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FARM MACHINERY INJURY

Injuries associated with grain augers in Australia

A report for the Rural Industries Research and Development Corporation

by A Athanasiov, L Fragar, M Gupta

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Research contact details
L Fragar
Australian Centre for Agricultural Health and Safety
University of Sydney
PO Box 256
Moree NSW 2400 Australia
Phone: 61 2 67528210
Fax 61 2 67526639
E-Mail: lfragar@doh.health.nsw.gov.au

RIRDC Contact details:
Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4218
Fax: 02 6272 5877
Email: rirdc@rirdc.gov.au.
Web: http://www.rirdc.gov.au

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Foreword

Injury on farms and its prevention is a key issue for the Australian agriculture and horticulture industries. The common causes of farm injury have been well documented in reports and papers.

This report is one of a series of reports of in depth investigations into preventable risk factors associated with the operation of specific items of farm machinery.

Grain and feed augers are found on many farms, and are in constant or frequent use in the grains and livestock industries. This report establishes that most augers in use on farms have significant safety risks and a multifaceted approach to reducing risk of death and serious injury has been recommended.

This project is funded by the RIRDC managed **Joint Venture in Farm Health and Safety** which is partnered by the Grains R&D Corporation, Meat and Livestock Australia, Australian Wool Innovation Corporation, Cotton R&D Corporation, Sugar R&D Corporation and the Rural Industries R&D Corporation.

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Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

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The Project Officer, Arthur Athanasiov is based at the University of Queensland, Gattan Campus.

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Aim
The aim of this project is to collect and analyse information related to accidents involving grain augers in order to:

- Define the auger-injuries problem and identify contributing factors.
- Identify, define and recommend a range of measures to minimise the frequency and severity of injuries associated with the use of grain augers.

Background
Augers are available in a wide range of sizes and configurations but the essential design of a screw or flight rotating within a tube has not changed much since Archimedes designed one for lifting water. Today, grain augers vary in size from 75 mm to 400 mm in diameter and from less than one metre to more than thirty metres in length. They are available as independent mobile items or as a part of other grain handling systems such as harvesters, field bins, dryers, storage or silo systems, and feed mixing and distribution systems.

The literature universally accepts that the grain auger is a very dangerous item of equipment and is often quoted as the most dangerous machine on a per-hour-of-use basis. Medical journals emphasise the severity of auger-related injuries, as do studies analysing the extent of auger-related injuries. Australian information from a number of papers, reports and fact sheets, suggest that it is not too different to that of the US (Read *et al.* 1996; Fragar and Coleman 1997; Ferguson 1999; Franklin 2001).

Method
Injury and fatality data were sought from a number of sources including hospitals, the ambulance service, the Queensland Division of Workplace Health and Safety, media reports and regional rural extension officers. While some of the data obtained from these sources were useful for gaining a clearer picture of individual cases, overall these data were not included in this study as it was not possible to determine whether some injuries were recorded in more than one data set.

Literature searches and reviews were conducted to gain a broad picture of the auger injury problem. Literature was collected from, the University of Queensland library, the Australian Centre for Agricultural Health and Safety, and the ASAE library via the Internet. Searches of the Agricola, Cab Abstracts and Medline databases and the Internet via Google were made using key words including: agricultural injury, auger, auger injuries, farm accidents, farm injuries, farm-related fatality, farm safety, workplace fatality, workplace injury, and work-related fatality.

Two focus group meetings were held in order to gain a broader perspective of the grain auger injury picture in Queensland. One was held at Dalby and the other at Toowoomba.

Results
Although auger-related injuries make up a small fraction of all the compensation claims for the 1992 - 2001 period in Queensland (52 from 654,457), they appear to be amongst the most severe in terms of compensation payments and days absent from work. On average, auger-related injury payments and days absent were more than twice the all-industries average of all other injury claims. The severity of auger-related injuries as indicated by time off work is shown in Table 5.2. Over 60% of those injured (in auger-related incidents) were absent from work for more than one week and 8% were absent for more than three months.

Risk factors were identified from the available and reported in relation to operator risk factors, risk factors relating to the machine and environmental risk factors. Consideration of these and of the nature of the injury and the body part affected allowed for options for risk reduction based on the “Hierarchy of Control” to be documented.

Recommendations

The following recommendations are made to the Farmsafe Australia Machinery Safety Reference Group for the reduction of risk associated with the operation of grain and feed augers:

1. That information material be prepared outlining the hazards associated with the operation of grain and feed augers and correct operating procedures to be followed to reduce those hazards, and that these materials be made readily available to rural workers. These materials should include information relating to guarding and modifications that may be possible to be carried out on existing machines.

   Manufacturers should be consulted and asked to participate in the development of such material. The document should be developed as a nationally endorsed Guidance Note.

2. That auger manufacturers be encouraged to ensure that the machines achieve the highest possible safety standards, and that safe operation be actively promoted by sales personnel and via improved operators' manuals.

   Operators should be made aware of those risks that the manufacturer has not been able to eliminate, and to ensure they do not use the machine in a way that will create new risks.

3. That suppliers ensure that safety information is provided to buyers of augers. The design and fitting of safety features is of little use unless sales personnel are required to discuss safety issues with customers, and emphasise the importance of features such as guards and cut out switches.

That an Australian Standard be prepared for the design of grain augers, establishing a level of safety that is economically achievable.

The available standards either do not provide adequate personal safety (eg. ASAE S361.3) or they are unclear, confusing and impractical (eg. AS 4024.1). A standard is required that provides not only performance specifications, but also clear examples of how the requirements of the standard can be met. For example, specific mesh guards, flexible flights, or other ideas deemed to comply. It should also make provision for the testing and inclusion of future innovations.

That a program of enforced compliance for guarding be undertaken by state work health authorities

Currently, the modifications required to make older augers comply with standard ASAE S361.3 are quite simple and inexpensive. The installation of a mesh guard over the exposed part of the auger flight, and guards over drive components is not beyond the fabrication skills of most farmers. However, guards that comply with ASAE S361.3 may not comply with AS 4024.1. In fact it is difficult to make a practical guard for a mobile auger that complies with the Australian Standard. Consequently, it seems reasonable to assume that any action to enforce compliance should occur only after appropriate standards are available.

That a program of subsidisation of retrofitment of improved guarding be undertaken. Given the apparent success of the ROPS Retrofitment Rebate schemes in Victoria and NSW, some subsidisation of the cost of modification of augers would appear to make modification of existing augers more acceptable to the farming community. However, gauging the level of subsidy that will provide sufficient incentive without over-capitalising old equipment is difficult.

As the auger flight is the part most involved in auger-related injury, subsidising the cost of appropriate guarding or the use of flexible flight devices at the exposed flight area of augers could result in significant reduction in the number and severity of auger-related injuries.

That promotion programs be developed to promote safe operation of grain augers. Based on responses to tractor safety field days run by the department of Workplace Health and Safety in South East Queensland, it is reasonable to expect that similar well developed and presented courses for auger manoeuvrability and overturning would be equally successful.

That research into improved auger design for safety be undertaken

The allocation of funds for competitions for “Ideas to make augers safer”, at regional, State and Federal levels may harvest practical ideas from those who use augers, as well as generate positive interest in auger safety issues at the user level.

Funding should be made available to adequately test new ideas so that guards and other devices not only provide an adequate level of safety, but they also do so in a manner that is acceptable to the user.

1. Aim

The aim of this project is to collect and analyse information related to accidents involving grain augers in order to:

- Define the auger-injuries problem and identify contributing factors.
- Identify, define and recommend a range of measures to minimise the frequency and severity of injuries associated with the use of grain augers.

2. Introduction

This project is part of the *National Farm Machinery Safety program* of Farmsafe Australia being implemented by the Australian Centre for Agricultural Health and Safety with funding from the Rural Industries Research and Development Corporation. The stated outcome of the program is “Implementation of the Farmsafe Australia Farm Machinery Strategy”. A specific outcome is to make “Recommendations for safe working practice, safer machine design, modifications of current standards, further research action for four key problems”. Grain augers were identified as one of the four key problems.

Augers are available in a wide range of sizes and configurations but the essential design of a screw or flight rotating within a tube has not changed much since Archimedes designed one for lifting water. Today, grain augers vary in size from 75 mm to 400 mm in diameter and from less than one metre to more than thirty metres in length. They are available as independent mobile items or as a part of other grain handling systems such as harvesters, field bins, dryers, storage or silo systems, and feed mixing and distribution systems.

That the grain auger may be a significant agent of injury is hardly surprising. Its rapidly rotating metal spiral flight can whisk a finger or hand about 1.5 metres away before the injured person has time to react (Beatty *et al.* 1982). Other components such as outside casing are regularly involved in electrocutions or tipping-over accidents, and moving parts such as cranking handles, drive chains and belts also contribute to injury. There seems to be general agreement that on a time-of-use basis, the auger is probably the most dangerous machine on the farm (Schwab *et al.* 2000; Read *et al.* 1996; Demmin 1994; Grogono 1973). As most farms that handle grain have at least one grain-auger, many farm workers and their families are exposed to the risk of injury.

This report presents injury information obtained from the National Injury Surveillance Unit and the Queensland Employee Injury/Disease Database project team (QEIDB). In addition, it presents the experience and opinions of two groups made up of auger users, suppliers, health and safety professionals and academics. Analysis of the information collected provides insights into the extent of the auger injury problem in Australia and forms a basis for further work. In addition, it touches on the hazards and safety features associated with the range of grain augers currently in use or available; the contributing human, environmental and machine factors that led to injuries and or fatalities; and the effectiveness of current user safety awareness programs, laws and machinery standards.

3. Background

3.1. Dimensions of the problem

The literature universally accepts that the grain auger is a very dangerous item of equipment and is often quoted as the most dangerous machine on a per-hour-of-use basis. Medical journals emphasise the severity of auger-related injuries, as do studies analysing the extent of auger-related injuries. While a detailed picture of the auger-injury problem in Australia is not yet available, information from a number of papers, reports and fact sheets, suggest that it is not too different to that of the US (Read *et al.* 1996; Fragar and Coleman 1997; Ferguson 1999; Franklin 2001).

Two types of auger-related injury studies are available. One based on the cases presenting to medical practitioners or medical professionals from their own practice or hospital records, and the second type undertaken by other professionals, and based on farm surveys and/or hospital, compensation or government records. Studies by medical professionals tend to focus on injuries and treatment while other studies use case studies, numbers, tables and graphs to produce snapshots of the auger injury problem in their corner of the world. Both types provide insights into the circumstances leading to injury and make recommendations for reducing the incidence of auger-related injury.

Doctors in the United States of America have been reporting treatment of patients injured by grain auger for some time (Young and Ghormley 1946; Powers 1950; Grogono 1973; Letts and Gammon 1978; Beatty *et al.* 1982). They consider the grain auger the worst machine in terms of the severity of the mutilating injuries it produces. Fingers were the most commonly injured body part, but many severe injuries to hands, arms, feet and legs were reported. A similar picture exists in Australia. Read *et al.* (1996) reviewed the hospital records of patients in the Wimmera region of Victoria during the period 1987 to 1995. They too found that fingers were most often injured and that the "*crushing-avulsion nature of the trauma often excluded the possibility of replantation and revascularization*".

Another interesting aspect of the medical literature is that it reports injuries to those who are not formally employed and therefore outside the worker's compensation umbrella. They show an alarming amount of injury to children, relatives and farm visitors. For example, Letts and Gammon (1978) conclude that *auger injuries are the main cause of traumatic amputation in children in Manitoba*. Unpublished data compiled by the Australian National Injury Surveillance Unit shows children as young as three years of age have lost fingers, and family members in their seventies have suffered injury as a result of contact with augers (Franklin 2001). Read *et al.* (1996) report the following incident involving a 77 year old farmer's wife:

"She sustained an extensive right anterior thigh degloving injury whilst unloading an auger from a truck. She was hospitalised for nine months and had multiple debriments and split skin grafts, complicated by persistent infection and skin graft failure."

A significantly different study by Schwab *et al.* (2000) assessed the condition of augers, auger-related injuries and farmers' perceptions of auger related injuries in Iowa. The study is important because it appears to be the only one to use a relatively large data set and surveyed population group. Other studies relied on 23 cases over a six-year period (Letts and Gammon 1978), or 24 cases over a three-year period (Beatty *et al*. 1982), and 18 cases over an 8-year period (Read *et al*. 1996). By comparison, the study by Schwab *et al.* (2000) was based on 437 auger-related injury records over the five year period 1993 to 1997, and the responses of 93 farmers surveyed in 1998.

Unfortunately it is difficult to compare results. An average of 87 auger-related injuries per year is huge, compared to the averages of about 2 to 8 reported in the other studies.

However, Iowa is a large producer of grain, and without details of the actual number of workers involved, or the tonnage of grain moved, meaningful comparisons are not possible. It is interesting to note that all authors feel that the reported injury count is lower than the actual figure.

Despite the difference in size of data sets, many of the findings or conclusions are similar:

- people of all ages from 2 to 77 years old sustained auger-related injuries, however injuries were more likely amongst the young (0-25 years) and the older (over 45 years) groups.
- full-time male workers are most likely to be injured.
- a significant number of children and other family members are injured.
- the most common body part involved is the finger, with fingers, hands and arms making up over 60 percent of injuries.
- laceration/avulsion injury is most common followed by fracture and amputation.
- the rate of injury increases around harvest time and is most likely to occur just before lunch or late in the afternoon.

One significant difference is the percentage of unguarded augers reported. Schwab *et al.* (2000) found that only 19% of *primary* augers were unguarded whereas 48% of *secondary* augers had no intake shielding. Beatty *et al*. (1982) found that inspection of "*100 consecutive grain augers revealed that 95 percent had the shielding altered or removed*", while Letts and Gammon (1978) reported that 70% of augers involved in injury did not have safety shields. An Australian study (White 2002b) reported that only 50% of augers in the survey sample had their intake shielded. This difference is possibly due to the difference in data sets. The higher values come from studies of actual injury cases while the lower values are from random surveys of farmers. In one survey less than one quarter of those surveyed responded, and there may be some relationship between farmers who take the time to respond and those more aware of safety issues.

It is interesting to note that back injuries and other sprains or strains not requiring hospitalisation or major medical treatment are not recorded in these data sources. As most studies appear to rely on hospital reports, Occupational Health and Safety (OHS) investigation reports and specialist medical practitioners' case studies, they do not include injury cases that do not present at hospitals or are not reported to OHS agencies.

Studies of all agricultural-work related injuries and fatalities tend to have very little information that can be attributed to the use of augers. Auger-related injuries are grouped or included under "other farm machinery" or "mobile farm equipment" or "electrocution" headings, so that it is difficult to glean any useful information specific to auger use.

Unfortunately much of the literature reviewed appears to contain very broad and (in some cases) almost meaningless findings. For example, Lyman et al. (1999) found that injuries to farmers in Alabama and Mississippi usually occurred either in open areas such as fields and pastures or enclosed areas such as workshops and sheds. Similarly, Zhou and Roseman (1994) made a significant contribution to injury knowledge when they found that farmers in Alabama were more likely to be injured in fields, pastures or ranges, and around animal facilities, farm buildings and barns or barnyards.

In general these broader studies of injuries and illnesses among agricultural workers serve to reinforce the fact that agricultural workers face the highest risk of injury and illness. In Australia, Franklin et al (2001) found that during the period 1989-1992 the *fatality rate per 100,000 workers was four times higher for agricultural workers (20.6) compared to the all-industry rate (5.5) during the same time frame*. Hard *et al.* (1999), Demers and Rosenstock (1991), Ehlers and Palermo (1999), and many others provide similar statistics for the US and various states.

In addition all these studies conclude that intervention strategies are needed to reduce the risk of injury.

Suggestions include prioritising farm workers' needs for regulatory action, and prevention through education (including mandatory education through competency-based certification programs), enforcement (particularly of standards at the point of sale) and engineering controls such tractor-roll-over protective structures (Etherton *et al.* 1991). Others, for example Hwang *et al.* (2001), suggest that education and intervention strategies should be targeted towards high risk populations such as young farmers, those working long hours, owner/operators and farmers with physical impairment such as hearing loss or joint problems.

A number of studies, such as those by Fragar and Coleman (1997) and Hard *et al.* (2002) see the need for the development of appropriate surveillance systems and interventions that effectively reach their target populations as the *primary challenges for the current decade*.

3.2. Auger types

In its simplest form an auger is a helical screw that can rotate within an enclosed cylinder (Figure 3.1). Material such as grain is fed onto the screw at one end and transported by the rotating screw to the other end. Augers can be independent, portable or integrated with other machinery such as combine harvesters, grain dryers, and storage bins. On farms, augers are used:

- in harvesting machines, to move grain from the cutting mechanism to the separators, then to the storage bin and later out of the harvester
- in mobile bins to transfer grain from bin to truck or another bin
- in flat bottom silos to direct grain from the floor to another lifting auger
- to move grain from the ground or the bottom of one silo to another silo or to a truck
- to move grain and other feed stuff such as chaff and mineral additives from silos or mills to mixers and feed bins
- to deliver animal feed (via flexible augers) to feeding points

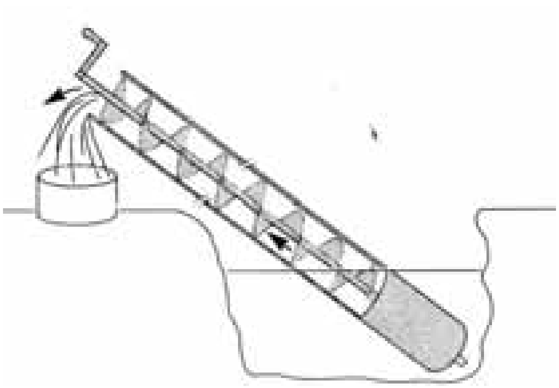

Figure 3.1: Archimedes' concept of using an auger to raise water (Beatty *et al.* 1982)

3.2.1. Mobile Auger

The essential components are a helical metal flight housed in a metal tube that is mounted on wheels, via a frame that allows the auger to be raised and lowered (Figure 3.2). The auger flight may be driven by an attached electric or combustion motor, or it may be powered by connection to the tractor power take-off or hydraulics. The lower end of the flight is exposed so that it may come in contact with grain (or any other material to be moved).

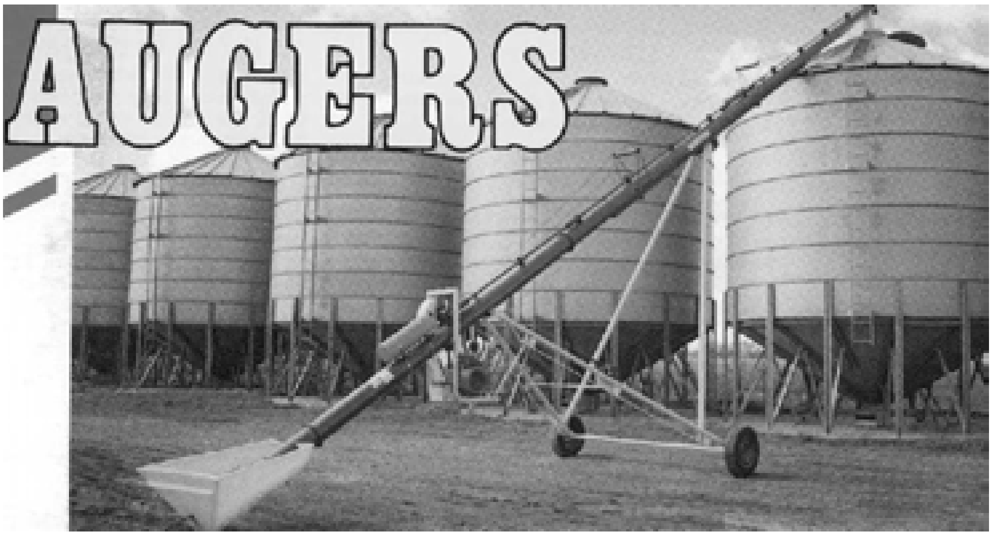

Figure 3.2: Typical mobile auger (Anon 2000a)

Unlike other augers, mobile augers present a number of hazards in addition to the possibility of contact with the auger's flight. While the majority of injuries are to fingers, hands and arms, and are due to contact with the exposed auger flight, a significant number of injuries, to many parts of the body, occur as a result of contact with other parts of the auger (Schwab *et al*. 2000). Some of the extra hazards presented by mobile augers include:

- crushing between a moving auger and a silo or other object
- being struck by a falling or rising auger
- contact with other moving parts such as drive chains, shafts or pulleys
- falling or jumping off an auger
- electrocution through contact with overhead power lines (Figure 3.3).

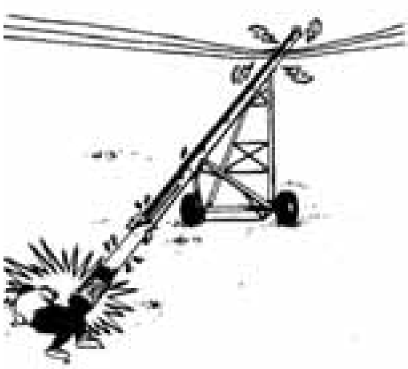

Figure 3.3: Overhead power lines are often low enough to contact with an auger (Anon 2000b)

The following incidents provide an insight into the type and severity of mobile auger injuries:

Case #1- Nine year old boy crushed by auger

> "*A nine year old boy received fatal chest injuries when he was crushed between an auger and a metal bar on a silo door whilst working on the family farm. The boy and his seventeen year old brother were* attempting to move a portable auger, *the boy stood on the feed end… so that* it *would not tip up into the air, whilst the auger height was being adjusted* by *his brother.* Suddenly the auger tipped and trapped the boy between *the feed end of the auger and* a *horizontal bar* above. *The post-mortem revealed injuries from which the boy would have died in a few minutes at most.* (Franklin 2002)"

Case #2 – Two electrocuted, three injured

> *"…,five farm workers were …moving a portable grain auger….from a 30-foot tall grain drying bin to another location, it was raised …35 feet to clear the top of the grain bin….As the workers pushed the auger….it contacted an electrical line which was about 25 feet above the ground. Two of the workmen were electrocuted and three others were injured.* (Millar 1997)"

Case #3 –Five year old girl loses arm

> *"A girl of 5 was helping to elevate grain…when her arm disappeared up the spiral flight until the engine stalled. Her arm was extracted with difficulty. When admitted to hospital, she had severe spiral laceration of the whole right forearm….Above-elbow amputation was carried out.* (Grogono 1973)"

3.2.2. Bin augers

Bin or grain tank augers consist of a horizontal auger built into the bottom of a vee-bottom grain bin, and an elevating collapsible two part auger attached to the outside of the bin. The horizontal auger moves grain to the external elevating auger, which lifts the grain to the delivery point. Examples include "Chaser" and "Feed" bins which are wheel mounted and used to take grain from the harvester or combine to a silo, or animal feed from the milling and mixing plant to the animals (Figure 3.4).

As these augers are normally only accessible from within the bin, it should be relatively easy to keep people from coming into contact with the auger flight. Unfortunately, people enter the bin to dislodge stuck grain, to clean out remnant pockets of grain or to carry out maintenance, and they can be severely injured. For example, grain tank augers were involved in 4 fatalities and 18 major injuries in the UK during the period 1986 to 1999 (Scarlett *et al.* 2002).

Figure 3.4: Typical grain bin (Anon)

Case #4 – Grain Auger Fatality

> *"A farmer was in a grain bin clearing out grain (either caught or wet wheat) with a shovel. The auger, which ran the length of the bin, was operating. The farmer slipped on the sloping floor and his left foot went under the cover of the auger (the auger guard). The auger was idling over slowly and caught the farmer's leg and severed it below the hip. The auger cover was installed in the 130 mm position and the gap between the cover and bottom of the bin measured 135 mm.* (Franklin 2000)"

3.2.3. Mixing augers

Mixing augers are used to combine the ingredients used in the preparation of animal food. Grain from one or more storage bins or silos and other ingredients such as chaff, medication, minerals and vitamins are fed in to the auger which mixes and transports the food to another bin for storage or feeding out (Figures 3.5 & 3.6).

Some mixing arrangements are inherently more hazardous than others due to the access they provide to small children and others who may be in the area at the time of mixing. Smaller units have an inclined auger which is just visible at the base of the inlet hopper. Its location makes it less likely to attract attention and less accessible to small children. Interaction with a person probably only occurs when inlet blockage has to be cleared or during maintenance. Other units have a horizontal auger lying in an open hopper, and ingredients are fed onto the auger over its whole length. These units can be low enough to allow children to reach in and feel the grain if the auger flight is not adequately shielded.

Figure 3.5: Animal feed mixing plant

Figure 3.6: Top view of horizontal auger shown in Figure 5.

Case #5 – Four year old boy's hand amputated
"A four year old boy was helping dad to mix grain, He forgot warning, and his hand caught in grain handling auger." (Franklin 2001).

3.2.4. In-ground augers

These are set into a pit in the floor and used to convey grain that is dropped onto the auger from bottom- emptying trucks, trains or mobile bins. They are normally found at grain depots or farms with large on-farm grain storage facilities. Although the potential for injury seems small, a number of severe injuries and fatalities involving this type of auger have been reported.

Case #6 – Man dies after getting his leg caught in a grain auger
"A 65-year old man …was unloading a gravity flow wagon of corn into a partially unguarded floor hopper. His right leg was caught in the auger in the bottom of the hopper, severing his leg in the mid-thigh region. The man was found lying unconscious next to the hopper with significant bleeding. A chewed up broom handle was found next to him…Since the wagon was empty, it appears that he was finishing the unloading, and possibly sweeping up spilled corn on the floor when his foot slipped into the uncovered hopper… The man was familiar with the equipment and procedures for unloading…. The man was taken to hospital where he was pronounced dead." (Johnson and Rautiainen 1996)

3.2.5. Sweep augers

As the name suggests, these augers are used to "sweep" grain horizontally towards another auger or conveyor. Unlike augers that are enclosed by hoppers or bins, sweep auger-flights are exposed along their entire length, and consequently appear threatening and dangerous (Figure 3.7). A number of ideas have been suggested for making use of these augers less hazardous, for example, the two part auger control unit designed by Sevart *et al.* (1991) to ensure that the auger can only be operated by one person, and Wickstrom's (1982) remotely operated hydraulic sweep auger that allows the operator to remain outside the silo. However, accidents continue to occur.

Case #7 – Boy's leg amputated by auger
"A 13-year old boy was cleaning inside an oxygen-limiting silo while a sweep auger was in operation. The unguarded auger swept slowly around the silo floor, pivoting about a central axis. As the boy stepped over the moving equipment, the hem of his pants caught in the auger and his leg was traumatically amputated below the knee as it became entangled" (Anon 1995a).

Figure 3.7: Sweep auger attached to a mobile belt conveyor (Anon 2001).

3.2.6. Harvester augers

Harvesters or combines have a number of augers built into them. The important two are the auger at the front of the harvester, that collects and feeds the harvested material into itself, and the auger in the bottom of the holding bin that empties the harvested grain out of the combine or harvester.

The auger in the bottom of the holding bin is similar to any other bin auger and therefore has the same inherent risks. The auger at the front is exposed and poses a different, more obvious threat. However, as the following incident shows, the perception of danger seems to diminish with time, and years of accident free activity can lead to dangerous familiarity.

Case #8 – Combine auger injury

> "*The combine funnelled six rows of planted corn into an auger,…a 16-foot rotating corkscrew. When the auger clogged with a few too many corn stalks,* the man *stepped down from the cab of the machine leaving it running, as he had done countless times before in his fifteen years of farming. He stood on a platform above the auger, cleared the obstruction, and began to step back to his cab…..the soles of his work boots slipped on the dusty platform above the auger. As he fell* he *could feel his left leg wrap twice around the whirling auger, breaking bones and stretching muscles. He couldn't feel his right leg so he assumed it had been severed…..the best efforts of medicine were not enough to save* his *leg"* (Wall 1998).

4. Method

Injury and fatality data were sought from a number of sources including hospitals, the ambulance service, the Queensland Division of Workplace Health and Safety, media reports and regional rural extension officers. While some of the data obtained from these sources were useful for gaining a clearer picture of individual cases, overall these data were not included in this study as it was not possible to determine whether some injuries were recorded in more than one data set.

Literature searches and reviews were conducted to gain a broad picture of the auger injury problem. Literature was collected from, the University of Queensland library, the Australian Centre for Agricultural Health and Safety, and the ASAE library via the Internet. Searches of the Agricola, Cab Abstracts and Medline databases and the Internet via Google were made using key words including: agricultural injury, auger, auger injuries, farm accidents, farm injuries, farm-related fatality, farm safety, workplace fatality, workplace injury, work-related fatality.

4.1. National Data

Injury data collected by the National Injury Surveillance Unit for the period 1988 to 1992 from a group of participating hospitals across Australia were obtained from the Australian Centre for Agricultural Health and Safety. Richard Franklin created a report that provided 43 records with the following fields: sex, location, context, job, industry, occupation, description (of the incident), mechanism, nature of injury, agency, safety device present, and age. Of these, 33 injury cases involved augers. Unlike the Queensland data set, these data are not representative of the whole or any population, however they are useful as they contain details of injury to children, older persons and others who do not appear on Workers Compensation records.

4.1.1. Queensland data

Queensland fatality data were obtained from Keith Ferguson (from the Division of Workplace Health and Safety) who carried had out a comprehensive assessment of work-related deaths on Queensland farms for the period 1990-1998.

Injury data were obtained from the Queensland Employee Injury/Disease Database project team (QEIDB), which created a series of reports by searching the Agriculture statistics narrative field for "Auger". Data fields provided included industry, period occurred, mechanism, nature of injury, agency, narrative, total payments, workdays absent and number of claims by worker's sex, age, month and year for the nine-year period 1992-1993 to 2000-2001. A report searching for "Electrocution" in the Agricultural Industry was created, in case incidents involving augers and electrocution were included in this area. In addition, an all industries report by total payments, workdays absent and number of claims was created for comparison.

The narrative (or incident description) field was invaluable for obtaining the data, and later for piecing together a picture of each injury event. By careful examination of the narrative, nature of injury and other fields it was possible to separate grain auger injuries from those involving drills, post-hole augers or other items of equipment. In addition, in most cases it was possible to identify the body part injured, the auger part causing injury (flight, drive pulley etc), the type of auger (feed-mixing, mobile etc), and the activity being undertaken at the time of the injury event.

As the auger was the agent of injury in all cases, a subset of agents was used to determine the relative involvement of the various auger parts or components. The whole auger was considered as a sub-agent, if it was involved in the injury event as a complete unit. For example if injury resulted from over balancing or tipping the auger, or while carrying or moving the auger. Whereas the auger's flight was considered a sub-agent when it was clearly the component involved in the injury event.

Similarly, the gears/pulleys/belts/shaft used to drive the auger and the mechanism for lifting and lowering the auger were considered as sub-agents of injury under the headings "Drive pulley/gear" and "Winding gear".

4.2. Focus group meetings

Two focus group meetings were held in order to gain a broader perspective of the grain auger injury picture in Queensland. One was held at Dalby and the other at Toowoomba.

4.2.1. Dalby focus group meeting

Participants were selected by contacting their relevant group or industry body. People from the following groups were invited to attend: the auger manufacturing and supply industry, the Department of Workplace Health and Safety (WH&S), the Queensland Ambulance Service (QAS), the Department of Primary Industries (DPI), the Australian Centre for Agricultural Health and Safety (ACAHS), and the grain farming industry. The meeting was held in Dalby as it is located in a grain growing area and is a centre for grain auger and conveyor manufacture and supply.

After the initial telephone contact, a list of interested persons was prepared and probable participants were contacted to finalise meeting time, date and venue. Participants were given very few details of the meeting agenda in order to minimise their preparation and development of set responses. Participants were told that the meeting was a part of a study to develop strategies for minimising grain auger injuries, and was intended for gaining an overview of the grain auger injury problem in Queensland. Also, they were told that representatives from a range of backgrounds would be invited to attend.

The final group consisted of:

- three representatives from two auger manufacturing/supply companies
- two QAS Officers
- an Industrial Relations Officer from WH&S
- an Extension Officer/Grain Farmer
- three Grain Farmers
- one representative from the Department of Primary Industries
- three representatives from the Australian Centre for Agricultural Health and Safety and
- two representatives from the Agricultural Mechanisation Centre at the University of Queensland Gatton.

A telephone reminder to each participant was made on the day before the meeting. As some participants had to drive for over 2 hours to attend, drinks and sandwiches were available at 6.30 pm, and the meeting started at 7.00 pm and concluded at 8.30 pm.

A person experienced in the management of focus-groups took charge of the meeting, and after introductions and permission to tape record discussion, presented participants with a short (5 minute) questionnaire "to start the group thinking" (Appendix 1). After collection of completed questionnaire forms, participants were invited to present their views and personal experience with grain auger injury or near miss incidents. Participants were thanked after the meeting and again by mail a few days later.

Over the next few days, the questionnaire responses and taped conversations were analysed to gain an insight into participants' feelings about the grain auger injury problem.

4.2.2. Toowoomba focus group meeting

A focus group meeting consisting largely of farmers was held at Toowoomba, Queensland. Toowoomba was chosen as it is about 1.5 hours drive from a range of farms that regularly use augers for the movement of grain or animal feed.

Farmers from the grain, cattle feed-lotting, dairy, pig and poultry industries were selected by contacting their relevant industry body and asking for a list of farmers who may be interested in attending a focus group meeting. Prospective participants were contacted by telephone and those interested were given further details by fax or e-mail. In all other respects this meeting was carried out in a similar manner to the Dalby meeting.

The final group consisted of:

- four representatives from feed-lotting enterprises
- three representatives from pig/ pig and poultry enterprises
- three representatives from mixed pig/ cattle/grain enterprises
- two representatives from the Australian Centre for Agricultural Health and Safety and
- two representatives from the Agricultural Mechanisation Centre at the University of Queensland Gatton.

5. Scale of the problem in Australia

5.1. Fatalities

Nationally, there were 587 farm related unintentional fatalities on Australian farms during the period 1989-1992 (Franklin *et al.* 2000). Of these fatalities, 6 were reported as being due to injury associated with grain augers. This study is the most complete study of farm fatalities ever undertaken in Australia. This gives a rate of 1.5 deaths per annum.

On a State level, South Australia's WorkCover Corporation data bases provide a "Description of what happened" field in their fatality records, and this is very helpful for determining the agent of injury. Their records show that there was only 1 auger-related fatality in South Australia during the period 1994 to 2002, and in this case the agent was electricity from faulty wiring in an auger.

In Queensland, K Ferguson, from the Division of Workplace Health and Safety, analysed 213 work-related deaths on Queensland farms for the period 1990-1998, however his results do not clearly show how many deaths were auger-related. One fatality is listed against the agent "Augers/Drives" and 11 against "Electricity". As these 11 fatalities occurred when farmers were "moving irrigation pipes, booms and augers under powerlines", it is difficult to determine the number that was auger-related (Ferguson 1999).

NSW WorkCover authority data shows that 151 farm fatalities occurred in New South Wales during the period 1990-2000, but it was not possible to determine the number of auger related fatalities during that time. However, data for the period July 1992-June 1996 shows that "Grain auger/elevator" was the agent of injury involved in 4 fatal incidents. It is interesting to note that NSW Workers Compensation Statistics for the 8 year period 1991/92-1998/99 record only 40 fatalities in the agricultural industry.

A similar picture exists for Victoria. The Victorian WorkCover Authority reported 116 fatalities in the agricultural industry for the period 1993-2000, but there is no indication of the number that was auger-related during that time. More detailed data is available for the period 1995-1997, but of the 26 deaths attributed to "Farm Machinery", none involved augers.

According to the Western Australian WorkCover authority, there were 10 fatalities in the agricultural industry during 1995-1998, but the statistics did not give any indication of the agent of injury.

No relevant data was obtained for Tasmania or the Northern Territory.

5.2. Non-fatal injuries

Over 650,000 injury claims for workers compensation were recorded in Queensland during the period 1992-2001. Of these, almost 16,000 came from the Agriculture, forestry and fishing industry, with just 52 being auger-related. On average there were almost 6 claims per year, with a maximum of 13 in 1994-1995 and a minimum of 1 in 1995-1996.

Workers compensation claims represent between 15 and 20 percent of farm related injuries presenting to hospitals for treatment. The scale of the non-fatal injury problem can be at least multiplied by a factor of 5 to determine the true scale of the problem. Queensland farms represent 19.9 percent of Australian farming enterprises (Fragar and Franklin, 2000). It is therefore estimated that there may be 125 and 150 serious injuries associated with grain augers each year in Australia.

5.3. Injury Cost in the Workers' Compensation system

The cost of auger-related injury claims and days lost by sub-agent of injury are shown in Table 5.1. Average yearly cost of auger-related injury claims was almost $33,000, and the average number of days lost per year was 188.

The average cost of auger-related injury claims of $5660 was more than double the all-industries average of $2500. The severity of injuries involving the auger flight is reflected in the high average cost ($8027) and number of days absent from work (45) of these injury claims. In both cases these values are more than three times the corresponding all-industries values.

Table 5.1: Cost of auger-related injury claims (Queensland 1992-2001)

Auger part involved in Injury	Cost of Claims $	Working days lost	Number of Claims	Average cost/claim $	Average number of days absent from work
Auger flight	248,846	1,400	31	8,027	45
Whole auger/body	34,693	191	12	2,891	16
Winding gear	3,069	25	2	1,535	13
Drive pulley/gear	501	4	1	501	4
Other – Unknown	7,244	73	6	1,207	12
Total	$294,353	1,693	52	$5,660	32.5

5.4. Severity of Injury

Although auger-related injuries make up a small fraction of all the compensation claims for the 1992 - 2001 period (52 from 654,457), they appear to be amongst the most severe in terms of compensation payments and days absent from work. On average, auger-related injury payments and days absent were more than twice the all-industries average of all other injury claims. The severity of auger-related injuries as indicated by time off work is shown in Table 5.2. Over 60% of those injured (in auger-related incidents) were absent from work for more than one week and 8% were absent for more than three months.

Table 5.2: Days absent from work due to auger-related injuries (Queensland 1992-2001)

Days absent from work	Number	Percent
<8	19	37
8 to 31	21	40
32 to 90	8	15
91 to 180	2	4
>180	2	4
Total	52	100

6. Risk Factors

6.1 Industry

Distribution of claims by industry is shown in Figure 6.1. It is interesting to note that most (65%) of the injuries occurred in the animal industries while 27% occurred in the grain, "crop and plant" and fruit industries. Services to agriculture accounted for the remainder. However, the data does not include self employed farmers, and there may be significant differences in the numbers of employees in grain growing and animal farming.

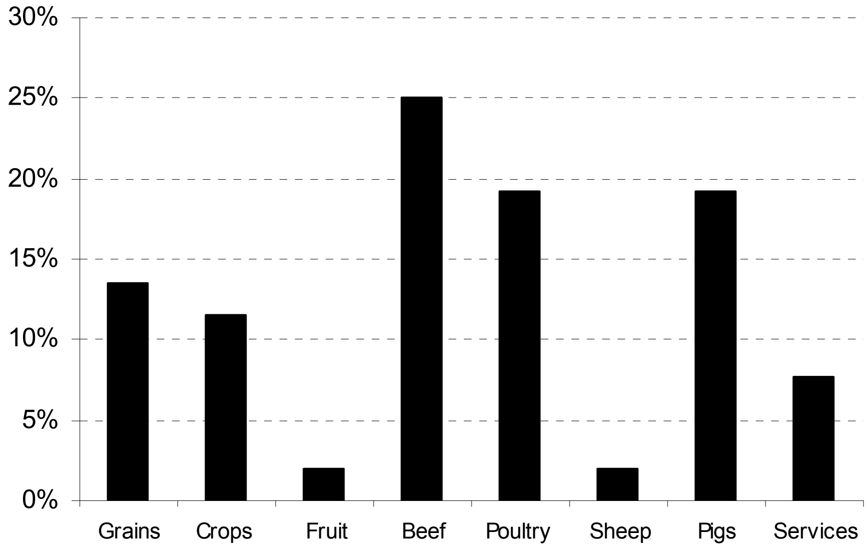

Figure 6.1: Distribution of injury claims by Industry (Queensland 1992-2001)

6.1.1. Month of injury

American studies (Schwab *et al.* 2000; Beatty *et al.* 1982) and anecdotal information suggest that there is relationship between harvest time and auger-related injuries however such a relationship is not clear from the Queensland data (Figure 6.2). The state's variation in regional climatic conditions tends to spread the harvest period over a number of months, and the storage of grain on farm means that grain may be handled several times before leaving the property. The increase in claims during March may reflect the sorghum, corn and bean harvest. June's data does not coincide with a period of intensive crop harvesting but may reflect the movement of grain stored on the farm.

The monthly fluctuation in injury claims in the intensive animal industries is interesting. Unlike the grain industry, the intensive animal sector does not have distinct periods of high and low auger use. Animal feed-stuff is prepared and fed-out on a regular basis, and one would expect a flatter injury claims curve throughout the year. However, injuries appear to be more likely during the winter months (June, July and August) and towards the end of summer (February). The Christmas-New Year holiday break may have an affect due to changes in staffing and the catch-up rush at the end of the holiday period, but the high injury rate during winter is surprising.

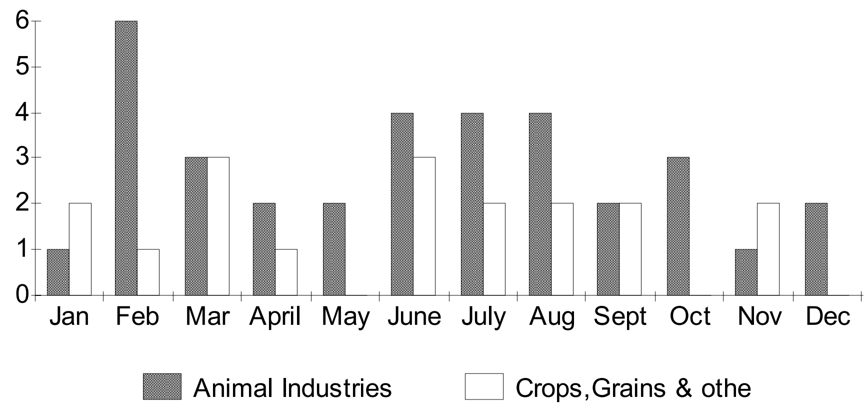

Figure 6.2: Number of auger-related injuries by Month (Queensland 1992-2001)

6.2 Operator risk factors

6.2.1. Age

As Queensland Employee Injury/Disease data for the period 1992-2001 includes details only for employed persons who have made a claim for compensation, it does not include details for persons under 15 years of age or those above 65. In addition, the age of each claimant was given as a range rather than the actual age. Table 6.1 shows that the 20-24 and 25-34 age groups make up over 60% of auger-related injury claims in Queensland.

Table 6.1: Age range of people involved in auger-related injuries

Age Range	National Injury Surveillance Cases	Queensland Worker's Compensation Data	Other Reported Incidents in Queensland	Accident Notifications in NSW
0-14	8	0	0	0
15-19	1	2	1	0
20-24	4	12	0	0
25-34	6	19	3	0
35-44	5	8	0	3
45-54	4	8	1	3
55-59	2	2	0	0
60-64	2	0	0	0
65+	0	1	0	0
TOTAL	32	52	5	6

Table 6.2 shows that the percentage of auger victims in the 20 to 34 age range is significantly higher than the proportion of workers in that group.

Table 6.2: Age group of Queensland farm managers and agricultural labourers and age group of auger victims (Percent)

Age Range	Farmers Owners /Managers	Agricultural Labourers	Auger accident victims
15-19	1.5	12	4
20-24	4	16.5	23
25-34	16.5	26	37
35-44	33.5	20	15
45-54	24.5	14.5	15
55-59	10	5	4
60-64	9	4	0
65+	11	2	2
Total	100	100	100

6.2.2. Gender

Only one of the fifty two Queensland claimants is female, while the National Injury Surveillance data shows that one female child and three adult females were injured in auger- related incidents.

6.2.3. Clothing/Grooming

Only three incidents involving entanglement of clothing were reported. One person's pullover was entangled by a grub screw on the drive shaft. Another person's (unspecified) clothing became entangled by the auger flighting when he was adjusting the choke, and the third person's sleeve became entangled in the flighting while pushing grain from around the edge of the hopper into the auger.

While the entanglement of draw strings, scarves and other loose items of clothing is expected, it is less easy to visualise how a sleeve or pullover could become entangled without getting very close to the auger flighting.

6.3. Work practice

6.3.1. Time of day

Focus Group participants felt that time of day, length of shift, the need to rush, operator experience, skill and state of mind, and climatic and environmental conditions were important contributing factors in auger-related accidents. Unfortunately the Queensland compensation data had insufficient detail to contribute in these areas, but the data did provide a guide to the time of injury by recording the period during a shift when injury occurred (Table 6.3). The majority (almost 77%) of injuries occurred during the early or middle periods of a shift. This may be expected in the animal industries, where the movement of animal feed tends to be carried out earlier in the day; however two thirds of auger-related injuries in the crop and grain industries also occurred during these periods.

Table 6.3: Period when auger-related injuries occurred

Period when injury occurred	Percent of injuries
Early in shift	42.3
Middle of shift	34.6
Late in shift	21.2
Overtime	1.9

6.3.2. Operator behaviour

Complacency, or being too familiar with auger operation, and rushing to finish and sacrificing safety for efficiency were seen as common dangers associated with auger use. Table 6.3 shows that a large number of injuries occurred when people acted without thinking about the danger involved. Whilst children may not be aware of the danger, experienced adults (some in their seventies) who should have known better seem to have ignored the danger.

Focus group participants suggested that there is a need to explore ways to improve the operator's state of mind while working with an auger for relatively long periods. It was generally accepted that there may be times during the day when an operator can lose concentration and do things without thinking about the safety implications of the action. Distinction was made between "mind slipping" actions such as putting a finger in the auger and "stupid" actions such as climbing into a grain bin to push grain into the auger with one's foot.

Table 6.4: Injuries where injured person's behaviour is recorded.

Number of injured persons	Activity at time of incident	Comment
19	Cleaning/emptying/pushing grain or concentrate into auger	Those injured were attempting to clean grain out of the corners of hoppers, mixers or bins without shutting the auger down. Injuries (including amputations) were reported to fingers, hands arms and feet.
27	Watching auger working	Those injured do not appear to have any reason for putting their hands close to the auger flighting. Comments include: "did not think" "end of day, tired, did not think" 6 of those injured were children.
3	Taking grain sample	Those injured attempted to take a grain sample adjacent to the auger flight rather than from a safer location such as the truck chute.

Results of the National Coalition for Agricultural Safety and Health survey showed that farmers appear to be knowledgeable concerning the dangers of their occupation but still tend to engage in unsafe practices (Elkind et al. 1998).

An earlier study by Schwab et al. (1992) found that the majority of respondents (72%) saw themselves as very aware of work-related hazards, but less than half (42%) were very careful in their work.

While a majority of farmers believe that farming is the most hazardous occupation (Farrar *et al.*1995), they perceive and rank hazards differently to safety professionals. For example, according to Rosenblatt and Lasley (1991) farmers rated chemicals amongst the most dangerous hazards on the farm, and machinery (excluding augers) as the least hazardous.

This different interpretation and rationalisation of the same information has important implications for the effectiveness of injury-minimisation strategies – particularly those relying on *educating farmers*. Sandman (1993) explains that perception of risk depends not only on the hazard and its likelihood, but also on a range of *Personal factors* such as *familiarity, dread, catastrophic potential and degree of personal control*. Similarly, Green (1999) concluded that a farmer's perception of risk is diminished by *familiarity with his work, along with the need to feel competent, in control and present-oriented.*

6.3.3. Activity at time of injury

The majority of injuries occurred while people were "on duty", but of those recorded, nine injuries involved children and other non-workers as they were playing, standing, walking or in other recreation activities. Two were watching augers load or unload grain. Three children were "helping dad". One fell off an auger whilst playing, and one was hit by a falling auger whilst walking past. Clearly, the workplace continues to be a place for play and recreation for those not employed as machinery-operators.

6.4 Auger related risk factors

6.4.1. Parts of Augers involved in injury events.

Table 6.5 shows that the auger's flight is the part most likely to be involved in injury events. The higher rate of involvement of the auger flight in the National data may be due to the inclusion of children in this data set. Personal experience of injury incidents reported at Focus Group meetings implicate the auger flight in 50% of incidents, while it was involved in 55% of incidents in the study of Iowa farmers by Schwab *et al.* (2000). These high rates of involvement verify the lack of adequate guards or their removal for cleaning and maintenance operations.

Table 6.5: Percentage of incidents attributed to various parts of the auger

Auger part involved in injury	National Injury Surveillance Cases	Queensland Worker's Compensation Data	Comments
Auger flight	82	60	Typically fingers, hand and feet coming in contact with auger flight
Whole auger/	9	23	Muscular stress while lifting, carrying or moving the auger or injury from dropping the auger
Winding gear	0	4	Being hit by handle due to failure or slipping of lifting mechanism
Drive pulley/gear	6	2	Fingers or hands coming in contact with belts or gears
Other - Unknown	3	11	Falling off augers or ladders, being hit by falling augers or other objects
TOTAL	100	100	

6.4.2. Auger type

While it is clear that the auger flight is the component most likely to be involved in injury, the data did not give a clear picture of the dominant auger type. In a high percentage of both the Queensland and National data there was insufficient detail to identify auger types (Table 6.6). However, where identification was possible, the mobile auger was involved in half of the injury events.

Focus Group discussions suggested that Mobile and Bin augers are the most likely to be involved in serious accidents. Certainly, mobile and bin augers are the most likely to be involved in accidents resulting from contact with overhead power lines, and those resulting in loss of hands, feet and legs.

Table 6.6: Types of auger involved in accidents

Auger type	Percent
Unknown	42
Mobile	29
Feed	13
Mixing	8
Bin	4
Sweep	2
Utility	2

6.4.3. Auger age

Schwab *et al.* (2000) found that 59% of augers used (by 90 farmers who responded to the survey in Iowa) were older than eight years, and 34% of these were unshielded. In Australia, the Kondinin Group's 2001 survey of 717 auger owners found that only 50% of augers had their intake shielded with safety mesh (White 2002b). Focus Group participants suggested that older augers made up the majority of augers currently in use and that many of these never had guards or had their guards removed.

Several suggestions were offered for improving the safety of older augers including the enforcement of guarding requirements and the marketing of short sections of self contained adaptors that could be bolted onto the ends of existing augers. Participants felt that “simple farmer based solutions were more likely to be effective than regulation”.

6.4.4. Auger guards

Guards or shields refer to barriers that are placed over otherwise exposed-moving parts of machines, to prevent people from accidentally coming into contact with those parts. Augers have a number of areas where contact with moving parts can occur, the most hazardous being the rotating auger screw or flight. Other moving parts include the drive components such as power-take-off shafts, belts, chains, gears or pulleys, and the lifting and lowering components such as winding handles and cables.

Apart from power-take-off shafts (which are regarded as a separate injury hazard problem and the subject of other studies), the essential difference between shielding for the auger flight and shielding for other components is the degree of access. The flight guard or shield has to be able to allow grain to flow freely through it and onto the flight, and at the same time not allow any parts of a person to come into contact with the flight. Other components, except the winding handle, can be completely enclosed and provide access only during routine maintenance or repair.

Focus Group participants recognised the difficulty in providing adequate guarding without increasing the frequency of blocking and the amount of grain deflected out of the hopper. While there was agreement that new augers were adequately guarded with guards conforming to current standards, participants felt that there was room for improvement in design to make access for cleaning and maintenance easier. It was felt that guards that are difficult to remove and replace are less likely to be replaced after removal.

Grain flow reduction by guards appears to be a serious consideration. One of the items listed on “An auger buyer’s checklist” for mobile-augers urges buyers to “Ensure that the guards fitted to the auger inlet do not restrict flow” (White 2002b). In other applications, such as unloading sumps in grain bins, guards increase the chance of blockage by clumps of mouldy grain, and may reduce grain flow to unacceptable rates. While flow rate through a given opening will vary with the size and shape of grain and its moisture content, Wilcke *et al.* (1990) found that substantial flow reduction was caused when a 7.2 cm square mesh was used to guard the opening. Although this mesh size is too large to prevent a child’s hand from passing through, it resulted in grain flow reduction of 50 to 70%. While this reduction in flow may occur in a shielded-fixed opening, the situation with a mobile auger may be quite different depending on the position of the shielding. For example, if the auger is shielded via a shielded hopper rather than a mesh “cowl” on the end of the auger.

Cleaning and, to a lesser degree, maintenance also pose serious design problems for guards. For example, remnant and bridged grain in feed bins or bunks is forced into the auger with sticks, poly pipe, brooms and feet. A number of fatalities have occurred as a result of foot contact with augers in these locations. Operators have entered bins, slipped or otherwise become entangled and even when they have managed to free themselves and climb out some have died due to massive haemorrhage (Anon 1995b). Clearly, guards must allow access for cleaning and ensure that human contact with the auger flight is not possible. The use of safety interlocking systems, that shut down the auger if the guard is removed or when a person enters a bin, seem to have the potential to satisfy cleaning and safety requirements (Scarlett et al. 2002).

6.5 Environmental risk factors

6.5.1. Surface/slope

The nature of the surface on which mobile augers are moved into position can affect the chance of having overturning or pinning accidents. For example one of the Focus Group participants reported experiencing an overbalancing incident when one wheel of the auger that he was manoeuvring into position rolled into a small pot-hole. In another (fatal) incident, a man was pinned to the silo by the auger he was attempting to move into position. The auger overbalanced and rolled forward crushing his chest against the silo.

While the number of reported incidents of this type is small, they highlight the inherent unstable nature of the mobile auger and the importance of working on a smooth and level surface.

6.5.2. Slipping or tripping

Table 6.7 details the 15 incidents that involved slipping or tripping. As grain augers generate dust, and individual grains bounce off the flighting and shielding at the point of entry, adjacent surfaces can become slippery due to a coating of fine dust or grain. Even natural ground surfaces can become slippery when coated with grains of corn. Given the amount of grain spilt and the slippery nature of ground surfaces near the auger inlet, 15 incidents, from a total of 119 reported, seems relatively small.

Table 6.7: Number of slipping or tripping incidents

Nature of slip or trip	Number of slip incidents involving contact with the auger's flighting	Number of slip incidents involving contact with other parts of the auger or other objects
Foot or feet slipped on spilt grain or other slippery surface	6	4
Hand slipped off auger or other object	1	1
Tripped over unspecified object	1	
Slipped on hatch cover	1	
Mobile auger slipped off supporting drum		1
Total	9	6

6.5.3. Overhead power lines

Table 6.8 indicates reported incidents involving auger contact with overhead power lines in New South Wales from 1998.

Table 6.8: Auger Incidents in NSW from 1998

Date	Location	Details
1998	Gunnedah	Property owner was relocating auger to another position on the grain shed when it was pushed into 22000 Volt power line. Electric shock and burns to the victims feet and hands resulted
6/3/1999	Taree	Auger on stockfeed delivery truck hit 11000 volt power line after driving off with auger extended. No injuries resulted. This incident occurred late in the day and fatigue and bad light may have been contributory factors
10/6/1999	Gunnedah	Grain auger hit 11000Volt power line while being towed. No injuries occurred.
12/11/1999	Mungindi	Auger hit overhead 22000Volt power line whilst being towed. No injuries resulted.
3/12/1999	Narrabri	Auger on grain chaser bin hit 22000Volt power line whilst carrying out operations in wheat paddock. No injuries resulted.
23/12/1999	Glen Innes	Auger being towed hit low voltage service to shed. No injuries resulted.
23/12/1999	Warialda	Victim was relocating auger around farm silos. The victim was a farm worker and was being assisted by a truck driver and son of property owner. Contact was made with 22000Volt power line. The truck driver was thrown clear receiving a minor electric shock and the son of property owner had released his hold of auger just prior to contact. The victim received electric shock and burns.
23/12/1999	Moree	Auger being towed hit low voltage service to grain shed. No injuries resulted.
4/1/2000	Bellingen	Auger on grain truck hit low voltage service while delivering grain to dairy. No injuries resulted
8/2/2000	Moree	Grain auger was being relocated and hit overhead power line and stated a fire. Grain auger was being towed by vehicle. No injuries resulted. Contact with 22000Volt power line
2000	Various (4 Incidents – 2 Central NSW, 2 Southern NSW)	Auger hit overhead mains. Injury resulted in one incident. Exact details unknown.

Source: NSW Country Energy

In Queensland, 11 fatalities resulted from contact with overhead powerlines during the period 1990-1998. All incidents occurred while farmers were "moving irrigation pipes, booms and augers under powerlines" (Ferguson 1999).

Focus group participants were aware of an incident in which two people were electrocuted when the auger they were moving contacted overhead powerlines. One person lost his toe and the other's foot had to be amputated. They were hurrying to finish before the arrival of an approaching storm and did not lower the auger before moving it between silos.
Responses to the questionnaire and comments made during Focus Group discussions emphasise overhead power lines, complacency, or being too familiar with auger operation, and rushing to finish and sacrificing safety for efficiency as the greatest dangers associated with grain auger use.

6.5.4. Dust and Noise

A weakness of this report is that problems associated with dust or noise were not investigated or raised at focus group meetings, despite the fact that the movement of grain by auger is generally a very dusty and noisy operation.

Personal experience, based on numerous farm visits and considerable work in the area, suggests that air borne dust is not generally perceived as a problem when working outside. No operators working outside were seen wearing dust masks. However, it is common for those working in enclosed spaces (such as feed milling sheds) to wear dust masks.

Only one incident related to dust was found in the injury data. A worker suffered eye problems while augering sunflower seeds containing a large amount of fine trash.

Another aspect that is difficult to measure in the field or assess from the data is the contribution that the fine coating of dust (that settles on working surfaces) makes to slipping and consequent injuries.

The Australian Centre for Agricultural Health and Safety conducted noise measurement on a range of farm machinery, including grain augers, in 2003. Noise levels at the ear of the operator for grain augers averaged 93 dB(A) and ranged from 89 to 96 dB(A)

The Kondinin Group conducted a number of tests on grain conveyors that give a reasonable indication of the noise level generated by augers in typical outdoor grain transfer situations. Their results ranged from 90 dBA to 105 dBA and were considered to be “exceptionally high” and in excess of the safe operating level of 85 dBA (Hamilton 1990; White 2002). Given the large number of “old” augers still in use, one would expect the noise levels generated to be well above that generated by the new conveyors tested by the Kondinin Group.

6.6 Injury outcomes

According to Sorock *et al.* (2001), “Acute hand injury is the leading cause of occupational injury treated in United States’ hospital emergency departments”. As expected, fingers and hands were the most commonly affected body parts in both the Queensland (Figure 6.3) and National data (Figure 6.4). However, there are significant differences between the two data sets. The Queensland data includes much higher percentages of foot, back and “other” injuries (Qld. 35%, Nat. 9%) but considerably lower finger, hand and arm injuries (Qld. 65%, Nat. 91%). This may be due to the difference in the ages of the two groups. The Queensland data does not include children under fifteen or persons over sixty five years of age, and it is unlikely that persons in these age groups would be involved in lifting and moving augers or entering grain bins to clear blockages with their feet.

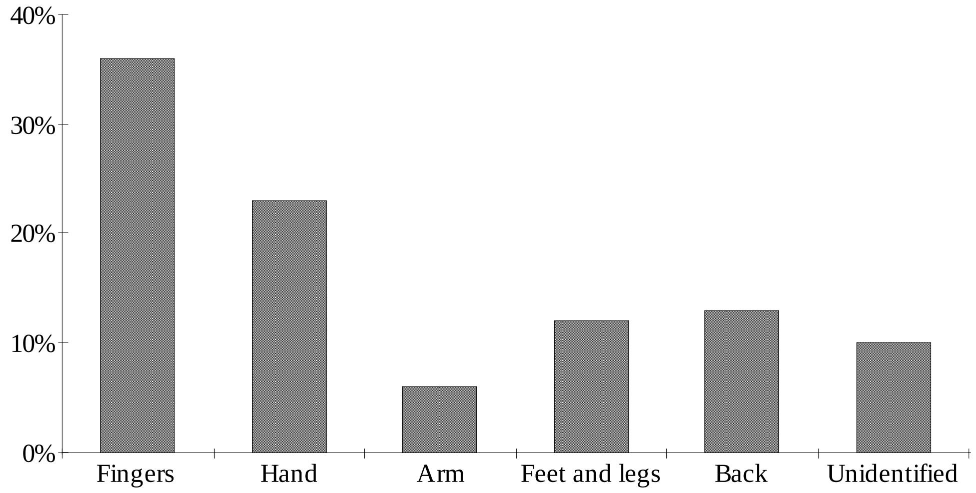

Figure 6.3: Injury distribution of affected body parts (Queensland 1992-2001)

Of the 52 auger injury cases reported 7 involved traumatic amputation including 1 foot, 3 hands and 3 cases of one or more fingers. The vast majority of cases (34 or 65%) involved injury to fingers, hands and or arms.

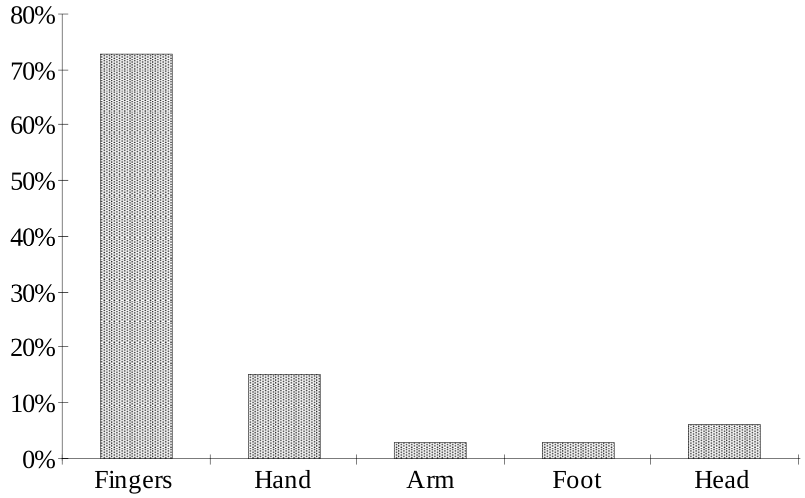

Figure 6.4: Injury distribution of affected body parts (National 1988-1992)

Almost 73% of injuries were to fingers, and over 90% of injuries involved fingers, hands and arms.

All farmers who participated in the focus group meetings had first hand experience of auger injury or "near miss" events that involved injury to themselves, a relative or employee. They reported equal numbers of incidents involving fingers/ hands and feet.

Although the literature confirms that the majority of auger-related injuries involve fingers and hands, there is little numerical data for comparison. A study of Iowa farmers (Schwab *et al.* 2000) found that 55% of injuries involved fingers and hands, compared to almost 60% and 88% in this study.

6.7 Options for Risk Reduction

The key risks to be controlled have been demonstrated to be:

Hazard	Risk
Auger flight	Crush injury/ amputation of fingers, hands, arms, feet and legs
Whole auger	Musculoskeletal injury associated with moving auger Injury associated with the auger falling Electrocution and burns associated with contact with overhead power lines
Winding gear	Injury due to being hit by handle
Drive pulley/ gear	Crush injury of fingers and hands associated with belts and gears
Other	Falling off augers or ladders

Consideration of methods of reducing the risks associated with hazards in the workplace follows the generally accepted "hierarchy of control" framework, viz:

- Elimination - removing the hazard or hazardous work practice from the workplace.
- Substitution – substitute or replace the hazard or hazardous work practice with a less hazardous one.
- Engineering/design controls, including isolation of the hazard from workers. – if the hazard cannot be eliminated or substituted engineering or improved design control is the next preferred measure.
- Administrative controls – ensuring safe work practice, labour organisation and operator skills.
- Personal protective equipment – considered when other control measures are not practical, and where it is possible to protect body parts from injury.

The higher order controls are considered to be more effective as their effectiveness is not dependent on human behaviour. Effective risk control in the workplace generally involves a combination of several control methods.

Formulating a risk reduction program to reduce injuries associated with grain augers is complex and must be made in the context that there are probably hundreds of thousands of existing grain augers in use on more than 120 000 Australian farms. It will take many years for these to be replaced with safer, newer augers, even if significant design improvements were available.

6.7.1. Elimination options

Elimination of the risks associated with grain augers would rarely be an option for in most grain and feed handling systems on Australian farms. However, the safety risks associated with operation of grain augers should be a factor in determining how and when grain or feed is moved. The aim should be to have grain or feed moved to its ultimate destination with as little handling as possible.

6.7.2. Substitution options

Auger-flight hazards can be eliminated by substitution. Belt and pneumatic conveyors can probably replace screw augers in most material handling situations, and, if one manufacturer's claims are true, belt conveyors are safer, wear better, require half the power of screw augers and cause less damage to sensitive produce (Anon 1983).

Unfortunately, belt and pneumatic conveyors are considerably more expensive than screw augers (White 2002a&b), but more importantly, most screw augers in use on farms are still working well, they do not need replacing and a large proportion of them have unshielded flights.

6.7.3. Engineering/design Solutions

Improved guarding

Legislation and standards

A number of Australian Standards and Guides relating to the design of guards are available. Australian Standards include:

- National Standard for Plant (NOHSC 1994)
- AS 4024.1 - Safeguarding of machinery-General Principles
- AS 4024.2 - Safeguarding of machinery-Presence sensing systems
- AS 1755 - Conveyors-Design, construction and operation-Safety requirements

These set out the general underlying principles for machine guarding, and whilst not providing specific guidance for any one machine they obviously apply to augers. There does not appear to be any Australian Standard specifically related to the guarding of augers.

A Standard specific to the guarding of augers is available from the United States. Unlike the Australian preference for performance based Standards, the American Standard *ASAE S361.3 Safety for Portable Agricultural Auger Conveying Equipment* (ASAE 2000) is prescriptive. It sets out the dimensions of guards and openings, as well as other aspects of safety such as the electrical specifications for motors, winch and rope details and typical safety-sign information. This Standard has the typical limitation of prescriptive specifications - the exclusion of other and perhaps better options - but more importantly, it sets limits that do not meet its stated purpose of providing a reasonable degree of personal safety for operators and other persons during normal operation of auger conveying equipment. The specified maximum guard opening size of 6450 mm^2, with the largest dimension of no greater than 121 mm, allows hands to easily reach through and contact the auger flight (Personal experience 2002; Sevart *et al.* 1991). This Standard is clearly designed to provide some level of safety, in cases such as falling onto the auger, but it provides little protection if a person reaches through to feel the grain or to remove straw or other obstructing material.

Inspection of new augers at a recent agricultural exhibition revealed that a number of different meshes were used for shielding, but (as shown in Figure 10) most of these allowed an adult hand to pass through and contact the auger's flight.


Figure 10: A person's hand can easily pass through the mesh shields provided on new augers displayed at a recent Agricultural field day.

Not withstanding the limitations of *ASAE S361.3*, prescriptive standards seem to have a number of advantages over performance standards such as the *National Standard for Plant* (NOHSC (1994). Prescriptive standards seem to be much simpler to comply with as they provide recipe-like steps to compliance. If a guard is built to the standard's specifications then it is deemed to be safe. There is no need for hazard identification, risk assessment, risk control and a host of other duties for obligation bearers, as hazards have been assessed and guards designed to adequately minimise risk. Another advantage is that all manufacturers can compete on an equal basis when they know exactly what is required of them.

All supplier/manufacturers consulted were concerned about changes to legislation that may result in increased manufacturing costs and give competitors an "unfair" advantage. They supported the use of standards such as ASAE S361.3, as their requirements were clear and easily applied. New augers inspected are supplied with guards to ASAE S361.3 and contain the required safety signage and instructions.

While the number of auger-specific standards is limited, there is a range of Guides designed to assist obligation bearers to meet their obligations under the relevant safety or machinery Act. For example, New Zealand's *Occupational Safety and Health Service Guide* (OSH 1989) for meeting the requirements of the NZ Machinery Act suggests that safety requirements for portable augers can be met by:

- Complete enclosure of the moving parts of the prime mover, transmission and associated drives.
- The fitting of guards at both intake and outlet, where necessary, of such dimensions that it is not possible to reach the dangerous parts.

In addition, the Guide provides opening width-to-distance dimensions and diagrams of suitable guards for drives and hoppers. These are particularly useful when fabricating guards for older unguarded augers, as farmers can see how to make suitable guards without having to "re-invent the wheel".
The Queensland Division of Workplace Health and Safety has a similar guide (WHS 2002) that is not auger specific but applies to all machines. While it appears to be more comprehensive, and it certainly

covers a broader range of issues such as hazard identification, risk assessment and control, ergonomic considerations, guard types and selection, and people's obligations, it seems a little overwhelming, and could easily fall into the "too hard basket". Unlike the New Zealand publication, this one seems to be too general, too thick and not practical enough for the farmer to easily use for making auger guards.

In addition, Queensland has *The Rural Plant Industry Code of Practice 1999* that includes a section on guarding machinery. The Code suggests that separation by guards should only be provided *when design, substitution and redesign are not practical*, and it continues in this meaningless vein over four pages without providing much guidance for manufacturers or users. It does not explain the limits of practicality nor does it provide any ergonomic or design information. It seems to be designed to ensure that *obligation bearers* (other than government agencies) bear all the responsibility for the safe operation of rural plant without giving any clues as to what constitutes a reasonable attempt to meet these obligations.

An area of contention that is common to most of these laws, advisory standards and codes is the requirement that plant be *properly used*. However, the decision of the Full Bench of the NSW Industrial Commission (in *Inspector Mulder v Arbor Products*) shows that a supplier cannot argue that a worker was not using the machine properly if the machine is inherently unsafe (WorkCover 2001b).

6.7.4. Design options

There appears currently to be no perfect guard or shield design for mobile augers that allows for efficient grain flow as well as ensures that the flight intake is isolated from the operator. The design problem is complicated by the ergonomic data provided by the various authorities. For example, a guard mesh small enough to prevent a hand from passing through it (40 mm square) is required to be some where between 200 mm and 300mm away from the auger flight, depending on whose ergonomic data is chosen. This requirement makes the use of a cowl guard impractical as it would be about 600 mm wide and therefore too wide for many hoppers.

An alternative arrangement is to place the mesh over the hopper, but while this offers the opportunity to increase the mesh or bar gap, it leaves the auger unshielded at the point of sale. A number of ideas for shielding the hopper are available. The Occupational Safety and Health Service of New Zealand published several designs for intake hopper guarding in 1980, including one that could be shaken to clear straw blockages. In the USA, Sevart *et al*. (1991) were aware that guards designed to ASAE standards will not prevent entanglement and injury by the auger's flighting, and they suggested the use of a mesh with smaller openings (of about 40 mm square) and the use of a vibration system to reduce the incidence of blockage.

6.7.5. Improved design of the intake

Vern Dutschke, an Australian grain farmer, has developed the "Auger-safe" device (Figure 13) that replaces the conventional inlet end of a mobile auger with a short length of flexible-flight-auger and a short section of flexible tubing. In addition, the plastic flight has an internal clutch to separate it from the main shaft in the event of a blockage (Anon 1999). The device has not been exhaustively tested, but there have been some very convincing public demonstrations ("Landline". ABC TV 2002) and preliminary safety and capacity tests carried out by the authors.


Figure 13: Auger-safe prototype.

A polyurethane flexible flight and short section of polyurethane tubing replace the conventional end of an existing auger. The unit comes complete with an internal clutch, tow point, metal housing and choke.

The device was tested using a very old 230 mm diameter mobile auger of 14 m length driven by a 16 Hp Briggs and Stratton petrol motor. Capacity and Injury tests were carried out using the auger prior to modification and repeated using the modified auger. Modification took approximately one hour and consisted of cutting off and removing the exposed segment of steel auger flight and replacing it with the flexible flight device.

Injury tests were carried out by slowly lowering pigs' trotters into the auger and observing the result. In addition two people touched the flexible auger flight with their hands and feet while it was operating.

The capacity tests showed that the auger delivered slightly more maize with auger-safe attachment than it did prior to modification (49 & 48 T/hr). This could be due to the tapered and slightly larger diameter flight of the auger-safe device.

The injury tests, while poorly designed, were more than adequate to demonstrate the potential of this device. Pigs' trotters lowered into the metal flight were whisked into the auger tube. It was not possible to safely hold the trotters against the flight and remove them. The pinching action of the flight and tube forced the trotters into the tube almost instantly. By contrast, the flexibility of the flight and tube of the auger-safe device produced the opposite action and tended to eject the trotters. It was possible to hold the trotters against the flight without having them pulled into the auger tube and without damage to the skin. Similarly it was possible to put one's hand or foot against the flight and withdraw it without damage. With some pressure it was possible to force one's foot into the auger and cause the clutch to disengage the attachment from the main shaft.

Although designed as a "retro-fit" safety device for existing augers, the concept could be incorporated into the design of new augers. It has the added advantage that it does not impose any change in the operator's attitude or current work procedures.

6.7.6. Routes for movement of mobile augers

Reduction of risk of contact with overhead power lines should include attention to design of routes that avoid movement of augers in the vicinity of power lines. This may involve movement of routes, movement of power lines and/or placement of powerlines underground at key points, eg around silos and where high equipment, including grain augers are moved.

6.8 Administrative controls

6.8.1. Safe work practice

Five work practice factors appear to be significant from the study findings:

- Loose clothing caught in auger intake
- Non-placement of guards at the auger intake
- Freeing of grain, or taking grain samples without shutting the auger down
- Bystanders injured having no apparent reason for being in the vicinity
- Fatigue of victim
- Contact with overhead power lines while being towed

Safe operation of grain augers will include attention to the following procedures:

- Train all operators in the safe operation of the equipment, including observance of recommended procedures in the operators manual
- Limit work hours to minimise fatigue
- Operators must not wear loose clothing or clothing having a drawstring, and should tie back long hair
- No person, worker or bystander should be permitted to approach the machine while it is in operation
- All guards should be in place during operation and be replaced after opening or for maintenance
- Where there is a blockage to flow the auger should optimally be shut down.
- Blockages should never be cleared using hands or feet
- Two people should be on the worksite while operating the posthole digger
- Plans for relocation of augers should include attention to the risks associated with overhead power lines, and routes selected to eliminate risk. A leaflet has been supplied by Country Energy NSW that provides advice regarding safe operation of equipment around power lines.

6.8.2. Training of operators

There are two levels of training that are required:

- Farmer/manager training that manages the risk associated with operation of grain and feed augers by identifying hazards associated with operation of the equipment, and the system of work, provides safe equipment and ensures that operators are trained in safe operation.
- Operators need specific training and skill top ensure that the operation is undertaken in a safe manner

Education strategies alone are unlikely to reduce the risk.

More than fifty years ago Young and Ghormley (1946) were convinced that "a*n educational program for the farmer is the first step in decreasing the number of accidents on the farm"*. Fifty years later, researchers are still calling for farmers to be educated. Shutske and Ohmans (1995) suggest that education is an approach favoured by health and safety promoters because they are seen to be doing something, and success can be measured by attendance and publicity generated. However, they point out that there is evidence to suggest that educational events that simply present injury statistics, descriptions of specific hazards and safety information do little to change hazardous behaviours. Similarly, Fragar and Coleman (1997) suggest that the broad availability of farm health and safety hazards data do little to improve the adoption of recommendations for reducing injury on farms. In addition knowledge of the size of the injury problem does not "equip farmers to be able to prevent injury", and may in fact add to the stress already faced by farmers.

The difficulty of changing attitudes to safety through education was demonstrated by Carrabba *et al.* (2000) in their study of the impact of the Indiana 4-H tractor program on safer tractor operating behaviour and attitudes of youth. While they found that participants in the program demonstrated safer and more skilful tractor operation than a control group of non 4-H operators, they did not find any significant difference in attitude to tractor safety between the two groups.

Cole (2002) believes that farm safety education efforts to influence the behaviour of farmers have failed because of their focus on presenting safety instructions and messages. He believes that the transmission of knowledge alone is not effective in changing behaviours, and suggests that safety education efforts have to be *reconceptualized* to take into account the *beliefs, intentions, tools and actions of social groups and communities*, in order to effectively change attitudes and behaviours. For example, an auger-related fatality may be reported in the local news as an "unlucky accident", implying that luck rather than the lack of guards was the reason for the accident. This reinforces the farmer's perception that factors beyond his/her control are at play, it does not prompt him/her to question safety practices except to reinforce the need to be careful in his/her current practice.

Earlier, Shutske and Ohmans (1995) recognised the influence of socio-economic factors on the impact of safety education efforts. They believe that behavioural change is more likely to occur through an educational approach that is part of a broad based community intervention. For example, they argue along the line that even if a farmer, who attends an educational session, is convinced that an "auger-safe" modification is a good idea, the farmer may not go ahead with the modification if the cost is excessive, or the item is not readily available. Conversely, the farmer may be more willing to make a change if the cost is subsidised in some way, or if the local machinery dealer participates in the session and makes it easy for farmers to take the next step in the process of change.

The focus on education also suggests a reluctance to use other less popular risk minimisation strategies such as enforcement or more expensive strategies such as subsidisation. The tractor roll-over protection campaign serves as an excellent example of an appropriate mix of carrot and stick to achieve its aims. However, whether or not it is as applicable in this case is doubtful as the auger injury picture is significantly different to tractor roll-overs.

6.8.3. Enforcement

Given the large proportion of unshielded augers on farms (White 2002b), farmers do not appear to be seriously concerned about the hazards associated with auger use, and there has been no serious attempt to enforce applicable statuary OH&S requirements (Gunningham 2002). However, the issue of compliance and the balance between *persuasion and punishment* is under consideration in the review of Queensland's Workplace Health and Safety Act (DIR 2001).

6.8.4. Personal protective equipment

Personal protective equipment that is required for grain and feed auger operation includes hearing protection and steel capped boots.

Recommendations

The following recommendations are made to the Farmsafe Australia Machinery Safety Reference Group for the reduction of risk associated with the operation of grain and feed augers:

1. That information material be prepared outlining the hazards associated with the operation of grain and feed augers and correct operating procedures to be followed to reduce those hazards, and that these materials be made readily available to rural workers. These materials should include information relating to guarding and modifications that may be possible to be carried out on existing machines.

   Manufacturers should be consulted and asked to participate in the development of such material. The document should be developed as a nationally endorsed Guidance Note.

2. That auger manufacturers be encouraged to ensure that the machines achieve the highest possible safety standards, and that safe operation be actively promoted by sales personnel and via improved operator's manuals.

   Operators should be made aware of those risks that the manufacturer has not been able to eliminate, and to ensure they do not use the machine in a way that will create new risks.

3. That suppliers ensure that safety information is provided to buyers of augers. The design and fitting of safety features is of little use unless sales personnel are required to discuss safety issues with customers, and emphasise the importance of features such as guards and cut out switches.

That an Australian Standard be prepared for the design of grain augers, establishing a level of safety that is economically achievable.

The available standards either do not provide adequate personal safety (eg. ASAE S361.3) or they are unclear, confusing and impractical (eg. AS 4024.1). A standard is required that provides not only performance specifications, but also clear examples of how the requirements of the standard can be met. For example, specific mesh guards, flexible flights, or other ideas deemed to comply. It should also make provision for the testing and inclusion of future innovations.

That a program of enforced compliance for guarding be undertaken by state work health authorities

Currently, the modifications required to make older augers comply with standard ASAE S361.3 are quite simple and inexpensive. The installation of a mesh guard over the exposed part of the auger flight, and guards over drive components is not beyond the fabrication skills of most farmers. However, guards that comply with ASAE S361.3 may not comply with AS 4024.1. In fact it is difficult to make a practical guard for a mobile auger that complies with the Australian Standard. Consequently, it seems reasonable to assume that any action to enforce compliance should occur only after appropriate standards are available.

That a program of subsidisation of retrofitment of improved guarding be undertaken. Given the apparent success of the ROPS Retrofitment Rebate schemes in Victoria and NSW, some subsidisation of the cost of modification of augers would appear to make modification of existing augers more acceptable to the farming community. However, gauging the level of subsidy that will provide sufficient incentive without over-capitalising old equipment is difficult.

As the auger flight is the part most involved in auger-related injury, subsidising the cost of appropriate guarding or the use of flexible flight devices at the exposed flight area of augers could result in significant reduction in the number and severity of auger-related injuries.

That promotion programs be developed to promote safe operation of grain augers.

Based on responses to tractor safety field days run by the department of Workplace Health and Safety in South East Queensland, it is reasonable to expect that similar well developed and presented courses for auger manoeuvrability and overturning would be equally successful.

That research into improved auger design for safety be undertaken

The allocation of funds for competitions for "Ideas to make augers safer", at regional, State and Federal levels may harvest practical ideas from those who use augers, as well as generate positive interest in auger safety issues at the user level.

Funding should be made available to adequately test new ideas so that guards and other devices not only provide an adequate level of safety, but they also do so in a manner that is acceptable to the user.

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Appendix 1: Focus Meeting Questionnaire

University of Queensland
Grain auger safety research project

Focus Group Meeting 20 March 2002

TO START YOU THINKING……..

Thank you for your interest in this project. Before we start discussion it would be appreciated if you could provide answers to the following questions.

1. Your experience with grain augers
   Are you
   - A user of grain augers — YES/ NO
   - Other interest (Describe) — YES………………………………………

2. **If you are a user, how often do you use an auger?**..

3. If you are a user, what type of auger do you use?

Mobile auger	YES/ NO
Fixed auger	YES/ NO
Field bin auger	YES/ NO
Sweep auger	YES/ NO
Header auger	YES/ NO
Portable auger	YES/ NO
Mixing auger	YES/ NO
Other (Describe)	…………………………………………

4. Have you experienced or observed an injury or frightening near miss while using an auger?
   YES/ NO
   If YES, what happened?

5. What do you think is the greatest danger associated with grain augers?

6. How could the use of grain augers be made safer?

THANK YOU