Three Point Control: Analysis and Recommendations 10 06 11

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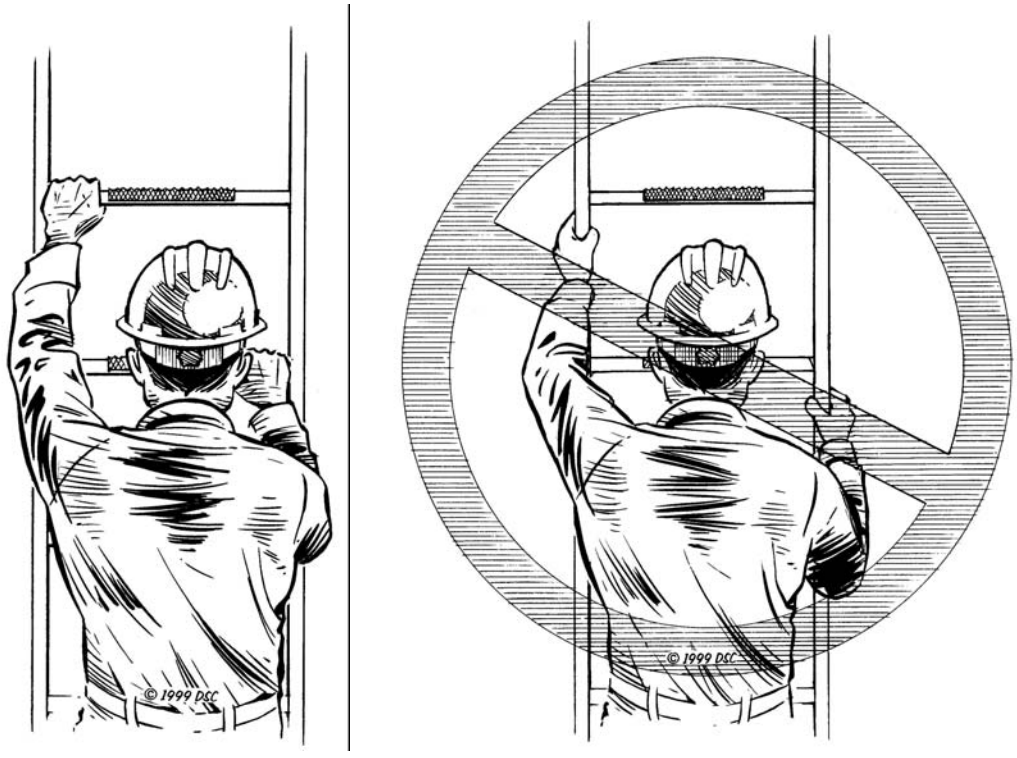
Ladder falls are the primary cause of fall fatality in the construction industry - BLS

Three Point Control is a design concept for climbing access and working at low heights to increase safety for workers primarily using portable and fixed ladders, but also accessing stationary vehicles and roof hatches. For engineers and designers, there is a quantifiable human factors balance issue and also a fall stopping issue which determines the degree of efficiency of this type system. At heights beyond the OSHA fall protection trigger height, independent personal fall arrest systems (PFAS) should always be considered. See also Federal Register 29CFR 1910.23-.27/1926.500-503 for trigger heights, Reference 1.

Three Point Control basically should consist of using three limbs for stability and reliability when moving or working above the ground where a fall can occur. See Fig. 1



Holding horizontal rungs is reliable Holding side rails is unreliable

Three Point Control on Fixed Ladder Fig. 1

Traditionally, 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 alternating with one hand holding a rung (or side rail) and two feet on a lower rung have been considered “Three Point Control” for a stable ladder climb up to now. This is also known as the 3-Point Ladder Safety Rule. There are two problems: The use of ladder side rails despite the possibility of continuity of hand contact, does not promote fall safety for climbing fall arrest, because of extreme difficulty in successfully grabbing vertical strip steel (fixed ladder) or small I-beam (portable ladder) and this must be communicated through training for climbers to grasp the rungs only. Also the alternating method of climbing a ladder using three limbs attached at all times is counterintuitive for most ladder designs and must be learned through repeated hands-on training. The principles of effective Three Point Control for the design of and the climbing of ladders is the key purpose of this white paper.

The designer of ladder systems and grab bars must consider human factors such as hand gripping capacity and also spacing, shape and geometry of handholds (grab bars). Ref. Young, Justin G., Thesis, Biomechanical Research Laboratory, University of Michigan, December 2010

The most important feature for control when exposed to a fall hazard is being able to hold onto a properly positioned and designed handhold. Falling force (in lbf) approximately consists of person’s weight x lbs. and free fall distance y ft. divided by the hand-gripping arrest distance. Based on a recent biomechanical study at the University of Michigan, Reference 2, research funded by CPWR/NIOSH, the choice of holding a horizontal round object or grab bar with a power grip was found to be unquestionably safer than holding a vertical object or side rail when the fall starts.

The vertical grab bar is not recommended for access design because the **hand will slide** in almost every fall **and** disconnect from the ladder when that hand first strikes an obstruction. For example, the time for the sliding hand to forcibly hit the next rung 12” below is ¼ second, yet it typically takes one third second minimum for full physical human muscular response. Ref. Thelen et al 1996. Thus the proposed maximum size limit for a vertical grab bar of one inch diameter is 10” overall length with a maximum 6” hand slide (Ellis). **Generally, holding a vertical side rail of any ladder or grab bar while climbing or**

working at height is not a recommended design or work practice for any reason.

Note: high friction gloves do make a difference ref. Young, Justin G. thesis University of Michigan Ladder Improvements, www.FallSafety.com. It is generally felt that climbing a fixed ladder is more difficult and more dangerous than climbing a sloped portable ladder with due to opportunity to fall vertically without restraint.

Minimum strength of a horizontal grab bar used in three point control should be 1000 lbs in all directions based on a dynamic 2x safety factor on the load. Any object that can be grabbed including webbings and ropes should meet strength this requirement to accommodate dynamic forces and be a minimum of ¾" diameter for fixed ladder rungs and preferably 1", or1.5" diameter with a flat top surface for portable ladders. (Ellis). Note: Foot space must also be horizontal and is usually centrally stepped on a rung so friction material can be added to the middle 8" of a rung but not the outside 4-5" which are reserved for the (gloved) hands. Tower structures often resemble ladders with rungs but climbing angled struts should be avoided in case the foot twists or the ankle turns, precipitating a fall.

Fixed Ladder Side Rail Extensions:

Side rail extensions for a walk-through fixed ladder are necessary for balance but if a fall occurs, the vertical rail is ineffective in stopping a fall due to low sliding friction. Sometimes the descending worker will "run out of flared side rail" due to a climbing routine. However, if the ladder has horizontal grab bars then sliding is avoided when a fall starts at the top 3 ft of a fixed ladder during transition due to high strength hook grip. See Fig 2. OSHA/BLS data determined 23 deaths over nine years of climbers of fixed ladders who fell to the base. Training to hold only horizontal rungs and grab bars, when possible, will be a vital addition to any current safety program.

Tool belts worn by users are typically passable with only a slight twist of the torso if the original ladder side rail extensions are approximately 24" apart (Ellis). On a fixed ladder, the center of the rung should be skid-resistant while the outside 4-5" should be smooth but not slick. See Fig. 1. Shoe penetration space

must be at least 7” for the entire length of the ladder rung which should be 16” between side rails for comfortable climbing especially with a shank. Ref. Sizes and lengths from OSHA 1910/1926 and ANSI A14.3

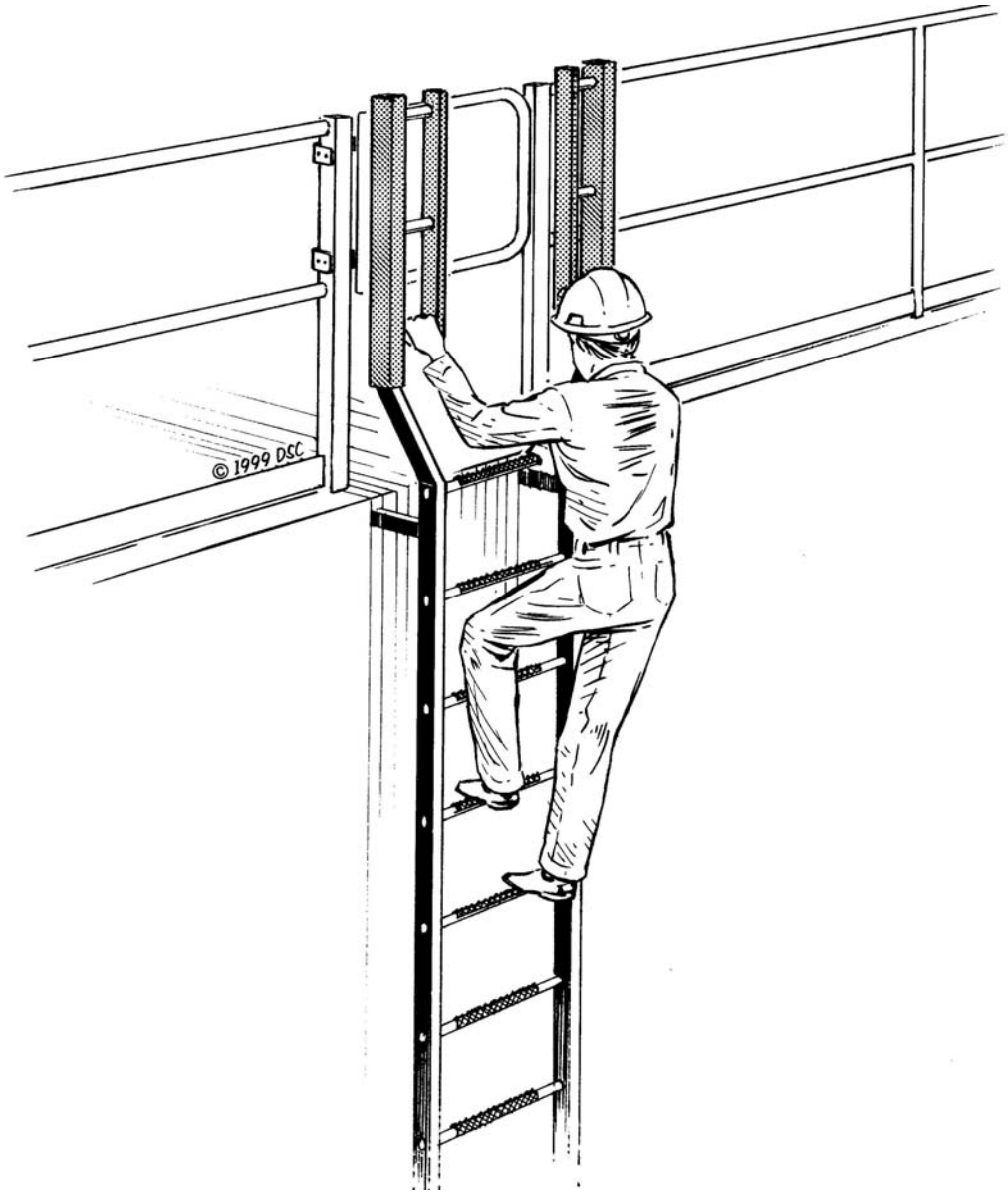


Fig. 2

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

Ship's Ladders and Alternating Tread Stairs:

These steep sloped ladders (50-70 degrees to horizontal) are a natural for effective three point control because their use forces both hands to hold the round sloped side rail (1-5/8"-2" OD) 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). Ref: Proposed OSHA 1910.25

The Hotel Bathtub:

Avoiding guest and staff falls related to the bathtub is a major goal to reduce incidents at hotels. Typically in standard rooms grab bars are placed indiscriminately on the back and side walls and each hotel appears to have its own brand of handholds instead of collaborating through the American Hotel and Lodging Association for one basic standard design.

Fig. 3

Typical proper grab bar placement for standard bathtub

Horizontal grab bars (24” length minimum, 1-1/4” – 1-1/2” dia.) should be straight across a bathtub wall to comply with ANSI A117.1 and Americans with Disabilities Act (ADA) for disabled persons (some would say we are all disabled from time to time so this standard is best practice), or at a slight raised angle (suggest max. 20 degrees to horizontal – Ellis) on bathtub walls to assist standing up from a sitting or laying down position. The only place a short vertical bar (12” maximum recommended) is warranted is at the edge of a bathtub at waist to chest height to assist different size persons stepping out of the tub, especially when the floor is slightly lower height than the tub base. This is to help avoid pitching forward when the vertical bar becomes in effect a horizontal restraint and similar to how a subway train car pole acts during acceleration and deceleration for riders to help stabilize themselves. Note: This grab bar should also be positioned at the opposite end of the tub away from a toilet location where the grab bar would be ineffective. Fig. 3

Portable Straight and Extension Ladders:

When Three Point Control is applied to portable ladder work such as use of a drill, Three Point Control means one hand use for gripping stability on a rung and the other hand for light duty work (eg 1.5 lbs drill but not 3.5 lbs drill ref. Lowe’s Tool Manager, N. Wilmington DE, 4 11) plus both feet on one 16” rung or 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 balance plus a horizontal rung power grip for one hand (with less than 20 lbs force applied to a tool for ladder stability, Ellis), and readings documented using an electronic recorder in the other hand, instead of the more traditional notepad requiring two hands.

Portable straight ladders come with uniform parallel side rails and rungs except possibly for a flared base section. Projection above a surface for dismount is recommended in safety texts and OSHA almost universally at three feet above the exit surface along with ladder shoes for urban surfaces and a 75.5 degrees angle to the ground. Stepping though a fixed or portable ladder onto a roof or other surface is safer if horizontal grab bars are positioned on the ladder to each side using an accessory ladder extension (Fig. 5b) or roof hatch mount extension walk through (Fig. 4A&B) which automatically achieves the desired three foot ladder extension above a roof edge or other dismount. Note:

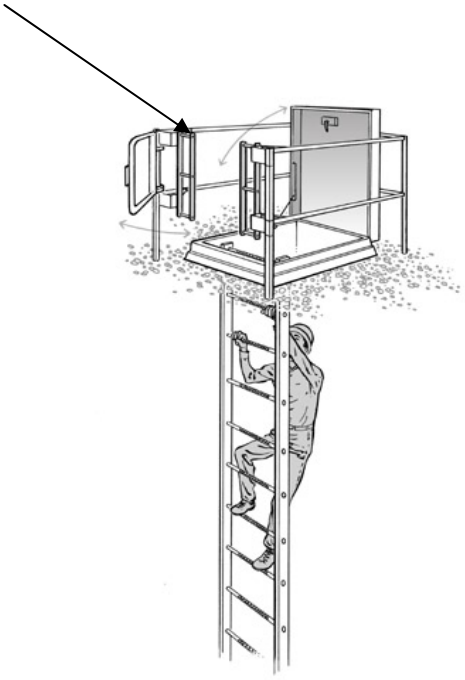
approximately 75% workers using portable ladders do not presently extend their ladder by the recommended three feet (ref Ellis). Grab bars for ladder extensions should be round, 4-5” horizontal length and be ¾” – 1-5/8” diameter compatible with the matching ladder rungs, and be a uniformly sized rung or horizontal grab bar for an encircling hand grip.

Roof Hatch access:

Grab bars for roof hatches are addressed in ANSI A14.3-2008 section 5.3.4.3 “to facilitate access and exit”. Reference 6. And also Fixed Ladders in US Corps of Engineers Safety and Health Requirements Manual, EM385-1-1 (2003) (mandatory) Appendix J, Fixed Ladders 2b, 3h and 4d require “elevated horizontal grab bars to facilitate grip in case of a fall” for ladder side rails, openings (hatches) and grab bars. See Fig. 4A and B.

Roof Hatch with Walk-In and Walk-Out Facility

Grab Bar must be Horizontal for a reliable handhold in a Fall Hazard exposure



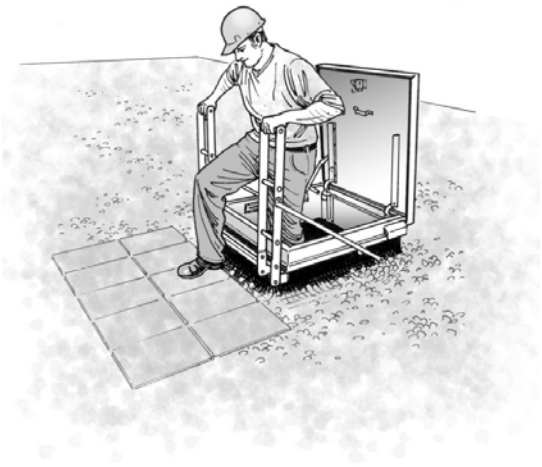


Fig. 4A

Ladder Continuous grab bars with guardrail

Fig. 4B

Ladder Continuous grab bars for walking in and walk out

Walk through Horizontal Grab Bars for safer access and exit to/from a roof. Top rung must equal height of step off when dismounting and the ladder secured adequately from sliding. Distance between grab bars should be 20-24”” (Ellis) to reasonably avoid small tool belts catching Fig. 5A and B

Fig. 5A and 5B

Portable ladder erection and use with Horizontal Grab Bar accessory

Horizontal grab bars provide the strongest grip possible

Truck Cab Access:

Three Point Control can also 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. Ref: SAE white paper Miller, James M.

Trailers and tank trucks access:

Flatbed trailers and tank truck access have not been addressed by FMCSA. The Principle of Three Point Control should be applied to flatbed trailer bed access and tank truck tops by OSHA for stationary vehicles to provide safer work conditions based on the large number of falls by drivers per BLS data, eg Fig 5. Example of horizontal grab bar extension rails: *Reference www.andersonladder.com; www.standfastusa.com

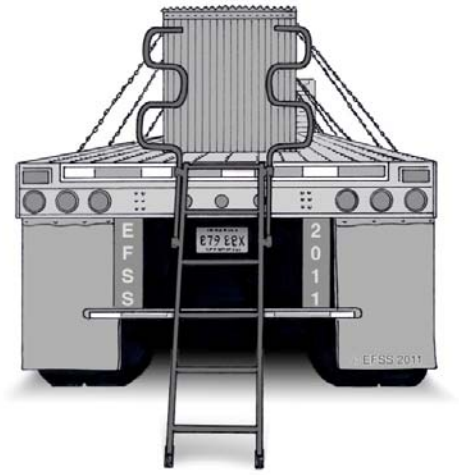


Fig. 6
Flatbed Access to Rear of Trailer

Stairs and Three Point Control:

If three point control is applied to standard stairs (30-50 degrees to horizontal), there must be two compatible stair rails (hand rails) to move the hands (slide and grip motion) while stepping. The designer should design a stair to the IBC Code (Section 1009) with a 7/11 slope (7” riser max. and 11” tread min.) and a graspable 1-5/8”- 2” dia. round or equivalent stair rail for adults. Stair rails should by code be a maximum of 48” apart to accomplish Three Point Control (suitable for an arm span of 60” or more). Needless to say that 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. See stair rail for continuous grip contact (Fig. 7)

Stair steps (treads) must be deep enough for the shoe and penetrate at least 11” for foot space stepping both up and down. Ref: OSHA proposed 1910.25 and NFPA 5000-2009

The hand must curl around the stair rail for a power grip without interruption.

Guardrails for stairs help prevent falls into a well or an outside edge over the handrail or stair rail for protection down the flight of stairs. The CoG of a male stair user is approximately 42” and when falling forward, the top of the guardrail must exceed the CoG or be at least 50” vertically above the stair tread nosing (7” riser and 11” tread).

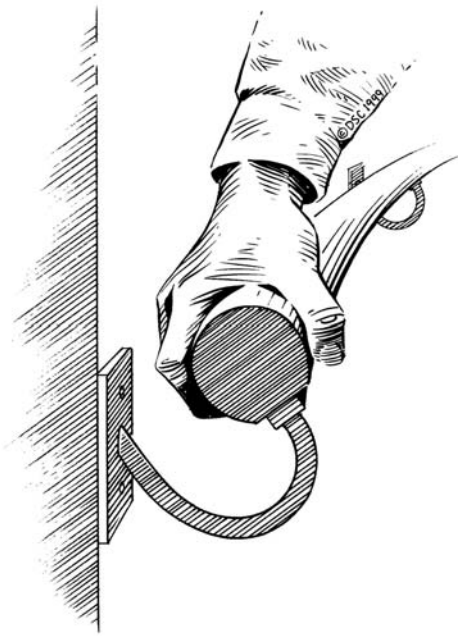


Fig. 7
Bracket design allows continuous hand hold of stair rail
Ref: Introduction to Fall Protection 4th ed. 2001

Ultra Hardware Products NJ

Tower Step bolts:

Use of single rail climbing step bolts (pegs) on towers and poles in the utility industries always requires independent safety cable or rail fall protection due to the hazard and uncertainty of sudden bolt fracture while climbing. Step bolts 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 and maintained that way so as to direct a fall and its arrest between the step bolts.

A-Frames (Stepladders):

A-Frames and stepstools typically have no horizontal round rail or grab bar to hold onto for balance and no self-leveling feet like a portable ladder.

Manufacturers usually provide warnings to help prevent unbalanced stepping onto the top two or three steps but these are often positioned where workers typically handle ladders and so become illegible. Safety can be increased with steps that are flat and broad (3” or more) 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. The stepladder while in use must be in the fully opened position with leg locking-bars engaged and be perpendicular to the work surface to reduce tip-over hazards. Stepladder side rails, if present, should be held horizontally while climbing and minimally be at waist height for work using the top step for leaning against if no rung is available (or as allowed by the manufacturer). Consider independent “first-man-up” (see Introduction to Fall Protection 4th ed.) plus “fast fall arrestor” (Z359.14-2011) 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. Note: Consider a scaffold or small scissor lift for more stability. Remember: grabbing for structure at the onset of a fall from a standard A-frame eg a gutter, can cut or slice the hand or arm very seriously. The climber should check the likely hazard outcome before stepping or reaching Fig. 8
NOTE: Mobile Ladder Stands & Platforms meeting ANSI A14.7-2006 supporting 4x their rated load (300 lbs+) are essential for maintenance work and often custom made for a specific application eg specific aircraft access, and must have handrails above 4 ft step or platform height

Fig. 8

Author's Best Practice stepladder (Ellis)

Reference 7.

Three Point Contact:

Three Point Contact should be distinguished from Three Point Control. The Contact is one step and two hand contacts alternating with two steps and one hand or body contact without a strength requirement. Some would argue to having the body (stomach) lean against a bar or surface as a point of contact and others would say for eg car carrier drivers that are asked to use the palm of the hand resting on the roof or hood of an auto as is sufficient for the driver's stability. The author believes that Three Point Contact is an unsound means of positioning the body because one hand must be able to grasp efficiently (horizontal power grip) to reasonably prevent a fall back and reduce stepladder tipping to provide "Control". Based on present A-frame design in the USA and UK, this upgrade requirement to Three Point Control may have to be postponed temporarily. The Health and Safety Executive (HSE) in the UK has promoted Three Point Contact on stepladders (A-frames) extensively through publications

instead of promoting mobile ladder stand (platforms) or small aerial lifts for example 8-15 ft height access. Reference 5.

Three Point Stance:

Another term, Three Point Stance is primarily 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 particularly trucking makes it more like Three Point Contact with little or no specific fall protection merit in terms of stability and physical grasping power.

Note: The term has been adopted in the trucking industry by FMCSA for referring to access in or out of the cab, and also other industries where climbing or traversing to a position is needed requiring two finger digits of a hand for support without cutting the hand. Also car carrier manufacturers have adopted Three Point Stance to allow drivers to step along foot rails (narrow catwalks) while holding customer car hoods, car roofs and other variable panels or crevices using the palm of the hand or single digits of the hand which the author disagrees with because it does not reliably aid the driver's balance while traveling and is unreliable in a tripping situation on narrow catwalks as compared with a horizontal power grip with the whole hand when above-shoulder grab bars or rails are present, affording a horizontal power grip.

Recommended Conditions for Work Use of Three Point Control**:

Note: Applies to light duty work off the ground on a portable ladder

1. Short duration

2. Light materials

3. Light tools for one hand use (reference 5)

4. Keep belly button between the side rails close to ladder; no overreaching

5. Both feet at same level eg on a rung but not for example on alternating step bolts for work

6. One hand grip on a horizontal object such as a round rung; no vertical hand grip which can slide in a fall. Hands and arms must be free to climb and work

7. Ladder is stabilized and used per manufacturer's instructions

8. Foot Height: 2-4 ft up to an estimated 10-12 ft based on height fatalities, from free falls at work, spike upwards (BLS report on annual work fatalities e.g. 1% at 6 ft, 9% at 10 ft, 20% at 15 ft)

Reference 3: US Army Corps of Engineers

(Note: Never use ladders or A-frames next to edges or guardrails without independent fall protection in case they tip laterally) Keep one length of ladder/A-frame away from a railings for example

**Most important: The judgment by a Competent Person from the Controlling and Exposing Employers is required for assessing points 1-8 for Light Work on the site. If these conditions are not met then the use of a fast fall arrestor (SRD, Reference 4) and a full body harness should be considered with first-man-up remote overhead anchoring ref Z359.18, draft, Anchorage Connectors. The higher the frequency of climb the more the need for guarding and/or PFAS.

Summary: 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.

References:

1. ANSI Z359-2007 and 2009 Fall Protection Code, and OSHA/DOL 29CFR1910/1926 and 49CFR FMCSA/DOT

2. a. Young, Justin G., Biomechanics of Hand/Handhold Coupling and Factors Affecting the Capacity to Hang On. Doctoral Dissertation, Department of Industrial and Operations Engineering, University of Michigan, Ann Arbor, 2011, University of Michigan.
   b. Human Factors, Vol. 51 No. 5., October 2009, pp 705-717.

3. US Army Corps of Engineers (USACE) guidelines adapted by Ellis, J. Nigel, author
4. ANSI Z359.14-2011 Self-Retracting Devices for PFAS 24" total fall distance models (pending)
5. The HSE in the UK permits body leaning into a stepladder top step for the third point of contact to justify use of two-handed work and use of tools like heavier drills usage from ladders. **www.hse.gov.uk/falls/usingladders/stepladderthreepoints.htm**
6. ANSI A14.3 – 2008
7. SAE Technical Paper, Revisions of TMC Recommended Practice RP-404 'Truck and Truck Tractor Access Systems, Timothy P. Rhoades and James Miller, University of Michigan
8. Yang and Ashton-Miller, Factors Affecting Stepladder Stability during Lateral Weight Transfer, Applied Ergonomics 36 (2005) 601-607 and

Yang and Ashton-Miller, Stepping onto Raised, Laterally Compliant Structures, Human Factors Vol. 48 No. 2 Summer 2006 pp 207-218

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COG= Center of Gravity

For further information and site fall protection engineering concepts call 302.571.8470 ext. 121 or send email to **efss@FallSafety.com**

www.FallSafety.com