



An Australian Government Initiative



FARM MACHINERY INJURY

Power take-off shaft guards

A report for the Rural Industries Research
and Development Corporation

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Farm Machinery Safety: Power Take-Off Shaft Guards

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Foreword

Power take-off (PTO) related injury occurs on Australian farms and is associated with serious injury and sometimes death. The research investigates the causes of PTO injury nationally and internationally. Implementation of the recommendations will improve PTO operation and reduce injury and death on Australian farms.

The key findings of the research are that PTOs are reasonably safe when new. However, they are vulnerable to wear and tear in the course of normal use which can make them unsafe.

It is recommended that the Australian Standard for PTO shaft guards be reviewed. It should incorporate international developments in improved testing standards that take into account design, materials used to manufacture guards and the effects of UV radiation, heat and cold, dust and salt on the durability of guards.

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Contents

Foreword.....	iii
Executive Summary	v
1. Introduction	1
2. Aim	v
3. Method	2
4. Findings	3
4.1. Guard Types.....	3
4.1.1. Non-Rotating guards	3
4.1.2. Rotating guards	3
4.1.3. Fixed or cover-type guards.....	3
4.2. Australian standard for PTO safety guarding	3
4.3. Damage to guards	4
4.3.1. The literature	4
4.3.2. Results of current inspections and discussions.....	6
4.4 Guard Materials	6
4.4.1. PTO shaft guards in Australia	6
4.4.2 HSE reports relating to guard materials	7
5. Discussion	8
5.1. Strategies for minimising damage to guards include:	8
5.1.1. Improved operator awareness and skill	8
5.1.2. Improved guard design and guard materials	8
5.1.3. Enforcement	8
6. Recommendations of the Machinery Safety Reference Group	9
7. References	9

Executive Summary

Background

Since its introduction in the late 1920s as a key mechanism for transfer of power from tractor to machine, the power take-off (PTO) shaft has been involved in large numbers of serious and disabling entanglement accidents, many resulting in death. Over the last 70 years or so a variety of guards, shields and couplings have been designed to try to eliminate or minimise the risk of entanglement.

Who the report is targeted at

The report is targeted at policy makers, farmers, machinery manufacturers and resellers.

Aim

This report briefly examines the problems associated with PTO shafts guards and considers options for improvement by:

- describing the materials currently used in PTO shaft guards.
- defining problems associated with current materials used in manufacture of PTO shaft guards
- identifying options for improved materials
- making recommendations for improved materials

Methods used

Key word literature searches were conducted via WebSPIRS and Google using key words such as Agricultural equipment suppliers, power take off shaft, PTO shaft, PTO guards, Guard manufacturers, PTO manufacturers, and PTO suppliers. Farmers were interviewed and their machinery was inspected for damage to protective housing around the PTO.

Results

The research shows that the design of most guards is probably satisfactory for providing a reasonable reduction in the risk of injury during the short period when they are new and undamaged. However, it seems difficult to find a perfect solution for guards that operate in a very aggressive environment. Physically, guards crash, rub and push against each other and other parts such as draw bars, frame members and linkage arms. In addition, they rust, age, become brittle and simply perish due to exposure to the elements. On farms, PTO guards can quickly become damaged and then make connection difficult and or increase the risk of injury. As a result, many guards are removed and not replaced. The farmers interviewed were not aware that PTO guards can be replaced cheaply and easily.

The Australian experience of PTO guard damage is consistent with UK findings.

The results of the research have been considered by the Farmsafe Australia Farm Machinery Safety Reference Group and action based on the report findings and the responses from Australian suppliers and operators have been implemented.

Recommendations

Strategies for minimising damage to guards include working with farmers to:

- Improve operator awareness and skill in working with PTOs
- Encouraging farmers to maintain accepted levels of safety and to replace damaged guards.

Manufacturers should be encouraged to improve guard design and guard materials.

The report recommends that Standards Australia be requested to undertake a review of Standard AS 1121-1983 in light of:

- Development of newer guarding systems
- Developments in the plastics industry
- Need for testing of guarding systems to account for UV radiation, heat and cold, dust and salt

1. Introduction



Figure 1.1 Clip-held removable Master Guard covering the connection of PTO shaft to tractor PTO.



Since its introduction in the late 1920s as a key mechanism for transfer of power from tractor to machine, the power take-off (PTO) shaft has been involved in large numbers of serious and disabling entanglement accidents, many resulting in death. Over the last 70 years or so a variety of guards, shields and couplings have been designed to try to eliminate or minimise the risk of entanglement.

Tractor “master guards” (Figure 1.1) cover the universal coupling joining the tractor and PTO shaft. Similar implement guards (Figure 1.2) are used to shield the coupling joining the PTO shaft to the implement, and the PTO shaft itself is enclosed in telescoping tubes to isolate it from people (Figure 1.3).

It was the experience of farmer and other representatives of the Farm Machinery Safety Reference Group that the PTO shaft guard was missing or damaged on at least one item of machinery on many if not most farms in Australia, despite there being occupational health and safety regulations requiring PTO guarding to be in place.

This report briefly examines the problems associated with PTO shafts guards and considers options for improvement.

Figure 1.2 The red circular metal guard covers the universal coupling joining the PTO shaft to the implement. Note the restraining chain and method used to stop the PTO shaft from falling onto the implement.



Figure 1.3: Generic PTO shield composed of : two telescoping black poly pipes or tubes, yellow bellows-like cones at each end, white nylon expandable bearings that clip into a groove on each end of the shaft, red plastic locking clips that lock the guard to the bearing, and restraining chains to stop the guard from rotating.

2. Aim

This report briefly examines the problems associated with PTO shafts guards and considers options for improvement:

- To describe the materials currently used in PTO shaft guards.
- To define problems associated with current materials used in manufacture of PTO shaft guards
- To identify options for improved materials
- To make recommendations for improved materials

3. Method

Manufacturers and suppliers of PTO shafts and PTO shaft guards were contacted either directly or via searches on the Internet.

Key word literature searches were conducted via WebSPIRS and Google using key words such as Agricultural equipment suppliers, power take off shaft, PTO shaft, PTO guards, Guard manufacturers, PTO manufacturers, and PTO suppliers.

Documents from the Health and Safety Executive of the United Kingdom relating to PTO shaft guards were downloaded and examined.

Informal discussions (either face to face or by telephone) were held with 10 farmers, 3 agricultural engineers and 3 local farm machinery suppliers in Queensland. Farmers were from a range of farm types including grain farming, intensive livestock farming and horticultural farming. They were selected as they were known to the author and were willing to contribute to the study.

Master, implement and PTO shaft guards were inspected on the farm, at the machinery-suppliers premises and at two agricultural field days.

4. Findings

4.1. Guard Types

4.1.1. Non-Rotating guards

The guard consists of two telescopic (usually plastic) tubes attached to the shaft via bearings at each end. As guards are not normally supplied with restraining devices, a “dog” chain and clip is often used on each end to stop the guard from rotating with the shaft. In practice, chains are often too short to accommodate the range of movement required, and they are pulled off the guard. As a result the guard can rotate and act as a “rotating” guard. This type of guard was predominantly available on the new and older equipment inspected.

4.1.2. Rotating guards

These rotate with the PTO shaft but stop if a person or object contacts the guard. Only two guards of this type were inspected.

4.1.3. Fixed or cover-type guards

These are generally used in situations where the shaft is fixed relative to the implement. For example, some hay balers have a conventional PTO shaft drive from the tractor to a point on the baler and then a fixed shaft extending beyond this point. This PTO shaft extension may be protected by a guard connected to the implement rather than the shaft.

4.2. Australian standard for PTO safety guarding

The relevant Australian standard to which manufacturers supplying PTO shaft guards for use in Australia is AS 1121-1983: *Guards For Agricultural Tractor PTO Drives*. This current standard was published in 1983 and was first published in 1971.

AS 1121-1998 broadly refers to a PTO guard that conforms to the design in Figure 1.1 of the Standard that is copied here as Figure 4.1.

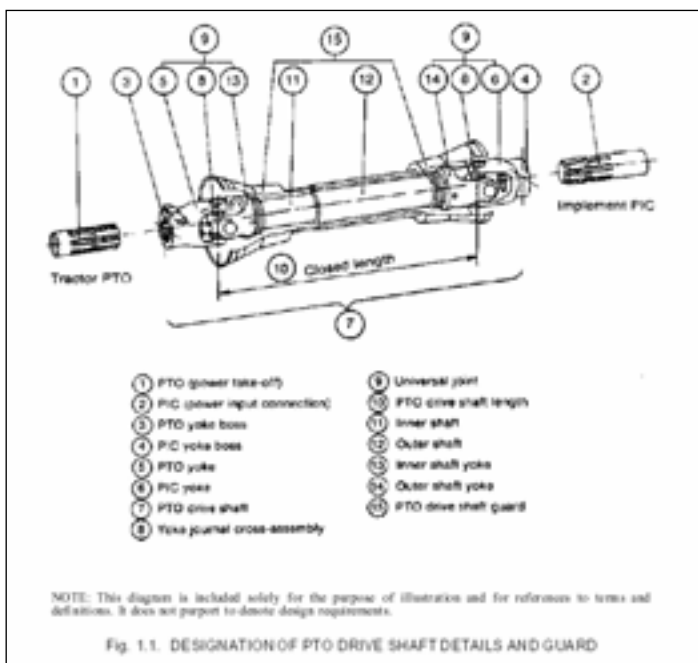


Figure 4.1: Design type of PTO drive shaft and guard to which Standard AS 1121-1983 refers

The Standard specifies requirements for either rotating or non-rotating PTO shaft guards, and specifies performance requirements in relation to:

- General (relating to testing procedures)
- Axial loading
- Radial loading
- Freezing
- Impact performance
- Non-distortion of the restraining member for non-rotating guards

In relation to materials, the Standard specifies as follows:

“Guards shall be constructed from materials capable of complying with the requirements specified in Section 2, Section 3 or Section 4, as appropriate.”

NOTE: Where guards are constructed from plastics material, the plastics should be a type that is known to be resistant to deterioration

due to the effects of exposure to sunlight or to high ambient temperatures.

AS 1121-1983 Section 1.5

4.3. Damage to guards

Damage to guards is a serious consideration as damaged guards may pose a greater risk of entanglement if they are damaged in a way that results in access to points of entanglement, or if the guard tightens on the shaft and they rotate as one. In addition, damaged guards that interfere with connection to the tractor or implement or with service to the shaft are often removed and not replaced.

4.3.1. The literature

In a survey of about 200 PTO powered implements in the UK, Tinker et al(1992) found that almost 70% still had their original guard, while about 25% had replaced either part of the guard, the whole guard or the complete shaft. The reason for the survey was to investigate causes of damage to guards in order to make test procedures “more representative of actual usage and, thereby, help to ensure that guards passing the tests will be more durable in service”. Results of the survey showed that:

Over half of guard tubes were damaged by contact with the frame, drawbar or lower link, or by being knocked in some other way. 5% of tubes could not telescope, a further 5% were tight and difficult to telescope and 22% were sticky. Of the remaining 68%, only 5% were regularly greased to facilitate sliding.

- Almost 40% of guard cones were damaged by rubbing on the master or implement guards, or on other parts of the implement, or by being cut to allow for greasing of universal joints.
- About 30% of shaft guard bearings were damaged.
- Only 40% of restraining chains were still in place, although only about 5% of the restraining eyes were broken.

The conclusions of Tinker et al are relevant to this Australian review report, and are reproduced on the next page.

6. Conclusions

Pto shaft guards are often used in a damaged or incorrectly fitted way. This investigation found some damage on 156 pto shaft guards used on the 201 implements inspected (78%). Not all damage was serious but it was estimated that the guards on 33% of pto driven implements needed immediate attention. The main faults for immediate attention were bearings, on 26% of machines, cones (12%) and tubes (11%).

Restraining devices are rarely intact, only 32% of guards had one at the tractor end and 48% had one at the implement end.

Simple tests on the load that can be transmitted by a restraining chain showed that the present 400N test standard can be exceeded by nearly three times for a poorly lubricated guard used at 1000 rpm, and nearly twice if used at 540 rpm. A single "snatch" can open the chain "S" link connector sufficiently for the chain to drop off during transport.

Guards are poorly maintained as is demonstrated by only 31% of guard bearings showing signs of having been lubricated.

Overall 29% of the shaft guard bearings were damaged or out of position. It was difficult to determine why but, apart from poor maintenance, the main causes appear to be:

- forced off when greasing UJ bearings
- dropped or rested on to cone when stored
- being forced against the master guard, clutch or frame during transport or operation
- high frequency axial loading caused by telescoping of tight tubes
- tubes locked or frozen together
- incorrect fitting, or refitting.

Damage was found on 38% of the cone guards and was caused by rubbing the master guard, particularly that of the implement, being cut to reach the UJ grease nipple or being incorrectly supported during storage or transport.

Half of the implements seen had at least one damaged tube. The damage was caused mainly by the lower links (20%) and implement frames (20%) and by other knocks.

4.3.2. Results of current inspections and discussions

All guards examined on Queensland farms other than new guards had some sign of damage. In most cases, damage was minor and ranged from scrapes, rubbing, small dents (that did not appear to interfere with sliding), missing restraining chains, and broken restraining eyelets. One steel PTO guard examined, whilst still serviceable, had minor dents and signs of rotation scrapes. The other steel guard was dented so that it could not freely rotate on the shaft.

Table 4.1 shows that of the 66 implements inspected on farms, 34 (52%) PTO shafts were unshielded, and shafts were generally left unshielded after removing damaged guards. In addition the master guard on three tractors was missing, and all but one of the others were dented and damaged.

Table 4.1: Results from inspection of 10 farms and 2 Machinery Suppliers

Farm/Location	Number of PTO driven Implements	Number without PTO shaft Guards	Nature of damage to guards
Sheep	3	0	Well maintained
Grain & Horticulture	9	9	Damaged guards removed and not replaced
Horticulture/ Hay	8	0	Minor scrapes and scratches, several restraining chains missing
Horticulture/ Grain/Hay	12	0	Minor scrapes and scratches, several restraining chains missing
Mixed	9	8	Damaged guards removed and not replaced
Grazing	3	3	Damaged guards removed and not replaced
Hay	4	2	Minor scrapes and scratches. Damaged guards removed and not replaced.
Intensive animal/Grain	5	5	Damaged guards removed and not replaced
Grain	8	7	One new implement. Other damaged guards removed and not replaced.
Grain	5	0	Minor scrapes and scratches
Total	66	34	
Machinery sales depot	Numerous	Approx 25%	Brittle fractures, dented, cut, parts missing,

All farmers agreed that much of the damage to PTO shafts could be minimised through greater care when connecting, using and disconnecting implements. However they pointed out that in some cases the design of the master guard or the implement linkage mounting was such that it was easy for the PTO shield to contact the guard or the implement when raised. Similarly, the drawbar arrangement made contact possible in the lowered position.

4.4 Guard Materials

4.4.1. PTO shaft guards in Australia

Master and implement shields have and continue to be made of steel and developments seem to have been limited to designing them to be hinged or otherwise moveable to allow access for connection of the PTO shaft. One new tractor had a hinged guard that could be moved to 3 spring-loaded positions. It was easily lifted from the horizontal position to about 45 degrees above horizontal and then again to just less than vertical. This ability to be lifted out of the way provided easy access for connecting the PTO, and the ability to keep it at a partially closed position if there was any chance of contact with the PTO shield. In addition, some new guards have a meshed section to allow the operator to see the shaft and make alignment with the implement easier.



Figure 4.2: Steel PTO guard. Note resting hook to support PTO when not in use, and avoid damage by dropping onto the drawbar below.

Shields or guards to the PTO shaft have consisted of metal (Figure 4.2) or plastic (Figure 4.3) telescopic tubes over the shaft connected to conical or spherical guard cones over the couplings.

Today, plastic is the most common material used to make PTO shields, and many of the early design problems associated with joint of cones to shafts, and lubricating bearings have been improved. Also, plastic is replacing steel for the guards on many new implements. In addition manufacturers continue to search for plastics more suited to the requirements of these components.



Figure 4.3: Plastic PTO shaft guard.

Polyethylene telescoping shafts (usually black to resist UV degradation) have the advantage of being very cheap, moderately flexible and capable of withstanding some physical abuse. A more flexible, usually yellow, version is used in bellows form for the cones, while bearings are normally of nylon.

Owners' comments

Owners felt that replacement of PTO shields was less important on some items of equipment than for others. They felt that PTO entanglement was less likely with linkage mounted implements such as slashers, rotary hoes and fertiliser spreaders than with drawbar mounted implements such as balers, and stationary items such as PTO driven hammer mills, grain driers, augers and post-hole augers. PTO shafts on drawbar mounted implements, such as balers (Figure 4.4), tend to be relatively long and provide more opportunity for entanglement. Stationary items such as driers and augers are worse because the operator or an assistant can move around and close to the PTO shaft.

Most participants were unaware of the cost of replacement PTO shields or complete shaft and shield assemblies.

They seemed genuinely surprised at the relatively low replacement cost.

Most were not aware that new PTO shaft guards were relatively easy to replace or that new shields were made of polythene and were now UV stabilised.



Figure 4.4: PTO transmission system for a rectangular hay baler.

4.4.2 HSE reports relating to guard materials

In 1999 a report was commissioned by the HSE in light of planned revisions to ISO 5674 - the International Standard for Power take-off shafts for Agricultural Tractors and their guards (Seward and O'Niell, 1999). A further report was prepared in 2001 with a view to determining better test standards that take into account the materials used to manufacture guards, the actions of physical agents such as UV radiation, dust and salt spray on the guard, and current designs of PTO shaft guards.

Recommendations were made for improved testing standards to apply.

5. Discussion

The Australian findings are generally in line with those reported in the three key documents commissioned for the HYSE in the UK.

The design of most guards is probably satisfactory for providing a reasonable reduction in the risk of injury during the short period when they are new and undamaged. However, it seems difficult to find a perfect solution for guards that operate in a very aggressive environment. Physically, guards crash, rub and push against each other and other parts such as draw bars, frame members and linkage arms. In addition, they rust, age, become brittle and simply perish due to exposure to the elements. On farms, PTO guards can quickly become damaged and then make connection difficult and or increase the risk of injury. As a result, many guards are removed and not replaced.

In an ideal situation, the tractor and implement would be perfectly matched to avoid any possibility of contact between the PTO shaft and any other component, guards would be made of indestructible materials capable of withstanding extreme loads and abuse, and they would never obstruct attachment or maintenance. In addition, operators would be well trained, careful and sensitive to the limitations of the equipment.

In practice, operators seem indifferent to the limitations of equipment, and therefore the cost of equipment (and material) is still a major design and purchase consideration.

5.1. Strategies for minimising damage to guards include:

5.1.1. Improved operator awareness and skill

Operators need to be made aware of the need to handle equipment with care. Apart from the obvious skills required for efficient production, operators need to be skilled in carefully connecting and disconnecting implements to avoid damage to PTO shields. There is no need to disconnect the PTO from the tractor and drop it, so that it crashes against the implement. In addition, they need to be aware of the limits of movement of linkage mounted equipment, in order to avoid contact of PTO shields with guards and other parts of the tractor or equipment.

Maintenance of “non-essential” items such as PTO shields is another area that is easily left for later and then neglected. Operators should be made aware that proper maintenance, such as cleaning and lubricating bearings, increases shield life and ensures safe and easy operation of the shield.

5.1.2. Improved guard design and guard materials

There seems to be reasonable scope for improving tractor master and implement guards, in order to reduce the chance of contact with and damage to PTO guard cones and tubes. Plastic guards on some new implements indicate that manufacturers are aware of problems in this area. Some tractors are equipped with well designed hinged master guards, but many others still have rigidly fixed guards that are unlikely to be replaced once removed.

Well-designed top-link support brackets and stops would help reduce the chance of the top-link dropping onto the master guard, cone or shaft, and thus minimise damage to those parts.

Plastics such as Polypropelene, Polyuerethane and other materials may be better able to resist contact damage, but at this stage cost may be a limiting factor as the current “after market” polyethelene shields are very inexpensive.

5.1.3. Enforcement

As shields are currently not essential for equipment operation, and until a PTO shaft is designed in such way that it will not operate unless the shield is in place and in good condition, damaged PTO shields will continue to be removed and not replaced.

Farmers, like most people need to be encouraged to maintain accepted levels of safety. Traffic policemen and speed cameras would be unnecessary if everyone voluntarily obeyed road rules. In this case, farmers have no incentive to replace a non-essential item for the PTO. However, as current PTO shields are very cheap, they are well made, they are easy to install and remove, and they are reasonably durable if properly cared for, there seems to be no reason for not having every PTO shielded. Until farmers are encouraged to maintain workplace health and safety requirements, they will continue to have unshielded PTOs.

6. Recommendations of the Machinery Safety Reference Group

The Machinery Safety Reference Group has considered the brief report and notes:

- The Australian Standard for PTO shaft guards has not been reviewed since 1983.
- Internationally there have been developments in defining improved testing standards for PTO shaft guards, taking into account design, materials used to manufacture guards and the effects of UV radiation, heat and cold, dust and salt on durability of guards.
- Australian experience of PTO guard damage is consistent with UK findings
- PTO related injury occurs on Australian farms and is associated with serious injury and sometimes death.

It is recommended:

That Standards Australia be requested to undertake a review of Standard AS 1121-1983 in light of:

- Development of newer guarding systems
- Developments in the plastics industry
- Need for testing to account for UV radiation, heat and cold, dust and salt

The Tractor and Machinery Association of Australia has undertaken to collate further information will be collated and will circulate this paper to members to assist.

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