Leading Edge Self-Retracting Lifelines

Calculating Fall Protection Clearance Distances

By Scott Wenholz and Thomas V. Rizzi

IN BRIEF
- **Miscalculating required fall clearance distances contributes to fatal falls in construction. The issue is further complicated when using leading edge self-retracting lifelines (SRL-LE) in situations in which the anchorage point is located below a worker's dorsal D-ring.**
- **The problem stems from unclear or misleading equipment documentation, as well as training programs and literature that inadequately address the issue. As a result, many authorized, competent and qualified fall protection persons may not fully understand the equipment limitations or how to properly calculate clearance distance when incorporating an SRL-LE.**
- **This article highlights information that may be missing from equipment manuals and provides a more accurate method for calculating clearance distances when using SRL-LEs anchored below the dorsal D-ring.**

Falls continue to be the leading cause of fatalities in construction, according to OSHA, accounting for approximately one-third of all industry fatalities. In 2014, falls caused 359 of the 899 total deaths in construction (39.9%) and are the third-leading cause of fatalities in general industry behind transportation and workplace violence, respectively (OSHA, 2016).

The miscalculation of required fall clearance distances is one factor contributing to these fatalities. This issue is further complicated when using leading edge self-retracting lifelines (SRL-LE) in situations in which the anchorage point is located below a worker's dorsal D-ring. Part of the problem stems from the SRL-LE information provided by the manufacturers; manuals can be unclear or misleading because typically only the maximum deceleration distance for overhead installations is listed. Additionally, most fall protection training programs do not adequately address SRL-LE applications, and existing published literature does not discuss this issue. Thus, many fall protection authorized, competent and qualified persons who use and evaluate SRL-LEs may not fully understand the capabilities and limitations of this equipment or how to properly calculate the necessary clearance distance.

This article highlights information that may be missing in SRL-LE manuals and provides a more accurate method for calculating fall protection clearance distances when using an SRL-LE anchored below the dorsal D-ring. This method becomes particularly important when the working surface is less than 18 ft from the next level or where an obstruction exists.

Definitions

To better understand the issue, let's start by defining several terms.

Clearance distance: The amount of free space below a worker, using a properly designed fall protection system, required to prevent the worker from striking a lower level or obstruction. For a fall over a leading edge, clearance dis-

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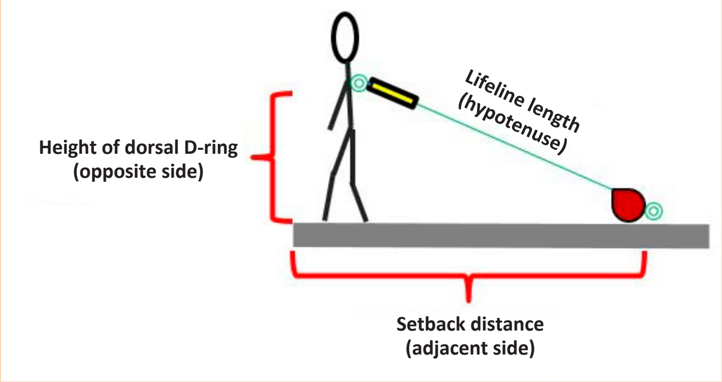
Figure 1
Lifeline Length



Note. *Figure is for a fall perpendicular to the anchorage point and does not account for swing.*

tance is defined as the sum of six components: 1) free fall below the working surface; 2) deceleration distance; 3) equipment stretch; 4) height of worker's dorsal D-ring; 5) safety factor; and 6) swing-fall distance, if applicable (this article does not address swing fall).

Maximum free fall (ff_{max}): The vertical displacement of the dorsal D-ring on the employee's body harness between onset of a fall and just before the system begins to apply force to arrest the fall. For the purposes of this article, maximum free fall is the sum of two components: free fall to horizontal and free fall past horizontal.

Free fall to horizontal: The vertical displacement of the dorsal D-ring from the start of a fall to the point at which it is horizontal to the anchorage.

Free fall past horizontal: The vertical displacement of the dorsal D-ring past the horizontal plane of the anchorage point. The free fall past horizontal is due to the lifeline being longer than the setback distance of the anchorage point (Figure 1).

Free fall past horizontal is calculated by subtracting the anchorage setback distance (adjacent side) from the total lifeline length (hypotenuse). *(Two items of note: Free fall past horizontal does not account for lifeline reel in. Based on industry standard SRL design specifications, reel-in length would be minimal. Also, if a worker travels laterally along the leading edge the lifeline length will increase, manifesting in an additional swing fall. As noted, this article does not address swing fall.)*

Deceleration distance: The vertical distance a worker travels from the moment of activation of the fall arrest system to the final fall arrest, as measured at the body harness dorsal D-ring.

Equipment stretch: The additional stretch of the body harness material, lifeline and other components while arresting a fall (typically 1 ft).

Height of dorsal D-ring: The vertical distance from the body harness dorsal D-ring to the horizontal plane of the anchorage point.

Safety factor: Additional vertical distance that is added to account for performance variables caused by improper fit of equipment, variations in system reactions, environmental factors (e.g., temperature, moisture), roof edge geometry, SRL condition and other unknowns.

Background

OSHA 1926.502(d)(16)(iii) requires personal fall arrest systems to limit free fall to 6 ft and to prevent the worker from contacting a lower level. Meeting the 6-ft requirement is not always possible with leading edge work. A worker with a dorsal D-ring 5 ft above the anchorage point attached to an SRL-LE standing on the edge of a building (i.e., the leading edge) could free fall as far as 10 ft before the system would begin to arrest the fall.

In response to questions regarding this concern, OSHA (1995) issued Interpretation M-3 that allows for a greater free fall "if the employer has documentation to demonstrate that [the] maximum arresting forces are not exceeded and that the personal fall arrest system will operate properly." To function properly, forces must be limited to protect the worker and the equipment integrity. In most cases, this requires a shock pack connected to the dorsal D-ring.

ANSI also recognized the need for equipment that would limit the arresting forces on the body generated by a free fall greater than 6 ft while maintaining the integrity of the fall protection system. Standardizing leading edge equipment design was first addressed with the publication of ANSI Z359.14-2012. To be considered ANSI-compliant, SRL-LEs must pass the ANSI class B overhead drop test and two additional ANSI leading-edge-specific drop tests. Per the ANSI standard, SRLs that pass LE testing should be marked on the housing as "LE rated." Additionally, drop test results must be available from the manufacturer upon request (ANSI/ASSE, 2011).

Problem

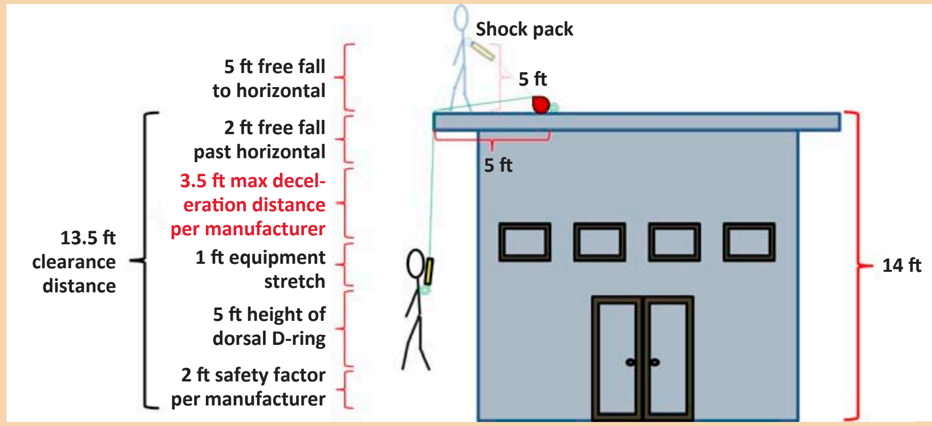
While reviewing elevated work surface plans (EWSP), the authors discovered that the manufacturer-listed deceleration distance was inaccurate when using the SRL in leading edge applications. An inaccurate deceleration distance can lead to workers striking a lower level or obstruction.

In the EWSPs being reviewed, the SRL-LE manufacturer for the proposed equipment did not list a unique maximum deceleration distance when anchoring the SRL-LE below the dorsal D-ring. The manual listed a maximum deceleration distance of 42 in. (3.5 ft) for all models in that product series, including the LE version with an incorporated shock pack. Based on this information, the competent person calculated the clearance required for the leading edge application under review (Figure 2).

As noted, the LE version has an incorporated shock pack, but the length of that shock pack is not noted in the cut sheet, instruction manual, technical bulletins or on the housing of the gear. The authors contacted the manufacturer; an engineer representing the manufacturer stated that the integrated shock pack had a possible payout of 60 in. (5 ft). Therefore, the total possible payout of the system (SRL plus shock pack) is 102 in. (8.5 ft). Competent persons are trained to plan for the worst-case scenario, and assume a full payout of the arrest system deceleration components. Thus, assuming a worst-case scenario, the calculated clearance distance when using the SRL-LE must be 5 ft greater than that indicated by the manufacturer's instructions (Figure 3).

Figure 2

13.5 ft Clearance Needed if Shock Pack Does Not Deploy

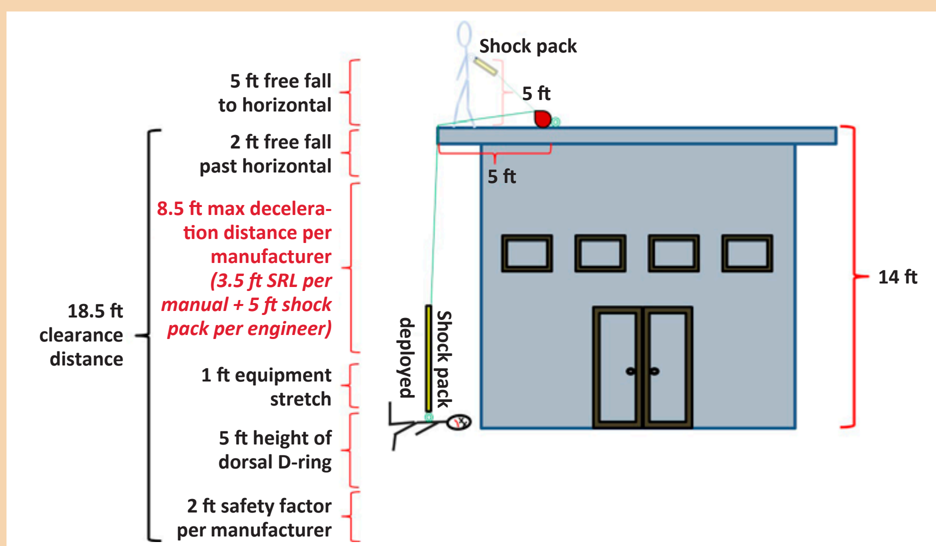


Note. *Figure is for a fall perpendicular to the anchorage point and does not account for swing.*

The conservative approach, assuming full payout of the fall arrest components, would likely be sufficient if the worker was on a two-story building. Since the worst-case scenario was not adequate, it was necessary to ask for clarification from the manufacturer as to how the SRL and shock pack deceleration components work as a unit. The manufacturer's engineer was unable to provide information as to how the SRL clutch and shock pack work in conjunction when arresting a fall, and stated that the 42-in. maximum deceleration distance only applied to overhead applications.

Figure 3

18.5 ft Clearance Needed if SRL & Shock Pack Fully Deploy



Note. *Figure is for a fall perpendicular to the anchorage point and does not account for swing.*

Subsequently, the overhead and LE drop tests associated with the SRL-LE listed in the EWSPs were requested. Physics dictates that the maximum deceleration distance must be greater when an SRL is anchored at foot level (vs. overhead) to dissipate the increased kinetic energy. In reviewing the requested drop tests, data confirmed that the resultant LE deceleration distances were 75% to 115% greater than the 42-in. maximum deceleration distance listed in the manual, a clear indication that the information provided in the manual was inaccurate for leading edge work.

To understand whether this was a problem across the fall protection industry, a product review was conducted to identify companies that offer LE-rated SRLs and to determine what information they provided for maximum deceleration distances. As of November, five manufacturers sell SRLs for use in LE applications. LE drop tests and maximum shock pack elongation lengths were requested from each. The responses were as follows:

•Two manufacturers provided drop test data and maximum elongation of the shock pack.

•One manufacturer provided a supplemental bulletin adding 42 in. to the fall calculation for the additional shock pack, but declined to provide drop test data.

•One manufacturer stated that it does not currently have an LE-rated SRL, but the SRL manual states, "In some situations, the addition of a (company-specific) shock absorber may be advisable to help mitigate leading edge hazards." *[Note: As of February 2016, this manufacturer has released an ANSI-compliant SRL-LE for which the manual lists "Typical (manufacturer) performance" for leading edge applications. The "Typical . . . performance" values should be used as the deceleration distance in the* *worst-case scenario evaluation of the elevated surface work plan.]*

•One manufacturer did not respond.

Based on the information obtained through this effort, the authors conclude that the maximum deceleration distances for SRL-LEs are either not available or not communicated adequately across the industry. Therefore, in situations in which the clearance distance (assuming worst-case scenario) is inadequate, the following method was developed to calculate a more accurate deceleration distance, regardless of equipment manufacturer.

Solution

To determine a more accurate deceleration distance, the equation listed in ANSI Z359.6-2009 4.4.3.2.2.2 was algebraically rearranged to find the worker's deceleration distance instead of the "maximum free fall distance permitted by the system."

Equation 1: Equation from ANSI Z359.6-2009 4.4.3.2.2.2:

$$h_{max} = \left(\frac{F_{avg} - w}{w}\right) X_{max}$$

$$\downarrow$$

$$X_{max} = h_{max}\left(\frac{w}{F_{avg} - w}\right)$$

$$\downarrow$$

$$X_{max} = \frac{h_{max} \times w}{F_{avg} - w}$$

In addition, two variables were renamed in the new deceleration distance calculation: h_{max} in Equation 1 was renamed ff_{max}; and x_{max} was renamed x (see Equation 2). This nomenclature change was effected to better represent the terminology used in the field.

Equation 2: Derived deceleration distance equation *(Note: Deceleration distance calculation should be performed or verified by a qualified fall protection person)*:

$$x = \frac{ff_{max} \times w}{F_{avg} - w}$$

Where:
x = deceleration distance of the arrest system in ft;
ff_{max} = maximum free fall distance in ft;
w = weight of worker in lb;
F_{avg} = average arresting force in lb.

The information required to perform this calculation is the height and weight of the individual worker and the average arresting force of the SRL-LE.

Considerations for using Equation 2:

•Deceleration distance (x) includes the combined payout of the SRL deceleration mechanism and shock pack elongation.

•ff_{max} is the maximum free fall as defined above.

•Weight of the worker (w) must include tools, equipment and a weight safety factor.

•The average arresting force F_{avg} can be found on the SRL housing or in the instruction manual.

Disclaimer
After consultation with legal counsel and out of abundance of caution, the authors have omitted specific references to fall protection equipment manufacturers.

•This calculation does not consider the performance variations due to environmental factors, such as temperature and moisture. Therefore, the manufacturer's recommended safety factor is still necessary for calculating the clearance distance.

As shown in Figure 3, the worst-case scenario would not be sufficient, but the deceleration distance calculation, as part of the clearance distance, may show that the worker would be adequately protected. The following example scenarios illustrate how the calculated deceleration distance, based on the worker's height and weight, will improve elevated work planning.

Scenario A: Average Size Worker

A 5-ft 9-in. worker has a dorsal D-ring at 5 ft. His total weight is 200 lb (170-lb worker, 20-lb tools and equipment, 10-lb weight safety factor).

$$x = \frac{7\text{ ft} \times 200\text{ lb}}{900\text{ lb} - 200\text{ lb}} = 2\text{ ft calculated deceleration distance}$$

The resulting deceleration distance then must be added into the standard fall protection clearance distance diagram (Figure 4).

In Scenario A, the worker would be sufficiently protected for a fall perpendicular to the anchorage point. However, the system would react differently to a taller or heavier worker, so clearance distance would need to be recalculated based on that individual worker's parameters.

Scenario B: Above-Average Size Worker

A 6-ft 6-in. worker has a dorsal D-ring at 6 ft. His total weight is 310 lb (280-lb worker, 20-lb tools and equipment, 10-lb weight safety factor). (Note: the combined weight of this worker is approaching the maximum allowable for SRL-LEs).

$$x = \frac{8\text{ ft} \times 310\text{ lb}}{900\text{ lb} - 310\text{ lb}} = 4.2\text{ ft calculated deceleration distance}$$

While the larger worker in Scenario B would likely be protected when falling perpendicular to the anchorage point, only 9.6 in. of the manufacturer's recommended 2-ft safety factor remain (Figure 5). The safety factor is meant to account for variables such as improper equipment fit, variations in system reactions, environmental factors (e.g., temperature, moisture), roof edge geometry and SRL condition. Any of these variables could adversely affect the system, allowing the worker to strike the ground before the fall is fully arrested. Since there is little safety factor remaining, it would be ill-advised to allow this worker to use this equipment in Scenario B.

Conclusion

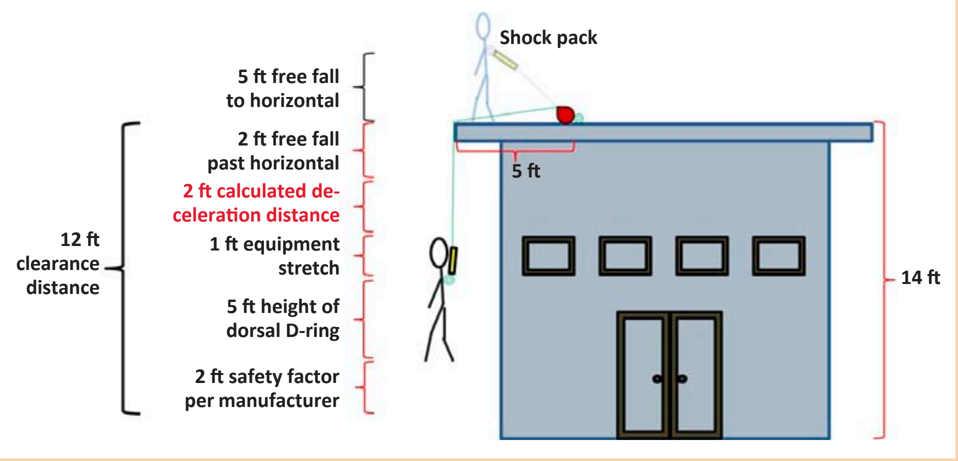
When developing an elevated surface work plan, fall protection safety professionals must be aware that the maximum deceleration distances for SRLs provided by manufacturers may be for overhead applications only. This can be misleading when planning work using an SRL-LE in a leading edge application. This may contribute to a safety professional's underestimation of the clearance distance required to adequately protect workers. This is not a serious concern when the working surface is significantly higher than a next level, in which case full payout of the arrest components (worst-case scenario) is adequate. It becomes critical when the available clearance distance below a working surface is less than 18 ft.

SRL-LE information may not adequately address the deceleration distances required to arrest a leading edge fall when clearance distances are limited; the methodology discussed in this article addresses this issue. Once an SRL-LE is selected for a particular job, regardless of the manufacturer, a competent or qualified fall protection person can accurately calculate the deceleration distance for a particular worker. The calculated deceleration distance can then be inserted into the overall clearance distance calculation, which will result in a more accurate and safe EWSP. In some cases, this equation may prove that adequate clearance to use a SRL-LE does not exist and indicate that the employer must explore other methods to protect workers.

The method described in this article is based solely on calculated values. Drop tests have not been performed to validate this theory specifically, but a review of SRL-LE drop test results and available manufacturer deployment distance versus free fall distance charts for energy-absorbing lanyards show a close correlation. Due to variability in real-world factors, the deceleration distance resulting from an actual fall may vary. This method is intended to be used for work planning purposes only. **PS**

Figure 4

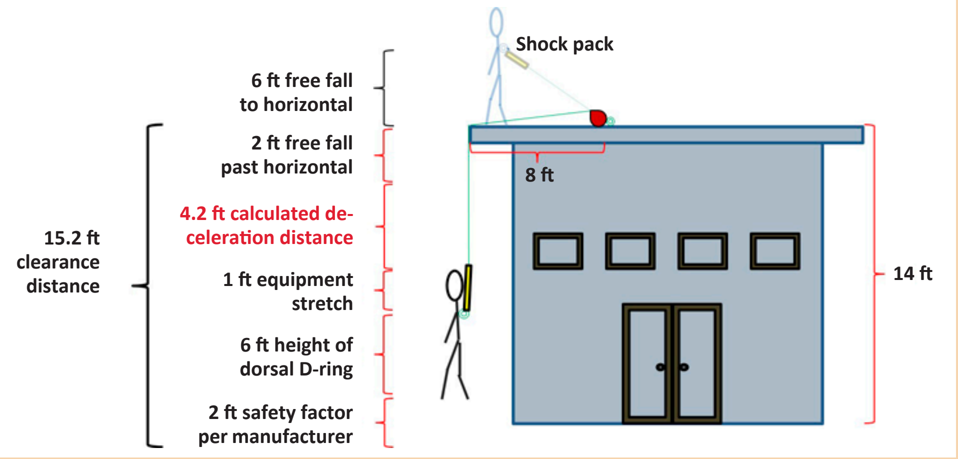
12 ft of Clearance Needed in Scenario A: Average Size Worker



Note. Figure is for a fall perpendicular to the anchorage point and does not account for swing.

Figure 5

15.2 ft of Clearance Needed in Scenario B: Above-Average Size Worker



Note. Figure is for a fall perpendicular to the anchorage point and does not account for swing.

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