

Power Take-Off (PTO) Safety¹

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The Power Take-Off (PTO) shaft is an efficient means of transferring mechanical power between farm tractors and implements. This power transfer system helped to revolutionize North American agriculture during the 1930's. It is also one of the oldest and most persistent hazards associated with farm machinery. This fact sheet discusses several aspects of PTO safety.

COMPONENTS OF AN IMPLEMENT POWER TAKE-OFF

Figure 1 is a diagram of component parts of an implement PTO. Two typical PTO system arrangements are shown. These drawings are helpful for understanding PTO hazards, guarding, and injuries. The top drawing is of a PTO system involving a pedestal connection, such as is found on many types of pulled machinery (hay balers, forage choppers, large rotary mowers, etc.). The lower drawing is of a PTO system where the implements input driveline connects directly to the tractor PTO stub. Examples of this type of connection include three-point hitch mounted equipment (post hole diggers, small rotary mowers, etc.) and augers.

PTO HAZARDS

The following parts of the PTO have been found to be hazardous.

Power Take-Off (PTO) Stub

The tractor's stub shaft, often called the PTO, transfers power from the tractor to the PTO-driven machine or implement. Power transfer is accomplished by connecting a drive shaft from the machinery to the tractor's PTO stub shaft. The PTO and drive shaft rotate at 540 rpm (9 times/sec.) or 1,000 rpm (16.6 times/sec.) when operating at full recommended speed. At all speeds, they rotate in proportion to the speed of the tractor engine.

Most incidents involving PTO stubs stem from clothing caught by an engaged but unguarded PTO stub. The reasons a PTO stub may be left engaged include: the operator forgetting or otherwise not being aware the PTO clutch is engaged; seeing the PTO stub spinning but not considering it dangerous enough to disengage; or, the operator is involved in a work activity requiring PTO operation. Boot laces, pant legs, overalls and coveralls, sweat shirts, and windbreakers are clothing items that can become caught and wrapped around a spinning PTO stub shaft.

Power Take-Off (PTO) Drivelines

The PTO driveline hazard (sometimes identified as a machinery wrapping point hazard) is one of the oldest and most common farm machinery hazards, and refers specifically to the part of the implement (machine) drive shaft that connects to the tractor. This drive shaft is

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known as the implement input driveline (IID). The entire IID shaft is a wrapping point hazard if the IID is completely unshielded. If the IID shaft is partly guarded, the shielding is usually over the straight part of the shaft, leaving the universal joints, the PTO connection (the front connector), and the Implement Input Connection (IIC, the rear connector) as the wrapping point hazards. Protruding pins and bolts used as connection locking devices are particularly adept at snagging clothing. If clothing doesn't tear or rip away, as it sometimes does for the fortunate, a person's limb or body may begin to wrap with the clothing. Even when wrapping doesn't occur, the affected part may become compressed so tightly by the clothing and shaft that the person is trapped against the shaft.

The machine's IID shaft is coupled to the tractor's PTO stub. Therefore, it too rotates at either 540 rpm (9 times/sec.) or 1,000 rpm (16.6 times/sec.) when at full recommended speed. At these speeds, clothing is pulled around the IID shaft much quicker than a person can pull back or take evasive action. Many IID shaft entanglements happen while the shaft is turning at one-half or one-quarter of recommended operating speed. This may be the situation on occasions when the tractor has been stopped but not turned off, and the PTO is left engaged. Why an operator might do this is discussed in the paragraph below. The point here is that even at slower speeds, once caught by a IID shaft, a person may not have time for evasive action. A 540 rpm shaft makes over two complete revolutions per second when operating at one-quarter speed. Even with a relatively quick reaction time of five-tenths of a second, the wrapping action has begun. Once wrapping begins, the person instinctively tries to pull away. This action simply results in a tighter, more binding wrap. The 1,000 rpm shaft roughly cuts in half the opportunity for evasive action.

PTO powered machinery may be engaged while no one is on the tractor for many reasons. Some PTO powered farm equipment is operated in a stationary position: it needs no operator except to start and stop the equipment. Examples are elevators, grain augers, and silage blowers. At other times, adjustments or malfunctions of machine components can only be made or found while the machine is operating. Additionally, many work practices such as clearing crop plugs leads to operator exposure to operating PTO shafts. Other unsafe practices include mounting, dismounting, reaching for control levers from the rear of the tractor, and stepping across the shaft instead of walking around the machinery. An extra rider while PTO powered machinery is operating is another exposure situation.

The wrapping hazard is not the only hazard associated with IID shafts. Serious injury has occurred when shafts have become separated while the tractor's PTO was engaged. The machine's IID shaft is a telescoping shaft. That is, one part of the shaft will slide into a second part. This shaft feature provides a sliding sleeve which greatly eases the hitching of PTO powered machines to tractors, and allows telescoping when turning or moving over uneven ground. If a IID shaft is coupled to the tractor's PTO stub but no other hitch is made between the tractor and the machine, then the tractor may pull the IID shaft apart. If the PTO is engaged, the shaft on the tractor end will swing wildly and may strike anyone in range. The swinging force may break a locking pin allowing the shaft to become a flying missile, or it may strike and break something that is attached or mounted on the rear of the tractor. Separation of the driveline shaft is not a commonly occurring event. It is most likely to happen when three-point hitched equipment is improperly mounted or aligned, or when the hitch between the tractor and the attached machine breaks or accidentally uncouples.

PTO ENTANGLEMENT INCIDENTS

This information is taken from the Purdue University source listed at the end of this fact sheet. This reference is the most comprehensive study of power take-off injury incidents to date. The percents shown include fatal and nonfatal injury incidents, and are best thought of as approximations. Generally, PTO entanglements:

- involve the tractor or machinery operator 78 percent of the time.
- shielding was absent or damaged in 70 percent of the cases.
- entanglement areas were at the PTO coupling, either at the tractor or implement connection just over 70 percent of the time.
- a bare shaft, spring loaded push pin or through bolt was the type of driveline component at the point of contact in nearly 63 percent of the cases.
- stationary equipment, such as augers, elevators, post-hole diggers, and grain mixers were involved in 50 percent of the cases.
- semi-stationary equipment, such as self unloading forage wagons and feed wagons, were involved in 28 percent of the cases.

- nearly all incidents involving moving machinery, such as hay balers, manure spreaders, rotary mowers, etc., were non-moving at the time of the incident (the PTO was left engaged).
- only four percent of the incidents involved no attached equipment. This means that the tractor PTO stub was the point of contact four percent of the time.

PTO GUARDS

Guarding a PTO system includes a master shield for the tractor PTO stub and connection end of the implement input driveline (IID) shaft, an integral-journal shield which guards the IID shaft, and an implement input connection (IIC) shield on the implement. The PTO master shield is attached to the tractor and extends over and around the PTO stub on three sides (Figure 2). This shield is designed to offer protection from the PTO stub and the front joint of the drive shaft of the connected machine. Many tractors, particularly older tractors, may no longer have PTO master shields. Master shields are removed or are missing from tractors for several reasons including: damaged shields that are never replaced; shields removed for convenience of attaching machine drive shafts; shields removed out of necessity for attaching machine drive shafts; and shields missing when used tractors are sold or traded.

There are many more injuries associated with the IID shaft than with the PTO stub. As noted earlier, machine drive shaft guards are often missing. This occurs for the same reasons tractor master shields are often missing. A IID shaft guard completely encloses the shaft, and may be constructed of plastic or metal. These tube like guards are mounted on bearings so the guard rotates with the shaft but will stop spinning when a person comes into contact with the guard. Some newer machines have driveline guards with a small chain attached to a non-rotating part of the machine to keep the shield from spinning. The most important thing to remember about a spinning IID shaft guard is that if the guard becomes damaged so that it cannot rotate independent of the IID shaft, its effectiveness as a guard is lost. In other words, it becomes as hazardous as an unguarded shaft (Figure 3). This is why it is important to always spin the IID shaft guard after attaching the PTO to the tractor (the tractor should be shut off), or before starting the tractor if the attachment has already been made. This is the best way to make sure that the IID shaft guard is really offering you protection.

PTO ENTANGLEMENT EXAMPLES

These examples of PTO injury incidents involving Pennsylvania farmers will help illustrate the serious nature of PTO hazards.

Case #1. A farmer was finished loading a load of green chop into the silo and was approaching the tractors PTO lever to turn off the forage blower. As he stepped onto the drawbar, the laces on his boot became caught on the spring loaded push pin of the forage blower PTO driveline coupling. He was thrown backwards off the drawbar, with his boot and denim trousers being forcibly removed. He suffered considerable muscle damage to his right leg.

Case #2. A teenager was helping her family load corn into a grain elevator when her jacket sleeve became entangled by the elevator PTO shaft. Her body was flung around the shaft and her arm torn from its socket before the tractor could be turned off.

Case #3. A small child was killed when as an extra rider on his fathers tractor, he slipped off and became entangled by a spinning PTO shaft. His father grabbed for the boy as he began to slip but was unable to hold him out of the shaft.

Case #4. A farmers clothing was caught by a spinning shaft, pulled him in, flung him around the shaft a couple of times, and then threw him clear. He suffered injuries to his head, leg, right arm and shoulder.

PTO SAFETY PRACTICES

Though not always easy or convenient, there are several ways to reduce the risk of PTO injury incidents. These safety practices offer protection from the most common types of PTO entanglements.

- Make it a specific point to keep all components of PTO systems shielded and guarded.
- Regularly test driveline guards by spinning or rotating them to ensure they have not become stuck to the shaft.
- Disengage the PTO and shut off the tractor before dismounting to clean, repair, service, or adjust machinery.
- Walk around tractors and machinery rather than stepping over a rotating shaft.

- Keep universal joints in phase. (Check the operators manual or with a farm implement dealer if you do not understand what this means).
- Always use the driveline recommended for your machine. Never switch drivelines among different machines.
- Position the tractor's drawbar properly for each machine used. This will help prevent driveline stress and separation on uneven terrain and in tight turns.
- Reduce PTO shaft abuse by observing the following: avoid tight turns that pinch rotating shafts between the tractor and machine; keep excessive telescoping to a minimum; engage power to the shaft gradually; and avoid over tightening of slip clutches on PTO-driven machines.

SUGGESTED REFERENCES

Campbell, W.P. 1987. *The Condition of Agricultural Driveline System Shielding and Its Impact in Injuries and Fatalities*. M.S. Thesis. Department of Agricultural Engineering, Purdue University, West Lafayette, IN.

Fundamentals of Machine Operation: Agricultural Safety. 1983. Second edition. Deere and Company, Moline, IL.

Safe Operation of Agricultural Equipment: Student Manual. 1988, Revised. Hobar Publications, St. Paul, MN.

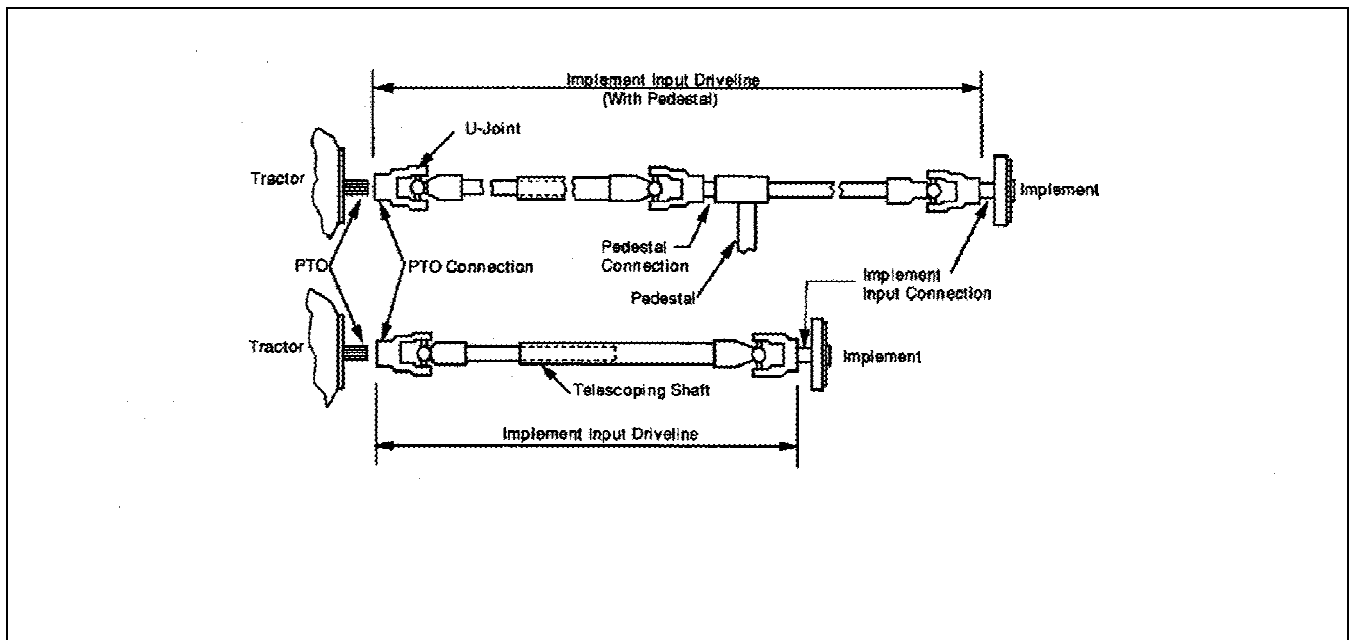


Figure 1. The major components of PTO systems.

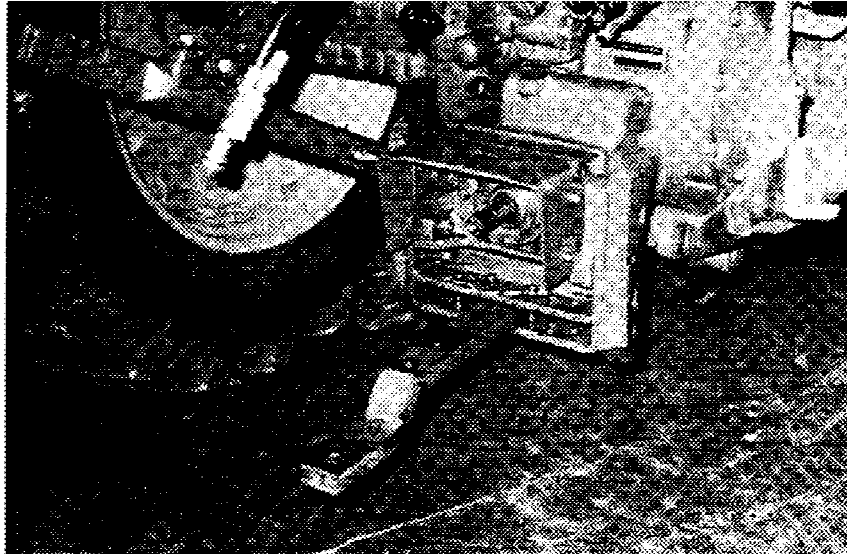


Figure 2. A master shield covering the tractor PTO stub.

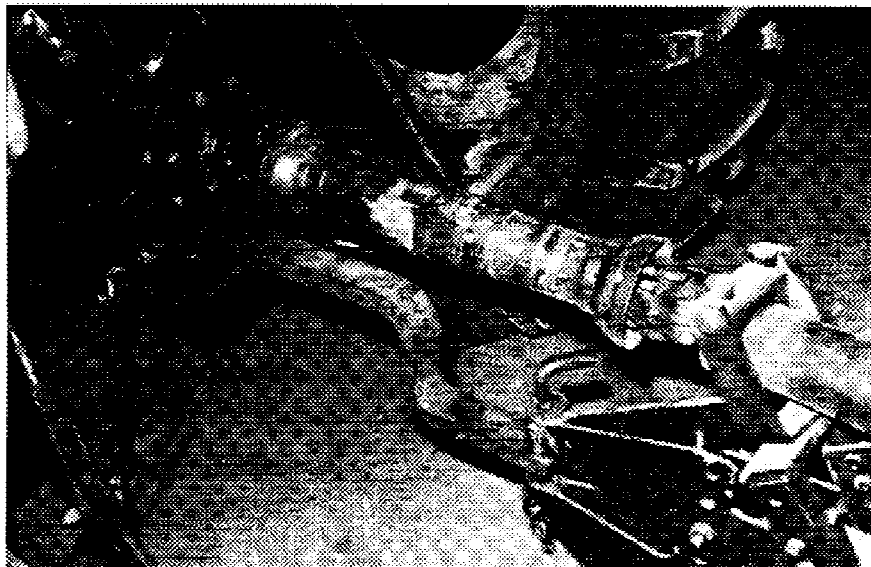


Figure 3. A bent shaft guard offers no protection from a spinning PTO shaft. Also notice the missing master shield and the inadequate guarding of the universal joint near the PTO pedestal.