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Occupational Fatalities in Victoria 1990 - 1993: A Case For The Control of Damaging Energy Not Behaviour

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Abstract

A comprehensive study of occupational traumatic fatalities occurring in Victoria in the years 1990–1993 was undertaken to identify opportunities for prevention. Using accident investigation reports compiled by the Victorian Occupational Health and Safety Authority, 100 fatalities involving employees or self-employed persons working for an employer were identified. This study was unique in that it classifies the source of damaging energy implicated in each fatality. Of ten sources of damaging energy, two-potential and kinetic-were identified as being involved in 75 percent of all fatalities. Mechanical power associated with fixed machinery, which has traditionally been the focus of government prevention strategies was under-represented in the number of fatalities. The fatality rate was the highest in the Mining Industry followed by the Transport and Storage Industry. The Agriculture, Forestry and Fishing Industry has a lower than expected rate because self-employed farmers were not included in the study. The study found that if future prevention programs are to be successful in reducing workplace fatalities, they will need to focus on work at height, suspended objects, objects with the potential to fall from a height and vehicle traffic in the workplace. The majority of fatalities occurred in an environment where reliance was placed on the individual to avoid the hazard. This was combined with a lack of commitment to elimination of hazards and a failure to adopt effective engineering controls. If occupational traumatic fatalities are to be reduced, passive control measures that do not require the co-operation of the individual to be effective will need to be introduced.

Keywords: Industrial Fatalities
Damaging Energy
Countermeasure Strategies
Behaviour Modification
Passive/Active Controls

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Table of Contents Page

List of Illustrations Page

1. Introduction

A feature of occupational fatalities is that by their very nature there will always be some aspect of human involvement. Therefore it is not surprising that attempts early this century to prevent fatalities and other occupational injuries focussed on identifying the traits and failings of the persons involved. One notable concept of the time that flourished was that of accident prone behaviour (Farmer and Chambers, 1939; and Rawson, 1944). These concepts invariably led to the development of programs to modify the behaviour of employees to prevent them injuring either themselves or fellow employees. A review of contemporary safety programs in the literature published from 1990 indicates that safety programs based on modifying the behaviour of employees is still a popular concept.

A major shift in the scientific approach to preventing occupational injuries occurred when Haddon (1963) identified the basic concept that injury prevention is dependent on the control of damaging energy. Haddon found that all injuries fit causally into one of two groups. The first group involves injuries caused by the interference with normal bodily energy exchanges. An example of such an interference would include suffocation by mechanical or chemical means. The second group of injuries are those in which injury is caused as a result of an exchange of damaging energy in excess of human injury thresholds. These concepts ultimately led Haddon (1963) to the conclusion that the prevention of injury is therefore the prevention of uncontrolled exchanges of energy.

In this study the circumstances surrounding 99 incidents which resulted in 100 fatalities were reviewed in detail to identify the involvement of sources of damaging energy exchanges and the type of countermeasures intended to be in operation at the time of the incident. This study has reiterated the importance of strategies that are targeted at controlling damaging energy on a continuum where prevention of creation of a hazard and behaviour modification are at the apposing ends of the spectrum.

2. Aim and Objectives

2.1 Aim

The aim of the study is to analyse occupational traumatic fatalities in Victoria from the period 1990 through to 1993, to identify opportunities for prevention.

2.2 Objectives

Classify the damaging energy source implicated, where loss of control has occurred, just prior to the event leading to the fatality.

Classify the major damaging energy source countermeasure being utilised in an attempt to prevent the damaging energy exchange just prior to the event leading to the to the fatality.

Describe the distribution of fatalities according to industry, occupation, sex and age of deceased, and pathophysiological cause of death.

Discuss the issue of passive countermeasures versus active countermeasures in the prevention of occupational fatalities.

3. Materials and Methods

3.1 Occupational Fatality

The study group covered occupational related traumatic fatalities occurring throughout Victoria between January 1, 1990 and December 31, 1993.

The fatalities of interest were those described as traumatic. For the purposes of this study, a traumatic fatality is one where a person is injured or has an acute exposure to a substance which results in their death. To be included in the study, death would need to occur within twelve months of the injury or acute exposure. In practice, in 84 per cent of fatalities that were the subject of this study, death occurred immediately or on the same day of the incident. In the remaining cases, death occurred within one month of the incident. Deaths that resulted from occupational illness and disease were not included in this study.

For the purposes of this study, an occupational fatality was a traumatic fatality that occurred in the Victorian civilian labour force where there was a traditional employer/employee relationship or an employer had engaged the services of a contractor. Self-employed persons with no employees and not providing their services to an employer at the time of the fatality were not included in the study. Fatalities involving unpaid workers, students (except apprentices), bystanders and persons less than 15 years of age were excluded from the study. The above method of classification provided greater certainty that all the fatalities reviewed occurred during the course of paid employment by the deceased.

The data was collected from the Victoria Occupational Health and Safety Authority's (OHSA) accident investigation files and Victorian State Coroners' reports.

One hundred and sixty six fatalities were identified by OHSA as being work related for the purposes of conducting an investigation. Excluded from OHSA's definition of work related, for the purposes of conducting an investigation, were the following fatalities:

- the occupants of motor vehicles involved in collisions on public roads while being driven in relation to the occupant's employment or to and from their place of employment;

- victims of deliberate assaults including armed robberies that occurred at a workplace; and

- victims directly employed by the Federal Government including the Defence Forces, Australia Post and Telecom.

Of the 166 fatalities judged to be work related by OHSA, 100 were determined to meet the criteria of an occupational traumatic fatality for the purposes of this study (a brief description of each fatality is provided in Appendix A). Self-employed persons with no employees and not providing their services to an employer were excluded for the purposes of this study (n=46). This group predominantly consisted of self-employed farmers (n=28).

Typical of the type of incident involving self-employed persons that were excluded from this study, was the death of a 33 year old self-employed logging and earth-moving contractor. This self-employed contractor was crushed while carrying out repairs on his truck in the backyard of his private dwelling.

The next group excluded from the study were persons injured fatally as a consequence of a workplace activity but not actually working at the workplace where the incident occurred (n=19). Included in this group were nine children killed on farms with ages ranging from one to thirteen years of age. Another two children included were a child who drowned in a caravan park swimming pool and another child killed in a tourist coach incident. A typical example of an adult included in this group was a 19 year old private citizen electrocuted while sitting at a work bench in an electrical appliance repair shop.

The last incident excluded from the original 166 fatalities investigated by the OHSA was an incident which, on review, indicated that the death was due to natural causes and not work related.

Data from the OHSA files and coroners' reports was then extracted for each of the 100 cases to determine age, sex, occupation, industry, pathophysiological cause of death, source of damaging energy implicated and the countermeasure being utilised in an attempt to prevent the damaging energy exchange just prior to the event leading to the fatality.

3.2 Damaging Energy Source

The source of damaging energy identified in each incident was the energy form existing immediately prior to control being lost and not the energy source at the point of exchange and subsequent injury. Where there were multiple sources of damaging energy implicated in the incident the source of damaging energy which gave rise to the most significant consequence has been selected. For the purposes of this study this is the source of potentially damaging energy which led to the fatality . The energy sources by energy type as described by Haddon (1963) and further refined by Viner (1991, pp 44-45) that were relevant to the classification of incidents in this study were as follows:

Potential Energy

- Gravitational Object Fall
- Gravitational Body Weight Fall
- Compressed Gas
- Compressed Liquid

Kinetic Energy

- Co-existed with Powered Vehicle
- Powered Vehicle
- Object

Mechanical Power

- Entanglement
- Crushing
- Shearing
- Impact

Electrical

Chemical Energy

- Explosion
- Fire
- Toxic Exposure
- Asphyxiation

3.3 Countermeasure Strategy

The description of the countermeasure being utilised just prior to loss of control and subsequent exchange of damaging energy were taken from the ten countermeasure strategies described by Haddon (1970, 1980). These strategies are summarised as follows :

1. to prevent the initial marshalling of the form of energy;

2. to reduce the amount of energy marshalled;

3. to prevent the release of energy;

4. to modify the rate of spatial distribution of release of energy from the source;

5. to separate the susceptible structure in space or time from the energy being released;

6. to separate the energy being released from the susceptible structure by interposition of a material barrier;

7. to modify the contact surface, sub-surface, or basic structure which can be impacted;

8. to strengthen the living or non-living structure which might be damaged by the energy transfer;

9. to move rapidly in detection and evaluation of damage and to counter its continuation and extension; and

10. all of those measures which between the emergency period following the damaging energy exchange and the final stabilisation of the process.

The information available for each incident was reviewed and the major countermeasure being relied on (although not always implemented), to control the unintended loss of control of damaging energy was selected. This being the source of damaging energy which gave rise to the most significant consequence.

Although a countermeasure is identified for a particular incident, this does not infer that the countermeasure strategy was effectively implemented at the time of the incident.

As this study was reviewing fatalities, countermeasures nine and ten were not relevant because death would have already occurred before these countermeasures came into operation.

3.4 Pathophysiological Cause of Death

The pathophysiological cause of death was ascertained from the information provided in the investigation reports and coroners' reports for each of the identified 100 fatalities. Where possible, it was related to the major body location and this was generally used in situations where there had been an exchange of kinetic energy with the victim. These types of event were classified as either head and neck injuries, multiple injuries or trunk injuries. More specific injuries were recorded as electrocution, burns, asphyxia and acute poisoning. The category of other was reserved for cases not fitting into the above categories.

3.5 Distribution by Industry, Occupation and Age

In determining the distribution of fatalities according to industry, occupation and age, denominator data was used. This was used to estimate the numbers of persons at risk of a fatality in the actual, industry, occupation or age range. The denominator data used was provided from the Australian Bureau of Statistics Labour Force Surveys that were conducted for February, May, August and

November in 1990, 1991, 1992 and 1993 covering the Victorian workforce. The mean from all 16 surveys was used to calculate annual incident rates per 100,000 persons exposed. In cases where only one fatality occurred in a particular group over four years, the actual denominator for that Labour Force Survey period was used.

The industry that a person was working in at the time of the fatality has been classified using the Australian and New Zealand Standard Industrial Classification (ANZSIC), produced by the Australian Bureau of Statistics (1993). In most cases the broadest level of Division was used. However, in five cases the industry was classified down to the next level of Sub-division.

The person's occupation at the time of the fatality has been classified using the Australian Standard Classification of Occupations (ASCO) produced by the Australian Bureau of Statistics (1986). Occupations were classified under the ASCO—Major Groups category.

Ages were classified into ten year age ranges, commencing at fifteen years of age and ending with the category 55 to 64.

4. Fatal Industrial Accidents: A Review of the Literature

4.1 Introduction

The literature concerning occupational accidents is extensive, and covers the problem from a multitude of aspects. This review concentrated on occupational incidents and only those that resulted in a fatal consequence and excluded death as a result of disease contracted or exacerbated by work. It covers persons employed in the civilian labour force. Workplace traffic deaths on public roads have not been discussed in this review.

A number of the published papers described the frequency and distribution of work related fatalities, identifying factors thought to be of value in future prevention activity. Recent studies covering the broad population of work related fatalities have included: Baker et al (1992); Bell, Stout and Bender (1990); Cryer and Fleming (1987); Harrison et al (1989); Kraus (1985); Low (1986); Mendeloff and Kagey (1990); Salminen et al (1992); and Jarl (1980). Other researchers have focused on specific industries or factors involved in work related fatalities. Flett (1992); Sorock, Smith and Goldoft (1993); and Trent and Wyant (1990) reviewed construction related fatalities. Erlich, et al (1993), looked at work-related agricultural fatalities and Collison (1994), examined fatalities in the South Australian mining and quarrying industry.

Fatal work related falls (Agnew and Suruda, 1993), confined space fatalities (Manwaring and Conray, 1990., and Pettit et al, 1996),work related fatalities due to fixed plant and machinery (Vira and Cloe, 1978., Heathershaw, 1992., and Mazengarb and Mandryk, 1994) and the role of migrant factors in work related fatalities. (Corvalan, Driscoll and Harrison, 1993) are studies of specific factors associated with workplace fatalities.

4.2 Data Collection

Various sources of accident data were used by researchers. In studies that attempted to enumerate all known fatal accidents in a particular category and/or time frame the integrality of the data was important. Larger studies like those conducted by Harrison et al (1989) relied on Coroners' reports. As all deaths resulting from traumatic circumstances are required to be reported to a Coroner in Australia the researcher could be assured that all possible deaths had been considered in the study. In other studies multiple sources for data collection were utilised (Cryer and Fleming, 1987) . Such sources generally included the multitude of government agencies responsible for investigating the various industrial fatalities. One important aspect of research that relies on accident records is that the results may relate to the way the accident was reported rather than solely the circumstances surrounding the cause of the injury (Hale and Hale, 1972, p.12).

4.3 Comparison of Accident Distribution to Other Variables

A number of variables were examined which were associated with the distribution of occupational fatalities. By studying both the situational and personal variables associated with occupational fatalities it may be possible to identify the factors which were implicated in contributing to the death.

It is not uncommon in occupational injury research to conclude that a variable is causal simply because it occurs frequently in the population of victims. In such cases a view of the total population may indicate that the variable occurs just as frequently in the injury free population (Hale and Hale, 1972, p.25).

4.4 Industry Type

Despite differences in reporting definitions and counting criteria in the various geographical research locations there was similarity in the various studies between the type of industry and the associated fatal injury rate.

Harrison et al (1989) looked at an Australian population, between 1982 and 1984, and found the incidence of workplace deaths highest in mining and rural industries (approximately 22 deaths per 100,000 employees). The construction industry was next with an incidence rate of approximately 12 deaths per 100,000 employees.

Cryer and Fleming (1987), who studied a New Zealand population found a similar trend. They calculated a fatal injury rate per 100,000 employees over a year at 63.4 for the mining and quarrying industry, 23.1 for the agricultural industry and 15.2 for the construction industry.

A study in the United States (Kraus, 1985) found similar results but rated agriculture with a higher fatal injury rate than mining.

The above studies utilised the number of fatal injuries per 100,000 employees in the particular industry averaged over a year. This method fails to account for exposure time being the actual hours spent on the job. It is conceivable that a number of employees only work part time or alternately work shifts in excess of eight hours.

To enable better comparison between studies and evaluation of comparative risks, use of the fatal accident frequency rate (FAFR) would be desirable. The FAFR is the number of fatalities that occur in a group of a thousand persons in a working life time. A working year is 2,500 hours and a working life is 40 years. The total exposure is therefore one hundred million working hours (Kletz, 1990, p.131). The ability to be able to identify accurately the FAFR within an industry is important in preventing fatal injures. Resources can be focused on the industry in greatest need and improvements or deterioration in safety standards can be measured over time and between industries.

4.5 Injury Resulting In Death

Harrison et al (1989) found the most prominent cause of death as a result of traumatic injury to be damage to the brain or other parts of the head. They reported 22.3% of all workplace fatalities to fit this category: The next most occurring injury was described as multiple injuries and accounted for 18.2% of workplace fatalities.

A smaller study by Salminen et al (1992) found 25% of fatal injuries occurred to the head, 50% to the trunk and 18% were classified as whole body, or unspecified.

Both studies are comparable as Harrison et al (1989) had a broad range of categories which would equate to the category of trunk described by Salminen et al (1992).

4.6 Age

Generally, the number of workplace fatalities increased with age and was particularly high in the age group of 65 years or more (Harrison, et al 1989, p.120). Cryer and Fleming (1987) showed a similar increase with age but also demonstrated a higher rate for younger workers. This was consistent with the findings of Hale and Hale (1972, p.33) in their review of fatal and non fatal occupational injuries. They found that during the age period of the teens and early twenties the number of occupational injuries is high; it then drops sharply, levelling out in the middle or late forties, then the incident rate increases until retirement.

A study by Agnew and Suruda (1993) identified an increased risk of work related fatal falls after the age of 45. A deterioration in postural stability beginning between the ages of 50 and 60 was one explanation. Another factor was the finding that the older workers were more likely to be killed in a fall from a lower height compared to a younger worker. It was postulated that the trauma sustained in a fall results from the energy imparted to the victim on impact and therefore less energy may be required for death to result with older workers (Agnew and Surunda, 1993, p.735).

Salminen found that elderly workers were injured with moving vehicles 28% of the time compared with 10% of the time for younger victims. In turn being run over by a moving vehicle was found to be fatal more often than other types of accidents (1993, p.100). Haddon et al (1961) also found that elderly pedestrians struck by vehicles are more likely to die than younger individuals.

4.7 Mode and Source of Energy Transfer

Fatal injuries were usually associated with high energy states (Low, 1986, p.122). Baker et al (1982, p.692) found that approximately 80% of work related fatal injuries resulted from mechanical energy applied to the body in doses in excess of human thresholds. In a study by Harrison, et al (1989) approximately one third of fatalities were attributed to persons struck by falling or projected objects. Twenty percent died as a result of being struck by a moving object at the workplace and falls were implicated in approximately 14% of fatal injuries. Another 10% of deaths were as a result of exposure to electricity.

In a specific study of fatal injuries in the construction industry 47% of deaths were as a result of falls (Sorock, Smith and Goldoft, 1993, p.918).

It is clearly shown that fatal accidents are associated with high levels of energy exchange with the victim. One exception to this is in the area of chemical and electrical energy where a fatal injury may result from a low level of energy exchange (Low, 1986, p.122-123).

4.8 Fatal Versus Non-fatal Accidents

Heinrich (1959) proposed a model that claimed that the same event that leads to a minor injury could just as easily have led to a more serious injury. He provided a ratio of 1 : 29 : 300 that represented a group of 330 similar incidents occurring to the same person. From these incidents 300 would result in no injury, 29 would produce minor injuries and one would result in serious injury. Allocation to either of the three groups was seen to be based on chance. Studies have found that there is no empirical evidence to indicate that accidents are related to the degree of injuries in a random way (Larsson, 1990; and Hale and Hale, 1972).

Salminen et al (1992) disputed Heinrich's (1959) identical causation hypothesis and found that fatal accidents differed from non-fatal accidents both in type of accident and the distribution of accident factors. Risk factors such as the victim working alone (Jarl, 1980, p.187) and accidents that focused great injuring energy to the head or trunk were found to be more likely to result in fatalities (Salminen, et al, 1992, p.116).

The identical causation hypothesis is further challenged by Low (1986, p.120) who found that the two most common types of incidents accounted for only 10% of fatalities. Alternatively the electrical and explosion categories of incidents which together comprised less than 1% of all disabling injuries, were found to be implicated in 10% of all fatalities (Mendeloff, 1984, p.354). Trent and Wyant in their study of hand tool injuries, found that deaths from hand tool power supplies or from activation of environmental energy represented a pattern of hand tool mishaps unlike documented non-fatal hand tool injuries (1990, p.712).

Baker emphasised that, "...factors playing an important role in minor injuries are not necessarily the same as factors that are important in severe and fatal injuries. Consequently, the choice of counter- measures may change as the severity of injury changes." (Baker, 1972, p.10)

4.9 Conclusion

The literature has revealed a difference in the processes involved in non fatal versus fatal incidents. Therefore, it can be argued that strategies designed to reduce the overall incidence of occupational injuries may need to be modified to reduce the number of fatal occupational injuries.

The variables identified as being implicated in workplace fatalities covered a relatively small number of categories. Further study of these variables and their inter-relationships could be the basis for the development of a strategy to reduce the incidence of occupational fatalities.

5. Injury Prevention By Controlling Damaging Energy Exchanges

5.1 Introduction

The concept that a hazard is a source of potentially damaging energy has seen the development of strategies to control abnormal energy exchanges. The most notable are those devised by Haddon (1970) and referred to as the "Ten Countermeasure Strategies".

The first countermeasure strategy is aimed at preventing the creation of the hazard in the first place. This is seen as a desirable approach. Such approaches are seen as providing passive control measures. Unlike active control measures, passive controls are not dependent on the behaviour of individuals for their success.

The above concepts can be seen as the basis for the hierarchy of control approach, as discussed in Hopkins (1995, pp. 9-12). This concept is now generally adopted throughout Australia as the desired method for managing occupational hazards. This approach is followed in the Worksafe, Control of Workplace Hazardous Substance Code of Practice (1994, pp. 49-51).

5.2 Abnormal Energy Exchanges

The now obvious concept, proposed initially by Gibson (1961), and refined by Haddon (1963) was that, "...injuries cannot occur without the initiation of abnormal energy exchanges" (p.644). Under this concept, hazards are sources of potentially damaging energy.

This discovery has had a significant impact on the development of contemporary strategies for injury prevention. The acceptance of Haddon's energy transfer theories had the immediate effect of shifting the focus of safety research away from that of behavioural psychology (Guarnieri, 1992, p. 156). The most notable changes took place in the United States of America in the area of road safety.

Haddon (1963) postulated whether there are common factors without which injuries cannot occur as a result of an insult to the body. He found that all injuries fit causally into two groups.

In group one, injuries occur as a result of an interference with the normal bodily energy exchange of a person. Such events would include suffocation by mechanical means (for example, strangulation), or suffocation by chemical means. Frostbite is included in this group as an injury resulting from the absence of a necessary factor, in this case, ambient heat required for normal health. Haddon refers to these specific agents of deficiency as "negative agents" (1980, p.413).

In the second group, injuries are those that occur as a result of the delivery of energy to a person in an amount that overcomes the injury threshold of the individual recipient.

Haddon also identified that the energy types which can be delivered are few in number (1963, p.636). It is possible to prevent injuries by focusing on control of the specific types of energy that have the potential to lead to those injuries. Haddon (1963) initially identified the sources of energy as:

- mechanical energy;
- thermal energy;
- electrical energy;

- ionising radiation; and
- chemical energy.

This list has been further expanded by Viner (1991). Viner has classified the sources of energy into those external to the person and those within the person. The complete list of energy sources by energy type proposed by Viner are as follows:

<u>External to the recipient</u>

- Potential energy;
- Kinetic energy;
- Mechanical power;
- Acoustic and mechanical vibrations;
- Electrical energy;
- Nuclear particle radiation;
- Thermal energy;
- Chemical energy;
- Micro-biological energy; and
- Muscle energy.

<u>Within the recipient</u>

- Gravitational potential energy
- Kinetic energy
- Muscle energy
- Chemical energy. (1991, pp. 44-45)

Potential energy external to the recipient can be either the potential energy in an object due to gravity, or the stored energy in compressed fluids and gases or the structural strain energy stored in objects such as a compressed spring. Potential energy can also occur within the recipient when the recipient has the potential to fall to a lower level due to the effects of gravity.

Kinetic energy is the energy stored in a body's mass due to its speed in a linear or rotational motion. This can include both animate and inanimate objects.

Mechanical power relates to the energy flow in machinery from the source of power to the point where the energy is absorbed in the action of the machine (Viner, 1991, p.44).

Chemical energy external to the recipient is molecular bonding energy generated in a chemical reaction and includes the outcomes such as fires, explosions and the production of toxic substances. Within the recipient, chemical energy could manifest as self combustion, although this is a rare occurrence.

When the types of energy source, whether external or internal to the recipient, are combined there are ten discrete sources of potentially damaging energy.

The source of potentially damaging energy may go through a number of transformations before there is a final exchange with the recipient resulting in injury. For example, a person falling from a height. The source of potentially damaging energy is gravitational potential energy but as the person falls there is a conversion to kinetic energy. On contact with the ground there is an exchange of kinetic energy and bodily injury results.

For the purposes of this study, the energy of interest is the source of energy existing immediately prior to the control being lost. This is defined as the hazard. The point at which the actual control is lost is defined as the event (Viner, 1991).

Following the conventions established by Viner (1991, p.78) where multiple energy sources are involved (ie multiple hazards), the source of energy which gave rise to the most significant consequence is selected. For the purposes of this study, this is the source of potentially damaging energy which resulted in the fatality under review.

The logical progression from the identification of the various forms of potentially damaging energy was the development of injury countermeasures.

5.3 Countermeasures

Initially, Haddon (1963) identified four rudimentary countermeasures to prevent unwanted potentially damaging energy exchanges. In the first instance the option was to prevent the marshalling of damaging energy. If this was not feasible its release could be prevented or modified. If these two options were not appropriate, an attempt could be made to remove the person from the vicinity of the damaging energy. Finally, if all these options were unsuccessful, an appropriate barrier could be interposed to block or ameliorate the action of the damaging energy on the person (Haddon 1963, p. 637).

The countermeasures were expanded to ten (Haddon, 1970) and further refined (Haddon, 1980) to incorporate strategies to reduce the loss once initial control of the damaging energy had occurred. The ten countermeasures also extended to the point of rehabilitation after an energy exchange has resulted in injury. The ten countermeasure strategies are described as follows:

- The first strategy is to prevent the creation of the hazard in the first place. This is achieved by preventing the initial marshalling of the energy. Examples of this strategy would include the elimination of the need to work at height, or not actually initiating the starting or movement of vehicles.

- The second strategy is to reduce the amount of energy marshalled. Examples of this strategy would include the use of transformers to reduce voltage levels or reducing the speed of vehicles by the use of governors.

- The third strategy is to prevent the release of the potentially damaging energy that already exists. Examples include the insulation of electrical conductors, handrails at the edge of a drop and preventing the escape of tigers (Haddon, 1973, p. 323).

- The fourth strategy is to modify the rate or spatial distribution of release of the potentially damaging energy from its source. Examples include the provision of brakes or shutoff valves.

- The fifth strategy is to separate in time or space the person and the potentially damaging energy. Examples include the provision of designated walkways for pedestrian traffic and evacuation programs.

- The sixth strategy is to separate the hazard and that which is to be protected by interposition of a material barrier. Examples include the use of machine guards and electrical insulation.

- The seventh strategy is to modify relevant qualities of the hazard. Examples include modifying the surface a person may make contact with, including the use of soft ground surfaces in playgrounds and the use of breakaway roadside poles.

- The eighth strategy is to make the item to be protected more resistant to the potentially damaging energy exchange. Examples include immunisation, strengthening exercises and making structures more fire resistant and the use of personal protective equipment.

- The ninth strategy is to begin the process of countering damage that has already occurred as a result of a damaging energy exchange. Examples include the provision of first aid facilities and the use of sprinklers and other fire suppression equipment.

- The tenth and final strategy is to stabilise, repair and rehabilitate. Examples include the rehabilitation of injured workers and the rebuilding of damaged plant.
  (Haddon 1970 and 1980).

In relation to incidents with the potential to result in a fatality, countermeasures nine and ten are not relevant.

Haddon did not place any hierarchy on the selection of the most appropriate countermeasure. However, he did acknowledge, "... the larger the amounts of energy involved in relation to the resistance to damage of the structures at risk, the earlier in the countermeasure sequence must the strategy lie." (1973, p.325).

As damaging energy exchanges implicated in occupational fatalities are generally associated with high energy states (Low, 1986, p.122), the selection of the earlier countermeasures would seem more appropriate in strategies targeted at preventing occupational fatalities.

It is also evident that the earlier countermeasures are generally more closely related to passive controls rather than active control measures. Therefore, the earlier countermeasures are generally more effective control strategies.

5.4 Passive Versus Active Control

Passive control measures refer to measures that do not require the co-operation of the individual to be effective (Haddon, 1974). At the other extreme, there is the active control measure which is dependant on the behaviour of an individual to be effective. Ultimately, passive control measures are those that operate independently of human behaviour.

Research by Wigglesworth (1976) demonstrated the effectiveness of passive control measures in comparison with active control measures. Trends in occupational eye injuries between 1960 and 1970 were compared between operators of machinery and operators of powered hand tools. The control measures for machinery involved the installation of guarding, a passive approach, whereas the control measures for powered hand tools predominantly relied on the use of personal protective equipment in the form of eye protection. The effectiveness of this active control measure was dependent on continual intervention by an individual to ensure it was worn. The study showed that while eye injuries on machines halved in the period between 1960 and 1970, they more than doubled on powered hand tools.

The passive approach is one of designing the equipment or the system of work to ensure that the hazard is controlled irrespective of the behaviour of individuals. Skilled operators carrying out a task that they have been trained in have an estimated probability of failing to perform the desired task one in one thousand times (Viner and Brooks, 1988, p.26). Therefore it can be concluded that if an active control measure relies on the actions of an individual it is likely that control will be lost approximately one in every thousand times that the task is undertaken, resulting in injury or death.

In research by Williamson and Feyer (1990), they investigated the incidence and nature of behavioural events preceding work-related fatalities. Not surprisingly, they found that behavioural factors were involved in 91.2% of fatalities and that in 62.4% of cases some kind of behavioural error was made. An example of behavioural errors were skilled based errors. The most common type of skill based error identified in the study were slips. They found that slips often occurred immediately before a fatality and that therefore an accident prevention strategy should eliminate slips. However, they acknowledged this would be difficult to achieve.

This study highlights the problems associated with focusing on the control of human behaviour as a credible prevention strategy. In any human pursuit, there will invariably be some kind of behavioural error, therefore it is not surprising to find that Williamson and Feyer (1990) identified 62.4% of cases involved behavioural error. What they have achieved is to further verify that behavioural error is the norm, is to be expected and needs to be considered in workplace design and any associated systems of work. The workplace should not be designed or a work practice developed that would allow a slip to ultimately lead to a fatal consequence.

It is not uncommon for individuals to be blamed for causing incidents because of a behavioural error when in fact the identified faulty human behaviour is predictable. If prevention is going to be effective, the focus needs to be on passive control measures that are not dependent on error free human behaviour.

5.5 Hierarchy of Control

By combining the strategies expressed in the first eight of Haddon's (1970) ten countermeasures and combining this with the advantages of passive versus active control measures, a hierarchy of desired controls can be established.

The hierarchy of control approach has been adopted, in slightly different variations, throughout Australia in codes of practice and legislation covering occupational health and safety.

An example of the application of the hierarchy of control measures, as discussed in Hopkins (1995, pp. 9-12) is as follows:

- Elimination is the most desirable control strategy whereby the hazard is removed in its entirety. This is a permanent solution and would equate to the first of Haddon's (1970) countermeasures. It would also be deemed a passive approach.

- Substitution is the next most desirable approach. The plant, substance or system of work is replaced by one that presents a significantly lower level of risk.

- Engineering controls follow in the order of effectiveness and involve changing the structure of the plant or environment for persons exposed to the hazard. Typical examples would include the guarding of machines and the use of localised extraction ventilation.

- Administrative controls are the last in the hierarchy and as they rely predominantly on human behaviour for their success are deemed to be least effective. They would equate to an active control measure. Administrative controls rely on instructions and procedures for the individual to avoid being exposed to the hazard. The use of personal protective equipment is also seen as an administrative control as it relies on the individual to ensure that such equipment is worn at the appropriate time.

The most desirable control measure is elimination through to the least desirable administrative controls. However, in practice, it may be necessary to use a combination of control measures to control a hazard and achieve an acceptable level of risk.

6. Contemporary Trends In Safety Programs Involving Behaviour Modification

6.1 Introduction

In the previous section of this report, injury prevention approaches relating to the control of damaging energy exchanges were discussed. It was concluded that strategies involving passive controls (ones that are independent of human behaviour) were more likely to be successful. A focus on controlling damaging energy and the preferential adoption of passive controls over active controls (Haddon, 1974) emerged as an injury prevention strategy in the 1960s.

The above approaches to occupational injury prevention were preceded for decades by strategies which focused on the traits of individuals and the modification of human behaviour. With the 1990s, a trend has emerged where once again there is a focus on behaviour modification as a strategy for occupational injury prevention. Aptly expressed by Gregory (1996, p.20), "Behaviour modification has been the 'bandwagon' of safety in the 1990s." He further adds, "In response to this wave of interest, some consultants have offered approaches based on the false theory that employees are to blame, and their behaviour is all that must change."

This emerging trend was further highlighted in a study by Planek and Fearn (1993) which examined the importance that safety professionals placed on specific safety related issues. The study compared earlier findings from a 1967 study with those from a study in 1992. Comparing the findings of the two studies it was revealed that there had been a shift in perceived importance towards managing the human element in the safety system, as opposed to addressing engineering factors.

The need for cultural change with workforce restructuring in the 1990s has led to a refocus on behavioural models as a vehicle for positive change in safety performance.

6.2 Historical Approaches on Injury Prevention

Early attempts directed at accident prevention were based on the assumption that employees were responsible for their own safety and that their inappropriate behaviour caused accidents. These beliefs were reinforced by researchers such as Heinrich (1931) who claimed that 88 percent of industrial accidents were directly caused by unsafe acts of persons, 10 percent were the result of unsafe physical conditions and two percent were attributable to acts of God. These assumptions led to the psychological approach to accident prevention which focused on the traits of individuals. One notable concept of the time that flourished was that of accident-prone behaviour (Farmer and Chambers, 1939; and Rawson, 1944).

Support for the concept of accident-prone behaviour was related to the observation that a large percentage of occupational accidents were incurred by a relatively small percentage of workers (Greenwood and Woods, 1919). However, Mintz and Blum (1949), who reviewed the concept of accident-proneness back to the 1920s, disputed the relevance of this observation. They were able to demonstrate that the previous observation, that a disproportionate number of employees were involved in more accidents, could occur purely by chance. Mintz and Blum (1949) were able to show that the distribution of accidents in earlier studies did not deviate substantially from a Poisson distribution. Accidents are expected to fit a Poisson distribution.

Enthusiasm for the concept of accident-prone behaviour faded when psychologists of the day acknowledged that no-one was able to identify a personality type that fitted the definition of accident-prone (Guarnieri, 1992, p.153). Just as the theories relating to accident-prone behaviour could not be substantiated, they also could not be translated into measurable prevention strategies. Finally, the acceptance of Haddon's (1963) energy transfer theories had the effect of shifting the focus away from behavioural psychology (Guarnieri, 1992, p. 156).

6.3 Behaviour Modification—The Focus of the '90s

The 1990s would appear to see a revival in the focus on human behaviour and the assumption that employees are responsible for their own safety. Even the concept of accident proneness still continues to emerge in the peer reviewed scientific literature. Engel refers to, "A section of the population [that] provides a disproportionate number of patients who are frequent attendees or absentees from work, who are liable to injury, illness or misfortune, who cause damage to themselves, to property and machinery all around them." (1991, p.163)

The focus of health and safety intervention programs in the 1990s has been on behaviour modification. The concept of behaviour modification was pioneered by Skinner (1938) and is based on operant learning theories. Skinner's research found that rewards tend to increase and strengthen behaviour that proceeds them. He described these rewards as positive and negative reinforcers. A positive reinforcer is stimuli that strengthens behaviour as a result of its presentation. Whereas a negative reinforcer is the removal of stimuli which strengthens behaviour. Both types of reinforcers can be seen as rewards (1953, pp. 73, 185). Komaki (1978), cited in Ray, Purswell and Bowen (1993), is credited with being the first to systematically apply Skinner's theories in an occupational setting. A behavioural safety program is generally divided into three phases. The first phase involves identifying specific safety behaviours, the second phase involves observation of behaviour and the final phase of such a program involves the provision of feedback (Ray, Purswell and Bowen, 1993, p.144).

The literature relating to behaviour modification programs fits into two broad categories. Those that promote behaviour modification as an end in itself and those that recognise that a behaviour modification program is to be used in conjunction with passive control strategies.

It was claimed by Scott Geller (cited in Tapas, 1992, p.46) that, "...human activities cause more than 90 percent of on-the-job injuries..." To further promote the concept of behaviour modification Geller concluded that, "...employees can be the biggest hazard to their own health and safety." Topf and Preston (1991, p.43) expressed the need for "...behaviour modification strategies, which interact to uncover the attitudes and beliefs that drive unsafe behaviour and then increase individual responsibility for and self-management of safety behaviour."

Walker (1992) was concerned that most of the attention on health and safety practice and research had focused on workplace conditions and not the behaviour of people in the workplace. However, he did acknowledge that it was important to recognise that both workplace conditions and behavioural factors were important (1992, p.11).

Two authors referred to the need for the behavioural modification approach because the classical approach of safety programs had plateaued (Ray, Purswell and Bowen, 1993; and Whiting, 1993).

Gregory acknowledged that management "...often develops an inadequate work environment that forces employees to fit into that system. As a result, employees are motivated to commit unsafe acts or behaviour." (1996, p.20) His paper then went on to discuss the importance of motivating employees toward safe behaviour.

With pressure on organisations to restructure to become more efficient and reduce costs, there would appear to be a trend to revisit behavioural based safety programs. The objective has been to use behavioural modification programs to go beyond changing individual behaviour and reshape workplace safety cultures, with the intention of establishing higher standards of health and safety performance. Saari and Näsänen (1989), in their study, demonstrated how improvements in health and safety performance exceeded the scope of the actual behaviour modification program. They found that all sorts of accidents were reduced, not only those which related to deficiencies in housekeeping, which was the subject of the behavioural modification program.

Although Gregory discussed the benefits of behavioural modification programs, he strongly emphasised in the first instance that, "effective accident prevention requires that the most technologically and economically feasible efforts be made to engineer out safety hazards." (1996, p.27). He was also critical of many practitioners who were focusing solely on behaviour modification as an effective intervention strategy.

6.4 Conclusions

The previously discredited assumptions that provided the foundations for concepts such as accident-prone behaviour are finding favour with contemporary promoters of health and safety behaviour modification programs.

There is concern that not unlike early this century, the focus on behaviour modification could detract attention away from sustainable passive control strategies.

The underlying assumption of any behaviour modification program is that the control of human behaviour will prevent occupational injuries and disease. To sustain such an assumption, evidence is required to demonstrate that individual behaviour is an effective strategy for controlling the range of workplace hazards. The author would challenge the concept that modifying individual behaviour is an effective means of risk control. Such approaches favour the use of the less effective active control strategies in preference to passive controls.

The range of countermeasure strategies available is reduced in a behaviour modification program. Haddon's (1970, 1980) fifth countermeasure strategy would dominate as a control approach under a behaviour modification program. The fifth countermeasure strategy relies on a person being separated in time or space from a source of potentially damaging energy. Using the behavioural control model would lead to the use of active controls associated with procedures and instructions. This approach would attempt to enable persons to avoid a time or space co-incidence with a source of damaging energy. Such approaches would be inferior to passive control approaches.

7. Results

One hundred fatalities resulted from 99 incidents over the four year period. All but one fatality occurred in the male population. The number of fatalities occurring in each of the calendar years starting with 1990 were 27, 22, 21 and 30 respectively.

Potential energy and kinetic energy accounted for 75 per cent of all incidents. Haddon's (1970, 1980) fifth countermeasure strategy, which relies on separating the person in time or space from the damaging energy source, was applied (although obviously not effectively) in 53 percent of incidents.

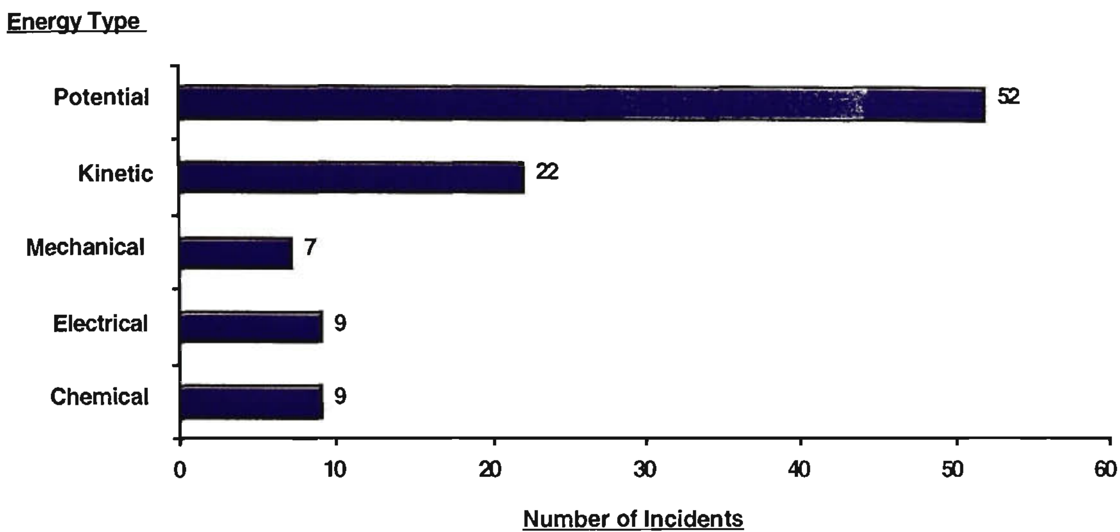
The highest fatality rate per 100,000 persons employed was in the Mining Industry followed by Transport and Storage.

In regards to occupation, the highest rate of fatalities was among labourers and plant and machine operators, and drivers.

7.1 Damaging Energy Source

Ten discrete sources of potentially damaging energy (hazards) have been classified by Viner (1991). Only five discrete types were implicated in the 99 incidents reviewed. This was the type of potentially damaging energy existing immediately prior to the control being lost and the energy source which gave rise to the most significant consequence. A summary of the results is depicted in Figure 1.

FIGURE 1. SOURCE OF POTENTIALLY DAMAGING ENERGY



The sources of damaging energy implicated were potential energy, kinetic energy, mechanical power, electrical energy and chemical energy. Two of the sources of damaging energy involving potential and kinetic energy accounted for 75 percent of all the incidents (n=74).

Potential energy as a source of damaging energy was implicated in fifty three percent of the 99 incidents reviewed (n=52). Fifty four percent of these incidents involved what is described as a "gravitational object fall" (n=28). These incidents involved situations where control of an object that was being acted on by gravity, was lost which in turn led to a fatality. "Gravitational object falls" included incidents where an object dropped from a height, objects toppled over, trees being felled and vehicles overturning due to the effect of gravity.

Still under the category of potential energy, thirty eight percent of these incidents were described as "gravitational body weight falls" (n=20). These incidents involved situations where a worker took a fall from a height and was killed. The height of such falls ranged from as low as 500 mm to a height of 28 metres.

The remaining sources of potential energy related to the stored energy associated with compressed gases and liquids. In two incidents the source of potential energy was a compressed gas and the remaining two incidents involved compressed liquids.

None of the fatalities reviewed and categorised under “potential energy” related to energy stored as a result of the structural strain on an object. For example, objects such as compressed springs.

Kinetic energy as a source of damaging energy was implicated in 22 percent of all the occupational fatalities reviewed (n=22). Seventy three percent of incidents occurred where loss of control of kinetic energy resulted in a person being struck by a powered vehicle (n=16). These incidents involved vehicles that are normally driven on public roads in seven cases and one case where a flagman was struck on a public road. Four cases related to persons being struck by forklifts, two involved persons being struck by trains and the remaining two cases involved a straddle carrier and a tractor.

The traditional “vehicle accident”, where a person was co-existent with the powered vehicle at the time that control of the kinetic energy was lost, occurred 23 percent of the time (n=5). In these incidents, one vehicle collided with a tree and a maintenance vehicle reversed along a railway line into an oncoming train. Two incidents involved horses where, in one case, horses collided and in another a horse bolted, dragging a strapper into a light pole. The final incident saw a person striking a bridge as he rode atop a railway ballast cleaning machine.

One incident involved loss of control of the kinetic energy in relation to an object. This involved a situation where the object was itself energised, in contrast to a powered vehicle. In this incident, control of the kinetic energy was lost and a strapper was kicked in the head by a race horse.

Mechanical power as a source of damaging energy was implicated in only seven percent of incidents (n=7). Three of these incidents involved entanglement in a machine. In one case, an employee was strangled when his clothing was caught in the drive shaft of a conveyor he was cleaning beneath. Another employee had his arm dragged into a conveyor, crushing his chest. The third case involved a working director entangled in the drive shaft of a rotating balancing machine.

A further three incidents were described as crushings. Two were similar in that an automatic function on a machine activated, crushing an operator in one case and a maintenance worker in another.

The final incident involving mechanical energy was described as an impact. A die setter, working on a power press, was struck on the head with a die setting bar he was using. The bar was being used to rotate the crank shaft on the press. The setter inadvertently neglected to remove the bar before restarting the press.

Electrical energy as a source of damaging energy was implicated in 9 percent of incidents (n=9). Four of these incidents involved domestic power supplies of 240 volts, one involved a 415 volt three phase supply and another involved the high voltage section of a radio frequency welder. The remaining three incidents related to high voltage transmission lines. Two of the transmission line incidents resulted in the deaths of linesmen working on the transmission lines. The third case involved a plumber who inadvertently made contact with overhead powerlines while ascending a ladder with a 6.5 metre length of pipe in his hand.

Four of the nine incidents involved electrical trades persons working on electrical supplies at the time of the incident. Two of the four trades persons were apprentices. The five incidents not involving an electrical trades person included two cases where damaged extension leads were dragged through water, a person making contact with exposed wiring on an electrical urn and a labourer deliberately cutting through an underground power cable he believed was not energised.

Chemical energy as a source of damaging energy was implicated in nine percent of the 99 incidents reviewed (n=9). Five involved an explosion, two a fire and two are described as toxic exposures.

Two of the explosions involved employees using an ignition source, in the form of welding equipment, in close proximity to an explosive atmosphere. In one case, an employee was welding a ladder on a storage tank containing a small quantity of a flammable liquid. In the other explosion, a contractor was attempting to remove a plug of resin in the drain hole of a storage tank using a cutting torch.

One employee was killed when a build up of gas in a kiln exploded and in another incident an employee was killed when flammable vapours generated by the work practice were ignited.

The final incident that led to an explosion was the result of the exposure of a pyrophoric substance to air that resulted in its ignition and a subsequent explosion.

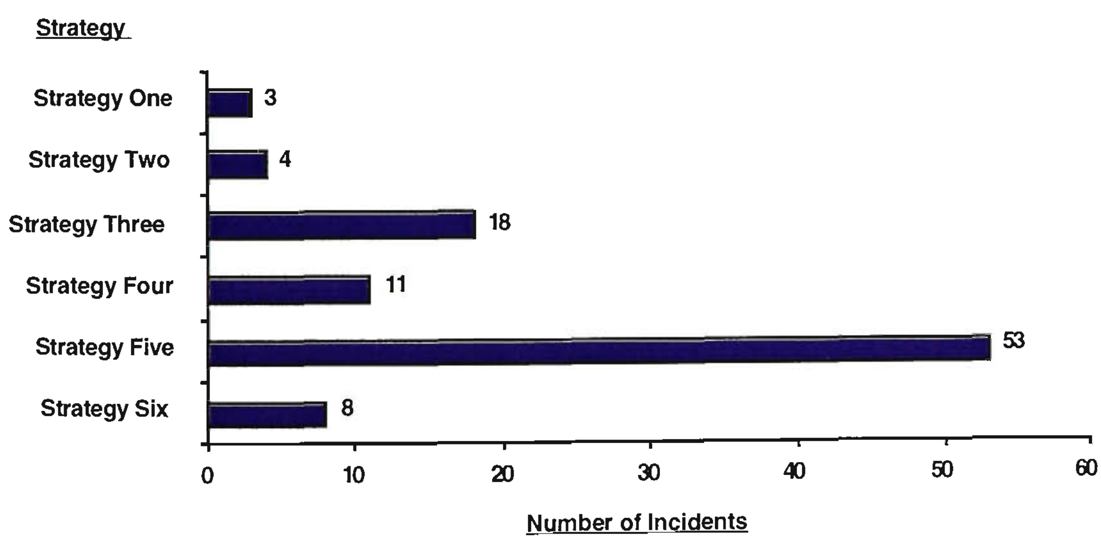
The two fires that led to a fatality involved the ignition of a flammable solvent, and the death of an employee burnt during a forest "burning off" operation.

The final two chemical energy incidents involved exposures to toxic substances. In one incident, an employee entered a sewer pit and was overcome by hydrogen sulfide fumes. In the other incident, an employee entered a degreasing tank containing trichloroethane fumes.

7.2 Countermeasure Strategy Utilised

Although Haddon (1970, 1980) proposed ten different countermeasure strategies, six categories were identified as being relevant to the 99 incidents reviewed. A summary of the type of countermeasures intended to be used which ultimately failed is contained in Figure 2.

FIGURE 2. HADDON COUNTERMEASURE STRATEGY INTENDED, WHICH ULTIMATELY FAILED



The countermeasure strategy being relied on was able to be identified in 97 of the incidents reviewed. The most common strategy which was intended to be utilised was Haddon's (1970, 1980) fifth countermeasure. This countermeasure relies on separating the person in space or time from a potentially damaging energy source. This countermeasure was utilised in 54 percent of incidents (n=53).

Forty two percent (n=22) of incidents where it was intended to utilise the fifth countermeasure occurred as a result of the loss of control of potential energy. Of these incidents, 12 were "gravitational body weight falls". In these incidents, the victims were attempting to maintain a separation in space from an elevated position from which a fall was possible. In the remaining ten incidents, nine were "gravitational object falls".

The countermeasure in these nine incidents generally focused on avoiding the space/time coincidence as the object fell to the ground. This was most evident in the four incidents involving the felling of trees. The activity of causing the object to fall (the tree or branch) was deliberate, however the victim was attempting to separate themselves in both time and space as the object fell. The tenth incident involved potential energy in the form of a compressed liquid. In this unusual incident, a large dam in a farm property had a breach in the wall. A diver attempting to plug the hole from inside the dam was sucked into the breach by the hydraulic pressure created by the escaping water. The countermeasure he was relying on was the separation in space from the point where he no longer had the strength to swim against the hydraulic pressure.

A further 30 percent of incidents, where it was intended to utilise the fifth countermeasure, related to kinetic energy where a person was struck by a powered vehicle (n=16). Sixteen was the total number for this type of incident out of the 99 incidents reviewed. The use of countermeasure five relied on the individual avoiding a vehicle in motion or the operator of the vehicle avoiding the individual to prevent an undesirable impact.

The next most common countermeasure was Haddon's (1970, 1980) third countermeasure. This countermeasure strategy is based on preventing the release of damaging energy and was intended to be utilised in eighteen percent of incidents reviewed (n=18). It was predominantly involved in an attempt to control potential energy. This occurred in sixteen cases. The countermeasures included the use of supports, lifting equipment and, in one case, a locking ring forming part of an inflated wheel assembly. The remaining two cases, where the third countermeasure was intended to be utilised, involved electrical and mechanical power. In both these cases, because of a failure to maintain equipment, the countermeasure strategy failed.

In eleven percent of incidents, Haddon's (1970, 1980) fourth countermeasure was intended to be used (n=11). This countermeasure strategy relied on the modification of the rate of spatial distribution of release of the energy from its source. A typical incident involving this strategy was the case of a dump truck being backed down a steep access track. The brakes on the vehicle were being used to control the release of gravitational potential energy. In this case, the brakes failed, the vehicle careered out of control and the driver attempted to jump clear but was subsequently run over by the wheels of his truck.

The sixth of Haddon's (1970, 1980) countermeasure strategies were intended to be used in 8 percent of incidents (n=8). The sixth strategy involves the separation of the potentially damaging energy from the individual by interposition of a material barrier. The incidents reviewed that intended to utilise this strategy related to matters where machine guards, the insulation of electrical leads, and in one case the blanking off of a chemical process line were the selected control strategies. However, in all cases, a failure to maintain or appropriately implement the countermeasure, ultimately led to its failure.

Haddon's (1970, 1980) second countermeasure strategy was intended to be utilised in four percent of cases (n=4). The objective of this countermeasure was to reduce the amount of energy marshalled. All four incidents relying on this strategy involved loss of control of damaging chemical energy. In three cases, control was dependent on the fugitive emissions of flammable vapours not manifesting within their flammable range. In the fourth case, reliance was placed on the design and maintenance of a burner on a kiln, so as not to allow for the explosive build up of gases.

The least used of Haddon's (1970, 1980) countermeasures was the first countermeasure strategy. This was the approach intended to be taken in three percent of cases (n=3). The first countermeasure strategy is to prevent the marshalling of the form of damaging energy in the first instance. Obviously, the three attempts to use this strategy were not successful or the incident would not have occurred.

In two cases, reliance was placed on not energising an electrical circuit. In both cases, persons ultimately made contact with a live electrical circuit and were electrocuted. The third case involved preventing a pyrophoric substance coming in contact with air and thereby preventing the marshalling of chemical energy. Once again, this was not achieved and an explosion ensued.

7.3 Pathophysiological Cause of Death

The physiological cause of death for each of the 100 fatalities was determined from information provided in coroner's reports and investigation reports prepared by OHSA inspectors. The results are summarised in Table 1.

An exchange of kinetic energy with the victim in 73 percent of cases generally led to massive injuries. Thirty three percent of cases were attributed to head and neck injuries and 26 percent were described as multiple injuries. A further 14 percent were attributed to injuries of the trunk.

The remaining 27 percent of injuries were not the result of an exchange of kinetic energy. Nine percent were attributed to electrocution, seven percent to burns, six percent to asphyxia (one of which was a drowning) and two percent were acute poisoning.

In the three cases referred to as "other", the death did not appear to be directly related to the incident. In one case, the injured 54 year old employee died in hospital from congestive cardiomyopathy 23 days after having both legs crushed. The coroner investigating the matter concluded, "I am satisfied on the evidence I have heard and seen, that the stress and anxiety would have aggravated the deceased's disorder and that, together with his hospitalisation in the presence of cardiomyopathy, those injuries precipitated his death." (State Coroner Victoria, 1991, p. 4)

In the second case, a 57 year old employee who received a crush injury and degloving to the lower leg died of pneumonia three days after being admitted to hospital. The cause of death was described as "complicated injuries sustained in an industrial accident, with past history of heavy smoking contributing to death". (State Coroner Victoria, 1993, p. 1)

In the third case, a 58 year old employee who suffered a fractured pelvis died ten days later from a pulmonary thromboembolism.

Table 1: Percentage of traumatic occupational fatalities by pathophysiological cause of death in relation to body location. 1990–1993.

Cause of death	Percentage (n=100)
Head and neck injuries	33%
Multiple injuries	26%
Trunk injuries	14%
Electrocution	9%
Burns	7%
Asphyxia	6%
Acute poisoning	2%
Other	3%

7.4 Fatalities by Industry

The distribution of fatalities was described as a total for each industry grouping and as a rate per 100,000 persons actually at risk in a particular industry. The results are summarised in Table 2.

This study didn't include self-employed persons not working for an employer. This excluded 28 fatalities involving self-employed farmers. If these fatalities were included, the rate per 100,000 persons in the Agriculture, Forestry and Fishing division would be 9.21.

The actual numbers of fatalities over the four year period was highest in the construction industry (n=25), followed by manufacturing (n=23) and transport and storage (n=19). (Refer to table 2.)

However, the number of fatalities in a particular industry is not the most enlightening factor. Consideration needs to be given to the population at risk, expressed as a mean annual incidence rate per 100,000 persons employed.

Mining, with three fatalities over four years, had a mean annual incidence rate of 13.39 fatalities per 100,000 persons employed. It should be noted that the mean total labour force in this industry in Victoria over the four year period was only 5,600 persons.

The next highest mean annual incidence rate was transport and storage with a rate of 5.43 with a mean total labour force of 87,463. These were followed by the electricity, gas and water supply industry with an incidence rate of 4.96 fatalities per 100,000 persons in a mean total labour force of 25,180 persons. Followed closely by construction with an incidence rate of 4.90 with a mean total labour force of 127,344 persons.

The manufacturing industry was ranked eighth with a mean annual incidence rate of 1.62 fatalities per 100,000 persons. The mean total labour force over the four year period for the manufacturing industry was 355,710 persons.

Table 2: Fatalities by Industry Division

Industry (ANZSIC Industrial Division)	**Number of fatalities in four year period**	*** Mean annual incidence**
Mining	3	13.39
Transport and Storage	19	5.43
Electricity, Gas & Water Supply	5	4.96
Construction	25	4.90
Libraries, Museums & the Arts (sub-division)	1	3.66
Sport and Recreation (sub-division)	2	2.58
† Agriculture, Forestry & Fishing	9	2.24
Manufacturing	23	1.62
Community Services (sub-division)	1	.91
Retail Trade	7	.62
Government Administration (sub-division)	2	.58
Wholesale Trade	1	.19
Business Services (sub-div)	1	.19
Education	1	.18

* Rate per 100,000 persons in each industrial group (ANZSIC, “division” or “sub-division” group).

7.5 Fatalities by Occupation

Of the 100 fatalities reviewed, all but one were able to be classified into a major ASCO (Australian Bureau of Statistics, 1986) occupation. The results are summarised in Table 3. As there was only one female fatality in the four year period, this was excluded from the classification. This enabled only the Victorian male Labour Force data to be used as a denominator when calculating the incidence rate per 100,000 persons in a particular occupation. The only female victim was working as a part-time strapper at the time of her death.

Three occupations accounted for 87 percent of all fatalities during the four year period. Most deaths were amongst labourers and related workers (n-41), followed by plant and machine operators and drivers (n=25) and trades persons (n=21). These same occupations had the highest incidence rate when consideration was given to the numbers of persons actually working in a particular occupation. Labourers and related workers had an incidence rate of approximately six fatalities per 100,000 persons. Plant and machine operators and drivers accounted for approximately five fatalities per 100,000 persons. Trades persons had a rate of approximately two fatalities per 100,000 persons. Interestingly, managers and administrators had eight fatalities over the four year period with an incidence rate of approximately one per 100,000 persons. The occupation of one person could not be established from the information reviewed.

Table 3: Fatalities by Occupation

Occupation (ASCO Major Group)	Number of fatalities in four year period	* Mean Annual Incidence
Labourers and Related Workers	41	5.78
Plant and Machine Operators and Drivers	25	5.33
Trades persons	21	1.95
Managers & Administrators	8	1.14
Para-Professionals	1	.35
Salespersons and Personal Service Workers	1	.23
Professionals	1	.16
Unknown	1	-

* Rate per 100,000 male employees in each occupation group (ASCO, "major group" classification)

7.6 Fatalities by Age

Fatalities by age were grouped into ten year age ranges, commencing at fifteen through to sixty-four. The results are summarised in Table 4. The ages of persons killed ranged from an eighteen year old apprentice roofing plumber through to a sixty two year old company director.

As there was only the one female fatality during the four year period, this was excluded from the classification to enable male Labour Force data to be used as a denominator. The female strapper was aged nineteen at the time of her death.

The highest number of fatalities occurred in the 25-34 year age group (n=33) and this group also had the highest incident rate per 100,000 persons (2.69). However, the incident rate was fairly constant throughout the age ranges 25-64.

The lowest number of fatalities was in the 15-24 year age group (n=8). The corresponding incident rate was also the lowest (.97).

Table 4: Fatalities by Ten Year Age Groups 1990–1993

Age	**Number of fatalities in four year period**	*** Mean annual incidence**
15–24	8	.97
25–34	33	2.69
35–44	27	2.34
45–54	22	2.63
55–64	9	2.12

* Rate per 100,000 persons in each ten year age group.

8. Discussion

This study of workplace fatalities has provided an opportunity to study a relatively unambiguous event. This in turn provides some certainty that all fatalities meeting the criteria of the study are actually captured.

The major findings of this study are that the types of damaging energy implicated in a fatality just prior to loss of control of the hazard are limited in number. Two sources of damaging energy involving potential and kinetic energy accounted for 75 percent of all incidents that led to a fatality.

In relation to the countermeasure strategy that was deemed to be in operation just prior to the fatality it was found that in over fifty percent of cases, reliance was placed on not being in a time or space co-incidence with the hazard. In essence, total reliance was placed on individuals in these cases to avoid the source of potentially damaging energy which ultimately led to the fatality.

8.1 Scope and Limitations of the Study

As this study has looked at fatalities in only one Australian jurisdiction, it has enabled the individual fatalities to be reviewed in greater detail than a number of other studies of work-related deaths. Harrison et al (1989) reviewed 1,544 deaths occurring throughout Australia during 1982 and 1984 and Cryer and Fleming (1987) reviewed 986 work-related fatalities that occurred in New Zealand between 1975 and 1984. Only 100 fatalities were identified as meeting the authors' criteria for an occupational related traumatic fatality. As a result, the numerator may have only represented one fatality over the four year period when industry and occupation fatality rates per 100,000 were calculated.

In addition, fatality rates calculated from industry and occupational categories with relatively small numbers of persons employed should be viewed with caution. For example, the Mining Industry had the highest fatality incidence rate of 13.39 fatalities per 100,000 persons employed in the industry. However, the Mining Industry has a relatively small workforce of approximately 5,600 persons in Victoria. This number was used as a denominator to calculate the fatality rate for the three deaths that occurred in this industry over the four year period.

The Labour Force Survey data used in rate calculations throughout the report was not adjusted to exclude Commonwealth employees, therefore the denominator used in the rate calculation may be larger than the population being studied. This may have led to a slight underestimation of the various rates per 100,000 but would not have impacted on the differences between the various rates.

This study has grossly under-represented fatality rates in the Agricultural, Forestry and Fishing Industry when compared with other fatality studies. Self-employed persons with no employees and not providing their services to an employer at the time of the fatality were not included in this study. This had the effect of excluding 28 fatalities involving self-employed farmers from the study.

The author is confident that all fatalities meeting the criteria of an occupational related traumatic fatality occurring between January 1, 1990 and December 31, 1992 have been included in this study. Employers had obligations to notify the OHSA during the review period if a workplace fatality occurred. The Victorian Police also had standing orders to notify the OHSA of industrial fatalities during this period. In addition, the Victorian State Coroner would bring industrial fatalities to the attention of the OHSA. The only opportunity for a relevant occupational fatality to go unreported and not be included in this study could be in cases where a person has died as a result of medical complications during the treatment of a relatively minor injury. Even if this was to occur it is still likely that the incidents would be reported and included in this study. There were three such cases included in this study where persons did appear to have died as a result of medical complications.

Without a diligent examination of all issues surrounding an occupational fatality it is possible to include fatalities that are not actually work-related. A study by Runyan, Loomis and Butts (1994) has placed doubt on the quality and comparability of occupational mortality data. Their study indicated that North Carolina medical examiners responsible for investigating fatalities were likely to classify some non-occupational fatalities as work-related.

The incidents they found difficult to consistently classify were those that involved farming, transport, unpaid workers and situations where the deceased was not working in his/her usual occupation.

8.2 Source of Damaging Energy and Countermeasure Utilised

Unlike other studies analysing occupational fatalities this study was unique in that it re-examined the source of damaging energy implicated in each fatality. This was the form in which the energy existed immediately prior to control being lost.

Although ten discrete sources of potentially damaging energy have been classified (Viner, 1991), only five were implicated in the 99 incidents reviewed. Of these five, two forms of damaging energy, kinetic and potential were involved in 75 percent of all incidents. This would indicate that intervention strategies with an objective of reducing occupational fatalities would need to focus on controls for damaging kinetic and potential energy.

8.2.1 Potential Energy

The incidents involving potential energy were generally shared between objects falling and striking a person (n=28) and persons falling from a height (n=20). Fatal falls were most common in the Construction Industry. Thirty five percent of falls occurred in this industry (n=7). Even when the size of the population at risk is considered, the Construction Industry has an incident rate of 1.37 fatal falls per 100,000 employees per year. This was followed by the Transport and Storage Industry with a rate of .85 fatal falls per 100,000 employees. A review of fatalities in the New Jersey Construction Industry (Sorock, Smith and Goldoft, 1993) found that 47 percent of deaths were the result of falls. This was higher than in Victoria where it was found that 28 percent of all deaths in the Construction Industry were related to falls.

In 60 percent of falls across all industries the only countermeasure in place was the attempt by the victim to maintain a separation in space, from an elevated position from which a fall was possible.

The control measures actually in operation at the time of these fatalities equated to “be careful”, “don’t step of the edge of the roof”, “don’t step through the skylight (if you can see it)”, and “don’t lean out too far you may fall”. In effect no control measures were provided.

In one incident where an apprentice roofing plumber fell 28 metres from a steeply pitched roof, fall arrest equipment was provided by the employer, but had not been used by the victim. The promoters of behavioural modification programs would claim that such a program could have been used to encourage the apprentice to use the personal falls arrest equipment provided (Zohar, 1980). However, on reviewing the circumstances, it would be unlikely that the apprentice could have been observed not complying with the desired behaviour on a regular basis without taking a fall. Behavioural modification programs would only be of benefit under such conditions where 100 percent adherence to the requirement to wear the fall arrest equipment could be guaranteed. Such a target would appear difficult to achieve in the short term and more difficult to maintain in the long term.

This example demonstrates the problems associated with using strategies low on the hierarchy of desired control measures, such as personal protective equipment, as a control measure for high levels of damaging energy. The use of passive controls as an effective prevention strategy where there is possible exposure to a "gravitational body weight fall" are not new. Haddon, cites Deuteronomy 22:8 as an example, "When you build a new house, you shall make a parapet for your roof, that you may not bring the guilt of blood upon your house, if any one falls from it". (1973, p.323). Passive controls such as wire mesh under fragile skylights and guardrails at exposed edges of roofs would have prevented a considerable number of the fatalities subsequently reviewed as part of this study.

In the majority of incidents where a "gravitational object fall" resulted in a fatality, Haddon's (1970, 1980) third countermeasure strategy had been attempted (n=12). In these incidents an attempt, although not adequate, had been made to prevent the release of damaging potential energy. In over fifty percent of incidents persons were working beneath a suspended load when control was lost (n=7). Approaches to eliminate the need to work beneath a load, in the first instance, or the use of formidable supports would have prevented these fatalities.

8.2.2 Kinetic Energy

Twenty two percent of the fatalities reviewed involved kinetic energy as a source of damaging energy (n=22). Sixteen of these incidents involved persons being struck by a powered vehicle of which four incidents involved a forklift truck. The countermeasure strategy relied on in all 16 incidents was Haddon's (1970, 1980) fifth countermeasure. Reliance was placed on either or both the pedestrian and the operator of the vehicle to avoid a space/time coincidence which would ultimately result in an exchange of damaging energy.

These incidents demonstrated a lack of physical separation between the vehicle and the pedestrian victim. Booth, (cited in Larsson and Rechnitzer, 1994, p 276) expressed the need for, "planning of the layout of factories and warehouses to minimise the risk of transport accidents...". He further claimed that, "... the wealth of knowledge and experience from road safety has not been adequately implemented inside [the] factory gate". Booth saw the importance of segregating pedestrians from site storage systems and site transport.

As a direct result of a truck driver being crushed by a forklift while he waited for his vehicle to be loaded the warehouse owner made substantial changes to the layout of the workplace. The warehouse was altered to allow trucks to back through openings in the warehouse. Drivers visiting the workplace would back their trucks into the warehouse and then proceed to a waiting room. The trucks would then be loaded by forklifts operating inside the warehouse. No pedestrian traffic was permitted inside the warehouse and all activity would stop if a pedestrian inadvertently entered. When loading was complete drivers were summoned back to their vehicles where they then tarped their trucks in a designated area. This approach not only improved safety standards but also drastically reduced the time taken to load vehicles.

At present the Victorian WorkCover Inspectors are focusing on the requirements for mobile plant to be fitted with flashing lights and reversing beepers. Although, active control measures are better than nothing, it still requires the individual, be it an operator or pedestrian, to take active steps to avoid a collision. Greater emphasis needs to be placed on the provision of passive controls such as designated pedestrian access and physical segregation of vehicle operating areas.

8.2.3 Mechanical Power

Mechanical power as a source of damaging energy was implicated in only seven percent of incidents (n=7). All seven of these incidents occurred in the manufacturing industry and involved a piece of fixed plant and equipment. Baker et al had similar findings where they found only eight percent of occupational fatalities involved fixed machinery (1982, p.696).

In total mechanical power was involved in approximately 30 percent of all fatalities which occurred in the Manufacturing Industry. In three of the cases which involved entanglement machine guards where not provided. In another incident the guarding system failed due to inadequate maintenance, although there were also deficiencies identified in the design of the guarding system.

In another two cases guarding was not an issue as the incident occurred during the set up of the machine and in the other case during maintenance of the machine. One incident involved the deliberate overriding of a safety interlock covering part of the guard. However, there also appeared to be design problems in relation to the ease at which the interlock could be made inoperative. Mazengarb and Mandryk, in their study of fatalities relating to machine guarding, found that in 16 percent of cases in which a guard may have prevented the fatality it had been removed or otherwise rendered inoperative (1194, p. 545).

Baker et al, referred to how contemporary preventative activities tended to reflect traditional problems and questioned the continued emphasis on safety programs in the Manufacturing Industry and in particular, the emphasis on fixed machinery (1982, pp. 695-696).

In the last ten years, this pre-occupation by health and safety enforcement agencies towards machinery guarding is evidenced by prosecutions, where between 46 and 72 percent of prosecutions have related to inadequately guarded machines (McLean, 1993, p.13). The author is not suggesting that the adequate guarding of machinery is not necessary but argues that there is a need to concentrate future prevention efforts into areas of greater need.

8.3 Distribution of Fatalities

8.3.1 Pathophysiological Cause of Death

The overwhelming majority of fatal injuries, 73 percent, were the result of an exchange of kinetic energy with the victims in doses that exceeded human thresholds. Head and neck injuries predominated at 33 percent, followed by multiple injuries, 26 percent, and trunk injuries, 14 percent. The number of head injuries in this study were slightly higher than the findings of Harrison et al (1989) at 22.3 per cent and Salminen et al (1991) at 25 percent. This variation could be due to the inclusion of neck into the classification of head injuries.

8.3.2 Industry

The Mining Industry stood out as having the highest industry annual incident rate of fatalities. However, this represented only three mining deaths over the four year period. As previously discussed because of the small size of the denominator data for this industry in Victoria, interpretation should be treated with caution. The study by Harrison et al (1989) found the mining and rural industries to have the highest accident rate. This trend was consistent with this study. The Harrison, et al study found the next highest category to be the Construction Industry. This was different from the findings in this review. Construction was rated fifth after Mining; Agriculture, Forestry Fishing and Hunting; Transport and Storage; and Electricity, Gas and Water Supply.

The incident rates per 100,000 employees put forward by Harrison et al (1989) are significantly higher than the findings in this study. These variations may be due to differences in the definition of what constitutes a workplace death. Harrison et al includes self employed persons and persons who worked without pay in a family business or on a farm (1989, p.119).

Harrison et al also acknowledged that they had difficulties allocating fatalities to specific industry groups and do not appear to have rigidly used the ANZIC classifications, as has been used in this study.

Looking at the actual figures for fatalities by industry, Construction (n=25), Manufacturing (n=23), and Transport and Storage (n=19) dominated, accounting for 67 percent of all occupational fatalities in the four year period. Any strategy to reduce the gross number of occupational fatalities in Victoria would need to focus on these three industries.

8.3.3 Occupations

The fatalities were classified by major ASCO groupings and as such don't provide assistance in identifying a discrete occupation that may have an increased risk of a fatal incident. As the total number of fatalities reviewed was only 100 there would be no benefit in subdividing occupations into minor group categories.

The three categories: labourers and related workers; plant and machine operators and drivers; and trades persons accounted for 87 percent of all fatalities.

The occupation designated as managers and administrators was represented with eight fatalities with an incident rate of approximately one fatality per 100,000 persons. This group consisted of four working directors, three managers (two of which were farm managers) and one supervisor. The four directors had significant control over the safety aspects of the activity that led to their death but in all four incidents this control was not appropriately exercised.

8.3.4 Age

The fatality rate by age indicated a lower rate in the teens and early twenties which then rose and was generally consistent throughout the various age categories. The traditional U-shaped distribution suggested by Hale and Hale (1972, p.33) was not evident. Fatalities were not found to be higher in the lower age categories and the higher age categories. Harrison, et al found workplace fatalities particularly high in the age group of 65 years or more (1989, p. 120). This was not relevant in this study as the oldest person identified as an occupational fatality was a sixty two year old company director.

9. Conclusions and Recommendations

A comprehensive study of occupational traumatic fatalities occurring in Victoria in the years 1990–1993 was undertaken to identify opportunities for prevention activity. Ninety nine incidents that led to one hundred fatalities were identified. This was the total number of workplace deaths in Victoria involving employees or self-employed persons working for an employer during the four year period.

The study was unique in that it reviewed the source of damaging energy implicated in each fatality. The most significant finding of the study was the observation that only two, out of a possible ten, forms of damaging energy were implicated in 75 percent of all fatalities. The two forms of damaging energy were potential and kinetic energy. Loss of control of these forms of energy generally involved a person falling from a height, being struck or crushed by a falling object or being hit by a moving vehicle.

Although the Construction Industry did not have the highest fatality rate across all types of hazard, it was over-represented in relation to fatal falls.

All incidents relating to mechanical power involved an item of fixed machinery. Mechanical power as a source of damaging energy was only implicated in seven percent of incidents. However, government resources appear to have disproportionately targeted prevention activity involving fixed machinery.

If future prevention programs are going to be successful in reducing the number of fatalities in Victorian workplaces, they will need to focus on work at height, suspended objects, objects with the potential to fall from a height and vehicle traffic in the workplace.

This study also investigated the countermeasure strategy utilised at the time of the fatality. In the majority of incidents, the only countermeasure in place was the attempt by the victim to maintain a separation in space or time from the source of potentially damaging energy. These approaches relied on the behaviour of the individual to avoid the space-time coincidence. Generally, the countermeasure strategy applied, incorporated an active control approach which was dependent on the behaviour of an individual to be effective.

The predominance of head injuries and multiple injuries indicated there had been high levels of energy exchange with the victims involved. Haddon acknowledged that when there are large amounts of damaging energy involved the earlier counter-measure strategies should be selected (1973, p.325). This was generally not done.

In summary, the majority of fatalities occurred in an environment where reliance was placed on the individual to avoid the hazard. This was combined with a lack of commitment to the elimination of hazards and the adoption of effective engineering controls.

The following recommendations should be considered when developing strategies targeted at reducing workplace fatalities:

- resources for workplace intervention programs need to focus on the areas of greatest need, which currently involve the loss of control of potential and kinetic energy; and

- where there is a likelihood of a fatality in relation to a hazard the earlier countermeasure strategies need to be implemented with an emphasis on passive control approaches.

The current trend of the 1990s in health and safety where there is a pre-occupation towards behavioural control approaches, needs to be reversed.

If occupational traumatic fatalities are to be reduced, passive control measures that do not require the co-operation of the individual to be effective, need to be introduced.

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Appendix A

Description of Fatal Incidents

1. A 32 year old apprentice plumber was crushed by a pre-cast concrete wall panel which had fallen from its standing position. The panel was supported by one telescoping brace. The locking pin for the telescoping brace was not in position. The incident occurred at 9.10 A.M. on 24th January, 1990.

2. A 29 year old labourer was crushed when a car body he was working under slipped off the tynes of a forklift truck used to support the car body. The incident occurred at approximately 1.47 P.M. on 8th January, 1990.

3. A 54 year old transport driver had both legs crushed when a 2400 kg Anhydrous Ammonia tank rolled off the tynes of a forklift in the process of loading his truck. The incident occurred at approximately 1.33 P.M. on 26th January, 1990. He died from congestive cardiomyopathy on 18th February, which was aggravated and precipitated following the earlier incident.

4. A 27 year old welder was hit by the force of a blast while welding a ladder onto the side of a storage tank when it exploded. A quantity of flammable liquid had seeped into the tank through a leaking valve. The incident occurred at approximately 10.05 A.M. on 16th February, 1990.

5. A 26 year old excavator driver was crushed beneath the wheels of an articulated dump truck. He fell from the step of the dump truck while trying to attract the attention of the driver. The incident occurred at approximately 12.55 P.M. on 23rd March, 1990.

6. A 21 year old apprentice linesman was electrocuted when he made contact with live overhead power lines. The incident occurred at approximately 2.45 P.M. on 10th April, 1990.

7. A 19 year old front end loader operator was crushed by his upturned front end loader when it overturned after impacting with a tree. The incident occurred at approximately 11.20 A.M. on 25th April, 1990. The operator died in hospital as a result of injuries received on 17th May, 1991.

8. A 48 year old labourer was crushed when the mast on the forklift truck he was operating broke away. He was lifting a road roller at the time, which exceeded the capacity of the forklift truck. The incident occurred at approximately 11.04 A.M. on 11th April, 1990.

9. A 33 year old scaffolder fell ten metres to ground. At the time of the incident he was walking on an asbestos cement sheet roof that gave way. The incident occurred at approximately 2.20 P.M. on 9th May, 1990.

10. A 42 year old truck driver was crushed between the counterweight of a reversing forklift truck and the driver's side rear section of his articulated truck trailer. The incident occurred while his truck was being loaded with packs of particle board. The incident occurred at approximately 10.35 A.M. on 2nd July, 1990.

11. A 28 year old truck driver was crushed between his truck and a utility being towed by another vehicle. The truck driver was standing at the front of his prime mover. The incident occurred at approximately 8.30 A.M. on 11th July, 1990.

12. A 57 year old roof worker fell 20 metres to the ground. At the time of the incident the roof worker was attempting to secure sheets of roofing in a strong wind. It is likely that a loose sheet of roofing driven by the wind pushed off the roof. The incident occurred at approximately 11.15 A.M. on 24th July, 1990.

13. An 18 year old apprentice roofing plumber fell 28 metres to the ground. At the time of the incident the apprentice was securing a stack of roof decking near the edge of a steeply pitched roof. The incident occurred at approximately 8.00 P.M. on 31st August, 1990.

14. A 35 year old knitting machine operator had his head crushed between the body of a circular knitting machine and a rotating arm. The interlock on a gate designed to deny access to the operating components of the machine had been overridden. The incident occurred at approximately 9.15 P.M. on 14th October, 1990.

15. A 26 year old production manager was brunt when a gas fired kiln exploded. The production manager was in the process of lighting the kiln when the explosion occurred. A malfunctioning safety shut off valve allowed the build up of unignited gas in the kiln before it was lit. The incident occurred at approximately 4.20 P.M. on 29th October, 1990.

16. A 31 year old railway guard was struck by an electric passenger train as he crossed railway lines leading into a station. The incident occurred at approximately 11.55 A.M. on 16th October, 1990.

17. A 30 year old cement mixer driver had his head crushed when the cement mixer he was under inadvertently started. The driver was under the truck carrying out repairs on the brakes with his head between the wheel. Unknowingly, the truck was in reverse gear when it was started by another person causing the truck to roll backwards. The incident occurred at approximately 12.45 P.M. on 1st October, 1990.

18. A 30 year old labourer was electrocuted when he cut through an underground power cable using a pair of tin snips. The power cable serviced a temporary power pole which the labourer was attempting to remove. The labourer had been informed that the power supply had been disconnected. The incident occurred at approximately 12.30 P.M. on 22nd October, 1990.

19. A 37 year old crossing supervisor fell through a fibre glass section of a verandah roof onto concrete below, a distance of three metres. The crossing supervisor had climbed out of a first floor window of a primary school and slipped onto the verandah roof while attempting to retrieve some cutlery that had fallen behind

a dishwasher. The incident occurred at approximately 2.45 P.M. on 9th October, 1990 and he died the following day from injuries received in the fall.

20. A 29 year old labourer was crushed under a hay bailer that fell on top of him. At the time of the incident the hay bailer was suspended in the air by chain slings attached to a jib that was, in turn, attached to the raised tynes of a forklift truck. The labourer was using an oxy-acetylene torch to dismantle the hay bailer which subsequently dislodged from the supporting slugs. The incident occurred at approximately 10.00 A.M. on 22nd November, 1990.

21. A 51 year old linesman fell backwards, hitting his head on the ground from a power pole he was attempting to turn using a lever. The power pole was positioned horizontally, approximately 500mm above the ground. The incident occurred at approximately 1.30 P.M. on 13th December, 1990. The linesman died in hospital on 20th December, 1990 as a result of injuries received.

22. A 30 year old front end loader operator was electrocuted when he dragged the damaged section of live extension lead into a puddle of water he was also walking in. The extension lead was attached to an arc welding unit he was carrying. The incident occurred at approximately 3.15 P.M. on 9th January, 1990.

23. A 42 year old die setter was struck on the head by a die setting bar. The die setting bar was used to manually rotate the crank shaft on a power press during setting up. The bar was inadvertently left attached to the crank shaft when the machine was operated. The incident occurred at approximately 5.40 P.M. on 10th January, 1991. The die setter died in hospital as a result of his injuries on 19th January, 1991.

24. The 30 year old driver of a dump truck was crushed when trapped beneath the cabin of the truck. The dump truck had careered out of control down an embankment. The incident occurred at approximately 12.10 P.M. on 12th February, 1991.

25. A 36 year old truck driver fell a distance of approximately 2.2 metres off the top of his loaded prime-mover, striking a steel crate and then a concrete surface. The driver was involved in tarping up his load at the time of the incident. The incident occurred at approximately 3.15 P.M. on 14th February, 1991. The driver died in hospital on 19th February as a result of injuries received.

26 & 27. Two workers aged 60 and 26 were crushed when a kibble bucket ¾ full of concrete fell on them. The two workers were at the bottom of a sewer trench when the hydraulic operated quick hitch on the bucket of an excavation let go, releasing the chain supporting the kibble bucket. The incident occurred at approximately 3.12 P.M. on 28th March, 1991.

28. A 46 year old refrigeration attendant was crushed by a container straddle carrier. The attendant was checking temperature records on shipping containers while the straddle carrier was moving containers in the same area. The incident occurred at approximately 1.30 P.M. on 27th March, 1991.

29. A 40 year old scaffolder was struck by a scaffold component. He then fell approximately 12 floors to the street below. At the time when he was struck by the scaffolding component he was attempting to pass it to an assistant working above. The incident occurred at approximately 8.00 A.M. on 2nd March, 1991.

30. A 37 year old rigger fell approximately 10 metres to the ground. The rigger was working on a structure with grid mesh flooring. The grid mesh flooring was secured in position and the rigger fell through the floor. The incident occurred at approximately 12.30 P.M. on 13th April, 1991.

31. A 37 year old plant superintendent was poisoned by exposure to hydrogen sulphide. The plant superintendent entered a sewer pit in a street to clear a blockage. The incident occurred at 12.05 P.M. on 9th April, 1991.

32. A 49 year old garage attendant was electrocuted when he made contact with the live wiring on an urn. The base plate on the urn was missing, which allowed contact to be made inadvertently with the live wiring. The incident occurred at approximately 8.00 A.M. on 14th April, 1991.

33. A 24 year old labourer was struck by a split locking rim forming part of a wheel assembly inflated to a pressure of 110 p.s.i. A hammer was being used by the labourer to attempt to fit the wheel back onto the hub of a trailer. The incident occurred at approximately 12.13 A.M. on 4th April, 1991.

34. A 35 year old factory worker was strangled when the clothing he was wearing was caught in a rotating universal joint forming part of a conveyor. The factory worker was cleaning paint overspray off the floor underneath the operating conveyor at the time. The incident occurred at approximately 4.30 P.M. on 20th May, 1991.

35. A 43 year old glazier fell 15 metres to concrete paving below. At the time of the incident, the glazier was preparing to replace a damaged glass panel on canopy forming part of a multi-storey building. The incident occurred at approximately 5.20 P.M. on 7th May, 1991.

36. A 31 year old part-time farm hand fell from his horse and hit the ground. He was mustering sheep at the time. The incident occurred at approximately 2.00 P.M. on 13th May, 1991.

37. A 31 year old driver was crushed between the rear of his truck and a shipping container when the truck rolled backwards. The driver was fitting a cable to the rear of the truck when it rolled backwards under the force of gravity. The incident occurred at approximately 7.00 A.M. on 6th May, 1991.

38. A 62 year old director of an automotive repair workshop fell through a fibreglass skylight onto a concrete floor seven metres below. The director had climbed onto the roof of the workshop to investigate a leaking roof. The incident occurred at

approximately 9.15 A.M. on 9th July, 1991.

39. A 54 year old flagman was struck by a car while controlling traffic on a public highway. The incident occurred at approximately 10.00 A.M. on 8th July, 1991.

40. A 60 year old electrical mechanic was electrocuted when he made contact with the high voltage section of a radio frequency welder he was repairing. Current passed through an adjustment screw on a high voltage probe being used at the time. The incident occurred at approximately 2.00 P.M. on 25th July, 1991.

41. A 28 year old linesman was electrocuted while attempting to open a 22KV three phase switch on a power pole. The linesman was standing on a packrack on a vehicle which was earthed with the ground due to grass and other debris making contact with the underside of the vehicle. The protective earth on the handle for the switch was measured to be 80 OHMS when the recommended level was 10 OHMS. Protective rubber gloves and a protective handle sleeve were not used. The electrical switch malfunctioned, sending live current down the switch handle to the linesman. The incident occurred at approximately 4.30 P.M. on 5th September, 1991.

42. A 49 year old working director became entangled in the rotating drive shaft of a dynamic balancing machine. At the time of the incident, the dynamic balancing machine was being used to balance a 1.5 tonne impeller blade. The incident occurred at approximately 12.05 P.M. on 9th September, 1991. The director died in hospital on the same day as a result of injuries received.

43. A 42 year old railway maintenance vehicle driver was crushed when the vehicle he was driving was struck by an electrical passenger train. The maintenance vehicle was struck by the train as it reversed out of a tunnel. The incident occurred at approximately 4.57 A.M. on 17th September, 1991.

44. A 27 year old farm manager left his horse after colliding with another horse and impacted with the ground. The rein on another horse at full gallop broke, causing

it to veer into the path of the horse ridden by the farm manager. The incident occurred at approximately 6.25 P.M. on 24th September, 1991. The farm manager died the next day in hospital from injuries received in the incident.

45. A 47 year old plumber and drainage contractor was crushed when the front end loader/backhoe he was operating overturned. The drainage contractor was working across a steep incline filling a trench when the machine overturned. The incident occurred at approximately 10.30 A.M. on 1st October, 1991.

46. A 34 year old skidder operator was struck by a section of tree. The section of tree had previously broken off and was supported against an old dead tree, referred to as a stag. A second tree felled by another employee struck the stag and dislodged the supported section of tree. The incident occurred at approximately 1.00 P.M. on 15th October, 1991.

47. A 46 year old plumber carrying a 6.5 metre length of pipe, while ascending a ladder, was electrocuted when the pipe made contact with 11,000 volt overhead power lines. The incident occurred at approximately 12.45 P.M. on 7th November, 1991.

48. A 57 year old foundry leading hand was struck by a forklift truck. The leading hand was walking through a doorway designated for vehicular traffic. The incident occurred at approximately 4.00 A.M. on 13th November, 1991. The leading hand died in hospital on 16th November due to complications resulting from his injuries.

49. A 38 year old chemical plant operator was covered in hot tar when the base of a large storage tank ruptured. A pyrophoric coke byproduct inside the storage tank was inadvertently exposed to the air which led to the auto ignition of the coke and subsequent explosion. The incident occurred at approximately 4.40 P.M. on 2nd December, 1991. The plant operator died as a result of burns received, on 15th December, 1991.

50. A 49 year old maintenance fitter was knocked down by a reversing rubbish truck and before he could get to his feet was crushed by the wheels of the truck. The incident occurred at approximately 9.10 A.M. on 11th December, 1991.

51. A 19 year old third year electrical apprentice was electrocuted when he made contact with live 240V wires in a ceiling space. The electrical apprentice was junctioning off wires where fluorescent lights had been previously removed. The incident occurred at approximately 8.30 A.M. on 9th December, 1991.

52. A 26 year old farm hand was crushed by a 400 kg round bale of hay. The farm hand was standing at the base of a stack of three round bales when the top bale unexpectedly fell. The incident occurred at approximately 3.30 P.M. on 8th January, 1992.

53. A 48 year old farm manager was stuck by a tree branch. The branch was dislodged when a tree he felled struck another tree, causing the branch to be dislodged. The incident occurred at approximately 2.15 P.M. on 13th January, 1992.

54. A 26 year old process worker fell through a suspended ceiling, striking the concrete floor approximately six metres below. He subsequently died as a result of the injuries received. Five other employees were also injured in the same incident, one critically. Six employees were assisting to position a 180 kg tank in the ceiling space when it gave way. The incident occurred at approximately 12.10 P.M. on 29th January, 1992. The 26 year old process worker died in hospital as a result of the injuries received, on 1st February, 1992.

55. A 39 year old foreman was struck by a shipping container. The shipping container was one of two being lifted by a forklift truck operator. The top container was dislodged and fell onto the foreman. Just prior to the incident, the foreman was a passenger in the forklift truck, however he departed when he saw the container begin to fall. The incident occurred at approximately 8.30 A.M. on 13th February, 1992. The foreman died as a result of his injuries in hospital on

24th February, 1992.

56. A 37 year old flagman was struck by an electric passenger train. The flagman was working as a lookout for a gang working in a railway yard and inadvertently stepped into the path of an approaching train. The incident occurred at approximately 9.45 A.M. on 24th February, 1992.

57. A 50 year old tree feller was struck by the trunk of a tree. The trunk of the tree had bounced up when the head of the tree hit the ground. The incident occurred at approximately 12.15 P.M. on 24th February, 1992.

58. A 26 year old operator of an historical tractor was crushed by the front wheels of the tractor. The operator, for some undetermined reason, passed out and fell from the seat of the tractor. The tractor was being used as part of a public display. The incident occurred at approximately 3.40 P.M. on 29th March, 1992.

59. A 32 year old boilermaker was struck by a steel column weighing approximately one tonne when it rolled off a trestle. The boilermaker was moving another column using an overhead crane when he hit the column which subsequently fell. The incident occurred at approximately 11.45 A.M. on 17th March, 1992.

60. A 19 year old part-time strapper was kicked by a race horse. The strapper was walking the hose in a public street when it appears the horse was spooked. The incident occurred at approximately 6.15 A.M. on 19th April, 1992.

61. A 52 year old labourer was burnt in an explosion of flammable solvent vapours. The labourer was using the solvent in an attempt to remove old linoleum from the floor of a private house. The solvent vapours produced have ignited, resulting in an explosion. It is suspected that the source of ignition was the refrigerator located in the house. The incident occurred at approximately 2.00 P.M. on 28th May, 1992.

62. A 47 year old general factory hand fell approximately three metres and made contact with a concrete floor below. The factory hand was working on top of a

stack of steel rod bundles, placing timbers for an overhead crane at the time of the incident. The incident occurred at approximately 12.45 P.M. on 15th June, 1992.

63. A 52 year old boiler attendant had his right arm entangled in a conveyor which dragged him in, compressing his chest. The attendant was caught between the belt of the conveyor and a piece of electrical conduit. The conduit had been placed between two conveyors to prevent material falling on the floor. The incident occurred at approximately 2.00 A.M. on 23rd July, 1992.

64. A 37 year old toolpusher was struck by a chain chaser. The tool pusher was working on a semi-submersible drilling rig at the time of the incident. The chain chaser, weighing approximately one tonne, was left unsecured and fell over when the rig moved. The incident occurred at approximately 10.00 A.M. on 21st July, 1992.

65. A 25 year old labourer was crushed by the trailer wheels of a prime mover fitted with a trailer. The labourer was under the trailer releasing the air on the trailer brakes when another person reversed the prime mover. The incident occurred at approximately 3.30 P.M. on 6th July, 1992.

66. A 41 year old truck driver was crushed by the bull bar of his truck when it fell on him. The driver was attempting to change the tyre on his prime mover when it slipped off the hydraulic jack being used. The incident occurred at approximately 3.45 P.M. on 2nd August, 1992.

67. A 60 year old builder's labourer fell from a ladder and made contact with the concrete slab below. He fell from a height of approximately 3.5 metres. The incident occurred at approximately 2.50 P.M. on 20th August, 1992. The labourer died in hospital on 25th August, 1992 as a result of injuries received.

68. A 49 year old waterside worker was struck by a reversing forklift truck. The forklift truck had just placed its load and was reversing out from the stack. The incident occurred at approximately 11.45 A.M. on 17th August, 1992.

69. A 20 year old diver drowned in a dam on an agricultural property. The diver was dragged into a break in the dam wall by the hydraulic pressure created by the escaping water. The incident occurred at approximately 3.20 P.M. on 14th September, 1992.

70. A 36 year old scraper driver was crushed by his scraper when it rolled down an embankment. At the time of the incident the driver was using an access road constructed on top of a stockpile of rock and clay. The incident occurred at approximately 1.10 P.M. on 11th September, 1992.

71. A 45 year old dump truck driver was stuck by the rapidly descending tipper tray of his truck. The tipper tray had been stuck in the raized position and the driver attempted to lower it by draining hydraulic oil from the lifting cylinder. The incident occurred at approximately 2.00 P.M. on 4th September, 1992.

72. A 30 year old strapper struck a light pole with his head while being dragged by a horse. The horse being ridden by the strapper bolted and he had his left leg caught in the stirrup as he was dragged. The incident occurred at approximately 7.00 A.M. on 10th October, 1992.

73. A 25 year old storeman fell approximately 3.5 metres to a concrete floor below. The storeman was standing on the tray of an elevated order picker, passing cartons to another worker at the time of the incident. The incident occurred at approximately 3.30 P.M. on 22nd October, 1992.

74. A 50 year old hands on director was burnt and died as a result of an explosion. Two additional employees were severely burnt in the same incident. The explosion occurred when a cutting torch was used to dislodge a plug of rosin in the drain hole of a storage vessel. The incident occurred at approximately 11.35 A.M. on 5th November, 1992.

75. A 54 year old fabric machine operator was crushed between the rollers and the frame of a cutting mechanism of a material processing machine. The operator stepped through a light curtain to remove an entanglement when the cutting

cycle on the machine automatically activated. The incident occurred at approximately 9.20 A.M. on 13th November, 1992.

76. A 50 year old senior chemist was engulfed in fire. At the time of the incident, the chemist was mixing a flammable solvent with an electric powered mixer. A spark from the electric mixer ignited the solvent vapours. The incident occurred at approximately 1.50 P.M. on 19th November, 1992. The chemist died in hospital on 7th December, 1992 as a result of burns received in the incident.

77. A 30 year old farm hand was crushed by a round bale of hay weighing approximately 400 kg. The bale of hay had been placed on a trailer on its edge from which it rolled off onto the farm hand. The incident occurred at approximately 3.15 P.M. on 10th November, 1992.

78. A 36 year old spray painter was crushed by a large steel wall panel weighing approximately two tonnes. The panel was supported by four hook and chain slings and was being spray painted from the underside. The incident occurred at approximately 3.00 P.M. on 14th December, 1992.

79. A 28 year old logging contractor was struck by a large section of tree which snapped off approximately four metres above the ground. The contractor had just previously felled another tree and was about to trim it when struck. The incident occurred at approximately 12.15 P.M. on 28th January, 1993.

80. A 39 year old cleaner was burnt with hot steam when a pressure cooker opened while still under 37 Kpa of pressure. The incident occurred at approximately 8.30 P.M. on 24th January, 1993. The cleaner died in hospital on 18th February, 1993 as a result of injuries received.

81. A 32 year old dump truck driver was crushed by the wheel of his truck. The brakes on the truck had failed as the driver was reversing down a steep rise. The driver tried to jump clear of the dump truck but fell under the front wheel. The incident occurred at approximately 4.50 P.M. on 5th February, 1993.

82. A 19 year old electrical instrument apprentice fell from a moving tarmac tug vehicle, striking his head on the tarmac. At the tome of the incident he was sitting on the bonnet of the tug as it drove across the tarmac. The incident occurred at approximately 5.40 P.M. on 24th February, 1993.

83. A 35 year old intellectually disabled man fell from a moving tray truck and hit the ground. The disabled man was involved in collecting waste paper while standing on the back of the truck, which was moving at a speed of 5-10 kph. The incident occurred at approximately 11.40 A.M. on 5th March, 1993.

84. A 33 year old welder was crushed by a 3 tonne counterweight attached to a mobile crane. The welder, while carrying out repairs on the crane, cut away the counterweight support frame using a cutting torch. This then allowed the counterweight to fall. The incident occurred at approximately 1.00 P.M. on 18th March, 1993.

85. A 28 year old tyre moulder was struck by the lid of a rubber curing press which opened whilst still under pressure. The press was on an automatic cycle and was designed not to open while there was still pressure in the press. The incident occurred at approximately 2.10 P.M. on 19th March, 1993.

86. A 39 year old apprentice maintenance fitter had his neck crushed when a clamping bar activated on a sheet metal production line. The apprentice was performing maintenance work beneath the operating machine. The incident occurred at approximately 2.05 A.M. on 19th April, 1993.

87. A 41 year old agriculture worker was incinerated during a slash burn in a state forest. The worker was last seen walking through the forest with a fuel drip torch before his incinerated body was located. The mechanism of contact with the drip torch and subsequent incineration could not be determined. The incident occurred at approximately 1.30 P.M. on 21st April, 1993.

88. A 44 year old foreman fell approximately four metres and contacted the concrete floor below. At the time of the fall, the foreman was working from an unsecured

ladder which had been placed against a large shotblasting machine he was refurbishing. The incident occurred at approximately 9.30 A.M. on 24th April, 1993.

89. A 29 year old catering assistant fell from a diesel locomotive travelling at 110 kilometres per hour. The assistant had left the kitchen car on the train via an outward opening door. There was no explanation how this eventuated. The incident occurred at approximately 9.00 P.M. on 6th May, 1993.

90. A 42 year old domestic carpet cleaner was electrocuted when he made contact with wet carpet in the back of his electrified van. An extension lead used to operate carpet cleaning equipment had a section of damaged insulation. This allowed a transfer of electric current through the wet carpet. The incident occurred at approximately 10.15 A.M. on 10th May, 1993.

91. A 38 year old forklift truck driver was struck with a reversing prime mover and trailer. The forklift truck driver was walking through the transport depot when struck. The incident occurred at approximately 2.40 P.M. on 26th May, 1993. The forklift truck driver died as a result of the injuries received on 30th May, 1993.

92. A 22 year old cherry picker operator was struck by a section of tree that fell into the bucket of the cherry picker. The operator was assisting another person to remove dead timber from a tree. The incident occurred at approximately 11.13 A.M. on 29th June, 1993.

93. A 42 year old forklift driver was crushed between the mast of the forklift he had previously been driving and the rear of a vehicle he had been loading. The forklift driver had alighted from the forklift truck when the forklift truck slipped into forward drive by itself and moved forward. The incident occurred at approximately 12.00 P.M. on 13th August, 1993.

94. A 24 year old cleaner was poisoned by exposure to 1,1,1-Trichloroethane vapours. The cleaner had entered a vapour degreasing tank that had previously

contained 1,1,1-Trichloroethane. The incident occurred at approximately 1.30 P.M. on 23rd August, 1993.

95. A 50 year old working director was asphyxiated as a result of being trapped beneath a van body. The director was working under the van body which was supported by a crane. It was found that there was approximately 23 mm of creep in the winch being used over a period of one minute. The incident occurred at approximately 5.00 P.M. on 24th August, 1993.

96. A 58 year old worker fell from a building scaffold. The scaffolding was being used for bricklaying. The incident occurred at approximately 1.30 P.M. on 30th August, 1993. The injuries sustained were not life threatening, however the worker died on 11th September, 1993 from a pulmonary thromboembolism.

97. A 33 year old railway labourer struck the lower support beam of a bridge while riding on top of a railway ballast cleaning machine. The incident occurred at approximately 8.30 A.M. on 22nd September, 1993.

98. A 39 year old labourer was struck by a metal plate weighing in excess of 700 kg. The labourer was in the process of cutting up a large conveyor for scrap when he inadvertently cut away all the sections supporting the metal plate. This allowed it to fall. The incident occurred at approximately 11.45 A.M. on 29th November, 1993.

99. A 55 year old road worker was crushed by the wheels of a reversing truck. The road worker was part of a gang resurfacing a road when he was struck by the rear of the truck. The incident occurred at approximately 12.10 P.M. on 3rd December, 1993.

100. A 56 year old tractor operator was crushed when the tractor he was driving rolled on top of him. At the time of the incident, the operator was slashing grass at the edge of a road with a steep embankment. The incident occurred at approximately 9.30 A.M. on 10th December, 1993.