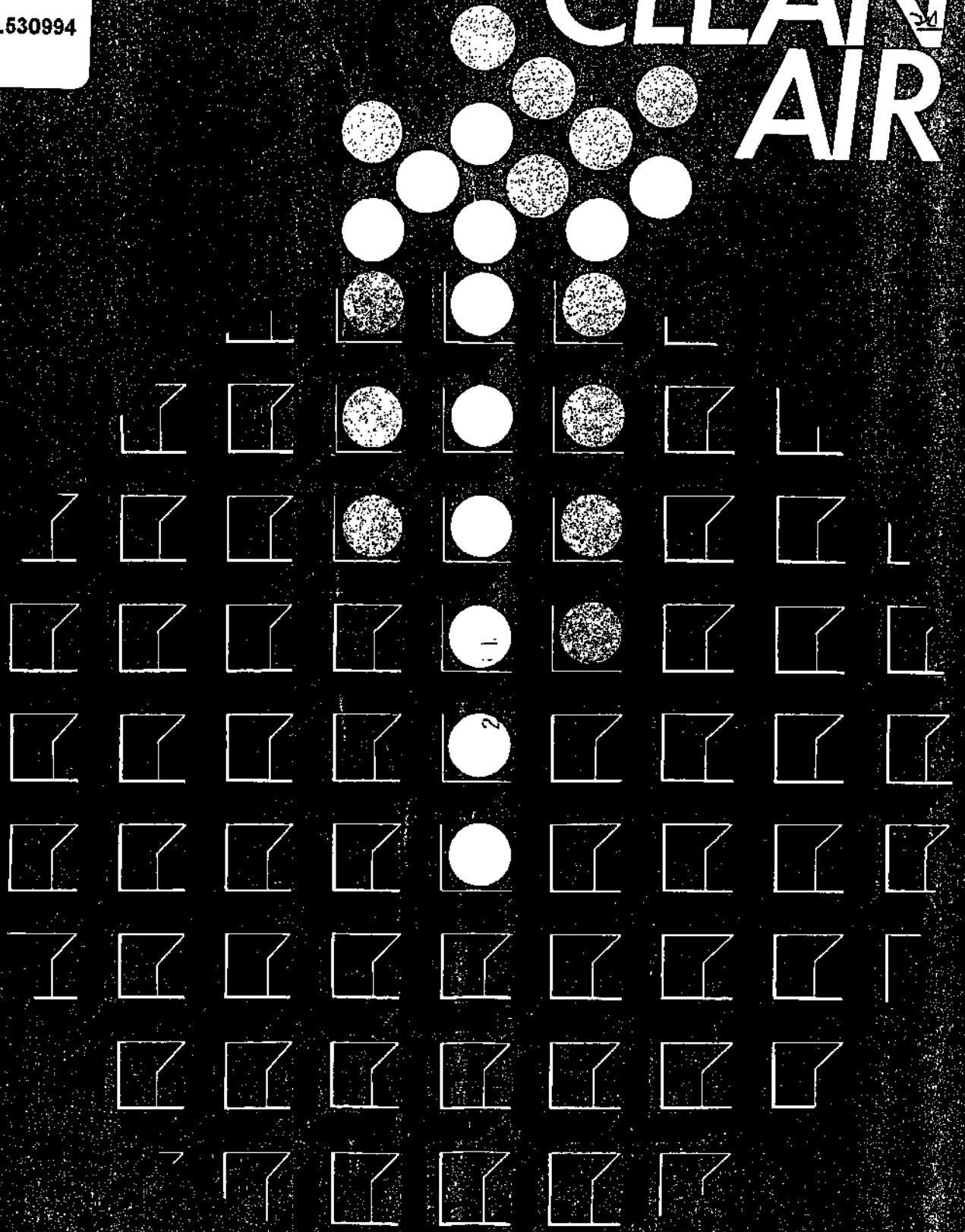


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THE CLEAN AIR SOCIETY  
OF  
AUSTRALIA AND NEW ZEALAND**

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Enquiries about subscriptions, payment of  
 invoices, and requests for back numbers  
 should be directed to the  
 Circulation Manager,  
 Mr. A. Crapp, Box 1 91 Eastwood,  
 N.S.W. 2122 Australia  
 Phone: (02) 265 8883

Publication is quarterly In February, May,  
 August and Novemcer.

Annual Subscription rates (Inc. postage) for  
 non-members and libraries:

Australia and New Zealand \$A16.00  
 Elsewhere SA20.00  
 Single copies SA5.50

*The opinions expressed by authors and  
 contributors are their own and do not  
 necessarily represent the view of the  
 Society.*

**PRINTER**

J. G. Holmes Pty. Ltd. (03) 51 6961

CLEAN AIR is listed in *Currant Contents*



## EDITORIAL

Air pollution and more particularly air pollution control is closely associated with change, both scientific and technological, and the rate of change in recent decades has been dramatic. One factor which does not change, however, is the fundamental cause of air pollution and that is people and their requirements.

Society requires development, high levels of employment and material gains, but also clean air. These are not incompatible requirements but this compatibility must be tempered by a degree of sensible compromise.

Ways in which we can minimise increases in emissions associated with development, and their effects, include continuing to improve the efficiency of control technology and avoiding the close geographical groupings of large emitters to avoid concentration of emissions. These can be particularly expensive requirements.

The limits on emissions we are prepared to accept depend upon air quality standards which in the main, reflect upper limits which will give protection to community health with a realistic margin of safety. At the same time we are constrained by economics as there will be levels of expenditure which are not economically bearable. For example, the loss of employment opportunities associated with the deferment of 'a development may not be politically acceptable and likewise a restriction on economic growth may be equally difficult to endure in the longer term. What this means is that the framework for achieving the goal of clean air has to be a realistic one.

Society is coming to realise that with our present state of development we cannot afford to remove all pollutants from the atmosphere: also that the removal of the last traces of a pollutant becomes increasingly costly. Ultimately, one has to set the benefits of a certain level of air quality against

the cost of maintaining that level. The latter is a relatively easy calculation, evaluating the former is more difficult. No! only is our understanding of the statistical laws governing relationships between air pollution, health and enjoyment of life minimal, but we are faced with the problem of putting a monetary value on these benefits of clean air. What are the dollar values of improved life style, improved health and longevity? Would the money spent on maintaining a certain level of air quality be better spent in other areas.

These are essentially sociological issues and the analysis of them and the answer to the questions they pose are fundamental to establishing how we achieve clean air, and more importantly, defining what society means by clean air.

It is thus disappointing that very few articles appearing in Clean Air address these issues and it is therefore essential the the Society, in considering its future, places adequate emphasis on exploring and developing the social and political dimensions of clean air as well as addressing the technological dimension.

PETER WILLIAMS

## BRANCH NEWS

### NEW ZEALAND

The Society's ninth international Clean Air Conference will be organised by the New Zealand Branch and will be held from 28th January to 2nd February 1990 at Auckland University.

The convenor of the Conference will be Norman Thorn.

The Conference will precede the Commonwealth Games by one week making it possible for delegates to combine the two events.

The New Zealand Health Department have promised to support the Conference.

### NEW SOUTH WALES

The Annual General Meeting of the NSW Branch was held on 3rd February. The out-going President, Mr. J.D. Court, in presenting his Annual Report highlighted a number of matters

-The death of Peter Murphy, a founding Member of the Society and Medallist in 1984. The expanded

Vehicle Testing Facility at Lidcombe was dedicated to him.

-The success of the 7th World Clean Air Congress as a technical forum and also as the first such Congress not to incur a loss.

-The long and devoted service of Steve Stanley as NSW Branch Secretary. Steve did not seek re-election to the Committee and was elected a Life Member of the Society.

Following the Congress, Ralph Goode was also elected a Life Member and Bob Hope an Honorary Member.

-Concern at the decline in membership.

-The programme envisaged for 1987 including participation in the Royal Australian Chemical Institute's Analytical Chemistry Symposium.

His thanks to all those who helped in the activities of the Society and in the organisation of the Congress.

There are some changes to the Committee. Steve Stanley, Bill Shannon and Ted Wziontek did not seek re-election and John Court did not nominate to continue as President.

The meeting recorded its appreciation of those members leaving the Committee with particular thanks to Steve Stanley.

The new Committee is as follows:

President:	Mr. L.M. Ferrari
Immediate Past	
President:	Mr. J.D. Court
Secretary:	Mr. R.M. Hope
Treasurer:	Mr. N. Lamb
Committee:	Dr. K. Basden
	Mr. D. Beard
	Mr. B. Carter-Smith
	Mr. A.J. Crapp
	Mr. A. Guthrie
	Mr. G.M. Johnson
	Mr. R.W. Manuell
	Mr. F. Sgammotta
	Dr. K.M. Sullivan.

The President welcomed new members of the Committee (Messrs Beard, Hope and Sgammotta). The incoming President, also expressed his thanks to the retiring President for his guidance of the NSW Branch during his long association with the Society.

The speaker was Dr. David Williams of CSIRO who spoke on 'Particulate Emission from In-service Motor Vehicles based on work supported by AIP ECE Motor Vehicle Emission Subcommittee. Dr. Williams acknowledged the assistance of Mr Mike Kimberley (Emtec), John Mills and Doug Roberts (CSIRO).

The increasing importance of emissions from diesel-powered vehicles, the strong relationship of par-

ticulate emissions with diesel engine timing and the need for parity between the importance of various emissions and the monitoring effort on those emissions were highlighted during the talk and the particularly lively discussion which followed.

### **A General Meeting of the NSW Branch was held on 7th April, 1987.**

The speaker was Dr. Keith Bentley, Deputy Director, Environmental Hygiene Section, Department of Health, Canberra.

Dr. Bentley described the role of NHMRC in particular and also of AEC, ATAC, SAA and Worksafe Australia in setting and applying criteria for Air Quality Standards and their method of operating.

He discussed priority criteria, those areas with which NHMRC did not deal (such as risk analysis except in the special cases of radio activity and carcinogenicity), and the current move toward matters of indoor air quality.

A large number of questions followed relating particularly to asbestos, lead, the current status of priority pollutant reviews and economics.

### **New NSW Branch President**

Mr. Len Ferrari is the new President of the NSW Branch. He has a wife, Carmel, and four children. He has been involved with the Society for many years and is Chairman of the Training Activities Committee which runs the successful Measurement and Control Courses.

After four years as research chemist at Colgate Palmolive he joined the Air Pollution Control Branch over 23 years ago and was subsequently absorbed into the State Pollution Control Commission where he is Principal Scientist - Air, with responsibility for the Technical Services - Air Branch. He has published over 30 papers on air pollution and co-edited the Society's Air Pollution Measurement Training Manual.

Len is Chairman of two Standard Association Committees: Methods for the Measurement of Air, and Reference Gases, and serves on the Air Quality Committee of the National Health and Medical Research Council.

In his spare time Len has recently completed a Real Estate and an Auctioneering course (with Carmel) and enjoys tennis, swimming, touch football, computers and touring around Australia.

### **New NSW Branch Secretary**

The new NSW Branch Secretary is Mr

R.M. Hope. Bob has been associated with CASANZ for many years as a representative of Shell Refining (Aust) Pty Ltd (a Sustaining Member).

He is an Associate of the Sydney Technical College (Industrial Chemistry and Chemical Engineering) and a Life Member of the Royal Australian Chemical Institute. He is a secondary industry representative on the Clean Waters Advisory Committee of the SPCC.

His career was with various companies of the Royal Dutch/Shell Group at Gore Bay (NSW), in the UK, at Geelong Refinery in Victoria and Clyde Refinery, NSW. He was involved principally with the operational, Economics and Scheduling and Environmental Conservation aspects of refining.

He retired from Shell in 1985 and amongst his activities since then has been assisting in the organisation of the 7th World Clean Air Congress in Sydney in 1986. Following this, he was elected as Honorary Member of CASANZ.

Bob and his wife Barbara live in Beecroft, NSW, and have three children and two grand-children.

### **New NSW Committee Members**

There are two new members on the NSW Branch Committee. They are Messrs David Beard and En/o Sgammotta.

David Beard graduated as Chemical Engineer from Universidad Tecnica del Estado, Chile. He arrived in Australia in 1969. After a short period with Monsanto Australia, he moved to Australian Lubricating Oil Refinery Ltd., a company of the Caltex Group.

In 1975 he obtained a M. Appl. Sc. Degree in Environmental Pollution Control from the University of NSW. He is currently Environmental Coordinator CRL ALOR. David has been associated with CASANZ for the past 10 years as the representative of Caltex Refining Co. Pty. Ltd. (a Sustaining Member).

Enzo Sgammotta is Acting Chief Combustion Engineer. BMP Steel International, Rod and Bar Products Division, Newcastle.

He has worked in Combustion Engineering in the Steel Industry for the last 17 years.

He graduated from the University of Newcastle in 1970 with a B.E. (Honours 11) in Chemical Engineering.

He has been active in the Newcastle Group of the Australian Institute of Energy, and is currently Chairman.

Enzo's Steel Industry experience

has been largely with process engineering aspects of existing and new capital projects of the Newcastle Steelworks, with particular emphasis on energy, environmental and process control.

Enzo is 38, married, with two children. His interests include squash, soccer, music and ecology.

### **NSW GLASS FACTORY ENQUIRY**

A proposal by Pilkinton-ACI to establish a float glass plant at Ingleburn, near Campbelltown, NSW, had met strong opposition from some local residents. The Campbelltown area has previously been identified as a receptor of photochemical smog formed in Sydney and the main concern of the residents relates to the role of the plant's nitrogen oxide emissions on local smog levels. To ensure that all issues relating to the proposal will be given full consideration prior to a decision being made, a Commission of Enquiry has been set up and is currently in progress.

### **Vehicle Exhaust Odours**

The CSIRO Division of Fossil Fuels and SPCC are collaborating to investigate the production of reduced sulfur compounds responsible for the odorous exhausts of catalytically-equipped vehicles as a function of vehicle operation and fuel sulfur concentrations. The study is being supported by the Commonwealth Department of Transport.

### **Update on Refuse-Burning Controls**

Total prohibition of refuse burning now applies in one-third of local government areas in Sydney. The remaining areas of Sydney, plus the City of Wollongong and the adjoining Municipality of Shellharbour are subject to non-burn days, when air pollution is predicted to be high and to time restrictions on other days during the cooler months when refuse burning is only allowed for a few hours.

The City of Queanbeyan, near Canberra, has also adopted time restrictions in the cooler months and year-round prohibition of open burning most types of refuse.

### **A.C.T.**

New Executive Committee Members and office bearers are as follows:

Dr R.W. Simpson (President)

Mr G.H. Miles (Secretary)

Mr J. Armstead (Treasurer)

Dr A.J. Jakeman

Mr T. O'Brien

## PROGRAMME OF MEETINGS

### A.C.T. BRANCH

The meetings and speakers that have been finalised so far for this year are:  
27th April. Executive Committee Meeting

27th April, Seminar. Dr K. Bentley. Secretariat Air Quality Committee. NH&MRC, presents - "the Establishment of Ambient Air Quality Criteria in Australia"

Date to be Announced, Seminar, Dr M. Glikson and Dr R. W. Simpson present "A Study of Particulate Air Pollution in Canberra".

### N.S.W. BRANCH

The 1987 Programme of the N.S.W. Branch is as follows:

7 April: Dr. Keith Bentley. Deputy Director, Environment Hygiene Section. Dept. of Health. Canberra. "Air Pollution. Morbidity and Mortality"

30 April: One-day Symposium at the 1987 Royal Australian Chemical Institute Analytical Chemistry Symposium at Centrepoint Exhibition and Convention Centre.

Kevnote Speaker:

**Dr. J.J. Wesolowski**

2 June: Prof. David Trimm (UNSW) and Mr. Mike Mowle (SPCC) "Catalysts and Rouen-egg Gas"

4 August: Dr. Barric Pittock. Principal Research Scientist. Division of Atmospheric Research, CSIRO "Climatic Change in Australia"

13 October: Seminar on Legislative Changes

7 November: (Saturday) Visit to Eraring Power Station, followed by a social function.

### Victoria and Tasmania Branch

**8th April** - Vapour Recovery from Storage and Transfer of Volatile Organic Liquids. Joint Meeting with Institution of Engineers. Clunies Ross House.

**1st May** - Seminar- Indoor Air Pollution, Jerome Wesolowski - 10.30 - 2.00. Joint Meeting with the Australian Institute of Occupational Hygienists.

**15th July** - Symposium -Environment Policy and Economics. Speakers to be determined, Clunies Ross House- 2.00 - 5.00 p.m.

**15th September**- Meeting, Hazardous Waste Incineration, speakers to be

determined. 6.00-9.00 p.m.

Mid November - Annual General Meeting and Dinner.

## COMPETENCES AND COURSES

### Air Pollution Control Course

To be held at S.A. Department of Environment and Planning, 310 Richmond Road, Netley.

The S.A. Branch of the CASANZ is offering a two day intensive course on air pollution control on the 25th and 26th June. 1987.

The course has been designed to provide sound, practical advice on air pollution control that plant managers, engineers and operators can use quickly and with confidence to solve air pollution problems when they arise at their plants. A comprehensive training course manual will be provided as an integral part of this course.

The lectures will be presented by S.A. Branch members and outside (local and interstate) experts in these areas. The venue will allow up to 40 people to be accommodated and the lectures will take the full two days including the inspection of an industrial plant exhibiting several forms of air pollution control.

The cost will be \$200 for members and \$240 for non-members of the Society. This cost includes tuition fees, course manual, lunches, morning and afternoon teas and the course dinner. Accommodation is not included in the cost.

For details or for enrolment forms, prospective applicants should phone one of the following

Geoff Penno "08-216 7639

Tom Whilworth 08-216 7655

The main topics to be covered in the course are as follows:-

Air Pollution General

Air Pollution Meteorology and sizing of stacks

Incinerators - Multichamber vs.

Pyrolysis

Fugitive Dust Control

Mechanical Collectors

Legislation and Licensing

Boilers - Coal, Oil to Gas Conversion

Fabric Filters Theory and Practical

Fume Hood and Piping Design

Scrubber

## WASTE WATER TREATMENT

The Department of Chemical Engineering at the University of

Queensland and the School of Civil Engineering at the University of New South Wales are jointly sponsoring three intensive continuing education courses in the field of wastewater treatment. The courses will be held at the Chevron Hotel, Surfers Paradise, Queensland. Details are as follows:

1. Principles of Wastewater Treatment, Design and Operation July 13th to 17th. 1987

2. Design of Wastewater Treatment Plants July 13th to 17th. 1987

3. Nutrient Removal from Wastewater Streams July 15th to 17th, 1987.

The principal lecturers for these courses will be Professor Wes Eckenfelder from the USA, Dr James Barnard from South Africa, Mr I. Law from Camp Scott Furphy in Australia, Associate Professor David Barnes and Peter Bliss from the University of New South Wales and Professor Paul Greenfield from the University of Queensland.

Further details may be obtained from either:

Professor P.F. Greenfield. Department of Chemical Engineering, University of Queensland. St Lucia. Qld, 4067 or Dr. D. Barnes School of Civil Engineering University of NSW Kensington. NSW. 2033.

## GLOBAL CLIMATE

Possible climatic changes through man made trace materials.

The VDI Kommission Reinhaltung der Luft will hold a symposium on this topic on Friday. 22 May. 1987 in Cologne - Maternus - Haus, Kardinal-Frings Strasse 1-3. This symposium is conducted in cooperation with the German Meteorological Society. Further information can be obtained from Vercin Deutscher Ingenieure, Abt. Tagungsorganisation, Postfach 1139 D-4000 Duesseldorf, Federal Republic of Germany.

## ENVIRONMENTAL METEOROLOGY

The VDI Kommission Reinhaltung der Luft is holding a three day symposium on this topic from 29 September, (Tuesday) to 1 October 1987 in the Congress Center at Wuerzburg. The symposium is supported by the German Meteorological Society. Papers have been called for but abstracts had to be in by 4 May, 1987 (1-2 pages). Conference language is English. The programme will be available in June. Further information can be obtained from:

Verein Deutscher Ingenieure.  
Abt. Taminasorganisation.  
Postfach 1139  
D-4000 Duesseldorf.  
Federal Republic of Germany.

## IUAPPA MEWS

### NEW PRESIDENT FOR APPA

The French association, APPA, has announced the appointment, of Vi. Pierre GAL'SSENS as its new President, with effect from 1 January 1987. Dr. Michel SOMMER, who held that office for many years and is a former IUAPPA President, has been elected APPA's President d'Honneur.

### IUAPPA COMPENDIUM

Contributions are starting to roll in for the IUAPPA Compendium, with texts received to date from Canada, Italy, Korea, South Africa and the United States of America. Many thanks to the hard-working authors and editors in associations representing those countries (APCA, CSiA, KAPHA and NACA). The Editor respectfully reminds other Associations that contributions are required this month, and thanks those associations which have given notice of the imminent arrival of their texts.

## AIR POLLUTION CONTROL CONSULTANTS

Dr. Terry Bellair has been wrongly listed in the February 1987 issue of the Air Pollution Control Consultants list. His new entry is shown below:

### Consulting Environmental Engineers

P.O. Box 431.  
Richmond Vic. 3121  
(03) 429 4644  
Dr. Terry Bellair  
1,4,5,6,7,8,9

1 — Air Pollution General  
4 = Dust Control  
5 = Health Studies  
6 = Industrial Emission Control  
7 = Meteorological Studies  
8 = Modelling  
9 = Outdoor Control

## PERSONNEL CHANGES

### FLAKT AUSTRALIA LIMITED

#### Ian Holden - Victorian Office

Born and educated in Glasgow. Ian came via South Africa to take up the position of Manager of Flakt's Victorian Branch Office.

A mechanical engineer, Ian spent 15 years in fans and gas cleaning before becoming Manager of the Flakt Division of the Company's South African representatives - Axel Johnson & Company. Ian was concerned with Flakt's equipment and systems in air pollution control, pulp and paper and the automotive industry during the six years that he held that position in South Africa, immediately prior to coming to Australia.

From the Melbourne office Ian's responsibility will also extend to South Australia and Tasmania.

#### John Briffett - New Zealand Office

The appointment of a resident New Zealander to manage our New Zealand operations is a further important step in our long term commitment to this market, very important to Flakt. John qualified in mechanical engineering in Monmouthshire, Wales before emigrating to New Zealand in 1973.

He joined Toyota as Project Engineer, progressing to Engineering Manager responsible for production, plant engineering and quality control. He has been closely associated with Toyota's \$20 million investment in New Zealand, recently as Project Manager for the new electrocoat plant.

John will assume responsibility for all Flakt activities in New Zealand.

### KINHILL ENGINEERS PTY LTD

Kent Fuller recently joined Kinhill Engineers Pty. Ltd. (formerly Kinhill Stearns) as Environmental Affairs Manager.

### EXXON CHEMICALS AUSTRALIA

**Lindsay Rex** has moved into Kent Fuller's previous position as Environmental Conservation Adviser for Exxon Chemicals Australia. He will be located at the Altona Petrochemical Company.

## OVERSEAS NEWS

### GLOBAL WARMING CHILLS EUROPE

The COLD snap that hit Europe last week might be the effect, of global warming. Climatologists fear that it is one of the first symptoms of the increasingly unstable weather that could accompany the greenhouse effect.

Some parts of Europe last week were the coldest they had been since the 1930s. Temperatures dropped to -41°C in Switzerland. Parts of southern England were still cut off at the start of this week after receiving nearly one metre of snow. About 200 deaths have been blamed on the cold.

Iceland, however, was sweltering at an unseasonal 10°C. At Sverdlovsk, within the Arctic Circle, temperatures soared to near freezing. The paradox of a warm north and a freezing south say climatologists, stems from a change in normal air movements throughout the northern hemisphere.

Land cools down in winter faster than oceans. This usually creates a huge, cold high pressure over Siberia. Cold snaps in Western Europe occur when the high pressure extends to form 'ridges' over the continent. But Mick Kelly of the University of East Anglia's Climatic Research Unit says the entire high pressure area has migrated farther west than usual, it is centred over Scandinavia.

Kelly says the most notable change in Eurasian weather over the past few years has been higher average winter temperatures in Siberia. Kelly says this is caused by the 'greenhouse' effect of the increase in atmospheric carbon dioxide during the past century.

"It is still pretty cold in central Asia, and the high-pressure zone still forms there," Kelly says. "It just isn't as strongly tied to central Asia this time, because the difference in temperature between the middle of the continent and western Europe isn't as great as usual.

"It is too early to be certain, but I am concerned that this is the first symptom of the greenhouse effect." Kelly says land-based weather systems should be affected first, since oceans will take longer to respond to changes in temperature.

(Reproduced from New Scientist, London, 22 January 1987 by permission).

# FUTURE DIRECTIONS FOR POLLUTION CONTROL IN VICTORIA

Dr. J. Brian Robinson,  
Chairman,  
Environment Protection  
Authority of Victoria

Address to the Victoria and Tasmania Branch of the Clean Air Society of Australia and New-Zealand on 17th February 1987.

As with many of the regulations in Australia pollution control has its origins in the measures adopted in the United Kingdom. In particular the concept of best practicable means (BPM) which originated in the mid-19th century from the effects of control emissions from the alkali industries, played a major role in the development of a pollution control philosophy in this country.

BPM was at the heart of the British Clean Air Act of 1956 and was carried over into the Act of the same name passed by Parliament in Victoria in 1958.

The departure from the BPM philosophy (but not practice) by the introduction of the Environment Protection Act in Victoria in 1970 was seen by some as a kind of heresy. The new Act introduced the concept of emissions being controlled to meet environmental objectives. The critics of this approach were not easily silenced but it is instructive to compare the Victorian experience since 1970 with that of other places.

The approach embodied in the 1970 Act has been developed considerably since that time and the policies and strategies that have been adopted have given substance to the original philosophical ideas. By allowing experience to dictate its development Victoria now has an Act which allows considerable pragmatism in implementing an overall philosophy. More than that, especially through its later State Environment Protection Policies, originally seen as the very antitheses of BPM, it is able to apply the best aspects of BPM to meet and protect declared environmental objectives. Pragmatism and ideology hand in hand.

If Victoria has moved from the philosophical to the practical the home of BPM has moved in the other direc-

tion. No doubt, in part, as a result of influence from its EEC partners the British have recognised the need to answer the question best practicable means to do what. The result is a move towards setting environmental objectives and the concept of BPI7C) best practical environmental option. This change has come about because while BPM achieved much in dealing with gross health threatening, pollution it has been found inadequate, on its own, to deal with the more subtle forms of pollution or the quality of life issues that governments have to deal with today.

Similar developments around the world seem to confirm that whatever the starting point environmental protection is best achieved by a combination of environmental quality objectives, practical engineering methods and good management practice. This is a succinct statement of the current approach to pollution control adopted by EPA in Victoria. The philosophical battles of the early 70's seem to have little merit in retrospect and in fact it could be said that Victoria arrived at the right combination ahead of most of the world.

The route by which EPA arrived at the present system had a number of milestones, but, perhaps the most significant for the audience was the declaration of the State Environment Protection Policy (The Air Environment) (SEPP) in 1981. There had been a number of water SEPPs declared in the 1970s but they had not made a major impact overall.

The Air SEPP showed very clearly, for the first time, that the Act could be implemented fully through combinations of environmental objectives and practical control measures.

The SEPP set out a number of concepts on which the control strategy was to be based. These included:

- Air Quality Control Regions which recognised the particular problems of certain airsheds.
- Different approaches for new and

existing industries.

- Offsets in special cases where existing discharges could be 'traded in' for smaller new discharges.
- Buffer zones to protect residential areas from accidental or residual effects from certain industries.
- A general requirement of good control practice for all industry incorporating management and maintenance as well as hardware.
- The specific development of a 'best practicable means' approach for individual industries (Schedule H) and its interpretation into an overall airshed management philosophy.
- The control of motor vehicle emissions and other diffuse sources as part of an overall strategy.

Much of this was not new but it was an explicit statement of a philosophy of integrated air quality management.

That general philosophy and many of the concepts can now be found through the Authority's operations.

The next major milestone was the introduction of air pollution abatement notices into the Act following the repeal of the Clean Air Act. These were followed by Noise Control Notices and in 1984 were extended to all areas through the Environment Protection (Review) Act. This was the first major overhaul of the legislation.

Largely because of the introduction of the notice system the Review Act was able to introduce scheduled premises.

This provided a more direct way of concentrating EPA's major technical resources on the major premises than through the more cumbersome exemptions approach.

The Review Act thus laid the foundation for future operations. Scheduled premises are not controlled through a combination of works approvals (noise notifications) prior to construction and licence to discharge. Minor premises are required to comply with regulations and policies but may also be subject to notices for specific problems.

The licensing system was of course introduced in the original Act along with SEPPs and these were the initial milestones or signposts that set us on our existing course.

During the early 80s major airshed studies contributed significantly to our understanding of the Melbourne and Latrobe Valley airsheds. They provided us with a great deal more certainty in our decision-making. The smog alert system which enables warnings to be issued that help asthmatics and others with respiratory problems,



to take precautions and hopefully avoid an attack is one example. Our modelling and MESO meteorological skills are also useful in assessing possible disaster situations. We can help the emergency authorities to plan more effectively for evacuations etc. and they complete our range of skills needed for a thorough assessment of any major project proposal.

The most recent milestone was the introduction of the Environment Protection (Industrial Waste) Act in 1985. For the first time this gave EPA direct control over industrial activities not intended to have an environmental discharge. In particular if brought the waste treatment and recycling industries under direct and close scrutiny.

Industrial waste management is clearly one of the major issues of the present and immediate future. Indeed it is not an issue that can be confined within a discipline in the way that air, water and noise have typically been treated in the past. It requires a truly multi-disciplinary approach, rather than straightforward control. It is these philosophies - waste avoidance or minimisation and proper management which will largely dictate the future directions of EPA in Victoria.

One further development of importance has been the retrieval of all delegations to other government agencies. To assist in the early establishment of EPA a number of functions, particularly licensing, was delegated to existing government agencies. As of 1 January 1987 the last of these were withdrawn and EPA assumed direct responsibility for implementation of the Environment Protection Act throughout the State. This has major implications for the shape of the organisation and its future priorities.

Our first priority for the immediate future will be to examine ways of improving service delivery to our customers. We have three sets of customers each with different needs. The Government which has administrative and political needs to be met: industry which looks to us for guidance and help in meeting its legal and social obligations and the public which expects a clean and healthy environment.

To better address these needs we will be establishing three non-metropolitan regions. The Gippsland Region based at Traralgon, the South West Region based around Geelong and Ballarat and the North with offices in Bendigo and Benalla but managed from Melbourne. Local knowledge and a regional presence (even on a limited scale) we believe are vital to servicing

the needs of the non-metropolitan parts of the State.

Within the metropolitan areas we will also be moving to a new management structure. The support, activities policy and scientific services, will be placed in one division while all control activities will be grouped together in a second division. Control will be carried out by multi-disciplinary teams who will be able to bring a more consistent, cohesive and co-ordinated approach to managing the Melbourne environment. This will also enable us to be more flexible with staff deployment, as well as more creative and should significantly reduce the number of contact points that industry needs to have with the Authority (in many cases to one). There will be a separate motor vehicles branch.

The major thrust will be for prevention rather than cure. We are largely on top of existing point source discharges. Future discharges will not be allowed to become problems. Diffuse sources of pollutants remain as problems, however, and management plans will be further developed to address these.

Pollution prevention and control is a basic responsibility of any industry that wishes to operate in a modern community. We will be helping industry to fulfill that responsibility by improving our communications and ensuring that every company is aware of the requirements of the Environment Protection Act and policies and regulations declared under it. We will work with industry to develop improved guidelines and to assist major companies to prepare environment improvement plans whenever appropriate. Self monitoring will be increasingly required but it will be made as cost-effective as possible. Monitoring for the sake of monitoring will be out. Ambient monitoring of the surrounding environment will continue to be asked for where a proposal warrants it. Reporting of monitoring results will be increasingly simplified with the emphasis on exception reporting.

Although EPA has always sought a co-operative relationship with industry, and this has generally been responded to, there are times when some encouragement is needed. Legal action will continue to feature in our approach but with the introduction of 'on-the-spot' fines for minor offences. These will particularly relate to motor vehicle and transport offences such as noisy or smoky cars, transporting scheduled wastes without a valid permit, or failure to properly complete a transport certificate. They will also apply to a range of

other offences including a failure to submit exception reports when required to do so. This procedure should still provide sufficient motivation without the expense and time commitment of court hearings. People aggrieved by this process can elect to have their case dealt with through the 'alternative procedures' of Magistrate's hearing in chamber or of course in open court in the usual way.

Since we are all part of the community we will be seeking ways to encourage industry, local government and local communities to talk together more to address their problems. We have had some success with this approach already and are anxious to see it extended.

EPA of course must also learn to communicate better with our major customer, the general public. We are reviewing our approach to public relations. In particular we will be seeking to become better known in rural areas and to strengthen our image in Melbourne and Geelong. However, communications is a two way activity and we must learn to be better listeners. Better listeners to each of our client groups but particularly to the public. We act on its behalf and it is vital that we listen with a more sensitive ear in future so that we have a better appreciation of community concerns. We had a very successful trial in the preparation of the industrial waste strategy. We employed a non-technical, non-'PR' person as a community relations officer. For the first time we learnt that much of what we consider to be information is gobbledegook to the public. Even those who consider themselves the 'great communicator' were somewhat humbled.

As we address the problems of our clients we must also be aware of our colleagues in other agencies. In today's complex and highly regulated society there is increasing scope for unproductive overlap between government agencies and with local authorities. This not only makes the outside world despair but at a time when government is seeking to do more with less and to take a corporate approach to running the State it is unacceptable to our political masters. More effort will therefore be put into working with our colleagues in developing complimentary programs that make the best possible use of our respective skills and experience. In particular a closer working relationship with local government is called for.

Specific future developments will include:

\* A waste minimisation policy (Waste Management Policy)

- \* A municipal waste management policy
- \* A groundwater protection policy
- \* Finalisation of the Waters of Victoria Policy
- \* Finalisation of the Noise from Entertainment Policy
- \* Specific waste management policies (e.g. PCBs)
- \* A long-term traffic noise policy
- \* Introduction of Industrial Waste Regulations covering Schedule 4 premises, transport permits and certificates. and prescribed wastes.
- \* Domestic noise regulations
- \* Amendments to the Environment Protection Act to introduce "on-the-spot" fines, provide for police powers of entry in special circumstances, allow for works approval of staged projects and sundry other amendments largely of a legal nature.
- \* Codes of practice relating to a wide range of activities especially in rural areas.
- \* Simplification of licences and further streamlining of the licensing system
- \* Expansion of the approved tester program for noisy cars.
- \* Development of standards for vibration.
- \* Work on helipad and airport noise (with the Commonwealth).
- \* Control over backyard burning.
- \* Extension of airshed studies into Geelong.
- \* Development of better hazard assessment skills and requirements for hazard studies for new projects.
- \* Development of higher level chemicals assessment and modelling skills.
- \* More attention to land-use practices, particularly forestry and agriculture.

From this you can see the future will be a busy one and since it will all have to be achieved within existing budgets, we will endeavour to improve our management skills significantly. Our training programs in management, technical and communications areas will be strengthened and we will be seeking to foster exchange programs with other organisations.

Mere I should like to return to an earlier point as a finale, a point that needs particular emphasis. All of this activity will be of little value unless it addresses the real problems in practical ways. To do this we need to listen to our clients. So more than anything else that is going to be EPA's emphasis for the future. We want to become the best lis-

teners in the business. Today is a good time to start and the Clean Air Society will certainly be one of the mechanisms we will use.

## VALOUR RECOVERY FROM STORAGE AND TRANSFER OF VOLATILE ORGANIC LIQUIDS

Measures adopted by BP Australia to meet the 1984 Victorian Regulations on Emissions of Volatile Organic Compounds from Stationary Sources.

Address to a joint meeting of the Victoria and Tasmanian Branch and the Institution of Engineers Australia on 8th April, 1987.

by Trevor Nichols, Manager Engineering BP.

### STORAGE OF ORGANIC LIQUIDS ON LARGE STATIONARY TANKS

The storage of organic liquids in large bulk storage tanks is the first subject of the Regulations which needs to be addressed.

The Regulations require external floating roof tanks to meet some basic criteria regarding

- the skirt plate around the edges
- the closure seal
- the weather protection of the seal

Floating covers are intended to prevent contact between product and air, thereby avoiding the evaporation of vapour from the product into the tank's atmosphere. In the process they reduce displacement, withdrawal and breathing emission.

External floating roof tanks under the Regulations have to be fitted with weather protection over the seals. The cost for this is approximately \$150/m but it increases the efficiency of the seal. The gap between the roof and the tank edge is sealed in the first place by a shoe and a primary seal fabric. Secondary seals are added to provide added security in this zone.

The provision of secondary seals reduced losses in general terms down to about 16% of those previously experienced.

Internal covers are required on normal bulk tanks and these also have skirts and closure seals.

We have fitted the tanks with servo gauges coupled to a computer to enable us to monitor the ongoing integrity of the blankets and seals, even though this is not prescribed by the Regulations.

The alternative to the modification of the tanks so as to minimise emissions is the connection of tank vapour spaces to an approved vapour recovery unit or an incinerator.

In practice it is more economical to prevent the release of emissions than to recover vapours continuously.

No vapour recovery units have been installed at Victorian terminals to reduce emissions from bulk tanks.

### TRANSFER OF ORGANIC LIQUIDS INTO DELIVERY TANKERS

Part IV of the Regulations deals with the transfer of organic liquids into delivery tankers and that is where vapour recovery units are needed.

As changes had to be made to comply with the Regulations, industry took the opportunity to modernise facilities, especially by installing new bottom loading filling stations to replace the old, inefficient top loaders which were labour intensive and of low productivity.

While introducing emission control improvements, industry also endeavoured to rationalise and reduce personnel. Automated truck loading facilities and computer controlled systems have been introduced to alleviate the need for additional manpower.

Every effort was made to ensure that the new plant being installed was as troublefree as possible and could be easily understood by personnel which was not highly skilled. This had to be carefully considered as plant of relative complexity was introduced while available manpower was being reduced.

In addition facilities were standardised throughout industry enabling companies to draw on each other in case stock shortages occur. A code of practice was developed under the auspices of the Petroleum Marketing Engineers Advisory Committee (PMEAC) a branch of the Australian Institute of Petroleum.

As far as vehicles are concerned the provision of automated truck loading has eliminated the need for operators to open hatches on trucks, to carry out dipping and to record temperatures. Vehicle loading takes place in a sealed environment and vapour displaced by the filling operation is recovered by means of a vapour recovery unit.

The vapour emitted is normally a mixture of

(a) Pre-loading vapour which is a residual vapour originating from the previous contents of the tanker which is being displaced by the product loaded.

(b) Vapour evolved through splashing and turbulence while Tilling. The percentage of vapour from (a) depends on the volume of vapour the driver brings back from service stations.

Different types of vapour recovery units which would satisfy the Regulations were considered. In the final evaluation the Adsorption-Absorption Vapour Recovery Systems were adopted by all oil companies in Victoria.

The refrigeration type vapour recovery system was not favoured as it requires considerable maintenance and a specialised operating staff.

Nitrogen systems were considered but because of the small base cost differential between nitrogen and motor spirits, this type of unit would not produce sufficient cost benefits.

The simplest system which also requires the least maintenance is, of course, combustion. This was considered but rejected as it destroys valuable product rather than recovering it.

In general the only rotating equipment at terminals consists of centrifugal pumps. Thus an acceptable vapour recovery unit should not be of greater complexity. Therefore the vapour recovery units in use in Victoria are fitted with liquid ring compressors which are not unlike centrifugal pumps in their maintenance requirements.

The law in Victoria requires a recovery of at least 110 mg/L. Units based on carbon adsorption-absorption invariably recover down to 5mg/L on a regular basis.

## **CARBON ADSORPTION VAPOUR RECOVERY UNITS**

The mixture of hydrocarbon emissions and air at atmospheric pressure is passed alternatively through one of two vessels containing activated carbon.

The hydrocarbons are adsorbed preferentially and outlet air containing only traces of hydrocarbon vapour is released to atmosphere. The inlet flow is switched to the second carbon bed before the carbon in the first bed becomes saturated with hydrocarbons.

The Carbon in the first bed is then regenerated by applying a high vacuum using a liquid ring vacuum pump which normally operates with a glycol-water solution as the sealant liquid.

The outlet stream from the vacuum pump first enters a separator where the sealant liquid collects and then passes

to an absorber column. The hydrocarbons are reabsorbed in counter current flow of liquid gasoline which is drawn from and returned to a gasoline storage tank. Residual hydrocarbon vapours leaving the top of the absorber are recycled into the inlet vapour/air mixture entering the activated carbon vessel acting as the absorber at the time.

The standard units are designed to recover 98% of the hydrocarbons contained in the inlet stream which is assumed to consist of 40% by volume of hydrocarbon vapours.

Technical considerations and recommendations for the application of vapour recovery plants.

Most proprietary plants are designed and supplied as packaged modular units for easy assembly at an installation with minimum site needs and modifications.

They can normally be obtained in different sizes to accommodate the required peak load conditions for whatever sustained periods of continuous operation are necessary. These conditions are carefully considered to allow a sufficient margin for a possible increase in required capacity.

An estimation is made of the liquid load and the "worst case" conditions for the quality of the inlet air/vapour stream which is to be treated. The composition of the hydrocarbon constituents is given in detail. It is very important to state if constituents other than hydrocarbons are likely to be present. These may include alcohols and other chemicals. These can impair the efficiency of the process or can have an adverse effect on materials and seals. This may necessitate some modifications in the design or the operating controls and this needs to be implemented to allow for these constituents.

Most proprietary units, particularly if they are destined for operation at marketing installations, are designed for fully automatic operation, with minimum or no manual intervention. Thus, once the process has been switched on for a day's operation, all (low, temperature and level controls are automatic. Any cyclic events which may involve opening and closing of valves at timed intervals are controlled by pre-programmed logic circuitry.

In order to minimise operating supervision requirements all vapour recovery units have the following features:

- Solid state control logic providing reliability and flexibility for in-Held changes.
- Trouble shooting aids.
- Total control monitoring to simplify

trouble shooting by monitoring separator levels, seal fluid flow, motor operated valve sequencing, carbon bed temperatures, indication of operating functions and faults.

In addition BP has the ability to log and monitor the operation of the complete site from the Terminal office and including the operation of the vapour recovery unit.

A lot still needs to be learned about the overall efficiency of vapour recovery systems. Typical factors which should be considered and taken into account when evaluating these systems include the following:

- (a) The cost of installing and connecting the vapour recovery units, e.g. provision of utilities, product lines, measuring instruments for quality and quantity. The cost of running the plants.
- (b) Any modifications, particularly to instrumentation and control equipment, which the user may deem necessary to render it compatible with existing equipment.
- (c) Where such equipment is not already available and in situ, the cost of essential vapour collecting and return systems will be significant, and will often exceed the purchase and installation cost of the basic recovery unit.
- (d) Reliable means of verifying the efficiency of plants and ways of calculating running costs versus product recovered.

## **CONVEYANCES**

Vehicles over 12000L are required to be modified.

## **TRANSFER TO SERVICE STATIONS**

Replenishing of service station tanks now has to be carried out in a prescribed manner.

The principal emissions from service station storage tanks occur during bulk transfers. Although the tanks are free vented, breathing emissions are very small due to the nearly constant temperature of the tank.

Tanks are not greatly affected by aboveground, daily ambient temperature variations.

To give some idea of losses from service stations, it can be stated that 15% is lost by breathing but 85% is now recovered and processed in the terminals.

## **CONCLUSIONS**

In conclusion the costs to industry for providing plant and facilities so as to

comply with EPA Regulations is given in Table 1 (only direct costs to the major companies in Melbourne are considered).

- Costs of bulk tank modifications to provide blankets and upgraded external floating roof seals.
- Cost of providing vapour recovery units at terminals.
- Cost of modifying road loading gantries to accommodate gasoline loading arms with vapour returns, or modifications to provide bottom loading with vapour return. In many cases it was necessary to extend a loading gantry or to provide a new gantry.
- Cost of modification of road tankers to enable them to receive vapours returned from service stations and to return vapours when being filled at the installation.
- Costs of providing vapour return from service station tanks, which individually are relatively minor. The total cost, however, is substantial as most service stations supplied in the whole distribution envelope have to be included.

	LOSS BEFORE NEW CONTROLS	EXPECTED LOSS WITH CONTROLS	COST TO PROVIDE CONTROLS
LOADING AND DISCHARGE OF TERMINAL BULK TANKS	0.24% \$3.1M	0.024% \$0.3M	\$2.5M
TERMINAL BULK TANK BREATHING	0.08% \$1M	0.008% \$0.1M	
LOADING ROAD TANKERS	0.11% \$1.4M	0.01% \$0.14M	\$4.8M
DISCHARGE INTO SERVICE STATION TANKS	0.11% \$2M	0.03% \$0.5M	\$8M
FILLING CAR FUEL TANKS	0.10% \$1.8M	0.10% \$1.8M	---
	\$9.34M	\$2.84M	\$15.3M

Table 1 Summary of cost to Industry in Victoria for providing plant to meet EPA Regulations.

## ENVIRONMENT PROTECTION (STORAGE AND TRANSFER OF VOLATILE ORGANIC LIQUIDS) REGULATIONS 1984

Address to the Victoria-Tasmania Branch of the Society and the Institution of Engineers, Australia on Wednesday, 8th April, 1987.

by Dr. Kevin Frayne, formerly Senior Air Quality Officer (Policy Development), EPA, now Manager, National Industry Extension Service.

### INTRODUCTION

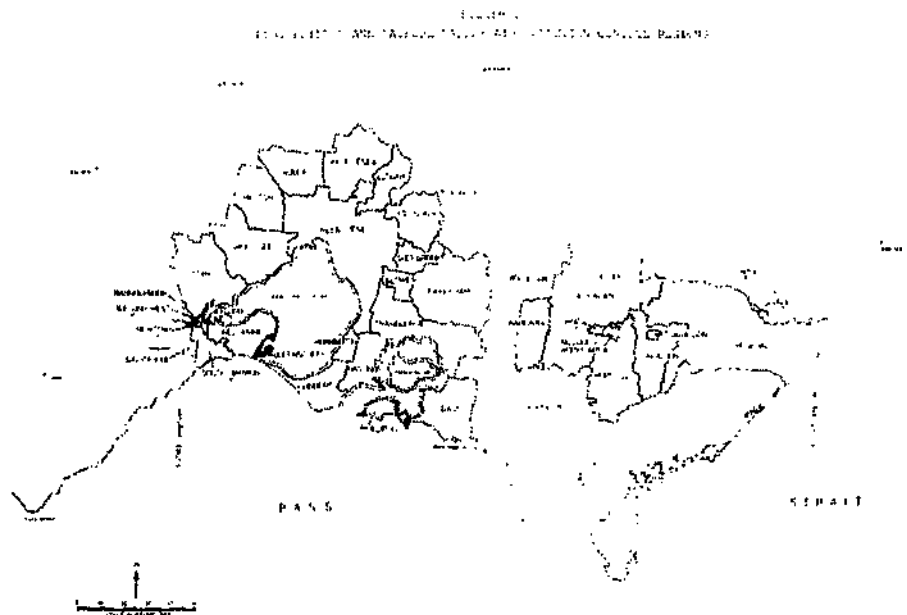
The Storage and Transfer of Volatile Organic Liquids Regulations were introduced in Victoria as part of a program to control photochemical smog by reducing non-methanic hydrocarbon (NMHC) emissions in the Port Phillip Air Quality Control Region. This region is shown in Figure 1, and is defined in the State Environment Protection Policy (SEPP) (The Air Environment) for the purposes of controlling regional air quality problems. The other controls which form part of this program include the Environment Protection Motor Vehicle Emission Control Regulations 1976 (ADR37),

the latter being achieved using catalysts and lead free petrol. Schedules F9 of the Air SEPP for Oil Refineries, F7 for the Can Coating Industry and possibly other Schedule Fs dealing with the Printing Industry, Transport Equipment, other large solvent users and petrochemical plants.

### PHOTOCHEMICAL SMOG

Photochemical smog is formed from the reaction of volatile organic compounds (non-methanic hydrocarbons NMHC) and oxides of nitrogen (NOX) in strong sunlight to produce new compounds such as ozone, aldehydes, nitrates and aerosols. The major concern with this type of air pollution is the effect of ozone, the principal constituent of photochemical smog, on human health.

The Air SEPP specifies air quality objectives for ozone at two levels, an acceptable level and a detrimental



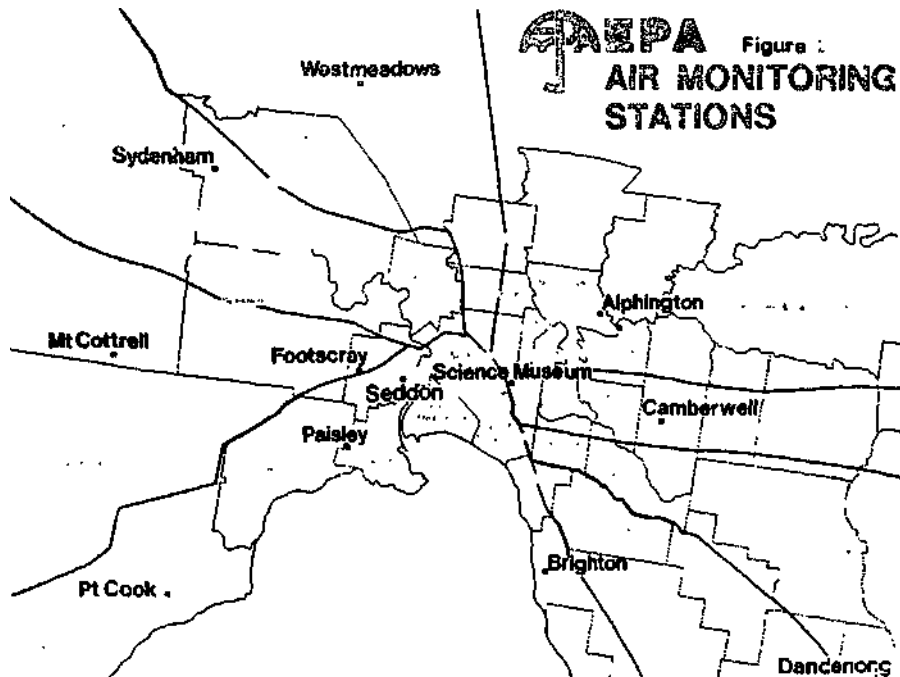
level. The acceptable level of 0.12ppm averaged over one hour should not be exceeded more than once a year and the detrimental should never be reached. The aim of this control program therefore is to reduce the concentration of ozone so that the second highest level recorded in each year does not exceed 0.12ppm over one hour and the highest level remains below 0.15ppm.

### MONITORING DATA

Since 1981 air quality in Melbourne has been monitored by a network of 12 stations, the locations of which are shown in Figure 2. Figure 3 shows that the SEPP air quality objective for ozone of 0.12ppm has been exceeded on a number of occasions each year from 1982/83 to the present. These exceedances, particularly those in earlier years, prompted the development of control programs to reduce photochemical smog, and in particular the development of the Storage and Transfer of Volatile Organic Liquids Regulations.

### CONTROL STRATEGY

The control of photochemical smog involves the choice of whether to control NMHC emissions or NOX emissions or both. Work carried out as a result of the Melbourne Air Shed Study suggests that it would be better to control NMHC emissions. Figure 4 shows typical NMHC/NOX ratios at a number of monitoring stations around Melbourne on a Dodge isopleth diagram which describes lines of equal ozone concentration for varying NMHC/NOX ratios. This diagram or relationship between ozone, NMHCs and NOX is the basis of the model used by Melbourne Air Shed Study to predict the effects of Newport on Melbourne's Air Shed Study to predict the effects of Newport on Melbourne's air quality. The NMHC/NOX ratios suggest that it would be more effective to



reduce NMHC emissions than NOX emissions or a combination of both. The high ratio at Point Cook is unusual and suggests that the NMHC concentration is being influenced by a local source. A hydrocarbon study is planned for the near future to investigate this as well as to conduct other studies.

### EMISSIONS INVENTORY AND FORECASTS

An emissions inventory was developed for the Melbourne airshed to identify major sources of NMHC emissions. These are shown in Table 1. Motor vehicles are the largest source (56%) followed by Solvent usage (15%), Evaporation of Petrol and Crude Oil (14%) and process emission from Oil Refineries and Petrochemical Plants (10%).

To reduce NMHC emissions in the Melbourne airshed emissions from major sources must be controlled.

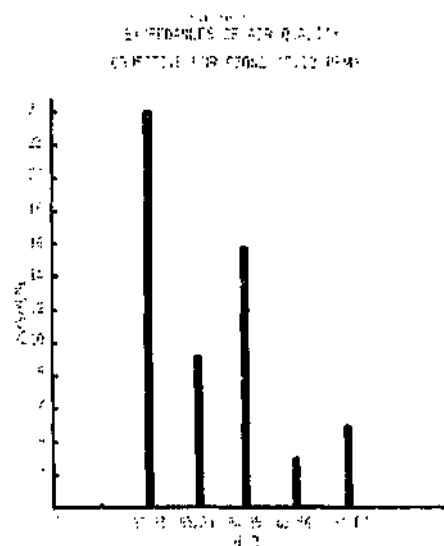


TABLE 1  
Estimated Annual NMHC Emissions  
Melbourne Air Shed 1982\*

Source	Tonnes/yr	%
Motor Vehicles	56,000	56
Petroleum Products		
Refineries & Petrochemical Plants	9,500	10
Evaporation	14,400	14
Solvents	15,000	16
Waste Burning	3,300	3
Miscellaneous	1,500	1

Estimated by Melbourne air Shed Study

Emission forecasts for Mobile, Stationary and All Sources are presented in Figures 5(a), 5(b) and 5(c) respectively. Figure 5(a)<sup>a</sup> shows that NMHC emissions from motor vehicles will decrease as a result of the 1976 and 1986 Motor Vehicle Emission Control Regulations until about 1997 and then gradually increase.

Figure 5(b) shows that the total NMHC emissions from stationary-sources have decreased as a result of the Storage and Transfer of volatile Organic Liquids Regulations. NMHC emissions from all other stationary sources are assumed to remain uncontrolled. If the regulations had not been introduced NMHC emissions from

<sup>a</sup> Forecasts were developed by COMVE (Committee on Motor Vehicle Emissions)

stationary sources would have continued to increase as shown in Figure 5(b)<sup>11</sup>.

Figure 5(c) shows that the total NMHC emissions from All Sources will decrease as a result of the Storage and Transfer and Motor Vehicle emission controls until about the mid 1990's and then increase thereafter if no further controls are introduced. It also shows the effect of not introducing the Storage and Transfer of Volatile Organic Liquids Regulations. In this case total NMHC emissions would increase after about 1988 to almost reach the 1976 level by the year 2000. Therefore in order to achieve a sustained reduction in NMHC emissions over the next 15 years regulations to reduce emissions from the Storage and Transfer of Volatile Organic Liquids were necessary. In addition a greater

<sup>11</sup> Emissions from Stationary Sources are assumed to increase by 2% a year.

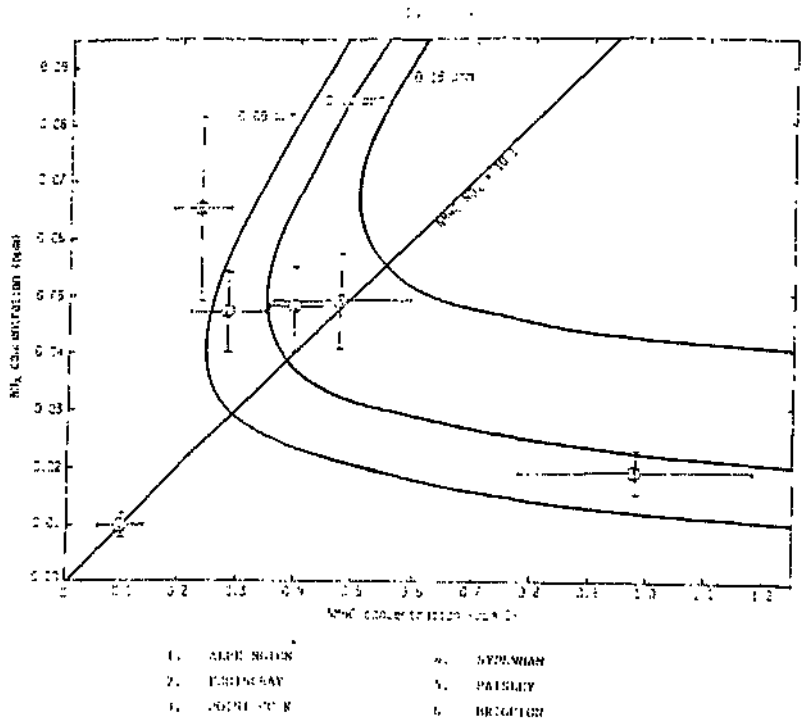
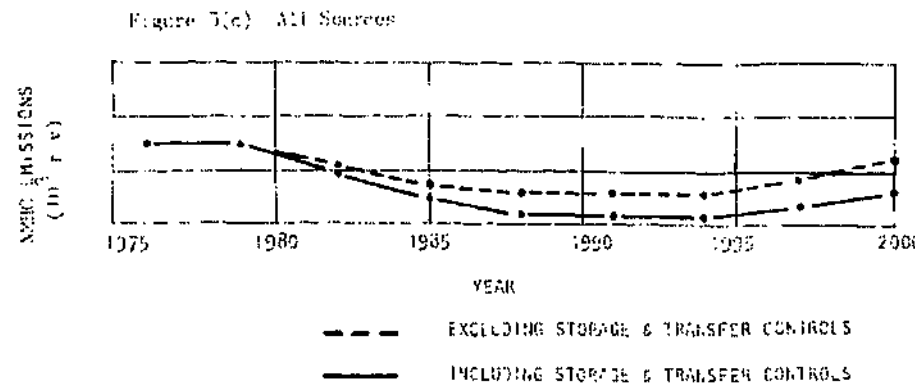
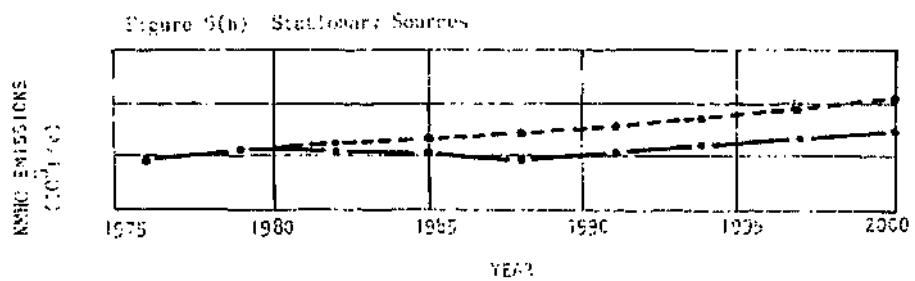
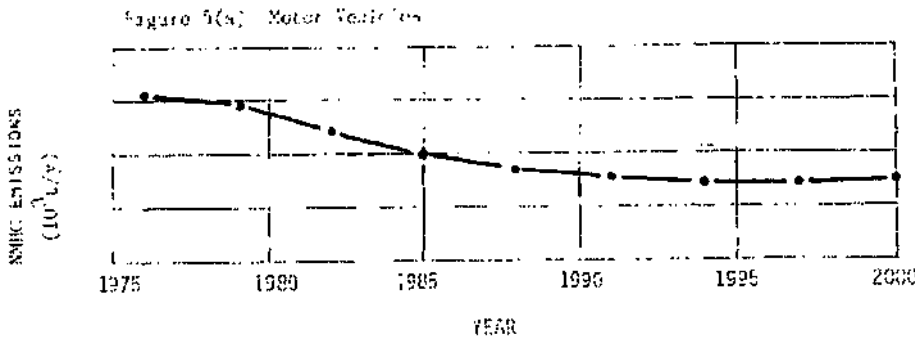


FIGURE 5  
NMHC EMISSION FORECAST FOR MELBOURNE



degree of reduction in NMHC emission will also be achieved with these controls which F.P.A. feels is required to achieve the SIIPP air quality objectives for ozone in Melbourne.

The cost and cost effectiveness of the controls are presented in Table 3. Controls on large storage tanks, road tanker filling operations and filling service stations, depot and other site tanks were all considered to be reasonably cost effective and were implemented.

## THE REGULATIONS

In order to develop a cost effective control program for the Storage and Transfer of Volatile Organic Liquids, a survey of Oil industry storage and distribution operations was carried out to quantify emissions and determine the costs of control and expected reduction in emissions from each major source.

To begin with the Port Phillip Air Quality Control Region was established as the region in which the controls would apply because it contained most of Victoria's population and Industry and was predisposed to photochemical smog.

The organic liquids contributing most of NMHC emissions in the region were Crude Oil and Petrol because of their high vapour pressures and volumes (Petrol consumption is of the order of 2.5M tonnes a year). Solvents had a much lower vapour pressure than petrol or crude oil and their usage was insignificant when compared to petrol.

The results of the emissions survey are presented in Table 2 which shows large storage tanks to be the main contributor (58%), followed by road tanker filling at terminals (14%), filling motor vehicle fuel tanks (12%) and service station/depot tanks (1%), filling rail tankers (3%), and filling road tankers at depots (2%).

The Regulations require control of emissions from road tanker filling and depots and terminals when the total volume of prescribed organic liquids (petrol) loaded is greater than 30 ML a year. Although the 30 ML a year cutoff point was considered appropriate by all parties at the time the Regulations were being drafted, this cutoff point is currently under review in view of the somewhat high cost (about \$350,000 for a vapour recovery unit) of controlling emissions from small bulk loading facilities (depots).

The cost of vapour controls for large storage tanks over a range of tank diameters is presented in Figure 6. The regulations require all storage tanks with a capacity greater than 150Kl to be controlled, which is approximately equivalent to tanks with diameters of 5 metres or more. From Figure 6 the cost effectiveness of controlling emissions from a 5 metre diameter storage tank is about \$300/bbl. Most storage tanks have diameters greater than 10 metres. A typical storage tank has a diameter of about 20 metres.

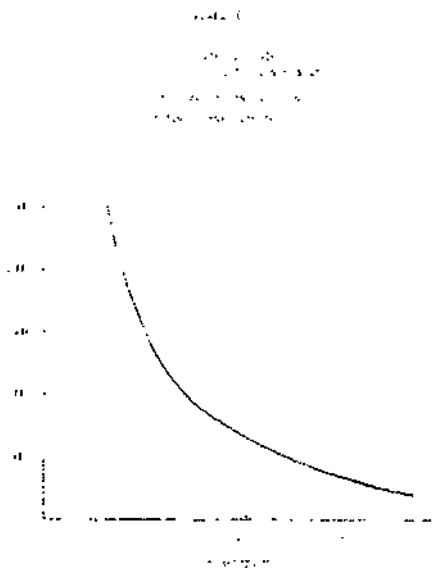
The cost of vapour control for small storage tanks (12-150Kl capacity) at service stations over several throughputs is presented in Figure 7. From Figure 7 the cost effectiveness of controlling emissions from a small service station (throughput 600Kl/year) is about \$600/bbl and about \$300/bbl for a medium service station (throughput 1200Kl/year). The regulations control emissions from filling service station tanks with throughputs greater than 600Kl/year in cities within the Port Phillip Air Quality Control Region, and from service station tanks in the Shires with throughputs greater than 1200 Kl/year. The higher throughput is applied to the outer lying areas of Melbourne where emissions are much lower and less critical.

The regulations came into operation on the 1st March 1984. Deadlines for implementation of the various stages of the regulations were staggered to allow industry to complete each step. The implementation dates are as follows:

Storage in large tanks	1 March 1986
Filling Road Tankers and conversion of road tankers	1 November 1986
Filling Storage Tanks (Service Station/Depots)	1 May 1987 (cities) 1 May 1989 (Shires)

### EFFECT OF CONTROL PROGRAM

Figure 5(c) shows NMHC emissions from all sources in the Melbourne airshed have been decreasing since the late 1970s. Reducing NMHC emissions should reduce both the peak



ozone levels recorded each year and the number of occasions on which the 1 hour SEPP objective for ozone (0.12 ppm) is breached compared to the number of occasions on which the policy objective is nearly breached. For the purposes of this exercise the near breaches are taken as the light pollution level where the concentration of ozone is greater than 0.09 ppm and less 0.12 ppm.

Table 4 shows that the peak ozone levels recorded each year decreases from 1982/83 to the present and the ratio of Policy breaches

TABLE 2

Source	Source Contribution	
	1982	
	Emissions KlYr	%
Large Storage Tanks	20.400	58
Service Stations/Depots		
Filling Tanks	3.900	11
Filling MV	4.000	12
Terminals (100 Kl yr)		
Road Filling	4.700	14
Rail Filling	900	3
Depots Filling Road Tankers (30-100 Kl/yr)	400	2
(<30 Kl/yr)	280	
TOTAL	34.550	

TABLE: 3

Cost and Cost Effectiveness of Storage and Transfer Controls (1982S)

Source	Cost \$M	Emission Reduction bbl	Cost Effectiveness \$,bbl
Storage Tanks	4.0	95,000	40
Road Tanker Filling	10.0	26,550	380
Rail Tanker Filling	4.4	5,090	870
Filling Tanks at Service Stations/Depots	7.5	16,550	450

( $O_3 > 0.12$ ppm) 10 near breaches ( $0.09$ ppm  $< O_3 < 0.12$ ppm) generally decreases. Unfortunately meteorological conditions can vary considerably from year to year and may be responsible in part, if not entirely for these observations.

EPA's summer Smog Alerts, however, are issued under standard meteorological conditions, that is where there is a high pressure system centred east of Melbourne with light north easterly to north westerly winds and a strong temperature inversion at less than 1500 metres above ground. Table 5 shows that the number of policy breaches to the number of near policy breaches on smog alert days decreased over the period 1985/86 to 1986/87, suggesting that photochemical smog over Melbourne is now reducing and our control program is working.

**TABLE 4**

Ozone  
Policy Breaches and Near-Breaches

Summer	Peak Ozone (ppm)	Policy Breaches ( $O_3 > 0.12$ ppm)	Near-Breaches ( $0.12$ ppm $> O_3 > 0.09$ ppm) Light Pollution Level	Ratio of Policy Breaches to Near Breaches
1982-83	0.23	24	38	.64
1983-84	0.21	9	20	.45
1984-85	0.20	16	25	.64
1985-86	0.17	3	17	.18
1986-87	0.15	5	22	.23

(Unvalidated data)

**TABLE 5**

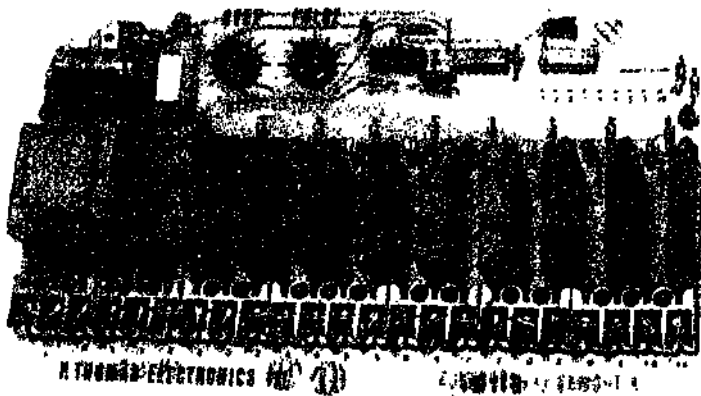
Ozone  
Policy Breaches and Near Breaches on Smog Alert Days

Summer	No of Correct Alerts	Policy Breaches ( $0.3 < 0.12$ ppm)	Near Breaches ( $0.09$ ppm $< O_3 < 0.12$ ppm)	Ratio of Policy Breakers to near Breakers
1984-85	10	7	3	2.3
1985-86	5	2	3	0.7
1986-87	11	3	8	0.4

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( $O_3 > 0.12 \text{ ppm}$ ) 10 near breaches ( $0.09 \text{ ppm} < O_3 < 0.12 \text{ ppm}$ ) generally decreases. Unfortunately meteorological conditions can vary considerably from year to year and may be responsible in part, if not entirely for these observations.

EPA's summer Smog Alerts, however, are issued under standard meteorological conditions, that is where there is a high pressure system centred east of Melbourne with light north easterly to north westerly winds and a strong temperature inversion at less than 1500 metres above ground. Table 5 shows that the number of policy breaches to the number of near policy breaches on smog alert days decreased over the period 1985/86 to 1986/87, suggesting that photochemical smog over Melbourne is now reducing and our control program is working.

**TABLE 4**

Ozone  
Policy Breaches and Near-Breaches

Summer	Peak Ozone (ppm)	Policy Breaches ( $O_3 > 0.12 \text{ ppm}$ )	Near-Breaches ( $0.12 \text{ ppm} > O_3 > 0.09 \text{ ppm}$ ) Light Pollution Level	Ratio of Policy Breaches to Near Breaches
1982-83	0.23	24	38	.64
1983-84	0.21	9	20	.45
1984-85	0.20	16	25	.64
1985-86	0.17	3	17	.18
1986-87 (Unvalidated data)	0.15	5	22	.23

**TABLE 5**

Ozone  
Policy Breaches and Near Breaches on Smog Alert Days

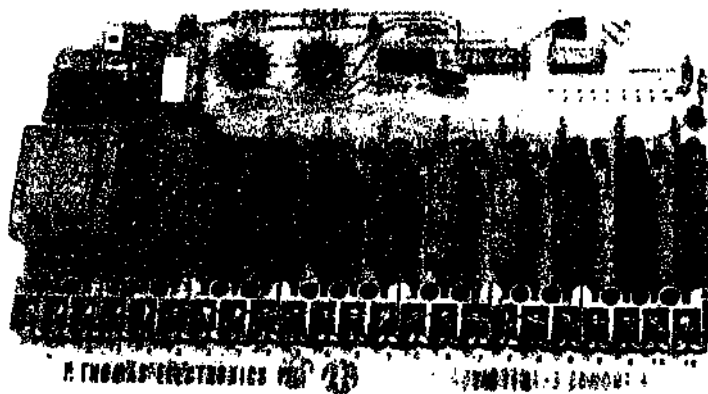
Summer	No of Correct Alerts	Policy Breaches ( $O_3 < 0.12 \text{ ppm}$ )	Near Breaches ( $0.09 \text{ ppm} < O_3 < 0.12 \text{ ppm}$ )	Ratio of Policy Breaches to near Breaches
1984-85	10	7	3	2.3
1985-86	5	2	3	0.7
1986-87	11	3	8	0.4

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# AMBIENT AIR QUALITY OBJECTIVES FOR FLUORIDE: AN AUSTRALIAN PERSPECTIVE

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## SUMMARY

Air quality objectives for fluoride that have been adopted or proposed for Australian and overseas authorities are reviewed. The need for objectives that protect fluoride-sensitive commercial and Australian native plant species is examined.

A two-tiered scheduled air quality objective for fluoride is proposed, one tier providing for the protection of fluoride sensitive plant species, and another for the protection of very sensitive species that occur in specified areas. The two objectives would specify maximum acceptable ambient fluoride concentrations for averaging times of 0.5, 1, 7, 30 and 90 days. For sensitive species, the 90-day average fluoride concentration would be  $0.5 \mu\text{g F m}^{-3}$ , and for very sensitive species it would be  $0.25 \mu\text{g F m}^{-3}$ .

These air quality objectives should be applied in conjunction with a comprehensive system of land use classification and planning that established preferred land use regions to which appropriate ambient air quality objectives might be applied. Provided adequate planning measures are established, it should be possible for air quality objectives to be negotiated between parties in situations where it can be demonstrated that there will not be unacceptable effects of fluoride on the environment.

## INTRODUCTION

Most ambient air quality objectives are designed to prevent disease or discomfort to human beings and, in so doing, they also prevent serious injury to other organisms. Fluoride differs from most other atmospheric pollutants in that it has adverse effects on plant species at about one thousandth of the concen-

trations that affect humans and other animals directly (1,2). It is appropriate that air quality objectives should be based on the responses of plants rather than those of humans or animals. Plants are most affected by gaseous fluorides, as the particulate forms are generally of low solubility in water and are therefore unavailable to plants (3). Ambient concentrations that may injure the most susceptible plant species are of the order of  $0.3$  to  $10.0 \mu\text{g F m}^{-3}$ , depending on the duration of exposure and other environmental conditions.

Meteorological and plant conditions will affect the rate of accumulation of atmospheric fluoride by plant leaves, so the connection between ambient and foliar fluoride concentrations is not always simple (4). Fluoride is generally considered to be not transported out of the foliage, but it may be transferred to other components of the ecosystem by grazing animals, or by the shedding of leaves and their decomposition in the soil (5,6). Accumulation of fluoride in soil animals, herbivores, and their predators may eventually lead to injury to animal species in the absence of any detectable effects on plants.

Establishment of a national air quality objective requires the definition of an acceptable level of effect or impact on the environment. This acceptable impact will vary from place to place, depending on the nature of the environment and the ecosystems under consideration, and in particular the plant components of such ecosystems. It is the determination of this acceptable impact that is most contentious, so it involves a compromise between the cost of pollution abatement measures and the costs associated with the changes in the ecosystem (7).

Furthermore, an air quality objective may be stated as a long-term goal, or a condition that is immediately enforceable. These two expressions of an objective may be very different, and they should be recognized as such. Whilst the definition of a long-term goal is commendable, pragmatic administration requires that

immediately enforceable regulations be developed that satisfy as far as possible the often conflicting wishes of a community.

## RATIONALE FOR PROPOSED GOALS

Air quality goals in the United States generally derive from those of Washington State, which define objective concentrations for averaging periods from 12 hours to 7 months (8). These objectives have also been adopted with some modification by Victoria (9). Experimental studies on approximately 150 plant species and field observations on a further 150 species in Australia (4) have enabled the Washington goals to be assessed in relation to the possible effects on Australian ecosystems (10).

It has been established that, for the great majority of plant species, young foliage is much more sensitive to injury by fluoride than is previously matured foliage (1,2,4). Therefore, environmental conditions that cause a cessation of growth are likely to result in a decrease rather than an increase in the apparent susceptibility of plants to fluoride.

The effects of other environmental factors on the development of fluoride injury symptoms are not fully understood. Symptoms of drought and fluoride injury may be almost identical, but there is only limited evidence so far that these two agents have interacting, or synergistic effects on symptom development (11). In fact, the imposition of drought at the same time as exposure to fluoride may greatly reduce symptom development. High temperatures or drought immediately after fluoride exposure may result in accentuated fluoride injury, and in one instance recorded on grapevines in the Hunter Valley, temperatures of  $40^\circ\text{C}$  following fluoride exposure resulted in 5-10% foliar necrosis (12).

Environmental modification for the promotion of crop growth may increase rather than decrease the visible effect of fluoride on plants, through the maintenance of physiological activity in plants at times when it would not normally be very great. This physiological activity would be associated with widely open stomata in the leaves, and would result in greater uptake of fluoride, with consequent effects, in managed rather than in unmanaged plant communities. In natural plant communities, it would be very important to establish the extent to which each of the agents of environmental stress (drought, flooding, late autumn cold.

salinity, pathogens), in addition to a pollutant, affected the plants before concluding that there were interactions between the agents of stress.

## OBJECTIVES

Air Quality objectives should:

(1) generally protect established or preferred forms of land use, recognizing that land use patterns may be changed deliberately for some purpose:

(2) for crop species, prevent significant economic loss, as assessed by the yield and/or quality (including visual appeal where relevant) of a product:

(3) for pastures, prevent the development of pollutant-induced disease in grazing animals:

(4) for natural ecosystems, prevent significant structural and/or functional changes as reflected in either plant or animal components, prevent the loss of rare and endangered species, and in areas of high aesthetic value, also prevent unacceptable visual effects.

It is useful to consider each aspect of the objectives summarized above.

## Protection of Established Land Use

The designation of established or preferred forms of land use implies that there is available a description of land usage for the area in question, and that a decision has been taken on the most important forms of land use for that area. However, a change of land ownership could clearly lead to a change of usage and, this should be taken into account when an air quality objective is being applied. For example, an industrial organization may purchase sufficient land not only to operate a process, but also to minimise the risk of adverse impacts of pollutants on the surrounding landholders. In this case, land use could change without the occurrence of adverse effects on established land uses in the area.

Where a region is designated for the use of industries that emit pollutants, the ambient concentrations of fluoride that would be acceptable at the boundaries of one property may be substantially higher than those judged to be appropriate if a fluoride emitter was located in a non-industrial area. A consequence of such a decision may be the modification of the vegetation existing in the area, and a reduction in the number of species that could be grown successfully. This constraint would not normally be important in an area managed as an industrial buffer zone.

## Prevention of Significant Economic Loss

Crop species should be protected from significant economic loss due to pollutant effects. This requires that the effects of fluoride on yield (or quality) of commercial products should be determined as precisely as possible. Even under controlled experimental conditions, it is difficult to demonstrate significant effects of treatments in individual experiments where the differences between treatments are less than 10% (13,14,15). Variations of the natural environment may lead to differences in crop yield of 30% or more between one year and the next, and simple comparisons of yields in different years with different average pollutant concentrations will not resolve pollutant effects.

The effects of a pollutant on plant growth can be established through experimental fumigations, either under

a range of carefully controlled conditions or over a considerable number of growing seasons or sites in the field, or by careful long-term field monitoring of the environment and plant responses. Field experiments have been used successfully to establish the effect of ozone on several crop species in North America (16,17,18), but the amount of information available on the effects of fluoride is relatively limited (19). For valuable crops, experimental fumigations may be required as part of the planning process leading to the establishment of a new industry. Some examples of responses of particular species to gaseous fluoride are discussed later in this paper.

## Protection of Grazing Animals

Pasture species accumulate fluoride from the air and from particulate forms in phosphate fertilizers, and the fluoride is then ingested by grazing

TABLE I  
AIR-QUALITY STANDARDS OR OBJECTIVES  
FOR FLUORIDE IN AIR.  
ESTABLISHED OR PROPOSED BY  
VARIOUS AUTHORITIES

Authority and Reference	Fluoride concentration ( $\mu\text{g HF m}^{-3}$ ) and averaging times (days)					
	0.5	1	7	30	90	210
<b>U.S.A. (8)</b>						
Oregon	3.68	2.86	1.64	0.82		0.53
Washington	3.7	2.9	1.7	0.84		0.5
Tennessee	3.7	2.9	1.6	1.2		
Kentucky	3.68	2.86	1.64	0.82		
New Hampshire						
New York, Texas						
<b>CANADA (21)</b>						
Federal <sup>a</sup>		0.85	0.55	0.35	0.2	
Federal <sup>b</sup>		0.4	0.2			
Ontario		0.86		0.34		
Newfoundland		0.9		0.45		
<b>COMMISSION OF EUROPEAN COUNTRIES (24)</b>						
Less sensitive species				2.0		1.4
Sensitive species				0.8		0.5
Very sensitive species				0.4		0.3
<b>AUSTRALIA</b>						
Victoria (9)		2.9	1.7	0.85	0.5	
New South Wales (22)				0.5 <sup>d</sup>		0.5 <sup>c</sup>
				0.1 <sup>c</sup>		
Western Australia (23)					0.5 <sup>c</sup>	
					0.2 <sup>f</sup>	
						0.1 <sup>g</sup>

Abbreviations:

<sup>a</sup>Upper limit of acceptable range; of concentrations, intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being; <sup>b</sup>Upper limit of desirable range of concentrations, defines the long-term goal for air quality and provides the basis for an anti-degradation policy for unpolluted parts of the country; <sup>c</sup>Sensitive native species can show visible injury; <sup>d</sup>For protection of horticultural species of intermediate sensitivity; <sup>e</sup>For protection of sensitive horticultural species such as gladiolus and stone fruits; <sup>f</sup>To provide overall protection, regardless of normal stress; <sup>g</sup>To protect horticultural species.

animals. Most studies of fluoride accumulation in pastures have been carried out in temperate countries, using green plant material (20). In Australia, where animals graze pastures throughout the year, and where forage is dry for several months, the relationships between ambient, forage, and animal fluoride concentrations are not known precisely, and may vary from those used in other countries (4).

### Protection of Natural Ecosystems

The value of a natural ecosystem is usually associated with the structure and composition of the vegetation, its physical position, or with the presence of a rare or endangered organism. In such situations, there are two principal issues: protection of the ecosystem as it exists, or modification of the ecosystem or habitat of a particular species to secure its survival. In the first case, the impact of pollutant must be reduced to the point where there is no measurable effect on the ecosystem, even over a long period of time. Clearly, this would require the enforcement of a very stringent air quality objective, as not all changes in the ecosystem can be anticipated. In the second case, the ecosystem may be modified by the introduction of other species that may shelter a sensitive species from fluoride accession, or the species may be established in another habitat. The selection of one or other of these measures requires a decision on the basis for the value of the ecosystem -the system as a whole, or a particular component of it, in relation to the value of the proposed industrial activity.

### EXISTING AIR QUALITY OBJECTIVES FOR FLUORIDE

Table 1 summarises some of the ambient air quality objectives that have been proposed or implemented in several countries. They represent either more recently developed objectives, or those that require relatively low ambient fluoride concentrations for compliance. The Washington objective has been widely adopted, although there are some important commercial species (stone fruit and gladioli) that may not be fully protected by this standard. Several authorities (21,22,23,24) have addressed this problem through multiple objectives for different categories of fluoride sensitivity in plants. Some of these objectives are compared in Figure 1, and their application to plant species of interest

TABLE 2  
STANDARDS OR OBJECTIVES FOR  
FLUORIDE IN FORAGE, ESTABLISHED OR  
PROPOSED BY VARIOUS AUTHORITIES

Authority	Fluoride concentration ( $\mu\text{g F g}^{-1}$ ) and averaging times (days)			
	1	2	6	12
U.S.A. (8)				
Maryland	80	60		40 <sup>a</sup>
Washington	80	60		40 <sup>b</sup>
New York	80	60	40	
Texas	80	60		40
Kentucky	80	60		
Idaho	80	60		40
NEW ZEALAND (8)	80	60		40
AUSTRALIA				
Victoria (9)	80	60		40
West Australia (23)	60	60		40

Notes: <sup>a</sup> The maximum concentration in maize or sorghum leaves intended for grain production is 35  $\mu\text{g F g}^{-1}$ . <sup>b</sup> the maximum concentration in cured forage is 40  $\mu\text{g F g}^{-1}$ .

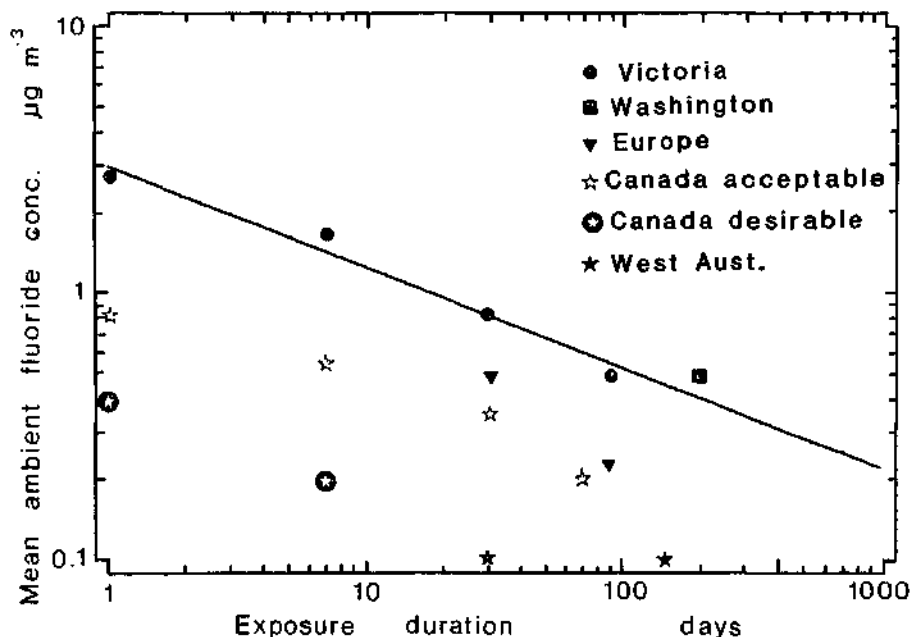


FIGURE 1. Comparison of some air quality objectives. The solid line describes the continuous relationship between averaging time and objective concentrations for Victoria.

in Australia will be considered below.

Objectives for the concentration of fluoride in forage are summarised in Table 2. Again, the standards applied in Washington and Maryland (18) have been generally adopted in New Zealand and Australia. The principal variation between the objectives is the application of the 40  $\mu\text{g/g}$  limit on a 6-monthly or a 12-monthly basis. Clearly, where animals graze a pasture throughout the year, a 12-month average would be required.

The State of Maryland includes in another vegetation standard a fluoride

concentration of 35  $\mu\text{g F g}^{-1}$  of leaf material in maize and sorghum intended for grain production. The rationale for this is not easy to grasp, since little fluoride would be transported from the leaf to the grain, and the only likely effect of fluoride on grain production would be through the inhibition of dry matter production, a response that has not been clearly shown to occur at a foliar fluoride concentration of 35  $\mu\text{g g}^{-1}$ .

It can be concluded that the objectives established for fluoride in forage in the States of Maryland and

Washington, and in New Zealand and Victoria are appropriate for use during the growing season, but their applicability to dry pastures under continuous grazing has yet to be confirmed.

## APPLICATION OF OBJECTIVES

Two courses of action are available for the attainment of a desired air quality, namely the application of scheduled and negotiated objectives. The selection of the more appropriate course depends on the information available on the responses of the critical species or ecosystem in question to the ambient fluoride concentrations.

### Scheduled Objectives

Air quality objectives have traditionally been established by legislation or regulation designed to protect most pollutant-susceptible organisms from injury. In the case of fluoride, where the effect of the pollutant can be described as the product of average concentration and exposure duration (1), the objectives have been applied as a range of concentrations that should not be exceeded during a specified averaging time (Table I). Contentions arise when a plant species of commercial, aesthetic or conservation value and of unknown but suspected fluoride susceptibility occurs in an area likely to be affected by fluoride emissions. To cover such a case, the air quality objective is usually designed to protect the most susceptible organism known or likely to occur in a particular area, taking into account the uncertainty of determination of the species susceptibility or the interacting effects of other environmental conditions. This uncertainty may result in the establishment of a relatively stringent objective as compared with that indicated from experimental or field observations.

If an industry is proposed for an area where there are no very fluoride-susceptible plant species, application of an air quality objective that protects such susceptible species may impose unnecessary restrictions on the operation of the industry. A solution to this problem is the application of an objective according to a schedule that allows for differing susceptibilities of different species or ecosystems. It follows that the schedule must be modified as more or better information becomes available on the effects of a pollutant on plant species.

### Negotiated Objectives

A refinement of the scheduled objective, and an alternative to the establishment and application of a complex series of objectives for each combination of species and environmental condition is an air quality objective negotiated between the regulatory authority and a prospective pollutant emitter. Such an approach requires an understanding of the responses to fluoride of the plant species or ecosystem recognised to be the most important in the area. The objective can take account of the effects of topography, meteorology, seasonal plant growth patterns and surrounding land use on the impact of atmospheric fluoride on a particular plant species.

Definition of the most important plant species or ecosystem would have to be accepted by parties to the negotiation, and this would require the existence of a land use document that not only described forms of land use, but also indicated land use priorities. A land use plan would identify areas in which existing forms of land use must be protected, where changes in use could be considered, and the likely sensitivity of ecosystems in these areas to the impact of a pollutant.

It is considered that the understanding of pollutant effects on ecosystems, and particularly on plant species, in Australia is approaching the stage at which such planning exercises are becoming feasible. Furthermore, the need for deliberate land use planning is becoming more pressing as the areas of "vacant" land diminish.

## APPLICATION OF OBJECTIVES TO SELECTED PLANT SPECIES

There has been considerable interest in recent years in the formulation and application of air quality objectives in Australia, and three examples of commercial species and ecosystems that are commonly regarded as fluoride-susceptible will be discussed.

### Grapevines

A detailed review of the effects of air pollutants on grapevines (25) describes the effects that have been observed when grapevines have been exposed to pollutants in the field or in experimental situations. One of the clearest conclusions is that there is a great deal of variation in responses, depending on the variety and on environmental conditions, whether the subject of the study is the accumulation of fluoride in foliage, visible injury, or effects of fluoride on yield of grapes.

As grapevines are principally a commercial crop, the yield and quality of fruit are the most important criteria for judging the response of plants to fluoride pollution. Other criteria (vegetative growth, foliar injury, or fluoride accumulation in the leaves) are secondary, and useful only if they accurately predict yield responses. It is necessary to establish that these secondary criteria are in fact useful indices of the yield response, under the conditions considered for the establishment of air-quality objectives.

Leaves of grapevines have been found to accumulate fluoride at more or less constant rate during the early part of the growing season, with the attainment of a more stable concentration in the latter part of the season (12). Numerous workers have indicated that visible injury to foliage can be observed when foliar fluoride concentrations are in the range of 20-30  $\mu\text{g F m}^{-3}$ , although there are almost equally numerous reports of much higher foliar fluoride concentrations being associated with no visible injury (25). Fluoride concentrations in visibly injured and in uninjured grape leaves from the Hunter Valley were generally not significantly different (12), and in experimental fumigations, a very poor correlation has been reported between foliar fluoride concentration and the extent of visible injury in one variety of grapevine (26). Weinstein (25) concluded that "F accumulation from plant-to-plant is extremely variable and a poor predictor of foliar injury".

Some explanation of this poor correlation between fluoride accumulation and injury is necessary, as the appearance of injury is often used as a measure of plant response to the pollutant. Fluoride accumulation induces necrosis as a result of either acute uptake, where necrosis is distributed throughout a leaf, or chronic uptake, where necrosis results from the redistribution of fluoride.

Fluoride uptake by a leaf is promoted by high conductance of the leaf to fluoride, which is associated with widely open stomata and consequently high light, water supply and atmospheric humidity, and with high wind speeds in the plant canopy. Redistribution of fluoride towards the leaf margins is promoted by high transpiration rate, and associated with high water supply and low atmospheric humidity. Drought conditions are associated with restricted water supply, low stomatal conductance and slow rates of fluoride uptake. There is no detailed information on the effect of water deficits on the fluoride susceptibility of grapevines. Severe

drought may cause necrosis through dehydration of leaf extremities, and may also lead to defoliation. There is no known confirmation of the suggestion that fluoride accelerates or accentuates drought-induced defoliation in grapevines.

[It is also necessary to examine the connection between foliar injury and fruit yield. Live leaf area is one of the important factors determining the amount of dry matter produced by a crop, and hence its commercial yield. The major processes involved in the conversion of light energy to commercial product, and the ambient fluoride concentrations likely to affect some of these processes, are shown in Figure 2.

Light interception by plants, and its subsequent use in dry matter production, is a function of leaf area, which will be affected by necrosis due to agents such as fluoride, especially under conditions of high temperature (12), low water supply, nutrient deficiency and pathogen development. Losses of functional leaf area usually occur from about the middle of the growing season (10,12), but these losses are probably inconsequential because of the usual practice of pruning vegetative shoots at this time (12). There was no evidence of any residual effect of fumigation in one growing season on the growth characteristics of shoots in the following season (10).

Fluoride may be expected to influence the efficiency of conversion of light energy to dry matter, the process of photosynthesis, but glasshouse studies (27) showed no significant effect of fluoride on rates of photosynthesis at ambient fluoride concentrations up to about  $0.3 \mu\text{g F m}^{-3}$ . Fluoride could have an influence on the patterns of distribution of dry matter within plants, but there is no evidence on this for grapevines. Some aspects of leaf development (initiation and chlorophyll formation) are not evidently affected at concentrations below  $1.0\text{--}1.5 \mu\text{g F m}^{-3}$ , but leaf-expansion late in the growing season may be reduced significantly at concentrations in excess of  $0.6 \mu\text{g F m}^{-3}$  (15). There is no detectable effect of fluoride on shoot growth in several cultivars of grapevine at ambient fluoride concentrations  $\mu\text{g F m}^{-3}$  (13,14). This would suggest that, for the grape varieties examined, the threshold for economic damage to grapes is in excess of  $0.28 \mu\text{g F m}^{-3}$  for the duration of the growing season.

Shoot growth and fruit yield are more likely to be closely related than are the accumulation of fluoride in

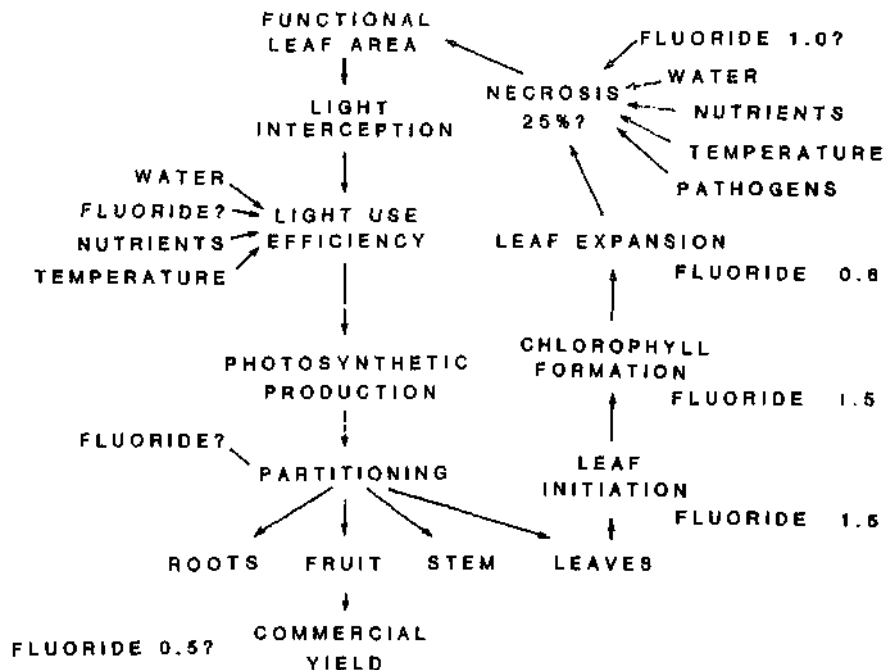


FIGURE 2. Fluoride effects on grapevine production. Ambient fluoride concentrations ( $\mu\text{g F m}^{-3}$ ) at which fluoride may have an effect are shown against the relevant process.

leaves and fruit yield. Therefore, it might be expected that grape yield would be reduced by ambient fluoride concentrations in excess of  $0.5 \mu\text{g F m}^{-3}$ , when the effect is measured in economic terms. It is suggested that, from a variety of studies, there is no reason to conclude that grapevines are so sensitive to fluoride that an air quality objective of  $0.1 \mu\text{g F m}^{-3}$  is required as a growing season average. Whilst this objective would certainly protect grapevines from any form of fluoride-induced injury, it may unnecessarily restrict other land use options.

The available evidence suggests that an air quality objective of  $0.5 \mu\text{g F m}^{-3}$  for an averaging period of 90 days would be sufficient to protect the commercial yield of grapevines. However, an argument could be made for a very conservative objective of  $0.3 \mu\text{g F m}^{-3}$  for a 90-day period if an additional requirement was the avoidance of visible injury to foliage.

### Stone Fruits

Little quantitative information is available on the effects of fluoride on stone fruits, but a recent study (28) indicated that suture red spot disease of peach developed as a result of the application of  $0.3 \mu\text{g F m}^{-3}$  for 90 days. On this basis, commercial stone fruit orchard areas should be protected by an objective of  $0.25 \mu\text{g F m}^{-3}$  averaged over 90 days. This corresponds very approximately with the proposed Canadian Federal objective of  $0.2 \mu\text{g F m}^{-3}$  for 70 days, as the upper limit of an acceptable range of concentrations "...intended to provide adequate protection against adverse effects on soil, water,

vegetation, materials, animals, visibility, personal comfort and well-being. (21). The Canadian objectives can be seen in comparison with several others in Figure 1. The Western Australian and New South Wales objectives call for a 90-day average of  $0.1 \mu\text{g F m}^{-3}$  to protect stone fruits. This objective is considered to be unduly stringent, and could be replaced by an objective of  $0.25 \mu\text{g F m}^{-3}$  over 90 days. It is important to emphasise that, under regulations operating in Australia, the objective is applied at the boundary of the industrial buffer zone, and not at the boundary of a stone fruit orchard that may be some distance farther from the pollutant source.

### Native Plant Species

Investigations on native plant species under experimental conditions, and observations in the field on a total of 250 species indicated clearly that there are few that show visible injury under ambient fluoride concentrations represented by the Washington objectives (4,10). That is, a three month average of  $0.5 \mu\text{g F m}^{-3}$  is sufficient to ensure protection of 97% of the plant species studied from visible injury.

One Australian native tree, *Eucalyptus citriodora*, shows visible injury symptoms and loss of growth under ambient fluoride concentrations of about  $0.6 \mu\text{g F m}^{-3}$  applied for 7 days (Figure 3). *Eucalyptus tessellaris* and *Xanthorrhoea preissii* show visible injury at ambient fluoride concentrations very close to those consistent with the Victorian objectives. *Acacia saligna* is visibly injured at low ambient fluoride concentrations, but

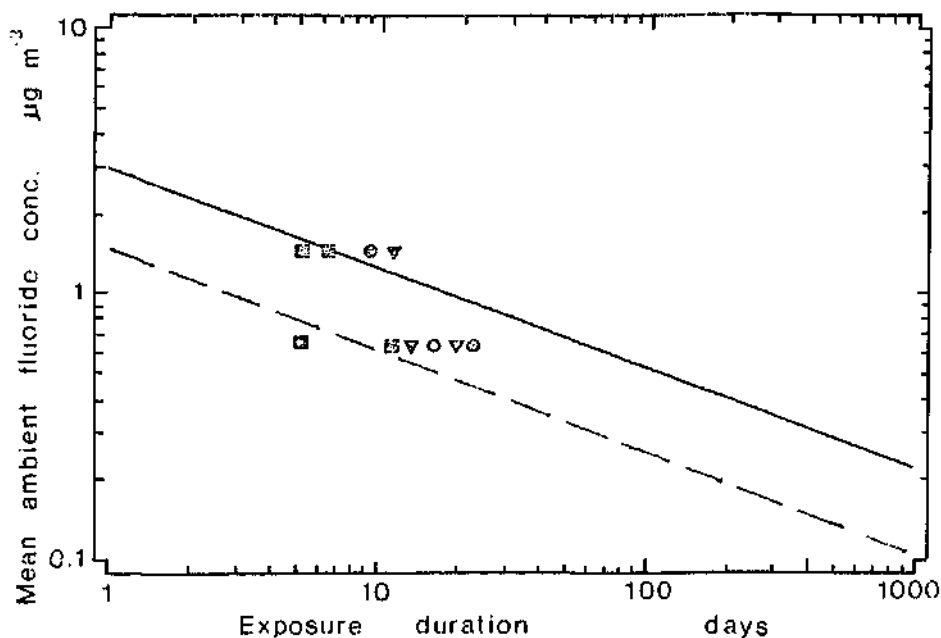


FIGURE 3. The relationship between ambient fluoride concentration and the time between commencement of exposure and appearance of necrosis (squares), chlorosis (circles) and cupping (triangles) in *Eucalyptus citriodora*, one of the most fluoride sensitive species examined in experimental fumigations. The solid line represents the continuous relationship between averaging time and objective concentration for Victoria, and the broken line shows the relationship for the suggested objective for the protection of fluoride-sensitive plant species. Where there is more than one symbol for a given concentration, they indicate the shortest and longest exposure times associated with the first appearance of injury on a plant.

growth appears to be unimpeded, and mature foliage carries little evidence of the effects of fluoride that occurred in young expanding foliage (4).

Protection of all these very sensitive species would require application of the Canadian "acceptable" objective (Table 1, Figure 1). The provision of such protection in every location where the species occurred would be a social rather than a technical decision, as none of the species so far identified as very sensitive is rare or endangered.

The direct effects on native fauna of ambient fluoride concentrations that conform with the air quality objectives are likely to be small and possibly not stringent. Indirect effects through ingestion of foliage containing fluoride are more obvious (16), but are as yet not well defined.

The case for an air quality objective of  $0.1 \mu\text{g F m}^{-3}$  is not supported by the evidence now available, but there is a case for a second standard to protect fluoride-sensitive plant species of high economic or conservation value.

## CONCLUSION

The great majority of Australian plant species would be protected from visible injury or reduction of growth by the Washington air quality objectives, but some would not, and these include several species of horticultural value. Where detailed information on the

fluoride susceptibility of species or ecosystems is not available, a scheduled objective as outlined in this paper is recommended, but where sufficient information does exist, it is suggested that an air quality objective that

provides protection for the existing or preferred land uses in an area could be established by negotiation.

## A Scheduled Objective

A two-tiered air quality objective is recommended:

Schedule 1: for the protection of fluoride-sensitive plant species and ecosystems where some alteration in structure and/or function and some visible injury to very sensitive species are acceptable;

Schedule 2: for the protection of plant species recognised to be very sensitive to fluoride and the prevention of any alteration in an ecosystem that contains organisms known to be very sensitive to fluoride injury.

Combinations of ambient fluoride concentration and averaging time for the two tiers of the objective are summarised in Table 3. The concentrations selected for the protection of fluoride-sensitive species are those adopted in the Victorian air quality objective, and the concentrations selected for the protection of very sensitive species are one half of those presently applied in the Victorian objective for each averaging time.

The objectives would apply at the outer limits of the buffer zone of a fluoride emission source. Unless specified otherwise, a location would be regarded as being subject to the

TABLE 3

### AMBIENT FLUORIDE CONCENTRATIONS FOR DIFFERENT AVERAGING TIMES IN A PROPOSED TWO-TIER NATIONAL AIR QUALITY OBJECTIVE

Averaging time	Maximum acceptable average ambient fluoride concentration ( $\mu\text{F m}^{-3}$ )	
	Species and land classification	
	Species: Sensitive General	Very Sensitive Restricted
12 hours	3.7	1.8
1 day	2.9	1.5
7 days	1.7	0.8
30 days	0.84	0.4
90 days	0.5	0.25
Equations	$C = 3.0 T^{-0.378}$	$C = 1.5 T^{-0.38}$

Abbreviations: C = interpolated air quality objective

Concentration: T = averaging time in days

Very sensitive species include stone fruits, gladiolus, and grapevines where these are grown in commercial quantities.

General land use includes areas designed for industry, and pasture and cropping areas not supporting very sensitive species, forests and other areas of natural vegetation.

Restricted land use includes designated areas of commercial cultivation of very sensitive species, dedicated reserves such as national parks or other reserve areas containing rare and endangered species, and ecosystems that are crucial for land stability and which contain very fluoride-sensitive plant species.

objective for the protection of sensitive plant species (Schedule 1). Examples of land uses that would be protected by the application of Schedule 2 would be stone fruit orchards, vineyards, commercial production of gladioli, and national parks or reserves of similar status containing plant species that are both very sensitive to fluoride and recognised as rare and endangered.

There is a general correspondence between the very sensitive objective concentrations and those regarded as the upper limit of the "acceptable range" by Canada, with the exception of the longer-term values which are slightly higher in the proposed objective (0.25 as compared with 0.2  $\mu\text{g F m}^{-3}$  for the Canadian objective). An example of the relationships between the two objective concentration-time relationships and the observed results of fumigation of lemon scented gum (*Eucalyptus citriolara*) are shown in Figure 3. This tree is the most sensitive of all the Australian native plant species subjected to experimental fumigation (4), and also appears to be very sensitive in the field. It is evident that the proposed objective would provide protection for the most sensitive individuals of this species.

## A Negotiated Objective

Negotiation of an air quality objective would be based upon the factors set out in the scheduled approach, but the final objective would take particular account of the variation in ecosystems and forms of land use throughout the area influenced by fluoride emissions. The negotiated objective would normally be expected to permit a higher ambient fluoride concentration at the boundary of the industrial buffer zone than those specified in the scheduled objectives, provided that no existing or preferred form of land use in the surrounding area was placed at risk by fluoride emissions.

## Association With Land Use Classification

Application of a scheduled or negotiated air quality objective would be feasible only if land use classifications were developed that incorporated indices of sensitivity of commercially important plant species and of ecosystems to pollutants such as fluoride. It would then be possible to define regions where only very low levels of pollutant emission could be tolerated, and other regions where higher ambient pollutant concentrations would be acceptable at the outer limits of an industrial buffer/zone.

In such industrial zones, pollutant-sensitive forms of land use may need to be excluded, or at least not defended or compensated, but other more tolerable forms of land use could continue without detriment. Land use classifications clearly would not be immutable, but once in place, changes should require deliberate consideration of all factors involved, including the implications for the maintenance of air quality.

A process of land classification is often followed informally during the selection of a site for a new industry, but with the competition for the use of land being certain to intensify, a formal system of land classification, or even reclassification, would be very valuable in the assessment of development proposals. Such a process is understood to operate already in some jurisdictions, but the formulation and adoption of a uniform national land use policy that considered deliberately the best use for land would both facilitate responsible industrial development and the protection of the Australian environment.

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## OVERSEAS NEWS

### CANADA OPENS ARCTIC BACKGROUND AIR POLLUTION MONITORING STATION

Canada has opened an important new research facility in the high Arctic region, which will continuously monitor background air pollution levels. The laboratory is part of an international network of stations - in Australia, the US, Japan, France, Germany, Norway and Sweden - coordinated by WMO under its Background Air Pollution Monitoring Programme to study the long-term effects of pollution on the atmospheric environment. The remote Canadian station will give a very good indication of background pollution of the Northern Hemisphere as a whole, as it is far removed from the major industrial regions. Among industrial pollutants to be sampled will be carbon dioxide, halogenated organic compounds, and sulfates.

*Source - Environment Canada, Update, November 1986*

### MODELLING THE CHERNOBYL RELEASE

An international study is underway to assess the ability of long range transport models to simulate the spread of the Chernobyl plume across Europe. The study aims to compare the results from such models and assess both their potential and limitations in such a situation. The project already has the approval and support of the OECD and it has been agreed that results should be made available to both the WMO and WHO.

From the UK, Dr. Helen ApSimon is conducting a pilot study which should contribute to the planning of the project. Dr. ApSimon, who is based at Imperial College of Science and Technology and is the Secretary of

EURASAP, is hoping to review the modelling activities which have already been undertaken or are planned following Chernobyl. She has drawn up a questionnaire asking for details from modelling groups about the models they employ, their data requirements, and what they have calculated in the context of the Chernobyl accident and/or could calculate within an international comparison study.

A copy of the questionnaire is available from IUAPPA's Editor, Jane Dunmore; questionnaire returns are required by March 1987.

### UK TREE SURVEY, 1986

Recently, the UK Forestry Commission has intensified its surveys of tree damage, looking for the impact of air pollution emissions and other stress factors. The results of its 1986 surveys of conifers and beech trees have just been published. The survey of conifers, or overall forest health, shows a marked increase in needle loss since 1985 and a substantially worse position than was recorded in 1984. There is also some evidence of an increase in needle discoloration although, in contrast, needle life did not change. The Forestry Commission have stated that, judging by needle loss alone, the health of British conifers must now be rated as only moderate, when set against fully-needled trees.

In comparison with 1986 results from West Germany, Britain appears to have appreciably more trees in the 'slightly' and 'moderately' damaged categories. However, with fewer trees

surveyed in the older (50 or 60 years plus) categories. Britain does not seem to have as many severely damaged trees as have been reported on the Continent.

As to probable causes, the report mentions three factors - changed perceptions in observers as they become more experienced in what to look for; a bad winter (1985/6); and, for pine only, attacks by fungi and insects. The report goes on to say that other factors such as drought, waterlogging, exposure, nutrient deficiencies and air pollution could all be involved but the Forestry Commission has been unable to determine their relative importance or extent of influence.

The surveys conducted by the UK Forestry Commission record changes from year to year, as opposed to the Continental surveys, which record the current state of the forests.

The health of beech trees presents a more encouraging picture. The main difference between the 1985 and 1986 data was the virtual disappearance of the premature chlorosis noted during 1985, and the report on beech trees concludes that most of those studied were in moderate to good health and that the data did not indicate any exceptional decline in the condition of woodland beech. However, the report mentions the visits to the UK made by two West German scientists, one of whom concluded that beech trees in England were worse off than most of those in Germany, while the other felt that Britain did not have a problem approaching that of Germany.

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# HEPA FILTER TESTING IN AUSTRALIA, HOT DOP OR NA CL - WHAT IS THE DIFFERENCE?

J.L. Gras

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## INTRODUCTION

High efficiency particulate aerosol or -EPA filters are at the heart of air-purification systems in such diverse applications as hospitals, the nuclear industry, micro-electronics, computing and a vast range of other industries that require an environment free from dangerous or contaminating airborne particles. Testing of filters during their production and after installation is clearly of vital importance to ensure that the integrity of these installations is maintained. During their production, filters are tested both for overall performance and are scanned for isolated leaks; the principal test is for the overall penetration of the completed filter by a standard aerosol and requires that a predetermined filtration efficiency standard is attained.

Because of the rapid development of particulate measurement techniques over the past several decades and a wide range of possible test aerosols, different test methods have evolved in various countries and become local standards. In Australia the two manufacturers of HEPA filters use different procedures for testing completed filters, both are independently based on recognised standards and are widely used in other countries. Disappointingly, there have been no attempts to date in this country to accurately compare these two test procedures. This has left users the task of assessing the relative merits and standards of the two test procedures with minimal knowledge of the actual details of the two methods. Experience elsewhere (eg Dorman 1981)(1) has indicated a wide divergence in the results of even carefully controlled comparisons.

Significant differences even between similar test rigs are apparently not uncommon (Hinds et al. 1979)(2) Understandably this lack of detailed knowledge of the two test procedures and how they should be compared has led to a degree of confusion (see for example "How absolute is absolute'." Aust.Hosp.Engineer. 5,p39,1983).

The purpose of this paper is to briefly describe the two test methods in use in Australia, demonstrate an independent method for determining (to first approximation) the expected ratio of filter efficiency using the two test methods and to show the type of information that is required to make a meaningful comparison of experimentally determined filtration efficiencies. These discussions will be based primarily on aerosol particulate and filter transmission properties determined in the Gelman Sciences sodium-flame test rig.

## THE METHODS IN CURRENT USE

At present one of the two test methods used in Australia is a recognised Australian standard (AS 1324). Known colloquially as a "Hot DOP" test it uses the U.S. Army developed Q107 penetrometer. This employs a nominally uniform-sized, or monodisperse, 0.15  $\mu\text{m}$  radius liquid test aerosol of di-octyl-phthalate (DOP) generated by carefully controlled condensation of hot DOP vapor in a Sinclair-LaMer type generator. Detection of the DOP aerosol is by a forward-scatter white-light photometer. For the Q107 penetrometer the photometer sensitivity allows determination of penetrations down to about  $10^{-5}$  (0.001%).

Mean particle size from the generator is monitored by measurement of the polarisation of light scattered by the test particles. As with most particulate production processes it is reasonable to expect the number distribution of these particles to be

approximately log-normal as a function of radius. However, there are no known measurements of the actual size distribution in the Australian Hot DOP test facility. The term "monodisperse" is often applied to narrow distributions, generally where the geometric standard deviation (gsd) is less than about 1.2. The original design of the hot DOP penetrometer aimed at such a monodisperse aerosol with a gsd of about 1.05 and a median radius of 0.15  $\mu\text{m}$ . However, recent studies suggest that the actual operating conditions may diverge considerably from these design values.

Skaats (1979)(3) reported size distribution data for a Q107 penetrometer; he found a count median radius of 0.19  $\mu\text{m}$  and a gsd of 1.28 at the specified operating conditions. For normal HEPA filters this would produce a lower penetration than an aerosol with the nominal radius. In contrast, Hinds et al. (1979/2; reported size distribution data for Q127 penetrometer (which uses a similar generator to the Q107). They found a count median radius of 0.115  $\mu\text{m}$  and a gsd of 1.15 at the specified operating conditions. This aerosol would produce a considerably greater penetration than an aerosol with the nominal 0.15  $\mu\text{m}$  radius for normal HEPA filters. Knowledge of the actual distribution is clearly important if comparisons are going to be made between different test methods or even similar penetrometers. In the absence of better knowledge the "nominal" aerosol properties will be assumed for the Australian hot DOP test rig although this point will be discussed again later.

The second test method used in Australia, the "sodium flame" method, is a British system developed at Chemical Defence Establishment, Porton Down and is incorporated in the British standard BS3928. It employs a dry, polydisperse test aerosol of sodium chloride. Particles are generated from an aqueous solution in a pneumatic nebulizer and dried to a low humidity (<25% RH) before passing to the test filter. In this method the detection system is a sodium flame photometer which responds to the mass of sodium contained in the test aerosol over the whole test aerosol size spectrum (that is from a radius of around 0.01  $\mu\text{m}$  to several micro-metres). The flame photometric technique is slightly more sensitive than the forward scatter method giving a penetration limit (by mass) of around  $1.5 \times 10^{-6}$  (Dorman 1981). Until now details of the actual size distribution of test particles in this test rig were not available.

One limber difference between the two test methods is the concentration of aerosol required to achieve the maximum sensitivity. Data from Dorman (1981) (1) shows that, to reach the limits given earlier the DOP test requires a mass loading in the test aerosol some twenty-five times that of the sodium flame test.

## MEASUREMENTS

### Measurement of Particle Size and Concentration in Sodium-Flame Test Rig

Particle size and concentration in the Gelman Sciences sodium-flame test rig was determined by the author with a Knollenberg ASASP-X active scattering single-particle size-spectrometer. This detector provides sixty size channels covering approximately 0.05  $\mu\text{m}$  to 1.5  $\mu\text{m}$  radius in four overlapping ranges. Before the main series of measurements it was calibrated with mono disperse polystyrene latex (psl) particles. There are two main sources of possible sizing error. For sodium chloride particles as used in the filter tests the refractive index is 1.50, whereas for the calibrating psl particles the refractive index is 1.59. However, because the wide range of scattering angles in the ASASP-X this difference in refractive index is expected to result in only a very small difference in response, as indeed the work of Garvey and Pinnick (1983)(4) confirms. The second source of sizing error is the difference in response between spherical calibration particles and cubic crystals, the most likely form of the test particles. There are no known published data on the response of the ASASP-X to cubic particles. But by analogy with other active-scattering instruments, for example the response of the Knollenberg ASASP reported by Pinnick and Auvermann (1979)(5), it is possible to conclude that this will also be a small effect, at most requiring an upward correction of about 10% in radius. It should be noted that all sizes quoted in (his paper are optically-equivalent psl sizes, the error in converting to cubic salt particles is estimated at less than 10%, except possibly in the region around 0.14 to 0.22  $\mu\text{m}$  radius, where the calculations of Garvey and Pinnick (1983)(4) indicate a possible underestimation of about 20% for spherical salt particles.

Particle concentrations in the filter test rig are relatively high upstream of the filter, that is, in the "challenge" aerosol. In order to avoid overloading

which would produce dead-time and coincidence problems, it was found necessary to dilute the upstream samples. This was done with a diluting chamber (a small wind-tunnel) in which a measured flow of absolutely filtered air and a measured flow of sample air were mixed. The size-spectrometer sample was drawn from the down-stream end of the diluter and excess air vented. A typical dilution ratio of 45 to 1 was used with an estimated uncertainty of less than 10%. The accuracy of the dilutee when connected to the test-rig was checked using a range of the counter which did not overflow with an upstream sample and which gave a measurable down-stream count. This produced a dilution ratio of 48.7 (from counts of 39872 and 818) compared with 45.6 calculated from flow rates. During the actual filter tests the size-spectrometer activity monitor indicated that no corrections for dead-time or coincidence were necessary.

The upstream particle size distribution for a typical determination is plotted in Figure 1 in log-log coordinates. As expected for the type of nebulizer used, a Collison type (with added baffles to decrease the concentration of large particles), the distribution is approximately log-normal. For computational purposes a log-normal distribution was fitted to the upstream distribution by least squares methods (in natural coordinates and with equal weightings). This distribution, also shown in Figure 1, has a geometric

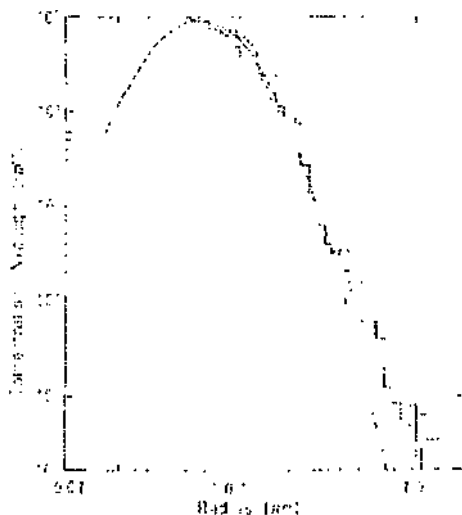


Figure 1: Size distribution of NaCl test aerosol particles as determined with ASASP-X size-spectrometer and log-normal distribution fitted by least-squares method.

mean radius  $R_m = 0.57 \mu\text{m}$  and geometric standard deviation  $\sigma = 1.7$  and gives a mass-median radius of 0.135  $\mu\text{m}$  the same value as determined directly from the cumulative distribution of measured particle volumes. The

divergence between the analytic and experimental curves at radii greater than about 0.4  $\mu\text{m}$  is the result of fitting in natural coordinates rather than log coordinates which would unduly weight the large particle end of the spectrum, where the contribution to the penetration is relatively small. This distribution parameters are within, although towards the lower end of, the range reported for a Collison type nebulizer operating with a 2% salt solution. There is a problem in obtaining representative data for Collison nebulizers because of variations in the actual design, inclusion of baffles (as here) to reduce large particle concentrations and different operating conditions. Some of the earlier size measurements also are probably of questionable accuracy, particularly at radii less than about 0.1  $\mu\text{m}$ . Dorman (1981) for example gives the mass median radius  $R_{mm}$  for NaCl particles from the BS3928 generator from a 2% solution as 0.325  $\mu\text{m}$  although the measurement method is not specified. Dorman also gives a mass median radius for a Collison type nebulizer used in the French uranine method with 1% sodium fluoresceinate as 0.075  $\mu\text{m}$ . For a 2% salt solution this would give a  $R_{mm}$  of approximately 0.095  $\mu\text{m}$ . May (1973)(6) gives data for a di-octyl sebacate aerosol (viscosity  $0.2 \text{ m}^2 \text{ s}^{-1}$ ) generated with a Collison nebulizer and measured with a cascade impactor. These results should be similar to water, and for a 2% solution would give a dry salt  $R_{mm}$  of 0.27  $\mu\text{m}$ . May (1973) (6) questioned the accuracy of earlier distribution data reported in Green and Lane (1957) (7) which gave about a forty percent larger mean radius.

### Measurement of Penetration Transfer Function

Calculation of the size dependent penetration function follows immediately from the size dependent concentrations determined for the upstream and downstream samples. All eleven filters tested exhibited very similarly shaped penetration functions although each was characterised by considerable statistical fluctuations at the large particle end due to the low number of particles penetrating in any one size bin. In order to obtain a better estimate of the properties of the filter medium itself, upstream and downstream concentrations for all the filters were lumped and a mean penetration determined. At the large particle end, several size bins were also amalgamated to give a minimum count per bin of twenty particles. The actual

penetration values and a quadratic function fitted to the penetration data by linear least squares methods are plotted in Figure 2 (for a face velocity of  $2.4 \text{ cm s}^{-2}$ ).

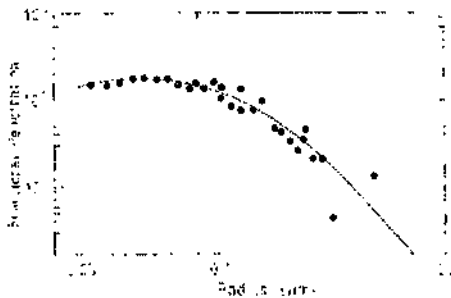


Figure 2: Mean fractional penetration determined by lumping together the respective upstream and downstream concentrations for the 11 good filters tested. The continuous curve is a quadratic fitted to the penetration values by linear least-squares methods.

This present quadratic approximation and some other reported penetration data for different HEPA filters are also plotted in Figure 3. In broad terms

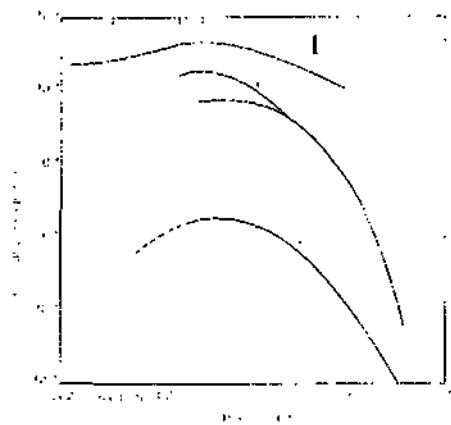


Figure 3: HEPA filter penetration as a function of particle radius;  
 (i) Dymont et al. (1983)(8), concentrations determined in electron microscopy;  
 (ii) Flanders filter using laser size spectrometry, from Email (1983)(9)  
 (iii) Deworm (1983) (10), laser size spectrometry;  
 (iv) present work, laser size spectrometry.

the typical radius for a maximum penetration is similar for all cases, that is around  $0.05$  to  $0.08 \mu\text{m}$ . There are some differences in the rate of fall-off in penetration for large particles and a noticeable difference in absolute penetration at the peak. Admittedly the data of Dymont et al. (1963) (8) would refer to a quite old filter type. This transmission curve was also derived differently to the others; size and concentration of particles were determined by electron microscopy whereas in the other cases laser size spectrometry was used. In

practical terms, as it will be shown later, there is not a great deal of difference between the Gelman and Flanders filter penetration distributions.

### Ratio of Penetrations Determined by NaCl and Monodisperse Particle Methods

Several possible avenues are open for determination of the ratio of penetrations obtained with the sodium-flame and hot DOP tests. The most obvious is to subject a number of filters to tests in both test-rigs. This approach has indeed been followed elsewhere but for a number of reasons the results obtained have often been somewhat conflicting and commercial considerations do not always allow this option. The indirect method as used here is to employ an independent measurement of both the volume penetration, simulating the NaCl test and the mono-disperse  $0.15 \mu\text{m}$  radius penetration simulating the DOP test, thus minimising errors that arise from sampling with two different instruments. Because the flame photometer response (ideally) is linearly proportional to the mass of sodium in an aerosol particle, penetrations derived from these measurements and those determined from the calculated volume distributions of the upstream and downstream particle size distributions should be equivalent. Figure 4 shows the actual relationship found between the calculated volume penetrations and the experimentally observed NaCl penetrations for the eleven test filters.

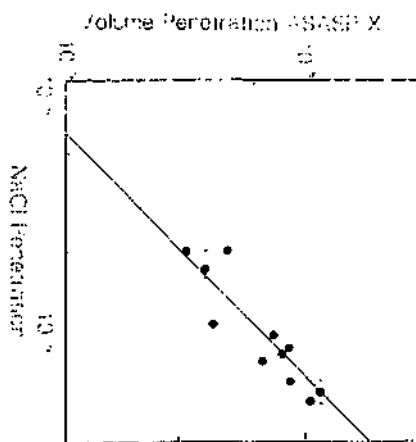


Figure 4: Fractional penetration calculated from laser size-spectrometer derived particle volumes as a function of sodium flame determined penetration for the eleven good filters. Error bars indicate typical change in penetration during a determination. The solid line is a linear least squares regression in log coordinates.

These show a reasonable degree of correlation. However, on average the

KaCl flame-photometer derived penetrations are around 37% smaller than the volume penetrations. Possible causes for this difference include size selective differences in sampling efficiency between the ASASP-X and the flame photometer, non-linearity in the flame-photometer response, error in ASASP-X dilution ratio and sizing error in the ASASP-X. Within the constraints of this experiment it was not possible to determine the main underlying cause of the difference, however, this magnitude of difference should not be of great concern. It is indeed quite typical of the scale of differences encountered when comparing independent measurement techniques with aerosol systems. A value simulating the penetration of a  $0.15 \mu\text{m}$  radius mono-disperse DOP particle, but which explicitly excludes possible differences due to particle composition, is easily determined from the upstream and downstream particle concentration-size distributions.

Volume penetrations from the ASASP-X ( $P_v$ ) data are plotted against penetrations for  $0.15 \mu\text{m}$  radius mono-disperse particles ( $P_m$ ) derived from the ASASP-X data in Figure 5. This

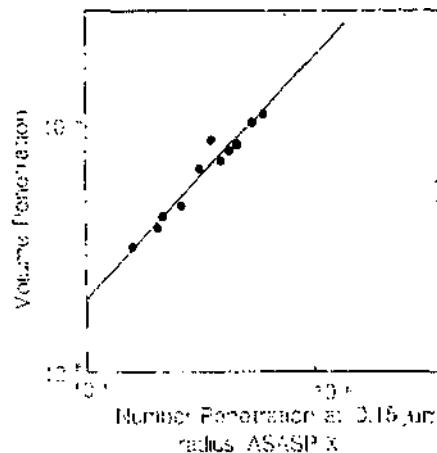


Figure 5: Fractional volume penetration as a function of penetration at  $0.15 \mu\text{m}$  radius, both values determined from the laser size-spectrometer. The solid line is a linear least squares regression in log coordinates and indicates a consistent ratio of 2 to 1 in penetrations.

shows a very consistent relationship with a ratio  $P_v/P_m = 2.0$ , a value somewhat at variance from the generally held notion that the ratio should be around 0.5 and requiring some explanation.

### Calculation of Penetration Ratio From NaCl Test Particle Size Distribution and filter Transfer Function

Dorman (1981)(1) has shown that laboratory tests on HEPA papers for

similar face velocities to those used here, typically produce a ratio of NaCl penetration to mono-disperse 0.15  $\mu\text{m}$  radius DOP penetration of 0.5 to 1. Tests of completed filters more typically give a ratio of 1 to 1. The indirect determination above indicated a ratio of around 2 to 1. To see how these differences could arise, it is instructive to calculate the expected volume and mono-disperse 0.15  $\mu\text{m}$  radius penetration values for a typical filter transfer function and a number of test distributions spanning the reported or likely range for Collison nebulizers.

Results of this type of calculation are plotted in Figure 6 based on an approximation to the integral penetration by summation from 0.01  $\mu\text{m}$  radius to 1.0  $\mu\text{m}$  radius at one-tenth decade intervals. These calculations are for test distributions that are log-normal and have gsd values of 1.7 or 1.9; values that span the most likely range. Two different filter transfer functions have been used, the first is for Gelman filters as determined above (continuous curves), the second for a Flanders filter using data from Email (1983)(9) (solid points). The dependent variable for these calculations is the test distribution mass-median radius although this could equally have been the number median since there is a simple conversion for log-normal distributions using the Halch-Choate relation.

$R_{nm} = R_{nm} \exp [3 \ln^2(\text{gsd})]$   
 where  $R_{nm}$  is the mass median radius and  $R_{nm}$  is the number median radius.

Given that the typical range of mass-median radii for Collision type nebulizers spans from around 0.1  $\mu\text{m}$  to 0.35  $\mu\text{m}$  it is immediately evident from Figure 6 that penetration ratios between 3 to 1 and 0.2 to 1 could be expected depending on the actual NaCl test distribution used. The indirect value of 2 to 1 obtained earlier (point A in Figure 6), is plotted at the experimentally determined test distribution mass-median radius of 0.135  $\mu\text{m}$ .

For comparison the "British standard BS3928" Collison nebulizer mass-median radius of 0.325  $\mu\text{m}$  would give a penetration ratio around 0.25 to 0.4. Point B in Figure 6 shows the penetration ratio obtained from the flame photometer mass penetration and ASASP-X number penetration values and in accord with the ratio of the NaCl to ASASP-X penetration ratios is somewhat higher than the completely independent determination.

### Effect of Variation of DOP Distribution

So far the discussion has assumed that

the distribution of DOP particles was close to mono-disperse and with a number geometric mean radius of 0.15  $\mu\text{m}$ , the design values for the Q107 penetrometer. Since, as shown earlier, there is some question of the accuracy of these nominal values it is instructive to examine the variation in penetration ratio expected for different DOP distributions. As an illustrative example it is reasonable to assume a log-normal distribution and arbitrarily select a geometric mean radius of 0.1  $\mu\text{m}$ . Penetrations were calculated as before with the quadratic penetration function for a Gelman filter but using 100 logarithmic size intervals between 0.1  $\mu\text{m}$  and 1.0  $\mu\text{m}$  radius; the results are given in Table 1. As expected from the filter penetration curve the penetration at 0.1  $\mu\text{m}$  is greater than at 0.15  $\mu\text{m}$  radius and for a monodisperse distribution is approximately 3.5 times greater. This DOP distribution would then result in a penetration ratio of  $P(\text{sodium-flame})/P(\text{DOP})=0.6$  at an NaCl mass median radius  $R_{m,m} = 0.135 \mu\text{m}$  and approx 0.1 at 0.325  $\mu\text{m}$   $R_{m,m}$ . Table 1 also illustrates the effect of increasing the geometric dispersion of a DOP distribution. As the dispersion increases and the distribution broadens the mass median radius increases and the integrated penetration decreases. The need to know the actual operating condition in the test rig is clearly evident.

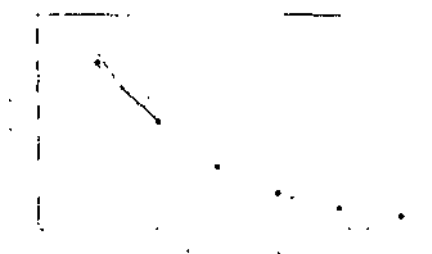


Figure 6: Penetration ratio, (volume penetration, penetration at 0.15  $\mu\text{m}$  radius) as a function of test distribution mass median radius and geometric standard deviation, calculated for two filter types. The solid curves are for the Gelman HFPA filters as reported here with distribution gsd values of 1.7 and 1.9, the solid points for a Flanders filter described in Email (1983) and a distribution gsd of 1.7. The point marked A is the penetration ratio determined entirely using the size spectrometer and that marked U the penetration ratio determined from the sodium flame test and the penetration at 0.15  $\mu\text{m}$  radius from the size spectrometer.

the test aerosol was found to be approximately log-normally distributed with a mass-median radius of 0.135  $\mu\text{m}$  and a geometric standard deviation of 1.7.

A value for the ratio of NaCl penetration/0.15  $\mu\text{m}$  radius penetration of 2 to 1 was obtained indirectly for Gelman top-grade HEPA filters using an ASASP-X single-particle size-spectrometer. This value was supported by calculations of the expected penetration ratio using an experimentally determined transfer function for Gelman filters and a product data value for Flanders filters with typical test distribution parameters.

Penetrations determined from the particle volume distribution and the sodium flame photometer while reasonably correlated showed a consistent difference, the cause of which was not determined.

It is abundantly clear from Figure 6 and Table I that meaningful comparison of penetrations expected from the two test methods by either direct measurement on sets of filters or by simulation can only be made if the actual test particle distributions are known and known to be stable and reproducible.

With the present test arrangements it is evident that the sodium chloride nebulizer flame-photometer test is at least as efficient a test for HEPA filters as the currently accepted DOP test. In a number of respects it appears to offer real advantages. Because of the wide range in challenge particle sizes and the shapes of the particle volume and filter penetration functions the effective penetrating aerosol size is smaller than in the hot DOP test (assuming the traditional value of 0.1  $\mu\text{m}$  radius). Much lower particle loadings are required to achieve the same penetration sensitivity and the aerosol is probably a much closer approximation to the aerosol likely to be encountered in practical applications.

In most applications either test method, hot DOP, or sodium flame should provide an entirely adequate criterion for filter acceptance. For critical applications size dependent single-particle counting as used in the tests described here (or with a white-light scattering counter for larger particles) provides a powerful means for ensuring that particles in particular size classes are adequately filtered and should be considered as a possible supplement to either the narrow size distribution hot DOP test or integrated-mass sodium flame test.

### CONCLUSIONS

For the present NaCl test arrangement

Table 1

Penetration ratio  $R_{p1}$  (penetration for test distribution/penetration for 0.15  $\mu\text{m}$  radius mono-disperse particles) calculated for a test aerosol distribution with a log-normal distribution, a number geometric mean radius of 0.1  $\mu\text{m}$  and other distribution parameters as given. Values of a penetration ratio  $R_{p2}$  (penetration at the mass median radius/penetration at 0.15  $\mu\text{m}$  radius) are also given.

Geometric Standard Deviation	$R_{p1}$	$R_{\text{mm}}(\mu\text{m})$	$R_{p2}$
1.001	3.6	0.10	
1.1	3.4	0.10	3.4
1.2	2.9	0.11	2.9
1.3	2.3	0.12	2.1
1.4	1.8	0.14	1.3
1.6	0.94	0.19	0.28
1.8	0.48	0.28	0.23

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## OVERSEAS NEWS

### BRITAIN TO OVERHAUL AIR POLLUTION LEGISLATION

New powers to control industrial air pollution have been proposed by the UK's Department of the Environment. The consultation paper, issued December 1986 and entitled, "Air Pollution Control in Great Britain - Review and Proposals", suggests giving local authorities powers to approve pollution control systems before factories start activities likely to result in pollution problems. Another important change proposed is the setting of both air quality standards and emission limits by the Secretary of State for the Environment. Among other measures being considered is the question of wider access to information about air pollution; the proposal is to publish public registers which would show, in some detail, what controls a particular plant is expected to operate under.

Under the existing air pollution control system, the most polluting industries are controlled by the national Industrial Air Pollution Inspectorate (shortly to become part of the combined Inspectorate of Pollution). These include most chemical processes, iron and steel works, coal transformation plant, and electricity generating power stations. At present the local authorities have powers to enforce the terms of the Clean Air Acts on small to

medium sized combustion plant, and apply the terms of Planning and Public Health Acts to prevent and abate nuisance.

The new proposals mark the first major review of air pollution control legislation in the UK since the 1956 Clean Air Act was passed. The aim is to give local authorities operating powers similar to those of the national Inspectorate, so that they can require the industries under their control to use the best practicable means to prevent and render harmless any noxious and offensive emissions. Before plant management can begin operation, or make significant changes to existing works, they will need to obtain prior consent from the local authority. To ensure consistency across the country, the best practicable means requirements for a type of works will be worked out in advance in discussions between representatives of central and local government and industry.

The new powers will have greatest effect on the range of middle-rank polluting processes, as defined in Annex 2 of EEC Directive 84/360, "Directive on the Combating of Air Pollution from Industrial Plant". These include small iron foundries, plants making glass and ceramics, and incinerators burning non-toxic wastes.

### CANADA 1ST TO RATIFY VIENNA CONVENTION ON THE OZONE LAYER

On June 4 1986, Canada became the first nation to ratify the Vienna Convention for the Protection of the Ozone

Layer. Under the terms of the Convention, participating nations commit themselves to protect human health and the environment from adverse effects resulting from modifications to the ozone layer. The Convention provides for international cooperation in related research, monitoring, scientific assessment and the exchange of information, and Canada has been one of the leading nations in promoting research and regulatory measures to protect the ozone layer. Since 1980, regulations under the Environmental Contaminants Act have banned the use of CFCs in hairsprays, anti-perspirants and deodorants, resulting in a 45% reduction in CFC use. Canada also operates the World Zone Data Centre for WMO, and a Canadian remote-sensing instrument, the Brewer spectrophotometer, is being sold internationally to modernise the global network of ground based ozone layer measurements.

Even small changes in the ozone layer are important; a 1% depletion of ozone produces a 2% increase in ultraviolet radiation and a 4% increase in skin cancer. Recent calculations suggest ozone depletions of more than 10% in the next 70 years if CFC emissions continue to grow. An unexplained 30% reduction in ozone over the Antarctic has recently been detected, and international efforts to protect the ozone layer are growing. However, Canadian scientists found no corresponding decrease in the ozone layer in the North polar region, in an experi-

(Continued on page 69)

# RAINWATER ACIDITY IN SYDNEY, AN ADDENDUM

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## ABSTRACT

A recently reported 3 month, 12 site study of rainwater composition in Sydney during the summer of 1980/81 has been extended over a further 20 months at three of the sites. The extended study shows that pH varied seasonally, with summer maximum and winter minimum, that sulfuric acid contributed about twice as much to summertime acidity as nitric acid, and that calcareous aerosol material is a major acid-neutralising agent in the Sydney atmosphere.

## KEY WORDS

Rainwater acidity, rainwater composition.

## 1. INTRODUCTION

A recent paper by Ayers and Gillett (1) described the first Australian work directed towards assessing the extent of rainwater acidification in an urban/ industrial region, namely Metropolitan Sydney. The purpose of this note is to extend that analysis to include data covering at least one annual cycle, to assess the relative contributions of sulfuric and nitric acids to summertime acidity, and to study the role of calcareous aerosol material as an acid neutralizing agent in Sydney rainwater.

## 2. EXPERIMENTAL

Of the 12 sites used in the original 4 months study (1), 3 were maintained (sites 2, 3 and 10) so as to provide data records over at least a full 12 months period. Site 10 was maintained for almost 2 years.

Rainwater sampling procedures were unchanged from the original study, and have been fully described by Ayers and Gillett (1). Analytical

techniques for pH and ammonia were also unchanged, however determination of the anions chloride, nitrate and sulfate in the supplementary study was carried out by suppressed ion chromatography using conductivity detection (Dionex columns). In this study dissolved calcium concentration was also determined by atomic absorption spectrophotometry. In both cases techniques used were standard (for example see Galloway et al., 1982), and gave analytical accuracies for all ions of better than 10% (95% confidence) for an individual determination, in the range of concentrations encountered.

## 3. Results

### 3.1 Rainwater Acidity

Monthly volume-weighted mean pH

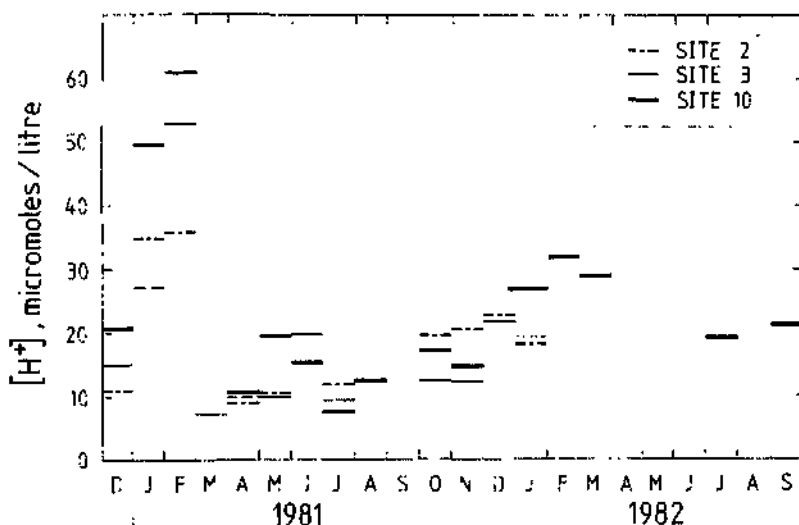


Figure 1. Time series of monthly volume-weighted mean  $H^+$  concentration in Sydney. Missing points at each site represent months when fewer than 3 samples were collected.

Table I. Vol-weighted mean concentrations in Sydney rainwater,  $\mu\text{eq. L}^{-1}$ . Calcium and sulfate concentrations in excess of the quantities contributed by seawater are prefixed by "xs"

	$H^+$	$NI_4^+$	xs $Ca^{2+}$	$NO_3^-$	xs $SO_4^{2-}$
Nov.80-Mar.81 <sup>a</sup>	36.3	18.8		13.6	
Nov.81-Mar.82 <sup>b</sup>	21.0	3.2	9.0	9.8 <sup>c</sup>	24.2

a. Ayers and Gillett (1984), all sites, 294 samples.

b. This work, sites 2, 3 and 10, 68 samples.

c. 59 samples.

values for each of the three sites are depicted graphically in Figure 1. Gaps in the records are shown when fewer than three events were encountered at the site in any month. Overall mean hydrogen ion concentrations calculated from all the data from each site are tabulated in Table I, which also includes the figures given by Ayers and Gillett (1984) for the first summer period (first 4 months). Three points can be made. The first is that acidity during the second summer was less than that during the first. We attribute this to interannual variability which is common with many meteorological phenomena. The second is that some seasonality is apparent in the time series, which seems to be indicative of a winter minimum and summer maximum in pH at all 3 sites. This suggests that on an annual basis rainwater pH will tend to be less acidic than indicated by the summertime observations alone, as in the case of Ayers and Gillett (1984). However, there is still some bias towards the summertime values on a volume-weighted mean basis since Sydney experiences a summertime peak in rainfall. Overall, the longer time series indicate a typical annual average pH in the vicinity of 4.6. The third point is that even in the less acidic

winter period the rainwater pH still shows evidence of acidification above the regional background level of about 5.1 (1): the volume weighted mean of the combined site data for the months April to October, inclusive (Figure 1) is 4.83.

These results are consistent with results from an independent study carried out over 14 months from January 1981 at Newcastle, 100km north of Sydney (3,4). This study also found a winter minimum, summer maximum in acidity, but with pH values averaging about 0.3 pH units higher than in Sydney, a difference explicable in terms of the different acid precursor source strengths: Newcastle has a population base of  $2.5 \times 10^5$  compared with  $3 \times 10^6$  for Sydney.

### 3.2 The Importance of Sulfuric Acid

The 1980/81 summertime work of Avers and Gillett (7), in which sulfate could not be measured, suggested that nitric acid contributed a maximum of only slightly more than one third to measured free acidity. In this supplementary study 68 rainwater samples, randomly selected during the summer of 1981/82 (34 from site 10, 17 each from sites 2 and 3) were analysed for chloride, nitrate and sulfate by ion chromatography. As discussed more fully in the earlier work, chloride levels were high as a result of the predominantly onshore summertime winds and the close proximity of the sites to the coast. Thus we use the measured chloride concentrations plus the seawater sulfate to chloride mole ratio (5) of 0.0517 to estimate the sea salt contribution of sulfate to each sample. The excess sulfate ( $xs\ SO_4^{2-}$ ) in the 68 samples had weighted mean concentration of 24.2  $\mu\text{eq/L}$ , compared with a mean nitrate concentration of 9.8  $\mu\text{eq/L}$ . An alternative way of comparing the concentrations of these two ions was to regress nitrate on sulfate ( $\mu\text{eq/L}$ ), which for the 68 data points yielded

$$\text{NO}_3^- = 0.4 + 0.48\ xs\text{SO}_4^{2-}$$
with intercept and slope standard errors of 2.0 and 0.05, respectively, and correlation coefficient of 0.78. The data thus indicate that sulfuric acid probably contributed about twice as much to rainwater acidity as nitrate, which is consistent with the inference drawn from the nitrate data alone, from the previous summer (1).

**Table 2.** Regression coefficients, 59 samples, summertime 1981-82. Concentrations in  $\mu\text{eq/L}$ ; standard errors in parentheses; r is the correlation coefficient.

Y	X	slope	intercept	r
H <sup>+</sup>	NO <sub>3</sub> <sup>-</sup> + xsSO <sub>4</sub> <sup>2-</sup>	0.12(0.04)	16.6(2.4)	0.39
H <sup>+</sup> + NH <sub>4</sub> <sup>+</sup>	NO <sub>3</sub> <sup>-</sup> + xsSO <sub>4</sub> <sup>2-</sup>	0.26(0.04)	16.1(2.5)	0.65
H <sup>+</sup> + NH <sub>4</sub> <sup>+</sup> + xsCa <sup>2+</sup>	NO <sub>3</sub> <sup>-</sup> + xsSO <sub>4</sub> <sup>2-</sup>	0.66(0.07)	14.6(4.1)	0.79

### 3.3 Contribution of Calcareous Aerosol to Rainwater Alkalinity

Ayers and Gillett (1) suggested that measured free acidity in their rainwater samples reflected a balance between rainwater acids and alkalinity contributed by ammonia, and some other alkaline species. They speculated that calcareous aerosol material was a likely source of rainwater alkalinity in addition to gaseous ammonia. In the supplementary study this speculation was addressed using data on calcium concentration determined in 59 of the 68 samples from the summer of 1981, 82 in which sulfate, nitrate and ammonia were also determined. For these samples excess sulfate was estimated as above, while excess calcium was estimated in similar fashion using the seawater calcium to chloride ratio (5) of 0.0188.

The balance between hydrogen ion plus excess calcium on the one hand and excess sulfate plus nitrate on the other, evident in Table 1, certainly implicates calcareous material in the acid-base balance of Sydney rainwater. Moreover, when hydrogen ion, hydrogen ion plus ammonium, and hydrogen ion plus ammonium plus excess calcium were regressed in turn against excess sulfate plus nitrate, the results shown in Table 2 were obtained. It is no surprise that the slope and intercept from each regression remain significantly different from unity and zero, respectively, since the cation-anion balance in the atmosphere can hardly be represented by the simple equivalences implied in the regression equations. However, the clear increase towards unity in both correlation coefficient and slope as first ammonium, then excess calcium is added to the cation sum points clearly to the conclusion that both gaseous ammonia and calcareous aerosol material act as neutralizing agents for sulfuric and nitric acids in Sydney rainwater.

### 4. CONCLUSIONS

Rainwater properties in Sydney that could not be investigated during the summertime studies of Avers and Gillett (1) were examined during the ensuing year in which rainwater collections were continued at 3 sites. Three conclusions could be drawn from the supplementary study: (1) rainwater acidity in Sydney varies seasonally, being higher in summer than winter. The wintertime rain was still mildly acidic, having a mean pH of 4.8, about 0.3 pH units lower than 'unpolluted' rainwater in the region; (2) in summertime samples sulfuric acid contributed about twice as much to rainwater acidity as nitric acid; and (3) in addition to gaseous ammonia, calcareous aerosol material plays a significant role in partially neutralizing nitric and sulfuric acids in Sydney rainwater.

#### Acknowledgement

We gratefully acknowledge the assistance of the Department of Chemistry, Macquarie University, for use of an atomic absorption spectrophotometer for the calcium analyses.

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(Continued from page 67)

ment conducted at a new remote monitoring site in the Arctic during April 1986.

Source: *Environment Canada, Update, Vol 6 No. 2, November 1980*



# WRITING A GOOD SPECIFICATIC FOR ENQUIRY DOCUMENTS

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## GENERAL INTRODUCTION

The extremes in enquiry documentation:

- 1) Please supply price for dust collector for our furnace.
- 2) A BMP or SECV document of 400 pages spelling out volumes, temperatures, filtering velocities plate thickness and wind directions and number of toilets.

The ideal is obviously a balance between these two extremes. This is an attempt to establish the major factors that need to be provided by the clients to allow the contractors to provide meaningful tenders for adjudication, which in turn will lead to the installation and operation of a successful system.

To make the task of formulating an enquiry document easier the use of a standardised proposal data list is suggested (Appendix 1).

## SECTION 1 GENERAL INFORMATION

This section is self-explanatory but highlights some general points which are very important for the contractor i.e. communication, information which indicates how much time needs to be spent on formulating a tender.

## SECTION 2 PLANT PROCESS

This section is for the purpose of describing the plant, process or application. Without this information the Contractor cannot make the correct equipment selection or recommendation.

Give a full description of the process or equipment generating the gas to be cleaned.

State the boiler, furnace kiln etc. type and give as much detail as possible

about the type, make output, continuous rating, peak rating and variations in operation.

Describe raw materials and if possible give analyses. If it is intended to use various types of raw materials information on type and the proportions to be used should be given. State which type will generally be used and for which the efficiency guarantee will apply.

This may seem a fairly unnecessary request, but to highlight how it can influence the design and operation of a plant let me give you two examples, from my own experience, where either incorrect or incomplete information has led to major problems after the installations were complete - both illustrations being from the steel industry.

- 1) We had a request to supply a fume extraction system for a 30 ton electric arc furnace producing steel.

The system provided incorporated a direct extraction system with watercooled duct leading to a forced draught cooler and bagfilter unit.

All the necessary information was gathered prior to final design and the application was considered to be fairly standard in our experience.

After some 4 months operation extraction was lost at the furnace and investigations revealed that the cooler was blocked.

The cooler consisted of 300 or so 100 mm diameter tubes through which the hot gas flowed - cold air being blown across the outside of the tubes for cooling.

The tubes were blocked top and bottom. After cleaning the cooler proceeded to block up every two weeks.

After many tests it was established that there was in excess of 35% zinc oxide in the dust making it very sticky. It was found that this excessive amount of zinc oxide was generated from the galvanised mild steel scrap being used in the furnace.

Yes we were at fault as well as the

client, as we did not highlight or mention that the use of galvanised scrap could influence the design of the system. Had we known we would have not utilised a forced draught cooler with 100 mm diameter tubes and the client would not have been landed with major extraction problems.

- 2) The other example is also related to raw materials being fed to an arc furnace. On this high power arc furnace the major raw material was sponge iron, oxygen being the major influence on the heat generated in the furnace during melting and decarburising.

After installation and some months after start up severe heating problems were being experienced.

Cutting a very long story short it was discovered that the sponge iron being used was of a sub-standard quality containing much more free oxygen than used in the design. Moreover it was found that, in order to minimise production time of each batch of steel, the operators were 'banging' in 50% more oxygen than was incorporated in the design.

We were therefore forced to point out to the client that their raw material was sub-standard and outside specification and that, the operators were operating outside the design limits of the extraction plant.

If a collector exists on a similar application within your company indicate its type and rating.

## SECTION 3 OPERATING CONDITIONS

In many companies the resources may not be available to establish extraction volumes and you would be relying on the Suppliers to establish the requirements.

Certain requirements and principles need to be adhered to, to ensure good dust and fume capture. I outline some of them below to allow you to consider establishing a preliminary volume yourself or at least to ask some relevant questions of the Supplier.

- 1) The major principle is to collect dust or fume at a point which is as close to the source as possible.
- 2) Correct hood design and configuration should be achieved to give maximum access for good operation and maintenance as well as good dust control.
- 3) Open areas and hence ingress air should be minimised to keep the overall extraction requirement

down.

Relating back to point 2 a good balance should be achieved between minimum open areas and general/maintenance access requirements. If a figure for openings is agreed and then during operation these open areas are considered not practical, the effective dust capture velocity is reduced and the efficiency of the system is destroyed. The principle to be achieved is that, of equalling the rate of generation of dust and air movement within the operating unit and hood by the ingress of air through the open areas.

In the case of a fume generated in a hot process the rate of fume rise may be 3 m/scc • it is therefore necessary to match this by ensuring that the ingress of air through the open areas around the hood exceeds 3 m/scc.

This section specifies the operating conditions for the collector listing:

1. Gas volume - continuous, peak and variations.
2. Volume on which performance guarantee is to be based.
3. Gas analysis - as this may affect gas density and hence sizing.
4. Moisture content - again this will affect either the sizing or the decision as to whether a bagfilter could be used.
5. Nature of the dust to allow for designed sizing of hoppers, collector support steelwork and dust conveying system.
6. Unusual characteristics of the dust may affect collector selection, provision of explosion venting, provision of flow assisting devices.  
If a representative sample of dust is available this will help, but the most realistic information can be gained from practical experience by the client.
7. If a particle size analysis is available state the basis - weight or number and the method of establishing the analysis.
8. Dust concentration if available is essential to allow (the Contractor to give a realistic guarantee. If you are unable to establish the concentration you may either have to rely on the Contractor's experience or have the loading measured by some outside agency.
9. Barometric pressure or elevation at plant site - an absolutely vital piece of information without which the system cannot be designed.

10. Other general operating conditions or requirements which may be felt relevant.

#### SECTION 4 REQUIRED PERFORMANCE

The required performance should be established by direct contact with the relevant State Air Pollution Control Authority. The contractor may be able to advise, but ultimately the operator must conform to the legislation laid down by the Air Pollution Control Authority.

Generally the Authority will advise a final emission figure in terms of mg/m and not a specific collector efficiency.

#### SECTION 5 LAYOUT DRAWINGS

Layout or location of a collector obviously plays an important part in the design of a total system. The routing of duct work in particular can affect significantly the pricing but also has to be fairly closely defined such that the system resistance and hence the fan static pressure can be established reasonably accurately.

#### SECTION 6 DESIGN FEATURES

Although most suppliers have standards to which their equipment is normally designed, the client may however have good reason to request specific design features.

It is suggested that the client has very good and relevant reasons for requesting changes to basic design levels of dust collectors as this will no doubt significantly increase the price. Changes in design pressure and temperature will result in a re-design of the casing and the production of a non-standard unit.

Where a scrubber unit is being considered the quality and availability of water should be clearly stated. Effluent treatment requirements and availability should also be indicated.

#### SECTION 7 AUXILIARY EQUIPMENT

Is the enquiry for a flange to flange unit? If not all the ancillary equipment which is required should be stated. It may be felt that the responsibility is with the supplier to define the equipment required for a successful installation. In this case it must be clearly spelt out that it is the supplier's responsibility. If this line of approach is taken it is absolutely essential that the client

carries out a thorough adjudication of all bids to ensure that tenders are judged on a comparable basis.

#### SECTION 8 ERECTION SCOPE

Estimating the erection requirements of a project at the tender stage is probably the most difficult and imprecise area of a proposal.

If more information can be given it will assist in minimising risk for all the parties concerned.

#### SECTION 9 AVAILABLE UTILITIES

Available utilities are self-explanatory.

#### SECTION 10 SPECIAL INFORMATION

Terms of payment, conditions of contract, escalation and other contractual requirements should be highlighted.

Ultimately the final order can be won or lost on variations in the contractual terms and conditions suppliers are prepared to accept. To simplify adjudication these should be standardised.

#### BID EVALUATION

Having issued a good enquiry and specification and received a number of quotations it is vital that these tenders are adjudicated in a realistic way.

The industry supplying gas cleaning equipment has found, especially during difficult economic times, that many clients do not carry out a full evaluation of the tenders and end up simply buying the system with the lowest initial cost. We do not believe that this is done with any improper motive, we believe that initial capital cost has the greatest impact on the buying office.

Obviously it will be established that all Contractors have quoted on the same scope of supply, terms and conditions of contract and that all guarantees and programme requirements can be met.

When all these are met and it is checked that the equipment can fit into the required space and that the contractor has prior experience in the application it is then necessary to carry out an economic evaluation.

## TENDER 1

Type of collector:	Electrostatic precipitator
Process gas temperature:	1 050 °C
Cooler type:	Evaporative
Cooler outlet temperature:	300 °C
Gas volume to collector:	46,90 Nm <sup>3</sup> /sec wet 113,0 Am <sup>3</sup> /sec
Dust loading at inlet:	19,5 g/Nm <sup>3</sup> wet
Collector efficiency (generated):	99,74%
Dust loading at outlet:	50 mg/Nm <sup>3</sup> wet
Pressure drop of collector:	20 mm w.g.
Fan static pressure:	120 mm w.g.
Fan motor installed power:	320 kW
Fan motor absorbed power:	250 kW
Transformer/Rectifier power:	200 kW
Ancillary motors:	21 kW
Cooling water power:	70 kW
Water consumption:	500 000 ℓ/h
Casing plate thickness:	5 mm mild steel
Design pressure:	300 mm w.g.
Weights - Cooling tower:	72 t
Precipitator casing:	107 t
Interior:	269 t
Support:	27 t
Cost - subject to escalation:	R2 845 000

## TENDER 2

Type of collector:	Wet venturi scrubber
Process gas temperature:	1 050 °C
Cooler type:	Wet scrubber
Cooler outlet temperature:	68 °C
Gas volume to collector:	27,5 Nm <sup>3</sup> /sec (dry) 80,4 Am <sup>3</sup> /sec
Dust loading at inlet:	19,5 g/Nm <sup>3</sup> wet
Collector efficiency (generated):	99,74%

Dust loading at outlet:	50 mg/Nm <sup>3</sup> wet
Pressure drop of collector:	1 200 mm w.g.
Fan static pressure:	1 400 mm w.g.
Fan motor installed power:	1 900 kW
Fan motor absorbed power:	1 580 kW
Scrubbing pump power:	140 kW
Water consumption:	160 000 ℓ/h
Casing plate thickness:	5 mm mild steel
Design pressure:	1 500 mm w.g.
Weights - Casing:	75 t
Refractory:	55 t
Support steelwork:	15 t
Cost - subject to escalation:	R1 250 000
Exclusions:	Effluent treatment

## TENDER 3

Type of collector:	Bag filter
Cooler type:	Water cooled duct radiant cooler
Cooler outlet temperature:	200 °C
Gas volume to collector:	75,3 Am <sup>3</sup> /sec
Dust loading at inlet:	30 mg/Nm <sup>3</sup> dry
Efficiency:	99,99%
Dust loading required at outlet:	100 mg/Nm <sup>3</sup> dry
Pressure drop across collector:	150 mm w.g.
Pressure drop across cooler:	150 mm w.g.
Fan static pressure:	400 kW
Fan motor installed power:	500 kW
Fan motor absorbed power:	430 kW
Ancillary motors:	40 kW
Compressor requirement:	25 kW
Water consumption:	10 000 ℓ/h
Casing plate thickness:	5 mm mild steel
Design pressure:	250 mm w.g.
Weights - Casing:	96 t
Cooler:	120 t
Support steelwork:	55 t
Cost - subject to escalation:	R 2660 950

## APPENDIX 1

### PROPOSAL DATA LIST FOR DUST COLLECTORS

Date:

Purchaser's Incentive Number

#### 1. General Information:

1.1 Purchaser .....

Address .....

Telephone Number .....

Telex Number.

1.1.1 L'scr (il'dill'ereiU from IIIJO(C) .....

Address .....

[2 Site location .....

13 Individual, title and address .....

1.3.1 To whom proposal is to be sent .....

1.3.2 To whom technical queries are to be addressed

1.3.3 To whom commercial queries are to be addressed

1.3.4 Number of copies of proposal .....

14 Date by which proposal is to be submitted, ...

- 1.5 Purpose of proposal: budgetary or firm? .....
- 1.6 Is formal proposal required, or priced letter? .....
- 1.7 When would order be placed? .....
- 1.8 Equipment delivery requirement date .....

1.9 Proposal basis (mark boxes):

Ex works  delivered to site  with erection  F.O.B.  C.I.F.

Other .....

**2. Plant Process**

2.1 Process to which dust collector will be applied .....

- 2.1.1 Design data of dust producing equipment .....
- 2.1.2 Type .....
- 2.1.3 Make .....
- 2.1.4 Output: Continuous rating ..... Peak rating .....
- 2.1.5 If process cyclic give details .....

2.2 Description of analyses of material or fuel .....

2.3 Expected variations in raw materials of fuel .....

2.4 Description and rating of existing collector equipment, if any .....

**3. Operating Conditions**

3.1 Gas volume to be treated ..... m<sup>3</sup> h

3.1.1 Continuous rating, actual m<sup>3</sup> h ..... at ..... C ..... =kPa .....

3.1.2 Peak rating, actual m<sup>3</sup> h ..... at ..... C ..... =kPa .....

3.1.3 Volume on which dust collector performance is to be based, continuous or peak .....

3.2 Gas analysis and density .....

3.2.1 Moisture content in gas ..... % by volume or ..... % by .....

3.3 Nature of dust to be collected (include specific gravity, bulk density with two values, one for volumetric capacity of dust hopper and the other for structural design) .....

3.3.1 Is dust known to have any unusual characteristics (hygroscopic, pyrophoric, explosive, sticky, etc.) .....

3.3.2 Is a representative sample of dust available? Yes/No .....

3.4 Particle size analysis (State method) .....

3.5 Dust concentration, g/Nm<sup>3</sup> dry/wet .....

3.5.1 Continuous rating, g/Nm<sup>3</sup> dry/wet .....

3.5.2 Peak rating, g/Nm<sup>3</sup> dry/wet .....

3.5.3 Condition on which collector performance is to be based: continuous or peak or cyclic .....

3.5.4 Barometric pressure or elevation at plant site ..... kPa or m

3.6 Is plant to be operated single/double shift or other schedule? .....

- 3.7 Maximum permissible pressure drop through equipment to be offered by supplier, kPa .....
- 3.8 Other operating conditions .....
- 4. Required Performance**
- 4.1 Collector efficiency .....
- 4.2 Permissible emission .....
- 5. Layout Drawings**
- 5.1 The dust collector should be installed generally in accordance with the attached drawing No. ....  
indicating any site restriction .....
- 5.2 Indicate single or multiple dust collector requirement .....

(Note: mg.m<sup>-3</sup> is to be understood as referring to milligrammes per cubic metre at 0° Celsius at site ambient pressure).

**6. Design Features**

The dust collector should have the following structural design features:

- 6.1 Operating pressure ..... = kPa
- 6.2 Design pressure ..... = kPa
- 6.3 Design temperature ..... C
- 6.4 Ground clearance to underside of dust discharge ..... m
- 6.5 Hopper material .....
- 6.6 Minimum hopper valley angle ..... from horizontal .....
- 6.7 Type of bottom: Hoppers (pyramidal, trough) drag scraper, wet or dry .....
- 6.8 Specific storage capacity ..... hours  
..... m<sup>3</sup>
- 6.9 Wet scrubbers (where applicable)
- 6.9.1 Water flow - l/s .....
- 6.9.2 Make-up water required l/s .....
- 6.9.3 Details of any additive required .....

**7. Auxiliary Equipment**

Auxiliary Equipment	By	Purchaser	Supplier
7.01 Supporting steel .....			
Access facilities - ladders, platforms, etc .....			
7.3 Ductwork and expansion joints .....			
7.4 Inlet and outlet mouthpieces .....			
7.5 Dampers .....			
7.6 Thermal insulation, cladding, weatherproofing, etc .....			
7.7 Hopper dust valves and conveyors .....			
7.8 Pumps and effluent treatment plant .....			
7.9 Fans and auxiliaries .....			
7.10 LV and MV wiring .....			
7.11 Instrumentation .....			
7.12 Control room .....			
7.13 Compressor and auxiliaries .....			
7.14 Dust conditioning .....			
7.15 Painting .....			
7.16 Other .....			

**8. Erection Scope**

- 8.1 Erection by purchaser or supplier .....
- 8.2 Erection supervisor services: separate quote or include in basic price .....
- 8.3 Commissioning engineer services: separate quote or include in basic price .....
- 8.4 Travel and subsistence costs for erection personnel by purchaser or supplier .....
- 8.5 Erection period: Starting date ..... Completion: date .....
- 8.6 Site information .....
- 8.6.1 Storage area m<sup>2</sup> ..... and distance from job site. .... m
- 8.6.2 Availability of secure storage area .....
- 8.6.3 Freedom of crane operation .....
- 8.6.4 Overhead obstacles .....
- 8.6.5 Distance utility sources are from job site ..... m
- 8.6.6 Is vehicle roadway and or railway right-of-way to storage area available to job site? .....
- If not, distance from unloading point to storage area ..... m
- 8.7 Scope of erection responsibility ..... Purchaser ..... Supplier .....
- 8.7.1 Foundations (piles or slabs) .....
- 8.7.2 Material unloading to storage .....
- 8.7.3 Material rehandling to job site .....
- 8.7.4 LV and MV wiring .....
- 8.7.5 Thermal insulation .....
- 8.7.6 Ductwork, dampers, expansion joints .....
- 8.7.7 Site lighting .....
- 8.7.8 Lifting equipment .....
- 8.7.9 Erection facilities: field office, changing and sanitary facilities .....
- 8.7.10 Erection utilities: air, water, power .....
- 8.7.11 Field Painting: (complete or remedial) .....

**9. Available Utilities**

- 9.1 For dust collector..... Volts.....phase.....Hz.....kVa.....
- 9.2 For erection.....Volts.....phase.....Hz.....kVa.....
- 9.3 For controls and instrumentation.....Volts.....phase.....Hz.....kVa.....
- 9.4 3 or 4 wire supply .....
- 9.5 Availability of water and steam and compressed air (kPa m<sup>3</sup> S) if applicable .....

**10. Special Information**

- 10.1 Standard specifications to be observed .....
- 10.2 Other remarks or comments .....
- .....
- .....
- .....
- .....

Signed on behalf of Enquirer.....  
 Date.....

## BOOK REVIEWS

### AIR • COMPOSITION AND CHEMISTRY

by Peter Brimblecombe  
Published by Press Syndicate of the University of Cambridge  
Distributed by Cambridge University Press, 10 Stamford Road, Oakleigh, Melbourne, VIC. 3166 Phone (03) 568 0322. Recommended price \$26.50 (paperback).

This book covers a wide variety of topics within its 224 pages on such diverse topics as geochemical, biological and maritime sources of trace gases to the chemistry and effects associated with gases, particles and rainfall from natural and anthropogenic sources.

It is well suited for teachers, students or anyone who wants a wide ranging general coverage of the atmospheric components near the surface of the earth or even on the distant planets.

The book contains many facts and figures on gas composition in a wide variety of atmospheres and there is sufficient explanation of the reactions in gas phase chemistry, photochemistry and chemistry in raindrops. There are a few topics in air pollution that do not rate a mention and many readers will be introduced to such areas as museum and library environments, indoor pollution, the chemistry of the ionosphere, tenuous atmospheres and the atmospheres of giant planets, satellites and small planets.

In covering such a wide scope it is possible to give only a brief introduction to many fields but at the end of each chapter there is a list of independent references to allow the reader to further research topics of interest.

In summary the book gives a concise overview of the composition and chemistry of air pollution in all of its forms, it is very readable and at the price of \$26.50 it should prove a suitable text for classes in environmental sciences.

LEN FERRARI

### PHYSICAL AND CHEMICAL CHARACTERIZATION OF INDIVIDUAL AIRBORNE PARTICLES

Edited by K.R. Spurny  
Published by Ellis Horwood Ltd., Chichester, Sussex and distributed by John Wiley & Sons Ltd., Chichester, (1986). xi - 418 pp..

\$55.00 (ISBN 0-85312-793-X).

This book, first published in 19X6, consists of 21 well-written chapters following an Fm induction by the Editor. Altogether there are 22 invited contributors in addition to the editor, and of these most are from the Federal Republic of Germany, whereas 6 are from the USA and 6 are from Belgium <5 from the University of Antwerp). The only contributor not encompassed on this listing is from the University of Vienna, Austria.

In addition to a treatment of the biological effects of particle inhalation the book is devoted to as the title would imply - to an in-depth discussion of the techniques available for identification and/or analysis of individual particles. The methods range through optical microscopy, a review of microchemical procedures, to modern instrumental techniques. A quick run through the Table of Contents reveals that the following methods are described: electron probe microanalysis (EPMA); laser microprobe mass analysis (LAMMA); particle induced x-ray emission analysis (PIXE); secondary-ion mass-spectrometry (SIMS); x-ray photoelectron spectroscopy (XPS). In addition, there are chapters devoted to the subject of measurement and identification of fibrous particles by both scanning and transmission electron microscopy, in which the techniques of wavelength-dispersive x-ray analysis (WDXA), energy-dispersive x-ray analysis (EDXA), electron energy-loss spectrometry (EELS) and selected area electron diffraction (SAED) receive mention.

The subjects referred to above are preceded in the book by earlier chapters which, inter alia, describe other fields such as the mathematical characterization of single particles and particle populations: sampling techniques; properties of filters; and determination of particle properties by light and laser scatter methods.

The book is well-written, adequately illustrated and well edited, and should be of considerable value to modern researchers in the field of aerosol technology in general and particle identification in particular. One omission noticed by this reviewer, in the section of the book devoted to optical microscopy, is any reference to the "dispersion staining" method of fibre identification in appropriate samples. This is unfortunate as the method is one of the USEPA approved methods for the identification of asbestos species in bulk and in some airborne samples; and hence a prospective purchaser could be excused for anticipating the topic

would be covered in a book with this title, and with a cover design depicting a photomicrograph of asbestos fibres amongst other particles. Nevertheless, this book contains considerable very useful information, and should find a place in the libraries of workers in various fields of aerosol technology.

K.S. BASDEN

### CHEMICALS AND SOCIETY

A guide to the new chemical age  
by Hugh D. Crone  
Cambridge University Press  
Paperback • 245 pages - \$19.95

The chemical age has brought us various blessings such as plastics, detergents, pesticides, herbicides, antibiotics and a number of other powerful drugs. These developments have enabled at least part of humanity to lead longer and more comfortable lives. Unfortunately, the new age has also brought us Bhopal, Minamata Ray and Thalidomide and a variety of other less spectacular threats to health and well-being. Fifty years ago most people believed in "progress" which meant to them among other things that "science" had the ability to find remedies for all of humanity's ills. The problems which we now face have shaken this belief and there is now a tendency to belittle the very real contributions which science and technology have made to modern life and to stress only the disadvantages arising from environmental pollution and health threats.

The author who is Head of the Personal Protection Group, Materials Research Laboratory, Melbourne believes that intelligent people have difficulty in assessing chemical matters because they do not have the conceptual background to digest the mass of information which is presented by the media and that this information is not, in general, objective and disinterested. His stated aim in writing this book is to provide this background and I believe that he has succeeded.

I remember being told fifty years ago that it was one of medical science's most cherished dreams to develop a completely safe anaesthetic. It was, however, even then realised that this was an impossible dream because: any chemical which has a marked physiological effect a low concentration must, of necessity be toxic at high concentrations.

The author makes the important point that there are no poisons, only poisonous concentrations. In other

words, no chemical is completely innocuous under all conditions. Even materials which are essential to life in small doses can be very toxic when administered in excess. Vitamins are an important example of this. A further important point is that there are no zero levels for any chemical in the environment. As our methods of detection and analysis are refined we find the presence of ever lower concentrations of all types of chemicals in any environment. Thus, the frequently voiced demand for zero concentrations of very toxic chemicals is impossible. Furthermore, there is no discernible difference between natural and synthetic chemicals. The natural environment contains many highly toxic chemicals. Asbestos, aflatoxins, morphia and other alkaloids are some of the better known examples.

The author deals at length with the entry of chemicals into the body and with their elimination and also with the protection of people exposed to chemicals both in industry and in the home. There are chapters dealing with cancer, chemical warfare and herbicides. A separate chapter is devoted to the public's perception of the herbicide problem.

The book concludes that we cannot eliminate all risks, only minimise them and evaluate whether overall the benefits from each chemical outweigh its deleterious effects. We also have to be alert and ensure that the people who produce, handle and use chemicals do so in a responsible manner.

The style is lucid and easy to read. The book gives a balanced view of the difficult problems which arise from the development of ever increasing numbers of chemicals in daily life.

HANNS HARTMANN

**"Environmental Planning - A Condensed Encyclopedia" by Alan Gilpin, Noyes Publications, Park Ridge (N.J.), 1986 (pp 348 with contents and subject index; \$US 48 cloth)**

Have you ever wondered what the 'Abercrombie Plans for London' were, what is meant by the term 'Ecosystem', what the 'Clean Air Amendment Act, 1970, US' was, or what is of interest in the major smelting operation at 'Sudbury, Ontario'? Should you ever seek answers to these questions, you will find the material in Gilpin's book.

With almost 900 subject entries listed alphabetically, the condensed encyclopedia provides a lot of precise

information across a wide range of fields and topics. The entries include:

- definitions of terms frequently used in environmental planning, such as 'Acid Rain', 'Hearings' and 'Swales'
- lists of Acts of parliament, relevant to environmental aspects, for most countries and for some selected Australian and North American States
- mention of the better known environmental legislation (e.g. 'National Environment Policy Act 1969')
- description of the major reports, agreements, commissions and organisations that have been involved with the environment: such as 'Han River Basin Environmental Master Plan, Korea', 'Brandt Commission', 'National Environmental Board, Thailand' and 'International Biological Program'
- explanation of selected techniques used in environmental planning (e.g. 'Visual Impact Measurement and Noise Exposure Forecast')

The entries are often cross referenced so that it is possible to find information about both the general and detailed aspects of an item.

However, the encyclopedia pays a penalty for being condensed, when trying to cover a field as large as environmental planning. Most readers will open the encyclopedia looking for something which is of particular interest to them, or to check how adequate the encyclopedia is, but they won't find the listing. The encyclopedia is, however, not designed to give such a full coverage, although the omission of specific entries does not detract from its general usefulness. Rather, Gilpin's work fills a gap in the range of available texts by bringing together many terms and pieces of information pertinent to the broad field of environmental planning. Provision of an introduction to the broader aspects seems to be where the condensed encyclopedia would be most helpful. Anyone who wants specific information on the air quality, environmental impact statements or transport planning will need to go to the readily available detailed texts.

In summary, Gilpin's condensed encyclopedia provides a starting point for anyone wanting information on the broad field of environmental planning. Sufficient background is also usually given to advise the reader of which direction to take to discover more. The book would be a valuable resource for libraries and people dealing in the wider aspects of the environment, but would be of limited use to those involved in the

detail of parts of the environment (e.g. air, water).

IAN THOMAS

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## REPORTS AVAILABLE

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### MORE THAN 1000 FOSSIL FIRED PLANTS SCHEDULED THROUGHOUT THE WORLD

In excess of 1000 planned utility fossil fuel fired electricity generating plants are now included in **World Utility Boiler Projects**. This continuously updated report is offered by The McIlvaine Company. Each month new projects and new information on planned projects such as contractor awards, fuel type and startup date are added.

More than 700 of the projects are outside the U.S. and 300 in the U.S. However, the number of planned projects in the U.S. is expected to expand greatly in the coming years. New projections by EPRI and the Department of Energy indicates that between 40 and 100 500 MW plants per year will be needed to meet electricity demands over the next 30 years.

While construction is proceeding at a modest pace in Europe and the U.S. it is proceeding at high levels in many other areas of the world. The report includes information on over 90 planned fossil fuel fired boilers in India. One of the most recent to come under consideration is a 1500 MW \$1.3 billion project by the Tamilnadu Electricity Board. It will be located in Pajakkamangalam in the Kanyakumari district.

A coal fired plant is under construction by the National Power Corporation for Mindanao in the Philippines. Consideration is also being given to replacing a nuclear plant with a coal fired plant on Bataan Peninsula.

Two 250 MW plants are planned for 1997 startup for Waikato New Zealand. An oil to coal conversion is slated for Auckland.

Much of the rest of Asia is also active. Twenty-two gas and coal fired plants are slated for Pakistan. South Korea has seven coal and one unspecified fuel plants scheduled. Coal, oil and gas are all represented in the seven plants scheduled to start prior to 1991 in Indonesia.

There are many oil and gas fired plants in the planning and construction stage in the Middle East including nine in Iraq, six in the United Arab Emirates, 14 in Saudi Arabia and 13



in Egypt.

There are 21 member countries of the IEA (International Energy Agency). They include European countries plus Australia, Canada, Japan and the United States. The IEA has forecasted that, electricity generation by member countries will increase from 1320 to 1824 GW by the year 2000. Solid fuels, which accounted for 413 GW in 1983 will account for 651 GW in the year 2000. Since the Chernobyl incident these plans have been scaled upward. But even at this level the requirement would be for 238,000 MW or 476 500 MW plants, since many new plants are 300 MW or smaller, the total number of plants to achieve this goal will exceed 600.

Encl in Italy is reconvening old coal fired plants back to coal and plans new plants which would mean that coal burning for electricity generation would rise from 9 million tons in 1985 to 35 to 40 million tons per year by the mid 1990s. 28 planned plants are described in the report.

Electricity generation in Portugal is now evenly divided between oil and hydroelectricity. Six coal fired plants are covered in the report. They are all part of Portugal's strategy to meet steadily growing demand and at the same time reduce oil dependence.

In Spain plans for new nuclear plants have been scaled back and plans for more coal fired plants are proceeding. Six plants in the planning or construction phase are reported.

The report has a handy startup index using each project title by year of startup. Outside the U.S. more than 50 fossil fired plants are scheduled for startup each year through 1990. More than 90 plants were commissioned in 1986. Most of the plants covered in the data base have planned operational dates prior to 1998. Only five plants have startup dates from 1998 to 2005.

There is also an extensive contractor index in the report. Flakt air pollution control equipment has been purchased for more than 30 of the scheduled projects in Europe and Asia. Combustion Engineering boilers are slated for various projects in South Africa, Israel and India. Mitsubishi Heavy Industries has sold turbines and boilers in 36 projects under construction in Mexico, China, Iran, Kuwait, Malaysia, Japan and Saudi Arabia among others. Kraftwerk Union is also a listed supplier in more than 30 projects.

**World Utility Boiler Projects** is available for \$190. for more information, contact: The McIlvaine Company,

2970 Maria Avenue, Northbrook, Illinois 60062, U.S.A., Telephone: 312-272-0010, Telex: 494-4829-MCILVN.

## CLEAN ROOM SALES TO EXCEED \$1 BILLION BY 1990

By 1990, annual sales of cleanrooms and components will be between \$1.2 and \$1.8 billion. This is one of the conclusions reached in a new report entitled Clean Room **Industry 1986-1996, Section III Section III'**, which has just been released, contains technical information, market shares and forecasts on cleanrooms, components and instruments. Section I. Industry Conditions and Forecasts and Section II, Cleanroom Companies, were published earlier. Section IV, Clean Room Supplies, Garments and Services, will be published shortly.

1986 sales of cleanrooms were just over \$500 million. A substantial increase in sales is forecast for 1987 and continuing increases are forecast through 1990 at which time annual sales will reach between \$1.2 and \$1.8 billion annually. If there are double digit increases in semiconductor chip production, the upper end of the forecast will be reached. In addition to the growth in end user industries such as pharmaceutical and electronics, the trend toward cleaner work spaces is having a big impact on all the components. This is because of the substantial difference in revenue of suppliers. For instance, the cost of HEPA filters per ft<sup>2</sup> of floor space is only \$4.50 in a Class 100,000 room, but is \$21 in a Class 10 room.

Another favorable trend is the purchase of higher priced equipment at higher capability. For instance, the forecast projects that the cost of monitor purchases per ft<sup>2</sup> of floor space in a Class 10 room will increase from \$16 per ft<sup>2</sup> in 1986 to \$23 per ft<sup>2</sup> in 1990. This increase is caused by the greater use of automated particle monitoring networks in cleanrooms.

Certain components will grow at a faster rate than the industry in general. Monitors, for instance, are estimated to quadruple in sales volume in the five year period. In contrast, prefilter sales are expected to increase less than 50 percent during the period. In the case of prefilters, the slower growth rate is attributable to the fact that the replacement market is much larger than the new equipment market and therefore total sales are less subject to the spurt in the growth of new facilities. Nevertheless, the prefilter sales volume is sur-

prisingly large. In 1987 it is estimated that prefilter sales will pass the \$50 million per year mark. While prefilters are much less expensive than HFPA filters, they are replaced frequently, whereas HEPA filters may not be replaced during the lifetime of the room. Many of the suppliers of prefilters supply identical filters for other applications and work through distributors. They are therefore unaware of the magnitude of the prefilter market to the cleanroom industry.

In the report, market forecasts are also made for many other components and services involved in cleanrooms. The market for fans to recirculate air in cleanrooms is also growing rapidly, due to the upgrading of classes in new and existing rooms. The cost per ft<sup>2</sup> for fans in a Class 10 room is \$25 where it is only \$1.25 in a Class 100,000 room. This is due to the much larger quantity of air recirculated in the cleaner rooms. Annual fan sales to the cleanroom industry are projected to increase from under \$30 million in 1986 to \$80 million per year by 1990. By 1990, Class 100 and Class 10 rooms will account for over 75 percent of the fan sales to the cleanroom industry.

Room design is provided by a variety of companies including turnkey cleanroom suppliers, large end users, architect/engineers and engineer/constructors. But in the aggregate, engineering and design is a big business for cleanrooms. 1990 projections for the dollar value of engineering and design of cleanrooms is \$134 million based on an economic situation with substantial semiconductor growth. This value would be only \$88 million if the semiconductor industry were to remain flat.

There are more than 600 companies supplying components and services in the cleanroom industry. Most are small, reflecting the youth of the industry. There is a chain of supply with ever-increasing numbers of suppliers as one approaches the final end user. For instance, there is only one manufacturer of glass fibers selling to several manufacturers of filter media. The media manufacturers in turn sell to some 20 manufacturers of filters. The filter manufacturers in turn sell to over 100 room and bench manufacturers. Room and bench manufacturers deal through more than 1000 distributors, representatives and salesmen. Most of the companies servicing the industry had experienced no growth in 1984 and 1985 but surprisingly few fell on really hard times despite the slump in the semiconductor industry. Over the last

five years the companies in the aggregate have showed substantial increases in sales and profits. The number of companies and market share percentages vary widely depending on the type of equipment. For instance, in benches, the top 7 companies account for 41 percent of the total bench market. The top 15 companies account for 60 percent of the total market. The consolidation is much greater in the filter category where the top four companies have more than 50 percent of the market. The room market is very splintered in that end users, architect/engineers and others compete with the conventional room manufacturers. The top ten conventional room manufacturers enjoy less than 25 percent of the total market. They, of course, have a much larger percentage of the available market when one excludes the rooms being designed by the end users and architect/engineers.

The wall and floor market is served by a few companies concentrating on the market but there are also substantial sales by companies who are offering standard products to a variety of industries.

Section III is more than 500 pages in length and provides forecasts and technical information relative to ionizers, robots, benches, rooms, filters, prefilters, ceilings, HVAC and other cleanroom components. Detailed information relative to company market shares, costs, market size, trends and other significant data are contained in the report. Section III is available separately for \$650. The entire four volume report is available for \$1150 from The McIlvaine Company. For more information on Clean Room Industry 1986-1996 contact: The McIlvaine Company, 2970 Maria Avenue, Northbrook, Illinois 60062, U.S.A.. Telephone: 312-272-0010. Telex: 494-4829-MCILV.

## NEW PRODUCTS

### RESPIRABLE DUST MONITOR PROFILES EXPOSURE DATA

Ecotech have released a personal dust dosimetry system from MDA Scientific, Inc., designed to detect, measure, and document respirable dust exposures. Lightweight and battery operated, the Personal Dust Monitoring System consists of the PDS-1 Personal Dust Sensor, direct-reading MDM-1 Mini Dosimeter, and a com-

pact Readout interface Unit.

A sensitive light-scatter detector, the PDS-1 measures respirable dust levels from 0.01 to 100 mg/m<sup>3</sup> and features a user-adjustable concentration alarm, it may be used alone as a passive personal alarm system or combined with the direct reading MDM-1 Mini Dosimeter to accumulate up to 800 1 • litre/minute exposure averages

Stored concentration data may be readout via the portable Readout Interface Unit or other desk-top computer systems, in a variety of formats, including a concentration over time profile that helps pinpoint periods of high exposures. The dedicated software program also automatically computes the 8-hour TWA (time weighted average) and other statistical information.

The Personal Dust Monitoring System is calibrated on Arizona Road Dust and features a built-in calibration standard for simple infield calibration. Precision is  $\pm$  0.5% of full scale.

For further information contact: ECOTECH PTY. LTD., 6/22 Bridge Street, Eltham, Vic. 3095; Telephone: (03) 439 5222; Fax: (03) 419 1207; Telex: AA39712.

### NEW VANE ANEMOMETER WITH VARIABLE TIME-BASE

Selby Anax are pleased to announce the introduction by AIRFLOW DEVELOPMENTS of a new version of their popular electronic rotating vane anemometer, the LC A6000. The latest model, the LCA6000VT (variable time-base), incorporates a microprocessor which enables continually updated averaging air velocities to be obtained over extended periods therefore providing the benefit of being able to carry out continuous traversing on grilles, registers or in large ducts.

The new instrument gives a direct digital readout of air velocity eliminating the need for a separate timer. Light weight and compact in design, the LCA6000VT is easy to operate, the only controls are a switch plate on the side and an on/off switch at the base of the handle.

The LCV6000VT is suitable for use in most heating, ventilating and air conditioning applications where the air stream is larger than the instrument head diameter. It can also be used to monitor laminar flow cabinets, fume cupboards and hoods. The LCA6000VT has a velocity range from 0.2 to 30 m/s. It is powered by one 9V battery and is supplied in a light weight carrying case.

For further details please contact Selby Anax - offices in all States. Selby Anax. 352 Ferntree Gully Road. Molting Hill, Victoria, 1368."

## NEW LOW OXYGEN RANGES

A number of industries and research groups have cause to analyse for trace oxygen. Teledyne Analytical have offered trace oxygen analysers down to 0-10ppm for many years, and these have been in successful use around Australia in a variety of applications.

Although the oxygen detecting fuel cell has always been capable of still lower ranges, it has not been until recently that low noise electronics could take advantage of this feature.

Now, with the introduction of new electronics, the Models 316R and 318R can be offered with full scale ranges of 0 to 1ppm while the Model 306WA can achieve a full scale range of 0 to 500ppb.

The new low ranges will be of particular interest to semi-conductor, new liquefaction and petrochemical industries as well as other applications where ultra low oxygen measurements are necessary.

For further information contact: ECOTECH PTY. LTD., 6/22 Bridge Street, Eltham, Vic. 3095; Telephone: (03) 439 5222; Fax: (03) 419 1207; Telex: AA39712.

## CARBON MONOXIDE SPECIFIC ANALYZER

The Model 48 Carbon Monoxide Analyzer is specific for the measurement of CO through the use of a gas filter correlation. This technique eliminates the interference from other compounds and provides measurement to as low as 0.10 ppm. The Instrument is U.S.A. - EPA reference method RFCA-0981-054. offering linear ranges from 0-1 ppm to 0-1000 ppm.

The analyzer is linear on all ranges, specific to CO. and incorporates many significant features over conventional analyzers. Uniquely designed optics, which are self-aligning, add to the stability for the optical bench eliminating field service problems. The microprocessor, in addition to performing data reduction functions, also corrects for pressure and temperature correction and provides a powerful diagnostic routine to assist the user.

For further information contact: Thermo Environmental Instruments\* Inc., 108 South Street, Hopkinton, MA 01748. Contact: C.J. Gabriel, Vice President of Marketing: (617) 435-5321.

## TOWARDS THE PRECIOUS-METAL MOTOR CAR

*New platinum-based car components improve performance, cut pollution and extend service intervals ... catalytic-combustion engines and fuel-cell power units under development*

New applications of platinum and related precious metals in car components are helping to improve performance, extend service intervals and reduce exhaust pollution.

Platinum-tipped spark plugs and engine-management systems equipped with platinum electrodes are among the latest products, report platinum refiners and marketing organisation Johnson Matthey PLC of London EC 1, England. In pollution control the company say that catalytic converters using platinum and rhodium are becoming more widely used. For the future, catalytic engines and fuel-cell power units that rely on platinum are now being developed.

### Sparked by platinum

Service life of the new platinum-tipped spark plugs will be 80 000 km when used with lead-free petrol. The platinum improves resistance to erosion and corrosion, and gives excellent high-temperature stability.

Self-cleaning temperature is only 400°C, so the new plugs will stay clean even in cars used mainly for local journeys at relatively low speeds. Starting from cold and with a weak battery are easier. On the road, the new plugs help prevent misfiring, and provide full engine power during acceleration, even throttle take-up and smooth engine running. The platinum-tipped spark plugs are now in production by several manufacturers.

Catalytic converters have now been in use in the United States and Japan for more than ten years, and are becoming increasingly employed in Europe as the introduction of new emission-control standards approaches. Three-way catalysts fitted in the exhaust system are the most efficient means yet devised of controlling the pollutants carbon monoxide, nitrogen oxides and unburnt hydrocarbons. They contain about 1.5 grains of platinum and rhodium, typically in the ratio 5:1, dispersed on a ceramic monolith support, and convert pollutants to harmless carbon dioxide, water and nitrogen.

The ceramic support has a surface area equivalent to two soccer pitches, but is contained in a canister smaller than a rugby ball. The precious metal

catalyst is dispersed extremely finely over this area, ensuring that all the metal is active in catalysing the reactions. Tests on a VW Scirocco fitted with a three-way catalyst were carried out on behalf of Johnson Matthey by the independent UK Motor Industry Research Association. After 80 000 km, mainly at a speed of 170 km/h, test emissions were still within the tough US limits.

### Electronic engine management

Catalytic converters can be used on a variety of engines, both stoichiometric and lean-burn. Maximum control of all three pollutants can be achieved by using the converters in conjunction with electronic fuel control, as the units work most efficiently when engines run at their ideal (stoichiometric) air/fuel ratio, i.e. when air and fuel are in balance - neither in excess.

Precise control is made possible by engine management systems equipped with sensors that measure the oxygen content of the exhaust gas and adjust the richness of the mixture entering the engine. The oxygen sensors employ platinum electrodes that transmit a voltage proportional to the partial pressure of oxygen in the exhaust gas.

Even greater precision can be achieved by adding a device that measures the mass of air entering the engine. This consists of a heated 100-micron-diameter platinum wire placed across the manifold inlet. Platinum is used because of its stability, corrosion resistance and ability to withstand short high-temperature bursts that are occasionally needed to clean the wire.

### Engines for the future

Platinum is likely to have a key role in new engines for the 1990s and beyond. Catalytic-combustion engines now being researched employ a catalyst and heater plug to ignite the fuel mixture without the aid of spark plugs and with a reduced requirement for valves and timing gear. Mechanical simplicity, fuel economy and low noise are expected benefits.

Fuel cells using platinum catalysts are a new candidate for electric propulsion systems that could be applied to city buses, delivery trucks and cars. The fuel cell converts fuel directly into power by combining oxygen from the air with a gaseous fuel such as hydrogen. The power unit would be silent, pollution-free and use fuels in plentiful long-term supply.

Ceramic engines are also being developed. Already some engine com-

ponents are being made of ceramic materials like silicon nitride, and the next step could be the production of materials that combine the best features of platinum and ceramics.

### Precious-metal coatings

Coatings based on platinum-group metals have been used to reduce heat build-up in cars with glass sunroofs. At least 70% of the ultraviolet and infrared radiation striking the glass is reflected by a 0.1-micron-thick layer of a metal organic compound containing palladium.

In future, precious-metal coatings may also be incorporated in rear-view mirrors, according to current investigations. A coating of electrochromic iridium oxide would "dip" the mirror automatically. Further information from: JOHNSON MATTHEY PLC, 43 Hatton Garden, London EC1N 8EE, England, Telephone: 01-430 0011; (Int.) T-44 1 430 0011; Telex: 267711; Fax: 01-831 2461.

### LOW-COST MONITOR WARNS AGAINST TOXIC GAS LEAKS

Ecotech have released an alarm-only instrument from M.D.A Scientific, Inc., designed to provide cost-effective toxic gas exposure protection. A Chemcassette-based monitoring system, the TLD-1 Toxic Gas Detector responds quickly to toxic, corrosive, and pyrophoric gas yet ignores other chemicals commonly used in semiconductor fabrication.

Dedicated to a specific process gas, the TLD-1 is preprogrammed to alarm at either 1 or 2 times the TLV (threshold limit value) of that gas. Response time is as fast as 15 seconds. When a hazardous concentration is detected, audio and visual alarms as well as alarm relays are activated.

The TLD-1 Toxic Gas Alarm is available for all semiconductor hydride gases as well as ammonia, chlorine, HCl, and HF. The instrument's compact size and low-maintenance operation make it ideal for monitoring gas cabinets and storage areas, scrubber systems, ventilation intakes and exhausts, maintenance corridors, cylinder receiving docks, and other areas where personnel are not normally present.

For further information contact: ECOTECH PTY. LTD., 6/22 Bridge Street, Eltham, Vic. 3095; Telephone: (03) 439 5222; Fax: (03) 419 1207; Telex: AA39712.