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ABSTRACT. This study sought to assess the feasibility of self-installing rollover protective structures (ROPS) and to identify any patterns of self-installation deficiencies in a sample of New York ROPS Retrofit Rebate Program participants. Inspection engineers looked for/at damage, rust, holes, deteriorated welding, location of attachment, axle housing, the presence of original plates/bolts, and adequate seatbelt installation. Results indicated that only 31% of farmers received correct parts and also installed these parts properly. Ten percent of self-installed tractors had installation problems so severe they were referred to a dealer for correction. Issues with seatbelts, torque, and unmarked or defective bolts in ROPS kits were also detected.

KEYWORDS. Fatalities, injury, intervention, machinery inspections, rollover protective structures, ROPS, ROPS installation, tractors

BACKGROUND

Each year approximately 250 individuals die as a result of a tractor-related incident.[1] Tractor overturns are responsible for approximately one half to two thirds of these fatalities.[2–3] Besides the devastating emotional impact these fatalities have on family and friends, Penn State University researchers (1999) indicate the cost of an agricultural fatality is approximately $790,000.[4] In addition, research conducted in Kentucky on tractor overturns indicates that

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for every tractor fatality there are at least five overturn injuries.[5] Approximately 13% of these overturn injuries result in a permanent disability.[7] A reduction in these overturn fatalities and injuries would have a sizeable impact on the overall rate and impact of farm fatalities and injuries.[6,7]

The installation of rollover protective structures (ROPS) on tractors lacking these devices is likely the most promising solution for reducing overturn fatalities. These devices are 99% effective in preventing injury or death in the event of an overturn when the seatbelt is worn.[8] Proof of their efficacy comes from the significant reductions in overturn fatalities experienced in other countries as a result of ROPS installation on a very high percentage of all tractors in productive use.[9–10]

Unfortunately, approximately half of US tractors lack these protective devices.[11] Many US tractors were manufactured without them and would require retrospective installation. However, cost, inconvenience, and perceived lack of need for ROPS in the farming community has substantially delayed increases in aftermarket ROPS installations in the United States.[12] Intervention programs that can make retrofitting affordable and easier, and convince farmers of the need to retrofit, would thus be key components of reducing tractor overturn fatality rates.

In response to these factors, the New York Center for Agricultural Medicine and Health (NYCAMH) developed a social marketing initiative that was launched in November of 2006.[13] This program was able to provide 70% of the owner's out of pocket cost to retrofit up to $600, assistance finding and pricing ROPS kits, and messages designed to persuade farmers that ROPS retrofitting is necessary. The program was designed to be flexible and was structured to allow farmers to choose an open station 2- or 4-post ROPS or cab and allowed for dealer or self-installation of ROPS. The program resulted in a 10-fold increase (from 5 to 48) in ROPS sales in New York in its first year (Personal Communication, Micheal DeSpain, John Deere Headquarters, November, 2007).

Hotline data indicate that the average cost of the ROPS ($N = 227$) and shipping was $822.40. The average cost for dealer installation was $248.31, with installation charges ranging from $65.00 to $1030.40 (these figures include the price of awning or cab installation). Since the rebate cap was set at $600, self-installing ROPS could potentially lead to considerable savings in retrofitting costs for owners. Out of 227 farmers installing ROPS through the program, 67% chose the option of self-installing.

Due to the overwhelming preference for self-installation of ROPS and the need for similar ROPS programs in other states, an important question to consider is whether ROPS can be installed by tractor owners in a manner that would ensure the tractor operator would remain safe in the event of an overturn. Although most tractor owners have basic mechanical skills, no formal assessment of farmer's ability to safely install ROPS has previously been conducted.

As a result, researchers at NYCAMH elected to conduct inspections on a random sample of ROPS that were not installed by a dealer or qualified installer. The purpose of the inspections was to (1) assess what percentage of ROPS could be reliably self-installed; (2) detect trends in faulty installation or installation complications; and (3) use this information to assess the efficacy of self-installation and if inadequate, whether there is the need to create a guide for self-installers to allow them to avoid common installation problems and improve the quality of ROPS self-installation. The results from the inspection of New York ROPS rebate program self-installed ROPS are presented here.

METHODS

In the initial year of the program, approximately 1004 tractor owners contacted the New York ROPS hotline to receive assistance finding the appropriate ROPS for their tractor. Basic demographic information was collected from each of these tractor owners, as well as information about the tractor they were seeking to retrofit. After gathering the initial tractor and tractor owner data, the NYCAMH ROPS facilitator forwarded a list of potential ROPS sources, as well as pricing information. If the tractor owner decided to retrofit, the owner

was then asked to provide a bill from the dealer as proof of purchase, if it was dealer installed, or a picture of the tractor before and after ROPS installation, if the owner chose to self-install. Once proof of installation was obtained, a check was issued, the participant's file was checked as "closed out," and their final decision on whether to self-install or dealer-install was noted. Within the first 9 to 10 months of the program, approximately 150 tractor owners had ordered ROPS, chosen to self-install, received their ROPS, and completed installation.

A random sample of these owners was chosen for the study. In order to generate the random sample, every third tractor owner from the list of completed self-installs was chosen for inspection, thus a list of 51 inspection participants was generated. Due to the stipulation that no more than one tractor could be retrofitted through the program per year, none of the participants had more than one self-installed ROPS on their farm, since participants were sampled in the first year of the program. Each participant was then pinpointed on a map of New York in order to create inspection routes for inspection engineers. If a randomly selected tractor was far from the inspection route, another tractor from the list of completed self-installs was selected that was closer to the inspection route and that matched the originally sampled tractor and ROPS as closely as possible. Prior to a visit by the inspection engineer, participants were contacted, the nature of the research was explained, and individuals were asked to give their consent to the inspection. Participants either gave a verbal consent over the phone or signed a consent form delivered at the time of inspection. The study and informed consent process was approved by the Mary Imogene Bassett Hospital Institutional Review Board.

Once participants were contacted and inspections scheduled, one of three inspection engineers was enlisted to visit the farm to conduct the ROPS inspection. Although conducting an interrater reliability analysis was discussed, the limited project funds and engineer staffing time made this unrealistic. However, in order to standardize inspections, engineers were given an inspection form (see Appendix), which addressed the following points of interest:

- ROPS condition—the presence of defects in the ROPS (e.g., damage, rust, welding, holes or deterioration).
- Inventory of ROPS parts—confirmation that all original ROPS parts and canopy (if purchased) were used in the installation.
- Proper installation of the ROPS—inspection of proper ROPS mounting location on the axle, presence of correct bolts, and use of torque wrench.
- Proper installation of the seatbelt—inventory of seatbelt parts (assurance that the seatbelt tested with the ROPS was the one installed), inspection of appropriate seatbelt mounting points.

At the conclusion of each inspection, tractor owners were given recommendations for correcting simple installation problems or were referred to a dealer for correction of more complicated installation issues. Each inspection took between 30 and 60 minutes to complete. This included follow-up time with the owner.

During these inspections, inspection engineers entered data on the previously mentioned inspection form. Once each of the sections was completed the inspector noted at the end of the form whether a dealer referral would be recommended. If the inspector checked "yes," this would indicate that either the ROPS, its parts (including seatbelt), or the installation was faulty and could fail in the event of an overturn. If the inspector checked "no," this would indicate that ROPS parts and installation would be functional in the event of an overturn.

Data from inspection forms were then entered into a Microsoft Office Access database and a copy of the form was sent to each of the participants along with a cover letter indicating whether the ROPS had passed the inspection or whether a dealer-referral was recommended. For those participants who had been referred to a dealer, the section of the inspection form that detailed the installation or part issue to be resolved was highlighted. No follow-up on dealer referrals was conducted.

RESULTS

Demographic Data

Altogether 51 tractors were inspected. Thirty-three inspections were performed by one inspector, 17 by another, and 1 by a third inspector. The distribution of commodity types in the group of self-installers whose tractors were inspected is given in Table 1. These proportions mirror the general distribution of commodity types retrofitting through the program, which was specifically designed to increase ROPS retrofitting in the small crop and livestock community.

On average, the number of operable tractors on inspected farms was 5, with a range from 1 to 34. The average proportion of these operable tractors with ROPS protection was 27%.

For most of the farmers participating in the inspection, the time required to install the ROPS was approximately 3.3 hours. The quickest installation took as little as 1 hour and the longest 16 hours. In response to the question "Did you get help installing the ROPS?" 30 (58%) tractor owners stated they received assistance from friends, family members, or professionals. Eight (17%) indicated they had managed to install the ROPS themselves and 13 farmers or 25% of the sample did not answer the question. When asked whether they would choose to self-install again, 34 (66%) tractor owners said they would.

In order to assess the factors motivating farmers to self-install, inspection participants were asked why they'd chosen the option of self-installation. The distribution of participant responses given to this question is featured in Table 2.

The median year of manufacture for inspected tractors was 1970 with a range from 1948 to 1995 (the ROPS of the 1995 tractor had been damaged and required installation of a new ROPS). A histogram of tractor years is provided in Figure 1. Data indicating the distribution of tractor types and ROPS types represented in the sample of self-installers selected for inspection are presented in Table 3.

During inspections, inspection engineers were asked to rate the general condition of the tractor on a scale of 1 to 5, 1 being poor and 5 being excellent. The average rating on tractor condition was 3.8, indicating that despite the age of these tractors, most were in fairly good condition.

TABLE 1. Distribution of Commodity Types in Group of Self-Installers

Farm type	Number of self-installers ($N = 51$)	Percentage of self-installers
Livestock	18	35%
Crop	17	33%
Dairy	7	14%
Tree	4	8%
Vegetable	3	6%
Organic	1	2%
Fruit	1	2%
Total	51	100%

TABLE 2. Reasons for Self-Installing

Farm type	Number of self-installers ($N = 51$)	Percentage of self-installers
Easier to do themselves	14	27%
Wanted to save money	10	19%
Believed they were capable	7	14%
Wanted to save time	4	8%
Distance too great to dealer	4	8%
Other	2	4%
No response	10	20%
Total	51	100%

FIGURE 1. Number of inspected tractors in the sample by decade of manufacture.

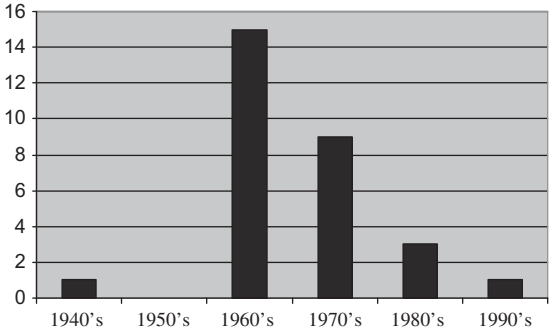

TABLE 3. Self-Install Inspection Tractor Types/ROPS Types

Tractor type	Number of self-installers ($N = 51$)	Percentage of self-installers	ROPS type	Number of self-installers ($N = 51$)	Percentage of self-installers
John Deere	29	87%	John Deere	29	56%
Ford	10	19%	Hercules	7	14%
International	2	4%	Laurin	4	8%
Oliver	2	4%	Saf-T-Cab	4	8%
Kubota	2	4%	BareCo	3	6%
Iseki	2	4%	Other	2	4%
Allis Chalmers	1	2%	Previously used	2	4%
Case	1	2%			
Massey Ferguson	1	2%			
Satoh	1	2%			

ROPS Parts and Installation Data

The inspection outcomes are summarized in Box 1. In order to provide detailed information about each of these bulleted inspection results, the following section has been broken into segments that correspond to each of the inspection outcomes.

BOX 1. Overview of Inspection Results∗

- **16 (31%)** were supplied with correct parts and installed according to manufacturer specifications**
- **5 (10%)** were referred to a dealer
- **19 (37%)** were found to have no seatbelts or seatbelts installed in a manner that deviated from manufacturer specifications**
- **4 (8%)** were found to have ROPS mounting bolts that were not at the manufacturer recommended torque
- **7 (12%)** were sent with bolts that were either the incorrect size or grade or of questionable quality

*These groups are not mutually exclusive. Tractors may have had multiple defects.

**In situations where installation instructions were not specific, the viability of the installation was left to the inspector's professional judgment.

Thirty-one percent were supplied with correct parts and installed according to manufacturer specifications. Of the ROPS installed on the 51 tractors selected for self-install inspections, 16 ROPS were supplied with all of the necessary parts/instructions and were installed by the farmers without any deviations or complications, (12 were John Deere, 1 Laurin, 1 White, and 1 Saf-T-Cab, 1 Bare Co.). Figure 2 shows a John Deere ROPS installed on a John Deere 4020.

Ten percent were referred to a dealer. Of the 51 self-installers selected for inspection, 5 self-installers were referred to dealers for issues so severe they could result in a failure of the ROPS (see Table 4 for a description of installation problems). For example, on one of the

FIGURE 2. John Deere ROPS installed on a John Deere 4020.

TABLE 4. Self-Install Problems Referred to Dealers

1. 2 × 6 axle mounting bolts were missing and replaced with 8.8 M
2. Self-installer received 2 right sides of the ROPS, needed to correct by replacing one right side with a left
3. Rollbar cut in half and pinned together with removable internal tube for low clearance
4. Self-installer spread ROPs apart for bolt holes in axle
5. Supplied bolts were not long enough. Antivibration bolts vibrated out and were replaced with regular bolts

FIGURE 3. ROPS installed on a Satoh 650G that has been cut and pinned together.

tractors, the installed roll bar was cut in half and pinned together with an internal tube to make it removable for low clearance (depicted in Figure 3). These five are among the eight cases in which substitution or modification of parts were noted by the inspectors. Such changes included using different washers or substituting bolts that were either the wrong length or had stripped during installation. Among those not referred to a dealer was a ROPS with a cross bar that was too short. Solid steel extensions were added to make up the difference (Figure 4). This farmer was not referred to a dealer, because the alterations were suggested by the ROPS supplier.

Thirty-seven percent were found to have no seatbelts or seatbelts installed in a manner that deviated from manufacturer specifications. Nineteen of the 51 (37%) tractors had seatbelt mounting issues or the seatbelt was not

FIGURE 4. Foldable ROPS installed with solid steel extensions (red).

installed at the time of inspection. Most of these seatbelt issues were caused by a misunderstanding regarding seatbelt mounting locations. On some John Deere models this was due to the fact that the proper threaded hole in the seat structure was hidden by the vinyl upholstery, whereas a visible, useable hole of the correct diameter for the seatbelt mounting bolt was present in the arm rest bracket (Figure 5). That appeared to be the perfect location for the seatbelt, even though the instructions pointed out the location of the proper mounting hole beneath the vinyl. In order to install the seatbelt, a small hole or "X" had to be cut into the seat so the bolt would

FIGURE 5. Seatbelt improperly installed.

FIGURE 6. Seatbelt properly installed.

go though the covering into the metal seat body (Figure 6).

Eight percent were found to have ROPS mounting bolts that were not at the manufacturer recommended torque. Four of the 51 sets of mounting bolts were either not at the recommended torque or a torque wrench was not used during installation. Some ROPS had more than one issue, i.e., issues with bolts and seatbelt placement.

Twelve percent were sent with bolts that were either the incorrect size or grade, or of questionable quality. During the course of inspections, unmarked bolts (Figure 7) and defective bolts (Figure 8) were detected in several ROPS kits. Following discussions with the manufacturer, improper bolts were replaced and unmarked bolts were marked with standard markings.

Comparison of Inspection Results

Tractor Manufacturer ROPS Versus Third Party Manufacturer ROPS

Of the 51 self-installed ROPS inspected, 32 ROPS were purchased from tractor manufacturers (i.e., John Deere and Kubota), whereas 19 ROPS were purchased from third party manufacturers (i.e., Hercules, Laurin, Saf-T-Cab, Bare-Co, and Custom Products). In order to identify potential installation trends based on type of ROPS manufacturer, data inspection results were stratified into two ROPS manufacturer categories (i.e., tractor manufacturer versus third party manufacturer; see Table 5). As demonstrated in the table, inspection engineers identified a high proportion of tractor manufacturer ROPS with seatbelt installation issues. However, of the third party manufacturer ROPS inspections, a relatively high proportion were referred to a dealer or demonstrated issues with bolts or improper torque. A high proportion of ROPS installations within this

FIGURE 7. Unmarked ROPS mounting bolts.

FIGURE 8. Defective ROPS mounting bolts.

TABLE 5. Comparison of Inspection Results Based on ROPS Manufacturer Type

ROPS Manufacturers	Total within sample	Correct parts/installation	Referred to dealer	Seatbelt issues	Improper torque	Improper bolts
ROPS from tractor manufacturers (% of tractor man. ROPS)	32	13 (41%)	1 (3%)	13 (41%)	2 (6%)	1 (3%)
ROPS from 3rd party manufacturers (% of 3rd party man. ROPS)	19	3 (16%)	4 (21%)	6 (32%)	2 (11%)	6 (32%)
Total	51	16	5	19	4	7

group (32%) also exhibited issues with seatbelt installation.

Limitations

The information gathered in this analysis of self-installed ROPS inspections has provided productive initial data with which to assess the efficacy of the self-install option for the New York ROPS Rebate program. However, a number of mitigating factors may limit the generalizability of these results to populations of tractor owners that fall outside the parameters of this particular study design. To begin with, the distribution of tractors and tractor owners retrofitting through the program was strongly influenced by ROPS affordability, availability, shipping delays, and owner retrofitting interest. Only those farmers who could afford to retrofit, find ROPS and get them shipped in the first year of the program and who were dedicated to the process enough to complete retrofitting were eligible for the inspection. Indeed, the fact that the proportion of ROPS protected tractors in the sample of self-installers (27%) was almost half the proportion of ROPS protected tractors documented nationally (59%) in 2006[12] provides evidence that our sample of self-installers may be somewhat different. In addition, in order to make inspections possible, substitutions for randomly selected tractors that were not in the vicinity of the inspector's route were essential, as inspector's time and travel money were limited. These substitutions would be problematic if there were reason to believe that ROPS installations located closer to inspection engineer travel routes would be systematically different in anyway than those located farther out. Although possible, this seems unlikely. Regardless, continued inspections of ROPS self-installations will be necessary in order to verify the degree to which the results reported here provide a valid measure of the efficacy of ROPS self-installation.

DISCUSSION

Despite these limitations, these inspection data provide an initial benchmark for assessing the utility and improving the viability of ROPS self-installations. On the promising side, the demographic data indicate that for most farmers, the process took little time and was preferable for those concerned with cutting costs and making the process easier (two considerable barriers to retrofitting outlined in previous research[15]). As the price of ROPS kits and shipping continues to climb due to cost increases in fuel and steel, efforts to cut the cost of retrofitting may become increasingly important.

In addition, a relatively low proportion (10%) of ROPS self-installers encountered problems considerable enough to warrant further discussion with a dealer. Although this number should arguably be zero to consider self-installing a viable option for ROPS intervention programs, it is also important to point out that the majority of these dealer-referred issues were related to problems with ROPS kits and not with the capabilities of the self-installers themselves. In general, the self-installers demonstrated that they were quite capable of installing ROPS in a manner that would ensure the safety of the tractor operator in the event of an overturn.

Although most complications were minor, our research indicates the pronounced need to improve and standardize the quality of ROPS kits and to provide guidance or assistance to self-installers should they encounter issues with ROPS kits. As the analysis of inspection data by ROPS manufacturer type indicates, tractor manufacturers could work to improve seatbelt installation instructions, whereas third party ROPS manufacturers will need to provide tested and certified bolts, parts, and seatbelts, along with clear and easy-to-follow installation instructions. In addition, ROPS programs can do much to alleviate identified issues by providing checklists to self-installers that caution them to ensure all parts and instructions are present and to avoid substitutions. Such checklists could play a vital role in reducing the potential for unnecessary or unsafe installation alterations.

CONCLUSIONS

Of the 51 self-installed ROPS inspected as part of this study, 31% were supplied with correct parts and installed without issue. Ten percent of inspected ROPS were referred to a dealer for issues so severe they could potentially result in failure of the ROPS in the event of an overturn. A considerable proportion (37%) were found to have improperly installed seatbelts or no seatbelts, whereas 8% of ROPS mounting bolts were not properly torqued. Issues relating to the supply of improper bolts were also identified in 7 out of 51 ROPS inspections. Although further research is necessary to evaluate the potential for self-installing ROPS, we believe the data gathered in these inspections provide a valuable initial evaluation of the self-install option for the New York rebate program. Inspection results indicate that self-installing ROPS could be a feasible option for New York retrofitters, if concerted efforts are dedicated to improving the quality of ROPS kits and to providing materials or guidance to self-installers.

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APPENDIX: ROPS INSPECTION FORM

ROPS Retrofit Self-Install Inspections									
Demographic Information				**Tractor Information**					
ROPS Inspector	Mark Purschwitz			**Make**		**Year**			
Date of Inspection	18-Oct-07			J. Deere		Ford			
Farmer Information				Intern.		Kubota			
Name				M. Furg		Case			
Address				Other					
	Phone			Model					
Primary Commodity				S/N					
Number of tractors				# Hours		Circle			
Operable		Inoperable		General Repair		P1 2 3 4 5E			
ROPS Information				**Self-Install Questions**					
Manufacturer				# of Hours					
Bare Co		Laurin		Did you have assistance?					
Hercules		Saf-T-Cab		Who					
Other				Would you self-install again?					
Tractor Manufacturer				Why did you self install?					
Model				Time		Financial			
S/N				Other					
New		Used							

Record any issues the farmer encountered during the ROPS installation:

Did the ROPS kit come complete?		Yes		NO	
Missing Items:	Bolts		Plates		Instructions	
	Seatbelt		Stickers		Other:	

Follow-up done by the producer (Check any that Apply)

	Received appropriate replacement from dealer/manufacturer
	Substituted parts not provided by dealer/manufacturer
	Parts equivalent to specifications in kit
	Parts not equivalent to specifications in kit
	Requested more readable/ understand able instructions
	Contacted dealer for guidance

ROPS Inspection Points

*If yes please give a detailed explanation

				Structurally Significant (Possibility of Failure)		
Damage event	**YES**	**NO**	**Location**	YES*	NO	
Evidence of Damage						
Rust						
Welding						
Holes						
Deterioration						

				Structurally Significant (Possibility of Failure)		
ROPS / Cab Attachment	**YES**	**NO**		YES*	NO	
Original Plates						
Original Bolts						
Bolt Grade						
Bolt Torque (ft-lb)						

Location of Attachment				
Axle Housing		**YES***	**NO**	
Proper location on load bearing area				
Fender/ Cab				

Pictures	**Check if Taken**	**Seat Belts**	**YES**	**NO**
Tractor-overall		Seatbelt installed		
ROPS		Properly Mounted		
ID Plate		Holds Operator in Place		
Bolts		Seatbelt installed certified with Kit		
Axle Housing		Mounting Location		
Canopy				
Damaged Area				
Seatbelt				
Other				

Comments/Recommendations to Farmer:

Confirmation

Manufacturer	
ROPS Guide	

Dealer Referral
Yes or No