PLOWSHARES #2

Breaking New Ground Technical Report

Hand Controls for Agricultural Equipment

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Introduction

The purpose of this paper is to provide suggestions, ideas and guidelines for designing and constructing hand activated controls to enable agricultural producers with physical disabilities to safely and efficiently operate their agricultural equipment. The paper focuses primarily on the conversion of foot operated controls, such as the brakes and clutch, to hand operated controls. The guidelines presented can be applied in modifying other controls such as hydraulic, throttle, and power take-off. The types of agricultural equipment that are discussed include tractors, combines, and other self-propelled machines.

Background

In 1979, Purdue University initiated a project to assist agricultural producers with physical disabilities who desire to remain actively involved in their farm or ranch operation. One of the primary goals of the project was to develop, identify, and compile practical alternative designs, modifications, and accessories to help these producers operate agricultural equipment and complete other essential farm-related tasks. One of the most frequent types of questions received by the project deals with the modification of operating controls on major pieces of agricultural equipment. For example, a farmer who is paraplegic due to a spinal cord injury cannot operate the conventional clutch and brake pedals on a tractor. A one-arm amputee has problems operating controls located on the same side of the cab or operator's console as the missing hand. A person with a back or neck injury might have trouble reaching the PTO or three-point hitch control levers, due to difficulty in turning or sharply bending his or her upper torso and neck. These are just three examples of situations calling for modifications to existing controls.

Over the past six years, the Purdue project has had the opportunity to evaluate numerous modifications to agricultural equipment. Most of those modifications have been made by the farmer, a farm family member, or a local mechanic or machinist. There has been little technical documentation completed on either successful or unsuccessful designs.[1] Because no established standard or guidelines exist for the design and construction of hand controls for agricultural equipment, concern has been raised over the quality and safety of controls that have been constructed.[2]

An extensive review of standards for automotive hand controls or hand controls in general (published by the American Society of Agricultural Engineers, Society of Automotive Engineers, American National Standards Institute, Department of Transportation and Veterans Administration) reveals that no standards apply directly to hand controls for individuals with disabilities who use agricultural equipment. However, the concepts presented by many of these standards appear to provide a useful starting point for our purposes.

Discussions with some manufacturers of adaptive aids for automotive applications suggest the following reasons why control conversion guidelines for agricultural equipment are not presently available:

1. Manufacturers of automotive-type hand controls generally are not aware of the need for control modification in the agricultural workplace.
2. There is not sufficient demand for hand controls to induce manufacturers to profitably produce them for agricultural equipment; this is probably a reflection of the tendency for farmers to make modifications themselves.
3. Because product liability issues associated with modifying agricultural equipment are not clearly defined, some manufacturers believe marketing the controls would be a risky venture.
4. Due to the diverse nature of agricultural equipment, it is difficult to design a set of controls that will fit more than one make or model of machine. Unlike most automobiles, there are no common mounting points (like the steering column) which allow design and manufacture of universal adapter sets. Exact location of tractor controls, direction of pedal travel, and force required to activate controls are other differences between tractor makes and models that make designing a universal set of controls very difficult.

Nature of Disabilities Requiring Modified Controls

Of the several physical disabilities to which the Purdue project has had exposure, spinal cord injuries are the injuries most commonly requiring the use of modified controls. The degree of paralysis from a spinal cord injury depends upon the vertical level and severity of the injury. Paraplegia, for example, is paralysis of the lower portions of the body and both legs. Quadriplegia is paralysis affecting all four limbs. The type of control design needed for individuals with these disabilities depends upon the degree of paralysis. Persons with good upper body strength and mobility can effectively use hand controls consisting of mechanical lever control assemblies. Persons with restricted upper body mobility and strength might require hand controls with small activation forces that are very conveniently located, such as toggle switches or small joysticks.

Back injuries often restrict operator mobility. In some cases, especially on older machines, hydraulic, three-point hitch and PTO control levels are inconveniently located, causing operators either to have to reposition themselves or to strain in reaching the levers as they turn, due to difficulty in turning their upper torso. Relocating levers or making lever extensions can solve this problem.

Arthritis and neuromuscular disorders limit the strength and mobility of operators. Again, controls may have to be relocated, extensions made, or hand control assemblies built.

Persons with foot or leg amputations often need to have relocated and/or hand control assemblies built.

Types of Hand Controls

Most existing hand controls for the brakes, clutch and differential lock are mechanical lever control assemblies. Mechanical lever control assemblies include lever extensions and mechanical linkages, including cable-pulley assemblies.

Lever extensions are usually constructed of either flat bar steel, steel tubing, or steel rod, and have been clamped, bolted or welded to the existing pedals. Lever extensions are usually simple and low in cost, but sometimes it is not possible to gain sufficient leverage with only a lever extension. *Figures 1 and 2* show lever extensions for tractor brakes. *Figure 3* provides an example of extensions for both the clutch and brakes. A quick attaching clutch lever developed at Purdue is shown in *Figure 4*.

Mechanical linkages are not necessarily complicated in design and may be relatively low in cost. Improved leverage can be gained through proper design of the linkages (leverage can, however, also be worse). Some examples of mechanical linkages are shown in *Figures 5 and 6*.

Less frequently used hand controls are electric or hydraulic actuators. These include electrical actuators and hydraulic cylinders which act upon the pedal linkages and only require movement of a toggle switch or hydraulic control level. These hand con-

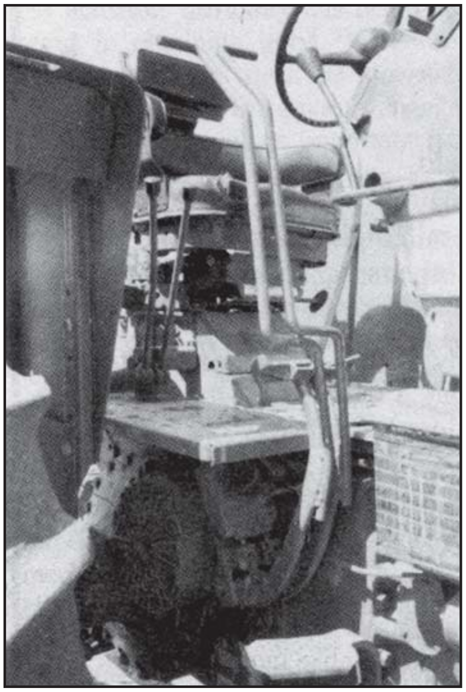

Figure 1. Brake pedal extensions constructed of barstock welded to the pedals.

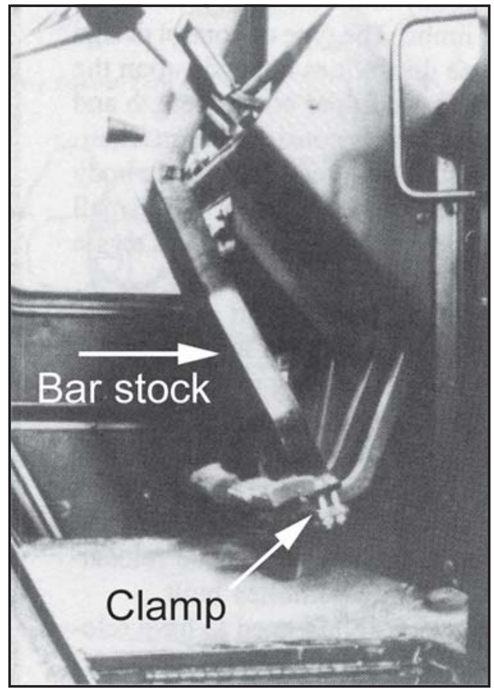

Figure 2. Brake pedal extensions constructed of flat stock clamped to the pedals.

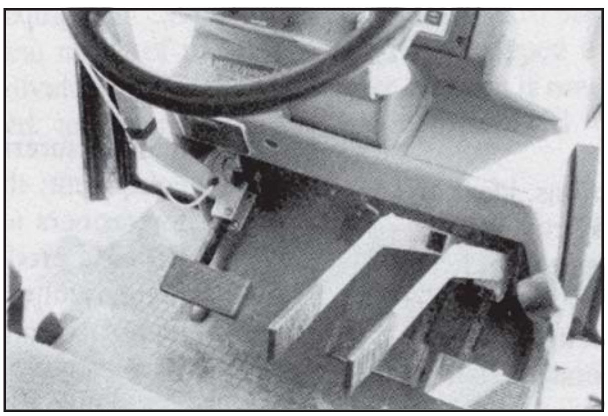

Figure 3. Clutch and brake pedal extensions constructed of tube/flat stock clamped to the pedals.

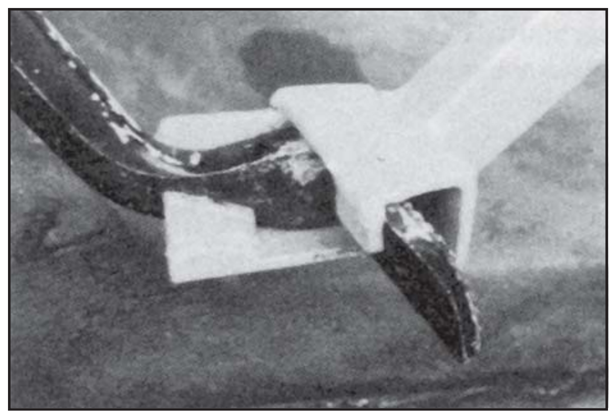

Figure 4. This simple clutch lever extension can be quickly mounted onto the pedal without bolts or clamps.

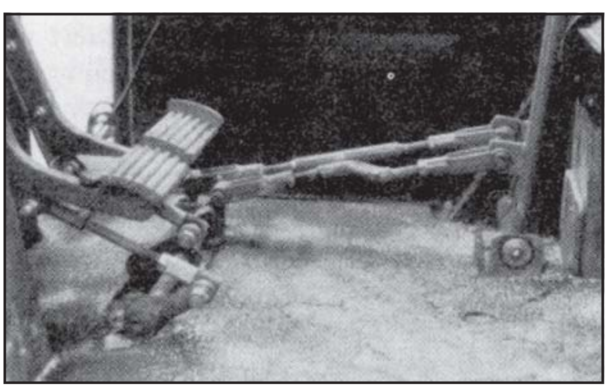

Figure 5. Modified foot brakes using vertical levers connected to the pedals with adjustable mechanical linkages.

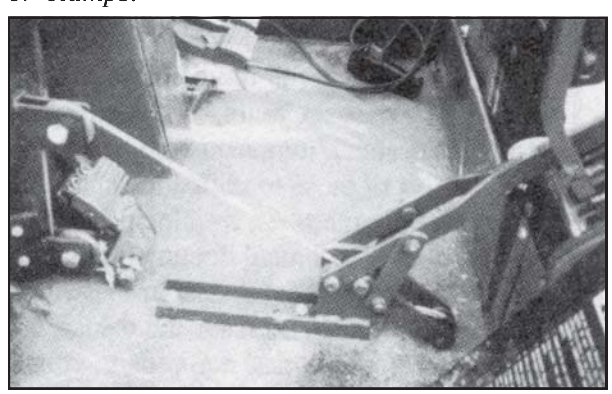

Figure 6. Cable actuated clutch with lever that locks in an over-center position.

trol designs are more expensive than mechanical controls, but are often the only alternative if an operator does not have sufficient strength and mobility to operate a mechanical lever assembly. Examples of this type of control modification are shown in *Figures 7, 8, and 9*.

Figure 7. Clutch operated by two-way hydraulic cylinder that runs off tractor's hydraulic system.

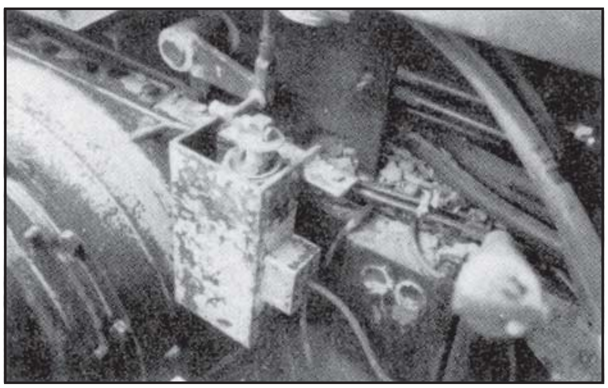

Figure 8. Clutch operated by a small 12-volt linear actuator.

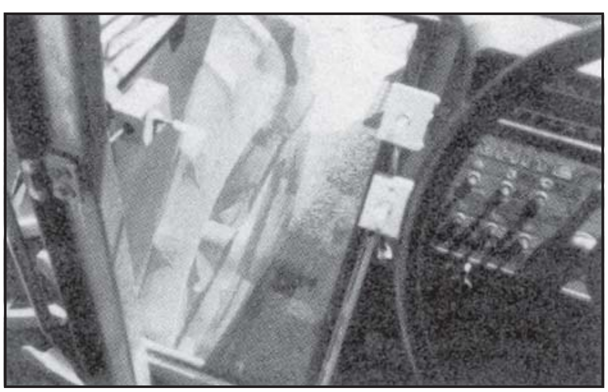

Figure 9. Electric brake and clutch control switches on tractor console. Each is connected to a linear actuator.

An example of a modified PTO control lever is shown in *Figures 10 and 11*. In this instance, the lever was relocated from a position where the operator had to twist his body to reach it, to a place easily reached by the operator.

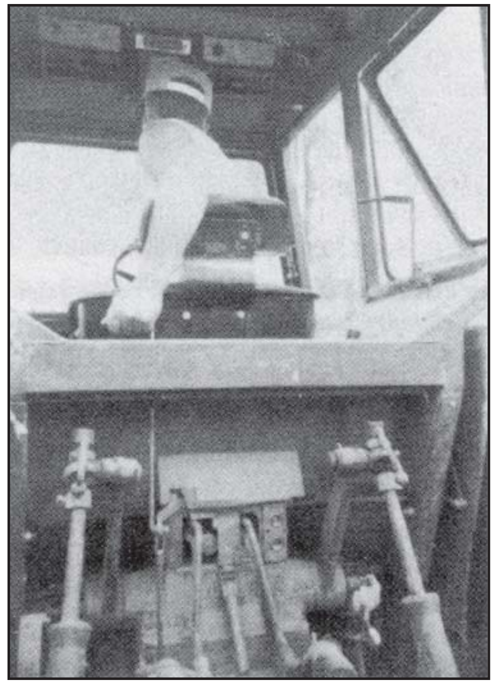

Figure 10. PTO control lever's original location.

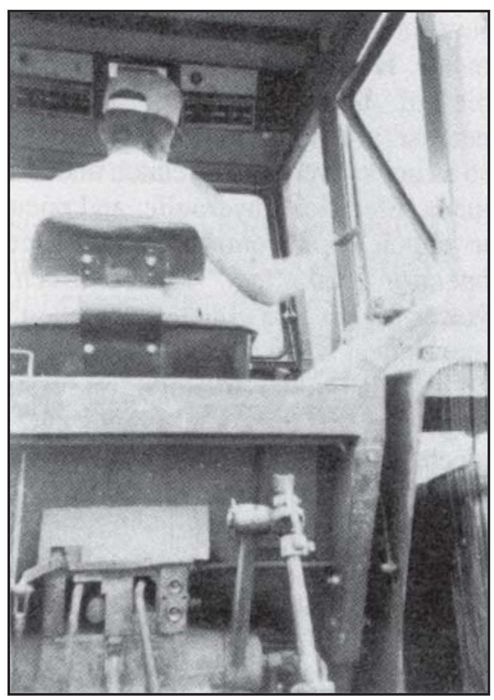

Figure 11. Repositioned lever providing easy and comfortable access to the lever.

Guidelines for Designing and Constructing Hand Controls

Hand controls should allow persons with physical impairments to operate their tractors safely and effectively; yet they should not interfere with an able-bodied person's use of the tractor. Based upon an evaluation of hand controls which have previously been constructed, Veterans Administration Standards for automobile adaptive equipment, Federal Motor Vehicle Safety Standards, Society of Automotive Engineers Standards, and American Society of Agricultural Engineers Standards, the following guidelines are recommended for the design and construction of hand controls. Keep in mind that they do not make up a comprehensive set of guidelines. In other words, each case must be examined individually, based on the capabilities of the operator and equipment being modified.

Location of Controls

1. Hand controls should be located where they can be easily and accurately reached and where maximum force can be applied. In general, this is between elbow and shoulder height, and approximately 16-28 inches from a vertical plane of the operator's back *(see Figure 12)*. (Refer to SAE J898 "Control Locations for Construction and Industrial Equipment"[3] and Air Force Systems Command DH l-3[4]). Undue strain and fatigue result when the operator must reach to his/her limits. He/she also has greater balance and control of the hand controls if within reach limits.

2. Hand controls should be located where they will not interfere with other controls or components. There should be at least two inches between all lever handles, and preferably more.[5] When designing controls, it is important to keep in mind that the seat usually adjusts from front to rear; some tractors have a hydraulic seat that raises when the tractor is started; and steering columns may tilt or telescope.

3. Hand controls should not interfere with the pathway to the seat to allow easier transferring for operators with disabilities. The American Society of Agricultural Engineers (ASAE) Standard S383, "Rollover Protective Structures for Wheeled Agricultural Tractors,"[6] also requires two unrestricted exits from the tractor cab; thus, hand controls should not block either of these exits.

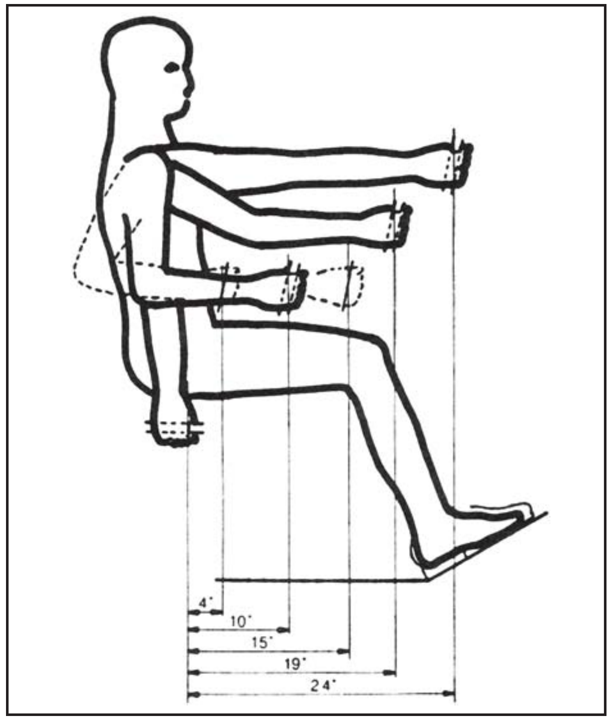

Figure 12. Frequently used controls need to be placed such that they allow the operator to use them without undue exertion or fatigue.

4. Hand controls should not come into contact with the operator's legs during operation. Persons with spinal cord injuries or other neurological disorders may not have sensation in their legs, thus can be easily bruised without even knowing it.

5. Hand controls should be positioned to allow for changes in body posture, such as natural body slump, stretching, and movement caused by vehicle acceleration and vibration.

Forces Required to Operate Controls

1. Forces required should be minimized through proper design of the linkages and proper loca-

tion of the controls. Excessive forces cause fatigue and reduce the alterness of the operator.

2. For persons with normal upper body strength, maximum push-pull forces required for one to five seconds should not exceed 30-40 pounds of force.[7] To avoid operator strain, use two-thirds of these values. Factors affecting force application include:
   - — the plane in which force is exerted relative to the body,
   - — the direction of the force,
   - — degree of arm extension,
   - — posture,
   - — bracing of feet and back,
   - — seat back angle,
   - — distance from the midplane of the body—8" to right is best for right-handers (see area labeled "Primary Control Zone" in *Figure l3*),[8]
   - — length of time forces are applied,
   - — whether or not the control must be finely positioned,
   - — how often the force must be induced.[9]

3. Strength in the preferred hand is generally ten percent greater than in the other hand.

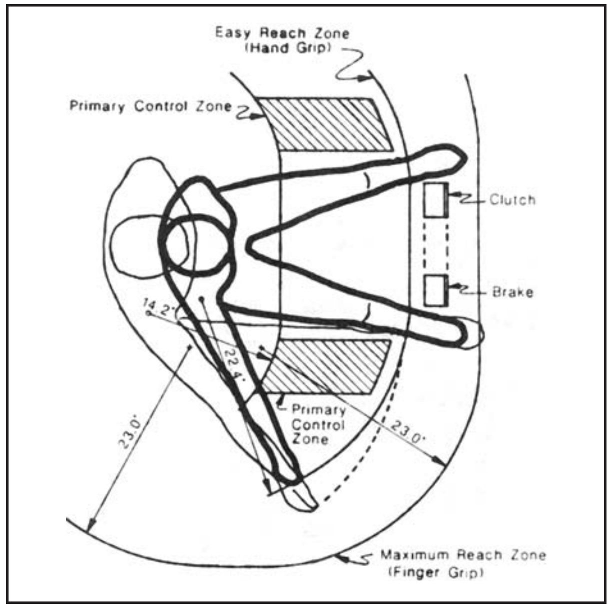

Figure 13. Optimum hand control positions.

Control Construction

1. Materials and components used to construct hand controls should be strong and durable enough that the controls will not encounter permanent deformation under the stress of normal operation.[10] Registered professional engineers should be consulted to verify all designs for strength.

2. All sharp and jagged edges should be eliminated to prevent injury to the operator or damage to his clothes during operation and access/egress.

3. All components should be resistant to corrosion. Corrosion weakens components and produces sharp edges.

4. The controls should be of an "add-on" nature. Permanent alterations to the tractor should be avoided (i.e. welding, cosmetic damage, etc.) so as not to depreciate the equipment's resale value. However, this is of secondary importance to the design of a safe, high quality set of controls.

5. During complex maneuvers, such as at row-ends and on hillsides, a person without the use of his legs runs out of hands to perform all of the necessary operations. Many farmers have designed their clutch hand control linkages to lock the clutch in the disengaged position in order to free the hand that normally operates the clutch to perform other tasks. Clutch locking mechanisms must securely lock the clutch in the disengaged position until the operator wishes to engage the clutch. *Figure 14* provides an example of a clutch locking mechanism.

6. Clutch hand controls should pull towards the operator (generally rearward) to disengage the clutch, as required by American Society of Agricultural Engineers Standard ASAE S 335.2, "Operator Controls on Agricultural Equipment."[11]

7. All two-wheel drive tractors have two brakes. If the conventional brake interlock between the two brakes is made inoperable by attaching hand con-

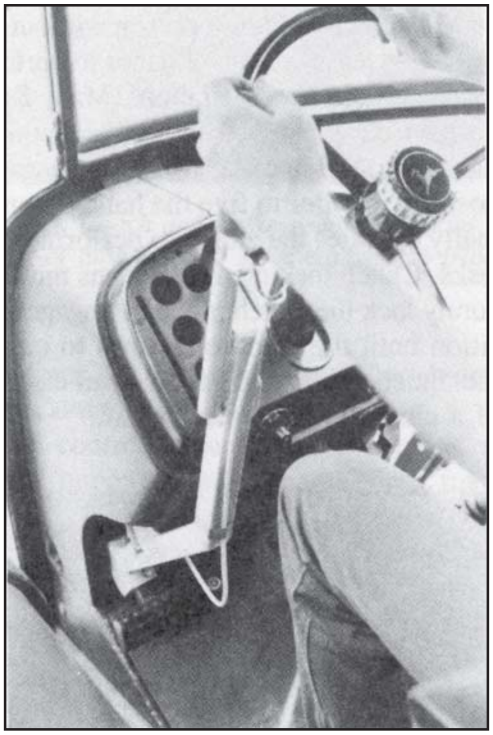

Figure 14. Clutch locking mechanism to keep clutch disengaged when using other controls.

trols, a locking mechanism must be included in the hand control design to allow for combined or equalized braking *(see Figure 15)*.

8. Hydraulic and pneumatic hand controls should be operable when the tractor engine is off. Hand controls using hydraulic cylinders that are powered by the tractor's hydraulic system should not be used, because these cylinders are inoperable when the tractor engine is not running. If a cylinder were used as the actuator for a clutch hand control, a tractor that stalled under load would be difficult to get out of gear without first disengaging the clutch. This type of hand brake control would also be inoperable if the tractor stalled.

9. With clutch hand controls using an electrical actuator, difficulty has been encountered in obtaining good "feel" for the clutch. Actuators must be slowed down enough to allow for smooth engagement (feathering), which is important for safe starts and ease in hooking up to implements. However, the clutch must be capable of being disengaged quickly if necessary. It must not engage too slowly, so as not to overheat the clutch under heavy loads. Electrical, hydraulic, and pneumatic clutch hand controls should give the operator good "feel" for the clutch.

10. Power brakes and clutches are often fully mechanical when a tractor stalls. Clutches on certain model tractors, for example, might require only a 15-pound pull on a mechanical lever assembly to disengage the clutch when the tractor is running. Yet, the force required to disengage the clutch with the same lever assembly when the tractor is not operating might be approximately 90 pounds of pull, exceeding both the capacity of the operator and the lever assembly. Some model tractors provide for limited power braking after the engine is stalled; however, power brakes on most tractors are fully manual when the tractor engine is not running. Hand controls should be properly designed to allow for safe operation when tractor power fails.

Other Important Notes

Transmission alternatives such as hydrostatic or shift-on-the-go transmissions require less clutching, freeing the operator's hands for other tasks. For example, the only time the clutch is needed on International Hydro tractors is when one is shifting from high to low range. Several manufacturers offer power-shift transmissions that can be used with little

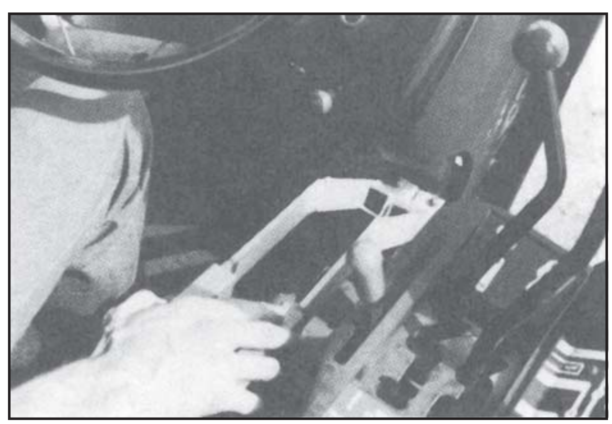

Figure 15. Hand brakes should be constructed to allow for independent or equalized braking.

clutching. Hydrostatic transmissions on some self-propelled combines have greatly reduced the need for extensive control modifications.

Summary

Guidelines have been presented in this paper that should assist farmers, rehabilitation professionals, and engineers in designing and constructing safe, quality hand controls for agricultural equipment.

Evaluation of numerous control modifications by the Purdue project indicates that nearly all equipment can be successfully modified to meet the needs of most individuals with disabilities. Nevertheless, further research is needed to identify all the hazards involved in operation of tractors and other farm equipment by operators with disabilities.

Because a great deal of time and effort has gone into development of hand controls for automobiles, it may be possible to borrow much from that industry. Also, cooperative efforts between rehabilitation professionals and agricultural equipment manufacturers in addressing the needs of farmers with disabilities could yield valuable information. It is clear that more information must be made available through ideas, plans, and standards for those with disabilities who wish to modify their tractors, in order to insure maximum safety and satisfaction for them in their farming endeavors.

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