Three-Point Control

Analysis & Recommendations for Climbing Ladders, Stairs & Step Bolts

By J. Nigel Ellis

IN BRIEF
- Ladder falls are a primary cause of fall fatalities in the construction industry. In 2010, 129 workers were killed as a result of falls from ladders.
- Use of the three-point control ladder climbing strategy could prevent many of these ladder fall injuries and deaths.
- Design and process changes would also better protect workers using ladders or stairs.

Fourteen percent of all work deaths are due to falls, with 34% occurring in construction and 20% being related to the use of ladders, according to Bureau of Labor Statistics (BLS, 2012). Falls from ladders in the construction industry are costly beyond the human toll. The latest figures compiled by OSHA (2012) indicate that the average workers' compensation cost of a fall from a ladder or scaffold by a roofer is approximately $68,000 and for carpenters is approximately $62,000.

Even falls from relatively low heights can prove fatal. BLS reports that 20% of fatal falls at work occur from heights less than 15 ft, whereas 50% of fatal falls are from heights under 35 ft.

This article asserts that the proper use of the three-point control ladder climbing strategy could prevent many of these ladder fall injuries and deaths. In addition to discussing principles of effective three-point control, the article reviews recommendations for design and process changes needed to better protect workers using ladders or stairs.

How Does Three-Point Control Differ From Three-Point Contact?

To start, let's distinguish three-point control from three-point contact. Three-point control involves a worker using three of his/her four limbs for reliable support, whereas three-point contact involves contact without necessarily requiring handgrip support (Figure 1, p. 32). So, a point of contact for three-point contact may include only the stomach, a palm or a few fingers rather than coupling the hand to the ladder in such a way that the hand can potentially bear the full weight of the body if needed in an emergency. Maintaining three-point control for reliable support, as opposed to simply maintaining three-point contact, is critical while a worker is climbing, moving or working at elevation. On the other hand, three-point control is a design concept used only for climbing access and working at low heights; it increases stability and safety for workers primarily using portable and fixed ladders, but also, for example, when accessing stationary vehicle trailers and roof hatches using ladders.

Three-point control is a climbing method that involves methodically using three limbs for support when moving or working above the ground whenever an injurious fall can occur. Three-point control requires using the upper limbs in a particular manner so as to optimize safety. It does so by decreasing the likelihood that a worker will lose the ability to save him/herself when using a hand to prevent a fall caused by an unexpected slip or loss of balance.

Keeping the belly button between the two side rails, two hands holding a ladder rung or side rail, and one foot on a ladder rung, then alternating with one hand holding a rung or side rail alternating with two feet on a lower rung has traditionally been considered three-point control for a stable ladder climb. This also has been described as the three-point ladder safety rule. This traditional method has two problems:

1) While the use of ladder side rails offers the reassurance of continuous hand contact with the rail under static conditions, if one or both feet should slip off a rung, then hand grip strength is simply inadequate to hold onto the vertical strip steel (fixed ladder) or small I-beam (portable ladder) rail to successfully counteract a force greater than body weight in order to prevent the fall (Young, Wooley, Armstrong, et al., 2009).

2) The alternating method of climbing a ladder using three limbs in contact at all times is counterintuitive for most climbers because the natural instinct is to move a hand and a foot in unison while ascending and descending. The less traditional method of three-point control for most ladder designs must be learned through repeated hands-on training.

Unlike three-point control, three-point contact requires only one foot and two hand contacts alternating with two steps and one hand or body contact. It does not require using the hands to grab

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and hold a support in such a way that one hand can support body weight or more in an emergency.

Some argue that having the body or stomach lean against a bar or surface is sufficient as a point of contact. An example is directing car carrier drivers to use their palm resting on the roof or hood of an auto as the third point of contact. However, if one or both feet slip, that hand support cannot reliably suffice to prevent a fall, especially if the surface is wet. Failure to understand this difference between simple contact and actual dynamic control is responsible, in the author's opinion, for many unnecessary injuries that occur when workers fall off car carriers and other structures while loading or unloading.

The author maintains that three-point contact is an unsound means of positioning the body on a ladder or horizontal access route. To reasonably prevent uncontrolled falls, and prevent stepladder tipping, one hand must be able to grasp efficiently in a fall scenario by gripping a horizontal support using a power grip at all times. The strength used to achieve that grip does not have to be more than sufficient for the task at hand, but upon demand it should be able to maximize the breakaway force without difficulty. This is why a gripping control rather than just contact is critical.

In some cases, three-point contact has been referred to as the *three-point stance.* Primarily, this is an American football term used to describe a lineman with two feet planted and one fist resting on the ground at the beginning of a play. Its limited use in the safety world, almost exclusively in trucking, is much like three-point contact with little or no specific fall protection merit in terms of stability and physical grasping power in an actual fall, which is the goal of three-point control.

The term *three-point stance* has been adopted in the trucking industry by the Federal Motor Carrier Safety Administration (FMCSA) when referring to access in or out of the cab. Car carrier manufacturers also have adopted the three-point stance to allow drivers to step along a stationary truck/trailer foot rails or narrow catwalks while holding car hoods, car roofs and other variable panels or crevices using the palm of the hand or single fingers as a contact point. The author disagrees with this practice because it does not reliably aid the driver's balance while moving, and it offers unreliable support when tripping on a narrow catwalk. By comparison, using a power grip with the whole hand on a horizontal support when above-shoulder grab bars or rails are present affords much more stability, including the opportunity for one hand to support full body weight to prevent a fall.

Ladder System & Grab Bar Design

A designer of ladder systems and grab bars must consider human factors while planning the use of effective three-point control in an access system or elevated work area. These factors include handgrip strength capacities, the maximum breakaway force if a hand is forcibly pulled away from a support (Young, et al., 2009), as well as the size, shape, orientation and spacing of handholds/grab bars.

The most important feature for control when exposed to a fall hazard is being able to hold onto a properly positioned and designed handhold during a loss of balance so that one's grab hand prevents the fall without slipping off. Holding side rails or vertically placed holds, provides a handgrip based on friction while holding a rung or horizontal bar is referred to as a *horizontal power grip* (Barnett & Poczynok, 2000).

Depending on the rung size, the horizontal power grip has been shown to result in a 75% to 94% larger breakaway force than when gripping a vertical rail of the same shape and size (Young, Wooley, Ashton-Miller, et al., 2012). Because of this safety factor, it is safer for a worker to hold on to a horizontal support member than a vertical support member.

Standard shock-absorbing 6-ft lanyards, including Y-lanyards, are not recommended below 18-ft elevation because there is not reliably enough distance to decelerate the individual before impact occurs with a surface in many applications (Maddux, 2011). The downward momentum acquired in a fall is equal to the mass of the individual multiplied by his/her downward speed of falling. The lanyard tension needed to arrest the falling body is the product of the lanyard tension and the time that it acts. Therefore, a large force acting for a brief time can be as effective as a low force acting for a long time, as long as the high force does not exceed the lanyard capacity, and the long time does not permit the body to strike something.

To prevent the body from acquiring downward momentum in the first place, a more precise definition and understanding of reliable three-point control is needed. Based on a recent biomechanical study at the University of Michigan, funded by Center for Construction Research and Training/NIOSH, the choice of holding a horizontal round object or grab bar with a horizontal power grip was found to provide an unquestionably greater safety margin for preventing a fall than holding onto a vertical side rail or object when the fall starts (Young, et al., 2009; Young, et al., 2012). That study showed that the breakaway force for the vertical rail (side rail) was found to be only slightly greater than one-half body weight for men and slightly less than one-half body weight for women (Young, et al., 2012).

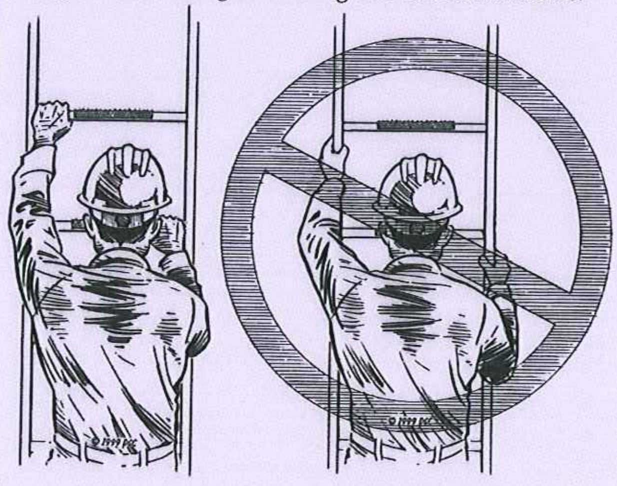
So, neither men nor women can support their full body weight through the use of one hand gripping a vertical handhold in the event that their feet slip off. In a fall, forces are liable to exceed one's body weight; Young, et al. (2012), show that a one-handed grasp of a vertical support member is potentially a disastrous climbing or descending scenario should a slip occur. Certainly, the outer grip of a horizontal rung should always be smooth with no rough surfaces to make gripping uncomfortable, but it should never be slick.

Therefore, the vertical grab bar is not recommended for access design or hand placement because the hand will slide down the bar under the magnitude of force that typically occurs in most falls, and will disconnect from the ladder when that hand first strikes an obstruction.

Figure 1

Three-Point Control

Three-point control on a fixed ladder requires particular positioning of upper limbs. Left: Holding horizontal rungs is reliable. Right: Holding side rails is unreliable.



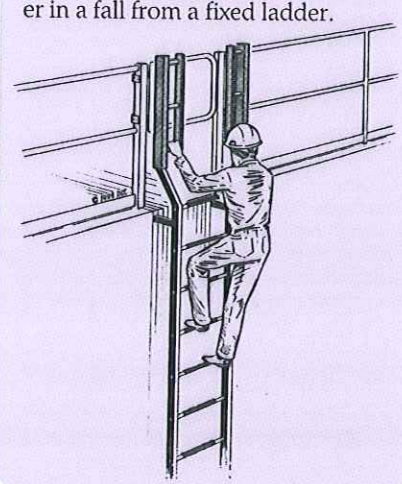
For example, the time for the sliding hand to forcibly hit the next fixed ladder rung 12 in. below is 1/4 second, yet it typically takes a minimum of 1/3 of a second for full physical human muscular response, meaning the climber's hand will hit the rung below before s/he has had the opportunity to fully grip in an attempt to stop the fall (Robinovitch, Normandin, Stotz, et al., 2005; Thelen, Schultz, Ashton-Miller, et al., 1996).

The author asserts that the length of a vertical 1-in. diameter grab bar should be designed to not exceed 10 in. in overall length, and should not allow a hand to slide more than 6 in. Holding the vertical side rail of any ladder or grab bar while climbing or working at height with a fall hazard is not a recommended design or work practice. However, high friction gloves make a slight difference in studies on fixed ladders, and wearing gloves and clean rungs should be recommended in most work situations (Young, et al., 2012; Young, Wooley, Armstrong, 2010).

Figure 2

Grab Bars

Side rail extension walk-through ladders should have horizontal grab bars to help protect the climber in a fall from a fixed ladder.



The minimum strength of a horizontal grab bar used in effective three-point control should be 1,000 lb in all directions based on a dynamic safety factor of twice the load. Any object that can be grabbed, including webbings and ropes, should meet this strength requirement to accommodate the dynamic forces. The handhold should be at least 3/4-in. in diameter for fixed ladder rungs and preferably 1 in. or 1.5 in. in diameter with a flat-top surface for portable ladder rungs.

Foot space also must be horizontal and is usually centrally stepped on, as is a ladder rung. Friction material can be added to the middle 8 in. of a rung, but not the outside 4 to 5 in., which are reserved for the hands. Additionally, OSHA recommends skid-resistant rung-top surfaces for fixed ladder rungs and portable ladder rungs [1926.1053(a)(6)(i) and (ii)].

Engineers and designers also must consider a quantifiable human factors balance issue as well as a fall stopping issue that determines the degree of efficiency of such a system. At heights beyond the OSHA fall protection trigger height, the use of independent personal fall arrest systems (PFAS) should always be considered (ANSI/ASSE, 2007, 2009; 29 CFR 1910/1926; 49 CFR).

Applications of Three-Point Control

Fixed Ladders

Side rail extensions for a walk-through fixed ladder (Figure 2) are necessary for balance; however, if a fall occurs, a vertical rail extension is ineffective in stopping a fall due to low sliding friction and lack of a power grip. Sometimes, a descending worker will run out of flared side rail due to a climbing routine. If the ladder has horizontal grab bars, then sliding is avoided when a fall starts at the top 3-ft extension of a fixed ladder during transition due to the high-strength, nonsliding hook grip. Training to hold only horizontal rungs and horizontal grab bars, when possible, is a vital element of any safety program. However, these horizontal grab bars must be provided by design or accessory for the worker in a commonly foreseeable work method.

Smaller tool belts can typically pass through the fixed ladder side rails with only a slight twist of the torso if the original ladder side rail extensions are approximately 24 in. apart. On a fixed ladder, the center portion of the rung should be skid-resistant, as recommended by OSHA 1926.502(a)(6)(i) and (ii), while the outside 4 to 5 in. on each side should be smooth but not slick. Shoe penetration space must be at least 7 in. for the entire length of the ladder rung, and there must be 16 in. at minimum between fixed ladder side rails for comfortable climbing equipped with a heel and a shank in the work boot (ANSI/ALI, 2008).

Portable Straight & Extension Ladders

When three-point control is applied to portable ladder work, one hand should be used for gripping stability on a rung and the other hand for light-duty work while both feet rest on one 16-in. rung or equivalent step. If required to read a meter or level gauge at heights, three-point control must be maintained with two feet on the same level for shared support and balance plus a horizontal rung power grip for one hand with less than 20-lb force applied to a tool for ladder stability. By taking readings using an electronic recorder in the other hand, instead of the more traditional notepad requiring two hands, then three-point control can be achieved.

Portable straight ladders usually have uniform parallel side rails and rungs except possibly for a flared base section. Projection of these rails above the surface for dismount has been recommended for several decades in safety texts and by OSHA almost universally at 3 ft above the exit landing, along with ladder self-leveling feet/shoes for urban surfaces and a 75.5° angle to the ground. Stepping through a fixed or portable ladder onto a roof or other surface is safer if horizontal grab bars are positioned on the ladder on each side using a ladder extension accessory or roof hatch mount extension walk-through which automatically achieves the desired 3-ft ladder extension above a roof edge or other dismount surface.

Estimates suggest that up to 75% of workers using portable ladders do not extend their ladder by the recommended 3 ft. In addition, many OSHA citations involve failure to have the ladder extended. Grab bars for ladder extensions should be round, 4 to 5 in. in horizontal length and have a 3/4 to 1-5/8-in. diameter compatible with the matching ladder rungs for an encircling handgrip.

Recommended Conditions for Working From Ladders Using Three-Point Control

These recommendations apply to light-duty work performed off the ground on a portable ladder

1) Work only for a short duration.

2) Use light materials and light tools designed for one-hand use.

3) Ensure that the ladder is stabilized and used per manufacturer's instructions.

4) Keep ladder height to the minimum possible. Fall fatalities increase as the foot height increases.

5) Keep belly button between the side rails close to the ladder and do not overreach.

6) Keep both feet at same level, for example on the same rung, not on alternating step bolts when performing work.

7) Maintain a one-hand grip on a horizontal object such as a round rung, rather than a vertical handgrip that can slide in a fall. Hands and arms must be free to climb and work.

If these conditions cannot be met in the judgment of a competent person from the controlling and/or exposing employers, use of a fast fall arrestor and a full-body harness should be considered with a first-man-up device. In addition, the higher the frequency of climbing, the more the need for fall protection guarding and/or PFAS (Ellis, 2012a).

Grab Bars for Portable Ladders

As noted, portable ladders can be fitted with grab bars when used to access roofs (Figure 3). Added to the top of the ladder, these bars provide the horizontal handholds necessary for three-point control when using a portable ladder to climb onto or off a roof or elevated deck surface.

Roof Hatch Access

Roof hatches should be equipped with walk-

Figure 3
Grab Bars for Portable Ladders

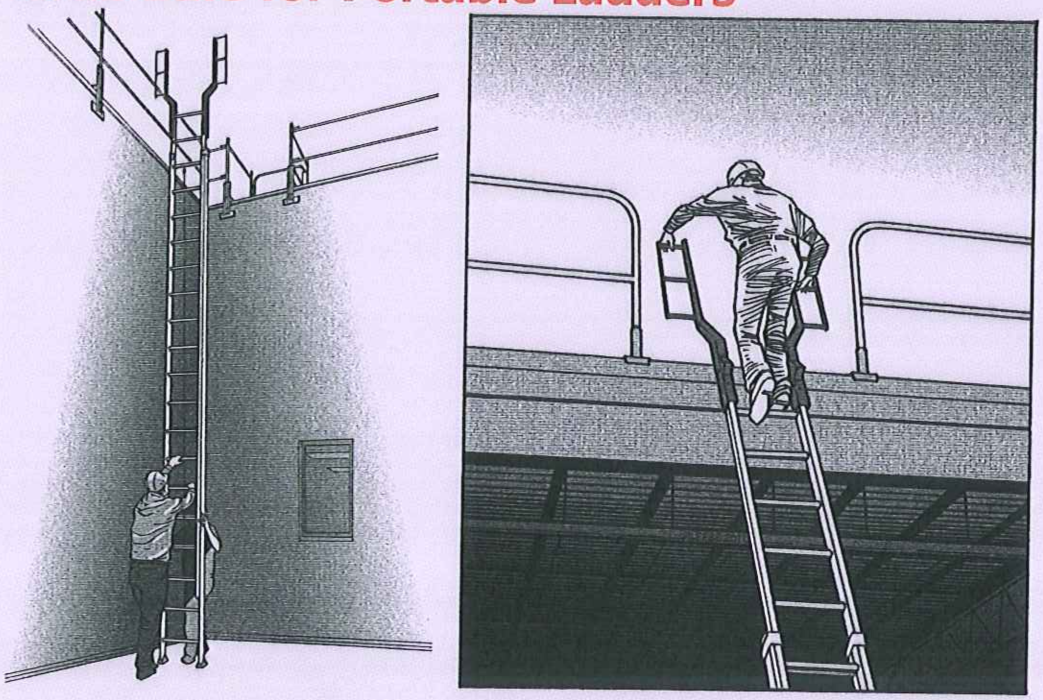
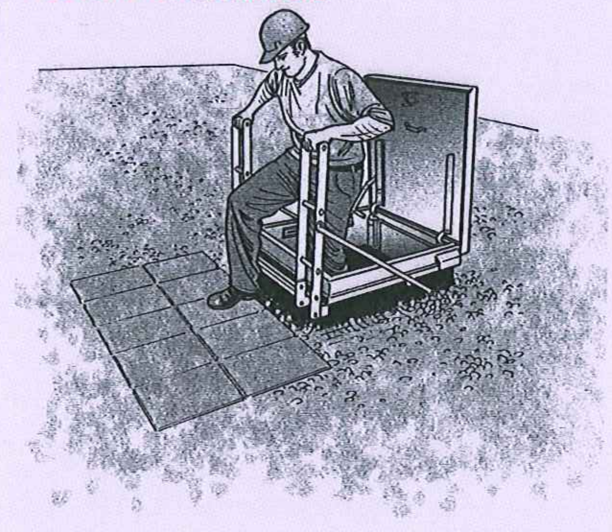


Figure 4
Grab Bars for Roof Hatches



through horizontal grab bars for safer access and exit to and from the roof (Figure 4). The grab bar must be horizontal for a reliable handhold in a fall hazard exposure. The top rung of the access ladder must equal the height of the step off when dismounting, and the ladder must be secured to prevent sliding. The ladder should have continuous extension grab bars to help a worker walk safely in and out of the hatch. The author recommends that the distance between grab bars be 20 to 24 in. to reasonably prevent small tool belts from catching on the bars. Grab bars for roof hatch requirements are addressed in ANSI/ALI A14.3-2008 (section 5.3.4.3) as well as by the U.S. Army Corps of Engineers (2003).

A-Frames

A-Frames or stepladders and step stools typically have no horizontal round rail or grab bar to hold onto for balance and no self-leveling feet as does a portable ladder. Manufacturers usually provide warnings to help prevent unbalanced stepping onto the top two or three steps, but the warnings often are located in areas where workers typically handle ladders and, thus, may become illegible. Safety can be increased with steps that are flat and broad (3 in. or greater), and stable for both feet without sway at lower heights. Hands are presently required to hold onto higher steps with fingers often curled around metal or plastic edges or onto the object being stepped up against.

While in use, the stepladder should be in the fully open position with leg-locking bars engaged, and it should be perpendicular to the work surface to reduce tip-over hazards. Then, the stepladder side rail, if present, should be held horizontally while further climbing and minimally be at waist height for work using the top step for leaning against above the knees if no rung is available, or as allowed by the manufacturer (Figure 5).

The stepladder needs to have adequate structural stiffness in a lateral direction, and the maximum safe tool force that can be exerted laterally by a worker on the ladder has been shown to decrease with increasing working height above the ground (Yang & Ashton-Miller, 2005, 2006). Project managers should consider using an independent first-man-up device with a fast fall arrestor and harness system for stepladders to supplement the balance with a PFAS having an overhead anchorage, especially at the open side or edge of a building or shaft (Ellis, 2012a). Project managers also should consider using a scaffold or small scissor lift for more stability. It also is important to remember that grabbing for the structure at the onset of a fall from a standard A-frame ladder, such as grasping at a sheet metal gutter, can cause significant cuts to the hand or arm. The climber should check the likely hazard outcome before stepping or reaching.

Mobile ladder stands and platforms meeting ANSI A14.7-2006 requirements supporting four times their rated load (more than 300 lb) are essential for maintenance work; these are often custom made for a specific application such as aircraft access. These stands and platforms should have handrails above the 4-ft step or platform height.

Based on present A-frame design in the U.S. and U.K., the official increased requirement to three-point control may have to be postponed temporarily. Health and Safety Executive (HSE) in the U.K. has promoted three-point contact on stepladders (A-frames) extensively through publications instead of promoting the mobile ladder stand (platforms) or small aerial lifts for 8 to 15 ft height access (**www.hse.gov.uk/falls/usingladders/stepladderthreepoints.htm**).

Ship's Ladders & Alternating Tread Stairs

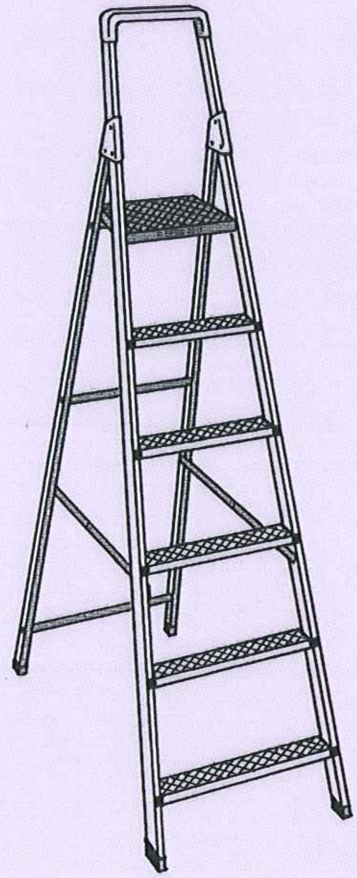
Ship's ladders are steeply sloped at 50° to 70° to horizontal, making them natural candidates for effective three-point control, in that their use requires both hands to hold the round sloped side rail (1-5/8 to 2 in. in diameter) continuously while each foot takes a step in the desired direction. This applies to whether the climber is facing the ladder or facing away from the ladder. They are really stairs with some useful safety features for use in a small area and should meet requirements of NFPA 101 section 7.2.11 (2006), ANSI/ASSE A1264.1 and International Building Code 1009.10.

Stairs & Three-Point Control

If three-point control is applied to standard stairs (30° to 50° to horizontal), there must be two compatible stair handrails to move the hands in a continuous sliding and gripping motion while stepping. According to International Building Code section 1009, stairs should be designed with a 7/11 slope (maximum 7-in. riser and an 11-in. minimum tread). In addition, there should be a graspable 1-5/8- to 2-in. diameter round or equivalent stair rail for adults.

By code, stair rails should be a maximum of 48 in. apart to accomplish three-point control, taking into account a suitable arm span of 60 in. or more. In all cases, the arm and hand must be free to exert maximum force to support the body if necessary and not be required to hold any object while climbing; objects, papers and tools should be stored in a backpack or hoisted (Ellis, 2012b). The hand should be able to curl around the stair rail for a power grip without interruption (Figure 6).

Figure 5
Best Practice Stepladder



Employers that control worksites should strive to integrate the concept of three-point control into the work process at the design or development stage, then ensure that it is followed at the actual job site.

Truck Cab, Trailer & Tank Truck Access

Three-point control also can apply when accessing truck cabs or dismounting while facing the cab. Several means can be designed to provide movement strategy through two horizontal handholds and one horizontal step and then alternate with one horizontal handhold and two horizontal steps (Rhodes & Miller, 1989).

FMCSA has not addressed access safety for flatbed trailers and tank truck access. The principle of three-point control should be applied to flatbed trailer access and tank truck tops for work on stationary vehicles and trailers to provide safer work conditions. Figure 7 (p. 36) depicts an example of horizontal grab bar extension rails for trailer access using the rub rail.

Tower Step Bolts

The ANSI/ASSE Z359 committee is working on a draft standard Z359.16 for fixed ladder fall arrestors that includes step bolt access. The use of single rail with climbing step bolts or pegs on towers and poles in the utility industries always requires an independent safety cable or rail for fall protection due to the hazard and uncertainty of sudden bolt fracture while climbing. Step bolts installed for climbing towers may alternate but should have same level steps for locations intended for standing and working. Cable for a climbing device carrier must be tightened regularly and maintained tight so as to direct both a fall of the climber's body and the fall arrestor device arrest process between the step bolts. Then, three-point control is an important addition to safety.

Conclusion

Three-point control is an often misunderstood concept that is confused with the more widely understood and practiced concept of three-point contact. Three-point control often is counterintuitive to the way workers regularly perform activities at elevation including ascending and descending ladders. Workers at elevation generally are familiar with the regulatory standards and conduct their work so as to meet the statutory requirements from a static point of view. What workers may not know and, therefore, do not practice is that they can greatly increase their personal safety by adhering to the concept of three-point control in addition to following the standards by recognizing the effects of a dynamic fall.

Employers that control worksites should strive to integrate the concept of three-point control into the work process at the design or development stage, then ensure that it is followed at the actual jobsite. It is neither difficult nor costly to infuse the concept. Consideration of the four basic goals in ladder use can help ensure effective three-point control:

1) Grip, do not lean.

2) Hold horizontally, do not simply touch.

3) Grip with the hand rather than use the stomach or other body part for stability.

4) Use flat step or rung, not a crevice, for foot stability.

Equally as important in the design and development stage is the commitment to provide horizontal grab fea-

Figure 6
Bracket Design for Continuous Handhold

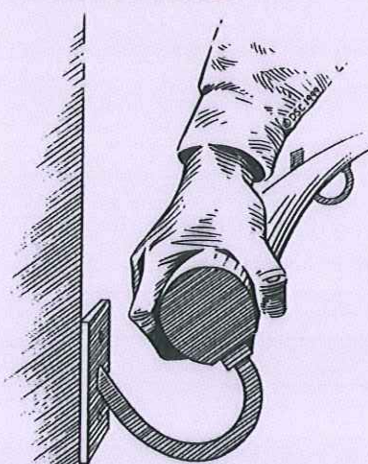
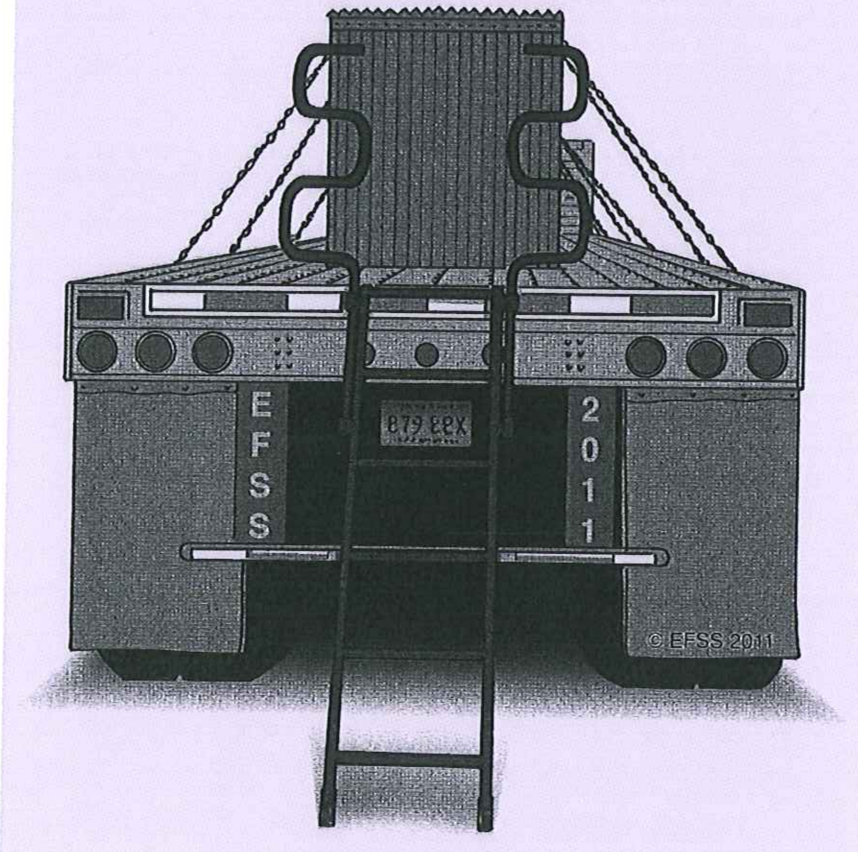


Figure 7
Flatbed Access to Side or Rear



tures at all elevated work locations. Because effective three-point control requires the use of a power grip, it relies on the presence of these horizontally placed design features. Providing the tools and training workers to hold horizontal grab bars and rungs, where equipped, for access to heights and work, will help reduce the toll of fatalities from ladder use in all industries. **PS**

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Disclosure

The author holds several patents on fall safety protection that have been licensed to outside interests.