



**MONASH** University  
Accident Research Centre

**MOTOR VEHICLE EXHAUST GASSING  
SUICIDES IN AUSTRALIA:  
EPIDEMIOLOGY AND PREVENTION**

by

Virginia Routley

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Monash University Accident Research Centre, Wellington Road, Clayton, Victoria. 3168

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**Abstract:**

Suicide is a major public health problem in Australia. In 1996 carbon monoxide poisoning from motor vehicle exhaust gas was the second major method, accounting for almost 22% of suicides. For some survivors there were lasting effects on the heart and brain.

The aim of the study was to reduce the overall suicide rate by making motor vehicle exhaust gas suicide substantially more difficult to undertake and complete. Since the method is common and relatively lethal this has high potential to reduce total suicides. The study involved a literature review and obtaining of background information on suicide and methods of suicide, particularly exhaust gas suicide, data analysis, personal communication with technical experts, being informed of other current or unpublished studies, an examination of a sample of exhaust gas suicide Victorian State Coroner's case files and an awareness of activities to reduce the method.

Motor vehicle exhaust gas suicides have increased in rates, as a proportion of suicides and in numbers since at least 1968, despite the introduction of catalytic converters in 1986. The method is most commonly used by middle-aged males. Its usage varies between states and it is a relatively favoured method in Australia compared with other countries. Hospital admissions have increased considerably in recent years, at a faster rate than deaths. In a sample of Coroner's records 36% of victims' vehicles had catalytic converters. Almost all used a hose or pipe leading into the interior of the vehicle with ventilation sealed. They were most frequently undertaken at home or at an open-air location away from home.

While recognising that the causes of suicide are complex there are design changes which potentially make the method more difficult to affect. These are multi-gas (CO, O<sub>2</sub> and possibly CO<sub>2</sub>) sensing devices installed in the vehicle cabin which emit a warning light followed by an alarm and then shut down the engine when the levels become life threatening, exhaust modifications which make it difficult to fit a hose or pipe and further improvements in engine design and catalytic conversion techniques.

Recommendations are for the introduction of mandatory regulations for new vehicles to ensure that life threatening gas levels cannot be reached by passing a hose from the exhaust into the vehicle over the lifetime of the vehicle. In-service vehicles should be required to replace existing exhaust pipes with new safety designs to make it substantially more difficult to attach a hose. A study of exhaust gassing suicide attempters and the Suicide Module of the National Coronial Information System should collect information which further clarifies potential countermeasures and risk factors.

The Australian Medical Association has convened a multi-sectoral committee, on which MUARC is represented. It is progressing research to reduce exhaust gassing suicides, relevant to the above design changes and recommendations, with the assistance of \$30,000 from the Department of Health & Family Services.

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**Key Words:**

suicide, exhaust gassing, carbon monoxide, prevention

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Monash University Accident Research Centre,  
Wellington Road, Clayton, Victoria, 3168, Australia.  
Telephone: +61 3 9905 4371, Fax: +61 3 9905 4363

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## EXECUTIVE SUMMARY

Suicide is a major problem in Australia. In recent years there have been approximately 2000 deaths each year from suicide. Since 1990 suicide has been more common than motor vehicles crashes as a cause of death. In 1996 motor vehicle exhaust gas was the second major method of suicide, accounting for almost 22% of suicides. It was the method most commonly used by middle-aged males.

There is evidence that reduction in access to a lethal means potentially reduces the overall suicide rate. The potential for reduction is greatest where the restricted method is commonly used. Motor vehicle exhaust gassing fits many of these criteria.

### **The study**

The study involved a literature review and obtaining background information, data analysis, personal communication with technical experts, being informed of other studies which were unpublished or in process and an examination of a sample of exhaust gas suicide Victorian State Coroner's case files.

### **Aim**

To reduce the overall suicide rate in Australia by making motor vehicle exhaust gas suicide substantially more difficult to undertake and complete.

### **Objectives of this study**

- To review published and unpublished literature on the aetiology of suicide focussing on access to the means, particularly motor vehicle exhaust gas suicides.
- To describe the epidemiology of motor vehicle exhaust gas suicides in Australia.
- To investigate :-
  - the transference between means of suicide
  - the relationship of exhaust gas suicide to vehicle numbers
  - the Victorian Coroner's files for the means and circumstances by which this method of suicide is usually attempted
  - possible solutions to exhaust gas suicide
  - whether the legislated environmental limits on carbon monoxide (CO) emissions have impacted on the numbers of suicide attempters selecting and succeeding by this method.
  - the international situation in regard to patterns, trends and possible solutions to exhaust gas suicide.
- To make recommendations to relevant authorities and to disseminate the findings of this study.

### **Suicide**

Social factors which are considered risk factors for suicide are those which relate to social bonding: unemployment; never married, widowed or divorced marital status and non-church attendance. Age, sex, immigration and country of birth are also found to influence suicide. Physical and mental health states are also known to be associated with the above risk factors eg. terminal illness, depression, schizophrenia.

### **Methods of suicide**

Physical availability and socio-cultural acceptability are considered necessary preconditions for the choice of suicide methods. Methods chosen vary considerably in lethality. Males have a propensity to use more immediate and violent methods than females (eg firearms, hanging) and this partially accounts for their higher overall suicide rates. Lethality rates have been reported at 85% for firearms, 80% for hanging, 77% for exhaust poisoning, 75% for drowning and 23% for drug overdose.

In Australia, in 1995, four methods accounted for 84% of suicides - hanging, motor vehicle exhaust gas, firearms and poisoning. There have been reductions over time in firearms and poisoning. Exhaust gassings have constantly increased since at least 1968, despite the introduction of catalytic converters in 1986. Hanging has seen the most dramatic rise. The less frequent methods - jumping from high places, drowning and cutting and piercing vital structures have varied little in the proportion of suicides they represent (approximately 3% each). Poisoning is clearly the preference for females, although not to the previous extent. Impulsiveness appears to play an important role, especially in youth suicide.

Cantor et al (1996) concluded that restricting the availability of a particular method of suicide often, but not invariably, reduces overall suicide rates. A complex interaction of factors will determine this outcome. If the method were made more difficult, then it could take longer to affect, thus enhancing the possibility of the potential victim changing their mind or being intercepted. Additionally, another method may not be acceptable.

### **Carbon monoxide**

Carbon monoxide (CO) is colourless, odourless and tasteless and is produced from the incomplete combustion of organic fuels. It attaches itself to the body's red blood cells, making the cells unable to carry oxygen. The brain and heart are the most susceptible to toxicity because they depend most heavily on oxygen to function. Lasting effects on these organs can include myocardial infarction, deterioration of personality and impaired memory. Symptoms of carbon monoxide poisoning are normally a headache, drowsiness, then loss of consciousness (LOC) and finally death. If the poisoning is not fatal hypoxic brain injury can occur with possible symptoms of confusion, disorientation, incontinence, amnesia, short-term memory loss and/or muteness.

### **Environmental CO requirements**

The required maximum levels of CO in motor vehicle exhaust gases have been 24.3g/km from July 1976 (ADR27A), 9.3 g/km from 1986 for new passenger vehicles (ADR37-00) and 2.1 g/km for new models (ADR37-01) from 1997 and for all new passenger vehicles from 1998. In order to cope with the unleaded petrol legally required since 1986, vehicles usually require catalytic converters (ADR37-00, AS2877).

## Data analysis

- The motor vehicle exhaust gas suicide (MVEGS) rates for Australia in 1995 were calculated to be 4.69/100,000 males, 1.02/100,000 females and 2.85/100,000 total. In 1995, there were 509 cases of motor vehicle exhaust gas suicides in Australia. These represented 21.5% of suicide cases.
- The preference for this method of suicide varies between states. It appears to be a relatively favoured method in Australia, particularly in the ACT and WA, compared with other countries
- MVEG has been more favoured in middle age and by males. In the 30-50 year age group MVEG has been the leading means of suicide and 82% of all motor vehicle exhaust gas suicides were male. Numbers were substantial in the 20-24 age group, this being the age group which has had the highest suicide frequency overall.
- Hospital admissions for Australian motor vehicle exhaust gas suicide attempts have increased steadily in recent years (1994/95 data are not available), with the data showing an exponential trend ( $R^2=0.99$ ). Deaths also increased, but show no clear trend.
- MVEG related self-harm represents a smaller proportion of hospitalised attempted suicides (2%) than successful suicides (21.6%). This is likely to be the result of the lethality of MVEG as a means of suicide compared to other means.
- The age and sex distribution of MVEG related admissions is generally similar to that seen for completed suicides. It appears however that younger males are relatively more common among hospitalisations. This suggests that attempts among younger males are more likely to be detected before death occurs presumably due to higher involvement of their family.

## Coroners' records

- Thirty-six percent of suicide vehicles had catalytic converters. This proportion was not significantly different from the 39% of vehicles with catalytic converters in the Victorian fleet.
- In the 93 cases where the method was specified, all but 4 used a hose or pipe leading into the interior of the vehicle with ventilation sealed.
- The location of the vehicle in the 85 cases, where it was specified, was most frequently at a home (51% cases), at an enclosed workplace (7%) or at an open-air location away from home (including farm paddocks) (43%).
- The median carboxyhaemoglobin level (COHb), for the 88 cases for which it was noted, was 79%. The median COHb level of victims in the groups with and without catalytic converters was identical (77.1%).
- Alcohol was detected in 24 cases, benzodiazepines in 10, paracetamol in 8, cannabis in 7 and other pharmaceuticals, usually in a 'cocktail' in 7.

Several overseas studies which have examined the relationship between suicides and MVEGS have found that the imposition of emission controls reduces MVEGS. This observation may in part relate to the comparatively newer vehicle fleet compared with Australia (and to lower allowable emission levels.)

### **Explanations for suicides in later model vehicles**

It appears that MVEGS have not reduced as much as expected with reductions in emission levels and it is of note that the pattern between Australia, Japan and the USA may have similarities ie a lagged levelling off after the introduction of CO exhaust limits. Considerably less reductions are anticipated than would be expected if exhaust emission CO levels of 2.1g/km made MVEGS impossible.

In explanation, it appears that there are several situations where the testing for these legislated environmental CO limits may not be particularly relevant to the suicide lethality situation eg 1) a hose or pipe is led into the interior of the vehicle and ventilation is sealed. In this situation other gases eg. oxygen and CO<sub>2</sub> and other factors such as heat and humidity may have a synergistic and additive effect. It appears inappropriate that CO limits are the same for each vehicle regardless of the vehicle's cabin volume 2) the engine idles. In environmental CO testing, there are 3 phases to the vehicle testing and none of these involves idle only.

There are several situations where CO emissions may exceed the legislated limit such as 1) where the engine idles from a cold start, with a delay of between 1.5 and 3 minutes before the catalytic converter has warmed up and is operating efficiently. Since carboxyhaemoglobin concentration rises most rapidly when first exposed to CO the initial absorption rate would be particularly high 2) modern vehicles may be better sealed ie. less ventilation and 3) the vehicle does not have a well-functioning catalytic converter.

### **Countermeasures**

The cost per year attributable to 509 Australian motor vehicle exhaust poisoning deaths was approximately \$386.6 million in 1996, based on conservative figures. If a device were developed which prevented 50% of these suicides and it cost \$36, the full costs would be recovered in just 2 years. Alternatively if a device cost \$72, or if it prevented only 25% of these suicides, the break even period would be 4 years. Furthermore there are additional benefits of preventing several hundred hospital admissions resulting from failed MVEGS attempts.

While it is considered that ultimately the solution should be in terms of performance requirements for the vehicle there are several design solutions possible for the prevention (or minimisation) of MVEGS:

### **Design Solutions**

1. The mandatory incorporation into new vehicles of a multi-gas sensing device which monitors carbon monoxide, oxygen and possibly carbon dioxide levels and when these become life threatening displays a warning light, then emits an alarm and finally shuts down the engine. The operation of window winding devices could also be incorporated.

Devices for the household which meet the Underwriters-Laboratory Inc. (UL) standard 2034 are available in the U.S for between AU\$43 and AU\$100 and a similar concept could

possibly be fitted to the engine management system of a motor vehicle. Currently these alarms are activated at CO levels which produce COHb levels of 10% or above.

A CO detector attached to the engine management system of a motor vehicle would have the added advantage of identifying and preventing unintentional poisonings and driver fatigue due to leaks of carbon monoxide from unsealed boots, rusted holes and access through open windows.

2. The exhaust pipe on new vehicles could be modified to incorporate a device inside the pipe, so a hose cannot be inserted, and to make the end of the pipe irregular, to make it difficult to fit a hose. New designs would need to overcome any problems of backpressure, vibration or noise and would need to meet current exhaust regulations (eg exhaust gases should be emitted beyond the vehicle).

Both approaches showed sufficient promise of a potential cost-effective contribution to the prevention of MVEG and warrant further expenditure on research. Research would better define what is involved and provide more precise estimated values for the assumptions made above.

3. Further improvements could be made to engine design and in catalytic conversion techniques to complete the combustion process and thereby virtually eliminate carbon monoxide emissions.

It is recognised that design changes will not eliminate all suicides. Complex social, economic and psychological reasons underlie the causes of suicide and the solutions for these require a multi-faceted longer term approach.

## **Recommendations**

1. Mandatory regulations should be introduced for new vehicles which will make exhaust gas suicide virtually impossible, by ensuring that life threatening levels of CO, O<sub>2</sub> and possibly CO<sub>2</sub> cannot be reached by passing a hose from the exhaust into the vehicle with sealed ventilation. A sensor is preferred because it would cater for deterioration in catalytic converter and engine performance over time.
2. Regulations should be introduced for in-service vehicles requiring replacement exhaust pipes to be of new safety designs to make it substantially more difficult to attach a hose.
3. A study of MVEGS attempters (ie those admitted to hospital) should collect information which further clarifies potential countermeasures and risk factors. Variables on which it would be important to collect data are: how long the vehicle ran, if they were interrupted, if they reneged, the reason for selection of the MVEG method, the practical details of how they made the attempt eg. equipment used, the blood alcohol content and if possible the presence of other drugs, if they had previously attempted suicide by exhaust gas or otherwise and information on the make, model and year of manufacture of the vehicle. Such data would be most useful in gaining further insight into how MVEGS are undertaken and the extent to which catalytic converters are making an impact. Data collected so far has concentrated on deaths.

4. The Suicide Module of the National Coronial Information System should collect information encoded and/or in text including the make, model and year of manufacture of the vehicle; COHb level; drugs, medications and other gases detected at pathology; practical details of the attempt including equipment used; details of previous attempts. Additionally there should a move towards consistency in the medical and legal definitions of suicide.

These actions should be undertaken quietly, without media attention. Adding to the risk group's knowledge of how to undertake this method, or risking 'copycat' suicides, should be avoided.

### **Progress**

The Mental Health Branch of the Department of Health & Family Services was given responsibility for the allocation of \$30,000 to alleviate exhaust gassing suicides.

Since November 1996 there have been four meetings convened by the Australian Medical Association and initially the Federal Office of Road Safety to reduce vehicle exhaust gas suicides with representatives from various interest groups.

The priority recommendations for the allocation of the H&FS \$30,000 have been revised. These are now:

- \$6,000 to bring Prof David Penney, Director of Surgical Research and Professor of Physiology, Wayne State University, US, an expert on the physiological effects of CO to the April 1998 meeting in Melbourne to determine an appropriate CO level for a CO detector. He will produce a report in September, 1998.
- \$15,000 to research MVEGS attempters who have been treated for CO poisoning at the Prince of Wales Hyperbaric unit. The study is in progress and the reasons for their method choice, demographic profile, details of psychiatric records and any previous suicide attempts by MVEGS or other methods and the details of their latest MVEGS attempt, including the presence or otherwise of catalytic converters are being studied.
- \$5,000 to an industrial design student at Flinders University to research the available exhaust pipe designs and to design a tailpipe which is low cost (including fitting), which does not cause problems of backpressure or reduce performance etc and which allows a vacuum or garden hose or other pipe to be fitted only with great difficulty. A design has been produced which meets these criteria.
- \$4,000 to develop a computer model which simulates the exhaust gassing suicide scenario. Mr Jerry Moller has now submitted a paper which includes a model of CO and O<sub>2</sub> exhaust gas concentrations to the Department of Health and Family Services Mental Health Branch.

In addition, the Australian Automobile Association has allocated \$15,000 to RMIT in Melbourne for the development of a CO sensor for the vehicle cabin. Currently the emphasis is on developing CO, O<sub>2</sub> and CO<sub>2</sub> detectors. The focus will then be to link these into a multi-sensor system. Additional funds are likely to be required for development to the next stage.

International enquires have identified very little activity to reduce suicides by this method and it appears that this committee is leading the way internationally.

## Glossary

AAA	Australian Automobile Association
AAAA	Australian Automotive Aftermarket Association
ABS	Australian Bureau of Statistics
ADR	Australian Design Rule
AMA	Australian Medical Association
AISRAP	Australian Institute of Suicide Research and Prevention
AS	Australian Standard
CO	carbon monoxide
CO <sub>2</sub>	carbon dioxide
COHb	carboxyhaemoglobin blood level
EPA	Environment Protection Authority
FORS	Federal Office of Road Safety
g/km	grams per kilometre
ICD	International Classification of Diseases
MUARC	Monash University Accident Research Centre
MVEG	motor vehicle exhaust gas
MVEGS	motor vehicle exhaust gas suicide
NOHSC	National Occupational Health and Safety Commission
O <sub>2</sub>	oxygen
ppm	parts per million
RMIT	Royal Melbourne Institute of Technology, Melbourne
STEL	short-term exposure limit
TWA	time weighted average
RACV	Royal Automobile Club of Victoria
US	United States
VISS	Victorian Injury Surveillance System
WHO	World Health Organisation



# **1. INTRODUCTION**

## **1.1 RATIONALE**

### **1.1.1 Australian Data**

Suicide is a major problem in Australia. In recent years there have been approximately 2000 deaths each year from suicide. Since 1990 suicide has been more common than motor vehicles crashes as a cause of death. In 1996 motor vehicle exhaust gas was the second major method of suicide, accounting for almost 22% of suicides. It was the method most commonly used by middle-aged males.

### **1.1.2 Potential for Prevention**

There is evidence that reduction in access to a lethal means potentially reduces the overall suicide rate. Cantor et al (1996) concluded in their report on youth suicide that restricting the availability of a particular method of suicide often, but not invariably, reduces overall suicide rates. There is potential for reduction where the method takes longer to affect thus increasing the possibility of interception or a change of mind, where the method may fail, where no culturally acceptable or accessible method is available for substitution or where the substituted method is less lethal. The potential for reduction is greatest where the restricted method is commonly used. Motor vehicle exhaust gassing fits many of these criteria.

## **1.2 BACKGROUND**

The Victorian Injury Surveillance System (VISS), a project of Monash University Accident Research Centre (MUARC), is funded by the Victorian Health Promotion Foundation. VISS identified motor vehicle exhaust gassing suicides (MVEGS), as a major means of death in Victoria, in its quarterly publications *Hazard 11* 'Victorian Injury Deaths and the Potential for Prevention' (June 1992) and *Hazard 20*, 'Non-traffic motor vehicle related injuries' (September 1994). Its importance was further validated in the MUARC report 'Injuries in the Middle Years'. MUARC staff wrote to motor vehicle manufacturers, automotive bodies, government departments, suicide prevention committees and the Australian Medical Association (AMA) outlining the problem and making recommendations for prevention. Papers on this topic were presented by MUARC staff at national and international injury and suicide prevention conferences and an article was published in the *Medical Journal of Australia* (19 January 1998).

The AMA has a history of periodically pursuing this issue, and in recent years undertook this through its Ethics, Science and Social Issues Committee. Influenced by MUARC, at the end of 1996 the AMA and the Federal Office of Road Safety (FORS) convened a meeting to examine the issue with interested parties. MUARC staff attended this meeting and have been involved in on-going activities. MUARC staff members were consulted for the Commonwealth Department of Health and Family Services Youth Suicide Prevention Advisory Group's background report 'Access to means of suicide by young Australians' by the Australian Institute for Suicide Research and Prevention. MUARC was represented on the 'Access to Means' Working Group of this Advisory Group. In 1997, MUARC prepared a submission to and was consulted by the Victorian Youth Suicide Taskforce.

Since mid-1994, MUARC has continued to research and be involved in activities to reduce exhaust gassing suicides. In addition, MUARC has assisted the Coroner to design a relational database, as a source of detailed death data for Victoria. All of these activities have been made possible by funding from the Victorian Health Promotion Foundation in supporting applied research and the translation of research into injury prevention.

### **1.3 THE STUDY**

#### **1.3.1 Overview**

The study involved a literature review and obtaining background information on suicide and suicide method, particularly exhaust gas suicide, data analysis, personal communication with technical experts, being informed of other studies which were unpublished or in process, an examination of a sample of exhaust gas suicide Victorian State Coroner's case files and checking registration records for age of vehicles.

#### **1.3.2 Literature review**

A literature search was undertaken of the Medline, Suicide Information & Education Centre (Canada) and SESAME (Monash University) library systems. Relevant references listed in the bibliographies of reviewed references were located.

The literature was initially reviewed and information sought to provide an overview of suicide, its patterns in Australia and factors which influence suicide rates. Methods of suicide were then reviewed, particularly determinants of choice, methods used and differences of classification. The restriction of means and the transference between means of suicide was also investigated. Finally there was a brief reference to parasuicide ie suicide attempts.

The second stage involved obtaining information on carbon monoxide poisoning and finally motor vehicle exhaust gas suicide.

#### **1.3.3 Aim**

To reduce the overall suicide rate in Australia by making motor vehicle exhaust gas suicide substantially more difficult to undertake and complete.

#### **1.3.4 Objectives**

- To review published and unpublished literature on the aetiology of suicide focussing on access to the means, particularly motor vehicle exhaust gas suicides.
- To describe the epidemiology of motor vehicle exhaust gas suicides in Australia.
- To investigate :-
  - the transference between means of suicide
  - the relationship of exhaust gas suicide to vehicle numbers

- the Victorian Coroner's files for the means and circumstances by which this method of suicide is usually conducted
  - possible solutions to alleviate the problem of exhaust gas suicide
  - whether the legislated environmental limits on carbon monoxide (CO) emissions have impacted on the numbers of suicide attempters selecting and succeeding by this method.
  - the international situation in regard to patterns, trends and possible solutions to exhaust gas suicide.
- To make recommendations to relevant authorities and to disseminate the findings of this study.

### **1.3.5 Method**

#### *Data*

Analysis was undertaken of Australian hospital admissions data for motor vehicle exhaust gassing suicide attempt trends. The most important source however was the Australian Bureau of Statistics (ABS) Australia wide death data for exhaust gas suicide and total suicides by age, sex and state of residence. US suicide data was also obtained and analysed. Comparisons were made with Dutch, Japanese, Norwegian and New Zealand data.

“Gases and other vapours” suicide rates (almost all exhaust gassings) were obtained from the Australian Institute for Suicide Research and Prevention and recent Australia wide hospital admission MVEGS frequencies and rates from the National Injury Surveillance Unit, Research Centre for Injury Studies, Flinders University.

Vehicle numbers, rates per head of population and the distribution by model, make and year of manufacture were obtained from ABS publications.

Exhaust gas suicide case lists collated from the findings of the Victorian State Coroner listed in the publication of the Victorian State Coroner's Office 'Unnatural Deaths 1993/94' were analysed for reasons for suicide.

#### *Victorian State Coroner's Files*

These were examined to:

- a) Determine if the vehicle used was manufactured post-1986 ie had a catalytic converter fitted (as required by Australian Design Rule 37-00 and Australian Standard 2877).
- b) Locate additional information relating to where the suicides were undertaken; the practical details of how they were carried out; the type of hoses, pipes if any, used; the blood level of carbon monoxide (CO) (carboxyhaemoglobin level (COHb)); any other drugs taken; if notes were left; any leads as to why they sought to end their life and the age and sex of the victim. It was expected that not every file selected would provide all variables.

Case numbers of a sample of thirty-three 1994 motor vehicle exhaust gas suicides were obtained from case listings in 'Unnatural deaths' 1993/94, State Coroner's Office, Victoria, the latest publication providing these details. The details in (b) were obtained where possible. Vehicle registration numbers were then checked for the make, model and year of manufacture.

Case numbers of 1995 and 1996 deaths were then provided from the Coroner's Facilitation System database and data on variables listed in (b) were collected from a sample of 1995 and 1996 cases where available. The year of manufacture, make and model were obtained where registration numbers were provided.

### ***Personal communication***

Discussions, mostly by telephone were held with experts in their particular field. These provided background and technical information. They occurred with staff from Environment Australia, the Hyperbaric Unit (Alfred Hospital), Royal Automobile Club of Victoria (RACV), some motor vehicle manufacturers, injury researchers in Australia and internationally, automotive mechanics, engineers and road safety researchers.

### ***Other***

Information on relevant news articles, researchers undertaking relevant studies etc were followed up.

## **1.3.6 Results**

The majority of the results are in the Results section, chapter 4 but it was considered more appropriate to include others in sections where they were highly relevant eg U.S. data with relevant information from journal articles.

The results of the analysis of the ABS suicide method data are presented as part of suicide background information in Chapter 2 and the data on the relationship between MVEGS and motor vehicle registrations in Australia as part of motor vehicle exhaust gas (MVEG) background information in Chapter 3. The ABS exhaust gas suicide data, hospital admissions for exhaust gas suicide attempts, reasons for suicide taken from the Coroner's Facilitation System MVEGS narratives, analysis of data extraction from the Victorian MVEGS Coroner's files are all included in chapter 4. Also in chapter 4, under 'Discussion', are details of other studies and additional information required. The results of the U.S data analysis are included in chapter 5, 'The impact on MVEGS of emission controls' under U.S data.

## **1.3.7 Recommendations, Conclusions and Progress**

These, with the costs and benefits of prevention are briefly outlined in chapter 6. Suggestions are made for design solutions and recommendations made for action. Progress to date is described.

## **2. LITERATURE REVIEW AND BACKGROUND INFORMATION - SUICIDE**

### **2.1 SUICIDE OVERVIEW**

#### **2.1.1 Introduction**

Suicide is generally accepted to mean the fatal, and suicidal attempt, the non-fatal act of self-injury, undertaken with more or less conscious self-destructive intent, however vague and ambiguous. Suicide is ubiquitous. There is no period in history without records of suicides, the belief that it does not occur in primitive societies has proved to be mistaken (Stengel, 1969).

However there is a range of definitions according to purpose. The Coroner's definition based on legal rules is the most strict. The Coroners must determine that the person had the intention to commit the act, that they had the intention to commit death by the act and that at the time of committing the act they were capable of understanding it would result in death. The Australian Bureau of Statistics and hospital admissions use the ICD E code definition which is more aligned with self-inflicted injury leading to death and is consistent with world health practice. Some deaths will therefore be included where the Coroner did not make a formal finding of suicide (Moller,1997).

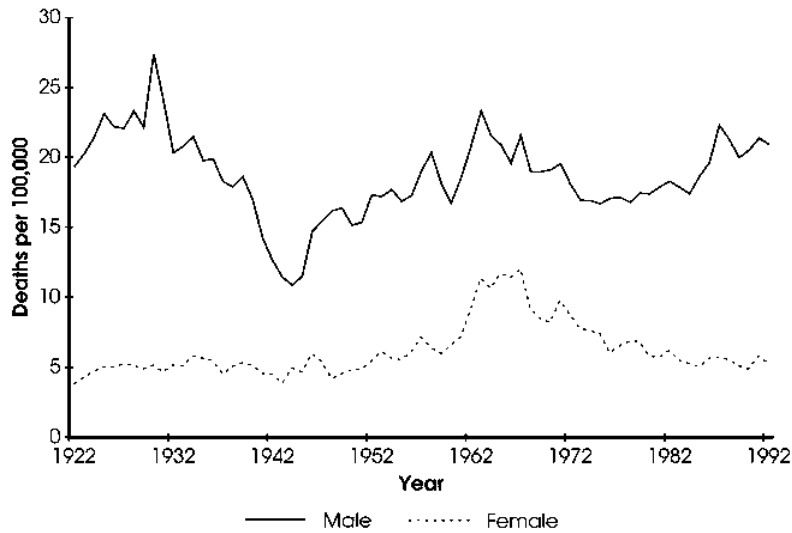
Some deaths, in Australian mortality data, are classified as being of undetermined intent (2.5% of injury deaths in 1992). Many of these were probably suicides, though some may have resulted from accidental causes or homicide (Harrison et al, 1994). Undetermined intent may also be an important factor in differentials between reported rates between countries.

In recent years there have been approximately 2000 deaths in Australia each year from suicide and there were 13,721 hospitalisations from intentionally self-inflicted injury in 1992/93. Since 1990, suicide has been more common than motor vehicles as a cause of death in Australia (Moller, 1996).

#### **2.1.2 Suicide Patterns in Australia**

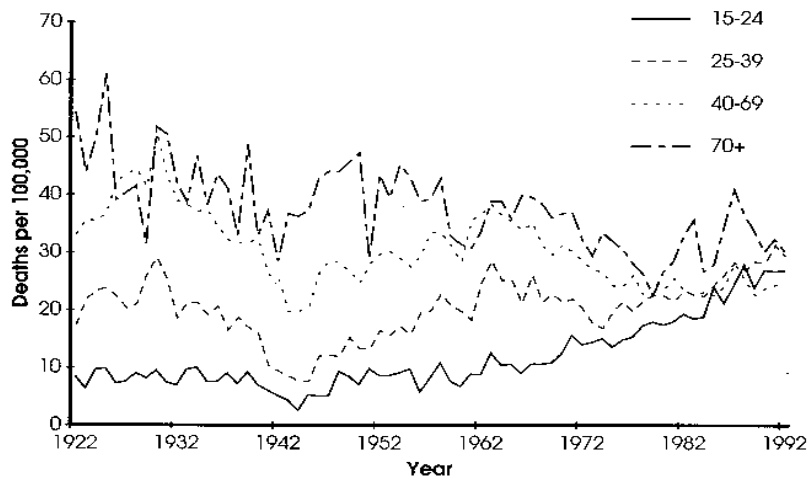
The trend in suicide since 1922 is shown in Figure 1. Over the last 20 years, the pattern of suicide in the community has changed, with suicide becoming less common among middle-aged men and women but more common among the young. Much of this increase is due to the growing number of suicide deaths among younger males (figure 2). Similarly to Australia, five industrialised countries, New Zealand, Norway, Switzerland, Canada and the USA, have high youth suicide rates (Commonwealth Department of Human Services and Health, 1995). There is also increasing prominence of males in rates of attempted suicide. Previously rates of attempted suicide, especially at young ages, were much higher for females than males (Harrison, 1994). Australia's suicide rate is similar to that experienced in many other countries, including the United States and Canada (10.4/100,000). It is higher than the rates recorded in the UK and Italy, but lower than the rates reported in Hungary and Finland (Australian Bureau of Statistics, 1994).

**Figure 1. Suicide-standardized mortality rates Australia 1922-92**



(Source: Harrison et al. Australian Injury Prevention Bulletin NISU Issue 5, February 1994.)

**Figure 2. Male suicide rates Australia 1922-92 by age group**



(Source: Harrison et al. Australian Injury Prevention Bulletin NISU Issue 5, February 1994.)

The age standardised suicide rates in Australia in 1993 were 19.3/100,000 for males, and 4.4/100,000 for females and 11.7/100,00 total. Female rates of hospital admission due to suicide attempts are higher than male rates. This suggests a propensity for males to choose more lethal means (Harrison et al, 1994).

### 2.1.3 Factors influencing suicide rates

Durkheim in *Le Suicide* in 1897 was the first to report on suicide from the sociological rather than the psychological perspective. He considered social bonds to relate individuals

to the society through integration or norms. If the social bonds are either too weak or too strong their integrative and regulative functions are rendered ineffective, in which case people are vulnerable to suicidogenic currents of 4 different kinds - *egoism*, *altruism*, *anomie* and *fatalism* (Cheek et al, 1996).

If the social bonds of attachment are weak the individuals are free from dependency on the group, its values and expectations, and with few social ties, an excessive individualism prevails such that more people are predisposed to *egoistic* suicide. Religion, marital status and political stability were included by Durkheim under this suicidogenic current. *Anomic* suicide can occur in societies undergoing such rapid and profound social change that traditional norms are dislocated and a sense of uncertainty prevails. People feel at a loss to know how to orient themselves towards society, how to behave and how to be in the world. He considered there to be 2 types of *anomic* suicide - *economic* and *conjugal*. (Cheek, 1996).

Durkheim observed that one of the strongest protections against suicide was to belong to an organised work force. Unemployment or work loss weakens the individual's social integration, deprives him or her of a social role and status and increases social isolation, all of which are positively correlated with higher risk (Hassan, 1995).

Similarly Kellehear more recently noted that 'unemployed people often experience social disapproval, dependency, abandonment and loss of social worth. Modern industrial economies place work at the centre of social experience and define self-worth accordingly. It is the overriding identification and status system of the day' (Kellehear, 1990).

Windshuttle studied relationships between Australian unemployment rates and suicide rates since 1900 and found, although female suicide rates fluctuated relatively little during the period, male rates showed peaks and troughs corresponding to the unemployment rate. The period of increasing youth suicide strongly corresponds to the current high youth unemployment rate (Windshuttle in Hassan, 1995).

Recent data from the Australian Bureau of Statistics strongly confirm the relationship between the various marital statuses and suicide. Between 1986 and 1990, married men and women had significantly lower suicide rates. Never married, divorced and widowed men had a suicide rate about twice that of the general population, and three times that of married men. The marital status pattern of suicide among women is similar to that of men (Hassan, 1995).

Church attendance rather than allegiance has been the variable of those associated with religion that is most closely tied to the variation in suicide attitudes. Pescosolido and Georgianna (1989) argued that denominations that are in tension with societal culture, conservative, and non-ecumenical and whose power structures are non-hierarchical should have lower suicide rates eg Seventh Day Adventists. These kinds of church structures facilitate friendship ties among members of their congregation and these ties act as important sources of social support which reduce suicide risk (Maris, 1992).

Other demographic and socio/cultural factors found to influence suicide are age, sex, immigration and country of birth.

Immigration to a new country or community invariably involves disruption of established social ties, thus adversely affecting the degree of social and community integration for the immigrant (Hassan, 1995). Ruzika and Choi found suicide rates to be higher for

immigrants than non-immigrant counterparts in their country of birth. Males in Australia who were born in New Zealand, Germany or Yugoslavia had significantly elevated suicide rates, while rates for men born in Italy or Greece were significantly lower than expected (case numbers were too small to allow analysis for many countries of birth) (Harrison, 1994).

Durkheim, writing in the late 19<sup>th</sup> century, considered social bonds to be stronger, and suicide rates therefore lower, in rural areas. Although the latter has been the situation in the past in Australia, rural suicide rates have been lower in the past decade for females only (4/100,000 rural v 5/100,000 urban, 1992). Males in rural areas, especially those in the 15-24 year age group, had higher suicide rates than those in urban areas (26/100,000 v 20/100,000, 1992) (Australian Bureau of Statistics, 1994). The relatively high rate for rural males can partly be attributed to the more frequent use of firearms, a highly lethal method. The firearm suicide rates for males were 3.5/100,000 for *capital cities*, 7.9/100,000 for *rural major*, 11.6/100,000 for *rural other* and 18.6/100,000 for *remote other* over the period 1990-92 (Moller, 1994). It appears that the more remote an area the higher the firearm suicide rate.

Moller in his analysis considered males aged 15 to 19 years and 40 to 59 years to show a pattern of elevated risk in rural and remote areas. A finer level of examination shows that the high suicide rates coincided with rural production areas (ie *rural other*) rather than rural towns, for the younger males. The higher rates of the male middle-aged group coincided with the age distribution of the agricultural and forestry industry male worker populations. He considered that these rates may reflect the impact of the rural recession (Moller, 1994). The social bonds of the past therefore may have been counteracted by the tougher economic climate.

Gibbs and Martin formed 5 postulates linking the suicide rate of a population with:

- the stability and durability of social relationships within a population
- the degree of status integration in that community
- the extent to which individuals in that population
  - conform to the patterned and socially sanctioned demands and expectations placed on them by others
  - are confronted with role conflicts
  - occupy incompatible status

(Hassan, 1995).

The issue of exposure of adolescents to information about suicides either through personal knowledge of cases or via the mass media (“copy cat” suicides) is an issue on which studies conflict and it cannot be regarded as resolved. The peak in numbers of deaths by hanging in police custody seen in several Australian states in 1987 might be an instance of this phenomenon (Harrison, 1994). A recent phenomenon is interactive suicide notes on the internet and these have been investigated by Baume et al, 1997.

In addition to these sociological factors there is the risk state of the individual. Some mental health professionals stress the influence of underlying pathology among completed suicides eg depression (Harrison et al, 1994).

## **2.2 METHODS OF SUICIDE**

### **2.2.1 Determinants of choice**

Little is known about the determinants of the choice of method. Researchers have suggested physical availability and socio-cultural acceptability are necessary preconditions for the choice of suicide methods (Clarke & Lester, 1989; Hassan, 1995). Socio-cultural acceptability is a measure of the extent to which a person's choice of method is shaped and circumscribed by the norms, traditions and moral attitudes of their culture. The existence of one without the other is unlikely to result in the potential method being selected eg fire is widely used for suicide in certain Asian cultures (Sheth, Dziewulski and Settle, 1994) but is rare in Australia despite the ready availability of matches and petrol. To date, most research into suicide methods has focussed on availability and method choice, without simultaneously considering socio-cultural acceptability (Cantor et al, 1996).

Clarke and Lester (1989) synthesised the results of numerous studies and determined a list of 'choice structuring properties' or key factors presumed to influence method choice. These were familiarity with the method, technical skills, planning, courage needed (high buildings, train), likely pain, disfigurement after death, danger/inconvenience to others (car crash, subway leap), messiness, gender association, scope for second thoughts, chances of intervention, certainty of death, contamination of the "nest", discovery of the body (loved ones or strangers), scope for concealing or publicising death (shame, insurance - car-crash, drowning), time taken to die while conscious (poisons, wrist cutting), symbolism (cleansing by fire) and dramatic impact (Clarke & Lester, 1989 in Cantor et al, 1996).

Methods chosen vary considerably in 'lethality' - the probability of death. Males have a propensity to use more immediate and violent methods than females (eg firearms, hanging) and this partially accounts for their higher overall suicide rates. Kleck (1992) reported a gun lethality rate of 85%, 80% for hanging, 77% for exhaust poisoning and 75% for drowning. Card, in 1974, had found similar figures, although he gave a figure of 23% to drug overdose, a figure which should by now have dropped considerably due to reduced availability and improved treatment methods. Lethality is partly dependent on the length of time that elapses between the suicide event and death (McIntosh, 1992) eg poisoning v hanging. Literature suggests that a much larger number of people survive actual suicide attempts than die by them (Cantor et al, 1996).

### **2.2.2 Methods used**

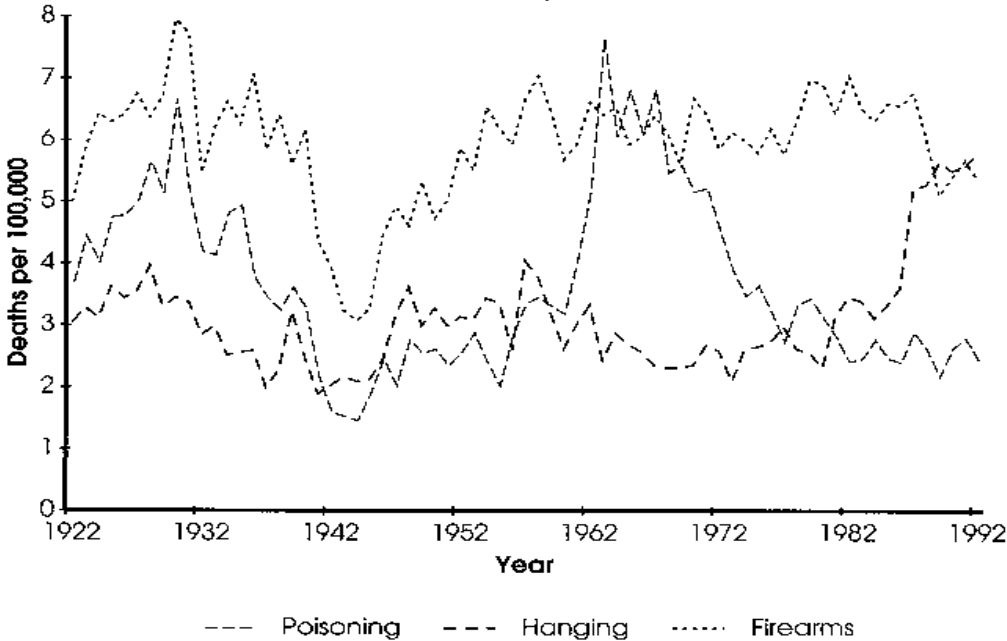
Epidemiological studies have shown that the popularity of particular methods of suicide changes within and between countries over time (eg Pounder 1991; Curran and Lester, 1990).

Despite the potentially large number of methods of suicide, only relatively few methods are widely used. These methods, in western countries, typically include poisoning by prescribed and non-prescribed drugs, poisoning by domestic gas and motor vehicle exhaust

gas, hanging, firearms, cutting and piercing, drowning, jumping from high places and lying or jumping in front of vehicles (Cantor et al, 1996).

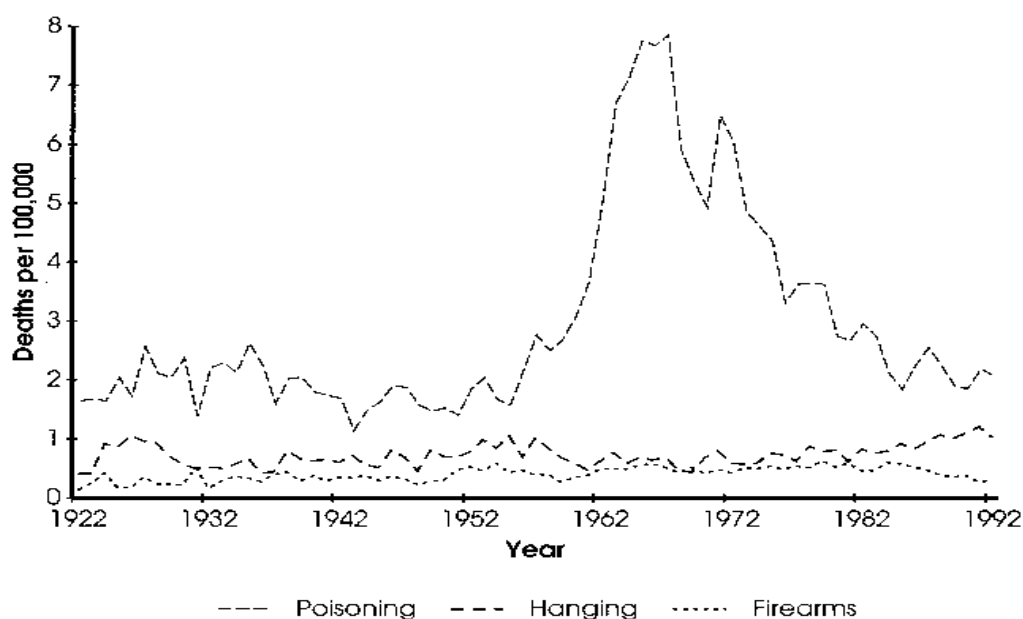
In Australia, in 1995, four methods accounted for 84% of suicides - hanging, motor vehicle exhaust gas, firearms and poisoning by solid or liquid substances. The trends in these methods over time, excluding vehicle exhaust gassings, are shown in Figures 3 and 4 and, more recently, including all major methods in figure 5. The high poisoning rates in the 1960's could be attributed to the easy availability of barbiturates and the subsequent decline due to restrictions on their availability. Unfortunately not shown on these graphs is the elimination of coal gas as a method in the late 1960's, early 1970's.

**Figure 3. Method of suicide-age standardized mortality rates Australia 1922-92, males**



(Source: Australian Injury Prevention Bulletin NISU Issue 5, February 1994)

**Figure 4. Method of suicide-age standardized mortality rates Australia 1922-92, females**

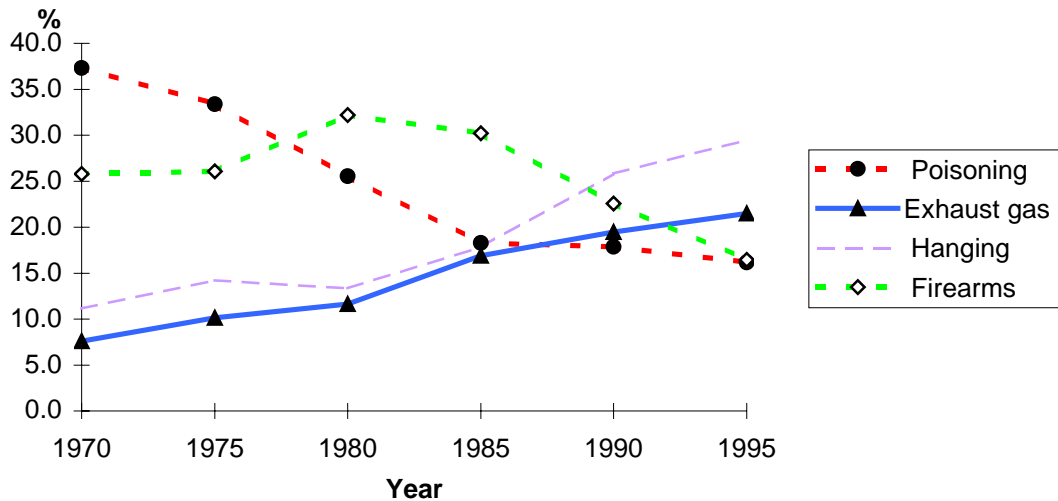


(Source: Australian Injury Prevention Bulletin NISU Issue 5, February 1994)

The past 25 years has seen a continuing reduction in the percentage of suicides represented by poisoning, due to stricter scheduling restrictions and better treatment methods. Since 1980, there has also been a reduction in firearm suicides. The latter would have been impacted on by the increased firearm restrictions in 1988 in Victoria. These were followed by a reduction in total firearm suicides of 32% for the 6 years post-legislation compared with the 6 years prior to legislation (based on ABS data).

Exhaust gassings have constantly increased since at least 1968, despite the introduction of catalytic converters in 1986. Hanging has seen the most dramatic rise (figure 5). The less frequent methods - jumping from high places, drowning and cutting and piercing vital structures have varied little in the proportion of suicides they represent (approximately 3% each).

**Figure 5. Means of suicide as a % of total Australian suicides**



(Source: Based on Australian Bureau of Statistics data.)

Suicide method preferences by sex are shown in Table 1. Poisoning is clearly the preference for females, although not to the extent previously. In 1970, 59% of female suicides were poisonings, compared with only 8% hangings and 3% vehicle exhaust (9% were domestic coal gas). For males in 1970, firearms accounted for 35%, poisoning 28%, but hanging and motor vehicle exhaust gas were only 12% and 10% respectively.

**Table 1. Methods of completed suicide - Australia**

Method	Males (n= 1931) %	Females (n=462) %
Hanging	34.8	26.0
Motor vehicle exhaust	22.4	15.2
Firearms	19.1	3.2
Poisoning	10.3	38.7
Jumping from high places	4.1	4.3
Drowning	1.6	3.5
Cutting & piercing	1.5	1.7
Other & unspecified	6.2	7.4
<b>Total</b>	<b>100</b>	<b>100</b>

(Source: Based on Australian Bureau of Statistics data, 1996)

### 2.2.3 Restriction of method

The rationale to restriction on access to the means of suicide is based on several elements. Firstly, impulsiveness appears to play an important role, especially in youth suicide. For practically all suicides, ambivalence is a prominent characteristic ie the determination to commit suicide waxes and wanes. For these reasons, many suicide prevention specialists argue that, if lethal means are not readily available when a person decides to attempt suicide he or she might either (1) delay the attempt, allowing for the possibility of later deciding against suicide or (2) use a less lethal means, allowing for a greater possibility of medical rescue. Means restriction, therefore, has the potential for preventing suicides, even if it does not decrease the incidence of suicide attempts. At least some portion of impulsive decisions to attempt suicide might never be acted upon if substantial efforts were needed to arrange for a method of suicide (National Center for Injury Prevention & Control, 1992). Additionally if the method were made more difficult, then it could take longer to affect, thus enhancing the possibility of the potential victim changing their mind or being intercepted.

A recent report on access to means reviewed the international and Australian literature on the relationship between 'access to means' and suicide rates and found:

- (i) Increased availability of a culturally accepted method of suicide tends to result in an increase in the suicide rate for that method.
- (ii) Restricting the availability of a particular method of suicide tends to result in a corresponding decline in suicide rates for that method (Cantor et al, 1996) e.g. the tightened gun laws in Victoria since 1988 have coincided with a reduction in suicide by firearms (ABS, 1996).

### 2.2.4 Transference between methods of suicide

Environmental influences appear to have a role in creating and combating suicide epidemics. The phasing out of coal gas and the introduction of petroleum gas in Australia was accompanied by a fall in such suicides in Australia. This intervention has been well documented in Britain as reducing the overall suicide rate (Harrison and Moller, 1997). In Britain, in 1975, the overall suicide rate was 75% lower than in 1960. In the UK circa 1960 coal gas suicides peaked at 2,600 pa - overall suicides circa 5,100. With subsequent domestic gas detoxification, coal gas suicides fell to almost zero by 1972. This was not associated with an inverse corresponding change in any other method of suicide. Moreover, overall suicides correlated with coal gas trends (Cantor et al, 1996). The widespread availability of relatively hazardous barbiturates in Australia coincided with high rates of suicide in the 1960's, especially for females. The restriction of these drugs coincided with a marked fall in overall suicide rates (Harrison et. al., 1996) (figure 4). These findings are consistent with different methods of suicide exerting independent influences.

Lester and Frank (1989) found that states in the USA with higher per capita ownership of cars had higher suicide rates by MVEG. Lester replicated this investigation for 28 nations and found that nations with more cars per capita had higher rates from *other gases and vapours* (the E-code category E952 which consists almost entirely of carbon monoxide suicides). However they did not have equivalent reduced rates from other means, indicating that switching to other methods for suicide did not take place (Lester, 1994).

As domestic gas was made less toxic in Northern Ireland during the period 1960-88, it was used less often for suicide. However, during the same period, as car ownership increased, the use of car exhaust for suicide increased in popularity, without there being a corresponding decrease in the use of other methods (Curran, Lester, 1990). Burvill likewise suggested that, in Australia, substitution of domestic gas with exhaust gas occurred with no significant reduction in the overall suicide rate (Burvill, 1980).

Another example where means restriction was not successful in reducing the overall rate of suicide was in Surinam where a government ban on the sale of undiluted acetic acid (a common means of suicide in that country) prevented virtually all suicides by that method. The decline in such suicides was almost completely offset by a concomitant increase in suicides by ingestion of paraquat, a potent herbicide widely available in Surinam. Suicides by ingestion of agricultural poisons were already on the rise in Surinam (National Center for Injury Prevention & Control, 1992).

Clearly, restriction of a means of suicide is more likely to affect the overall suicide rate if that suicide method is common. Marakush and Bartolucci (1984) and Lester (1984) have shown that the availability of firearms is related to their use for suicide and to the overall suicide rate in the U.S. (Lester, 1989). Lester found that the greater availability of guns in a country, the lower the suicide rate by other methods, and that people appeared to switch to this method as firearms became increasingly available (Lester, 1990,1994).

Cantor et al concluded that restricting the availability of a particular method of suicide often, but not invariably, reduces overall suicide rates. A complex interaction of factors will determine this outcome. There has been a tendency to neglect the influences of independently evolving methods of suicide.

It may be erroneous to suggest that societies respond uniformly and collectively to changes in the availability of different methods of suicide. Restrictions on methods of suicide will have different impacts according to complex psychological, social and environmental phenomena at the time. The relevant question is: to what extent, and under what circumstances, does substitution occur? (Cantor et al, 1996)

### **2.3 ATTEMPTED SUICIDES**

According to Maris, depending on their age and sex, nonfatal suicide attempters (not necessarily hospitalised) outnumber suicides by at least 8 or 10 to 1 (Maris, 1992). Other estimates have been considerably greater. As indicated by hospital admission rates, self-inflicted injury victims are more likely to be female and drug overdose cases. The average annual rates for Victoria between July 1987 and June 1993 were 54/100,000 for male self-inflicted injury, 43/100,000 for male self-inflicted poisonings; 78/100,000 for female self-inflicted injury and 72/100,000 for female self-inflicted poisonings (Watt, 1995).

### **3. LITERATURE REVIEW AND BACKGROUND INFORMATION - CARBON MONOXIDE**

#### **3.1 CHARACTERISTICS OF CARBON MONOXIDE POISONING**

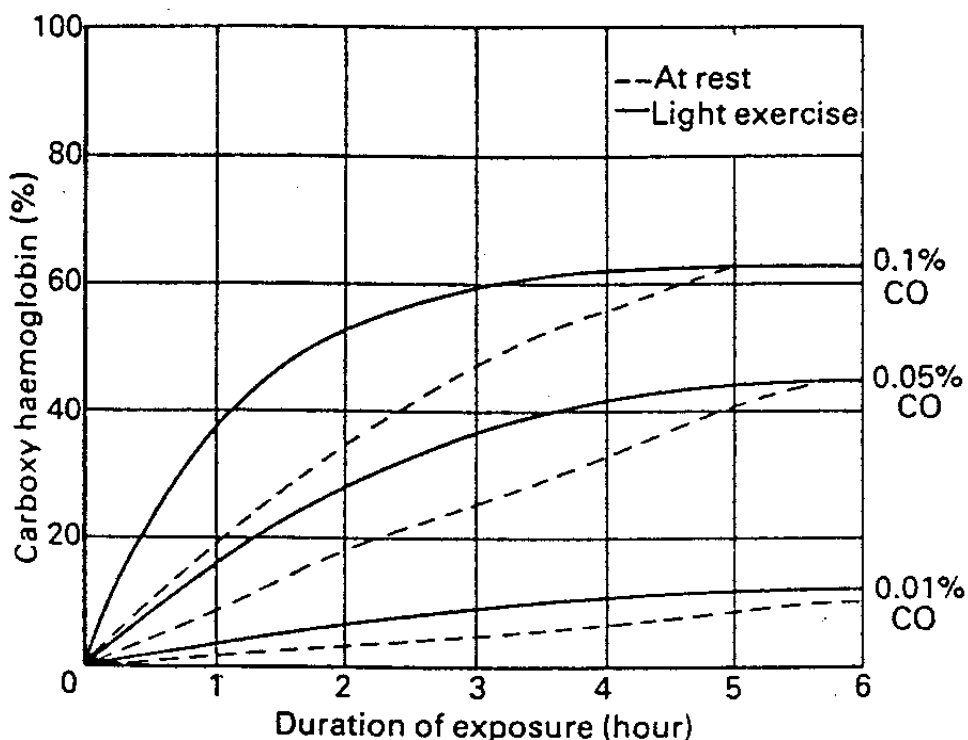
Carbon monoxide (CO) is colourless, odourless and tasteless and is produced from the incomplete combustion of organic fuels. CO has been a problem for humans ever since our ancestors learned to build fires in unventilated shelters. Although the primitive fuels of preindustrial societies produced large amounts of CO, they also emitted irritating gases that warned of a dangerous exposure. Today's clean fuels provide us with a much greater opportunity for exposure to CO (Cobb, Etzel, 1991). It is present in smoke from fires, cigarettes and charcoal burners and from motor vehicle exhausts.

Poisonings are caused by CO binding to the 5 points of the haemoglobin molecule faster than oxygen, thus not allowing oxygen to penetrate. Normal concentrations of carboxyhaemoglobin (COHb) in non-smokers living in an urban environment are less than 2% and in smokers concentrations may reach 5%. Levels that exceed 50% saturation are considered life threatening (Victorian Coroner's autopsy notes, 1996), although the victim's age and pre-existing morbidity may affect this (New et al, 1996).

The presence of CO is not detectable by humans. CO attaches itself to the body's red blood cells, making the cells unable to carry oxygen. As blood travels through the body, CO is passed to the organs rather than oxygen. All systems of the body can be affected by CO poisoning. However, the brain and heart are the most susceptible to toxicity because they depend most heavily on oxygen to function. Lasting effects on these organs can include myocardial infarction, deterioration of personality and impaired memory (Willis Hurst et al, 1990; Smith, Brandon, 1973).

The carboxyhaemoglobin concentration in the blood rises rapidly at the beginning of the CO exposure and then progressively more slowly to an equilibrium. The time taken to reach equilibrium depends on the concentration of CO in the inspired gas and the level of pulmonary ventilation (figure 6) (Ernsting and King, 1988). CO uptake is also influenced by the levels of carbon dioxide (CO<sub>2</sub>) and oxygen (O<sub>2</sub>) and to a more minor extent by heat, humidity and up to ten other factors (Penney,D, 1998). Figure 6 shows COHb levels for very low levels of CO, for example at a CO concentration of 0.05%, the 50% COHb concentration may never be reached. There is not complete agreement on these measures and the influences of other gases and factors have not been taken into account in the plotting of this graph.

**Figure 6. The time courses of the concentrations of carboxyhaemoglobin in the mixed venous blood on exposure to breathing CO at inspired concentrations of 0.01%, 0.05% and 0.1% in air, at rest (broken lines) and during light exercise (solid lines).**



(Source: Ernsting & King, Aviation Medicine, 2nd ed. Butterworths, 1988.)

Symptoms of carbon monoxide poisoning are normally a headache, drowsiness, then loss of consciousness (LOC) and finally death. The tissues most sensitive to hypoxia, such as those of the nervous system, are the first to be affected (Ernsting & King, 1988). Young fit males absorb CO at a relatively high rate and therefore record higher levels of CO at death. If the poisoning is not fatal hypoxic brain injury can occur with possible symptoms of confusion, disorientation, incontinence, amnesia, short-term memory loss and/or muteness. Independent living is not always possible after the event and the survivor and their family will require counselling. Brain injury may not always be immediately apparent and symptoms may not manifest themselves until several weeks later (New et al, 1996).

**Table 2 Symptoms induced by various blood concentrations of CO (at sea level with normal haemoglobin level)**

Saturation of haemoglobin with CO % COHb	Symptoms
Less than 10	None
10	No appreciable effects other than mild headache and slight dyspnoea on vigorous exertion
20	Slight headache, fatigue and dyspnoea even on mild exertion
30	Headache, increasing fatigue, impaired judgement and gross dyspnoea and impairment of vision on exercise
40-50	Severe throbbing headache, confusion, fainting and collapse even at rest
60-70	Unconsciousness

(Source: Ernsting & King, Aviation Medicine, 2nd ed. Butterworths, 1988.)

Table 2 refers to the symptoms associated with various COHb levels. The Victorian Coroner's autopsy notes refer to a mean of 72% and levels above 50% being life threatening.

### 3.2 CO STANDARDS

In May 1995 the Australian National Occupational Health and Safety Commission (NOHSC) released a new exposure standard for CO, a reduction from levels published in 1991. The time weighted average (TWA) exposure standard, is now 30 parts per million (ppm) measured over an 8 hour work day, 5 day work week. NOHSC also state 'to maintain compliance with 5% COHb, a short term exposure limit (STEL) of 100ppm would have to be applied'. The STEL is measured at four 15 minute intervals, each separated by one hour, provided the TWA is complied with. The NOHSC exposure standard is set to ensure that CO exposure from work results in a blood COHb below 5%, a level which provides protection against the adverse effects of CO (Victorian Workcover Authority, 1996).

The World Health Organisation recommends a range of lower COHb concentrations of 2.5-3.0% as a standard for the protection of the general population, including those who have impaired health. They have published tables relating time, ambient air CO ppm and sedentary, light or physical work to COHb values (WHO, 1979). They have also published exposure conditions to prevent COHb levels exceeding 2.5% - 3% in non-smoking populations (eg CO TWA of 50ppm for periods of exposure not exceeding one hour).

Carbon monoxide levels from vehicle exhausts have been required to be reduced over the past decade, as measured at warm idle, for environmental reasons (prior to 1986, 95% of carbon monoxide in the air could be attributed to motor vehicle exhaust). The required

maximum levels have been 24.3g/km from July 1976 (ADR27A), 9.3 g/km from 1986 for new passenger vehicles (ADR37-00) and 2.1 g/km for new models (ADR37-01) from 1997 and for all new passenger vehicles from 1998. In order to cope with the unleaded petrol legally required since 1986 vehicles usually require catalytic converters (ADR37-00, AS2877).

Testing involves analysing the volume of CO in the exhaust, over three drive cycles, and then relating the resulting measure of parts per million to the distance covered, in order to give a reading of g/km (Environment Protection Authority, Motor Vehicle Section, 1994).

### **3.3 MOTOR VEHICLE EXHAUST GAS**

Motor vehicle exhaust CO levels vary from a cold to a warm start and according to the presence or otherwise of a well-functioning catalytic converter. According to the EPA typical late model vehicle exhaust CO readings range from above 45,000ppm (4.5%) at a cold start to under 1,000ppm (0.1%) at warm idle. Older vehicles, especially those not fitted with catalytic converters will show higher readings.

Morgen et al (1998), in Denmark, found that car exhaust CO levels ranged from an initial proportion of greater than 9.5% in a car without a catalytic converter at a cold start to a negligible quantity in a warm vehicle with a well-functioning catalytic converter. In the vehicle cabin this corresponds to 6000 ppm soon after commencement, 3200 ppm after 30 minutes in the former vehicle without a catalytic converter and negligible quantities in the latter vehicle (Morgen et al, 1998).

In a cold start situation, even with a well-functioning catalytic converter, death could occur within 15 minutes. In a car without a catalytic converter and a warm or tepid start, death could occur in one hour. In a warm start, with a well-functioning catalytic converter, no toxic effect is likely to result from CO. CO<sub>2</sub> and O<sub>2</sub> depletion however may cause loss of consciousness (Morgen et al, 1998). See recent work by Penney, 1998, Moller, 1998 and Morgen et al, 1998 for further details on the interaction between CO, CO<sub>2</sub> and O<sub>2</sub> in the exhaust suicide situation. It is of relevance that the rate at which exhaust gas concentrations change in a space into which exhaust gas is emitted is dependant on the concentration of CO in the exhaust stream, the speed and capacity of the engine and the size of the enclosure into which the exhaust gas is collecting (Moller, 1998).

## 4. MOTOR VEHICLE EXHAUST GAS SUICIDES – DATA ANALYSIS AND OTHER STUDIES

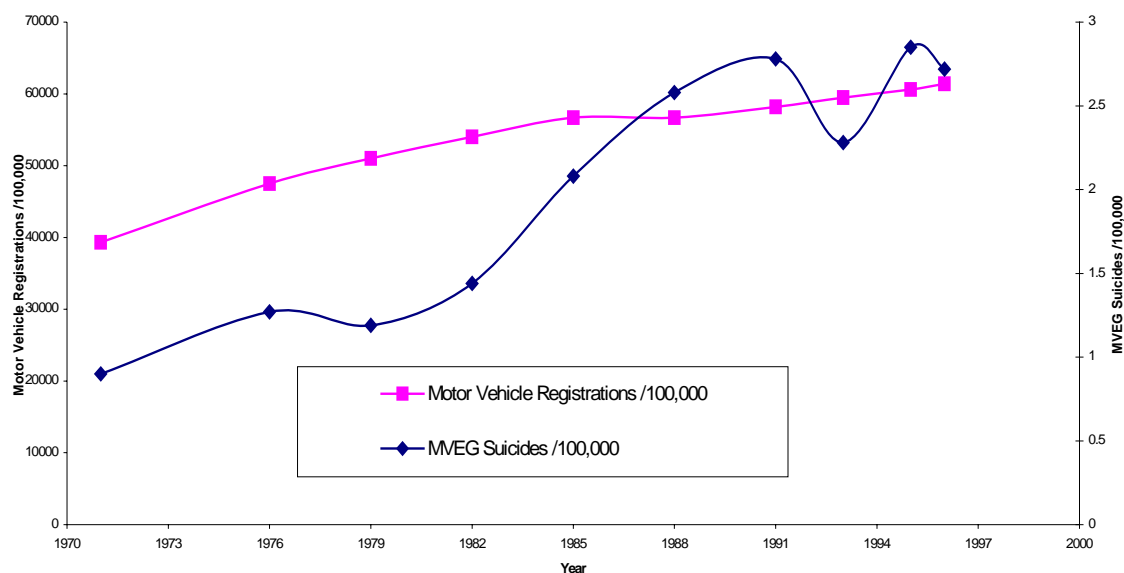
The MVEGS rates for Australia in 1996 were calculated to be 4.73/100,000 males, 0.77/100,000 females and 2.72/100,000 total (National Injury Surveillance Unit, 1998).

### 4.1 DATA ANALYSIS

#### 4.1.1 Australian Bureau of Statistics (ABS)

- Australian MVEGS and motor vehicle registration rates were compared for the ABS Motor Vehicle Census years since 1970. Since 1993 only new rather than total registrations have been published by the ABS. Suicides show an increasing trend, with dips in 1979 and 1993 ( $R^2=0.58$ ), while motor vehicle registrations follow an exponential trend ( $R^2=0.90$ ), showing a steady rise (figure 7). Between 1979 and 1991 such suicides increased at a faster rate than motor vehicle registrations (Routley, Ozanne-Smith, 1998).

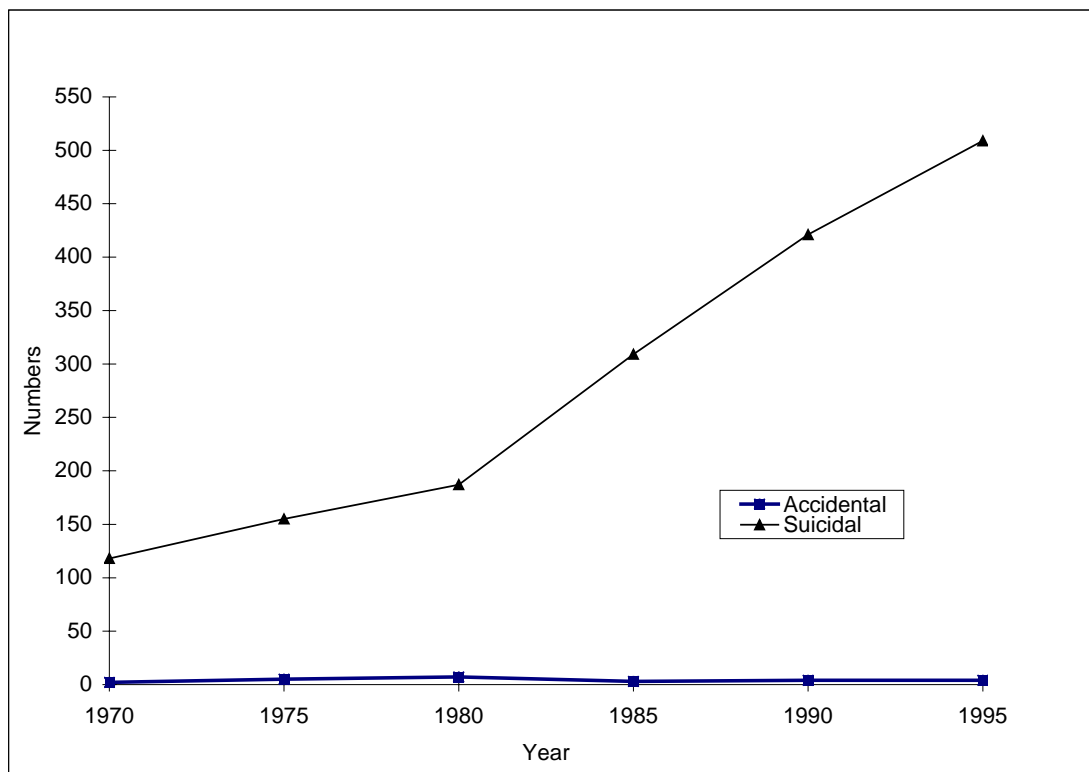
**Figure 7. Motor vehicle exhaust gas suicide and motor vehicle registration rates, Australia. (1971-1996)**



(Source: Based on data from the Australian Institute for Suicide Research and Prevention and the Australian Bureau of Statistics).

- In 1995 there were 509 cases of motor vehicle exhaust gas suicides in Australia (Attachment 1 represents 1 of 8 pages of case listings for Victoria 1993/94 only). This was the highest frequency for which annual data is available. The number of cases has increased by more than 400% since 1970 (figure 8). The most recent figure is 505 cases for 1996.

**Figure 8. Motor vehicle exhaust gassings for Australia, 1970-1995**



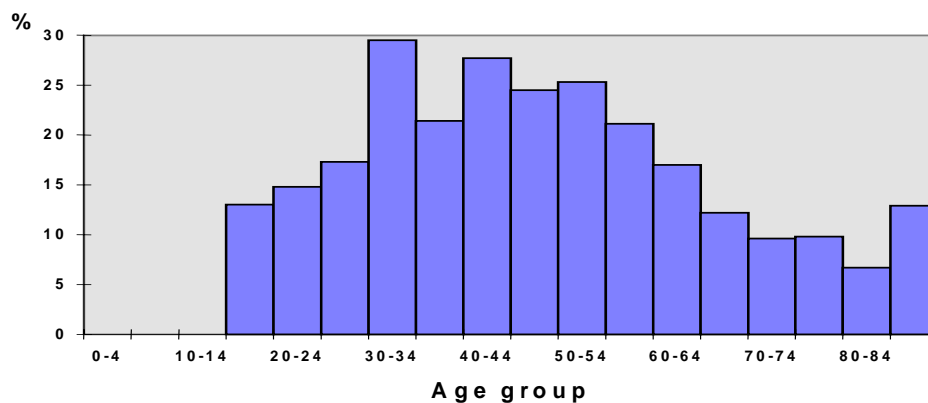
(Source: based on data from the ABS, stationary vehicles only).

- These 509 cases in 1995 represented 21.5% of suicide cases. Motor vehicle exhaust gas suicide was the second most frequently used method of suicide. It ranked second to hanging for men and third to poisoning and hanging for women. Since 1990 it has represented approximately 20% of suicides p.a. (figure 5). Its most rapid rise was in the 1980's.
- The preference for this method varies between states (proportions of all suicides in 1994 by this method were highest in the Australian Capital Territory (39%) and Western Australia (30%) and lowest in the Northern Territory (11%)) (ABS, 1995). It appears to be a relatively favoured method in Australia compared with other countries (eg 10% New Zealand (1994), 5.6% U.S (1991), 5% Norway, 2% The Netherlands (1990-94)) (Langley, personal communication 1998; US National Center for Health

Statistics, 1996; Wiik, personal communication, 1998; Consumer Safety Institute, Amsterdam, personal communication, 1997).

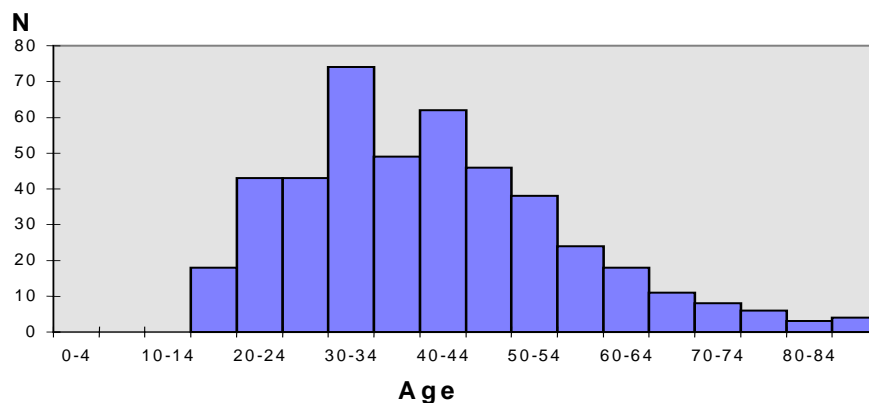
- MVEG has been more favoured in middle age and by males. In the 30-50 year age group MVEG has been the leading means of suicide and 82% of all motor vehicle exhaust gas suicides were male. Numbers were substantial in the 20-24 age group, this being the age group which has had the highest suicide frequency (ABS, 1995) (figures 9 and 10).

**Figure 9. Exhaust gassings as a % of all suicides by age group.**



(Source: based on ABS suicide data, 1994).

**Figure 10. Exhaust gassing suicides Australia: frequency by age group**



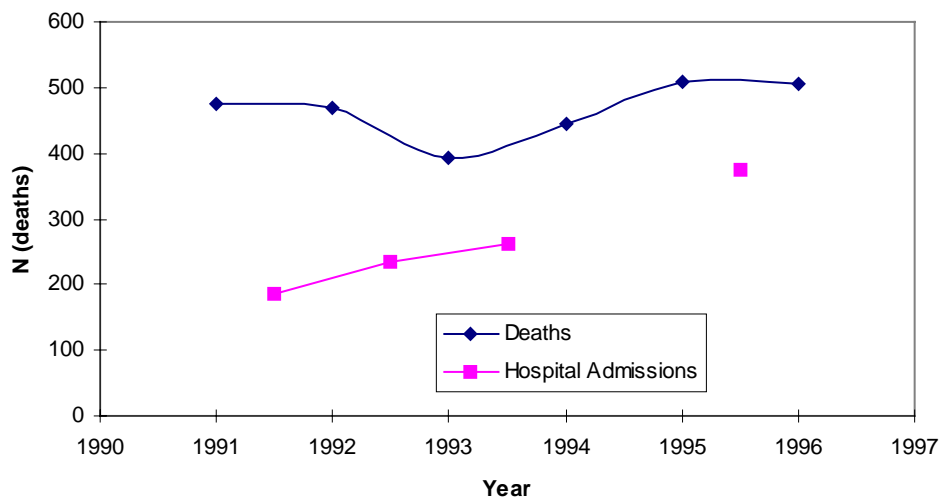
(Source: based on ABS suicide data, 1994).

- There have been almost no suicides from CO in Australia other than from MVEG. Unintentional deaths directly attributable to MVEG have been relatively rare in

Australia (figure 8), though higher rates are reported in the USA (figure 12), especially in the colder states. The contribution of MVEG to driver fatigue and resulting vehicle crashes is unknown in Australia - blood CO levels are not measured except in the case of a vehicle fire. Also accidental poisonings from CO, generated by vehicles in motion, cannot be separated from other causes of death within a broad category.

- Hospital admissions for Australian motor vehicle exhaust gas suicide attempts have increased steadily in recent years (1994/95 data are not available), with the data showing an exponential trend ( $R^2=0.99$ ). Deaths also increased, but show no clear trend (figure 11).

**Figure 11. Deaths and hospital admissions for motor vehicle exhaust gas suicides and suicide attempts, Australia, 1991-1996.**



(Sources: ABS; Australian Institute of Health & Welfare, National Injury Surveillance Unit. 1994/95 data are not available).

#### 4.1.2 Victorian Coroners Facilitation System (CFS) 1993/94

An analysis of the reasons given for the suicides, from the case narratives, are summarised in Table 3. (See attachment 1 for examples of case narratives)

**Table 3. Reasons for MVEG suicide, Victoria. (1993/1994)**

<b>Reason for suicide</b>	<b>No. *</b>	<b>%</b>
Relationship breakdown	31	24
Depressed	13	10
Personality/psychological disorder	10	8
Medical condition	10	8
Financial problems, unemployed	10	8
Dispute	9	7
Death close friend/relative	6	5
Incest/rape/homosexual	4	3
Drinking problems	3	2
Other specified	8	6
Non-specified	24	19
<b>Total</b>	<b>128</b>	<b>100</b>

\* There were 13 cases for whom 2 categories were noted and they have therefore been placed in both of these categories. These were principally those of relationship breakdown and financial/unemployed problems.

#### **4.2 VICTORIAN CORONERS' FILES**

Case numbers of motor vehicle exhaust gas suicides undertaken in 1994 were obtained from case listings in 'Unnatural deaths' 1993/94, State Coroner's Office, Victoria, the latest publication providing these details. Case numbers of 1995 and 1996 deaths were provided from the Coroner's Facilitation System database. Data on the practical details of how MVEGS were undertaken, the type of hoses used etc were obtained from a sample of thirty-three 1994 cases, thirty-three 1995 cases and thirty-four 1996 cases. The intention to have the year of manufacture for 25 cases for each year determined the number of files finally selected for examination. Twenty-five was considered a realistic number to determine evidence of a trend, if present.

The year of manufacture, make and model were obtained for twenty-five each of 1994, 1995 and 1996 cases.

An investigation of a total sample of 100 MVEGS Victorian Coroner's files for the years 1994, 1995 and 1996 therefore revealed the results shown below. It should be noted that not all case files provided information on each variable, so that totals may vary.

- The 100 cases of exhaust gas suicide obtained from the records of the Victorian Coroner comprised 33 of a total of 96 in 1994, 33 of 140 in 1995, and 34 of 136 in 1996. The year of manufacture had been recorded for only 75 of these cases (25 in each of 1994, 1995 and 1996). Of these 75, 20% in 1994, 56% in 1995 and 32% in 1996 involved vehicles manufactured in 1986 or later. In total, 27 of the 75 vehicles (36%) were 1986 models or later. This proportion is not significantly different ( $p=0.62$ ) from the 39% of vehicles in 1986 or later in the Victorian fleet of 2,799,310 vehicles in May 1995 (ABS Motor Vehicle Census) (Routley, Ozanne-Smith, 1998).

- It is interesting that, at this early stage, of those vehicles fitted with catalytic converters, there appears to be some variation in vehicle makes compared with their representation in the Australian fleet. In the absence of comprehensive data this needs further investigation.
- In the 93 cases where the method was specified, all but 4 used a hose or pipe leading into the interior of the vehicle with ventilation sealed. Twenty-two used a vacuum hose, 17 used a garden hose, and 50 used another or an unspecified type of hose or pipe. Tape of various kinds or cloth was most frequently used to secure the hose to the vehicle. The hose most often entered the motor vehicle through the closest window and the gap was sealed with tape or the window closed tightly onto a towel or clothing. The 4 cases not using a hose or pipe were in a closed garage.
- The location of the vehicle in the 85 cases, where it was specified, was most frequently at a home (51% cases), at an enclosed workplace (7%) or at an open-air location away from home (including farm paddocks) (43%). A more detailed description is given in Table 4.

**Table 4. Deaths from Car Exhaust Gassings - Location**

<b>Location</b>	<b>No.</b>	<b>%</b>
Inside vehicle in:		
-Garage	21	25
-Workplace (enclosed)	6	7
-Carport	7	8
-Home (outside)	11	13
-Bushland/parkland	15	17
-Roadside	11	13
-Paddock	5	6
-Car park	4	5
-Cemetery	1	1
Outside vehicle in garage	4	5
<b>Total</b>	<b>85</b>	<b>100%</b>

Forty-six percent of the MVEGS were undertaken at the victim's own home, 5% in another home. There is possibly an indication here of why MVEG is a relatively popular method of suicide in Australia. Australians have a high incidence of vehicle ownership and home ownership combined with suburban living, often with garages to conceal a vehicle and remote areas where MVEGS can be attempted undisturbed.

- The engine was still running when the victim was found in two thirds of the 76 cases, where this could be determined.
- The median carboxyhaemoglobin level (COHb), for the 88 cases for which it was noted, was 79%. The range was from 58% (no other drugs) to 95%. The measure, however, is not necessarily regarded as accurate above 80% (Sugo,E, 1994). There were lower levels (included in calculating the median) of 2%, 37% (combined with a detected presence in the blood of paracetamol), 47% (with morphine and heroin), 49%

(with alcohol 0.18%) and 51% (with alcohol). In explanation of the 2%, a low level of COHb in the blood does not exclude toxicity due to CO poisoning as the cause of death if the clinical situation is strongly suggestive of it. It is possible that, by the time a blood sample is taken, the CO may have been blown off from the lungs. Even if the dose of CO is lethal, the person may not die immediately but continue to breathe long enough to blow off the CO.

- For the 75 cases in which both the victim's COHb level and the age of the victim was known, 26 involved vehicles manufactured in 1986 or later and 48 involved earlier models. The median COHb level of victims in these two groups was identical (77.1%).
- Information was collected on drugs detected in the autopsy. Alcohol was detected in 24 cases, benzodiazepines in 10, paracetamol in 8, cannabis in 7 and other pharmaceuticals, usually in a 'cocktail' in 7. All of the above drugs and medications were used in combination with others.
- Hayward et al (1992) found that alcohol is immediately involved in 20 to 50% of suicide cases in the Australian context and suggests that this involvement can be viewed in two ways. 'Firstly, alcohol through its disinhibiting and depressant effects, can contribute to the decision to suicide, which is often impulsive. Secondly alcohol can be used for so-called "Dutch courage", to facilitate the fatal action or to anaesthetise against the discomfort of a slower form of death'. Similarly, the ingesting of drugs has been implicated as a precipitating factor in suicidal actions (Hayward et al, 1992)
- Additional information was collected on age, sex and reasons given from the Coroner's files for the sample of cases studied but the data reported on these factors has been taken from more comprehensive sources - the ABS and the Coroner's caselists.
- There have been at least 2 cases of MVEGS in recent years resulting from asphyxia from carbon dioxide identified by Victorian Coronial inquests. The technique used in one case was as for CO poisoning from MVEG (hose from exhaust into the interior of the motor vehicle). The victims' vehicles had catalytic converters and Environment Australia tests 'at idle' and 'in drive' measured no CO in the exhaust.

### **4.3 OTHER STUDIES**

#### **4.3.1 International Studies**

Similar studies were undertaken in Sweden and Denmark.

- In East Denmark 228 medico-legal certificates from 1990 to 1993 were examined. Similarly the MVEGS were predominantly male (88%) and middle-aged. The median age was 49 for men and 46 for women. Sixty-five percent took place outdoors and 25% in garages (20% inside a closed vehicle, 5% outside the vehicle) (Thielade et al, 1998).
- Ostrom et al in Sweden scrutinized necropsy, police and hospital records for 194 victims over a 4 year period. Again middle-aged males dominated. Most committed suicide in a car outdoors by means of a vacuum cleaner hose. Suicide notes were found

in 40%. Severe disease, mostly psychiatric, was seen in 61% of victims. Blood alcohol was detected in 51% of victims (Ostrom et al, 1996).

Studies completed in recent years in Australia which have provided useful information on MVEGS deaths and hospital admissions are:

#### **4.3.2 NSW Institute of Forensic Medicine**

The Institute of Forensic Medicine in the N.S.W Department of Health undertook a study *Suicidal inhalation of CO - a reappraisal of variables affecting lethal levels* involving the investigation of NSW Coroner's records for 112 vehicle exhaust gassing suicides over the period 1991 to 1995. The study investigated the inter-relationship in suicidal CO fatalities between COHb levels, exhaust characteristics, other toxicological findings and the presence of natural disease processes which may affect the outcome.

The study concluded, inter alia, that there was no support for the view that current catalytic converters (1986) are effective in reducing suicide by CO inhalation. Vehicles tested had a mean 20g/km CO emission for non-catalyst equipped and 11.3g/km CO emission for catalyst equipped. There was a small but not significant reduction in COHb levels for persons using catalyst equipped vehicles. One fifth of vehicles were found to have catalytic converters. The mean CO level was 72% (Sugo et al, 1996).

#### **4.3.3 National Injury Surveillance Unit**

Moller, from the National Injury Surveillance Unit, has also analysed ABS MVEGS data, over the period 1990-92, and the following were of relevance.

The fall in suicide numbers in 1993 and 1994 was accompanied by a fall in the proportion of MVEGS. This reflects the high lethality of MVEG, where a decrease in the use of this means in suicide attempts is likely to result directly in a similar reduction in deaths.

If MVEG had been eliminated as a means of suicide since 1979, the upward trend in male suicide would have been less marked and in female suicide would have remained relatively constant.

There was little difference between urban, rural and remote regions in the rate of MVEGS in the period 1990 to 1992.

Approximately 2% of MVEG self-harm hospitalisations result in death in hospital, and about 70% of them require admission for less than 3 days with a mean length of stay of about 6 days.

MVEG related self-harm represents a smaller proportion of hospitalised attempted suicides (2%) than successful suicides (21.6%). This is likely to be the result of the lethality of MVEG as a means of suicide compared to other means.

The age and sex distribution of MVEG related admissions is generally similar to that seen for completed suicides. It appears however that younger males are relatively more common among hospitalisations. This suggests that attempts among younger males are more likely to be detected before death occurs presumably due to higher involvement of their family.

Of relevance here is a Chicago study by Maris (1981) who found that suicide completers were much more likely than non-fatal attempters to be responded to by no-one, police officers or firefighters, and much less likely to be responded to by family members or friends. He considered that these factors clearly contributed to their suicide attempts being fatal.

#### **4.3.4 New et al, May 1996**

The above author presented the results of the study on '*Neurological Outcomes after Carbon Monoxide Poisoning*' at the Royal Australasian College of Physicians Annual Scientific meeting (May, 1996, Canberra). The researchers found four possible outcomes in addition to death: delayed deterioration, progressive recovery, delayed recovery and progressive deterioration. Increased risks were associated with extremes of age and pre-existing circulatory diseases.

They noted that approximately 75% of patients progressively recovered with varying degrees of residual deficits. Those who progressively deteriorated include those with akinetic mutism and severe Parkinsonian features. In some studies up to 20% of patients make a partial recovery but then experience a delayed deterioration between 1 and 6 weeks after exposure. Case studies have also documented patients who make very little improvement over many weeks despite treatment, but then experience a limited delayed recovery up to 2 months after exposure. The varying patterns can probably be explained by the heterogeneous nature of patients regarding poisoning severity, varying co-morbidities and different treatment regimens.

#### **4.3.5 Further Research**

Greater knowledge of the aetiology of MVEGS could be gained from detailed data on patients who have not 'succeeded' ie completed their suicide attempt. The reasons for the choice of method, the duration of the attempt, why the suicide was not completed, details of previous attempts and information on the make, model and year of manufacture of the vehicle would provide most useful data. To date, studies focusing on the means of exhaust gassings have been confined to deaths. Comparisons of completed and non-completed cases may lead to the identification of further potential points of intervention.



## 5. IMPACT ON EXHAUST GAS SUICIDES OF ENVIRONMENTAL EMISSION CONTROLS

### 5.1 NATURE OF CONTROLS

Carbon monoxide levels from vehicle exhausts have been required to be reduced over the past decade, as measured at warm idle, for environmental reasons (prior to 1986, 95% of carbon monoxide in the air could be attributed to motor vehicle exhaust). The required maximum levels have been 24.3g/km from July 1976 (ADR27A), 9.3 g/km from 1986 for new passenger vehicles (ADR37-00) and 2.1 g/km for new models (ADR37-01) from 1997 and for all new passenger vehicles from 1998.

In order to cope with the unleaded petrol legally required since 1986 vehicles usually require catalytic converters (ADR37-00, AS2877). These convert the harmful exhaust pollutants of carbon monoxide, hydrocarbons and oxides of nitrogen into the relatively harmless by-products of carbon dioxide and water.

The converter itself is a stainless steel canister that looks like a small muffler. It is usually inserted into the exhaust system between the engine and the front muffler. The canister consists of a ceramic honeycomb with a fine coating of alumina, containing platinum or paladium metals to act as a catalyst. Harmful vehicle exhaust gases pass through the converter, where the catalytic metals trigger the reaction of pollutants with each other. The effectiveness of the CO converter depends on a number of factors including air:fuel mixture which in modern vehicles is constantly monitored by sensors. The catalytic converter does not work efficiently until warmed up. This usually takes about 100 to 200 seconds, longer in colder weather (EPA, March 1986).

### 5.2 IMPACT OF CONTROLS

#### 5.2.1 Literature

The following is an example of case reports which have appeared in the international literature attributing the victim's recovery to a catalytic converter.

*A 43 year old man was admitted to hospital in Britain after a MVEGS attempt in a SAAB fitted with a catalytic converter. The engine had been running for about 5 hours when discovered by police; he was semi-conscious. On arrival at hospital he was found to have a COHb concentration of 21%. He made a good recovery, with no evidence of cognitive impairment. Pre-catalytic converter, death would have been expected within 20-30 minutes. At this stage, COHb concentrations would be above 50-60%. CO controls, requiring catalytic converters, have been in operation in the UK since Jan 1993, in accordance with a European Community directive on standards for emissions (O'Brien & Tarbuck, 1992).*

Several overseas studies which have examined the relationship between suicides and MVEG have found that the imposition of emission controls reduces MVEGS. For example, Lester (1989) examined the changing rates of suicide by MVEG in men and women in the US after the concentration of toxic gases were reduced in exhaust emissions. The introduction of federal emission control standards in 1968 led to a considerable reduction in the CO content of MVEG. This produced two measurable effects. First, the failed suicide rate for CO poisoning increased (Hay and Bornstein, 1984). Second there was an

immediate decrease in the rates of successful suicide in men, and a delayed but reduced rate among women. Curiously, the MVEGS rate for both males and females began to show an upward trend again in the 1980's (Lester, 1989).

Further, Clarke and Lester (1987) compared the US and Britain in terms of their suicide rates for MVEG emissions. As noted, the US introduced emission controls in 1968, whilst Britain imposed no such controls. Suicides by MVEG subsequently declined in the USA, whilst no decline was found in Britain. O'Brien and Tarbuck (1992) presented case-study evidence in support of the introduction of controls on exhaust emissions in Britain (introduced 1993).

However, if emission controls were clearly so effective, there would have been a decline in MVEGS in Australia from 1986 and MVEGS would not be occurring in vehicles with catalytic converters. The upward trend noted in the 1980's in the USA is also puzzling.

One problem in assessing impact is that the availability of one method is unlikely to be the only factor affecting national suicide rates. Information is relevant on the availability of other methods for suicide, which typically are also changing at the same time. A substituted method will need to satisfy many of Lester's selection of method criteria. There appears to be no obvious method to replace MVEG - perhaps drugs (which have a high chance of recovery) or single vehicle crashes because they are vehicle related or hanging because it an increasingly common method. National suicide rates are, as previously mentioned, also affected by social and economic variables, such as the quality of life, unemployment rates, marriage and divorce rates, and changing patterns of religious behaviour (Lester, Abe, 1989).

Although the current and potential impact is not clear, some understanding can be gained from the following:

### **5.2.2 Australian data**

- As shown in figures 5, 8 and 7 MVEGS have increased as percentage of suicides, rates and absolute numbers, rather than reduced, since catalytic converters became mandatory in 1986. In 1995, 43% of Australian motor vehicles were 1986 models or later (ABS, Aug 1996). If catalytic converters and the 1986 emission standards of 9.3g/km had made MVEGS in post-1986 vehicles impossible, then MVEGS should have reduced from 2.08 to about 1.19 per 100,000, between 1985 and 1995 (assuming a similar distribution of vehicles to the Australian fleet and an unchanged number of attempts). In fact, rates per 100,000 population have been about 2.5 for the past five years and peaked at 2.85 in 1995.
- Hospital admissions for MVEGS attempts in Australia have doubled between 1991/92 and 1995/96 (figure 11) (excluding 1994/95) suggesting some impact of lower toxicity, resulting in hospital admission rather than death in some cases.
- In an examination of 75 MVEGS Victorian files, where year of manufacture could be determined, 27 (ie 36%) had catalytic converters.

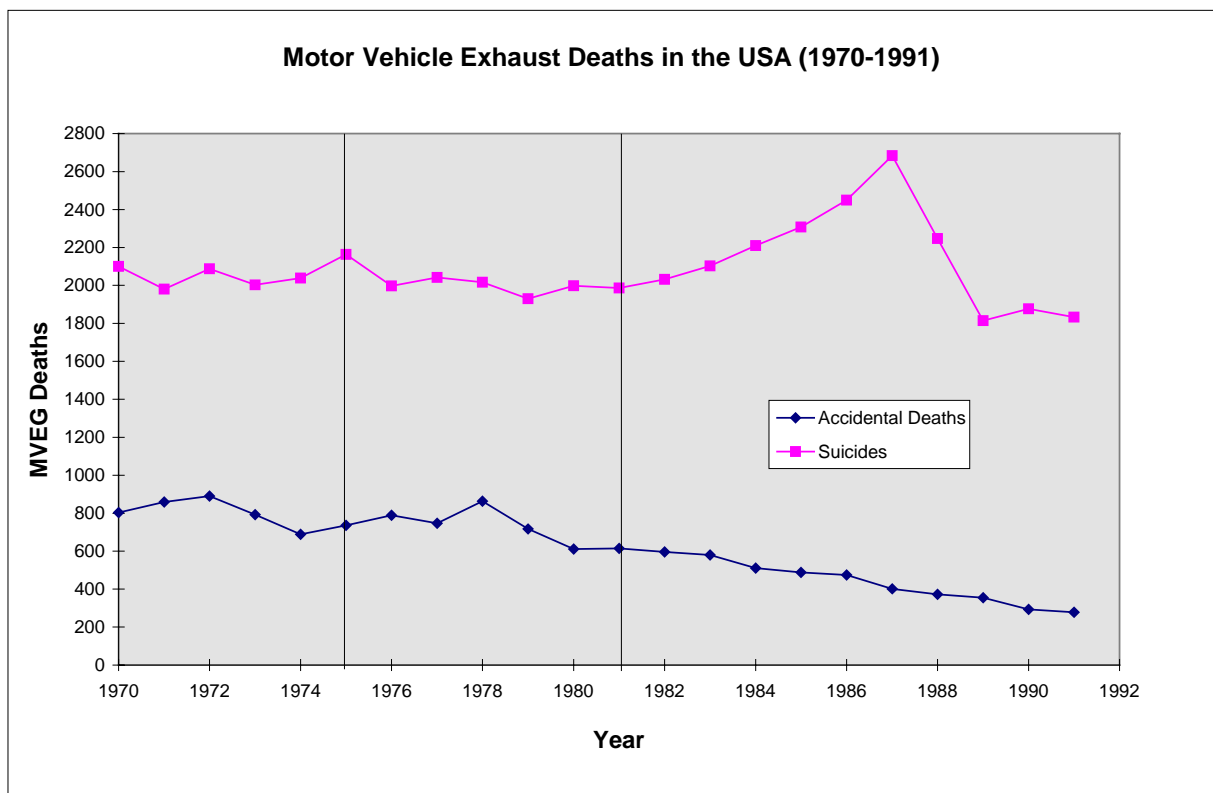
### **5.2.3 USA Data**

The CO environmental limits in the USA are below those for Australia. They were 9.3g/km in 1975 (associated with catalytic converters) (compared with 1986 in Australia)

and 2.1g/km in 1981 (compared with 1997 in Australia) (Code of Federal Regulations, 1997). The USA trends, therefore, should have some relevance to the Australian situation, especially since the test conditions are similar. It should be noted that the average age of vehicles is 7 years in the USA and 11 years in Australia, suggesting a longer lag time for new vehicle exhaust emission changes to have an effect in Australia.

- Data from the USA shows a progressive increase in the number of MVEGS from 1981 to 1987, followed by an apparent decline to levels some 10% below the pre 1982 numbers and rates. For accidental MVEG deaths there has been a progressive decline since 1978 (figure 12). The latest available year for USA MVEG data is 1991 (cf Australia 1996).

**Figure 12. Motor vehicle exhaust deaths in the USA (1970-1991)**



(Source: graphed from US National Center for Health Statistics data)

- Data from other sources show MVEGS in the U.S.A have reduced from 8.9% of suicides in 1970 to 7.4% in 1980 and 5.6% in 1991 (Hay and Bornstein, 1984; Lester, 1996 ). The easy accessibility to firearms makes them by far the most common method.
- According to Lester, the rates of men and women committing suicide by using MVEG responded differently to the imposition of emission controls on cars. The male rate dropped immediately after emission controls were imposed, whereas that of females continued to rise. Eventually both rates dropped until the early 1980's, whereupon they began to rise again (Lester, 1989).

- Lester adjusted the number of cars for toxicity and found there was only a moderate fit between exhaust suicides and the ‘toxicity’ of the total vehicle population (ie the adjusted measure of cars in use). He interpreted these results as generally supporting the potential for opportunity-reducing preventive measures, but also demonstrating that much more research is needed into the complex nature of the opportunity structure for suicide (Clarke & Lester, 1987).
- In 1991, up to 56% of USA vehicles were post-1981 models (based on calculations from registered numbers in the publication ‘World Road Statistics’). If the 1981 emission standards of 2.1g/km made suicide in these vehicles impossible, then MVEGS should have reduced from 7.2% to about 3.1% (as a proportion of suicides between 1981 and 1991 ignoring any impact from pre-1981 vehicles). The actual value was 5.6%. This reduction assumes MVEGS have a similar distribution of vehicles to the USA as a whole and the number of attempts is unchanged. A literature search yielded no USA studies which investigated the age of vehicles used for MVEGS.
- Shelef noted that, after accounting for the growth in population and vehicle registration, the yearly lives saved in accidents by MVEG in the US were approximately 1200 in 1987 and avoided suicides approximately 1400. He attempted to explain the unabated reduction in accidents compared with the MVEGS plateau between 1981 and 1983 in suicides by the latter being a voluntary act and therefore subject to many factors and that suicide can occur with “tricking” ie in a closed, sealed space, a vehicle can be tricked into a richer mixture after prolonged idling (Schelef, 1994). However this will be an explanation only if suicides with the vehicle inside closed garages rather than in the open are common (not so in Australia).

#### **5.2.4 Japanese data**

In 1975 the Japanese tightened emission controls (4.5% while the engine was idling) and the accidental death rate from MVEG declined (Lester, Abe, 1991).

Ownership of cars continued to increase in Japan from 1950 to 1980, but emission controls were gradually introduced in the 1970’s. The accidental death rate using MVEG peaked in 1970 and the suicide rate in 1981, at a time when this was the latest year of data. The correlation between the 2 rates was 0.58 (Lester, Abe, 1990).

### **5.3 EXPLANATIONS FOR SUICIDES IN LATER MODEL VEHICLES**

It appears that MVEGS have not reduced as much as expected with reductions in emission levels and it is of note that the pattern between Australia, Japan and the USA may have similarities ie a lagged levelling off after the introduction of CO exhaust limits. Considerably less reductions are anticipated than would be expected if exhaust emission CO levels of 2.1g/km made MVEGS extremely difficult to achieve.

In explanation, it appears that the testing for these legislated environmental limits may not be particularly relevant to the suicide lethality situation where:

- A hose or pipe is led into the interior of the vehicle and ventilation is sealed. In this situation, it appears inappropriate that CO limits are the same for each vehicle regardless of the vehicle’s cabin volume.

- The engine idles. In environmental CO testing, there are 3 phases to the vehicle testing and none of these involve idle only.
- Other gases are involved (eg. oxygen depletion, CO<sub>2</sub>) which have a synergistic and additive effect.
- Heat and humidity buildup in the cabin may exacerbate the effects of CO.
- CO from smoking may increase the level of CO in the cabin.

Situations where CO emissions may exceed the legislated limit are where:

- The engine idles from a cold start, with a delay of between 1.5 and 3 minutes before the catalytic converter has warmed up and is operating efficiently. Since carboxyhaemoglobin concentration rises most rapidly when first exposed to CO, the initial absorption rate would be particularly high (Ernsting & King, 1988).
- Fuel vapours are purged from the catalytic converter when the vehicle is started.
- Vehicles have a closed loop system ie an oxygen sensor controlling to an ideal air:fuel ratio. A closed loop system may not operate at idle causing increased CO emissions.
- Extensive idling after being driven may reduce the combustion temperature to a point where the catalytic converter does not operate efficiently.
- The air:fuel mixture of an idling vehicle is lean, causing the engine to operate roughly. Adjustments may result in more CO being produced to make the engine operate more smoothly.
- The condition of the catalytic converter has deteriorated (eg. through being driven at high speeds) or the engine may require tuning (under ADR 37-00 a catalytic converter is required to operate effectively for 80,000km or 5 years, whichever occurs first).
- Destruction of the exhaust system by the use of leaded gasoline, can increase the CO content, and thus the lethality of this method for suicide (Lester, 1989).
- The pollution performance has deteriorated. The pollution performance of 4-9 year old cars has been found to deteriorate faster than older cars (FORS, 1996).

Additionally:

- Modern vehicles may be better sealed ie less ventilation and modern exhaust systems are made of less corrosive material and, therefore, are a more efficient director of CO into the vehicle.
- Cigarette smoking may provide an additional risk. It elevates the COHb by an average of 2% per pack per day. It can be assumed that COHb levels while, or shortly after, smoking would be higher than these average levels.
- East Denmark researchers set up 3 vehicles (one without a catalytic converter, one with a malfunctioning 3 way catalytic converter and one with a well-functioning 3 way catalytic converter) to donate exhaust gases to a vehicle cabin under three different

starting conditions (cold, tepid and warm). Measurements of CO, CO<sub>2</sub> and O<sub>2</sub> were made in both the cabin and exhaust pipe. A model was developed describing the transient CO concentration in the vehicle cabin. They concluded that it is possible to commit suicide by CO poisoning using a vehicle with a catalytic converter when the engine is started cold or if the catalytic converter is not functioning well. They considered it more difficult to successfully complete a suicide attempt using car exhaust when the catalytic converter is well-functioning and the engine is started warm. However, when the setup was very airtight, CO<sub>2</sub> concentration high and oxygen low, in the cabin, loss of consciousness and possibly death could occur (Morgen at al, 1998).

## **6. PREVENTION, RECOMMENDATIONS AND PROGRESS**

### **6.1 RATIONALE FOR PREVENTION**

There are many examples to show that society believes in preventing suicide. For example, \$31 million has been allocated to the National Youth Suicide Prevention Strategy by the Commonwealth Government over a 4 year period. Three hundred thousand dollars of this is specifically for prevention of 'access to the means' (Commonwealth Department of Health and Family Services, 1997).

Society does, in various ways attempt to prevent suicide through particular methods eg in prisons and youth training centres, prisoners cannot have belts, shoelaces etc. There is some monitoring of favourite suicide locations and follow-up preventive action eg monitoring of vehicles on the Westgate bridge in Melbourne and intervention when a vehicle stops for too long; restriction of access to the roofs of high-rise public housing. Also MVEGS victims are frequently physically healthy middle-aged men with dependents. This issue should not, therefore, be confused with the euthanasia debate.

In order to justify changes to regulations, it is necessary to demonstrate the size and nature of the problem which is to be overcome, the effectiveness of proposed solutions and the likely benefits over costs.

### **6.2 COSTS AND BENEFITS**

The cost of a road death was calculated to be \$759,516 by the Bureau of Transport and Communication Economics (Steadman and Bryan) updated to September 1996 by the Consumer Price Index. Thus the cost per year attributable to 509 Australian car exhaust poisoning deaths was approximately \$386.6 million in 1996. This represents a cost of \$36.30 per year distributed over each of the 10.65 million motor vehicles in Australia (Census 31st May 1995, excluding motorbikes, caravans, trailers; ABS). If a device were developed which prevented 50% of these suicides and it cost \$36, the full costs would be recovered in just 2 years. Alternatively if a device cost \$72, or if it prevented only 25% of these suicides, the breakeven period would be 4 years. It seems likely that at least the second of these scenarios could be achieved (based on costs and benefits in Routley, 1994). Furthermore, in this calculation the additional benefits of preventing several hundred hospital admissions resulting from failed MVEGS are excluded. If the current US Consumer Product Safety Commission cost of death figure of US\$5 million were applied, the benefits would even more quickly exceed the costs (ie in less than one year)

While it is considered that ultimately the solution should be in terms of performance requirements for the vehicle, there are several design solutions possible for the prevention (or minimisation) of MVEGS. These are intended to be neither prescriptive nor exhaustive.

### **6.3 DESIGN SOLUTIONS**

#### **6.3.1 Sensing Device**

The mandatory incorporation into new vehicles of a multi-gas sensing device which monitors carbon monoxide, oxygen and possibly carbon dioxide levels and, when levels become toxic, displays a warning light, then emits an alarm and finally shuts down the engine. The operation of window winding devices could also be incorporated.

Devices for the household which meet the Underwriters-Laboratory Inc. (UL) standard 2034 are available in the U.S for between AU\$43 and AU\$100 and a similar concept could possibly be fitted to the engine management system of the motor vehicle. The U.S Consumer Product Safety Commission recommends CO detectors which meet this voluntary standard, UL 2034, the UL Standard for Safety for 'Single and Multiple Station CO Detectors', April, 1993 edition, with revised requirements from October 1, 1995. Detectors that meet UL 2034 measure both high CO concentrations over short periods of time and low concentrations over long periods of time (CPSC Document #5010, Underwriters Laboratories Inc., 2/4/96).

The U.S Consumer Product Safety Commission has been investigating technical requirements to overcome sensitivity problems with currently available designs of CO detectors. Potential tests include the use of chemicals (a chemical becomes darker in the presence of CO and the alarm is activated by a light sensor), plug-in semi-conductors and infra-red technology. Currently alarms are activated at CO levels which produce COHb levels of 10% or above. They are not intended to alarm below 10% (Leyland, 1996, personal communication). It should be noted that this is considerably above the 5% COHb guideline of Australia's National Occupational Health and Safety Commission.

The Recreational Vehicle Industry Association (RVIA) in the USA requires CO detectors in motor homes made after September 1, 1993. RVIA requires CO detectors in all recreational vehicles that are motorised. RVIA's membership includes approximately 90% of all US recreational vehicle manufacturers (US Consumer Product Safety Commission, CO fact sheet, document 5010, 3/11/96). Such CO detectors appear to have relevance to the MVEGS situation and warrant further investigation.

A multi-gas sensor could be incorporated with an anti-fatigue device or possibly an anti-theft device, thus not drawing attention to its suicide prevention role (Moller, 1996). A sensor attached to the engine management system of a motor vehicle would have the added advantage of identifying and preventing unintentional CO poisonings and driver fatigue, drowsiness and poor coordination due to oxygen deprivation and leaks of carbon monoxide from unsealed boots, rusted holes and access through open windows. Recent research on CO levels inside motor vehicles and on motorways has indicated the levels inside tunnels, car parks and vehicles may approach 30 parts per million, which is the upper limit of what is considered safe for the workplace over an 8-hour average. This level may be sufficient to affect the ability of a smoker to think clearly (5% COHb level, compared with 2% non-smoker).

The detection level should not be set so low, however, that the sensor would stop the vehicle in peak hour traffic or cold underground car parks where carbon monoxide levels are often high. The graph from Ernsting and King showing the relationship between time, ambient CO levels and COHb levels (figure 6) and similar graphs, plotted by others, plus those of CO<sub>2</sub> and O<sub>2</sub>, are relevant to determine the correct setting.

### **6.3.2 Exhaust Modifications**

The exhaust pipe on new vehicles and at the time of replacement could be modified to incorporate a device inside the pipe, so a hose cannot be inserted, and to make the end of the pipe irregular, to make it difficult to fit a hose. A model which incorporates current design features is likely to be most acceptable - eg cross inserted and 2 oval-shaped pipes immediately adjacent to each other (Attachment 2). If such a design or a performance

standard were regulated for replacement parts, older exhausts would gradually be replaced with the modified exhausts.

New designs would need to overcome any problems of backpressure, vibration or noise and would need to meet current exhaust regulations (eg exhaust gases should be emitted beyond the vehicle).

Since the average life of a rear muffler and tail pipe assembly is approximately 5 years, about 50% of existing vehicles would have been retrofitted within this period.

A paper by Professor Peter Vulcan for the working party on 'Reduction of Suicides – vehicle exhaust systems' provided a crude estimate of the likely effectiveness over time and cost-effectiveness of carbon monoxide detectors and exhaust pipe modifications. The calculation of such crude cost-effectiveness estimates is often done in considering future motor vehicle safety measures as a guide to selection of the most promising approach. Assumptions on the likely values of several factors were made, but if information or opinion is provided which leads to a different value this can be substituted. The analysis concluded that fitting a CO detection device to all new vehicles is likely to result in a greater number of suicides being prevented ultimately than modification of the exhaust tailpipe, at a similar cost per life saved, but with a slower rate of achieving the ultimate result.

Both approaches showed sufficient promise of a potential cost-effective contribution to the prevention of MVEG, to warrant further expenditure on research to better define what is involved and to provide more precise estimated values for the assumptions made (Vulcan, 1997) (Attachment 3).

### **6.3.3 Further Improvements in Engine Design**

Further improvements could be made in engine design and in catalytic conversion techniques to complete the combustion process and thereby virtually eliminate carbon monoxide emissions. Some vehicle makes are more advanced than others in this regard.

### **6.3.4 Other**

Design possibilities, such as placing a potentially pungent odour in petrol to operate when CO emissions are in heavy concentrations or oxygenating petroleum, could also be explored.

### **6.3.5 Discussion**

While there may be ways and means of circumventing these preventive measures, they would require mechanical knowledge and planning and, therefore, more time for the potential suicide to change his/her mind. Unlike safety and environmental design changes, modifications to reduce suicide may need to be undertaken quietly ie without publicity or media attention and possibly with the dual functions of another feature eg CO and O<sub>2</sub> sensor for driver fatigue; anti-theft device.

It is of relevance that Ostrom et al concluded that environmental changes may reduce the number of MVEGS eg introduction of a law requiring catalytic converters, of automatic idling stop and of exhaust pipes incompatible with vacuum cleaner tubes. They stressed the importance of appropriate treatment of psychiatric patients (Ostrom et al, 1996).

It is recognised that design changes will not eliminate all suicides. Complex social, economic and psychological reasons underlie the causes of suicide and the solutions for these require a multi-faceted longer term approach.

## **6.4 RECOMMENDATIONS**

1. Mandatory regulations should be introduced for new vehicles which will make exhaust gas suicide virtually impossible, by ensuring that life threatening levels of CO, O<sub>2</sub> and possibly CO<sub>2</sub> cannot be reached by passing a hose from the exhaust into the vehicle with sealed ventilation. A sensor is preferred because it would cater for deterioration in catalytic converter and engine performance over time.
2. Regulations should be introduced for in-service vehicles requiring replacement exhaust pipes to be of new safety designs to make it substantially more difficult to attach a hose.
3. A study of MVEGS attempters (ie those admitted to hospital) should collect information undertaken which further clarifies potential countermeasures and risk factors. Variables on which it would be important to collect data are: how long the vehicle ran, if they were interrupted, if they reneged, the reason for selection of the MVEG method, the practical details of how they made the attempt, eg. equipment used, the blood alcohol content and if possible the presence of other drugs, if they had previously attempted suicide by exhaust gas or otherwise and information on the make, model and year of manufacture of the vehicle. Such data would be most useful in gaining further insight into how MVEGS are undertaken and the extent to which catalytic converters are making an impact. Data collected so far has concentrated on deaths.
4. The Suicide Module of the National Coronial Information System should collect information encoded and/or in text including the make, model and year of manufacture of the vehicle; COHb level; drugs, medications and other gases detected at pathology; practical details of the attempt including equipment used; details of previous attempts. Additionally there should be a move towards consistency in the medical and legal definitions of suicide.

These actions should be undertaken quietly, without media attention. Adding to the risk group's knowledge of how to undertake this method, or risking 'copycat' suicides, should be avoided.

## **6.5 PROGRESS**

### **6.5.1 Department of Health and Family Services**

The Australian Institute of Suicide Research and Prevention (AISRAP) produced a report "Access to means of suicide by young Australians" for the "Access to Means" committee of the Youth Suicide Prevention Advisory Group of the Department of Health and Family Services and made recommendations for reducing access to the means of suicide including exhaust gassing. The Mental Health Branch of the Department of Health & Family

Services has responsibility for the allocation of \$30,000 to conduct research into alleviating exhaust gassing suicides.

### **6.5.2 Australian Medical Association (AMA)**

There have been four meetings of a working group convened by the AMA, and initially the Federal Office of Road Safety, to reduce vehicle exhaust gas suicides since November 1996, with representatives from various interest groups: automotive organisations - Federal Chamber of Automotive Industry, Australian Automobile Association, Australian Automotive Aftermarket Association, Australian Institute of Petroleum; government bodies such as the Federal Office of Road Safety, Environment Australia, Health & Family Services and the Australian Building Control Board; universities eg MUARC, AISRAP, NISU and representatives from forensic medicine and psychiatry. The Secretariat has been undertaken consecutively by the Federal Office of Road Safety, the AMA and the National Road Transport Commission.

The initial meetings concentrated on becoming familiar with the issues and filling in information gaps. The priority recommendations for the allocation of the H&FS \$30,000 have been revised. These are now:

- \$6,000 to bring Prof David Penney, Director of Surgical Research and Professor of Physiology, Wayne State University, US, an expert on the physiological effects of CO to a meeting of the working group in Melbourne to determine an appropriate CO level for a CO detector. He is expected to produce a report in September, 1998.
- \$15,000 to Dr Michaela Skopek of the Prince of Wales Hospital in Sydney to research MVEGS attempters who have been treated for CO poisoning at the hospital's hyperbaric unit. The study is in progress and Dr Skopek is attempting to identify the reasons for their method choice, their demographic profile, details of their psychiatric record and any previous suicide attempts by MVEGS or other methods and the details of their latest MVEGS attempt, including the presence or otherwise of catalytic converters.
- \$5,000 to an industrial design student at the University of South Australia in Adelaide to research the available exhaust pipe designs and to design a tailpipe which is low cost (including fitting), which does not cause problems of backpressure or reduce performance etc and which deters the fitting of a vacuum or garden hose. A design has been produced which meets these criteria.
- \$4,000 for a computer model which simulates the exhaust gassing suicide scenario. Mr Jerry Moller has now submitted a paper, which includes a model of CO and O<sub>2</sub> exhaust gas concentrations, to the Department of Health and Family Services Mental Health Branch.

The AAA has allocated \$15,000 to RMIT in Melbourne for the development of a CO sensor for the vehicle cabin. Currently the emphasis is on developing CO, O<sub>2</sub> and CO<sub>2</sub> detectors. The focus will then be to link these into a multi-sensor system. Additional funds are likely to be required for development to the next stage.

International enquires have produced very little activity to reduce suicides by this method and it appears that this committee is leading the way internationally.



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# Attachment 1

DUMP OF SELECTED DATA (MANNER OF DEATH AND INTENT ORDER)  
(Coroners' Facilitation System, Victoria, Australia)

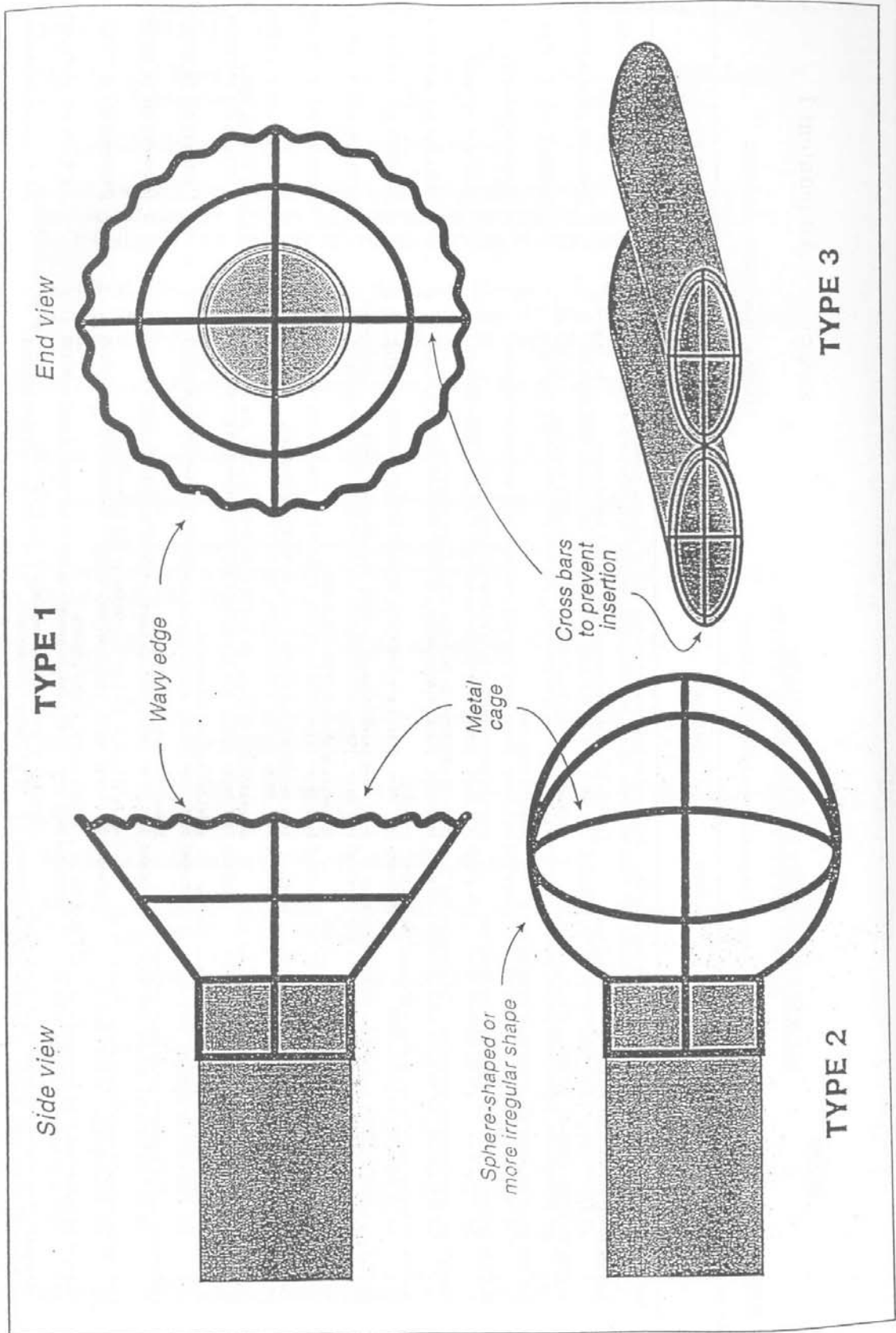
FOR DEATHS FROM 01/07/93 TO 30/06/94

(one of 8 pages of exhaust gassing suicide cases)

MANNER OF DEATH = GASSING FROM CAR (6)

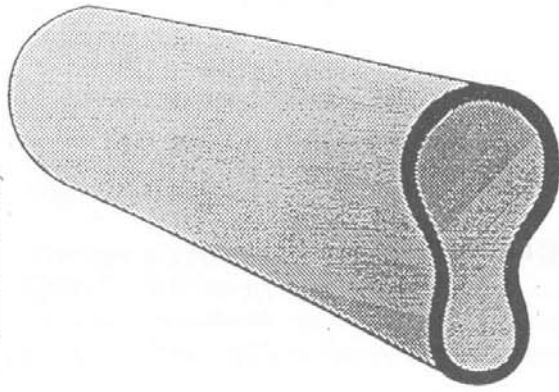
AGE       	SEX       	STATUS       	LOCATION	CONTEXT	INSTRUMENT	INTENT	FACTOR 1	FACTOR 2
70	M	Retired	OWN HOME GARAGE GARDEN	He lost the will to live due to his wife constantly talking about suicide and that he should join her	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
64	F	Retired	OWN HOME GARAGE GARDEN	deceased was depressed for no apparent reason, and got her husband to join her.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
25	M	Employed, bu	OWN HOME GARAGE GARDEN	deceased was depressed over the break up of his relationship with his girlfriend.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
24	M	Hot Known, o	OTHER OUTDOOR AREAS	deceased had a domestic dispute.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
65	M	Retired	OTHER OUTDOOR AREAS	deceased was severely depressed due to his deteriorating health	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
40	M	Employed, bu	NATIONAL PARK OR OTHER	deceased had in the past attempted to take his life on two occasions.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
41	M	Employed, bu	PUBLIC ROAD	deceased had marital problems.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
32	F	ALL Benefits	OTHER PRIVATE HOME GARA	deceased had been deeply depressed since an alleged rape about six years previously.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
32	M	Employed, bu	OWN HOME GARAGE GARDEN	deceased was depressed after a marital break-down.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
21	F	Child, stude	SCHOOL (HOT PLAYGROUND)	deceased suffered from depression and dysfunctional personality disorder.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
24	M	Employed, bu	OTHER OUTDOOR AREAS	deceased was depressed due to the death of his brother-in-law, and the fact that he had separated from his wife.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
37	M	Hot Known, o	PUBLIC ROAD	deceased had no reason for the suicide has been discovered.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
56	M	Employed, bu	FACTORY, WAREHOUSE	deceased had a history of heavy drinking.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
36	M	Unemployed	PUBLIC ROAD	deceased was depressed after having broken up with his girlfriend.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
47	M	Employed, bu	PARKING AREA	deceased felt he could not handle life anymore.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION
31	M	Employed, bu	OWN HOME GARAGE GARDEN	deceased was depressed after having broken up with his girlfriend and over being unemployed.	Cars, stationwagons, va	Self-inflicted	CARBON MONOXIDE	PASSENGER CAR OR STATION

# EXHAUST PIPE DESIGN CONCEPTS

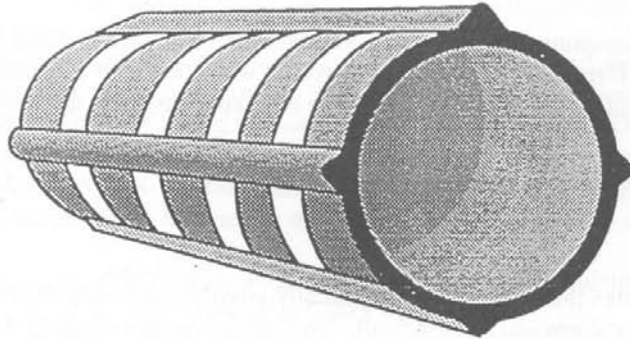


EXHAUST PIPE DESIGN CONCEPTS

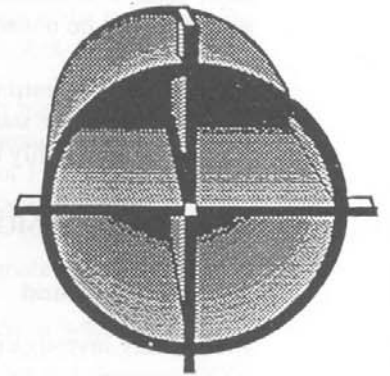
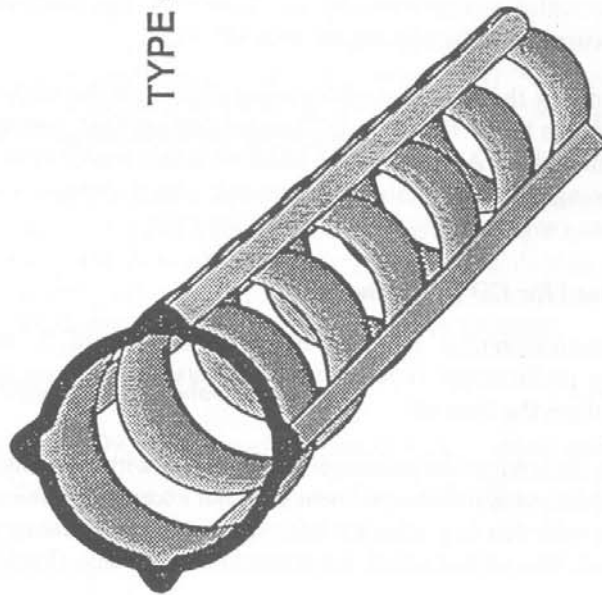
Attachment 2 (continued)



TYPE 5



TYPE 4



TYPE 6

# **ATTACHMENT 3**

Committee Draft

## **PAPER FOR AMA CONVENED WORKING GROUP TO REDUCE MOTOR VEHICLE EXHAUST GAS SUICIDES**

### **COST-EFFECTIVENESS OF VEHICLE EXHAUST GAS SUICIDE COUNTERMEASURES**

#### **1. INTRODUCTION**

This paper attempts to provide a crude estimate of the likely effectiveness over time and cost-effectiveness of two of the proposed countermeasures for exhaust gas suicides. The calculation of such crude cost-effectiveness estimates is often done in considering future motor vehicle safety measures as a guide to selection of the most promising approach. In most cases it is extended to estimating benefit/cost ratios (but this may not be necessary here if people do not wish to place a value on human life).

In making these estimates, assumptions on the likely values of several factors must be made and these are stated. If information or opinion is provided which leads to a different value, this can readily be substituted, or a range of values can be used (sensitivity analysis).

#### **2. CARBON MONOXIDE DETECTORS**

##### **2.1 Background**

Preliminary investigation indicates that it should be technically possible to design/develop a CO detector that will sound an alarm and automatically shut off the engine when the CO concentration inside the car reaches critical values. The critical values of CO concentration are likely to be dependent on the period of exposure, being lower for longer periods so that a critical level of carboxyhaemoglobin is not exceeded (see Figure 1). The alarm can be set at lower CO levels for respective times than the engine shut off.

It is not known whether some of the new cars which more than meet the latest exhaust emission standards would remain below the critical CO concentration/time envelope. The proposed tests would determine this. A performance standard would enable new vehicles to comply either by producing an engine/catalytic converter which complies with the critical CO concentration/time envelope or by fitting the CO detector.

##### **2.2 Performance Standard for CO Inside the Car**

Once the critical CO concentration/time envelope has been determined, it would be relatively easy to develop a performance standard that prevents the CO concentrations exceeding these levels, e.g. along the lines of:

“When the exhaust gases are ducted into the passenger compartment with all windows and vents sealed, the CO concentrations in the compartment shall not exceed the values shown in Figure 1, at any time from cold start (e.g. after 12\* hour storage at a temperature of

2°C\*) until a full tank of fuel is used. The engine speed and manual choke (if any) should be set at levels resulting in the highest CO concentrations for the first 60\* minutes and then at idling speed for the remainder of the time.

The horn of the vehicle shall be continuously activated when the CO concentration reaches 90%\* of the levels in Figure 1.”

Note: Figure 1 to be supplied by the working group on Project 1, but it will be based on Figure 1 in this paper.

This type of performance standard would be suitable for new vehicles, provided that any difficulties of a unique Australian requirement could be overcome. It may also be possible to adapt it to vehicles already in use but installation is likely to be more expensive and enforcement through State law could present some problems.

### **2.3 Likely Effectiveness**

Assuming the device can be made tamper-proof for at least 95%\* of persons attempting suicide by this means and that the critical CO concentration/time requirements have been chosen to protect at least 95%\* of the population (there is likely to be a small percentage with CO tolerance well below the average e.g. heavy smokers smoking at the time) then the effectiveness in preventing a specific suicide attempt is  $0.95 \times 95\% = 90\%$  (at least).

An important unknown factor is the percentage (P) of persons who having failed in their attempted suicide by motor vehicle exhaust gassing would be persuaded not to make another attempt (using the same or a different method). The value of P is important to the work of this committee, and attempts should be made to determine its likely value. It is not unique to this countermeasure and needs to be estimated for all countermeasures. Professor Pierre Baume has suggested that 40%\* would be an appropriate value.

Hence the effectiveness in preventing all subsequent suicides by persons who chose motor vehicle exhaust gas suicide is  $0.90 \times 40\% = 36\%$ .

### **2.4 Time Period for Implementation**

If the standard was applied only to new cars, assuming the age of distribution of the car fleet remains as at present, after 10 years only approximately 50% of cars would comply and after 20 years the figure would be approximately 90%. A further 4-5 years should be added to these figures to allow for development of the regulation and then lead time between its promulgation and implementation.

If also required as a retro-fit, say as a condition of registration, the period to achieve complete fitting could be determined, based on how long it would take to supply and install approximately 9 million CO detector/engine disabling devices – say 2-3\* years, with a lead time of perhaps 1-2\* years. Note this would be an expensive exercise, costing perhaps \$50-100\* more than confining the requirement to new cars.

### **2.5 Number of Suicides Prevented**

On the basis of 509 suicides each year using motor vehicle exhaust gas, when all cars have been fitted, the annual number prevented would be  $509 \times 0.9 \times \frac{P}{100} = 183$ , assuming  $P = 40\%$ .

However even after 20 years, only 90% of cars in the fleet would be fitted and it is possible that some of those attempting suicide would search out the old (pre-fitting date) cars. Hence it may be necessary to assume say 20%\* of persons attempting suicide would find cars not fitted even 20 years after fitting of new cars began.

Thus number prevented  $183 \times 0.8 = 146$

During the first 20 years after the implementation of the new car requirement the numbers in the first year would begin at approximately  $\frac{1}{20}$  of the above, progressively increasing by a further  $\frac{1}{20}$  each year, thus averaging approximately half the above values, for these 20 years.

Retro-fitting of existing vehicles if it were feasible would achieve similar final numbers, much more quickly, but at increased costs.

## 2.6 Cost of Implementation

It is difficult to estimate the cost of the CO detection/engine disabling device. If the performance standard were a new vehicle requirement, after a reasonable lead time, it could average approximately \$60\*. This figure is based on an assumption that some vehicle manufacturers may be able to achieve compliance by developing very low CO concentration exhaust even when starting from cold and hence may not need to fit a special device.

Estimation for retro-fitting all vehicles is even more difficult, but it could well be in the range of \$100-160, say \$130\*, for fitting say 90% of cars (with the remaining 10% defying the requirement).

## 2.7 Cost-effectiveness

When 90% of vehicles have been fitted the number of persons saved each year has been estimated as 146.

For the new car requirement, assuming the present rate of 0.5 million new cars coming into the fleet each year, the cost per annum =  $500,000 \times \$60 = \$30$  million p.a.

Then after 20 years, when 90% of cars have been fitted,

$$\text{cost effectiveness} = \frac{30,000,000}{146} = \$205,000 \text{ per life saved}$$

and approximately double this value during the first 20 years of “build up”.

For retro-fitting, the initial cost of fitting 90% of 9 million vehicles is  $\$130 \times 9,000,000 \times 0.9 = \$1,053$  million.

The benefits over the 20 years after fitting has been completed would be  $20 \times 146$  lives saved.

$$\text{hence, cost effectiveness} = \frac{1,053,000,000}{20 \times 146} = \$361,000 \text{ per life saved}$$

Note: These calculations have ignored the discounting of future benefits to present day values, which economists would use to account for the fact that the vehicle device must be paid for now, with benefits to accrue over the next 20 years. This would result in even higher costs per life saved. They have also assumed that the devices have a 20 year life and have ignored any maintenance costs for the devices during that period.

### **3. EXHAUST PIPE MODIFICATIONS**

#### **3.1 Performance Standard**

A performance standard could be developed to make it difficult if not impossible to fit a hose to the end of the tailpipe. For example, it could be along the following lines.

“It shall not be possible for more than one person in ten\* randomly selected persons aged 15-60 years\* to successfully attach within 20\* minutes a hose selected from a collection of standard hoses (say 4\*) to the end of the tailpipe. The following tools would be available to the persons: hammer, pliers, hacksaw, vice, sharp knife, etc.\*”

“Successfully attach” could be defined as capturing more than 30% of the exhaust gas flow.

#### **3.2 Likely Effectiveness**

The effectiveness of this countermeasure depends on what proportion of attempted suicides could be completed without the use of a hose/piping.

Virginia Routley found that in a sample of 93 exhaust gas suicides, where the detailed method was specified, all but four used a hose or piping leading into the interior of the vehicle, with ventilation sealed. These four were in a garage with the doors closed. However, the fact that these four suicides were completed, indicates that preventing use of a hose/piping attached to the tailpipe will not prevent all suicides, if the car is in a garage with the doors closed.

Further information on this may become available from the research projects being planned. In the meantime, it is assumed that only 50%\* of those who were unable to “successfully attach” a hose would be able to complete suicide. This is a reasonable assumption as in the sample examined by Routley, only 25% occurred in a garage.

The performance specification would require that at least 90% of persons would not be able to attach successfully a hose to the tailpipe. Hence effectiveness in preventing a specific suicide attempt using a hose/piping is approximately  $90\% \times 50\% = 45\%$ .

Hence effectiveness in preventing all subsequent suicides by persons, who choose motor vehicle exhaust gas suicide is  $0.45 \times P\% = 0.18$ , where P is 40%\*.

#### **3.3 Time Period for Implementation**

Mr. David Wright has advised that the frequency of car exhaust replacements varies according to the age of the vehicle, as follows:

Pre-1985	passenger vehicles – average	2 years
1985-1990	passenger vehicles – average	5 years
1990-current	passenger vehicles – average	6-8 years

If fitting of the “hose resistant” tailpipe was required at the time of rear exhaust replacement – through all replacement pipes meeting the performance standard then there would be nearly 100% fitting within seven years.

Allowing say three years for the new standard to be formulated and implemented, the total time for complete fitting would be 10 years from now.

The rate of fitting could be improved somewhat if at least the Australian car manufacturers decided voluntarily that their tailpipes would meet the new standard (approximately 50% of cars in the Australian fleet are less than ten years old).

### **3.4 Number of Suicides Prevented**

On the basis of 509 suicides each year using motor vehicle exhaust gas, the number prevented would be  $509 \times 0.18 = 92$  per annum.

These values apply after seven years when almost the complete motor vehicle fleet has been fitted. Over the first seven years of the introduction period the average savings will be approximately half the above value.

### **3.5 Cost of Implementation**

Given sufficient lead time and a guaranteed market, it is expected that a modified tailpipe design could be produced for up to an additional \$10\*. This estimate could be refined after some preliminary work on what type of design would be required to meet the performance standard. Mr. Wright advises that there would also be a need to evaluate proposed designs to ensure that they did not produce an unacceptable restriction to exhaust gas flow. The proposed project to refine these costs is now required.

Based on an average exhaust pipe life of five\* years and assuming the device must be replaced whenever the exhaust pipe is replaced, the annual cost of the program would be  $\$ \frac{10}{5} = \$2$  per vehicle per year, i.e. \$18 million p.a. for the fleet of nine million cars.

These costs would be proportionally reduced if the average life of exhaust pipes increased, or the additional cost of the tail pipe modification were reduced or an “add-on” device could be re-used when the tail pipe was replaced.

### **3.6 Cost-effectiveness**

When all vehicles have been fitted, the estimated number of persons saved each year is 92 at a tailpipe replacement cost of \$18 million per annum.

Hence, cost effectiveness is  $\frac{\$18,000,000}{92} = \$196,000$  per life saved

This value would rank quite highly on a scale of cost per life saved by different countermeasures. It also compares favourably with commonly used values of a human life of \$0.5 to 1.0 million.

During the first seven years, the average cost per life saved would be approximately twice the above values.

Note: The benefits of prevention of hospitalised failed attempts have not been included in these calculations.

#### **4. CONCLUSIONS**

This set of crude estimates has shown that based on the assumptions made and set out in each section, fitting of a CO detection device to all new vehicles is likely to result in:

- (i) a somewhat greater number of suicides being prevented ultimately than modification of the exhaust tailpipe (146 versus 92)
- (ii) at similar cost per life saved (\$205,000 versus \$196,000)
- (iii) but with a much slower rate of achieving the ultimate result (20 years versus 7 years after the start of implementation)

The rate of fitting of the CO detection device could be accelerated by requiring retro-fitting of the device to all vehicles over say three years, but the cost per life saved would be considerably increased (e.g. \$361,000 versus \$205,000).

Both approaches show sufficient promise of a potential cost-effective contribution to the prevention of motor vehicle exhaust gas suicide, to warrant further expenditure on research to better define what is involved and to provide more precise estimated values for the assumptions made in this paper.

#### **5. ACKNOWLEDGEMENTS**

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Peter Vulcan

Monash University Accident Research Centre

Fax (03) 9905 4363