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Institute for Safety, Compensation and Recovery Research

Work Related Fatality project
Department of Forensic Medicine, Monash University

Unintentional Work Related Fatalities Research Programme
Caught in Machinery Fatalities

November 2010

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Research Report no.: 1110-005-R5

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EXECUTIVE SUMMARY

The research utilized a whole of population case series analysis method. Cases were extracted from the National Coroners Information Service (NCIS) and the Victorian Work Related Fatality (VWRF) databases according to an agreed definition. The cases thus retrieved were coded to extract information about the driver and the fatal incident.

National and state workplace related fatality data identified a series of instances where people died from injuries received when they were caught or drawn into, or by, one or more machines with moving parts.

- Persons being caught in and between machines and suffering fatal injuries accounted for at least 92 deaths in Australia between 2000 – 2010 (except WA).
- Workers clothes being caught in spinning or moving parts of machinery represents a discrete type of fatality process.
- There were more workers killed aged between 50 – 59 than any other age group.
- 25% of deaths occurred performing maintenance or repairs on machines, rising to approximately a third (37%) when all tasks that were not merely operating the machine were included.

Factors relating to the person, place, plant, process and policy associated with each fatality were identified. The most frequent locations of the fatalities were industrial sites and rural properties, with crush / asphyxia being the most common medical cause of death. The majority of cases identified were in Victoria (45), where detailed data collection tends to be more complete than for other states and territories, and therefore not necessarily reflecting Victorian over-representation, but rather that the problem is further under-recognised elsewhere in Australia.

There were 9 instances of workers having clothing caught in a machine, notably tractor power take offs or augers.

These fatalities were investigated for the purpose of describing the problem and identifying possible prevention strategies. Caught in machinery deaths are largely preventable, and common factors identified, such as task (e.g. repair & maintenance), or specific equipment (power take off / augers) allow preventions targeted to those factors to be proposed.

Key prevention strategies identified were:

- Incorporation of safety features in machine design, such as guarding moving parts and incorporation of machine- or person- mounted sensors for emergency shutdown.
- Redesign of tasks to include cross checking procedures, such as tag-in tag-out, especially for repair and maintenance tasks,
- Encouragement of the use of suitable personal protective equipment (PPE), particularly the use of snugly fitting clothing around machinery with spinning parts (e.g. Augers and tractor power take offs),
- Targeted inspection of augers and power take off equipment for suitable guarding, and
- Dissemination of information when risks with particular machines are identified, and if solutions have been designed.

Areas for improvement to data collection or further research:

- Design of a form for police to allow a minimum common data set to be collected. Forms could be modified to allow for broad fatality types e.g. road crash, farm injury, and industrial incident to be selected.
- Agreement upon a common medical cause of death nomenclature or classification scheme by pathologists, and
- Assess the feasibility of a design solution clearing house accessible by relevant stakeholders.

Introduction

This report addresses work related deaths attributed to being caught in machinery (CIM) in Australia between 2000 – 2010. It is divided into three sections:

- Section A: Review of the scope of CIM fatalities;
- Section B: Review and analysis of CIM fatalities in Australia; and
- Section C: Prevention opportunities analysis.

SECTION A: REVIEW OF THE SCOPE OF FATALITIES ATTRIBUTED TO BEING CAUGHT IN MACHINERY

Scope of the Issue

In the period July 2007- June 2008 SafeWork Australia (SWA) identified 27 fatalities as a result of being trapped between stationary and moving objects or being trapped by moving machinery, from a total of 301 identified work-related fatalities (9%) (SWA 2008, 2010). In the period July 2007 – June 2008 this represented the fifth most frequent circumstance of work-related death after vehicle accidents, being hit by moving objects, and falls from a height. In the United States of America, the National Traumatic Occupational Fatalities Surveillance System (NTOF) ranked machinery-related deaths as the second leading cause of occupational deaths from 1980 – 1989, and the third highest cause of occupational deaths (13%) from 1980 – 1995 closely following homicide (Pratt et al. 1996; Marsh and Layne, 2001).

Reports and discussions in the literature discuss CIM fatalities in the context of an industry, job task, or a piece of specific machinery, and generally not as an issue in its own right. This discussion will look at CIM fatalities as a whole to determine if there are any trends evident that might otherwise be obscured by a focus on industry, job task or a specific machine.

Heightened safety risks exist in industries where workers are required to work closely to moving machinery in which they can be caught (e.g. Ruff et al, 2010). By their nature, caught in machinery incidents are often highly traumatic, involving transfers of energy far beyond human capacity to withstand, leading to injuries including scalping and amputations and ultimately death (National Institute of Occupational Safety and Health, 1994). Furthermore, in 1990, NIOSH assigned incidents involving being "caught in, under or between" to the highest ranking on a priority research index they had created based on factors such as probability of success and expected reduction in injuries (Etherton and Myers, 1990).

Certain industries have been identified as having a particularly high risk for machine-related injury and death, including:

- Manufacturing. 41% (78 of the 189 deaths) of caught in machinery deaths in 1997 in the USA (Windau, 1998);
- Mining. 41% of all severe accidents at mining operations were machine-related in the period from 2000 – 2007 in the USA (Ruff et al, 2010);
- Farm related deaths. Entanglements in machinery accounted for 9.8% of fatalities in the period 1991 - 1995 in Canada (Pickett et al, 1999).

Definitions

The term "machinery-related" is broad and discussions to date have included incidents ranging from being run over, burned by, cut or pierced by machinery (Pratt et al, 1997).

The definition used in this study is that a death was caused due to being caught, and drawn into, or by, a machine or machines with, or by, moving parts.

Additionally, "Machine" is defined as "A complex device, consisting of a number of interrelated parts, each having a definite function, together applying, using, or generating mechanical or electrical power to perform a certain kind of work" (Oxford Online English Dictionary).

Cases where the death is of an occupant in a vehicle crash, and cases where there has been contact between a machine and the external environment (e.g. the ground, or a wall) are excluded from this definition.

Risk factors

In addition to the high risk industries discussed above, a number of high risk machine types have also been identified in the literature. In the mining industry, Ruff et al (2010) identified conveyor systems as the top machine type for severe accidents (15%, n=80). Since 2007 in Victoria, Australia, metal lathes have been identified as being associated with 3 fatalities and a number of serious injuries (WorkSafe Victoria, 2010).

Fatalities can also be approached by considering the task being performed by or on the machine at the time of the fatal injury. From a job task perspective, maintenance and repair activities have been identified as being associated with machine-related injury. Windau (1998) found that in over half of the worker fatality cases identified, the individual was undertaking maintenance or service related tasks at the time of death. More recently, in a review and analysis of US mining industry machine-related injuries, Ruff et al (2010) found the most common activity being undertaken was maintenance and repair (25%).

Prevention Strategies

Barrier guarding is a well known way of safeguarding the worker from injury, by physically separating the worker from the moving or otherwise dangerous part of the machine.

The “Lock out / Tag out” procedure, where the machine is required to be shut down, disconnected from power and tagged to prevent reactivation, is another intervention that is utlilized particularly during repair and maintenance activities, and has been mandated since 1989 in the USA (29 CFR 1910.147). Nevertheless, as an administrative control, “Lock out / Tag out” will not work as designed if not adhered to, and workers continue to be fatally injured whilst undertaking maintenance tasks contrary to these regulations (Bulzacchelli et al, 2008).

In the Finnish context, Lind and Nenonen (2008) note that maintenance and repair are rarely considered in overall workplace design although they may have been considered in the original machine design. Likewise in Australia, Driscoll et al (2008) found that poor design can contribute to fatal injury, and cited the absence of, or inadequate guarding as a major design issue.

Potential future interventions that focus on removing the human element of non compliance, have been proposed. For example, Ruff et al (2010) conclude further research should be conducted on the feasibility of sensors, which can detect the presence of workers near hazardous machine components, and shut down the machine if a person enters an area within a certain distance of it.

This report aims to explore the nature and pattern of caught in machinery deaths in Australia, and to provide detail about the incident circumstances. In addition, the scope of potential interventions will be discussed.

SECTION B: THE PREVALENCE OF FATALITIES ATTRIBUTED TO BEING CAUGHT IN MACHINERY IN AUSTRALIA, 2000-2010.

Aims

To investigate fatalities which occur by being caught in machinery in Australia between 2000 – 2010, involving workers or bystanders to another's work.

Method

The National Coronial Information System (NCIS) is an Australia wide data storage and retrieval system of all coroner-reported deaths that commenced July 2000[1]. When a fatality is reported to a coroner, the details of the case coded according to an agreed minimum dataset and are sent to the central NCIS database (NCIS, 2007). Other relevant material such as police reports, toxicology and autopsy results and coronial findings are attached where available. This database is then searchable by registered users by code and free text keyword search. As all work related deaths are likely to fall into the definition of a 'reportable death' (e.g. s4 *Coroner's Act, 2008 (Vic)*), there is a high probability that this database will contain all fatalities of interest.

The Victorian Work Related Fatality Database (VWRFD) is a database collated from surveillance of fatalities reported to the Victorian Institute of Forensic Medicine (VIFM). This database is therefore limited to one jurisdiction (Victoria), however it specifically identifies work-related cases, and codes additional information for work relatedness and occupation. In combination, the NCIS and VWRF databases provide a comprehensive source of information that enables the identification of population based case series, and the subsequent identification of potential risk factors that can be analysed to point to potential prevention actions.

[1] Queensland data is from January 2001

To create a case series of work related fatalities associated with being caught in machinery from these two databases, the following inclusion and exclusion criteria were used:

Inclusion criteria:

1. The death was caused due to being caught, and drawn into or by a machine or machines with or by moving parts; and
2. The incident was coded as external causes, unintentional and work-related.

Exclusion criteria:

1. Occupants of vehicles involved in a crash; and
2. The contact in the incident was between a machine and the external environment

Thus a driver crushed between a tipper tray and a vehicle chassis when the hydraulics system failed would be included, while being crushed underneath a truck whilst undertaking repairs would not.

The VWRFD and the NCIS databases for the period July 2000 – October 2010[2] were interrogated according to the criteria above. Police narratives accompanying the cases identified were examined by a researcher to confirm case inclusion.
After the case series had been constructed, the available material for each case (including coronial finding if available) was then analysed to gather information according to the factors of person, place, plant, process and policy (Table 1).

Note: The selection criteria are inclusive of both workers and bystanders to the work of others.

[2] Excluding Western Australia

Table 1. Information extracted from NCIS and VWRFD.

Person	• Age at death, • Gender, • Post mortem toxicology status, if available • Medical or health conditions
Place and time	• Jurisdiction, • Year in which the fatality occurred, • Location of the incident causing death (e.g. farm, factory)

Plant	• Type of machine(s) involved,
	  o fixed or mobile
	  o single or multiple units

Policy	• Worker supervision • Coronial recommendations, • Safety factors (procedures followed or not; failure of equipment), • Ownership of worksite
Process	• Injury type, • Mechanism of injury (e.g. fall, electrocution, crush), • Task being undertaken, • Occupation and industry of deceased.

Demographic and contextual narrative material was utilised to explore causation via a universal model (McClay, 1989a,b), assisted by the use of NVivo software (QSR International Pty Ltd).

Ethics approval was granted by the Monash University Standing Committee on Ethics in Research involving Humans, The Victorian Department of Justice Human Research Ethics Committee and the Victorian Institute of Forensic Medicine Ethics Committee.

Results

<u>Person</u>

There were 92 fatal cases identified Australia wide that met the selection criteria. Of these cases, 5 were female and 87 were male, however caution is advised when drawing any conclusions from this fact, as the industries and occupations identified at risk for fatal caught in machinery deaths tended to be those which in which the working population is overwhelmingly male (e.g. transport). 90 cases were of workers and 2 of bystanders, both of whom were children.

The age range of death in the case series was 9 – 77 years (Mean = 42 years). Of those working, the range was 15 – 77 (mean = 43 years) which is older than the average Australian worker (male & female) (38.6 years) .The peak of fatalities occurred in the 50-54 year old range (Table 2).

Table 2: Age and Sex of Caught in Machinery Fatalities, Australia 2000 - 2010 (Excluding WA)

Sex	Age Group	Total
Female	< 15	≤3
	15-19	≤3
	35-39	≤3
	45-49	≤3
Female Total		5
Male	15-19	4
	20-24	7
	25-29	6
	30-34	10
	35-39	8
	40-44	7
	45-49	7
	50-54	21
	55-59	10
	60-64	≤3
	65-69	≤3
	70+	≤3
Male Total		87
Total		**92**

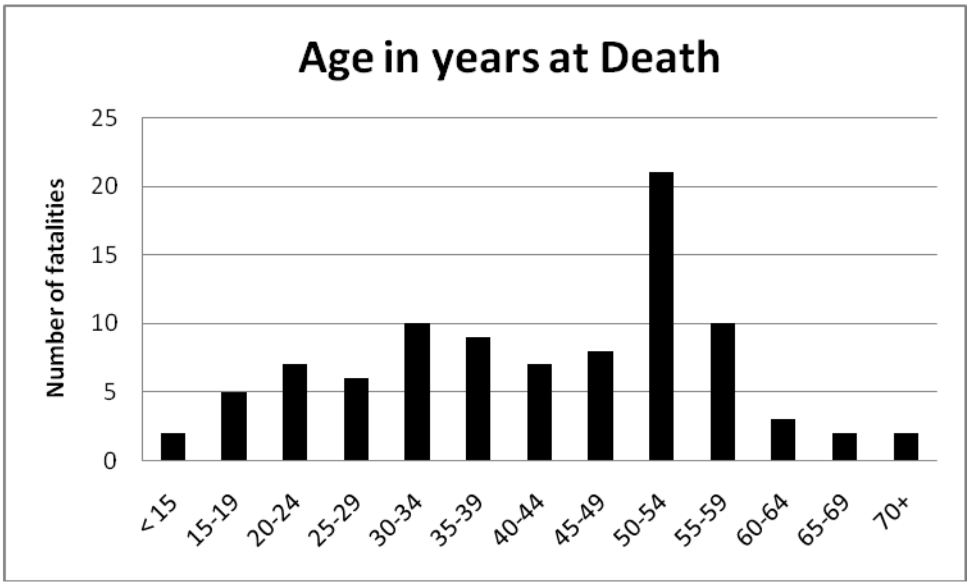


Figure 1: Age of Caught in Machinery Fatalities, Australia 2000-2010 (Excluding WA)

For those cases with toxicology tests available (42, 46%), metabolites of cannabis were detected in 4, but alcohol was not detected in any of the cases. Therapeutic drugs were detected in four cases, and other drugs (caffeine) in one.

Twenty four of the autopsy reports included a comment about the general health of the deceased, and in three cases, there was a comment that an underlying health condition may have contributed to the death. In two further cases, a condition was reported as present, but not considered to be implicated in the cause of death.

Place

For each year in the study, there were at least two fatalities, peaking at sixteen in 2002. An apparent downward trend for fatalities over time should be treated with caution as the figures for 2009 and 2010 are likely to be lower due to a large majority of cases still undergoing the coronial process. Therefore these cases were unavailable for investigation. Discounting 2009 and 2010, Table 3 shows that the number of deaths per year as a result of being caught in machinery appears to be steady.

Table 3: Number of work-related caught in machinery fatalities per year, Australia 2000 – 2010 (Excluding WA).

Year of Death	Total
2000	10
2001	10
2002	16
2003	9
2004	8
2005	8
2006	10
2007	6
2008	8
2009	5
2010	≤3
Total	**92**

Fatalities occurred in all jurisdictions examined (Table 4). The distribution of fatalities suggest that caught in machinery deaths are far more prevalent in Victoria than other jurisdictions. However caution is urged in relation to this interpretation, as it is more likely that relative jurisdictional frequencies are an artefact of the way that the data has been recorded and provided to the database by the various state and territory jurisdictions. In some jurisdictions the textual description of the event is more detailed than in others, resulting in fewer cases being excluded that met the inclusion criteria. There is reasonable confidence in the completeness of the Victorian data. It follows from this that the likely incidence of this fatality type is in fact higher than the sample described here.

Table 4: Jurisdiction of fatalities, Australia 2000 – 2010 (Excluding WA).

Jurisdiction	Number of Fatalities
VIC	45
NSW	18
QLD	18
TAS	5
SA	4
ACT	≤3
NT	≤3
Total	**92**

Table 5 lists the locations at which the fatal incidents occurred. The two most frequent locations were industrial sites and rural properties.

Table 5. Location of caught in machinery fatalities, Australia 2000-2010 (Excluding WA).

Location		N(%)
Industrial site (e.g. factory)		33 (36)
- *Agricultural processing site*	*(5)*	
Rural property		21(23)
Mine or quarry		10(11)
Road or street		9(10)
Unknown / insufficient information		8(9)
Residential		4(4)
Dock		≤3
Ship		≤3
Construction site		≤3
Total		**92**

Plant

Of the 92 cases of caught in machinery identified, 64 involved a single machine (70%) either fixed or mobile, while the remaining 28 involved two or more machines (30%) (Table 6).

Table 6: Number of machines involved in fatalities resulting from being caught in machinery, Australia 2000 – 2010 (Excluding WA)

Machines involved		Number
Single machine		64
- Mobile	(*41*)	
- Fixed	(*23*)	
Multiple machine		28
Total		**92**

When a single machine was involved, 23 cases involved a wide variety of fixed plant of which the most common were conveyer belts (n=3). The remaining 41 cases involved a mobile plant where a truck, tractor and bobcat/front end loader was the most common machine (Table 7).

Table 7: Machinery involved in fatalities resulting from being caught in a single mobile machine, Australia 2000 – 2010 (Excluding WA)

Type of machinery involved	Number
Truck and/or attachment*	12
Tractor and/or attachment*	11
Other**	8
Earth moving equipment	8
Auger	≤3
Total	**41**

* such as harrows, cranes etc

** The category encompasses machines such as forklifts etc

Similarly, when the incident involved multiple machines (n=28 cases, 56 machines), trucks or trailers were most often implicated (n=23, 41%) (Table 8).

Table 8: Machinery involved in fatalities resulting from being caught in multiple machines, Australia 2000 – 2010 (Excluding WA), n=28 cases, 56 machines

Type of machinery involved	Number
Truck and/or trailer	23
Other	8
Mining/quarry equipment*	6
Other vehicles**	6
Forklift	5
Other heavy vehicle attachment	4
Fixed object	4
Total	**56**

* The category encompasses machines such as continuous miners, shuttle cars etc

** This category includes vehicles such as buses, tractors etc

Policy

Of the 70 cases where it was possible to determine, 35 (50% of available cases) were fatalities where the worker was alone at the time of the incident, 31(44% of available cases) occurred in an environment where other people were in the general vicinity, but not directly with the worker, and 4 (6% of available cases) occurred when the worker was directly working with someone else on a task when the incident happened.

Of the 64 cases in which the ownership of the workplace at which the fatality was mentioned, 19 (29%) were the property of the deceased, and for 46 (71%) the deceased was employed, or contracted, to work at that location.

There were 14 cases in which a coroner made recommendations, ranging from specific recommendations about machinery types and work processes, through to more systematic suggestions for industries and governments. These will be discussed in more detail in Section C, below.

The question of whether safety procedures or features were used or not can be difficult to answer, especially when the worker was alone. Therefore the following discussion is based on the observations of those making reports of the incident, or less frequently, from a considered opinion of a coroner, and should be interpreted with caution (Table 9). In some cases, more than one comment may have been made.

Table 9. Safety policy mentioned

Safety policy or failure type	Number of cases
Deceased was not following procedure	20
Machine faults (including poor servicing & maintenance)	15
The safety policy was poor or non existing	12
A colleague of the deceased did not follow a safety procedure	5
Deceased was following safety procedures, but the incident still occurred	4
Total cases one or more safety policy or failure type mentioned	**43**

Process

Individuals were performing a range of different tasks at the time they were caught in the machine. The most frequent was performing a repair or maintenance task, which accounted for approximately one quarter of cases. More generally, the machine involved was not being used in its regular mode of operation in 34 (37%) of the cases. Tasks being performed are displayed (Table 10).

Table 10. Task undertaken/worker activity at time of death.

Task	Number (%)
Repairs / maintenance	25 (27)
Operating machinery	19 (21)
Unknown / insufficient information	13 (14)
Standing near machine	10 (11)
Walking / moving near machine	9 (10)
Trying to fix an error in the machine while it was operating	4 (4)
Coupling / uncoupling truck / trailer	4 (4)
Getting into/out of machine	≤3
Performing a work around	≤3
Preparing (installing etc) a machine	≤3
Disassembling a machine	≤3
Total	**92**

The medical cause of death was extracted and consolidated in Table 11. Although autopsy reports can record more than one cause of death, the vast majority recorded only one cause. Only the main medical cause of death (reported as cause of death 1a in the NCIS) is reported here. The most frequent medical cause of death was traumatic asphyxia followed by crush injuries to the chest. Crushing / asphyxia as a broad group account for almost half of the fatalities of the case series (40, 43%).

Table 11. Medical cause of death.

Medical Cause of death	N (%)
Traumatic Asphyxia	21 (23)
Crush - Chest	19 (21)
Head Injuries	14 (15)
Multiple Injuries	13 (14)
Massive blood loss	10 (11)
Cervical Spine Trauma	4 (4)
Hypoxic Brain Injury	≤3
Unassigned	≤3
Extensive skeletal and soft tissue injury	≤3
Exposure shock	≤3
Strangulation / Neck compression	≤3
Total	**92**

The most common occupations were Machinery Operators and Drivers (n=33, 35%) or Labourers (n=30, 32%), followed by Technicians and Trade Workers (n=19, 21%) (Table 12).

Table 12. ANZCO Major and Sub-Major Groupings for Caught in Machinery Fatalities, Australia 2000 – 2010 (Excluding WA)

ANZCO Major Group	ANZCO Sub-Major Group	Total
Machinery Operators and Drivers	Road and Rail Drivers	15
	Machine and Stationary Plant Operators	8
	Mobile Plant Operators	5
	Sub-Major Group unavailable	5
Machinery Operators and Drivers Total		**33**
Labourers	Farm, Forestry and Garden Workers	15
	Other Labourers	4
	Sub-Major Group unavailable	4
	Construction and Mining Labourers	≤3
	Factory Process Workers	≤3
	Food Preparation Assistants	≤3
Labourers Total		**30**
Technicians and Trade Workers	Automotive and Engineering Trades Workers	14
	Electrotechnology and Telecommunications Trades Workers	4
	Construction Trades Workers	≤3
Technicians and Trade Workers Total		**19**
Managers	Hospitality, Retail and Service Managers	≤3
	Specialist Managers	≤3
Managers Total		≤3
Professionals	Business, Human Resource and Marketing Professionals	≤3
	Design, Engineering, Science and Transport Professionals	≤3
Professionals Total		≤3
Unlikely to be Known* Total		≤3
N/A Total**		**4**
Total		**92**

* Cases where there was no occupation given

** Cases where the occupation was retired, or student

Study Limitations

A limitation of this study is that the coding accuracy and amount of information available from these databases relies on a wide range of actors including police, coronial staff and scientific laboratories (for autopsy and toxicology data) across the jurisdictions, which can result in inconsistency in the database. This will inevitably be amplified when non-standard, or under-recognised issues are being investigated for which the databases are not specifically designed, and for which specific codes do not exist.

Therefore there is a risk that any case series extracted from these databases may misrepresent the size of the problem to an extent that cannot be estimated. Thus, the current research is not intended to provide a quantification of the relative burden of caught in machine fatalities in Australia; it is to provide a description of their characteristics as a basis for prevention.

SECTION C: PREVENTION REVIEW

LITERATURE STRATEGIES

Searches of the literature revealed a number of strategies that have been implemented to address different risks. Particular strategies that have been implemented are:

1. Separating workers from the risk:
    - moving parts of the machine by guarding and interlocks (e.g. Vaillancourt and Snook, 1995),
    - ‘Lock out tag out’ procedure, particularly for maintenance and repair situations (e.g. Tengs et al, 1995).

These strategies are effective, and in particular may be relevant for retrofitting to machinery that is old or non-commercially manufactured and does not have newer design features. Extensions of these strategies could include further research into incorporating personal sensors into the lock-out tag-out procedure, to automatically shut down a process if the person wearing the sensor comes to close to a point of danger.

2. Design that takes into account Human Factor concepts (e.g location and layout of controls),
3. Drug and alcohol policies, and
4. Worker health and fitness policies.

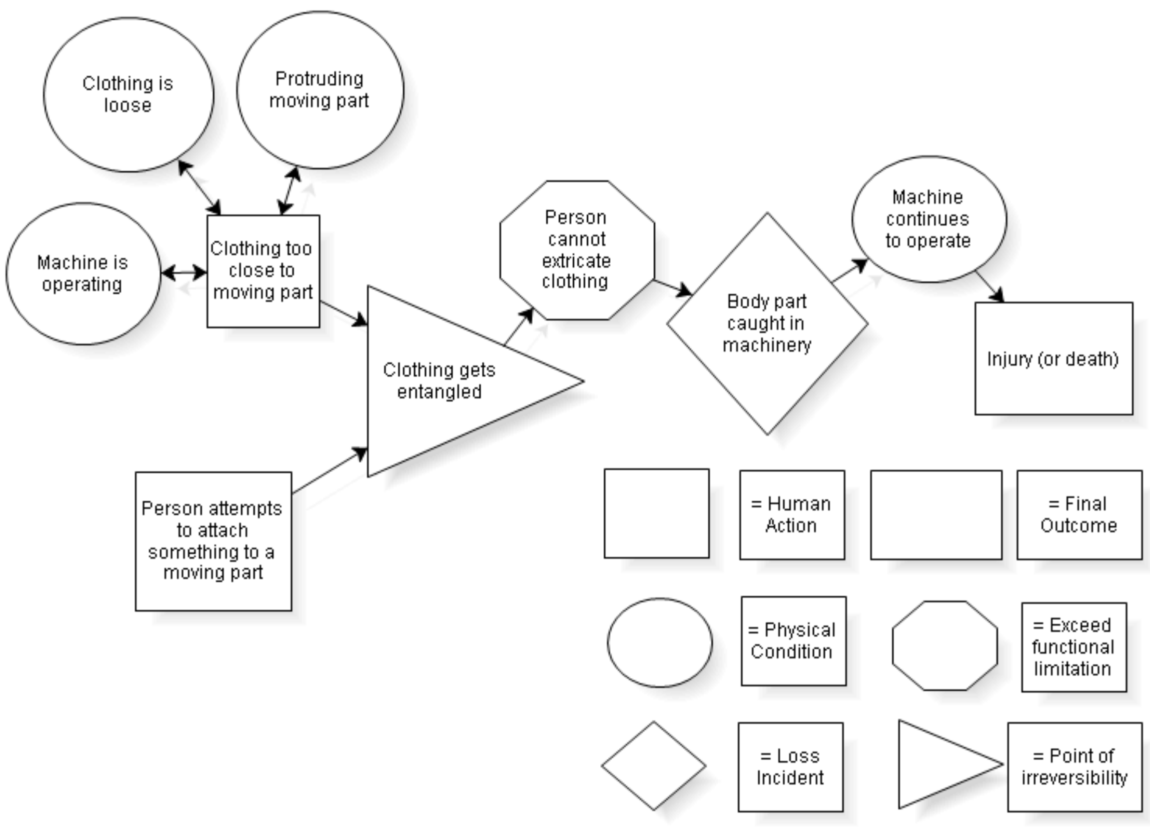
It should be noted that alcohol was not detected in any of the cases for which toxicology reports were available, while metabolites of marijuana (THC) were detected in four (9.5% of 42 available) cases. This is lower than the 22% presence in Victorian worker fatalities over a similar time period (2000 – 2006) (McNeilly et al, 2010).

Universal model and Haddon’s Matrix applied to caught clothing scenario (“caught clothing”)

The current research has indicated that there are specific typologies of incident that have occurred for which specific prevention initiatives may be appropriate. One such typology is the circumstance when an individual has an appendage caught in rapidly spinning machinery, often after their clothing becomes caught. This occurred in nine of the cases in series. A trajectory model can be created for the Clothing entanglement scenario of injury based on the Universal Model technique proposed by (McClay, 1989 a, b) (Figure 2).

This technique requires identifying the proximal causal factors (those factors which occur in the same time and space as the incident), distal causal factors (those factors which do not occur in the same time and space as the incident), the point of irreversibility (the point at which loss cannot be stopped) and factors that are unrelated (or that there is no evidence that they are related) to the incident.

Figure 2. Universal Causation Model for Clothing Entanglement



In order to generate prevention possibilities, the Haddon's Matrix technique[3] (e.g. Haddon, 1980) was applied to the error pathway described in Figure 2. A summary of the results of this process is described in Table 13.

Table 13. Summary of Haddon's Matrix applied to clothing entanglement scenario.

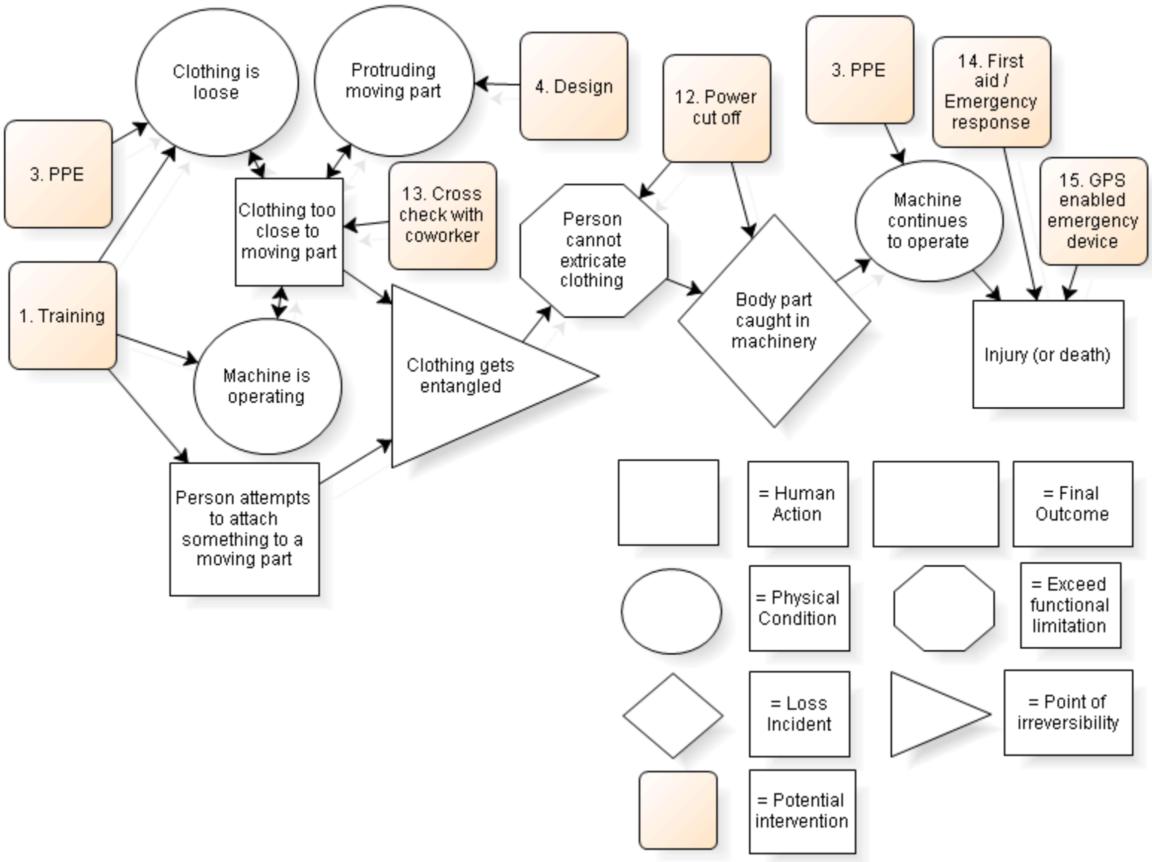
	Person	**Agent (machine)**	**Social Environment**	**Physical Environment**
Pre-event	1.Training 2.Drugs/ alcohol/medical conditions (health) 3. PPE*	4. Design 5. Maintenance 6. Age of equipment	7. Attitudes 8. Pace of work 9. Working alone 10. Fatigue	(Weather) (Working outside) 11. Isolation
During-event		12.Power source cut off - Sensors	13. Cross check with fellow workers	
Post-event	14. First aid & emergency response 15. GPS enabled alerting devices	16. Process for redesign	17. Dissemination of information 18. Legal proceedings	18. Communication with emergency services

* PPE: personal protection equipment

These numbered interventions can be placed in the Universal Model to indicate the point at the trajectory that they would be expected to be effective (Figure 3). Those in brackets refer to factors that may be relevant, but that are not able to be influenced, other than avoiding outside work in inclement weather.

[3] The Haddon's Matrix technique involves assessing what changes could be made to human factors, (e.g. drugs / alcohol), the social environment (e.g. training), the physical environment (e.g. terrain) and the agent or carrier (the machine) at three conceptual phases: pre-event, during the event and post-event.

Figure 3 Haddon's Matrix Interventions as Applied to Clothing Entanglement Scenario.



As indicated, there are a number of interventions that could be implemented in an attempt to halt progress through the error pathway, however some are likely to be more practical or useful than others. Some of the interventions refer to factors more distal to the injury pathway, and others refer to improvement to feedback loops and are therefore not relevant to the diagram.

The results of section B indicated that in the case study, the person factors relating to drug use and underlying medical conditions were present in a small number, but represented contributing factors that may be responsive to workplace drug and health policies respectively. After the event, first aid and emergency response procedures need to be considered, and in particular integrating the use of GPS technology, which is now becoming near ubiquitous in many devices particularly including mobile phones and (newer) tractor guidance systems may assist in the efficient delivery of rescue and medical assistance. A particular barrier to delivery of emergency assistance is the tendency for a number of the tasks in the case series to be carried out while working alone, particularly when in a rural setting, which has resulted in others only becoming aware of a problem hours (or even up to a day) later. Designing work process so that they are carried out with others also allows for procedural cross check or tag-in/tag-out steps to be included.

Personal protective equipment (PPE), particularly in context with design where the PPE represents snug fitting clothing and the design eradicates or shields moving or projections of moving parts would also appear to provide particularly straight forward intervention opportunities. PPE can be purchased that has built in tie downs and straps, so that loose elements can be tightened without the need to purchase additional equipment. This type of PPE is commonly used in the military.

Related to design is age of machinery and maintenance. The literature notes, and the case series also reflects, that older machinery may not have the relevant safety features that are available on newer models, and maintenance procedures particularly when they involve modifications, or removal of safety guards or other features may expose latent catch points. Targeted inspections of augers, power take off and other equipment with similar, spinning action may be relevant in this regard.

Machine design is an issue that has been raised in the literature (e.g Driscoll 2008), and which may be relevant for interventions in the pre-, during-, and post- phases as described in the Haddon's matrix approach. Thus, as mentioned, design processes can include guarding and removal of protruding elements, and guarding or design of control systems to avoid unintentional activation. During an incident, sensors or devices that allow for immediate (and preferably automated) power shut down or disengagement could be considered. Finally, for those systems already in place retrofitting or replacement programs may be warranted, such as the tractor rollover protective structure scheme in the 1990s (Day and Rechnitzer, 1999). It may also be possible to incorporate identified design problems in information dissemination processes to new stakeholder groups that have a design focus. For example, university design and engineering departments may find awareness of current industry issues useful, and in turn may have ideas for specific redesign/retrofit solutions, or may set these issues as student projects.

The attitude of a workplace has been studied in the literature and is often referred to as the ‘safety climate’. In the context of this discussion, some of the relevant elements of the safety climate include the attitude of the workers towards their tasks (particularly in Agriculture: ASCC, 2006), whether they are working alone, and the pace of the work (which when combined with the timing of work can lead to fatigue issues). Changing the cultural practices associated with these tasks would involve a much larger process, as it would not just be this fatality type that would be targeted, and as such is outside the scope of this report. However, specific interventions including encouraging working in teams when using this sort of machine, and dissemination of information may be useful. Finally, prosecution (or use of other instruments) under Occupational Health and Safety, or other laws may also be appropriate interventions in certain circumstances.

Coronial Recommendations

Of the identified cases, 14 had a coronial report with recommendations included. 10 were from Victorian cases, and two each were from New South Wales and Queensland, and related to fatalities occurring between 2000 – 2006. Most coronial recommendations are directed towards specific issues of the case at hand, although in some cases the coroner will make a more general recommendation. Examination of these recommendations may highlight any issues that coroners have collectively thought worthy of making recommendations for Caught in Machinery cases. It should be noted that these recommendations are from 2000, and they may have been acted upon since they were released. These prevention recommendations are presented according to the same conceptual framework used in Section B (i.e. Person, Place, Policy, Plant and Process) in Table 14.

Table 14. Coronial recommendations for Caught in Machinery cases, Australia 2000-2010.

Theme	**Recommendation**	**To Whom**
Person	Develop a training package for drilling	Industry and government agencies
	Industry alert(s) to be developed for known risks (Multiple recommendations)	Regulator; manufacturers; companies; industry groups
	Alerts should be developed to a common format to enable exchange with other authorities (and internationally)	Regulators
	Ensure appropriate PPE is worn	Individuals
	Policies should be developed to assist particular industries implement drug & alcohol policies (incl. Therapeutic drugs)	Government agencies, industry bodies
Place	None	-
Plant	Controls on mobile plant should be designed to keep operator away from moving parts	Manufacturer / designers
	Controls should be guarded against unintentional operation	Manufacturer / designers
	Modifications of equipment (including hybridization) should be subjected to risk assessment	Companies in association with manufacturers
	Individual manufacturer recommended to address a specific design issue (multiple recommendations)	Manufacturer

	Authority should work with manufacturers to design out/ modify a particular flaw	Manufacturer / regulator
	Develop a plan to retrofit older machines (multiple recommendations)	Industry and government agencies
Policy	Systematically examine mobile plant (Multiple recommendations)	Companies; Authorities
	Monitor use of safety tags	Companies
	Regulators & Industry groups should work with members to conduct safety audits of machinery (multiple recommendations)	Regulators, Industry groups, members of industry groups
	Individual companies should adopt specific policies (multiple recommendations)	Companies
Process	Processes should be risk assessed	Companies
	Safety processes should be of substance, not form	Companies
	Operations manuals need to be developed for all processes	Companies

Conclusions

This study has looked at CIM fatalities together rather than as a sub set of fatalities that occur by, for example, industry or occupation, and this has allowed fresh insights to emerge about the issue. In particular, it has been possible to identify, as demonstration, an injury pathway related to clothes being caught in spinning machinery.

Other factors to be highlighted are the peak of fatalities for the 50-59 age range, and that almost one half of the fatalities occurred when the machine was not in normal operation. That is to say, it was being installed, maintained, repaired, modified or decommissioned, rather than simply running. The common theme to all of these actions are that they are infrequently performed (perhaps only once ever for that machine), and even for workers who frequently, for example, repair or maintain machines, it is unlikely that they would perform that task on that particular machine on a regular basis. Therefore, it can be hypothesised that the errors that lead to fatalities in these circumstances may show similarities to novel task errors. Research (e.g. Reason, 1990) has shown that different types of error are committed when performing novel tasks, and this may provide additional insight into prevention possibilities.

While there was relatively easily accessible and comprehensive statistical information, the literature yielded relatively sparse interpretive or applied research material, particularly for Australia. National coordination or information sharing between jurisdictions about raw data trends, information collection processes and prevention efforts, particularly formal assessments of interventions would be useful in this regard. This would also assist in the dissemination of best practice information nationwide, and allow for greater use of evidence based policy development processes.

Data collection and access

One clear gap in the data that was collected relates to the inability to readily access coronial data from Western Australia. This is due to the additional processes required to obtain ethical clearance for research purposes. To obtain a national picture it would be beneficial to access the WA data, and a review of the access approval processes may be warranted to allow maximum benefit to be obtained without additional hurdles from the coronial data of that jurisdiction.

Importantly, the less detailed information provided to the NCIS by some states and territories and the lag in case closure by the coronial system results in substantial underreporting of cases and details of incidents that may assist in formulating interventions for prevention.

The data in the NCIS and VWRFD are collated from four sources, police report, coronial finding, autopsy and toxicology reports. However, the majority of the circumstantial data that this report has utilized is based on the report of the police officer(s) investigating the fatality. Currently there is no standardised check list or form that officers use when investigating incidents that have been tailored to prompt the elicitation of information that might be useful for injury prevention. The design of a check list that is accessible nationally by officers attending CIM fatality sites could be beneficial, both for research and prevention efforts, and to assist the officers collect the most useful information while they are also managing other aspects of the investigation.

Likewise, the medical cause of death as reported at autopsy by pathologists is not reported according to a consistent methodology. For example, the two most common causes of death listed (Traumatic asphyxia and Crush – chest) may well refer to similar circumstances. A common reporting mechanism may enable more use to be made of the cause of death finding.

Another minor data gap exists in the autopsy process when a full autopsy is not performed due to an objection being raised. While this is the result of an understandable attempt to balance the wishes of the family and community in relation to invasive medical procedures, it does result in less information being available, particularly in relation to underlying medical conditions, which may have contributed to the incident or outcome.

Summary of key prevention strategies:

1. Incorporation of safety features in machine design, such as guarding moving parts and incorporation of machine- or person- mounted sensors for emergency shutdown.
2. Redesign of tasks to include cross checking procedures, such as tag-in tag-out, especially for repair and maintenance tasks,

3. Encouragement of the use of suitable personal protective equipment (PPE), particularly the use of snugly fitting clothing around machinery with spinning parts (e.g. Augers and tractor power take offs),
4. Targeted inspection of augers and power take off equipment for suitable guarding, and
5. Dissemination of information when risks with particular machines are identified, and if solutions have been designed.

Summary of data improvement and future research directions:

1. Design of a form for police to allow a minimum common data set to be collected. Forms could be modified to allow for broad fatality types e.g. road crash, farm injury, industrial incident,
2. Agreement upon a common medical cause of death nomenclature or scheme by pathologists, and
3. Assess the feasibility of a design solution clearing house accessible by relevant stakeholders.

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Documents accompanying this report	
Title	**Report number**
Caught in Machinery fatalities – Research brief	1110-005-R5B