Ventilation for contaminant control

Research into methods of controlling air movement are proceeding apace. *Paul Appleby* reports on the international symposium Ventilation '88, where several novel ideas have been proposed.

The January 1986 issue of *Building Services* contained an article "Industrial ventilation comes of age". In it were reported some of the exciting developments in this field presented at the first international symposium on ventilation for contaminant control - Ventilation '85, held in Toronto, Canada.

A wish was expressed in the concluding remarks to that article that CIBSE could be involved in a second similar symposium since "in Canada the engineers and occupational hygienists are talking and working together ... it is imperative that we do the same in this country".

Three years on, the second symposium has been staged at the Imperial College, London, jointly organised by the British Occupational Hygiene Society (BOHS), the Institute of Occupational Hygienists (IOH), the Health and Safety Executive (HSE) and CIBSE. Unfortunately, the building services sector was very poorly represented in terms of numbers of delegates. Perhaps industrial ventilation still hasn't come of age in the UK.

So what have you all missed? Numerically speaking there were approximately 74 papers, 16 professional development (pd) sessions, 16 posters and an exhibition, covering a wide range of topics relating to contaminant control in industrial and commercial premises; from coal mines to clean rooms, printing works to offices, tyre factories to schools.

As one might expect from a symposium which catered for a variety of disciplines, there were many different types of paper presented, including the results of laboratory and computer simulations, the validation of measurement techniques and equipment performance, reviews and overviews. However the most numerous type of paper was the case history, the "this is how I did it and it worked" approach.

This technique was ably demonstrated during the plenary session by a multidisciplinary team from Birmingham University and their industrial clients, who were promoting the case history approach to airborne contaminant control. Their aim is to establish a database of case histories, written up according to a protocol which has already been published. A working group is to be set up to actively pursue case histories for publication by BOHS[1].

A similar programme has been established in Australia by the Ballarat College in Victoria province. This programme has been given the acronym SHARE, or Safety and Health Accumulated Research and Experience.

The case histories presented at the conference should form a useful start to these databases. Many of the papers demonstrated that control of source emissions could be of equal or greater importance than design of the ventilation system: for example the paper from Hewitt and Madden of Bradford suggested methods by which fume formation can be reduced during arc welding.

Goodfellow and Smith, at the University of Toronto, have been establishing the dustiness of a number of materials and developing techniques which enable the dustiness index to be used in the evolution of dust control strategies. Other applications examined included:

- ☐ a British nuclear reprocessing facility;
- ☐ a French nuclear laboratory;
- ☐ Canadian uranium mines;
- ☐ British and Swedish coal mines;
- ☐ a French electric arc furnace;
- ☐ a British car factory;
- ☐ a British tyre factory;
- ☐ vehicle brake drum servicing in the States;
- ☐ Australian steel coil painting;
- ☐ processing cadmium pigments in the USA and controlling toluene exposure in a Finnish printing works.

Smaller scale, laboratory-based and high technology industries were also represented by papers on clean rooms, biological safety cabinets and post-mortem rooms. Fume cupboards received comprehensive coverage, including a pd session of their own.

Ljungvist and Waering from Stockholm have developed a fume cupboard which uses an "ejector air diffuser" to set up a vortex at the top edge of the cupboard. This is in order to reduce the risk of reversed flow at the opening due to the wake set up by air flowing around the operator.

A number of papers from the USA addressed the complete design of fume cupboard installations, particularly with regard to energy conservation, variable volume control of supply and exhaust, and the use of distributed microprocessor control systems.

Local exhaust ventilation

The core of most ventilation systems for contaminant control is the exhaust hood. Much work has been carried out over the years to enable designers to predict hood performance, both more accurately and for a wider range of applications. It might be considered surprising, therefore, that the classic formulae developed by Dalla Valle and Silverman in the 1930s and 40s still form the basis for most designs, since they are reproduced in the *Industrial Ventilation Manual*, the *ASHRAE Handbook* and, until recently, in the *CIBSE Guide*.

There were a number of papers at this

symposium which sought to broaden our knowledge of hood performance. Most sought to produce fairly sophisticated computer models, validated in the laboratory or field. General guidance was also available to those who attended the pd sessions on extract hood design and push-pull local exhaust ventilation.

Cesta of Hatch Associates, Toronto, has examined the application of lateral exhaust hoods for removal of bouyant contaminants, such as molten metal handling and furnace charging, where overhead access is required. Flynn *et al* from North Carolina University have carried out similar work to predict the capture efficiency of welding bench hoods.

Conroy and Ellenbecker from Harvard and Lowell Universities respectively have used the concept of capture efficiency in modelling air flows close to flanged hoods with constant cross-draughts. Jansson of the National Institute of Occupational Health in Sweden has concentrated on modelling the flow fields around hoods of various shapes and aspect ratios.

Garrison and Wang from the University of Michigan also use finite element modelling techniques, simplified, in the case of two-dimensional models, for use on personal computers. These techniques allow considerable variation of inlet design parameters, including the influence of surfaces, obstructions and cross-draughts. 3-D models for use on a mainframe computer are being developed.

A poster mounted by Alenius of NIOH, Sweden, demonstrated a computerised technique for visualising air velocities and particle trajectories induced by local exhaust hoods. This programme has been designed for use on a modern small computer and incorporates all the parameters mentioned above, but also models the dust generation variables, such as starting velocity and position, and particle size and density.

Kelly of AFOS Ltd, Hull, described the application of perforated tables to the exhaust of formalin from histopathology laboratories and post-mortem rooms. These were found to be more effective than earlier slot-ventilated models and have gained wide acceptance.

The concept of capture efficiency has been applied by Tapola of Air-Ix, Finland, to the rating of local exhaust hoods for hand tools. His results indicate that this technique could be used for product comparison and the assessment of new products.

Air cleaning and heat recovery

The ventilation system having been designed to remove effectively contaminants from the workspace, the condition and disposal of the exhaust air requires close consideration. PD sessions on ventilation and energy loss, discharging to atmosphere from laboratory-scale processes and industrial air cleaning provided useful design guidance; while papers from Brown of the UK Health and Safety Executive and Armand *et al* of K-Konsult in Stockholm provided an insight into recent developments in filtration equipment.

Brown described how an electrical charge can considerably reduce the penetration of fine aerosols through a wide range of fibrous filter media. Armand described a recently developed centrifugal absorber for relatively small-scale removal of solvent vapours and gases.

A poster from Sansone and Keimig of the NCI-Frederick Cancer Research Facility in the USA revealed that vapours adsorbed onto an activated carbon filter commence desorption soon after adsorption, hence filter efficiencies determined over a short time span are not valid.

Air supply

The question of how best to supply air to a space was not restricted to the lecture halls. Stratos, a company formed by the marriage of Bahco and Flakt, sponsored a bar-room debate on the likelihood of the conventional methods of air supply from high level being supplanted by low level displacement ventilation.

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A number of presentations examined recent developments in these competing systems. A fascinating paper from Japan cut across the argument by proposing a radically new method of creating room air movement, through the generation of a vortex.

Nagasawa and Matsui from the Takenaka and Japan Air Curtain Corporations respectively have been investigating the use of vertical manifolds positioned in each corner of a space setting up a broad-based vortex extracted at a central position in the ceiling. Capture of contaminants in the occupied zone is very effective and when applied to a smoking area which formed part of a larger room, escape of smoke to the surroundings was prevented.

Another paper from Japan suggested a novel approach to the design of a more conventional air terminal device. Kubota of the Murora Institute of Technology has discovered a relationship between the percentage of dissatisfied occupants and the design of ceiling slots for variable air volume applications. He has found that minimum dissatisfaction occurs when the slot width is proportional to the ⅓ power of the sensible cooling load.

Danielsson of Stratos in Sweden demonstrated the performance of displacement ventilation systems with varying volumes. Laboratory measurements indicate that air movement in the space does not alter greatly across a wide range of supply air flow rates.

Appleby outlined a new system for air supply to fixed-seat auditoria using personal air supply via slots in a desk or seat back, with air supply to each seat switched by seat operation, thus providing occupancy-dependant variable volume control with considerable energy savings when occupancy varies significantly.

Indoor air quality and building sickness

The significance of ventilation in the multi-factorial causation of building sickness has been recognised for some years, particularly in North America, where the term tight building syndrome was coined. In the plenary session Dr Sherwood Burge, a chest consultant from Solihull hospital, described the findings of the Building Use Studies team, one of the groups who have identified a strong link between air conditioning and symptoms of building sickness. He concluded that "buildings should be more humanely designed and... simpler to operate effectively".

Collett and Stirling from Vancouver concentrated on ventilation inadequacies, suggesting that in the 484 problem buildings investigated by NIOSH by the end of 1984, reinforced by their own experience, seven main causes had been established:

- □ insufficient fresh air;
- □ poor air distribution;
- □ poor temperature control;
- □ poor design;
- □ inappropriate modification;
- □ lack of maintenance and lack of understanding by building operators.

Rosenzweig-Witherspoon and Landrus from Ontario suggested a "total building performance" approach to investigating indoor environment concerns, covering all the above parameters but also looking at psychological, ergonomic and sociological factors, and involving all occupants in the planning and operation of their environment.

Tracers, visualisation, measuring and commissioning

Tracer gases have been used by a number of workers as a way of determining the effectiveness of ventilation systems. Although the techniques are well established, there is a continuing debate on the application and accuracy of the various different methods available.

Breum of the Danish National Institute of Occupational Health has compared three methods: the step down, step up and pulse injection techniques, to establish the air exchange efficiency and age of air for a hall with displacement ventilation, occupied and unoccupied. Efficiencies were higher for the occupied hall. Niemela and Saamanen of the Finnish IOH have used a nitrous oxide tracer to simulate the release of styrene during a spray operation to more easily measure local contamination levels, although it was not possible to simulate the curing or drying operations.

Kvisgaard of Bruel & Kjaer and Collet of the Technical Institute of Denmark have used a computer-controlled tracer-gas measuring system to establish control and maintenance strategies for ventilation systems. Continuous monitoring was used to provide a check over the effectiveness of maintenance and identify deficiencies in the room air movement and fresh air control. Tracers have also been used in water models in simulating ventilation phenomena. Fontaine *et al* from INRS in France used salt water as a tracer in their physical model to evaluate the performance of general ventilation, showing good correlation with their numerical simulations. Lane-Serff from Cambridge University used salt and fresh water to simulate density differences when physically modelling the transfer of air between a cool hall and warm living room via an open door.

A very simple approach to flow visualisation in the field was demonstrated by Kennedy of the UK Department of Health. He has used a nebuliser to create a visible fog to examine the airflows at the door openings to fume cupboards and other partial enclosures.

A more sophisticated approach to visualisation was described in a poster mounted by Janhunen and Kultanen from Lappeenranta in Finland. The team used a combination of infrared imaging, videoing of smoke tests and digital image processing to detect air contaminants in the workplace. Comparisons were made between the spread of various tracers and a number of solvent vapours. The latter were very difficult to visualise at the low concentrations normally found in the workspace.

The future

It is hoped that much of what has been described above will find its way into the design guidance available to the CIBSE member in the fullness of time. In the meantime if you would like to obtain a copy of the proceedings they will be published by Pergamon Press around April 1989 and available to CIBSE members at the reduced rate of £40. Pamphlets of abstracts and PD notes are available from the BOHS, 1, St Andrews Place, Regents Park, London NW1 4LB.

The third symposium of the same name will be held in Cincinnati in 1991, where the hosts will be the National Institute for Occupational Safety and Health.

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[1] If any reader would like to participate in this scheme contact Mark Piney, c/o BOHS, 1 St Andrew's Place, Regent's Park, London NW1 4LB, or phone him on 021 449 8908.

Case study preparation

Please use the following headings and notes as a basis for case study preparation. The protocol is written as guidance and if certain items of information are not available this does not necessarily detract from the value of the case study.

It would also be helpful if you could indicate where information can be gathered that is not available at present. The assumption is made that most problems will be concerned with airborne contaminants but on occasion, problems associated with other routes of entry to the body may make the basis of a case study.

Abstract

Once the case study is completed prepare a summary of the main points in less than 200 words.

The process

Give a short description of the process(es), along with the machinery involved, the work layout, the number of people and work stations and the approximate dimensions of the area in question.

The type(s) of contaminant(s), rate of application/use, the scale of the problem and the magnitude of exposure should also be supplied where data is available. Other possibly significant routes of exposure, apart from inhalation, should be identified.

Selection of control solution

Give a short description of the way in which the problem was analysed and how the particular control solution was selected from the various alternatives under consideration.

Wherever possible an attempt should be made to identify the job categories of the people involved in discussions or decision making, eg maintenance works engineer, occupational hygienist, workers etc.

Design procedure and control solution

Explain how the control solution was developed to take account of factors such as:

- ☐ the work method of the operators;
- ☐ the size and mobility of the source(s);
- ☐ the velocity and rate of evolution of the contaminant;
- ☐ the motion of the source or the air motion induced by it;
- ☐ whether the process was intermittent or continuous;
- ☐ indicate whether the design procedure involved a mock-up stage or what other methods were used to validate the design;
- ☐ describe the control solution including detail with sketches, line diagrams, or photographs of the essential features. The information should include, where possible, appropriate design values for hood face velocities, volumetric flow rates, target capture velocities, transport velocities, and air cleaning and heat recovery as appropriate.

Degree of success

A statement should be made about the effectiveness or otherwise of your control strategy, including if possible results of measurements of airborne contaminant levels achieved before and after operation of the control measures.

Alternatively a visual assessment of control success could be made, supplemented by the use of a dust lamp or other qualitative method of assessment, where appropriate.

Indication should be given of physical parameters which differ from design values, eg air velocity at point of origin of contaminants.

Reasons should also be advanced for failure of the system if it has been found to be inadequate to control exposure or emissions below target levels.

Supplementary points

It would be helpful to indicate whether the solution is experimental, in use on a pilot scale, or tried and tested and used routinely throughout the site or organisation.

Describe benefits accrued: eg improved production, reduced loss or increased recovery of product, cost savings (capital, energy and other consumables), improved industrial relations.

A brief statement of the probable capital and running costs of the control measures should be given, with an indication of the year to which costs refer. Give also probable recurrent costs, such as maintenance (annual cost or labour time), replacement parts.

Indicate also pattern of use, eg a 40 h working week or continuous year round production. Indicate also whether waste process heat is being recovered, how it is being used and payback periods of the heat recovery plant, if available.

Discussion

A critical analysis of the design should be given, summarising what has been learnt from the design, commissioning and monitoring process and outlining any improvements which could be made.