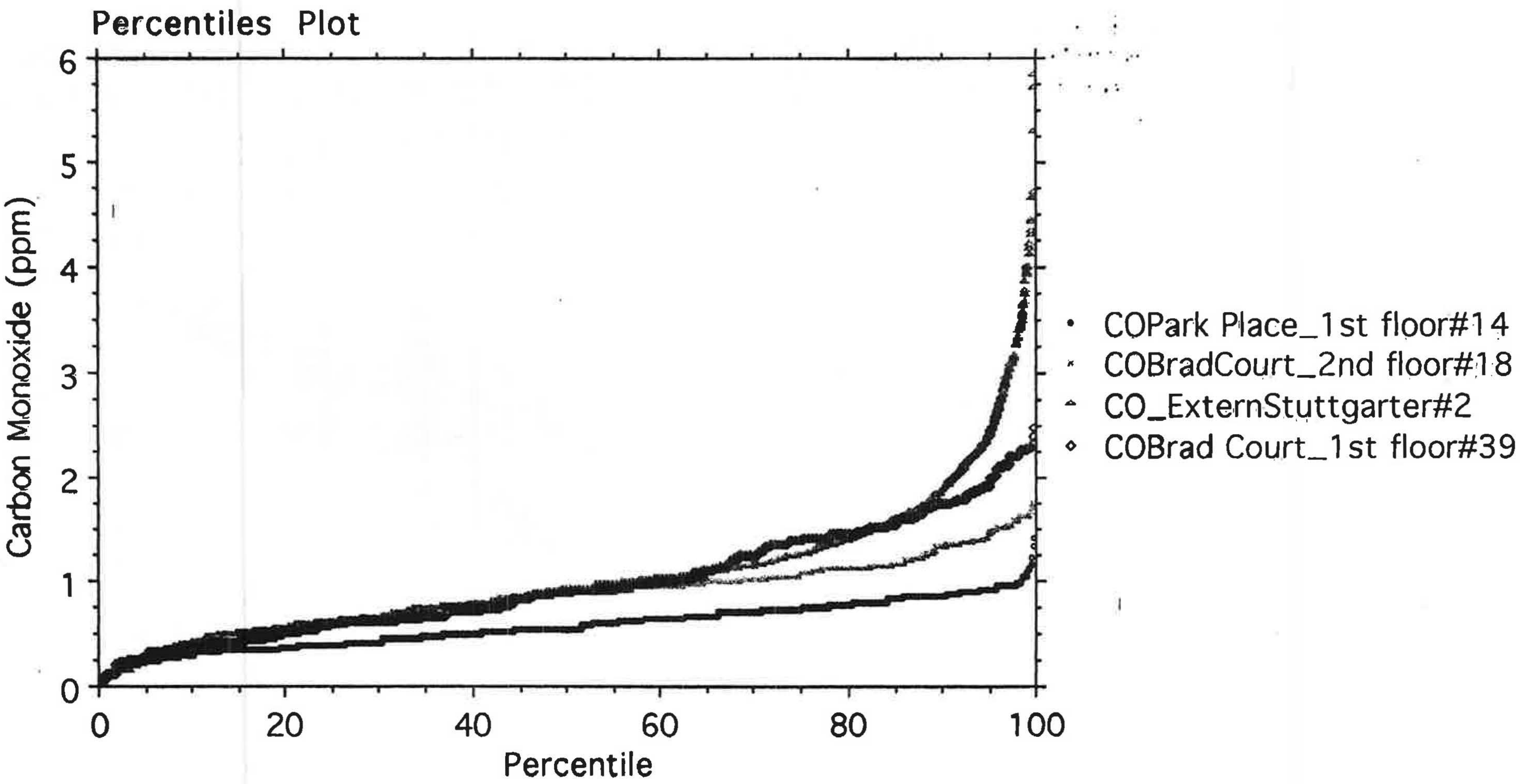
30/1/97 to 5/2/97

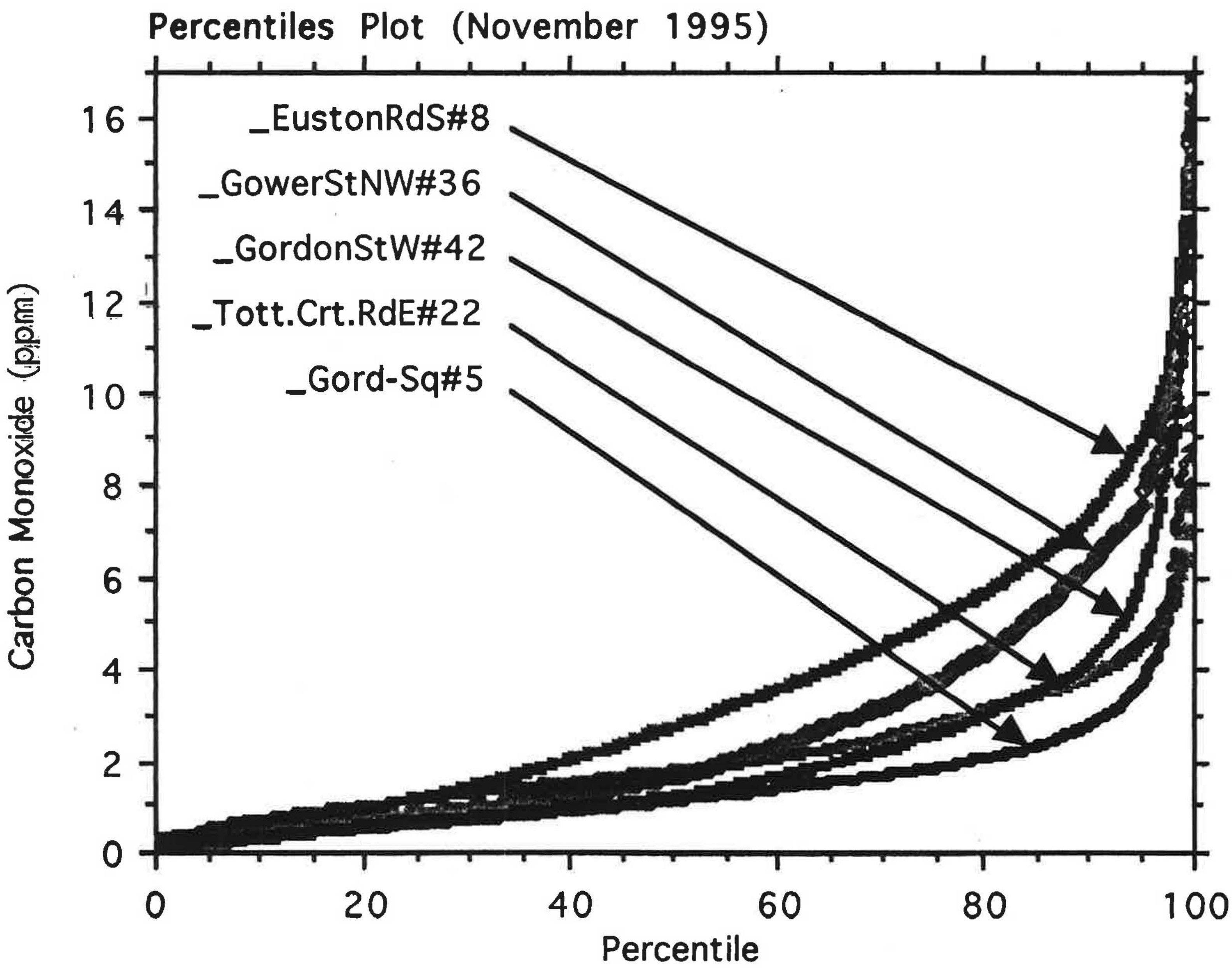




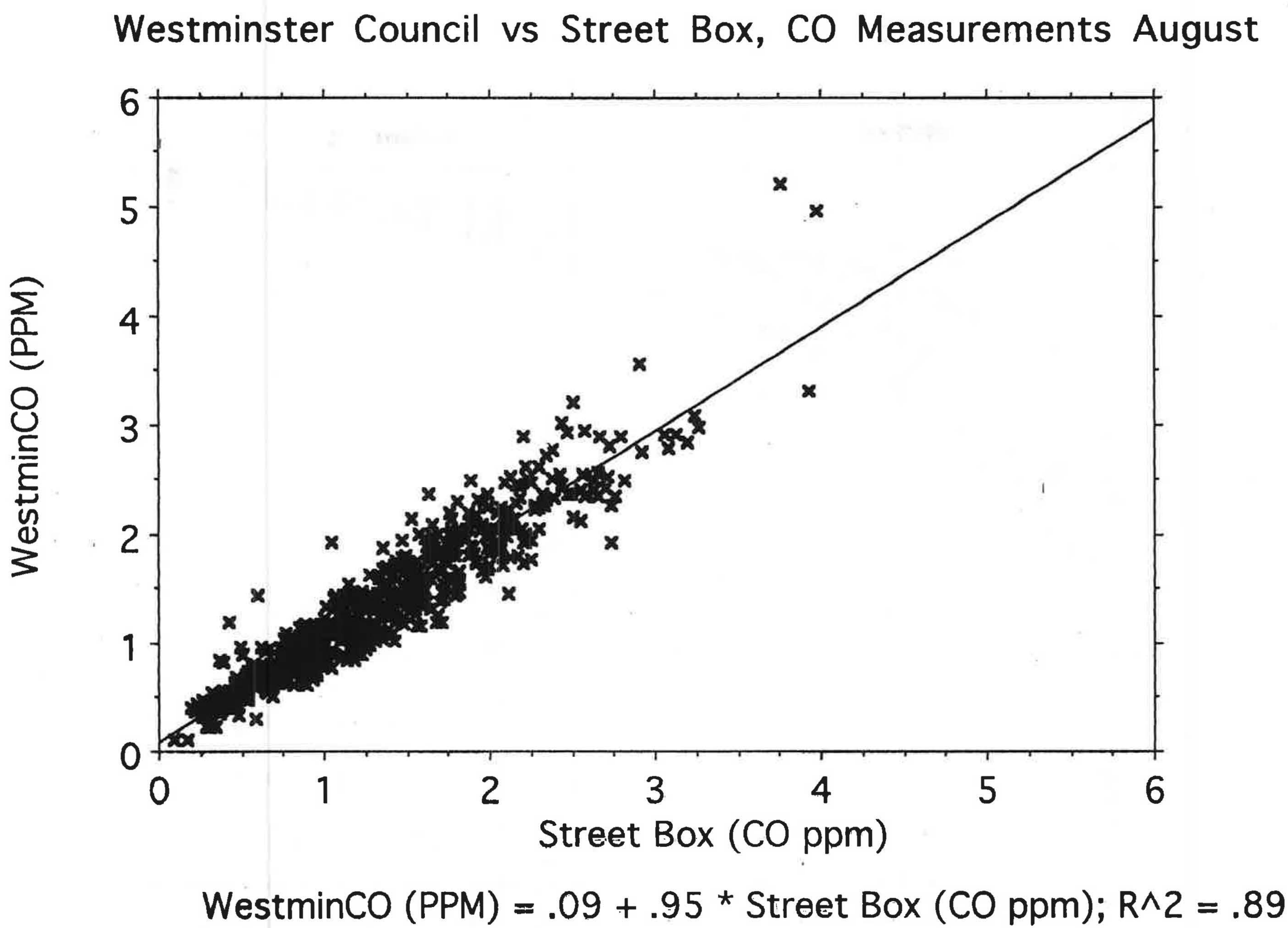
COPark Place_1st floor#14 = .26 + .33 * COBrad Court_1st floor#39; R^2 = .61
COBradCourt_2nd floor#18 = .31 + .55 * COBrad Court_1st floor#39; R^2 = .65

Cardiff study: Highest curve is CO external (Stuttgarter)
Brad court 1st floor then Brad court 2nd floor, Park place 1st floor



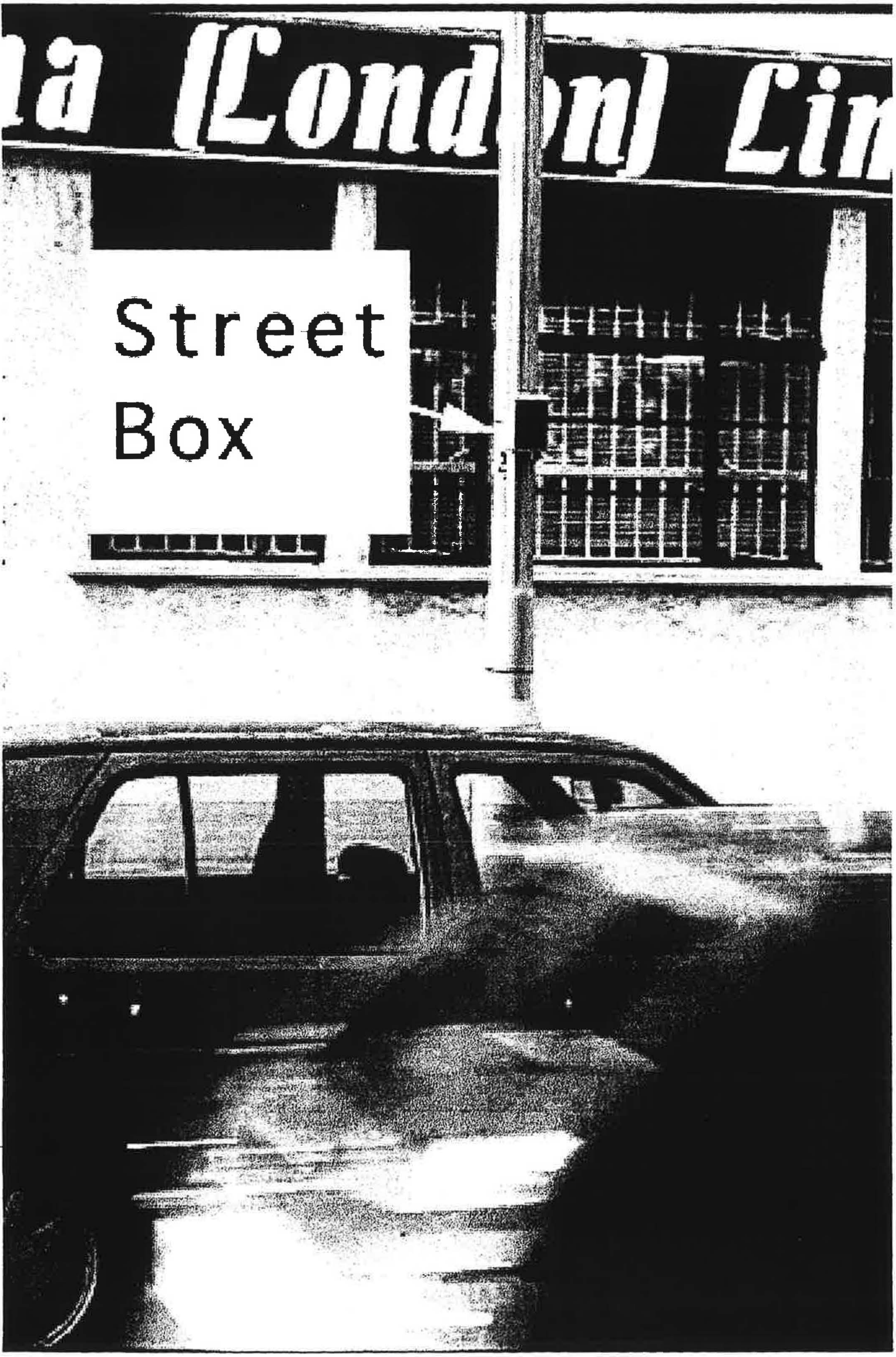


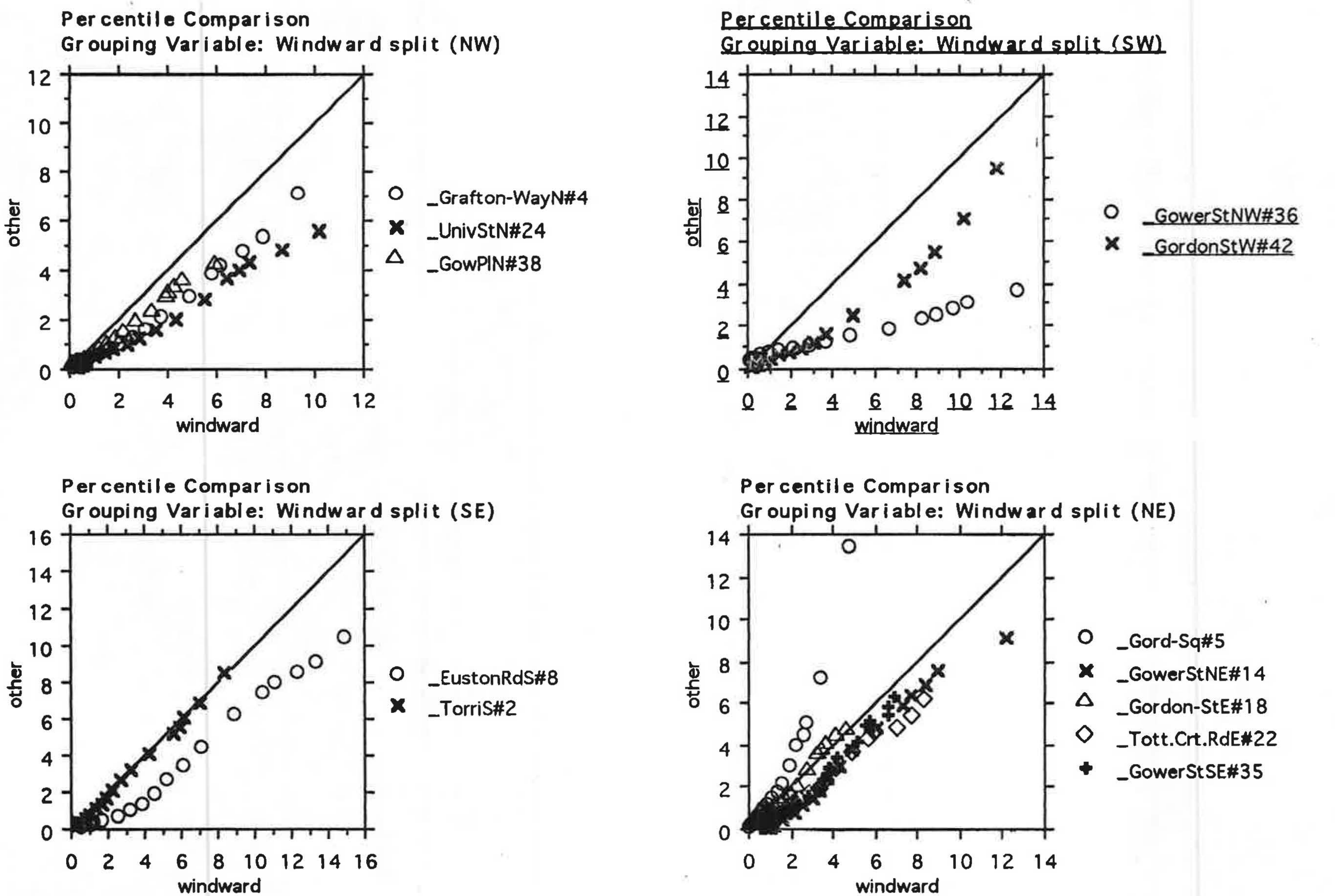
Comparison of CO levels in Nov 1995



Calibration graph of Westminster councils CO box Vs Street box

Street Box





Figures 6,7,8 and 9: Windward splits for the streets that have sensors on the NW, SE, SW, and the NE sides of the road, split by when the wind is blowing from that particular direction (x-axis) and all other directions (y-axis). The figures are carbon monoxide in ppm.

Carbon Monoxide percentile comparison

AIR QUALITY IN THE UK:
PRACTICAL ASPECTS AND GUIDELINES

Roy M.Harrison
The University of Birmingham

Summary

Sources of air pollutants will be reviewed briefly and the role of road traffic as the dominant source of air pollution in urban areas highlighted. General trends in urban air pollution will be described as well as some discussion of future prospects. Data on air quality are available from a number of national networks as well as local authority activity, although site location is a very important consideration in interpretation of air pollution measurements.

Air quality standards for the UK are recommended by the Expert Panel on Air Quality Standards. The current status of EPAQS standards will be described, including some discussion of the basis upon which they are set. Their relevance to the indoor environment will be discussed.

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AIR QUALITY IN THE UK: PRACTICAL ASPECTS AND GUIDELINES

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PRIMARY POLLUTANTS

EMITTED DIRECTLY INTO THE ATMOSPHERE

CONTROL:
"LINEAR ROLLBACK" MODEL PREDICTS
DECREASE IN SOURCE STRENGTH
LEADS TO PROPORTIONATE DECREASE IN
ATMOSPHERIC CONCENTRATIONS

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SECONDARY POLLUTANTS

NOT EMITTED DIRECTLY; FORMED BY CHEMICAL REACTIONS IN THE ATMOSPHERE.

NITROGEN DIOXIDE: FORMED BY OXIDATION OF NITRIC OXIDE (MAINLY FROM COMBUSTION SOURCES)

TROPOSPHERIC (LOW LEVEL) OZONE: FORMED BY CHEMICAL REACTIONS OF NITROGEN OXIDES AND HYDROCARBONS - A PROBLEM FOR BOTH HEAVILY POLLUTED AND BACKGROUND REGIONS

CONTROL: REDUCTION OF PRECURSOR EMISSIONS MAY NOT LEAD TO A LINEAR REDUCTION IN CONCENTRATION FOR SECONDARY POLLUTANT

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ENVIRONMENTAL PROBLEMS

1. **GLOBAL**: AFFECT BOTH HEMISPHERES AND HAVE SOME IMPACT UPON ALL LOCATIONS

2. **REGIONAL**: AFFECT LARGE GEOGRAPHIC AREAS BUT NOT WHOLE HEMISPHERES

4. **NATIONAL**: EFFECT ONE OR MORE COUNTRIES, BUT NOT AN ENTIRE REGION

5. **LOCAL**: AFFECTS ONLY PART OF A COUNTRY

AP33

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KEY TRAFFIC-RELATED POLLUTANTS

- CARBON MONOXIDE
- OXIDES OF NITROGEN
  - NITRIC OXIDE (NO)
  - NITROGEN DIOXIDE (NO_2)
- HYDROCARBONS (VOC)
  - BENZENE
  - 1,3-BUTADIENE
- PARTICULATE MATTER
  - PM_{10}
  - BLACK SMOKE
- LEAD

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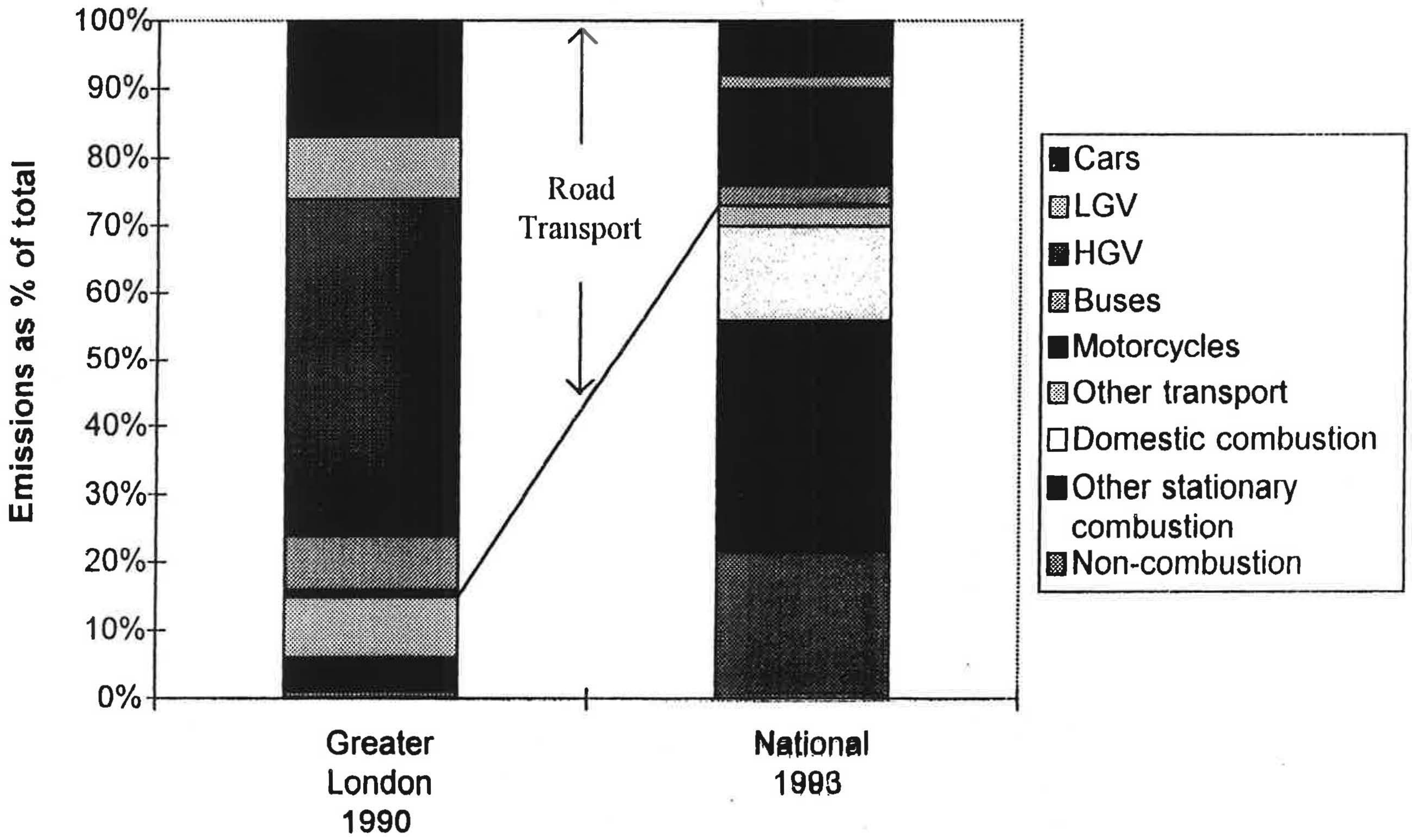
COMPARISON OF LONDON AND U.K. EMISSIONS OF PM10



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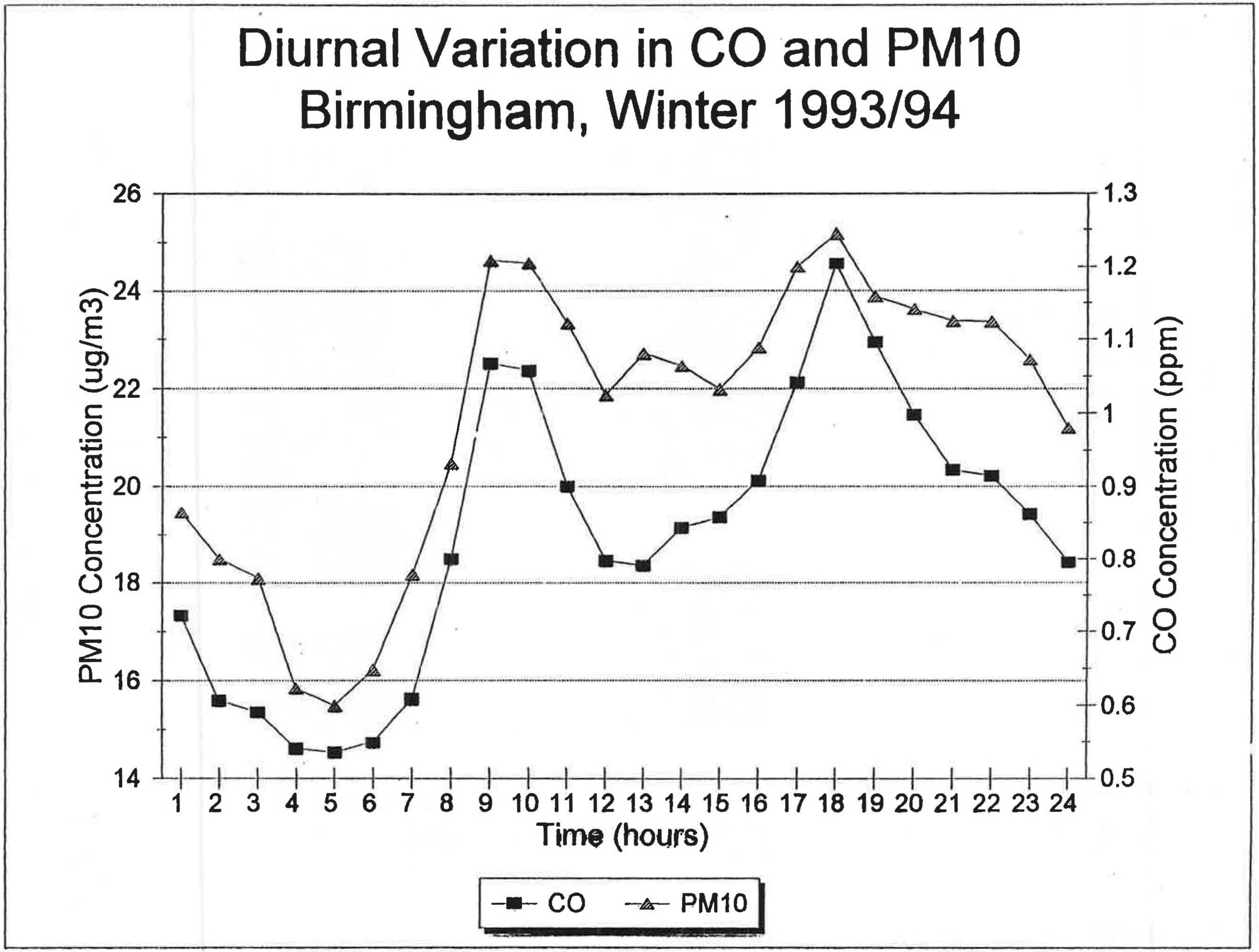

Diurnal Variation in CO and PM10
Birmingham, Winter 1993/94
PM10 Concentration (ug/m3)
CO Concentration (ppm)
26
24
22
20
18
16
14
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (hours)
CO
PM10

AF269

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LOCAL AIR POLLUTION IMPACTS

EMITTED SUBSTANCE	PERCENT DUE TO ROAD TRAFFIC IN WEST MIDLANDS
NITROGEN OXIDES	85
BENZENE	99
1,3-BUTADIENE	97
PARTICLES (PM_{10})	56
CARBON MONOXIDE	98

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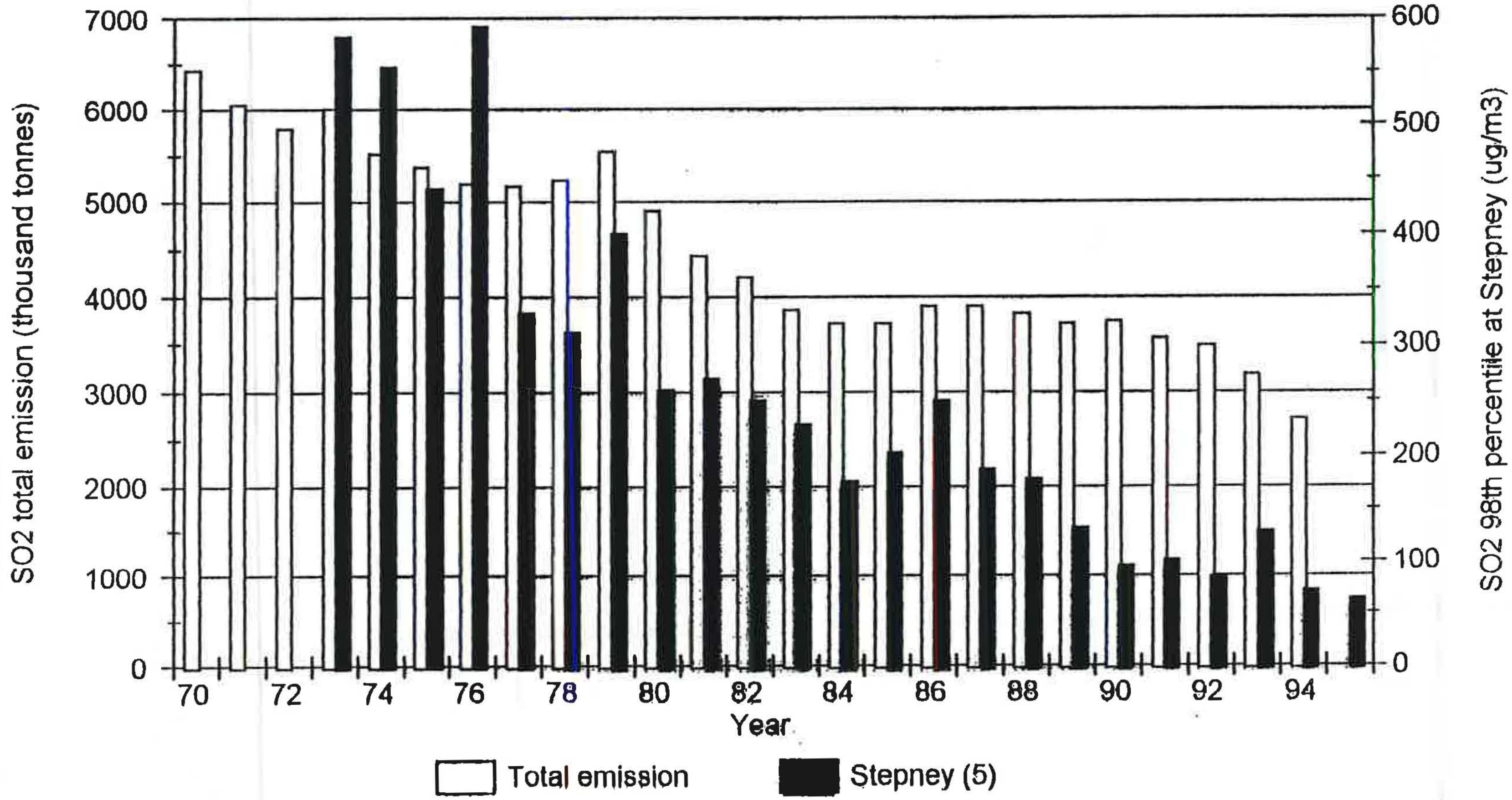
U.K. NATIONAL EMISSIONS OF SULPHUR DIOXIDE AND 98 PERCENTILE AMBIENT CONCENTRATION AT STEPNEY, LONDON, 1970-1995



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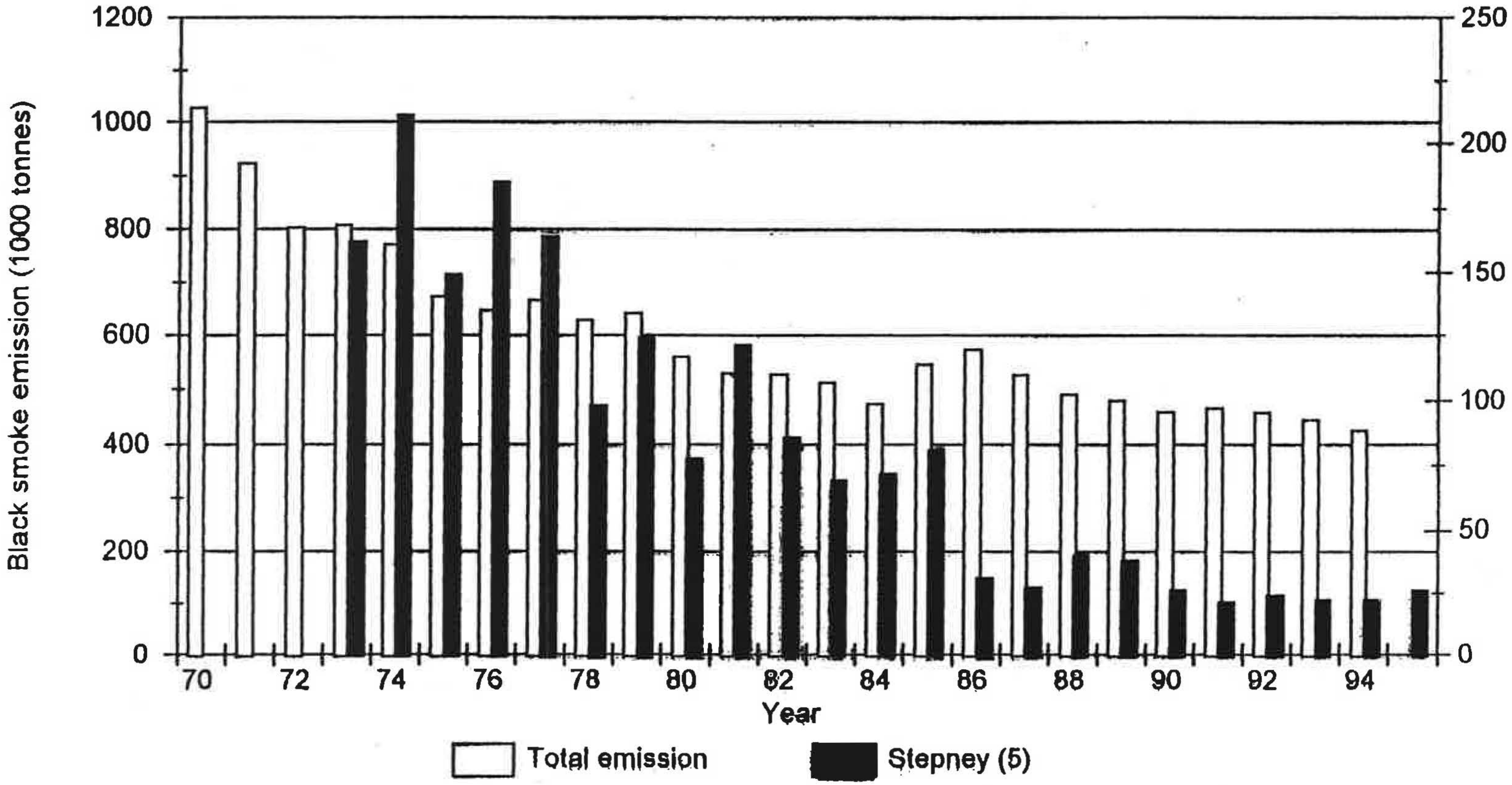
TRENDS IN U.K. EMISSIONS OF BLACK SMOKE AND 98 PERCENTILE AMBIENT CONCENTRATIONS AT STEPNEY, LONDON, 1970-1995



AP91

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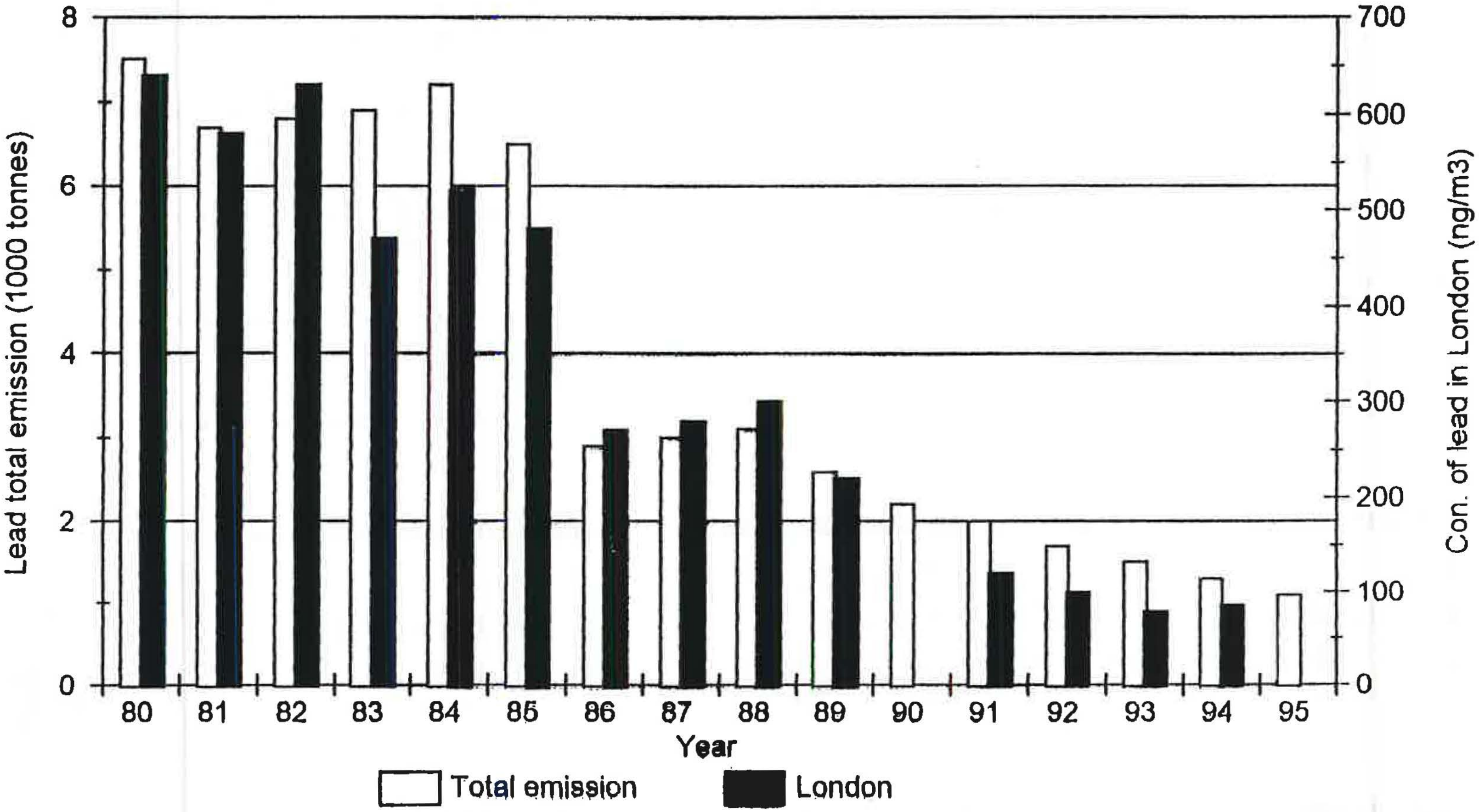
TRENDS IN EMISSIONS OF LEAD FROM MOTOR TRAFFIC AND AIRBORNE CONCENTRATIONS IN CENTRAL LONDON, 1980-1995



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CHANGES IN AIR POLLUTANT EMISSIONS FROM ROAD TRAFFIC REFLECT THE BALANCE OF TWO FACTORS:

(1) GROWTH IN TRAFFIC VOLUMES (MORE VEHICLE-KILOMETRES DRIVEN)

(2) REDUCED EMISSIONS FROM EACH VEHICLE (LESS POLLUTANT PER VEHICLE-KILOMETRE)

AP108

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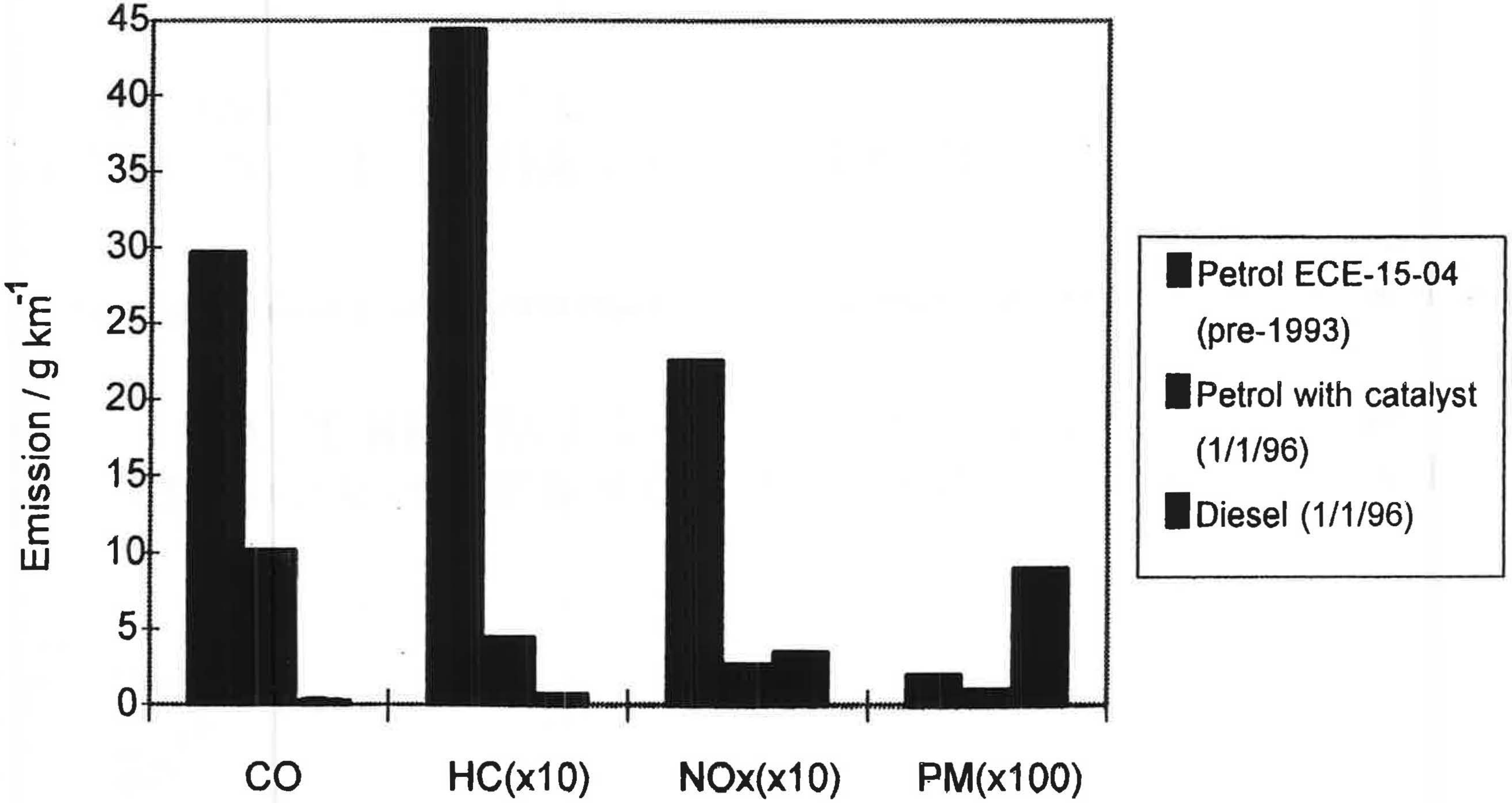
EXHAUST EMISSIONS FROM PASSENGER CARS (MEDIUM CAR; URBAN CYCLE)



AP109

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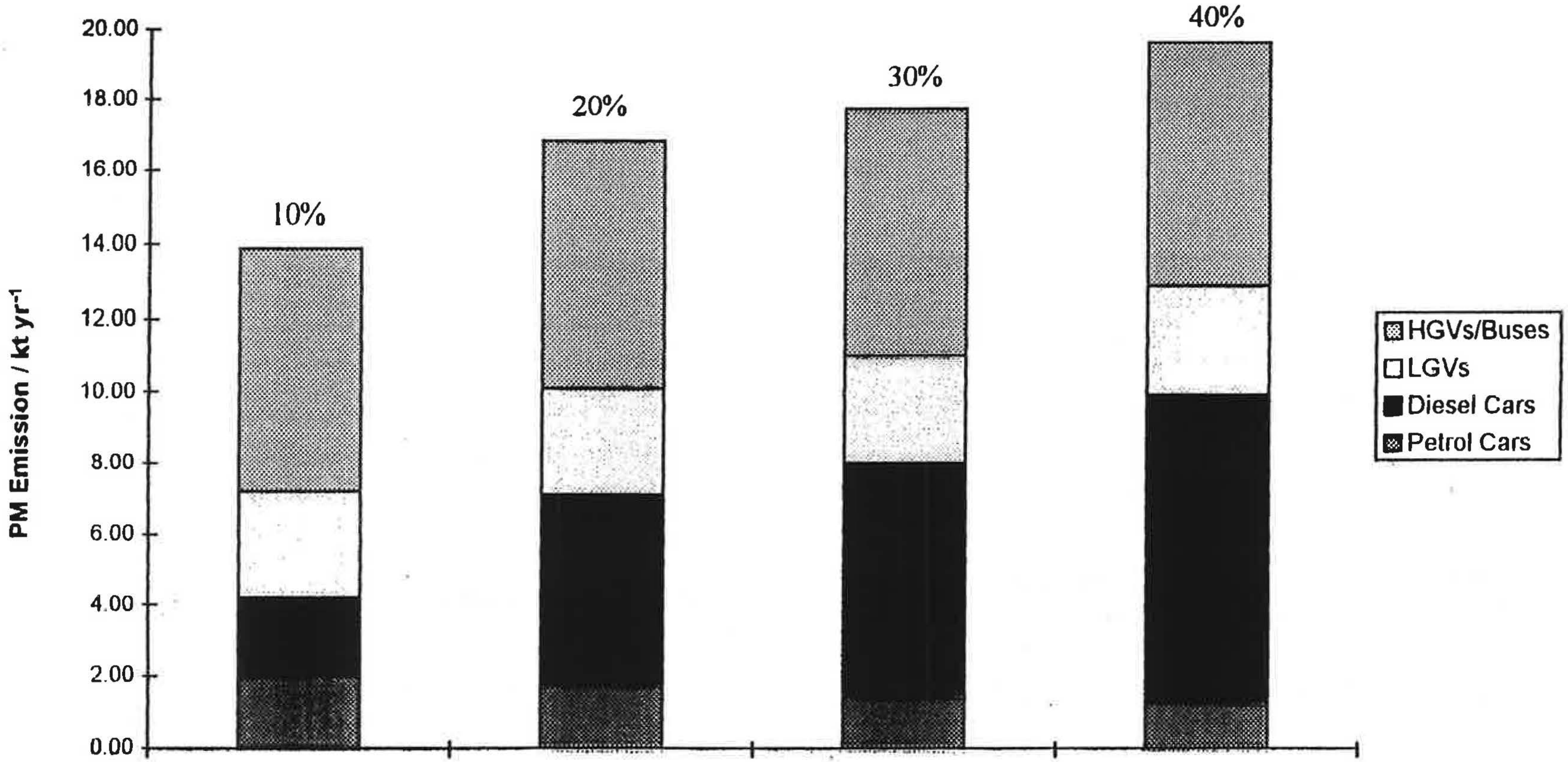
INFLUENCE OF PROPORTION OF DIESEL CARS UPON URBAN EMISSIONS OF PARTICULATE MATTER IN 2005 (ETSU, 1995)



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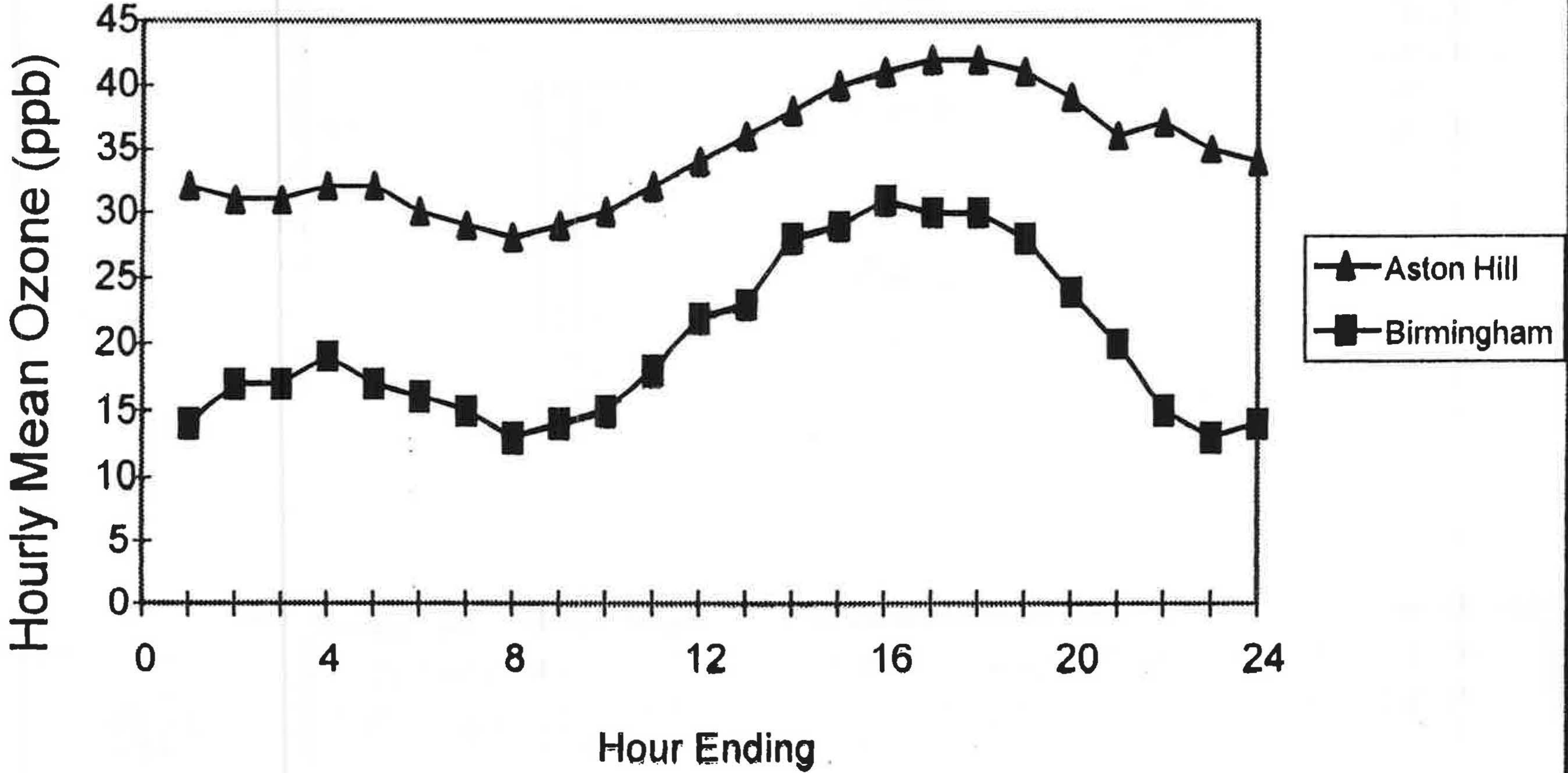
SUMMER MEAN DIURNAL OZONE PROFILES AT URBAN AND RURAL SITES IN CENTRAL U.K.



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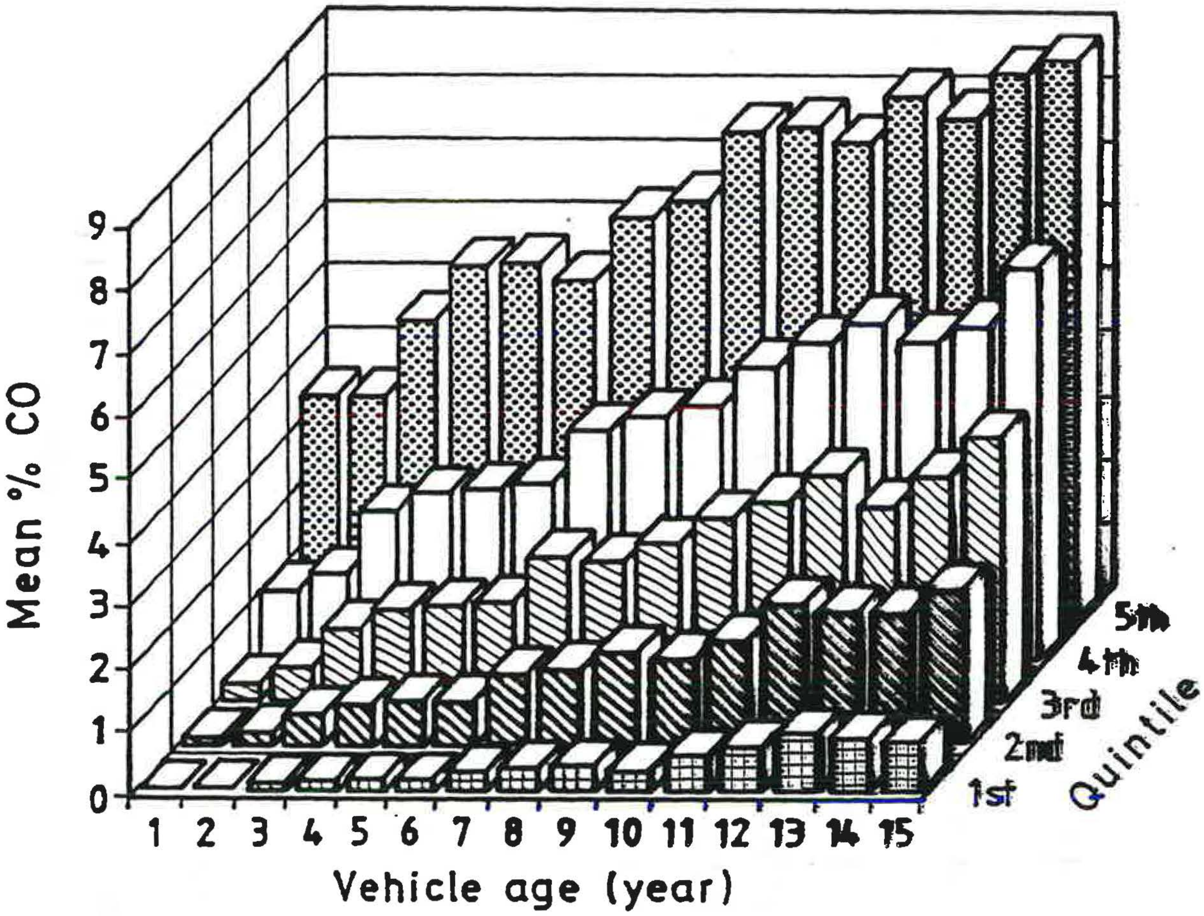
FUTURE TRENDS IN URBAN AIR QUALITY

BECAUSE OF TIGHTENING EMISSION CONTROLS ON NEW VEHICLES, AN IMPROVEMENT OVER THE NEXT TEN YEARS CAN BE EXPECTED IN AIRBORNE CONCENTRATIONS OF:

CARBON MONOXIDE
BENZENE
1,3-BUTADIENE
NITROGEN DIOXIDE
LEAD

THE PROGNOSIS IS LESS CLEAR IN RESPECT OF:

OZONE
PARTICULATE MATTER (PM_{10})



Exhaust Gas Concentrations of Carbon Monoxide Measured in Leicester by Vehicle Age, Divided into Quintiles (from Zhang et al., 1995)

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CONCLUSIONS

1. THE REDUCTION IN EMISSIONS AFFORDED BY CATALYTIC CONVERTERS WILL LEAD TO A REDUCTION IN AIR POLLUTION BY CARBON MONOXIDE, NITROGEN OXIDES AND HYDROCARBONS (SUCH AS BENZENE) OVER THE NEXT FEW YEARS.

2. POOR VEHICLE MAINTENANCE IS HIGHLY DETRIMENTAL TO AIR QUALITY.

3. PROGRESS IN CONTROLLING PM_{10} POLLUTION IS HIGHLY DEPENDENT ON USE OF FUELS WHICH GIVE LOW PM EMISSIONS (PETROL, GAS).

4. URBAN AND RURAL OZONE CONCENTRATIONS ARE LIKELY TO CONVERGE, AS URBAN CONCENTRATIONS RISE IN THE SHORT-TERM TO MEET DECLINING RURAL LEVELS.

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SUMMARY OF U.K. URBAN AIR QUALITY NETWORKS *

NAME	APPROX. NO. OF URBAN SITES	SPECIES MEASURED
Automatic Urban	40	O_3, NO_x, CO, SO_2, PM_{10}
Hydrocarbon	11	Specific Hydrocarbons
Basic Urban	155	SO_2, Smoke
EC Directive	157	SO_2, Smoke
Multi-Element	5	Trace Metals
Lead	14	Lead
Nitrogen Dioxide	1100	NO_2 (Diffusion Tube)
TOMPS	3	Dioxins, PCB, PAN

* Site numbers at May 1996; subject to change

AP97

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WHAT IS PM_{10}?

PM_{10} IS AIRBORNE PARTICULATE MATTER WITH A SIZE (EXPRESSED AS AERODYNAMIC DIAMETER) OF LESS THAN 10 MICROMETERS

PM_{10} INCLUDES MOST AIRBORNE PARTICLES IN THE U.K. ATMOSPHERE (SOME ARE LARGER THAN 10 µm). IT INCLUDES MOST PARTICLES CAPABLE OF PENETRATING INTO AND DEPOSITING WITHIN THE HUMAN RESPIRATORY SYSTEM.

PM_{10} PARTICLES ARISE FROM A DIVERSE RANGE OF SOURCES, BUT ROAD TRAFFIC AND SECONDARY PARTICLES (FORMED FROM SO_X AND NO_X OXIDATION) ARE PARTICULARLY IMPORTANT SOURCE CATEGORIES.

STUDIES OF PM_{10} AND MORTALITY

THERE ARE TWO TYPES OF STUDY:

TIME SERIES STUDIES

These use data for 24-hour average PM_{10} and 24 hour mortality and examine correlations between mortality and PM_{10} concentrations, after controlling for other variables influencing mortality (most notably temperature).

Outcome: 10 $\mu g\ m^{-3}$ increase in PM_{10} corresponds approximately to a 1% increase in daily mortality.

CROSS-SECTIONAL STUDIES

The Harvard Six-Cities Study is a prospective cross-sectional study. Established in 1974, it looks forward in time from that date at the mortality amongst 8111 known individuals living in six cities with differing levels of air pollution. The results are controlled for socio-economic status, smoking and body-mass index.

Outcome: Mortality rates in the six cities correlate with fine particle concentrations. In the most polluted city, death rates were 26% higher than in the least polluted.

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AIR QUALITY STANDARDS

WHAT IS AN AIR QUALITY STANDARD?

AN AIR QUALITY STANDARD IS A CONCENTRATION OF AN AIR POLLUTANT BELOW WHICH EFFECTS ON HUMAN HEALTH ARE EXPECTED TO BE ZERO OR NEGLIGIBLY SMALL AT A POPULATION LEVEL

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AIR QUALITY STANDARDS

- **Benzene** - 5 ppb/running annual mean reduction in due course to a target of 1 ppb
- **1,3-Butadiene** - 1 ppb/running annual mean
- **Carbon Monoxide** - 10 ppm/8-hour running mean
- **Ozone** - 50 ppb/8-hour/running mean
- **PM_{10}** - 50 µg m^{-3}/24-hour running mean
- **Sulphur Dioxide** - 100 ppb/15 minute mean

AP103

RESEARCH ACTIVITIES

POLLUTANTS AND THEIR DISPERSION IN URBAN AREAS

Dr David Hall, Senior Scientist, Environment Group, BRE

The talk describes the characteristics of different types of pollutant sources in the way that they are experienced in a fixed locality in an urban area. The locality in this sense can also be a building or part of a building (a ventilation inlet example). The most important parameter is the distance of the polluting source and therefore the characteristic features of sources at different distances are discussed. The relationship between 'local' sources and 'background' levels of pollutants, their contributions to the total pollution levels and the vertical and lateral gradient of pollution are considered. The discussion is illustrated by examples from measurements of dispersing plumes and of pollution levels experienced during a specific investigation in al large urban area.

Pollution levels can show fluctuations, which increase with reducing time scales, and significant spatial variation over short distances. Measured pollution levels on four sites in a large urban area, the West Midlands, showed these characteristics for averaging times down to one minute and spatial separations of 500m. Data correlation's between the sites were generally poor.

The work is part of the POLIS project in the EC JOULE 95 programme.

A full report is available from David Hall /Vina Kukadia, BRE, Garston, Watford, WD2 7JR. Tel.01923 664878.

Exposure of Buildings to Pollutants in Urban Areas - A Review of the Contributions from Different Sources.

D.J. Hall, A.M. Spanton, V. Kukadia, S. Walker.

Building Research Establishment Ltd.
Garston, Watford, Hertfordshire WD2 7JR, UK

SUMMARY

The paper describes the characteristics of different types of pollutant sources in the way that they are experienced in a fixed locality in an urban area. The locality in this sense can also be a building or part of a building (a ventilation inlet for example). The most important parameter is the distance of the polluting source and therefore the characteristic features of sources at different distances are discussed. The relationship between 'local' sources and 'background' levels of pollutants, their contributions to the total local pollution levels and the vertical and lateral gradient of pollution are considered. The discussion is illustrated by examples from measurements of dispersing plumes and of urban pollution levels experienced during a specific investigation in a large urban area.

The paper has been prepared as part of the POLIS project (JOR3-CT95-0024) in the EC JOULE 95 programme.

INTRODUCTION

The high density of human activities in urban areas leads to a related high density of emitted air pollutants. As a result, urban areas tend to be amongst both the major sources of and sufferers from pollutants. Both pollutant sources and their effects are multifarious. Pollutants carried by the wind disperse to cover steadily increasing areas and those from different sources overlap and combine to generate the overall level of exposure that is experienced at particular sites. From the point of view of the recipient, whether human or inanimate, the individual sources that form this total exposure may not be readily distinguishable. For example, a given level of exposure may come from a relatively small polluting source close at hand or a large source at a much greater distance. Similarly, the contribution of individual sources to the total cannot be readily distinguished at the point of reception unless they have markedly different characteristics.

This distinction is of more than academic interest. There is a natural and practical desire to avoid the effects of air pollution where possible. From a local point of view there may be no effective possibility of avoiding large polluting sources at long distances, which may pervade the whole urban area. However, there are greater possibilities for avoiding and controlling local sources so that their effects can be diminished by planning and regulation. Apart from the desire for pollution control in a public sense, there is also a more individual element of interest, for example in the choice of preferred sites for buildings or of the characteristics of buildings designed to suit particular sites. A particular example is the choice of ventilation systems and the placement of ventilation inlets and exhausts in order to minimise internal contamination problems

It is difficult to deal with problems of this sort without some understanding of the character of discharged pollutants from different sources, especially those at varying distances, and the way in which their dispersion contributes to the overall pollution levels at a particular site. A major factor in the dispersion of pollutants in urban areas is the severe topography due to the large number of surface obstacles, mainly buildings but including a variety of other structures. The effect of the urban topography on wind effects is well known and much discussed (see, for example Cook(1985, 1990)), but its effects on the dispersion of pollutants at short ranges within the 'urban canopy' is less well understood. The requirements for simple short range dispersion models in urban areas have recently been reviewed by Hall et al(1996a) who discuss these problems in more detail.

The relationship between pollution levels at these different scales is the subject of discussion here. One of the most important features that distinguishes the character of different pollution sources is their distance from the point of interest, so that in the discussion that follows the characteristics of pollution sources are mainly treated in terms of increasing distance.

The present paper is taken from a longer work, by Hall et al(1996a), which considers these matters in more detail.

DISPERSION OVER DIFFERENT SCALES IN URBAN AREAS

The Definition of Scales and Spatial Variability.

The term 'scale' of air pollutants can apply to both space and time. Both are important for various reasons and they are to some extent connected by way of the mean windspeed, which sweeps pollutants over a specific area in a given time while dispersing them. In his thorough and very interesting monograph on 'The Design of Air Quality Monitoring Networks', Munn(1981) covers a number of aspects of urban pollution that are relevant to the present problem. In a discussion of time and space variability, he defines some characteristic scales of spatial air pollution patterns, which in order of increasing size are:

microscale (0-100m)
neighbourhood scale (100-2000m)
urban scale (5-50km)
regional scale (100-1000km)
continental, hemispheric and global scales

These are roughly the different scale orders that have been used here, as they correspond fairly well to the different types of dispersion patterns that occur. Only the first three scale orders are of direct interest as variables within the scale of urban areas. Pollution levels at the larger two scales would show no significant variation over the scale of an urban area and would class as contributors to the 'background level' pollutants in the area.

In a similar way, Munn defined a number of characteristic time scales associated with pollutants:

minute to minute variations
the daily (diurnal) cycle
large scale weather fluctuations (3-5 days)
weekly emission cycles
annual emission and weather cycles

It can be seen that these are associated either with natural meteorological cycles or with patterns of human activity. For the shorter ranges mainly of interest here, it is useful to subdivide the shortest time scale into two further divisions related to the stochastic (that is, the unsteady) nature of dispersing pollutant plumes:

times below which the fluctuating characteristics of dispersing plumes are apparent (typically seconds)

times beyond which the time-averaged concentrations in dispersing plumes are stable (typically minutes)

The spatial and time scales are related to some extent by the windspeed. Thus, taking typical UK windspeeds around the mean, say 3-5m s^{-1} , the microscale and shorter neighbourhood scales are associated with time scales of seconds, the longer neighbourhood scales and lower urban scales with time scales of minutes and the upper urban scales and regional scales with time scales of hours. The continental and larger scales correspond to time scales approaching days and beyond.

It is the combination of the multiplicity of discharged polluting sources from this range of distances in the generally upwind direction that produces (simply by the summing of instantaneous pollutant concentrations) the overall pollution level that is experienced at the point of interest. In principal, the contributions of these sources to the overall level are not distinguishable and one of the major reasons for dispersion modelling is as a means of making this distinction. However, there are differences in the character of the contribution from sources at different distances, both in their spatial and temporal characteristics, that help to identify them and their contribution to the total. The ensuing discussion attempts to characterise these differences and the ways in which they affect the combined pollution levels experienced at the point of interest.

Dispersion at Short (Microscale) Ranges.

The definition of 'short' ranges is a little arbitrary but implies here sources which are mostly within direct line of site of the point of interest or where dispersing plume widths are relatively small compared with the scale of the surface obstacles. The practical range may be anywhere from 10m to 1km, and in exceptional cases further. Thus this may embrace both the microscale and neighbourhood scales.

The critical characteristics of dispersing plumes within this scale range are their high pollutant concentrations, small footprint, rapidly fluctuating intensities and (especially within urban areas) meandering qualities. The majority of polluting discharges are from 'point' sources, that is their cross section at discharge is small compared with the plume cross section even at short distances. This applies, for example, to most combustion and process plant discharges, vehicle exhausts and many ventilation discharges. In these cases undisturbed discharge plumes are highly concentrated, most of the pollutant material is contained within a subtended angle from the source of about 10°. Thus within the small area of the dispersing plume there are high concentrations of pollutant, with little pollutant material elsewhere. Also, because of the stochastic (unsteady) nature of dispersion, there will be large variations of concentration within the plume itself. A at distances within a few hundred metres it is possible for small regions of undiluted source material to exist and this has been observed in field experiments by Jones(1983).

Besides the internal variability of pollutant concentration in the plume itself, the wind environment near the ground in urban areas usually shows a high degree of variability in speed and direction due to the aerodynamic disturbances from buildings and other large structures. This introduces an additional variability in the plume path, usually described as plume 'meandering'. Thus the overall characteristic of exposure to a dispersing pollutant at short ranges is usually of relatively infrequent, highly intermittent exposure over short periods (of the order of seconds) to relatively high pollutant concentrations. The importance of rapid fluctuations in pollutant levels in a number of applications has recently been discussed by Jones(1996).

In urban areas one strongly modifying factor to this description is the ability of buildings and other large structures to generate rapid dispersion of discharged pollutants over large areas in the aerodynamic wake regions behind their downstream faces. This generally results in a much larger area of exposure to the pollutants, though at lower concentrations than with the slender plume, and in a more persistent and time-continuous form.

Figure 1 shows an illustration (Taken from Hall and Kukadia(1994)) of these two types of exposure to a dispersing plume at short ranges. It shows measurements made in the field by Helen Higson of the Environmental Technology Centre, UMIST, of a pollutant plume approaching and dispersing around a rectangular building in otherwise smooth terrain. The plots are of pollutant concentration against time and show two cases, in the undisturbed plume upwind of the building (case a) and in the region of rapid dispersion in the wake region behind the building (case b). On both plots the mean concentration is shown as a broken line. The traces are typical of the two types of dispersion. That in the undisturbed plume shows large variations in concentration , with fluctuations well in excess of the mean, over periods of seconds, and a high degree of intermittency (that is, there are significant periods when no pollutant is present in the plume). The concentration/time trace downwind of the building shows the continuous presence of pollutant with relatively low levels of fluctuation, so that levels of concentration remain close to the mean. If the plume were dispersing in an urban area, the concentration trace upwind of the building would show additional intermittency due to meandering of the plume and thus longer periods without the presence of any pollutant.

Exposure to pollutants at short ranges in urban areas is a combination of these two types of dispersion pattern, depending upon the siting of the discharge and the presence of buildings and other surface structures

Polluting sources at short ranges generate high levels of spatial as well as temporal variability in urban areas. The disturbed windflows that are a feature of urban areas generate a spatial variability that is not only high but which is also sensitive to source position and to the meteorological parameters, especially wind direction. There can, for example, be very large variations in pollutant concentrations across the corners of a street intersection or between the windward and lee faces of a building. It is not proposed to discuss this complex subject in detail here, but a few examples of small scale plume behaviour at short distances are given which show the effects clearly enough. Figure 2, taken from Dabbert et al (1973), shows an over-simplified representation of the flow pattern in the space between buildings in an urban area, frequently described as a 'street canyon'. Figure 3, from Oke(1987), shows some mildly misleading representative dispersion patterns in urban areas covering a variety of source positions and shows the complex plume paths that can occur

Dispersion at Neighbourhood Scales (100-2000m)

Within the greater distances of neighbourhood scales, the high levels of spatial and temporal variability that mark out microscale dispersion patterns reduce. Though spatial and temporal variability in concentration remain, the associated time and distance scales increase. Apart from distance itself, the most important factor influencing this change remains the surface topography, mainly the buildings and other surface obstacles. At these greater ranges, however, it is the size, layout and packing density of the structures in urban areas that are the most important features, rather than the shapes of individual structyures and their immediate surroundings, as is more the case with microscale dispersion patterns.

Once a source of pollutant is out of line-of-sight in an urban area, the effects of building wakes on dispersion become more important, so dispersion patterns become more stable and the short term variations in concentration should pass from a state like that of Figure 1a to one more resembling that of Figure 1b. With increasing distance the diffusing effects of larger numbers of buildings come into play and the variability further reduces.

The spread of pollutants at neighbourhood scales is not presently a well researched subject, though this is a rapidly growing interest (Hall et al's(1996b) review discusses most of the existing literature). It is difficult, therefore, to provide a clear description of pollutant dispersion at these distances. The most recent research suggests that, of the characteristics of the urban form affecting the spread of pollutants, it is the mean height and across-wind widths of the surface structures which has the greatest effect. The typical characteristic of the spread of pollutants at neighbourhood scale is a rapid vertical mixing over (and a little above) the heights of the surface structures in distances covering 3-4 rows of buildings in the direction of the wind. Beyond this distance there is a slower rate of vertical spread to greater heights. Lateral spreading is fairly rapid over the individual building widths and further lateral spreading at greater distances depends upon the relationship between building widths and spacing.

It is within the neighbourhood scales and microscales that significant vertical gradients of pollutants can occur. This is a matter of practical interest, for example for human exposure and for the placement of ventilation intakes. It might be considered that pollutant sources at or close to the ground would produce falling levels of pollutant concentration with increasing height and that pollutant sources at or above the building heights would produce rising pollutant concentrations with increasing height. In urban areas the dominant near-ground pollutant source is vehicular traffic. A recent emission inventory for the UK West Midlands area has suggested that vehicle emissions are now the major urban polluters (Anon(1996)); similar estimates have been made for Copenhagen and Milan(Vignatti et al(1996)). The dominant pollutant sources at or above building height are mainly discharges from combustion plant and industrial process, for most of which activities there are regulatory requirements in the UK that discharges should be above their immediate surroundings. However, there are in addition a variety of other pollutant discharges at intermediate heights, for example ventilation exhausts (which are often associated with odour problems) and discharges from some types of gas-fired heating plant.

This broad generalisation for vertical gradients of contamination is of limited reliability. The plume paths sketched in Figure 3 indicate that at the shorter scales there may be substantial short term local variations in the vertical pollutant gradient for sources at any height from changes in the dispersion patterns due to local aerodynamic effects. The longer term mean of the vertical gradient of pollutants can also vary. Figure 4 shows measurements of the vertical variation of pollutant from sources at the ground in a small scale simulation of an urban area in a wind tunnel, using arrays of cubes set in rows. Here , there are both positive and negative vertical concentration gradients depending upon the detailed circumstances of the discharge and its surroundings.

There seem to be few field measurements of the vertical gradient of pollutants in urban areas. Measurements by Georgii et al(1967) of carbon monoxide (CO) on either side of a street showed falling concentration with increasing height. Since vehicular traffic is the major source of CO, the measurements are largely for a distributed, ground-based source. Figure 5 (taken from QUARG(1993)) shows the results of a scan by a remote sensing device (a LIDAR) of the contours of NO_2 in a London street with dense traffic. The concentrations fall with increasing height above the ground, but show another maximum above building level.

Dispersion at Urban Scales (5-50km)
Pollutant sources at these distances and beyond disperse to heights well above the heights of the surface structures and spread over relatively large widths. At 5km distance the bulk of the pollutant from a single source is contained within a height of about 250m and a width of about 1km. At 50 km distance the respective heights and widths are about 600m and 8km. Pollutants are then starting to mix uniformly within the depth of the surface boundary layer. Also, the large numbers of pollutant sources likely to be contained in the upwind fetch at these scales, which contribute to the total pollution level at a point by addition, produce a more diffuse and slowly changing pollutant level. Thus there are negligible vertical and lateral concentration gradients over all but the very largest surface structures. This is also the regime for which pollutant residence times in the atmosphere are sufficient for chemical processes to occur, for example the oxidation of nitrogen monoxide, NO, to nitrogen dioxide, NO_2, and the generation of photochemical smog.

Figure 6, taken from Ott (1977), shows a hypothetical example of the distribution of urban pollution from traffic sources.

Dispersion at Regional and Continental Scales (100km +).
Pollutant sources at these distances uniformly pervade the surface boundary layer, and thus to heights usually well above those of the surface structures, and show only small variations over large areas and long times. At the same time, the pollutant level at a point is usually comprised of the sum of the contributions from a very large number of individual sources. At the longer distances of these regimes even diurnal variations in pollutant discharges are smoothed out and pollutant levels mainly vary with changes in the weather pattern or long term patterns of use. The 'upwind' pollutants may have followed complex wind trajectories generated by the weather pattern. These are also the scales at which longer term atmospheric chemical processes occur, such as the further oxidation of nitrogen and sulphur oxides to nitrate and sulphate.

Pollutants at these distances thus constitute the true 'background' concentration levels of urban areas in that they pervade the whole area at a uniform level which changes only slowly. They cannot be controlled or avoided within the scales of an urban area. Ott's diagram in Figure 6 includes a base level of background pollutant concentration to which the local sources additionally contribute.

The Overall Pollutant Concentration Level Due to the Contribution of Sources at Varying Scales and 'Background' Concentrations.
From the descriptions of the temporal and spatial character of the pollutant levels from sources in the different distance regimes it will be appreciated how the overall pollutant level is built up from components with a variety of characteristics. Figure 7 shows a hypothetical example of this, with the components from the different distance scales summing to produce the total pollutant level at some point in an urban area. The level of temporal fluctuation and its frequency increases as the scales of the pollutant source distances increase. Thus the high frequency component of the overall pollutant level is due to the microscale and neighbourhood scale components and the stable long term base level of the pollutant concentration is due to the urban, regional and continental scale components. The spatial variability can be expected to follow the same sort of pattern, with the microscale and neighbourhood scales sources producing the greatest spatial variability and the urban, regional and continental scales the lowest. It will also be appreciated that it is not readily possible to determine the precise contributions of pollutant sources at the different scales to the total pollutant concentration level except, within limits, by their different frequencies of fluctuation.

The form of the overall pollutant concentration curve with time in an urban area will depend upon the relative contribution from the different distance regimes. For example, in the UK if there is an anticyclonic weather pattern with light easterly winds during a holiday period, then the long range contribution of pollutant sources from Europe will be high and the urban and smaller scale contributions will be low. Thus the overall curve will show low relative levels of short term fluctuation and low spatial variation. Alternatively, if there are westerly winds carrying relatively uncontaminated air from the Atlantic during a busy working day, the long range contributions will be low but the urban and smaller scale contributions will be relatively high. Thus the overall curve will show a higher level of short term fluctuation over a relatively small 'background' concentration.

CONCLUSIONS.
The paper has outlined the way in which pollutant sources, especially from varying distances, contribute to different features of the total concentration at a point. Both spatial and temporal variations of pollutant concentration can be large and generally increase with reducing averaging time and spatial scale.

ACKNOWLEDGEMENTS.
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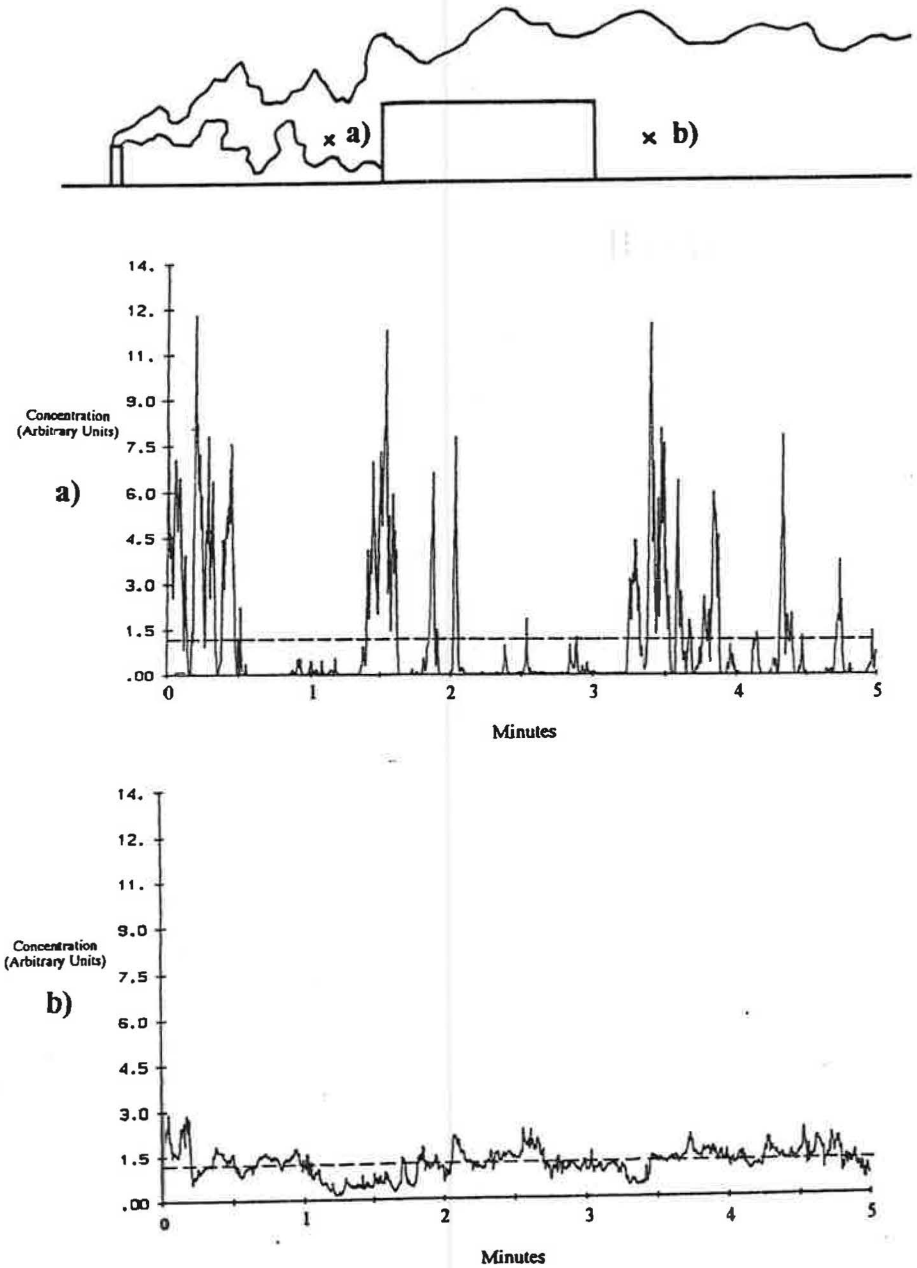


Figure 1. Concentration/Time Measurements of the Pollutant in a Plume Dispersing at Short Ranges Near a Rectangular Building.
a) In the Undisturbed Plume Just Upwind of the Building.
b) In the Wake Region in the Lee of the Building.

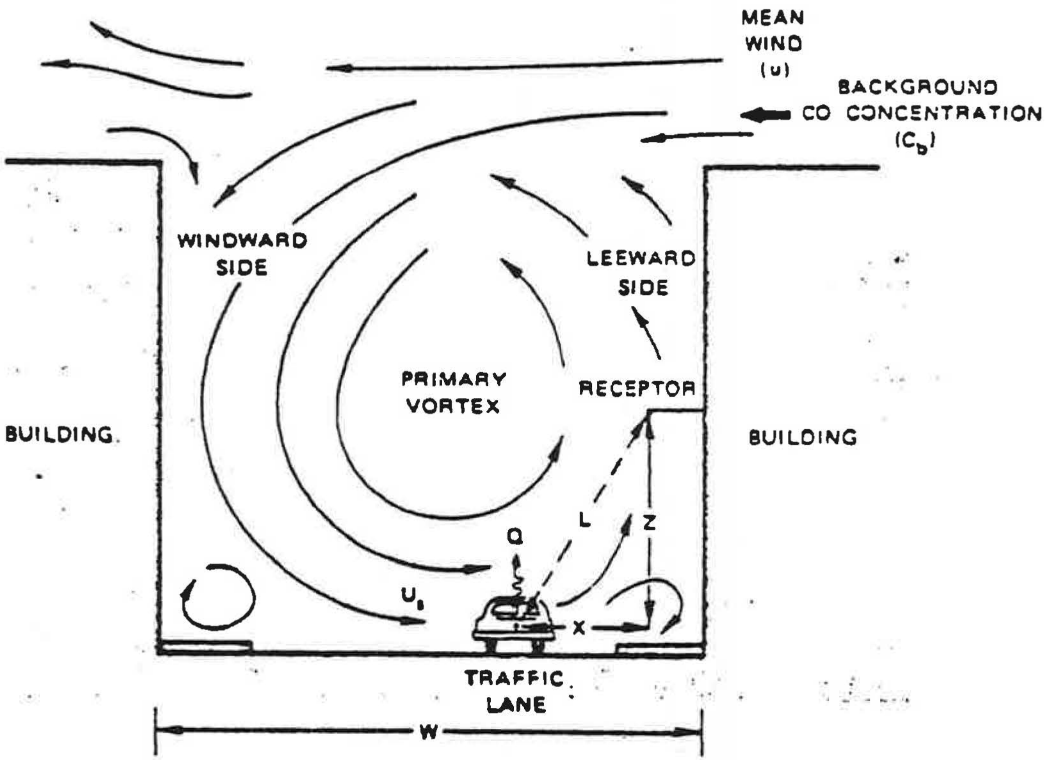


Figure 2. Simplified Flow Pattern in a Street Canyon. From Dabbert et al(1973).

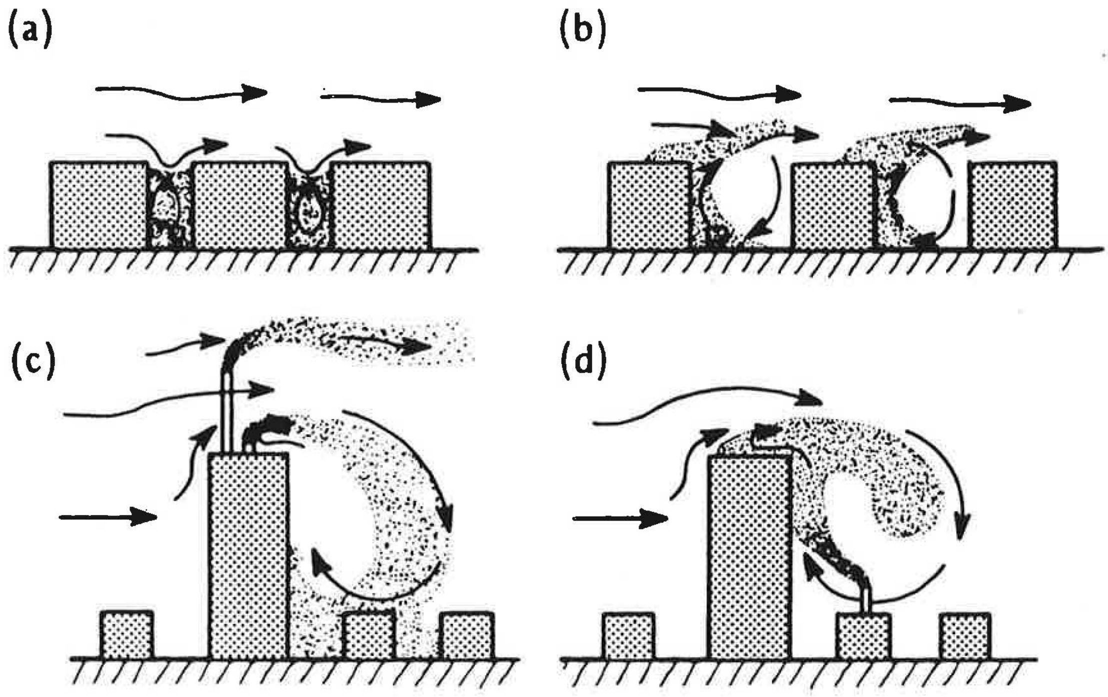


Figure 3. Potential Pollutant Plume Paths at Short Ranges from Sources in Urban Areas. From Oke(1987).

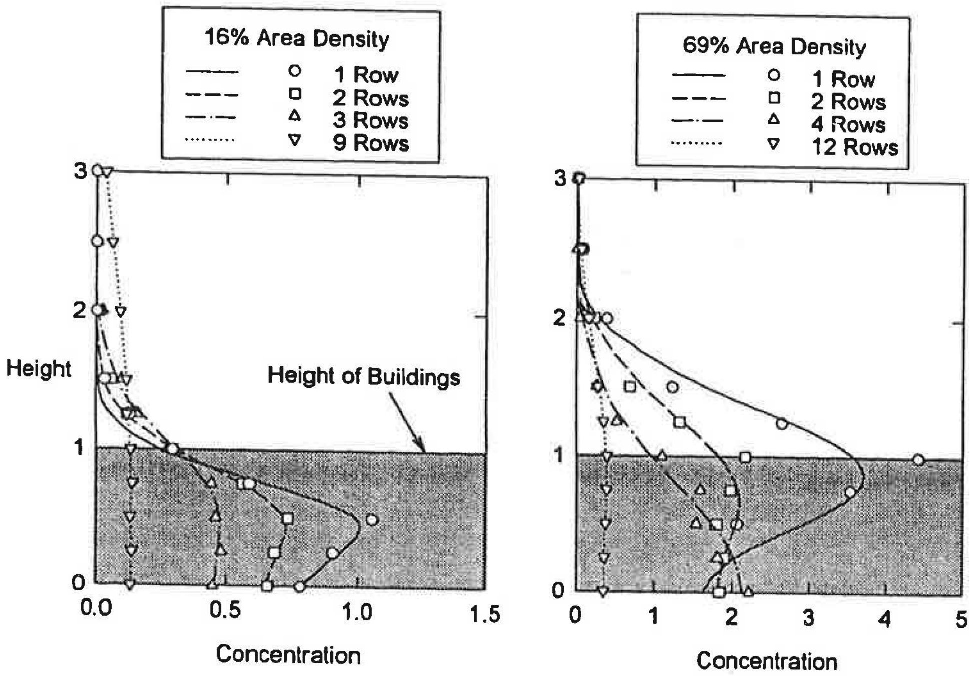


Figure 4. Vertical Profiles of Pollutant Concentration at Different Distances Through Simulated Urban Arrays with Two Different Densities of Building Occupation, 16% and 69%.

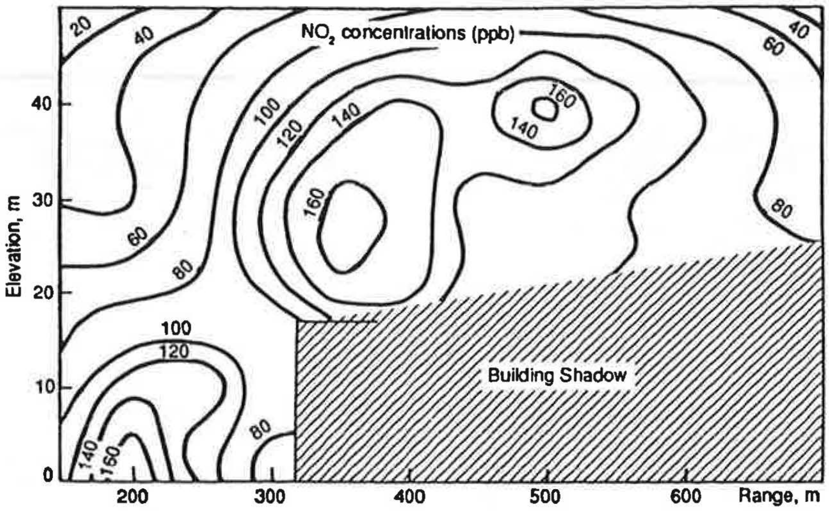


Figure 5. Remotely Sensed Contours of NO_2 in a London Street with Dense Traffic. From QUARG(1993)

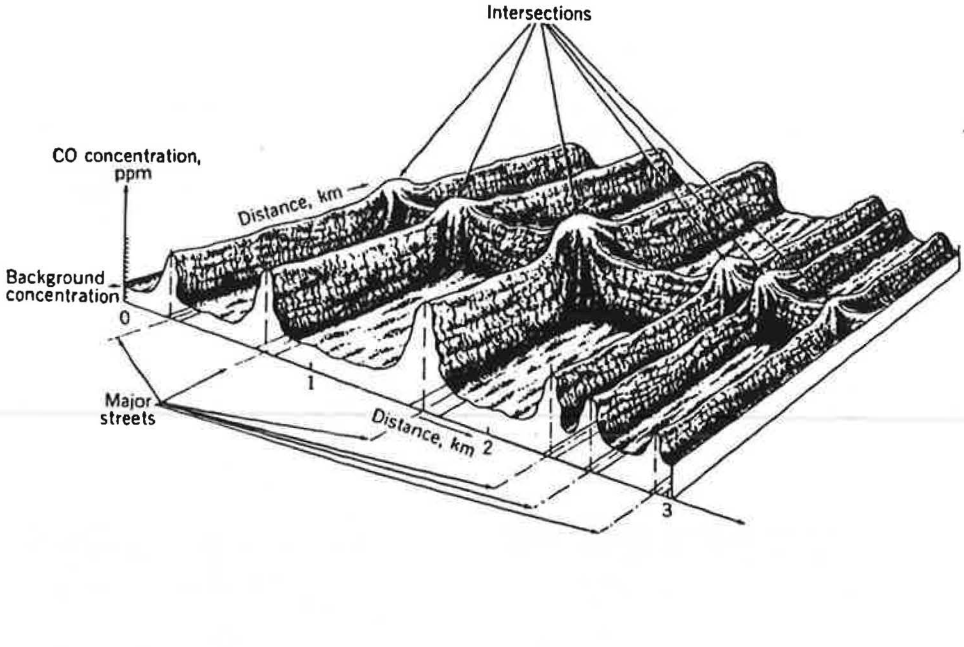


Figure 6. Hypothetical Map of Urban Pollutant Levels from Vehicular Traffic on a Grid of Streets. From Ott(1977).

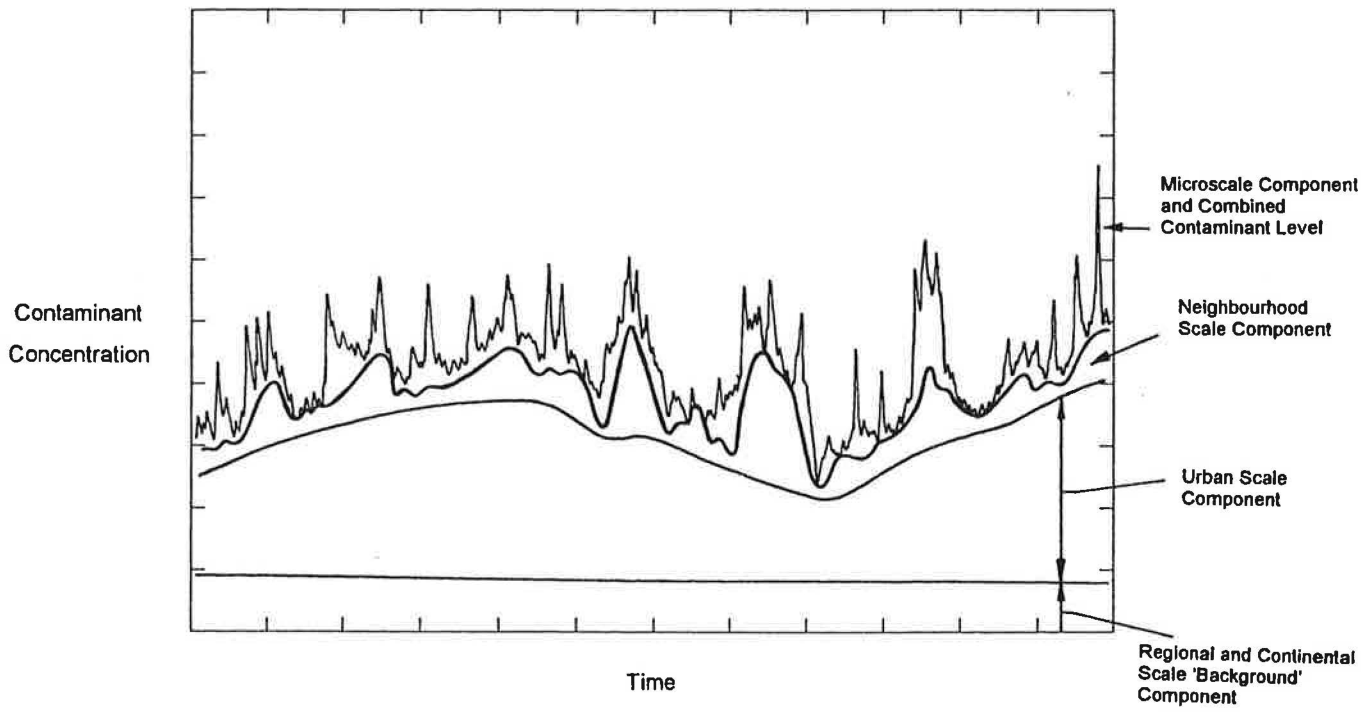


Figure 7. Hypothetical Example of the Contributions of Pollutants from Different Source Regimes to the Combined Pollutant Level at a Point.

LOCATION OF VENTILATION INLETS TO MINIMISE CONTAMINATION: STATE-OF-THE-ART REVIEW

Steve Irving and Dr Gary Palmer - Oscar Faber Applied Research

The paper gives an overview of the current status of an ongoing DOE funded project aimed at improving guidance on the appropriate location of ventilation inlets. The purpose of the work is to provide usable guidance for designers to achieve acceptable indoor air quality (IAQ) by suitable positioning of ventilation inlets relative to the position of known pollutants sources. The design process involves four key stages.

- Identify the position and strength of the pollution source(s). This aspect is covered in other seminar papers.

- Based on rules of thumb, design experience etc., position the inlets to minimise the interaction between exhausts and inlets. Recommendations from emerging North American and European standards will be summarised.

- Estimate the dilution of the pollutant between the source and the inlet position. This will be influenced by the prevailing meteorological conditions, the surrounding terrain class and the specific building geometry. Various methods for estimating dilution will be outlined. This will range from simple prediction tools through to physical modeling in wind tunnels and water channels. The potential for computational fluid dynamics (CFD) will also be discussed.

- Determine the effect of the inlet concentration on the IAQ of the space, depending upon ventilation rates, filter/cleaner efficiency and position, space volume and any internal source of the same pollutant. A simple design tool which can be used to assess different strategies will be presented.

As well as providing improved design guidance, the project aims to highlight those areas where more information is required. This will help specify the direction of future research programmes.

Location of Inlets to Minimise Contamination

Steve Irving & Garry Palmer
Oscar Faber Applied Research

Project Objectives

DoE Funded (still in progress)

- Provide guidance on inlet location
- Provide understanding of sources
  - background, local and interactions
- Examine effects of roof top air flow on heat transfer processes
- Identify areas for future research

Guidance on Positions

CIBSE Guide B 1986

- Intake points "away from cooling towers, boiler flues, oil tank vents etc"
- If on the same facade, then short circuiting is more likely
- If on different facades, then wind will have greater effect on ventilation system

Guidance on Positions

ASHRAE Fundamentals (1)

- Remote as possible from exhausts except for single point exhaust - then place inlet at base of exhaust stack
- Where possible, combine exhausts before release to maximise dilution
- Not near roof or wall edges (turbulence)

Guidance on Positions

ASHRAE Fundamentals (2)

- Exhausts in top third of facade; if inlet in same face put in lower one third
- Inlets placed on roof to avoid windblown debris
- Remote from stationary vehicles (canopies are not effective)
- Exhausts not in enclosures

Minimum Separation Distances

ASHRAE 62 - 1996

- Property line - 1 m
- Vehicle loading bay - 7m
- Street - 3m
- Ledges - 1m
- Landscaped ground - 2m
- Cooling towers - 5m

Minimum Separation Distances for an Exhaust

CEN 1995

Exhaust air quality	Window below	Window above	Grade / paving	Adjacent building
1	2	2	1	2
2	2	3	2	2
3	4	6	3	5
4	6	10	5	8

Predictive Guidance

3-step process

- Characterising the pollution sources
  - constituents, spatial and temporal variation
- Calculating dispersion from source to inlet(s)
- Estimating impact on IAQ and health and comfort

Background Pollutants

BSRIA study on traffic pollution

- Roof level concentrations relative to those at street level
  - CO -13% (decreases with windspeed)
  - NO_x -31% (reduce with solar radiation)
  - O_3 +56% (increase with solar radiation)
  - PM_{10} +10% mass load, fewer in submicron range

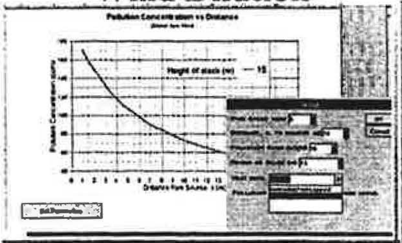
Dispersal from Specific Sources

- Dilution of pollutants
- Modelling of plumes
- Adjacent structures
  - Effect of stacks
  - Effect of other buildings
- Other methods of predicting dispersal

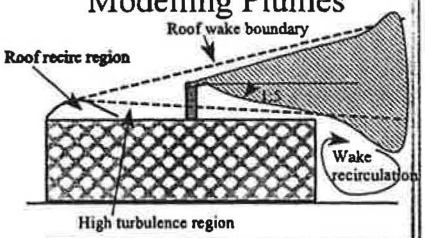
Influencing Factors

- Source strength
- Meteorological parameters
- Physical geometry
- Dispersion calculation method

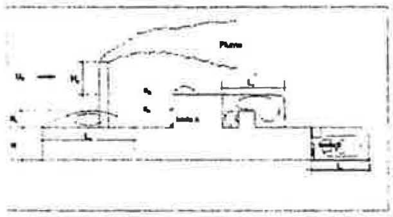
Wind Dilution



Modelling Plumes

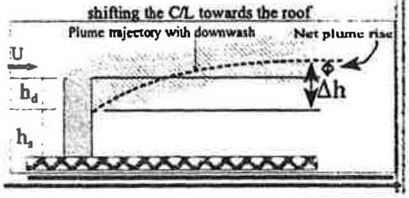


Modelling Plumes

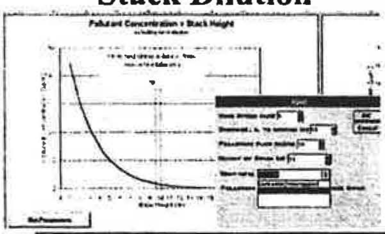


Plume downwash

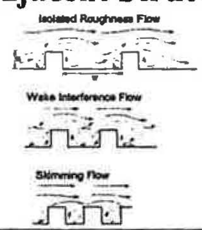
Increasing wind speed decreases the plume rise shifting the C/L towards the roof



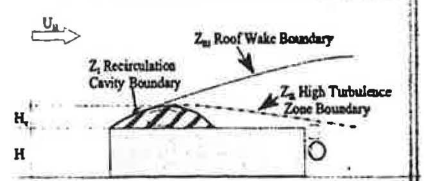
Stack Dilution



Adjacent Structures



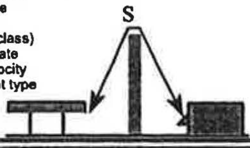
Local effects at Roof Level



Minimum separation

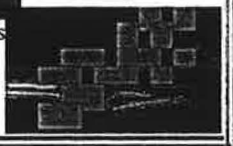
ASHRAE 62-1996

- S = K*0.04√Q(√D-V/2
- S = String distance
- D = dilution
  - = f(exhaust air class)
- Q = exhaust flowrate
- V = discharge velocity
- K depends on inlet type

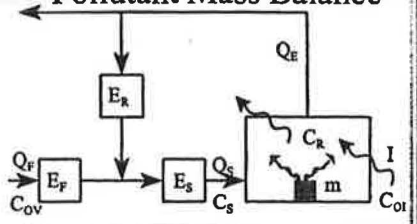


Other Methods

- Physical Models
- Wind Pressures
- CFD

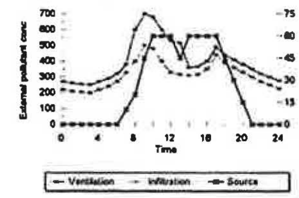


Pollutant Mass Balance

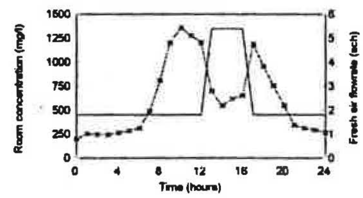


External	$Q_F.C_{OV}.(1.0-E_F)(1.0-E_S)$	+
Recirc	$(Q_S - Q_F)(1.0-E_R)(1.0-E_S)$	+
Infiltration	$Q_{INF}.C_{OI}$	+
Room source	m	=
Exhaust	$(Q_S+Q_I).C_R$	+
Concn rise	$V\ \{dC_R/dt\}$	

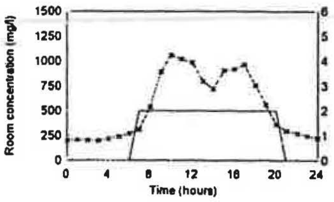
Pollutant load profiles



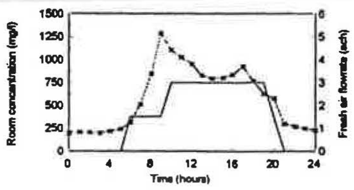
Background + Rapid Ventilation



Constant Mech Vent + 50% filtration



Demand Controlled Mech Vent



Provisional Conclusions

- Some quantitative guidance is available
- Reasonable for relatively simple geometries
- More work required to confirm/refine methods for more complex situations
  - Wind tunnel and CFD
- Importance of ventilation strategy and internal sources

VENTILATION AND AIR POLLUTION: CURRENT RESEARCH AT BSRIA

Peter Jackman - Director of Research, BSRIA

One of the main areas of BSRIA's recent and current research has been the internal environment created within low-energy buildings. This work involves monitoring the conditions within a number of existing buildings both by measuring the key environmental parameters and by obtaining the occupant's subjective assessment of the conditions at their workplaces.

In the current study, four buildings are being surveyed, three of which are located in urban areas.

Measurements are made of the thermal, acoustic and illuminance values as well as of CO_2/CO and airborne dust concentrations. Questionnaires are used to gather relevant information from the occupants. Other features of the building and their operation are collected manually.

The resulting data is analysed to determine the range of conditions that occur within each building and the variations that occur with time. In addition, analysis is conducted to determine the correlation's between the physical data and the responses from the occupants.

The output from this work will provide an impartial assessment of the performance of low-energy buildings in the provision of satisfactory indoor environments.

The presentation includes material drawn from other research projects that relate to ventilation and air pollution. For example, a BSRIA study nearing completion concerns the potential for the adoption of natural ventilation in buildings originally designed with mechanical cooling. Three actual buildings are being used as case studies with information being gathered on the policies and procedures used in determining the refurbishment options as well as on the indoor environment conditions established by the low-energy solution. An assessment of the savings attributed to the refurbishment is also included in the study.

Where relevant to low-energy buildings, aspects of other BSRIA work on air filtration and the control of ventilation rates in response to indoor and outdoor air quality will be covered.

The results of BSRIA's recently completed research on the outdoor pollution at high and low levels outside buildings at city-centre sites is included in the presentation on the location of ventilation inlets by Steve Irving.

Ventilation and air pollution

current research at BSRIA

Peter Jackman
Research Director

BSRIA's research

- external pollution distribution
- air leakage
- air filtration
- ventilation control by air quality
- cooling by night-time ventilation
- internal environment

Assessment of modern ventilation techniques

Starting Point

- comparison of air-conditioned and non air-conditioned buildings
- concern about the ability of low-energy buildings to provide acceptable indoor environment
- need for an impartial assessment

Objective

- to monitor and evaluate the internal environmental performance of low energy buildings which incorporate passive and mixed mode techniques, with particular emphasis on assessing occupant well-being

Methodology

- identification of four suitable buildings
- environmental monitoring
  (winter and summer)
- occupant questionnaire
- comparative analysis of data

Building One

- large office building (1993)
- 450 occupants, 4 floors, 7500 m^2
- government department
- urban site

Building Two

- large office building (1994)
- 600 occupants, 3 floors, 11,700 m^2
- private sector
- green-field site

Building Three

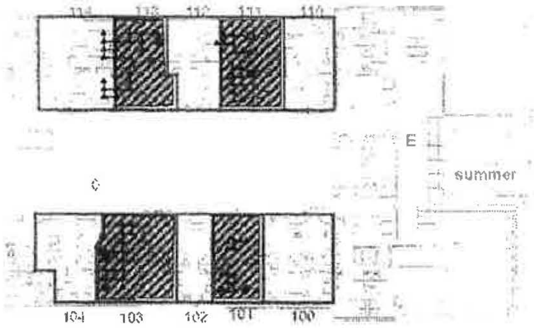
- office building (1994)
- 320 occupants, 3 floors, 4000 m^2
- private sector
- semi-urban site - near ring-road

Building Four

- day mental hospital/clinic (1995)
- <50 occupants, 2 floors, 1400 m^2
- NHS Trust
- city-centre site

Zone Monitoring

- CO_2/CO concentration
- temperature
- room air movement
- sound level measurements
- air change rates
- window and blind use

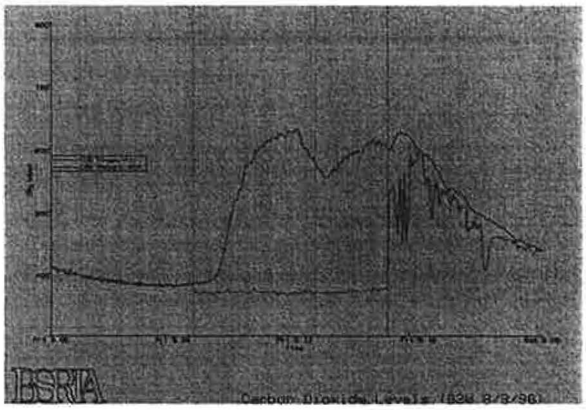


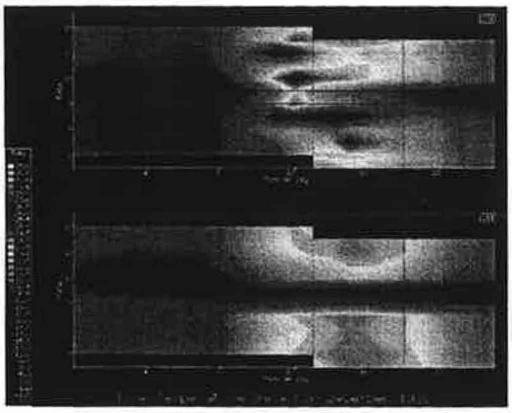
Seat-based monitoring

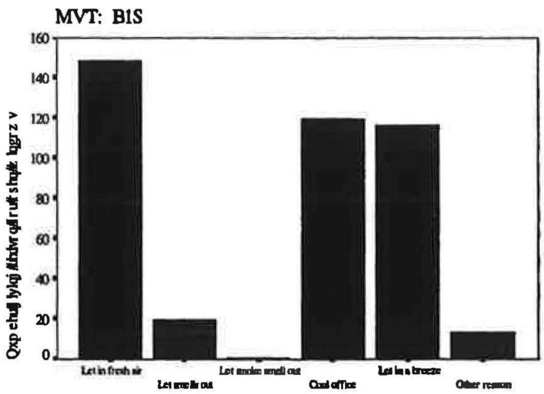
- respirable particulates
- thermal comfort
- illuminance
- simultaneous questionnaire feedback

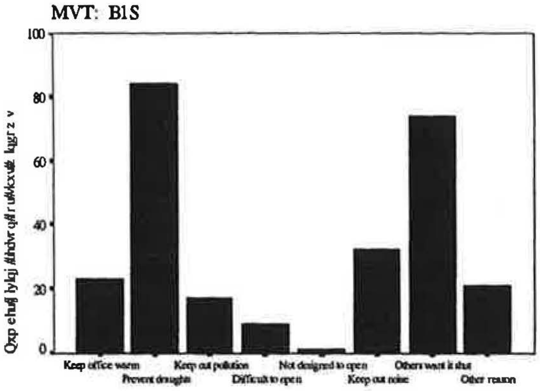
Data Analysis

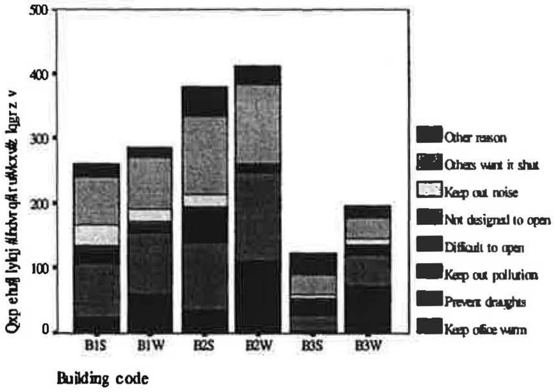
- many data types
- uni-variate and multi-variate
- zone based reference system
- presentation











Current Position

- all four buildings monitored for both seasons
- questionnaire data compiled
- external meteorological data obtained
- comparative analysis underway
- completion due end of March 97

Refurbishment of air-conditioned buildings with natural ventilation

Objectives

- to assess internal environment following refurbishment
- to assess occupant perception of the environment before and after

Building A

- 1970's office
- city centre
- 5 storey
- refurbished 1991
- warm air to hot water heating system
- new openable windows

Building B

- 1960's office
- urban
- 8 storey
- refurbished 1980s
- warm air to hot water heating system
- louvres fitted to existing windows

Preliminary conclusions

- natural ventilation successfully applied in place of air-conditioning
- little difference in level of acceptability
- window opening behaviour could be improved

STRATEGIES AND SOLUTIONS

VENTILATION AND AIR POLLUTION

BRE/CIBSE SEMINAR Watford 27 February 1997

Low Energy Strategies in Urban Areas

Chris Twinn Associate Director Ove Arup & Partners
13 Fitzroy Street, London W1P 6BQ, UK
Tel +44 (0)171 465 3411 Fax +44 (0)171 465 3673 E-mail chris.twinn@arup.com

DEFINING THE PATH

So what is likely to influence the HVAC form of the urban office of the future? There seems little doubt that where external noise levels are not too intrusive, natural ventilation with its cost and user perception advantages will predominate. Indeed as the techniques of acoustic shielding, buffer zones and passive cooling develop its application is likely to expand. However, what about the parts of our urban environment from which there has been an abdication in favour of the internal combustion engine? Until such time as the true cost of this so called individual freedom is established we will be obliged to provide an alternative internal environment behind a sealed facade.

The path we tread must have as its ultimate objective a truly sustainable built form. Following this path involves addressing issues of pollution levels, conserving the dwindling earth resources and the increasing frailty of our natural world. It also concerns maximising the use of our urban centres to reduce transport needs and to preserve the countryside. A significant part of this overall equation is reducing our dependance on fossil fuels. Fortunately, as far as the built form is concerned, there is a clearly defined path opening up for us to pursue. This can be summarized as the following steps:

1. Identifying and then eliminating the most energy intensive components of a building.
2. Designing the building fabric as the primary internal climate modifier.
3. Introducing building engineering systems to assist the building fabric to recycle ambient energy.

4. Ultimately, designing these systems so their motive force is ambient energy.

Step 2 is represented by the new generation of naturally ventilated buildings. Typically they tend to use the building fabric in association with advanced digital controls to take advantage of night cooling to maintain suitable daytime room temperatures. However, they need significant heating energy to cope with winter ventilation and fabric heat loss. Step 3 seeks to address this by identifying, recovering and reusing a wide range of ambient energy sources to reduce the need for high grade delivered energy. The New Parliamentary Building being constructed in Westminster, London addresses this Step 3. The path to Step 4 takes many features used on this project to allow a future where the building becomes a zero net user of imported high grade energy .

AN URBAN MODEL

The New Parliamentary Building is located on a central urban site dominated in pollution terms by the automobile. The brief demanded the highest quality internal room conditions in terms of air quality, temperature and acoustics. Starting with the pre-requisite of a sealed facade, the design fully uses the passive abilities of the building's materials and form to maintain the indoor climate. Only then were building services systems chosen to enhance these abilities and introduce energy harvesting and recovery.

At the conceptual stage the project started with an analysis of the major ambient energy flows entering the building, how they could circulate through it and finally, how they would leave. The architecture together with the engineering services systems were developed to complement these flows. Added to this process was a brief requirement for a building with a minimum fabric design life of 120 years, so cost in use, material durability, replacement strategy, and effective use of space, all became significant design factors. It is interesting to find that the long life of the building fabric and systems means the embodied energy pales into insignificance compared with the building lifetime energy consumption. The resulting design has an energy consumption target of 90 kWh/m² per annum (based on a 50 hour week including ventilation, heating, cooling, lighting, office small power allowance and miscellaneous electrical power use).

The Building Facade

The cladding system provides an integrated solution to the provision of outdoor view, room daylight control, passive and active solar energy collection, excess solar heat protection, the minimising of room heat loss, ventilation supply and extract, and heat recovery.

The fenestration super glazing consisting of triple glazing with mid pane ventilated blinds. The outer double glazed unit is argon filled with a low emissivity (low E) coating to retain winter heat. The inner cavity contains retractable dark louvre blinds designed to maximise the absorbed solar heat. This cavity is ventilated with a proportion of room extract air and acts as a solar collector. The blind material and finish are specifically chosen to maximise short wave solar absorption and minimise long wave heat loss, in association with low E coatings on the glazed surfaces either side of the ventilated cavity. This arrangement results in less than 25 W/m² summer solar heat gain across the floor area of a 4m deep perimeter room. In shading performance terms the glazing system is comparable with external shading, but in energy efficiency terms far exceeds it because of its solar heat recovery ability.

The window arrangement uses a lightshelf to preserves room daylighting when solar shading is in use, so avoiding the 'blinds down, lights on' scenario, with its additional luminaire heat gain and energy use. The lightshelf form has a corrugated reflective surface designed to maximise high altitude skylight reflections but to reject the lower altitude direct shortwave sun radiation.

In many senses the facade is a highly active system. It has many elements serving a wide variety of functions at differing levels and for differing orientations. Yet it is predominantly a passive system, with the only moving component being the blinds operated by the room occupants across which the air is drawn.

Cooling

To satisfy the brief requirement of an occupied room temperature range of 22±2°C using passive cooling needed a detailed in-depth understanding of the heat flowing into and out of the room. With a facade with an overall high level of thermal resistance most of the room daytime heat gain is retained, so for the majority of the year there is a heat excess to be managed. This heat is stored, first to deal with the night heat loss and to avoid boost heating prior to morning occupancy, and then to allow night ventilation to remove any surplus from the building. High thermal capacity room surfaces with a density range between 50 and 200kg per m² are provided at the rate of 2.5m² per m² of room floor area. This is used as the heat storage medium with its ability to function with small temperature difference changes and to take full advantage of both radiated and convective heat transfer.

The room thermal capacity handles the internal room heat gains, but for ventilation when the outside air is above 19°C, groundwater at about 14°C is drawn from two on site boreholes to cool the outside supply air down to room temperature. A displacement ventilation system is used to allow this cooling to be achieved without any mechanical refrigeration.

Ventilation System.

The mechanical ventilation system serves a network of linked floor plena throughout the building via ductwork in the facade to provide 100% outside air ventilation to each room. High efficiency heat recovery is the key benefit mechanical ventilation has over conventional natural ventilation. Not only does it allow generous year round ventilation with outside air, together with the higher supply temperatures needed of displacement ventilation, but it also permits the recovery of solar heat from the window system, the occupants, their electrical equipment and the room radiators. Rotary heat exchangers operating at efficiencies of more than 85% provide this function. They are of the hygroscopic type to simultaneously recover winter moisture from the exhaust air and so reduce supply air humidification requirement.

The selection of very low pressure loss air handling and duct system components mean the ventilation energy use target is 1 Watt per litre of air supplied. The fan total pressure generated by supply and extract fans together is 640Pa with fan efficiencies (fan, drive, motor and inverter combined) of 65%. Typically the air handling plant component face velocities are 1.2m/s, with the filters at 0.8m/s. Fans are inverter driven so that when commissioned the sizing margin does not becoming a lifelong energy penalty, and fan efficiency can be retained for half speed night operation.

The same full fresh air system is able to serve all different room types, so allowing future changes of room function without dictating a services refit. Not only does this make the services more compatible with the long life of the building fabric, but it considerably reduces the embodied energy content of the engineering services across the building lifetime.

Heating

For most of the year a significant proportion of the building will have internal heat gains, from occupants, machines, lights and beneficial solar gain, that more than satisfy the fabric heat loss. Heating of the outside supply air then becomes the dominant heating demand. Consequently the ventilation system design centres on developing its ability to recover heat from all the internal heat sources and the window solar collectors so allowing heat recovery to do most of this ventilation heating.

The heating system is a variable water volume system with thermostatic valves on the room heat emitters, allowing the system to throttle in response to beneficial internal and solar heat gain, and occupant temperature trim control. The water has a 70°C flow and a 50°C return design temperatures to promote flue gas condensation efficiency in the condensing natural gas boilers. Compared with standard UK practice the mass of water to be circulated round the building is almost halved and using pipe sizing at 50Pa /m results in significant pump power reductions. Thus for this 23000m^2 building the duty pair of perimeter heating pumps generate a head of only 40kPa with a peak energy consumption of 450W each. The low pressure head also allows thermostatic radiator valves to operate with a 1°C proportional band without the proliferation of pressure reducing valves on each branch and their accompanying pressure head requirements.

THE NEXT STEP

The development of the urban building model has been the subject of a series of Joule II research programmes. This research has had many strands to it including, full scale component and assembly mock-ups, PASSYS cell testing, wind tunnel research, daylight modelling, thermal and energy computer analysis and software development, and computational fluid dynamics (CFD) modelling. The research aims to fill the technical knowledge gaps to allow the implementation of the model within the overriding consideration of an integrated and stimulating architecture.

Many of the initial research results have been applied to the New Parliamentary Building but its most exciting prospects relate to the ultimate potential of a building fabric requiring no refined energy consumption. In essence one starts with a strategy which is purely based on the use of ambient energy inputs from:

- solar gain
- daylight
- occupant activity
- cool outside air
- wind
- photovoltaic (PV)

With an urban building facade closed due to external pollution, the internal ventilation is driven by buoyancy stack affect through low pressure routes from roof level down to the rooms and then back up to the roof . These routes can be in a variety of forms, for example, staircases, atria, within the facade or dedicated air ducts. Direct wind pressure is used to drive the incoming outside air supply through roof top air to air heat recovery, with negative wind pressure drawing the exhaust air out through the heat recovery. Not only does a rooftop location give the best access to wind but it provides the freshest source of supply air. The rooftop cowls are arranged as wind scoops with the ability to rotate to face the incoming wind direction. A highly insulated building facade allows almost all the internal heat gains to provide extract air buoyancy and to satisfy the fresh air intake heating via the exhaust air and the heat recovery. There is a critical balance between the level of heat recovery and maintaining adequate stack affect.

The glazing system develops the principles of allowing high levels of natural daylight while providing practically total protection from the summer sun direct solar heat component. The window solar collection allows the recovery of the incident solar radiation via the exhaust ventilation so it is also available for heat recovery.

Large areas of high thermal capacity surfaces are arranged to temper the ventilation air supply on its route to the rooms, as well as in the room to smooth out heat gain excesses and deficiencies. The ability to do this will considerably increase as phase-change heat storage materials are integrated into the building fabric.

To reduce winter ventilation air dryness and summer excess humidity, room finishes are chosen to allow the building fabric to function at a hygroscopic level, absorbing moisture at times of room excess and emitting it at time of deficiency. This supplements the moisture recover function done by the ventilation system.

Photovoltaics generate the high grade electrical power needed for the building occupant's office machines. This electrical power in turn provides waste room heat recoverable via the exhaust ventilation. In addition when used in hybrid configuration the photovaltaic cells heat provides buoyancy assistance to the ventilation extract air and further enhances fresh air pre-heat.

Mid-sized wind turbines replace the conventional collection of rooftop plant to provide additional high grade electrical power with an availability profile which compliments photovaltaics. The National Grid infrastructure then becomes the manager of the individual building harvested energy using pumping systems and fuel cell type technology to store and then redistribute electrical energy.

THE CHALLENGE

The more one fundamentally re-examines the conventional methods available for achieving an appropriate internal climate, the more opportunities it opens up for addressing the serious environmental and resources issues currently facing our society and our urban concerns.

To date the assumption has been that a facade sealed to cope with external pollution, means air conditioning with an energy consumption a factor of two times or more greater than that for natural ventilation. What is becoming clear is that buildings which integrate the building environmental approach with simplified engineering system support have the potential to use considerably less energy than their naturally ventilated counterparts. In essence the challenge is to develop fabric and systems with the ability to capture and repeatedly recycle ambient energy and to use those same energy sources for the system's motive force . Used in unison with the principle of low embodied energy achieved by long life building and systems, we will be well on our way to the zero energy building and a sustainable future.

Chris Twinn CEng, BSc, MCIBSE, MinstE. Associate Director, Ove Arup & Partners

Ove Arup & Partners	Environmental, building services & structural engineers
Michael Hopkins & Partners	Architects
Conphoebus, Sicily	Test laboratory & PV research
Bartenbach Licht Labor, Austria	Lighting consultant
CSTB, France	Aerodynamic engineers
MBM, Germany	Prototype development

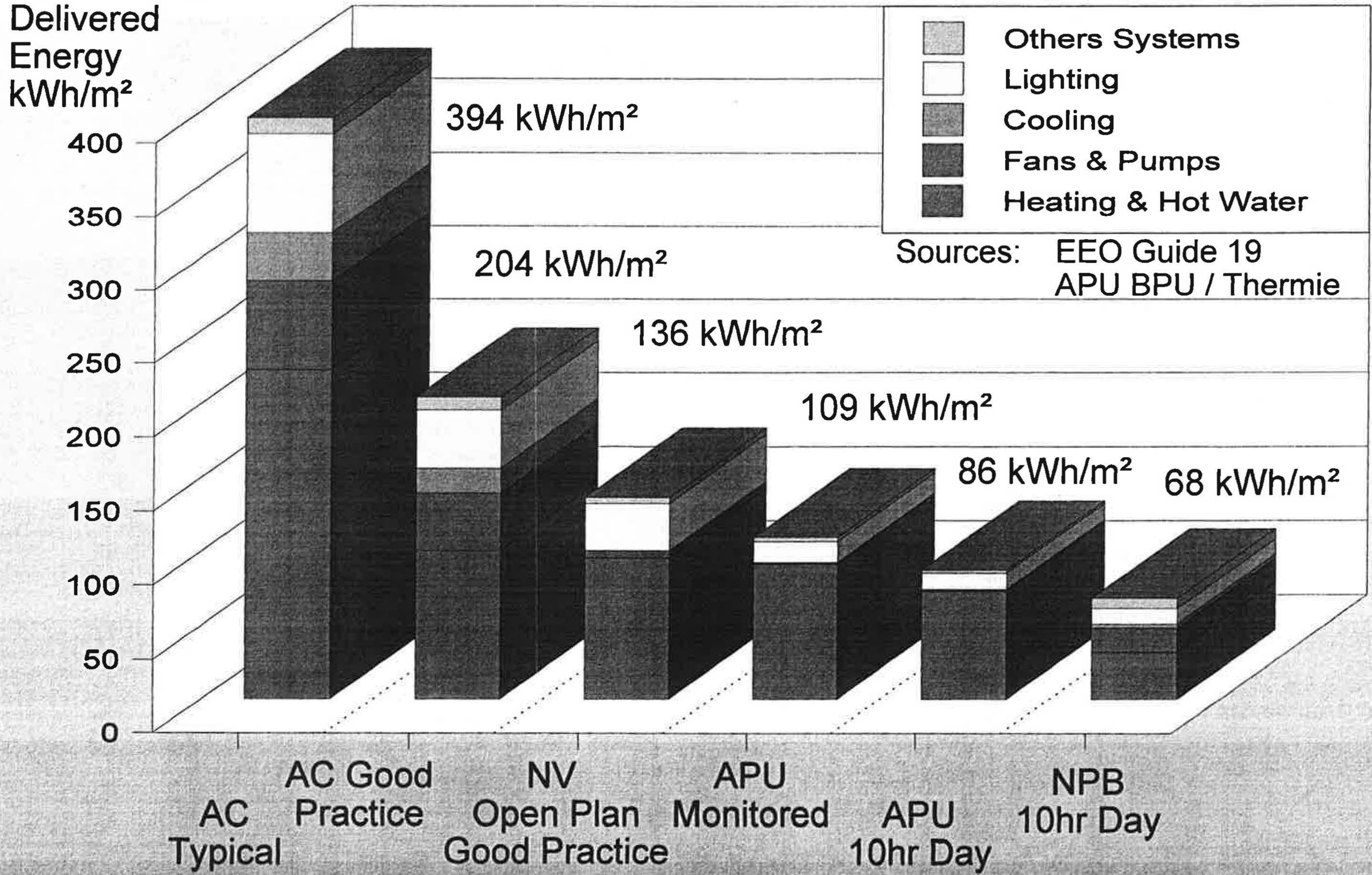
Ventilation and Air Pollution

BRE / CIBSE NVG Seminar 27 February 1997

Low Energy Strategies in Urban Area

Chris Twinn BSc(Hons) CEng MInstE MCIBSE

Associate Director Ove Arup & Partners

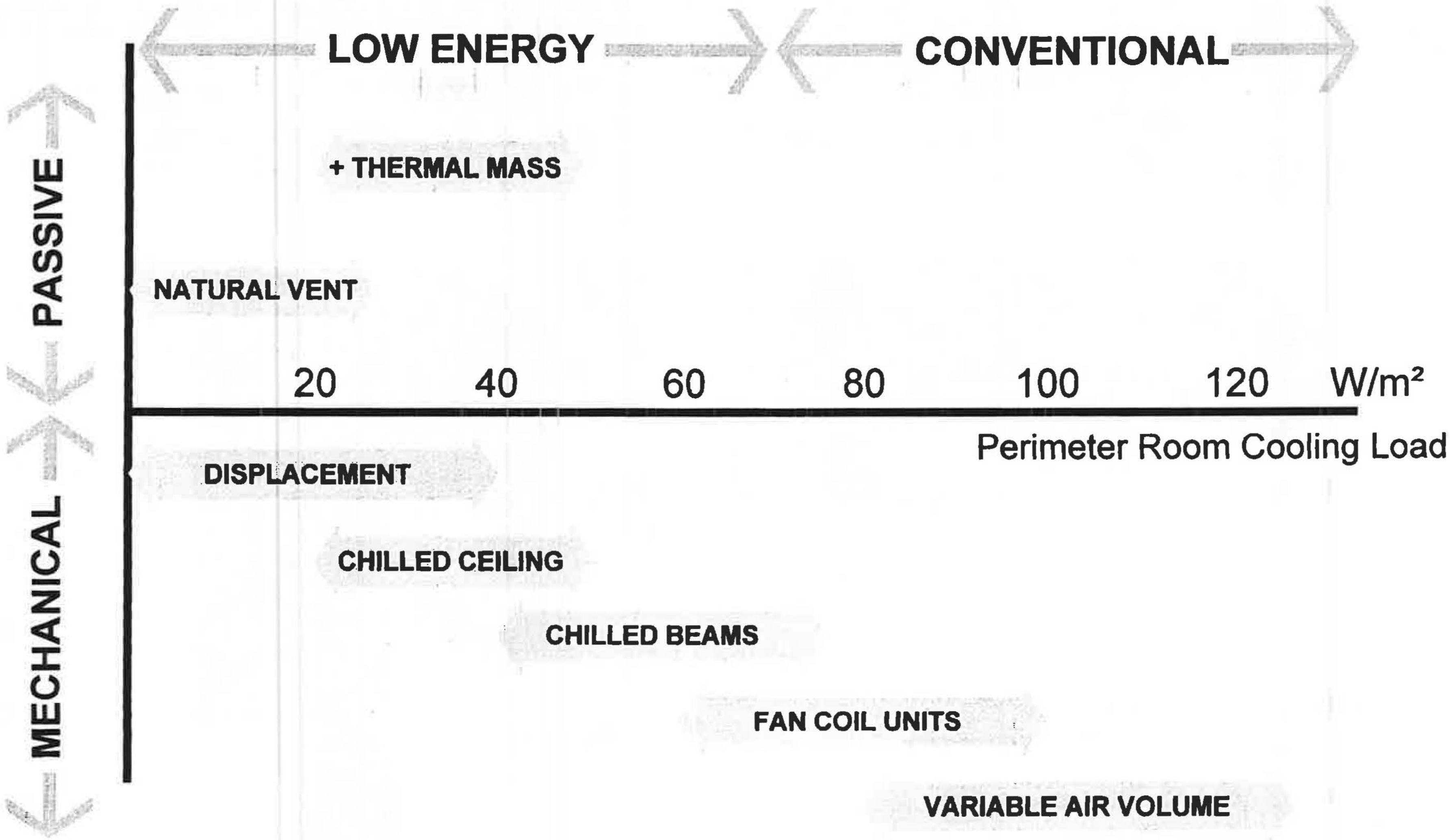


Energy Consumption

ARUP

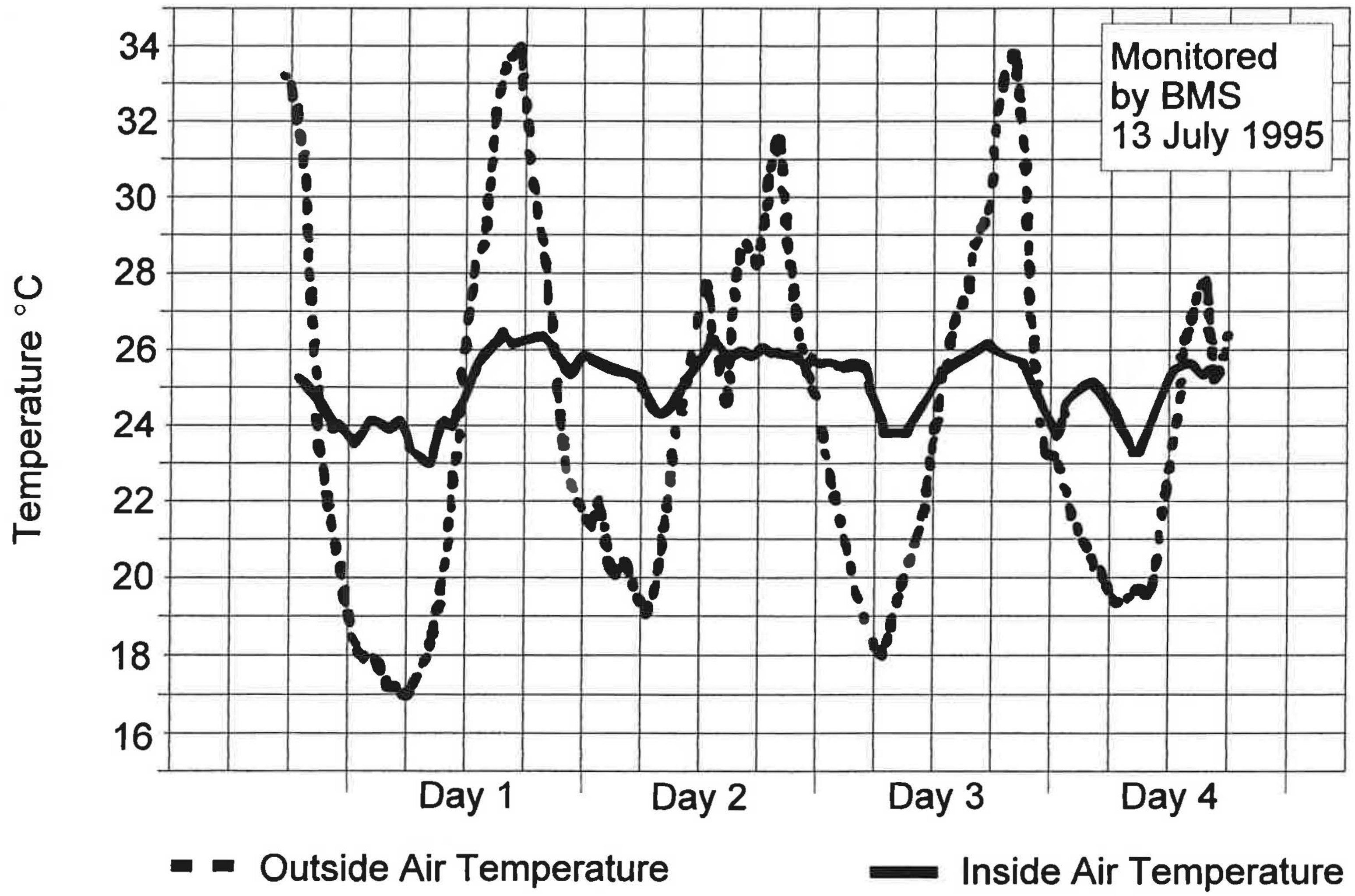
CHRIS TWINN ENERGY3.SHW

Room Cooling Methods



ARUP

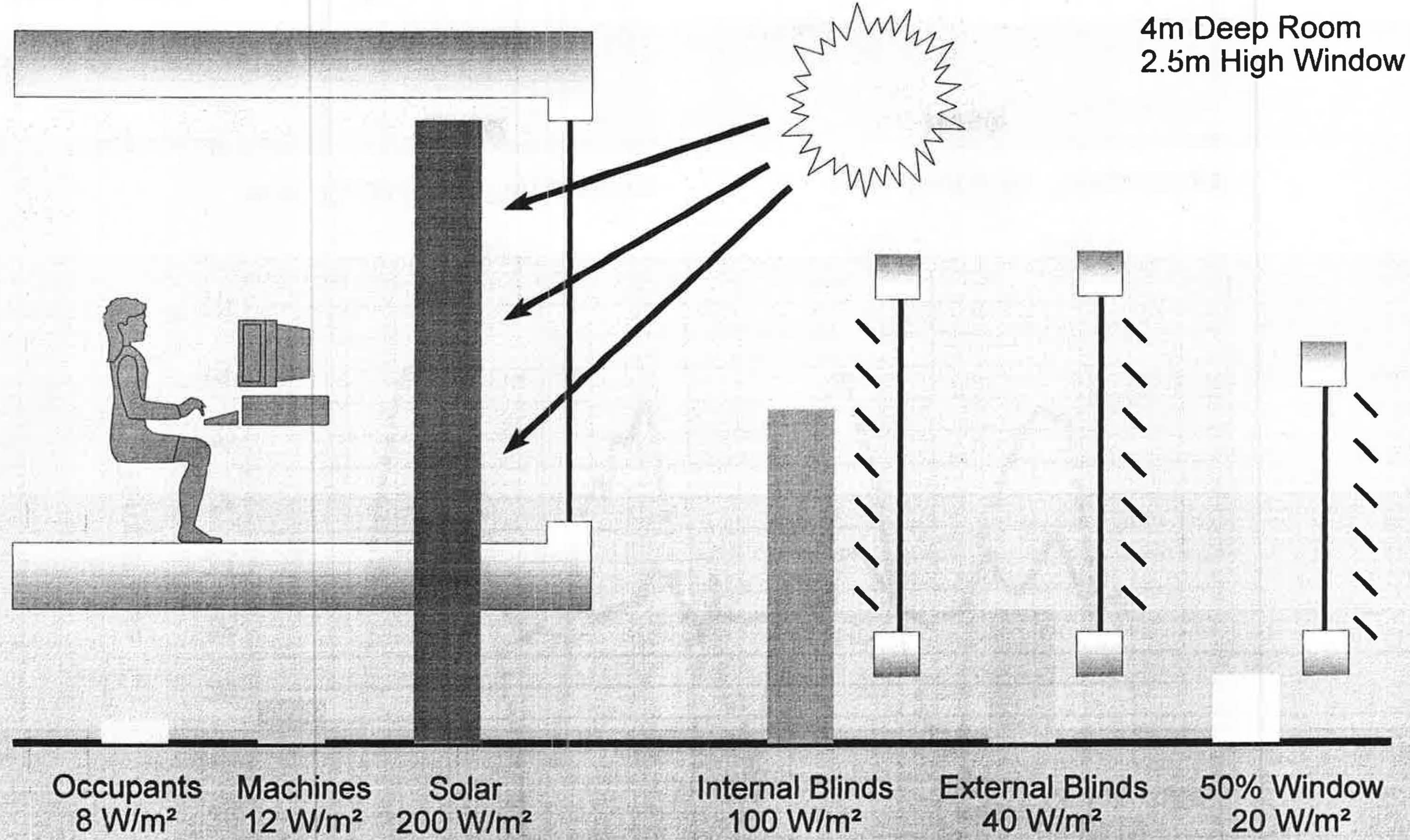
CHRIS TWINN SYSTEM1.SHW



Recorded Peak Temperatures

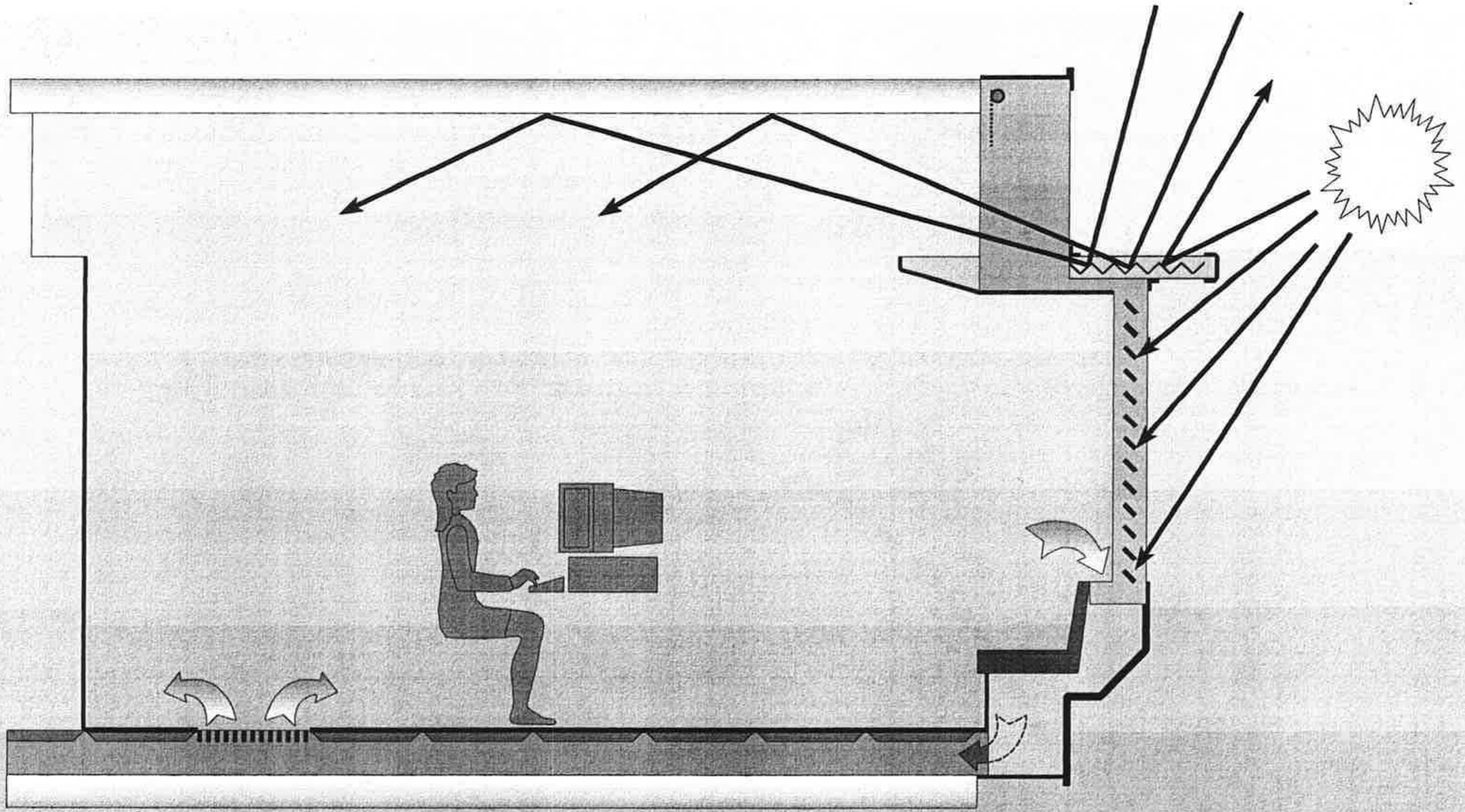
ARUP

CHRIS TWINN APUTEMP1.SHW



Solar Heat Gain

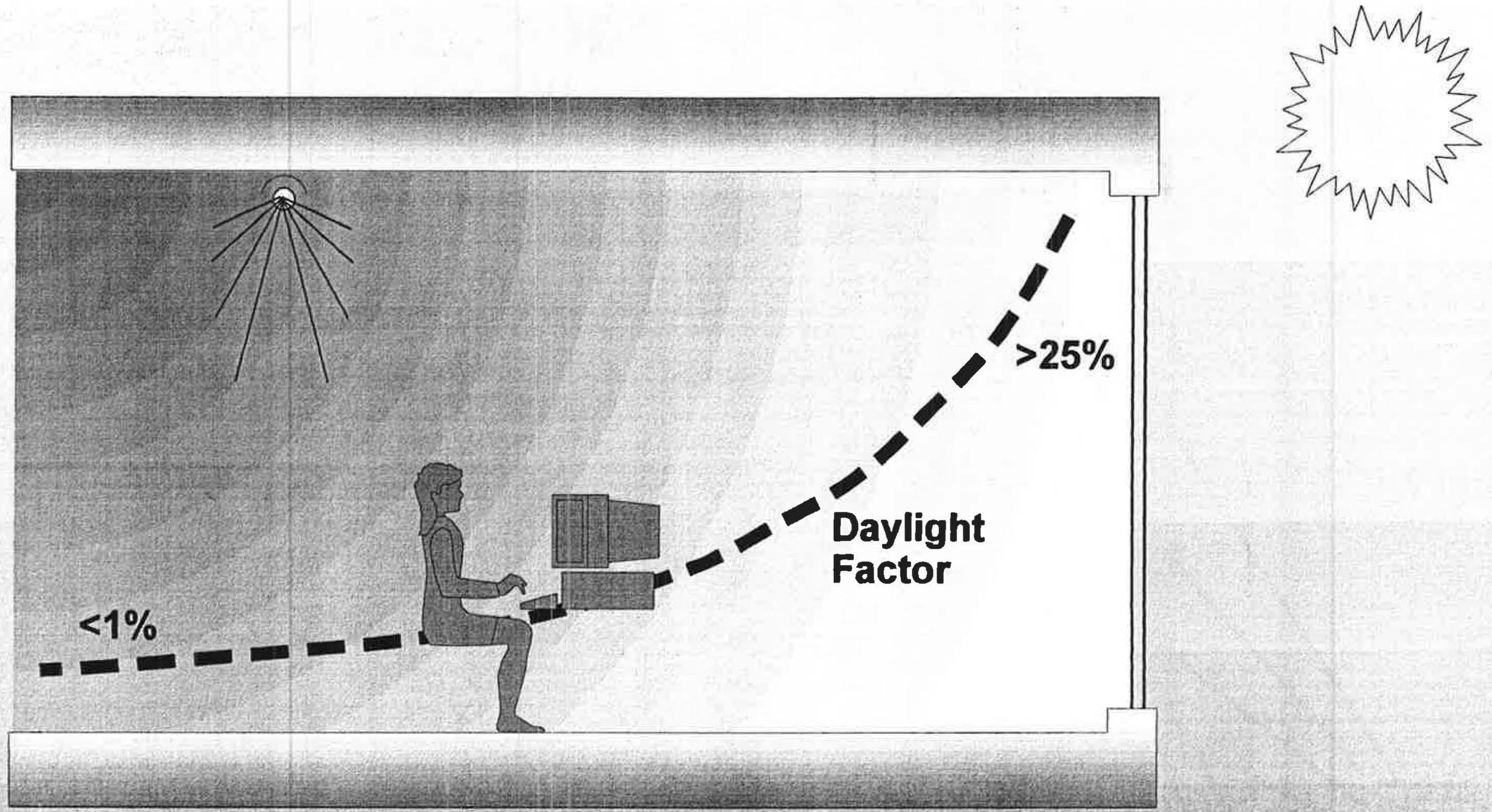
CHRIS TWINN GLAZING4.SHW



Daylight & Solar Control

ARUP

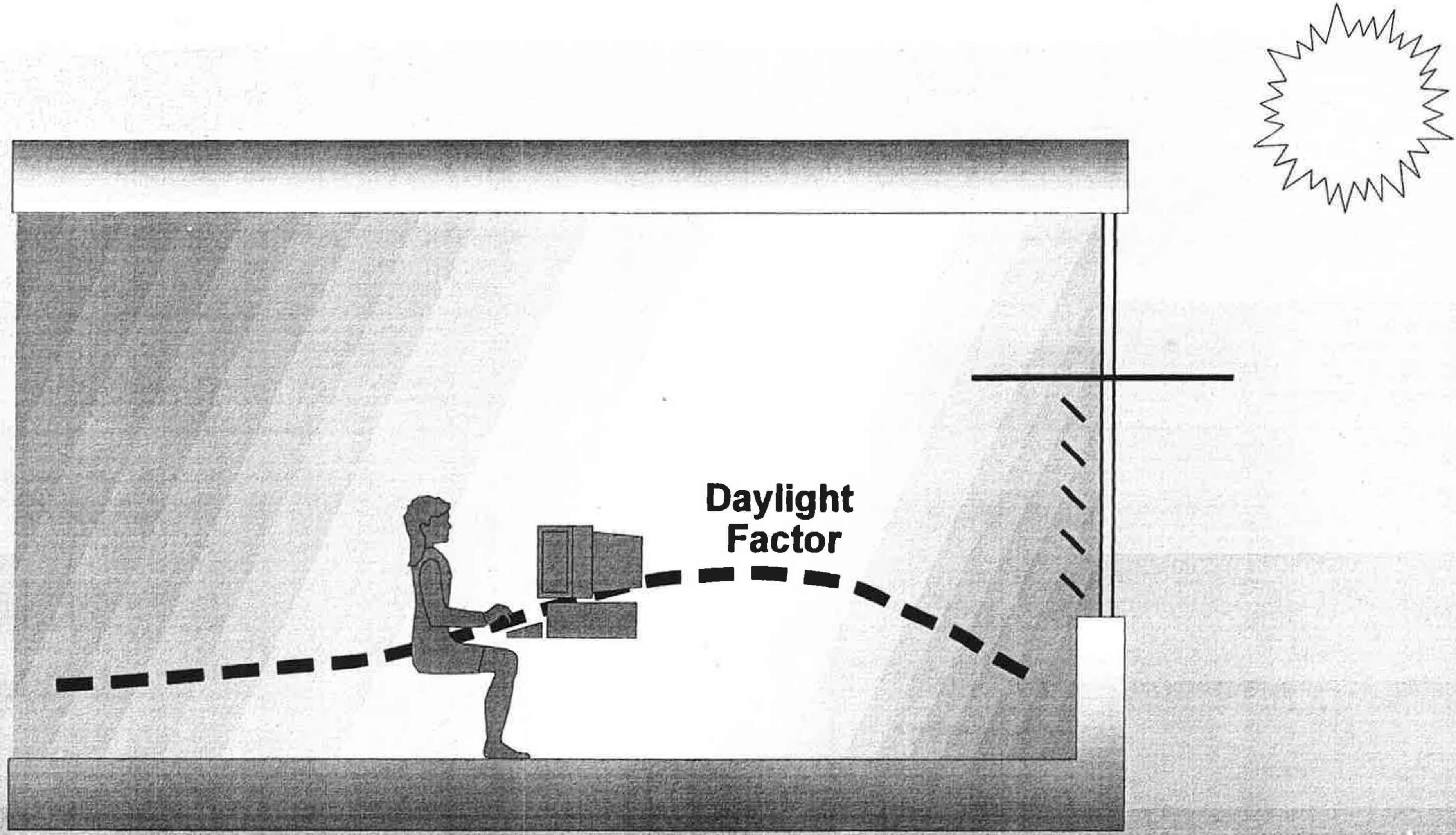
CHRIS TWINN NPB4RM.SHW



Daylight Contrast

ARUP

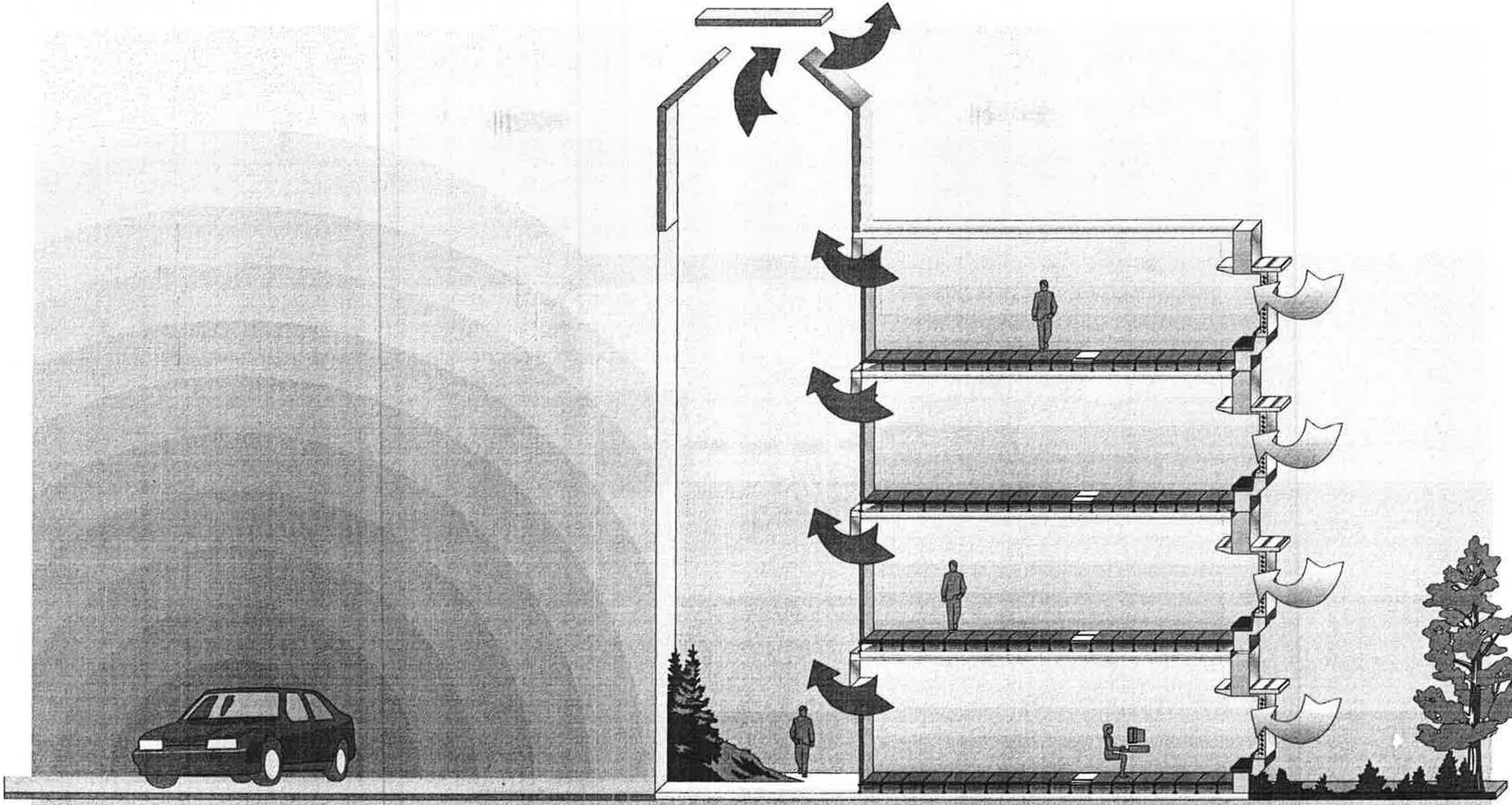
CHRIS TWINN GLARE1.SHW



Daylight Control

ARUP

CHRIS TWINN GLARE2.SHW

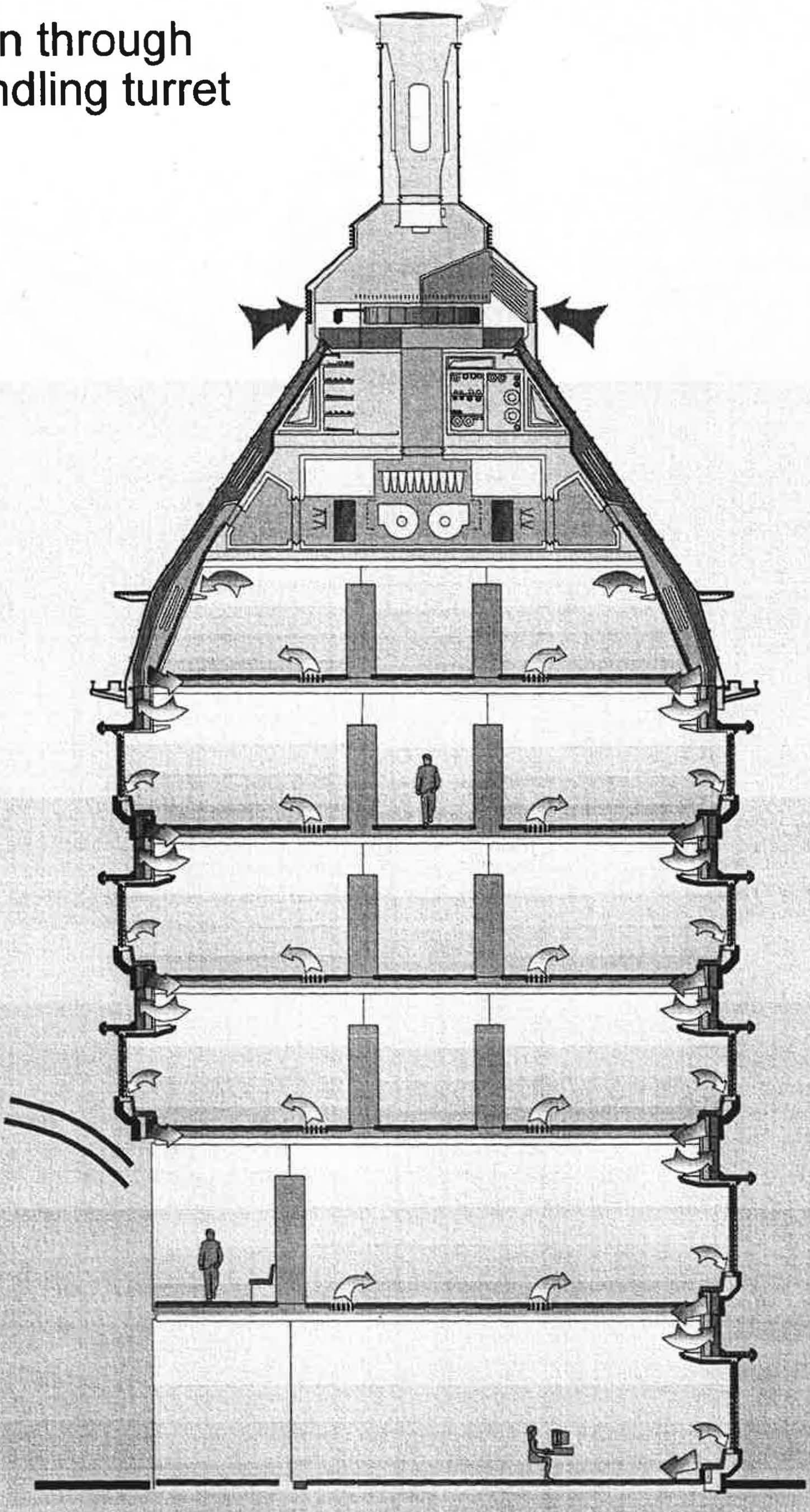


Barrier zoning

ARUP

CHRIS TWINN NV1BAR.SHW

Section through air handling turret

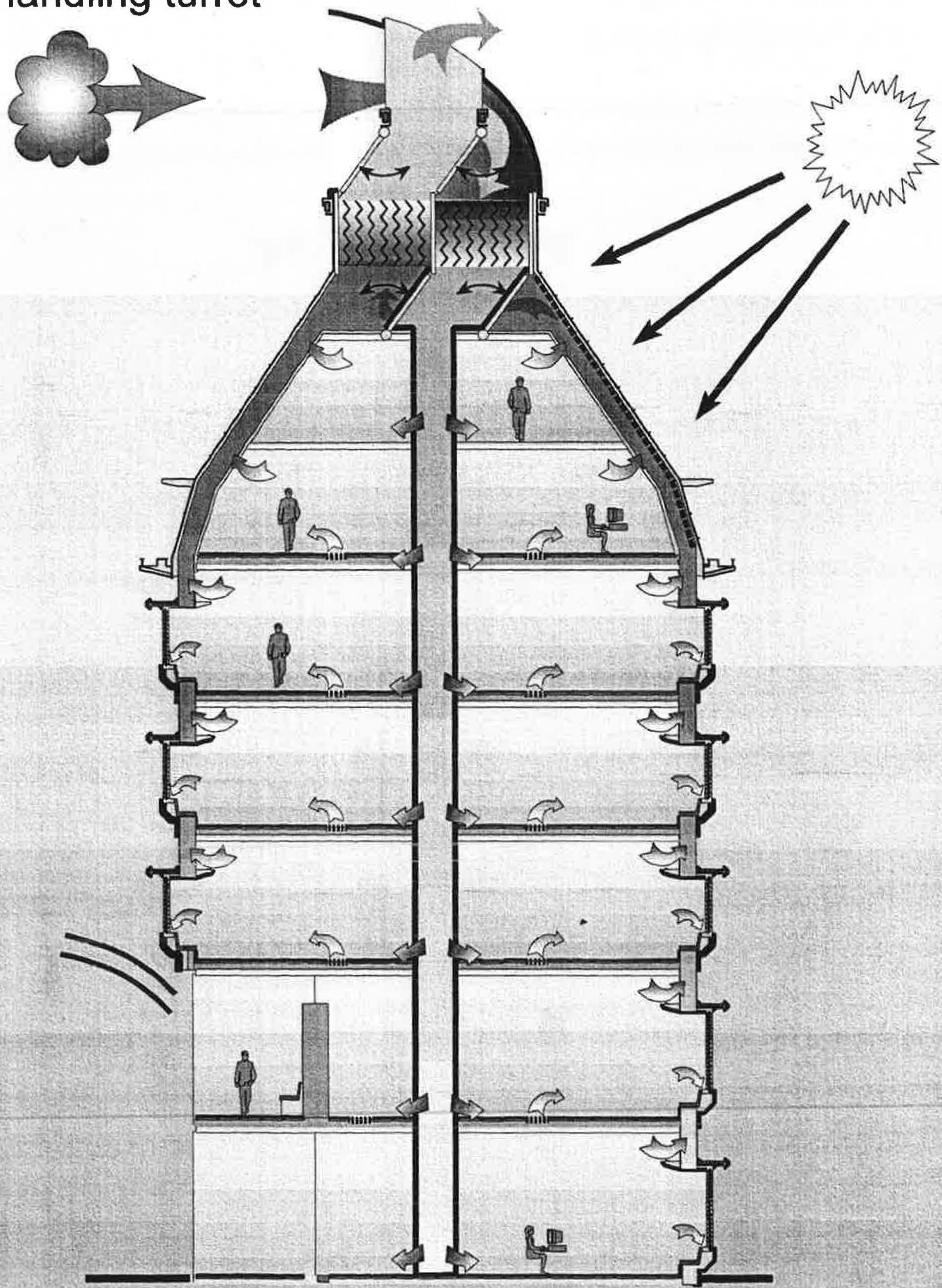


New Parliamentary Building

ARUP

CHRIS TWINN NPB1SECT.SHW

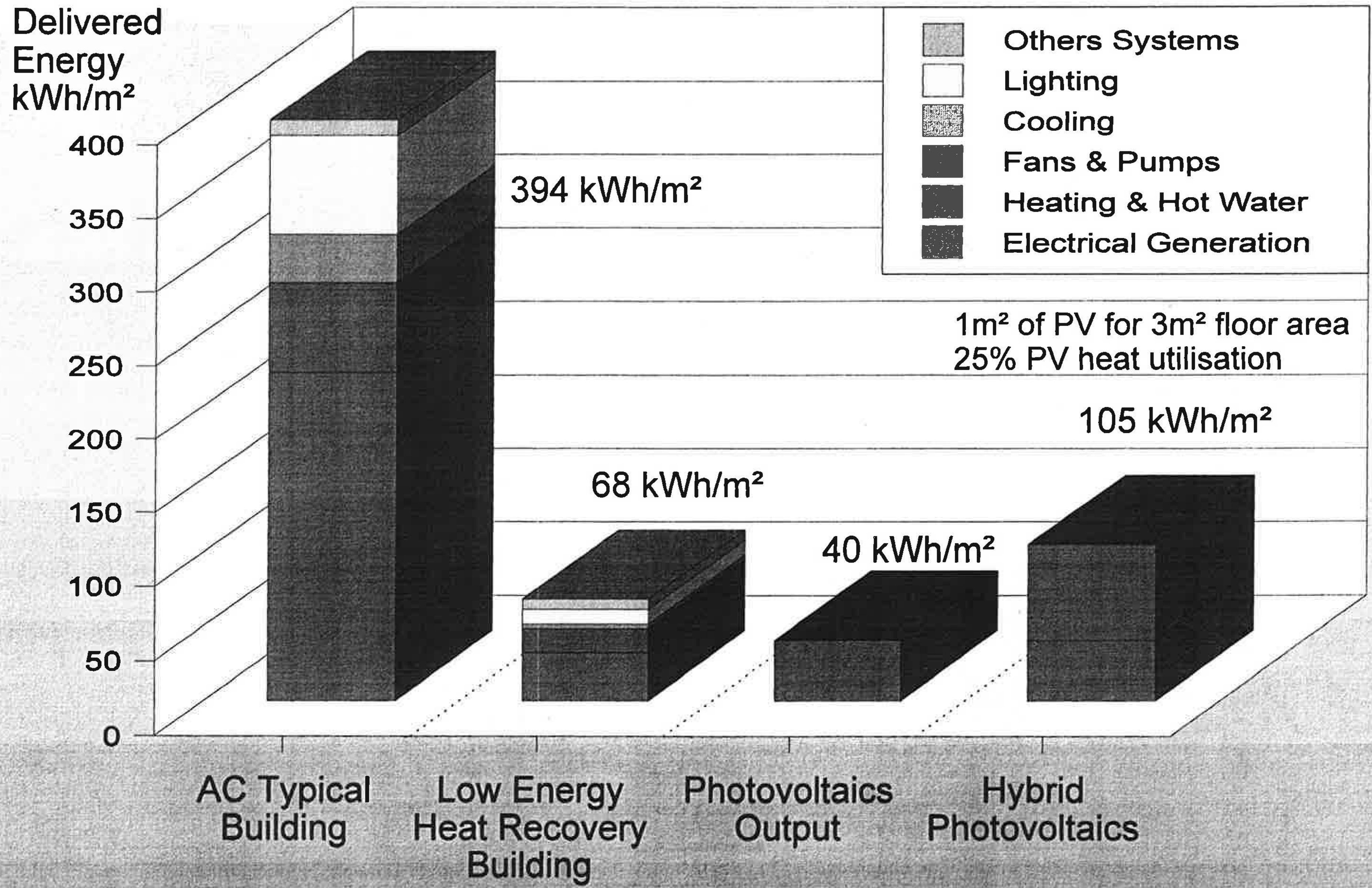
Section through
air handling turret



Wind & Buoyancy Driven Ventilation

CHRIS TWINN URBAN4.SHW

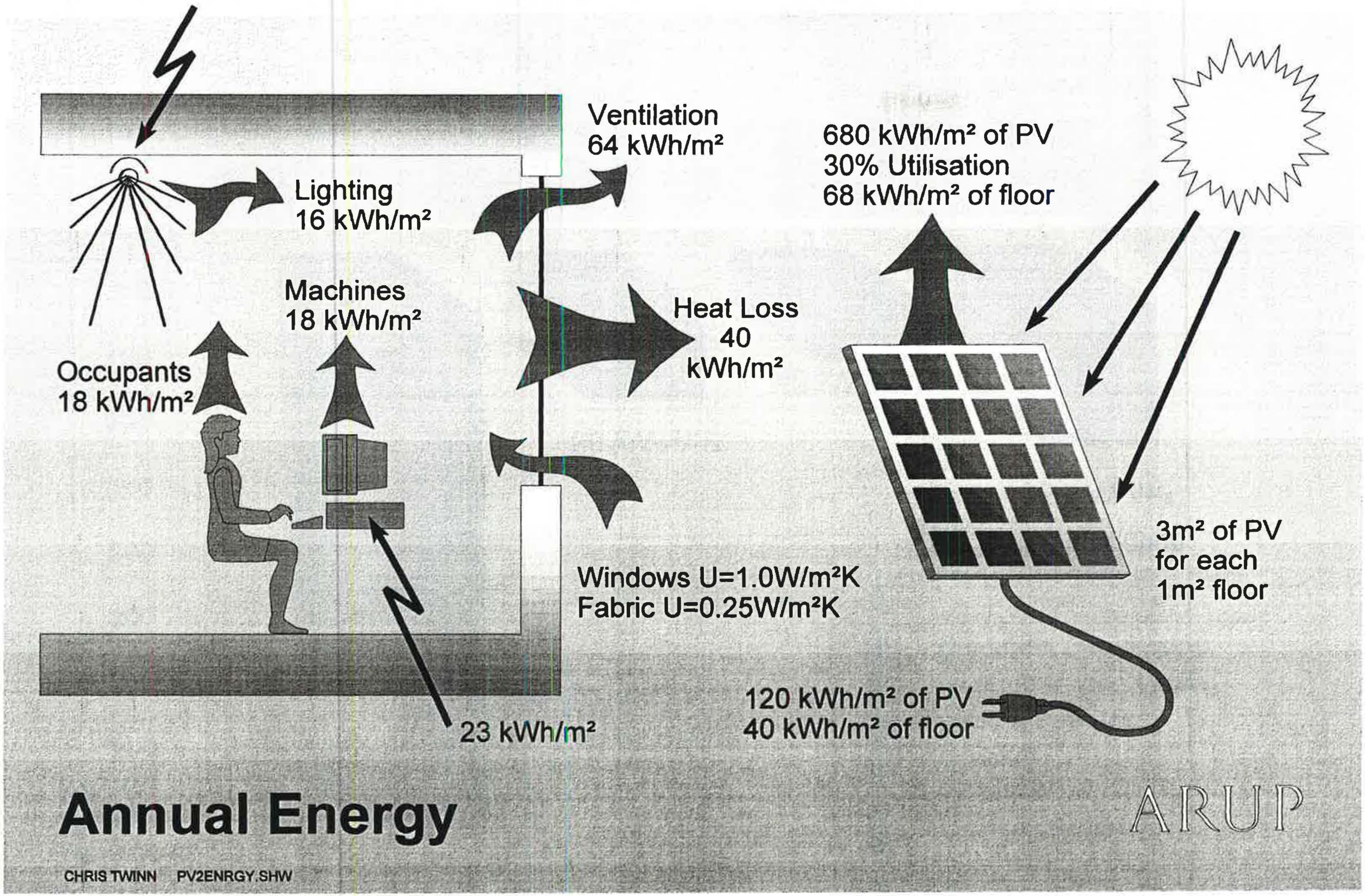
ARUP

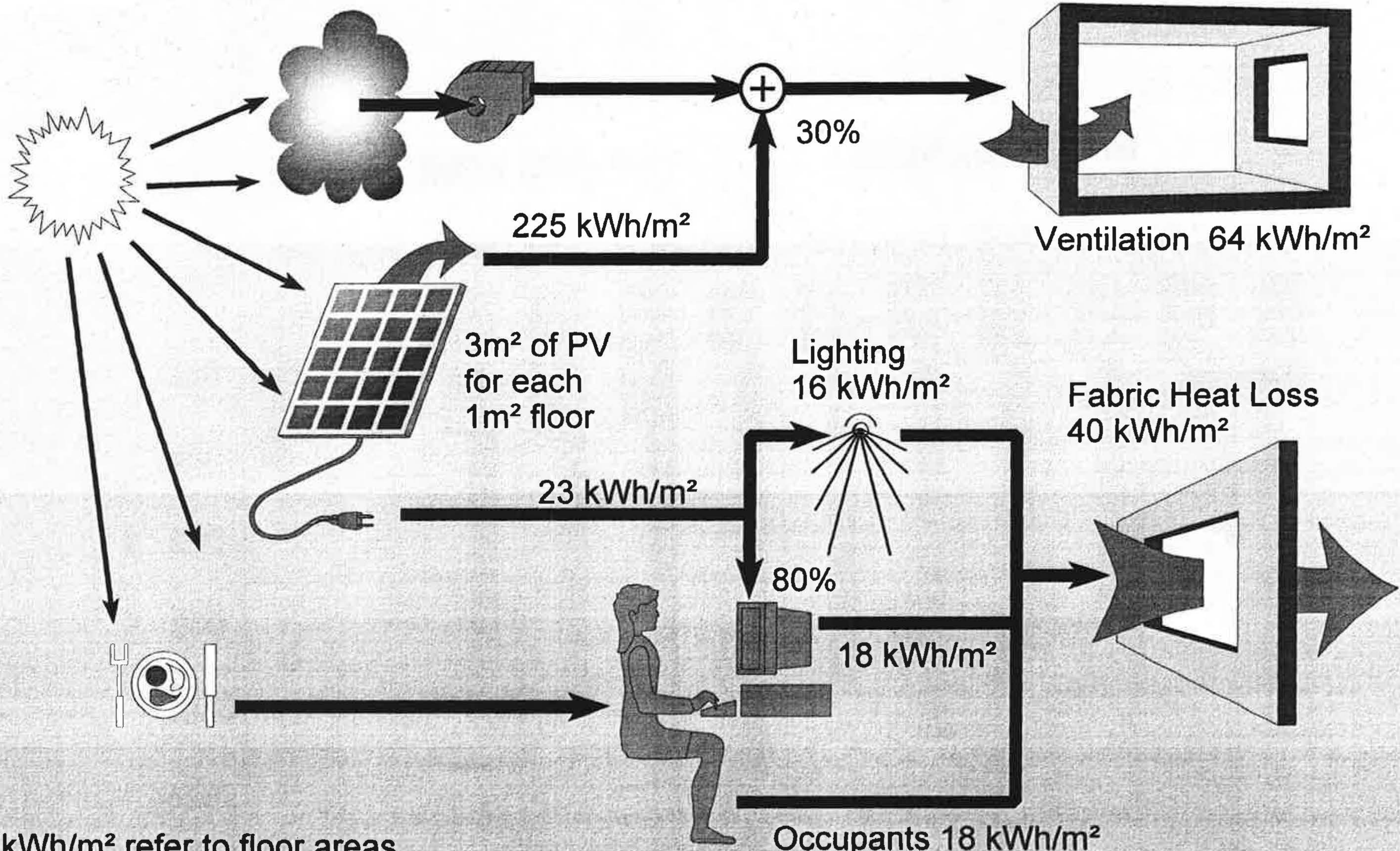


Energy Consumption

ARUP

CHRIS TWINN PV4ENRGY.SHW


Ventilation
64 kWh/m²
Lighting
16 kWh/m²
Machines
18 kWh/m²
Occupants
18 kWh/m²
Heat Loss
40
kWh/m²
680 kWh/m² of PV
30% Utilisation
68 kWh/m² of floor
Windows U=1.0W/m²K
Fabric U=0.25W/m²K
3m² of PV
for each
1m² floor
23 kWh/m²
120 kWh/m² of PV
40 kWh/m² of floor
Annual Energy
ARUP
CHRIS TWINN PV2ENRGY.SHW

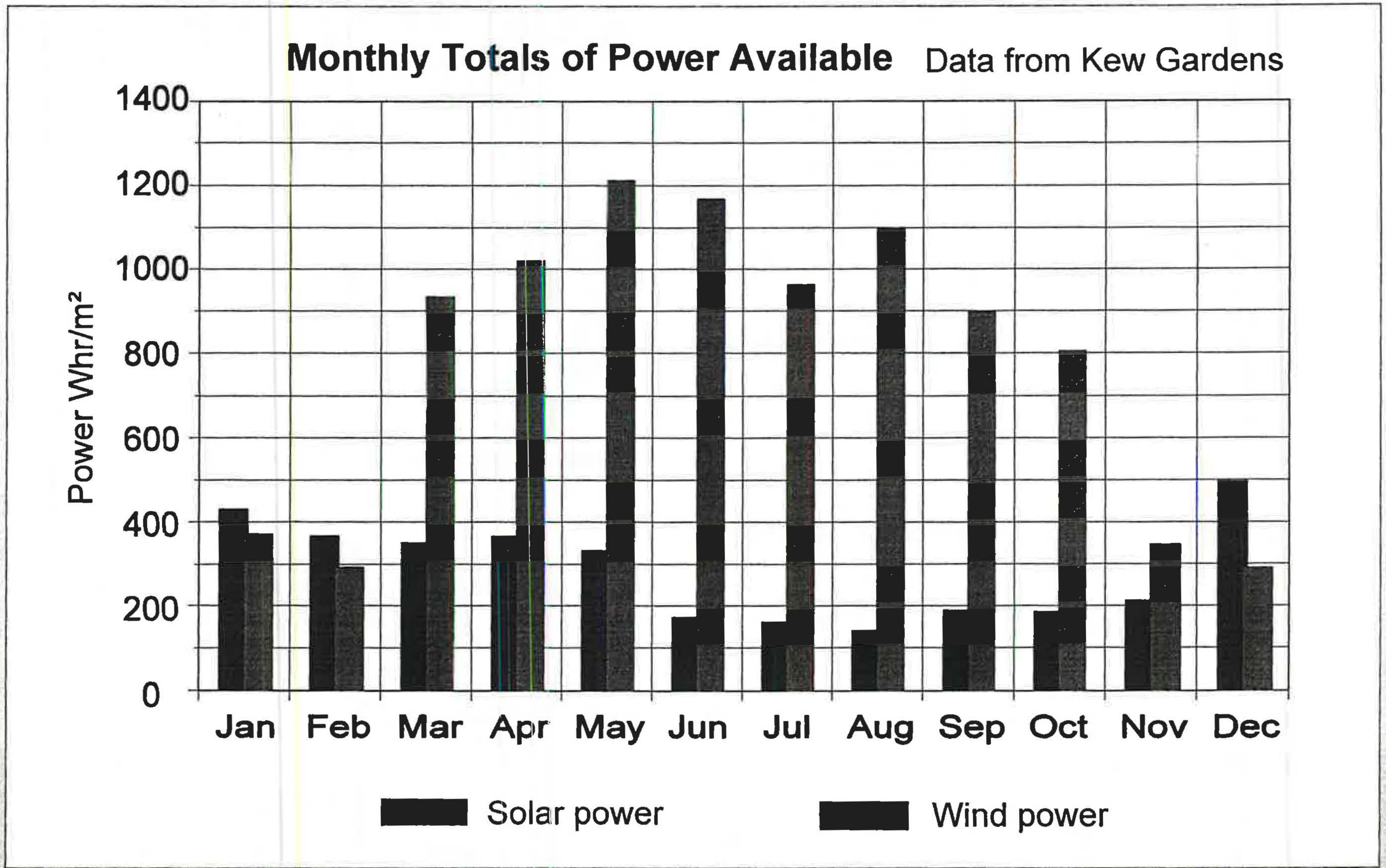


kWh/m² refer to floor areas

Building Energy Flows

ARUP

CHRIS TWINN PV3ENRGY.SHW



Hybrid Photovoltaics

ARUP

CHRIS TWINN PV7WIND.SHW

CASE STUDY: CANNING CRESCENT CENTRE

Ian Logan - MacCormac, Jamieson, Prichard Architects
Patrick Bellow - Atelier 10

Summary

The Canning Crescent Centre is a naturally ventilated building located on a busy high street in North London where air pollution and noise levels are perceived to be high. The background to its design together with its ventilation strategy are presented in some detail. At present monitoring activities by the Building Research Establishment Ltd are ongoing. Results from these will be forthcoming in the near future.

MᶜCORMAC ◆ JAMIESON ◆ PRICHARD

9 HENEAGE STREET, SPITALFIELDS, LONDON E1 5LJ

telephone 0171 377 9262 *facsimile* 0171 247 7854

"The important prerequisites for effective care and treatment – security, privacy, peace and safety in a domestic, non-clinical environment,"

"Accommodation for Adults with Acute Mental Illness" – NHS Estates Design Guide

THE CANNING CRESCENT CENTRE

Canning Crescent Community Mental Health Centre was conceived as part of the programme of moving services out of Friern Barnet Hospital, a large and austere 19th century psychiatric hospital, closed as part of the Care in the Community initiative in March 1993. The Centre provides counselling, treatment and support for people who would otherwise have to attend hospital.

The Centre is a relatively new building type, created by policy changes, bringing facilities for mental care into the community. Although much controversy surrounds these changes, the basic movement has been to de-institutionalise and de-stigmatise this area of health care and make it more accessible and humane.

The Centre is intended to be part of a future network of facilities throughout the borough, which will replace the old hospital. The funding was directly drawn from the hospital closure and subsequent sale. The building was deliberately located on this site, a short distance from the centre of Wood Green, as it offered a high street location, which is essential in making the Centre easily accessible and approachable to those seeking help, but possibly anxious or inhibited.

The building contains two day care facilities, a Community Mental Health Centre (CMHC) and an Acute Day Hospital (ADH), which require autonomy operationally, but must pragmatically share staff, catering and administration facilities.

The plan was developed in response to these requirements with the CMHC on Wood Green High Road and the ADH in Canning Crescent. The shared space is contained in the corner, where the two wings meet.

The Centre is entered close to the corner, visitors are reassured by the lightness and openness of the double volume space of the reception and waiting areas. The two wings radiate from this space, ensuring that the building is easily understood. The corner location of the reception area allows commanding but discreet supervision of the central corridors of each wing, as well as the waiting area, lift and entrance.

These corridors are enhanced at ground and first floor by a series of double volumes, which, in addition to creating informal waiting and meeting spaces, allow daylight and natural ventilation to penetrate to the heart of the ground floor. This strategy utilises an efficient double banked plan, but avoids the historically oppressive internal corridors of institutional building, typified by Friern Barnet Hospital.

Partners Richard MacCormac CBE MA(Cantab) PPRIBA RA, Peter Jamieson MA(Cantab), David Prichard BSc DipArch RIBA
Associates Stephen Cherry, Jeremy Estop, Michael Evans, Ian Logan, Liz Pride
Architects Alice Brown, Helen Brunskill, Matthew Dean, Gordon Fleming, David Franklin, Toby Johnson, Freddie McBride, Rosalind Pajakowska Oliver Smith, Richard Thompson, David Whitehead, Keith Whitworth

The choice of materials and development of space and volume further dismiss institutional connotations, with natural colours, textures and building materials selected for tactile qualities, ambience and aging qualities.

Ventilation, Chimneys and Cross Walls

No provision had been made within the budget for mechanical ventilation, let alone air conditioning, since the building size and type of spaces could be accommodated on a relatively shallow floor plan. However, it would have been unacceptable to ventilate rooms facing the busy high street simply by opening windows. The consultations provided by the centre are of a highly confidential and sensitive nature and, apart from the privacy aspect, the noise from the street would be intrusive and the air quality poor, due to traffic pollution.

To solve these ventilation problems, the diaphragm cross walls were developed to provide a series of chimneys which allow fresh air to be drawn through the building, using the naturally occurring stack effect. These diaphragm walls also articulate the two wings "architecturally" into bays of domestic scale and character, which reflect typical terrace housing and is not dissimilar in scale to the buildings which previously existed on the site.

Fresh air is drawn in at low level from the garden courtyard and the "used" air is expelled at high level through the "chimney tops" which are not only demonstrative of the ventilation but have a role in accelerating the air movement as it leaves the building.

The diaphragm walls logically become multi-functional, forming the structural framework for the building, with the floor slabs spanning between them and the rafters of the butterfly roof hung between them. They also act as vertical service ducts containing rain water pipes, soil and vent stacks and mechanical and electrical risers. Storage cupboards with matching hard wood grilles are incorporated into the brick chimney walls completing the functions.

Using these diaphragm walls, each room could connect into a vertical 'outlet' chimney to exploit the stack effect and wind effects and achieve a variable level of exhaust ventilation. The rooms on the noisy high street side of the building also have an air inlet at low level, fed through a supply duct routed within the footings to allow clean air to enter silently, displacing Co_2 and contaminants up towards the outlets. At the top of each chimney, but within the insulated envelope of the building, an opposed blade volume control damper, controlled by the occupants and by a central control system, allows the passive effects to be optimised without compromising energy efficiency in winter (when the stack effect is most effective).

Having established the principle of the vertical movement of air, attention turned to the form of the outlet and its effect on the roof profile. It was eventually decided to opt for a chimney-type outlet that functions independently of wind direction.

At this stage, it was also decided to introduce the glazed 'clerestorey' to serve two functions, one as an access panel to the damper at the head of the shaft and the other as a solar accelerator, which adds heat at the top of the shaft in summer and increases the up-draught when wind stack effects are slight.

The integration of the ventilation system in this way provides other advantages that are critical to the control of summer time temperatures in densely occupied buildings:

- the minimum of services at ceiling level allows concrete ceilings on the ground floor to be exposed, so increasing the thermal mass, and on the first floor allows a high ceiling to maximise stratification where mass is not practicable

- the exposed mass of block and brick, forming the diaphragm walls, also adds to the thermal capacity of the building

- secured ventilation and centralised control allow the operation of the vents at night to purge heat from the previous day and store 'coolth' for the following day

- individual controls in each room allow the occupants to operate the ventilation damper

- lack of a service void at ceiling level increases the effective room height without adding to storey height

Throughout the project, Haringey Healthcare were extremely supportive of the aspirations of the combined design team and the final solution is testimony not only to a stimulating dialogue between architect and engineers, but a genuine and satisfactory co-ordination of the design disciplines, client support and contractor's skill and care.

Ian Logan : MacCormac Jamieson Prichard
Patrick Bellew : Atelier Ten

Canning Crescent Centre, view from high street

Canning Crescent Centre, view from courtyard

Stack Intake grill from courtyard

Room on courtyard side - exhaust duct

Direct Passive Cooling
in
Naturally Ventilated Offices

David Arnold
Troup Bywaters + Anders

Direct Passive Cooling in Naturally Ventilated Offices

There has been a recent growth of interest in avoiding air conditioning by the use of passive cooling in buildings. The main techniques are either, a) using the building thermal mass and overnight cooling or, b) the use of convective and radiant chilled ceilings with some means of mechanical cooling.

Each technique places different constraints on the designer. For example, with overnight cooling the difficulty in exposing and coupling thermal mass and, avoiding the risk of condensation on cold surfaces with chilled ceilings

This presentation describes how these problems have been overcome and the results and experience gained during the installation of passive cooling in a number of naturally ventilated buildings in different locations in the SE of England over the couple of years.

Main Points

Naturally Ventilated buildings can be cooled directly using chilled ceilings and/or beams without condensation problems.

Direct mechanical cooling i.e. refrigeration is a viable energy efficient option to overnight ventilation for naturally ventilated buildings.

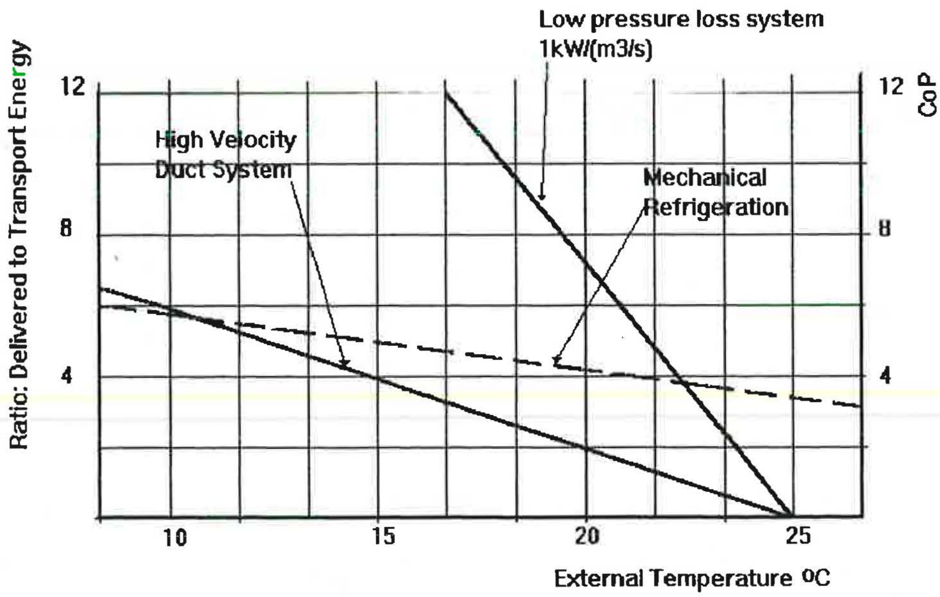
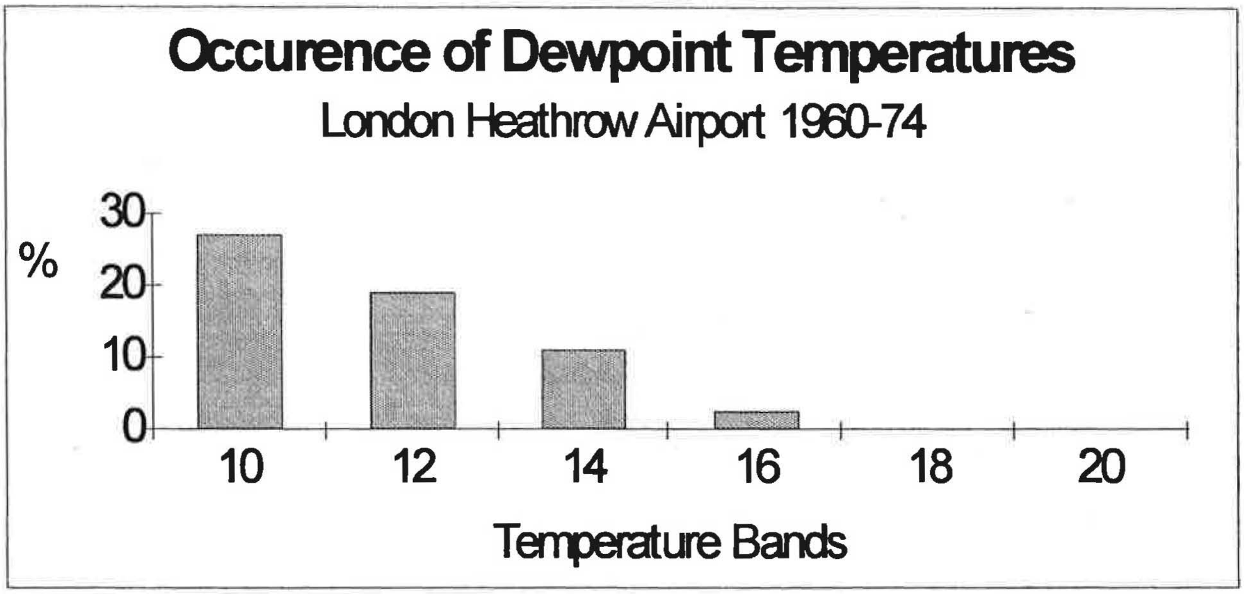
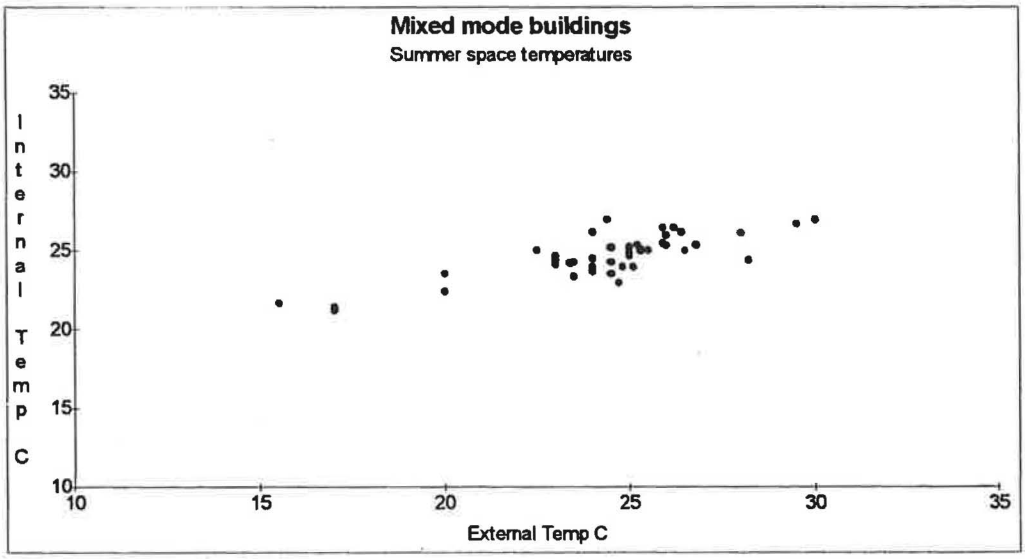


fig.3 Energy required for cooling : Mechanical Ventilation vs. refrigeration

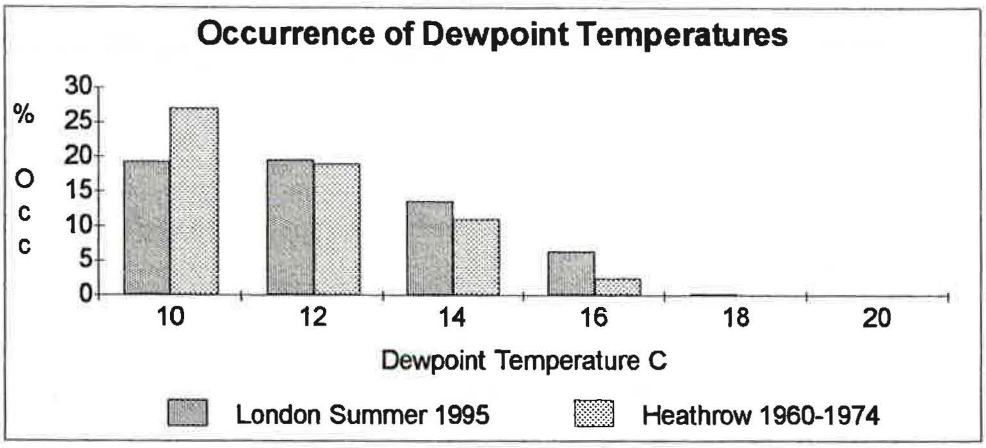
Dewpoint Design Temperatures



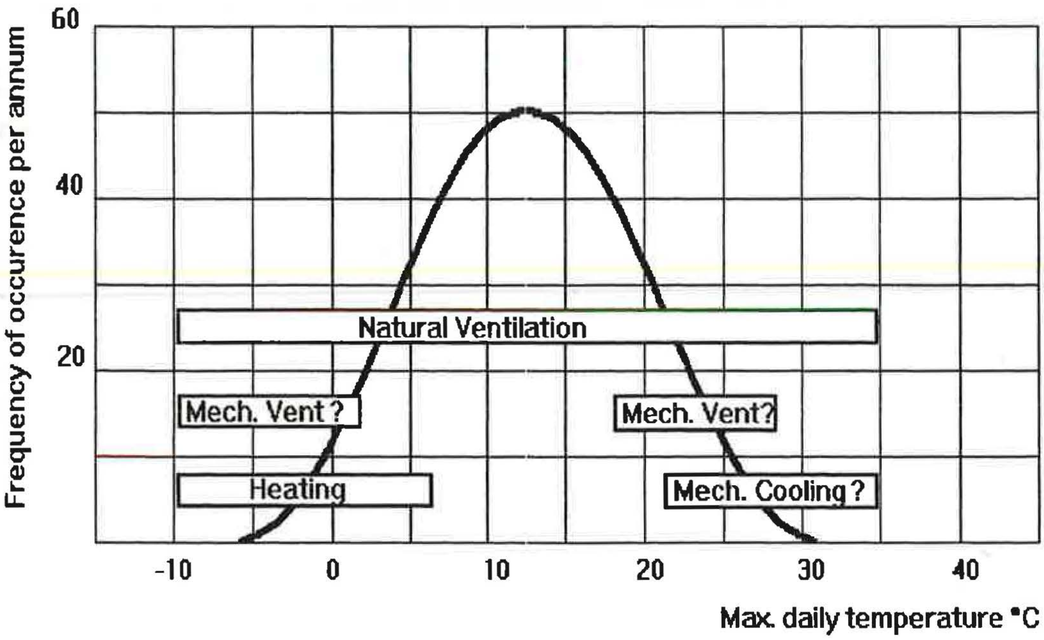
Internal Temperaures



Occurence of Dewpoint Temperatures



Mixed Mode



Practical Lessons

a) building users soon learn to keep windows closed and retain the coolth on hot days,

b) when systems failed there appears to be a critical temperature around 27oC above which people will open windows regardless of the consequences, ie to obtain some air movement,

c) as these systems have limited capacity it is important to avoid starting the day with an overheated building,

d) condensation is not a major problem and, of the three buildings monitored, there was less risk of condensation with the naturally ventilated one than mechanically ventilated. This was due to the lack of dehumidification in the existing systems,

Conclusions

1. Naturally Ventilated buildings that are likely to overheat can be cooled directly using chilled ceilings and/or beams without condensation problems.

2. Direct mechanical cooling i.e. refrigeration is a viable energy efficient option to overnight mechanical ventilation for cooling naturally ventilated buildings.

DISCUSSION AND ROUND UP

Dr Martin W. Liddament, Head of Air Infiltration and Ventilation Centre

Urban pollution can have an enormous affect on the indoor environment. This is especially the case in buildings that rely on window opening or other forms of natural ventilation for fresh air supply, since the potential for air cleaning is very limited. In view of increasing concern about urban pollution and its impact on the indoor environment, this seminar was developed with the objectives of reviewing the underlying issues, examining current research and identifying solutions. The contributors covered these needs admirably and provided the confidence that potential problems are being investigated with extreme vigilance.

In his introductory presentation, David Warriner, Assistant Director, Environment Group, BRE, provided an overview of current concerns. In essence, urban areas are an essential aspect of economic infrastructure in which the preference is for urban renewal rather than further encroachment of green field sites. On the other hand, the demands of modern society result in increased pollutant emissions and consequential air quality problems. While the impact on the indoor environment can be reduced by sealing buildings and introducing full air conditioning, this adds substantially to energy demand and is not a seen as a viable solution. Instead the challenge is to find low energy solutions for achieving optimum indoor air quality. For this reason, the role of natural ventilation for meeting both fresh air and cooling needs is of much interest. To be effective, however, this approach demands the highest quality of outdoor air.

Following these introductory remarks, Les Fothergill of the Department of Environment outlined the development and role of regulations in meeting health and energy efficiency needs. The overlying objective is to reduce the level of harmful pollutants both inside and outside buildings. Much research is initiated through the needs of regulations and there is strong co-operation between the DoE, various agencies, universities and industry to progress realistic regulations. A current Partner in Technology Project (PIT) is looking at carbon monoxide prediction and the ventilation of car parks. In the last few years ventilation requirements and guidelines have been developed considerably and now cover the provision and sizing of ventilation openings, requirements for mechanical and natural ventilation, and guidelines on airtightness.

Professor Patrick O'Sullivan, Dean of Faculty for the Built Environment University College, London, reflected on various problems associated with both the indoor and outdoor air. In support of natural ventilation Professor O'Sullivan highlighted the dangers that step changes in environmental conditions (particularly thermal) when entering an air conditioned building had on the human auto-immune system. However, from a property owner's view, sealed buildings with air conditioning attract higher rents. For air quality analysis, a good dispersion model was still needed. Based on monitoring results the following basic 'rules of thumb' were suggested by Patrick for minimising the impact of poor outdoor air quality on the office environment:

- kerbside pollution is always greater than indoor pollution.
- the pollutant concentration of many outdoor contaminants generally decrease with height above ground.
- pollutant concentration is less at the back of a building than at the front.
- inside a building pollution reduces with height and distance from open windows.

He stressed that a similar pattern emerges in housing although, the greatest pollutant concentration is usually in the kitchen.

Professor Patrick O'Sullivan cautioned against 'fixating' on a single problem or pollutant. Invariably air quality or other indoor health problems were influenced by a multiplicity of factors. One of the problems, however, especially in urban environments, is that the 'dilution' capacity of the air is running out, thereby limiting its potential for ventilating pollutants from indoor spaces. Currently, this capacity is being taken by the motorist.

Professor Roy Harrison, Chairman of Quality of the Urban Air Review Group and Professor of Environmental Health, Birmingham University, presented an overview of the physics behind urban pollution. He emphasised the fundamental differences between primary pollutants, which are emitted directly into the atmosphere, and secondary pollutants, which form by chemical reaction between pollutants in the atmosphere. While the atmospheric concentration of primary pollutants vary linearly with emission rates, the characteristics of secondary pollutants are more complex and do not necessarily reduce in proportion to emission controls. In the urban environment, traffic pollution can account for up to 85% of total emissions compared to a national average of 25%. For this reason, traffic is a major contributor to urban pollution with problem pollutants covering carbon monoxide, oxides of nitrogen, carbon dioxide, hydrocarbons and particulates. Although vehicle exhaust emission control is having a beneficial effect, reduced emissions of the oxides of nitrogen are influencing the production rate of low altitude ozone, which is increasing in concentration in urban areas. Fortunately, however, this was not perceived seen as a serious problem for the indoor environment because ozone quickly recombines into oxygen when in contact with surfaces.

Monitoring in urban sites, away from the kerbside, illustrate a diurnal pattern in concentration with prevailing weather conditions influencing peak concentrations. 'Hot spot' concentrations are found close to specific pollutant sources. Although such point sources affect a reduced number of people, care is needed to ensure that air inlets are not located close to such sources. In investigating trends, Professor Harrison stressed the need to monitor data over several years. Trend analysis shows a considerable decline in urban sulphur dioxide and black smoke concentration, primarily resulting from smoke control measures. Lead has also shown a considerable decline as a result of the introduction of unleaded fuel. While substantial data are now available, it was stressed that care was needed in its interpretation. In particular it was important to understand the monitoring site especially in relation to its vicinity to specific pollutants.

Research evidence from the United States was cited which linked increases in death rates with the most polluted of cities.

Dr David Hall, Senior Scientist of the Building Research Establishment continued the discussion on the characteristics of urban pollution. He considered sources in terms of spatial scale (i.e. micro-scale, neighbourhood, urban, regional, continental, hemispheric and global) and in terms of time scales (i.e. ranging from seconds, minutes and daily to weekly and annual). Each has specific characteristics and influences. Also pollutants ultimately 'add up'. The complex mixing of pollutants on different spatial and time scales result in a complex pattern of pollutant distribution and behaviour which makes prediction and evaluation difficult. While some generalisations are possible, measurement results show that the characteristics of some pollutants are not easily definable, especially in relation to their concentration with respect to height and spatial distribution pattern. Examples included carbon monoxide concentration which tends to decay with height while nitrogen dioxide can be very variable with respect to height. Much depends on the density of spacing of buildings and surrounding conditions and sources.

Dr Vina Kukadia, Senior Scientist, also of the Building Research Establishment spoke of the need to understand how the outdoor environment exerts an influence on indoor air quality. Currently there is little information available to designers on minimising the impact of such pollutants. To develop an understanding BRE has undertaken a considerable number of monitoring studies in occupied buildings located in urban environments. One such study has concentrated on comparing indoor air quality parameters from a naturally ventilated and a mechanically ventilated building in central Birmingham. Monitoring included the measurement of carbon monoxide, carbon dioxide, oxides of nitrogen, sulphur dioxide and particulate matter. Carbon monoxide monitoring indicated that the outside concentration was greater than the indoor value and that both the naturally ventilated and the mechanically ventilated buildings had similar concentrations. NO2 concentrations in the naturally ventilated building was similar to the outdoor value but there was some evidence that the mechanically ventilated building occasionally intercepted additional NO2 from adjacent flues resulting in peak concentrations occurring in the mechanically ventilated building. Some preliminary results were also presented on the monitoring of a purpose designed naturally ventilated building in Canning Crescent, London. Intake air was taken from the rear courtyard to serve the roadside rooms. As a consequence, similar pollutant concentrations were measured throughout the whole space, thus providing a justification for the air intake strategy.

Steve Irving and Dr Gary Palmer, of Oscar Faber Group Ltd., described analytical work currently being undertaken on optimising the location of fresh air inlets. Currently, guidance is very qualitative and vague yet evidence suggests that the location of inlets in relation to local polluting sources is critical. At present only the latest draft ASHRAE Standard 62 on ventilation for acceptable indoor air quality provides any quantitative guidance on setting the minimum distance between air inlets and nearby exhausts but there is some concern that these recommendations are not practicable for some building densities. In improving on existing information, computational fluid dynamic techniques and other modelling methods are being used to combine the dispersal characteristics of specific pollutants with various influencing factors. A simple design tool is also being developed that attempts to relate pollution distribution at the air intake with resultant indoor air quality.

Remaining presentations concentrated on case studies and the analysis of natural ventilation approaches in urban environments. Peter Jackman, Director of Research at the Building Services Research and Information Association, reviewed case study results and questionnaire analysis. A key consideration was the need to cope with conflicts in a multi-occupied space, especially in relation to window opening and thermal comfort. Nevertheless an example was illustrated of a building renovation in which mechanical ventilation with air conditioning had successfully been replaced by natural ventilation. Occupant surveys and environmental measurement indicated a good indoor environment.

Chris Twinn, Technical Director of Ove Arups, continued by describing a variety of natural ventilation solutions including a conceptual ventilation heat recovery approach which is able to operate at a pressure drop of only 3-5 Pa. This is well within the range of driving pressure available from natural ventilation.

Ian Logan, Partner of MacCormac, Jamieson, Pritchard and Patrick Bellew of Atelier Ten Engineers, described the design and architectural objectives behind the naturally ventilated Canning Crescent building. This building which is dominated by its ventilation chimneys was based on observation of the natural cooling achieved in ant colonies. Ventilation is achieved by a mix of air ducted from the building courtyard to the front and direct window opening at the rear.

Finally, David Arnold described various retrofit solution to maximise the benefit of natural and mixed mode ventilation. Examples were taken from the UK and Switzerland and included the use of chilled beam ceilings to accomplish cooling needs.

In summary, this seminar proved to be an important educational event offering a very positive outcome. The overwhelming message was that extreme vigilance is being taken over the urban environment. There is strong cohesion between all those with responsibility for the health of building occupants and much positive progress was reported. This seminar revealed a good focus on needs combined with research that is leading to solutions. Above all there is an awareness of the problems associated with urban air quality. In addition several case studies and demonstration projects showed the viability of natural ventilation in the urban environment. Measurements indicate that pollutant concentrations need not necessarily be worse in naturally ventilated buildings than in mechanically ventilated buildings and that air conditioning has been successfully replaced by natural ventilation. On the pollution front, there are also many positive developments. There has been a decline in urban concentration of sulphur dioxide, black smoke and lead, while recent controls on traffic exhaust emissions have resulted in a reduction in oxides of nitrogen. Nevertheless traffic is still the main source of pollution in the urban environment.