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Tractor-Mounted Vertical Lifts

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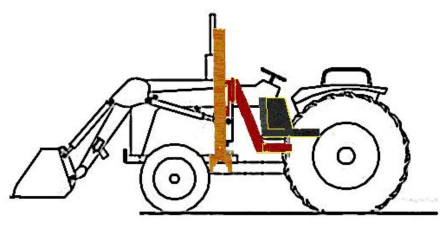
Introduction

In an effort to provide disabled farm workers safe access to the seat of a tractor, Virginia AgrAbility has been engaged in the design of tractor-mounted mechanical lifts. This effort has resulted in the design of two types of mechanical lifts - vertical and inclined that can be mounted on a tractor. This work has also resulted in the publication of the following three fact sheets:

1. Tractor-mounted lifts
2. Tractor-mounted vertical lifts
3. Tractor-mounted inclined lifts

The goal of these publications is to familiarize the potential users with the types of designs, pointing out the advantages and disadvantages of each type, components, safety considerations, cost estimates, and design criteria. This particular factsheet deals with the design of a vertical mechanical lift and it provides a case study of system components, maintenance, detailed design, parts list and estimated cost. Those who are interested in a vertical mechanical lift should use this factsheet together with Factsheet #1. When technical assistance is needed for the adaptation of this design, it may be sought by contacting the Virginia Department for Aging and Rehabilitative Services and Virginia AgrAbility. One may also go to (http://www.agrabilityproject.org/) for additional information.

The Need



Kubota L3400 with front-end loader.

Mr. M is a highly motivated paraplegic who is keenly interested in working on his farm. He has been in a wheel chair since a 1996 automobile accident. He has been operating a 15 acre farm with a Kubota L3400 tractor. He has used different methods for mounting the tractor ranging from having someone lift and push him into the seat, to using a stationary harness lift (very uncomfortable for him), to transferring from a platform deck. None of these methods have been acceptable to the operator and they have high potential for secondary injuries. When Virginia AgrAbility program became aware of his situation, Mr. M was selected for a case study for developing a small and affordable mechanical tractor lift.

Lift Selection

A team of professionals from the Virginia Department for Aging and Rehabilitative Services , Virginia AgrAbility, and County Extension Agent assisted Mr. M to evaluate his situation and develop a plan in establishing his level of need and options that fit his strengths and aptitudes. After evaluating his specialized needs, operation, and equipment, the team concluded that a custom designed and locally fabricated small mechanical lift will be the best choice. From the evaluation of tractor specifications, they further concluded that an electrically powered vertical lift with a seat will be ideal for his application. They recommended an electric motor driven lead screw system to take the seat and user up and down.

Design Criteria: Issues for Consideration

Brief remarks on key design criteria will be followed by more detailed discussions in subsequent sections.

1. *Platform versus Seat-type Lift.* Both platform and seat lifts were considered to take the operator up and down. Since Mr. M could not stand up, seat type was selected. Provisions for safe transfer from the wheel chair to the lift seat at the ground level and from the lift seat to the tractor seat had to be incorporated. To bring lift seat from the ground to the tractor seat level was estimated to be 3-4 feet. Transfer the lift seat to the tractor seat had to be across level surfaces.
2. *Lift Location.* The farm was a single tractor operation and the access to this tractor was a primary goal. So the design focused on mounting to the tractor and keeping the lift attached to the tractor.
3. *Design for Easy Mounting and for Minimal Alterations on the Tractor*. Design for easy mounting on the tractor without obstructing the vision was a goal since the tractor had a front-end loader attachment. The mounting and dismounting of the lift assembly had to be easy. One of the design goals was to minimize the mounting alterations needed on the tractor or loader. It was desired to mount the system on the left-side of the tractor without obstructing operator's view and leave the right hand side open for other operators to access the tractor seat. Thus, using the mounting plate and holes already available on the tractor was selected.
4. *Lift Capacity*. Actuator selection depends on required load and speed capacity and the length of travel of the lift. The cost of actuator goes up as the weight, speed and travel distance increase. So, in order to keep the cost down, it is important that the system not be over designed. A lift speed of approximately 4-20 feet per minute, and a load capacity of 300 pounds were targeted for Mr. M's lift.
5. *Power Source*. An electric actuator that can be powered by the tractor battery was selected. A properly sized actuator could operate the lift without turning on the tractor engine. From the safety point of view, this feature is very important.
6. *Safety Features.* Fail-safe lift operation should protect the person in the event of power or drive mechanism failure. The lead screw allows free-wheeling down, in the case of power failure. No mechanism failure was anticipated that will prevent the person from free-wheeling down.
7. *Safe Escape Routes*. Specify safe exit alternatives for use in the event of an emergency. The primary exit option is to de-activate the actuator and free-wheel down, in a controlled fashion, using gravity. During lift and tractor operation, it is recommended that an individual be within sight or hearing.

8. *Operational Flexibility*. Lift design should be such that safe access to the tractor seat is available to all interested operators. The lift mounted on the left side of the tractor should free the right side for those able bodies to access the tractor seat.
9. *Fabricate with Available Parts*. For most disabled operators the cost will be a controlling factor for selecting a lift design. Often, one can keep the cost down by carefully selecting locally available materials and fabricating the system locally. Cost was a major challenge because of the unavailability of available "person-certified actuators." The actuator is the most expensive component of the system. Its careful sizing and selection is critical for keeping the cost down. Even though this goal was accomplished, the labor cost for Mr. M's unit turned out to be higher than anticipated. However, the experience gained during the fabrication should help reduce the labor cost in the future.
10. *Review Alternative Designs*. Alternative designs (Table 1 in VCE factsheet *"Tractor-Mounted Lifts"*) were considered in the process of determining a lift configuration that had a best fit. Many alternate design elements were discussed as separate items in the checklist of design criteria above. Alternative design details will be discussed in the next sections. Universal design concepts were implemented in most aspects of the design. The design assumed that "variation in human ability is ordinary, not special," and the electrically powered actuation was intended to accommodate users with varying levels of strength and mobility.
11. *Design for Wide Range of Tractor Types and Sizes*. The lift designed should be easily adaptable to different tractors of the same size. The lift designed and developed for Mr. M was fitted to a small tractor, and the design that works well on a small tractor can very easily be adapted to larger tractors.
12. *Actuating Devices.* The most challenging part of the design was the selection of the actuator certified for human lifting. Most suppliers contacted were not willing to provide certification.
13. *Identify Proper Location on the Tractor to Mount the Lift.* Generally this is one of the first design steps when designing tractor lift. Location should be selected taking into consideration factors such as ease in mounting and dismounting, safety, and operator's visibility. If a portable lift is to be used, one needs to make sure that the entire lift can fit into the space available close to the tractor.

Lift Safety Considerations

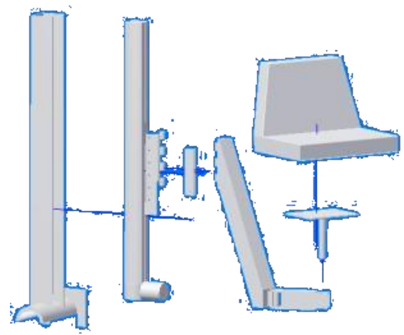
A discussion on modifying agricultural equipment is not complete without addressing the injury potential it may create when it is used by a person with severe disability. The primary reason for developing the lift is to provide safe access to the tractor seat. Poorly engineered lifts, made primarily from off-the-shelf components from a hardware store, may not meet the safety requirements. In Mr. M's case, the additional cost to improve safety is fully justified because this design takes into consideration several relevant SAE/ASABE standards [Yoder, 2009], and established standards for electrical components.

Several of M's limitations and characteristics were addressed as mentioned in the notes regarding design criteria above. The design took advantage of his upper-body strength and technical leanings towards adapting equipment for personal use. For example, to moderate the complexity of the design, the actuator was not required to swivel the client when the lift takes him to the same level as the tractor seat. The client is expected to manually swivel the lift seat until it is at the right location for the transfer to the tractor seat. When the client is in place in the lift seat, he is not exposed to any sharp edges or hot or cold surfaces. Instructions on operating the lift include a strong recommendation that the client always have someone else within sight and hearing, during embarking or disembarking from the lift.

To eliminate pinch points at any place where the seat moves past stationary components, the trajectory during up-and-down travel, and the path locus during seat-to-seat transfer were carefully traced. This process was also repeated during lift installation and the initial runs.

The action plan, for exit from the lift upon power failure, was outlined under the design criteria. Client training included instructions on what to do in emergencies. Required, standard safety equipment for the lift includes a two-way radio or a cell phone and a fire extinguisher. The cell phone or two-way radio must be checked prior to every usage of the lift. Future product generations will require that a functioning, fully charged, cell phone be inserted in an instrumented holster, which will then allow the on-switch of the lift to work.

Training and documentation included reminders on miscellaneous, reasonable, safety precautions. Do not operate the lift with the tractor engine on. Wear seat belts (and leg braces, as needed). Do not mount the controls to the seat to ensure that it cannot be accidentally triggered if it is brushed in transport. The best place for the control would be in a holster so that it can be taken into the tractor driver's seat as well. Identify and avoid all pinch points. The tractor operator will be reminded of standard safety precautions aimed at preventing injuries due to solar ultraviolet radiation, dehydration, and insect bites.



Design of the vertical lift for small tractor.

Description of a Vertical Lift Design

This section deals with the lift system designed to provide Mr. M safe access to the seat on his 34-hp utility tractor. The lift described herein may easily be adapted to utility tractors in the 30 to 75 hp range. The lift actuator, an electric-motor driven screw was selected to move the lift seat up and down vertically on the actuator track. The electric motor/actuator assembly is the most expensive component of the lift. This assembly may be purchased as a unit. The driven screw can be either a lead screw or a ball screw. The ball screws are more expensive because they are known to be more precise, smooth and efficient. Since these qualities are not essential for a tractor lift, lead screw was selected to keep the cost down. Another cost cutting option that can considered is using a certified person-lifting cable winch [Yoder et al. 2000] instead of motor driven screw. From the safety point of view, this may not be the most desirable choice.

Complete vertical lift assembly on support structure (picture in a machine shop).

An auxiliary electric motor with appropriate seat swivel could be used for rotating and aligning the seat. Considering Mr. M's upper body strength it was decided not to motorize the seat to keep the cost down. Another item that is useful for transfer from the lift seat to the tractor seat is a sliding board.

Mounting Frame

Vertical lift mounted on Kubota 3400.

The lift assembly was designed to mount on the left hand side of the tractor at the location designated for the front end loader. A vertical support post was mounted at this location provided the support for the linear actuator. This mounting frame may be adapted to work with different makes and models of tractors with minor alterations.

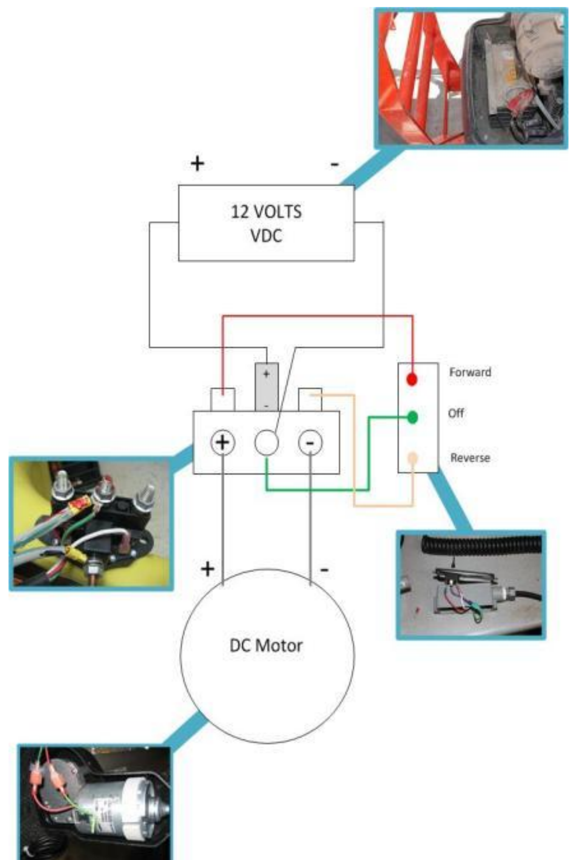
Construction Details

Aligning the mounting bracket with existing bolt holes on the tractor chassis turned out to be a challenging task during the lift installation. A lawn mower seat with a simple swivel arrangement was used as the lift seat. The controller was a simple on-off toggle switch (DTDP) on a retractable cable. The actuator was powered by the 12 volt DC tractor battery. A detailed listing of parts and estimated costs are shown in Table 1.

The entire lift assembly was painted for aesthetics and rust protection. Sealants were used to protect internal moving components such as the lead screw from dust and rain.

Cost Estimate

The entire tractor lift, with the exception of the actuator, could be fabricated using relatively inexpensive angle iron and/or channel iron which can be easily reinforced or repaired. Major components of the lift included the actuator system (motor and the leadscrew), the hardware for mounting, the lift seat with swivel, and the lift controller. An actuator operated with 12 VDC tractor battery was selected for cost savings. A hand-held control device was used to move the lift seat up and down.



Circuit diagram for controller.

During initial testing of the system, it was observed that the battery used was not providing the current needed for the operation. This problem was resolved by adding a 12 VDC reversing solenoid in the circuitry shown below. This step helped to minimize the electrical losses in the circuitry. This observation showed that a deep cycle marine battery fully dedicated for the operation of the lift might be necessary for the smooth operation of the lift. Even though this addition will add to the total cost of the lift, it may potentially avoid many problems. The total cost of the vertical lift designed and built was in the range of $1,500 to $2,000.

Concluding Remarks

Client transferring to the lift seat.

This design and the factsheet resulted from a case study conducted with the goal of assisting a disabled farmer by providing safe access to his tractor seat. This factsheet is developed primarily to familiarize the interested users with the steps involved in the design and development of a vertical mechanical lift. In addition to the factors that need to be considered during the design, the design criteria used, lift components and the estimated total cost are included in the factsheet. Even though the design presented herein is for a specific tractor, the design can be altered to fit different makes and models of tractors. Finally, the point that needs to be emphasized is that the design must be carried out by giving prime importance to the specific needs and safety of the intended user. When engaging in ventures of this type it is of utmost importance that the user will not be exposed to opportunities for any kind of injuries.

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Reference to commercial products in this publication is strictly for informational purposes. Virginia Cooperative Extension is neither endorsing these products mentioned nor discriminating against other suitable products. Information included in this document is from the National AgrAbility Program and other reliable sources. However, neither the AgrAbility Program nor the authors of this document guarantee the accuracy of the information included in this document.

The purpose of this publication is to transfer general information to clients interested in selecting or designing a mechanical lift for heavy equipment such as a tractor. If and when engineering or other professional assistance is needed, one may contact appropriate state agencies and/or private consultants.

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National Resources:

AgrAbility National Project. http://www.agrability.org/
CoachLift. www.coachlift.com
Disabled Dealer. http://www.disableddealer.com
Life Essentials. http://www.lifeessentialsweb.com
Foundation for Rehabilitation Equipment & Endowment (FREE). http://www.free-foundation.org/
National Center for Chronic Disease (CDC) Prevention and Health Promotion. http://www.cdc.gov

Virginia Resources:

Centers for Independent Living (CIL's) http://www.brilc.org/
Virginia Department for Aging and Rehabilitative Services http://www.vadrs.org/
Easter Seals Virginia (ESV) http://www.va.easter-seals.org/
Virginia AgrAbility Project http://www.agrability.ext.vt.edu
Virginia Assistive Technology Partnership (VATS) http://www.vats.org/
Virginia Disability Service Agencies http://www.vadsa.org/
Virginia Farm Bureau Safety (FB) http://www.vafb.com/
Woodrow Wilson Rehabilitation Center (WWRC) http://www.wwrc.net/

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Table 1. Vertical Lift: Parts List / Cost Analysis

Item and *Web address* ***(accessed September 12, 2012)***	Cost Estimate
I. Lift Seat:	
Seat: lawn mower seat: $35 (Included in Miscellaneous)	
Swivel: (Included in Miscellaneous) Hinge and seat support bar: (Included in Miscellaneous)	
Seat belt (PN JUO101): $20 (Included in Miscellaneous) <http://www.julianos.com/lap_belts.html>	
Seat position lock: (Included in Miscellaneous)	
II. Lift Railing-Actuator:	
Channel-iron rail (One 4" channel, 6 ft long): $44.96 (Included in Miscellaneous) <http://www.yalesteel.net/servlet/the-steel-channels-cln-4-inch/categories>	
Bottom support bracket (Support webs and flat plate): (Included in Miscellaneous)	
Linear actuator (motor + lead screw + carriage + brake): <http://www.danahermotion.com> (Distributor price). Best prices often may require actuator shipment from overseas and potential delays in shipments. *Alternate actuator sources:* <www.CoachLift.com>	$1,215.85
Connecting pins for seat: (Included in Miscellaneous)	
III. Customized Mounting Assembly:	
Bottom mounting (Brackets, T-slot kit, bolts and nuts): (Included in Miscellaneous) and Lift-Railing-Actuator T-slot kit, Cost included in actuator pricing: $22.74, <http://www.danahermotion.com> (Included in Miscellaneous)	
IV. Hand Controls:	
Toggle on-off switch (DTDP) with retractable cabling: (Included in Miscellaneous)	
Alternate #1, Switch (DCG controller) Requires 24V <http://www.danahermotion.com> *(Distributor price): $292.69* *Additional: Control pendant without cabling* <http://www.danahermotion.com> *(Distributor price): $56.29* *Alternate #2, Very cheap solution, Toggle Switch* <http://www.danahermotion.com> *Distributor price: $29.06* *Potential source for 12V controller with control pendant:* <http://www.arjo.com/us/ProductTechnicalInformation.asp?PageNumber=532&ProductCategory_Id=14&Product_Id=105>	
Miscellaneous: Includes paint, nuts & bolts, pins, hinge, plate for support web and brackets, seat belt, springs for soft stops, switch, reversing 12v DC solenoid.	$400.00
Labor: 100 hours (estimate for prototype)	
GRAND TOTAL (excluding Labor)	***$1,615.85***