Session No. 641

Your Employees Use Fall Protection, But Are They Really Safe from Harm?

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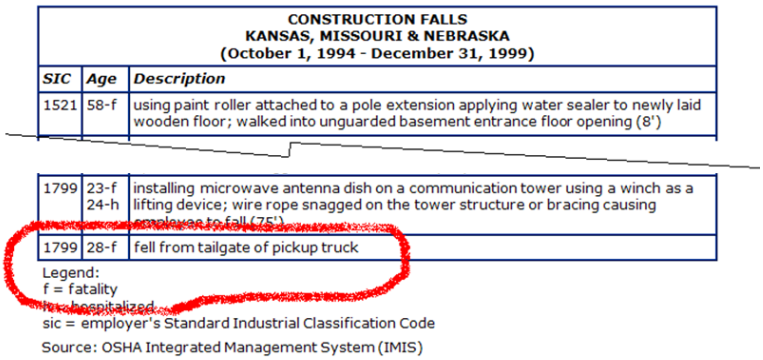
Introduction

Fall protection equipment and components are becoming more and more commonplace throughout industry. As a result, fatalities due to falls from height have been dramatically reduced over the past few decades. Now that industries are in the habit of using fall protection to save lives, let's review how we can choose and use specific equipment that can minimize secondary injuries and recovery times, and allow the user to simply return to work with no lost time and no lost production. This paper will review how to best identify hazards, pick components, and eliminate most of the commonly overlooked, but serious and potentially fatal, misapplications of equipment. This paper will also review some innovations that can not only prevent serious injuries and fatalities, but also minimize many types of hazards so workers may immediately return to work injury free.

Background

We all know that fall protection is required when working at substantial heights. Since the passing of the Occupation Safety and Health Act (OSHA) by Congress in 1970, fall protection has become more and more commonplace throughout industry.[1] That's the good news. The downside is that industry in general, and especially newcomers, needs proper education by the fall protection community in selection and usage of fall protection equipment.

For the benefit of all, let's start with the basics. OSHA law requires fall protection starting at four feet for general industry and six feet for construction. Why four feet? When an accidental fall occurs, the person can be falling in any random orientation and most certainly not in control of, nor anticipating, the fall or impact. Unfortunately, fatalities can occur at very low heights, even as low as pickup truck tailgates.



CONSTRUCTION FALLS
KANSAS, MISSOURI & NEBRASKA
(October 1, 1994 - December 31, 1999)

SIC	Age	Description
1521	58-f	using paint roller attached to a pole extension applying water sealer to newly laid wooden floor; walked into unguarded basement entrance floor opening (8')
1799	23-f 24-h	installing microwave antenna dish on a communication tower using a winch as a lifting device; wire rope snagged on the tower structure or bracing causing employee to fall (75')
1799	28-f	fell from tailgate of pickup truck

Legend:
f = fatality
h = hospitalized
sic = employer's Standard Industrial Classification Code
Source: OSHA Integrated Management System (IMIS)

Figure 1. Fatal fall from less than 4 feet[2]

Fall Protection Code Protections

Throughout the '70s and '80s, the federal government realized that OSHA could not keep up with the rapid changes and expanding knowledge and understanding of the fall protection limitations within the fall protection industry, so they petitioned the American Society of Safety Engineers (ASSE) to write a national standard for the American National Standards Institute (ANSI). The *Fall Protection Code*, ANSI Z359, was released in 1992.[3]

We have established that the minimum of four feet for the beginning of fall protection may not be enough. Another example where OSHA law may not be "safe enough" is OSHA's allowance of a fall's maximum arresting force (MAF) to be up to 1800 lbs. It is understood that the limit of "G-forces" that a healthy human body can withstand is about 10 G's.[4] Unfortunately, a 90-lb person subjected to an 1800 lb deceleration force would result in 1800/90= 20 G's, or twice the limit. A 130-lb person would see about 14 G's.

In 1992, ANSI Z359 started to define a more reasonable 900-lb MAF, and also defined weight limits. If an energy absorber is made to ANSI standards, and not OSHA law, you will see a 900-lb upper limit, and a body weight limit of 130 lbs. This results in a much safer maximum possible deceleration of, 900/130, or 6.9 G's.

The most important ANSI standard for anyone working with the specifying of or usage of fall protection is Z359.2, *Minimum Requirements for a Comprehensive Managed Fall Protection Program.*[5] This standard not only outlines the requirements and regulations that will best protect your employees, but also defines the requirements that OSHA will be looking for if your organization was ever inspected by OSHA.

The Z359.2 standard covers the requirements of a designated "competent person" at every organization who will oversee the proper implementation and usage of fall protection equipment. A brief summary of these requirements includes that the competent person:

- Knows the proper usage of the equipment used in his/her organization or department.
- Knows how to properly inspect the equipment.
- Knows how to train others in the proper usage of the equipment.
- Knows how to identify fall hazards and write a hazard analysis.
- Writes a rescue plan for every occurrence of fall protection.
- Provides supervision (monitoring) of users while at height.

- Receives update training every two years or sooner if new equipment is introduced.

All individuals working with fall protection, not just competent persons, need to know how to select and apply fall protection properly to maximize safety and minimize injuries.

The most common assumption that a newcomer to fall protection will make is that all fall protection equipment is safe in every application. This is not true. Most fall protection products are made for very specific applications, and, as a result, have very specific limitations. Most users (and some fall protection professionals) do not know the entire breadth of these limitations. Unfortunately, misapplications are all too common. And it's these misapplications that set up the user for potential injuries, which can range from traumatic to potentially fatal.

Let's review the most common equipment, restrictions of use, and common misapplications.

Lanyards—Types and Uses

Energy-absorbing lanyards (EAL) (Figure 2) should be attached as high as possible above the user's head, and directly above the user's head. This is by far the biggest misuse. Attaching the far end of the lanyard to a point below its maximum vertical extension will result in a larger free-fall distance. The lower the attachment point, the greater the free-fall distance. The greater the free-fall distance, the greater is the extension (controlled tearing out of stitching) of the energy-absorbing "shock pack." The human body can impact hazards or fall onto or into hazards during this free-fall and extension distance. Furthermore, the greater this total distance, the more likely the user will not be able to rescue himself/herself, and climb back to safety.

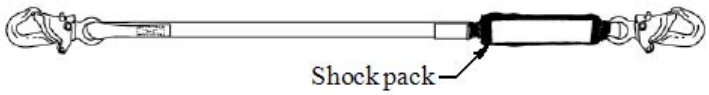


Figure 2. Common energy-absorbing lanyard (EAL)

If the user attaches the end of the lanyard to a point below his/her harness D-ring, the dangers increase significantly. Almost every EAL sold today (to current ANSI Z359.1 (1992) standards) is engineered for only a six (6) foot free fall. If a common 6-ft EAL or a 10-ft EAL is attached at foot level or below, the total free fall can exceed 12 feet and 20 feet respectively, dramatically exceeding this 6-ft free fall limitation. Figure 3 below shows a 120-inch-long EAL that was engineered for a maximum 6-ft free fall. The resulting free fall of 21'-3" is almost four (4) times the allowable free fall!

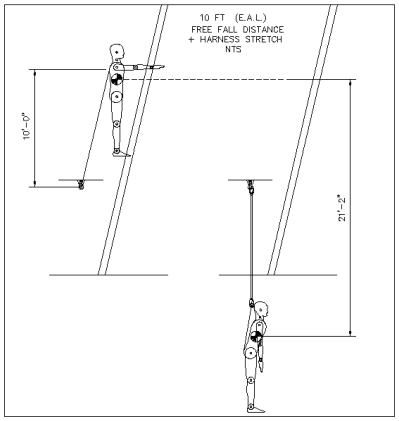


Figure 3. Incorrect use of 120-inch-long EAL (free fall is about four times the allowable free fall)

If the energy-absorbing capability of the shock pack is used up during a fall over six (6) feet (all energy-absorbing stitching is torn out of the shock pack), the human body will be jerked to a violent stop by the backup strap. In this situation, the remaining potential and kinetic energy from the fall must be absorbed by the internal organs and/or skeleton of the human body. The maximum G-forces that a healthy human body can withstand without injury, as we covered already, are 10 G's. As the backup strap is required to have a breaking strength of 5000 lbs, the maximum G's the human body would be subjected to would be as follows:

130 lb person = 5000 lbs. / 130 lbs = 38.5 G's
310 lb person = 5000 lbs. / 310 lbs = 16.2 G's

These values of 38.5 G's and 16.2 G's may result in very serious internal organ or skeletal injuries, or even a fatality.

Another danger of large fall distances is the cutting action of leading edges. Fabric lanyards and even steel cable lanyards up to 3/16" diameter may be completely severed if they drag over or impact sharp leading edges during a fall (Figure 4).

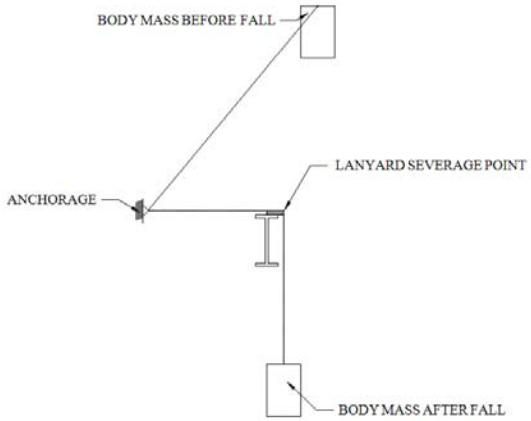


Figure 4. Potential severing of lanyard on a sharp leading edge

Special care must be taken when using lanyards on platforms or structures that have relatively sharp steel edges. Even the ubiquitous wide flange beam commonly used in building construction has an edge sharp enough to sever a 3/16" steel cable when a 220 lb weight is dropped just four (4) feet above the leading edge of the beam flange.[6]

To protect the user, all new lanyards must be clearly labeled per the new standard Z359.13, *Personal Energy Absorbers and Energy Absorbing Lanyards*, just released this past November of 2009 (Figures 5 and 6).[7]

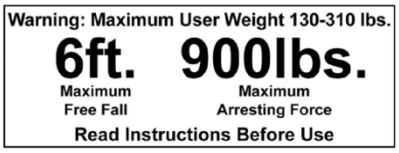


Figure 5. New 6-ft free fall label

If a six-foot long lanyard is anchored in any position below the users harness D-ring, then the 12-ft maximum free fall lanyard must be used (Figure 7).

Figure 6. New 12-ft free fall label (limited to 6-ft free fall if user exceeds 310 lbs)

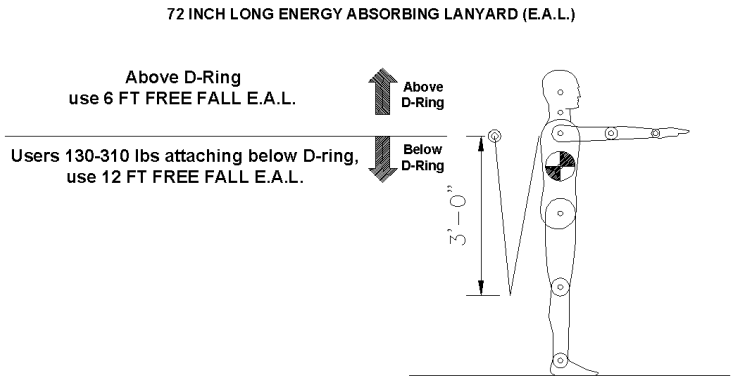


Figure 7. When to use the new 12-ft maximum free fall lanyard

EALs are also available as "double leg" lanyards (also known as "Y" lanyards). The second leg is provided only to make a transition from one fixed point anchorage to another. In no other circumstance should both legs be attached to the same anchorage. Some users "store" the second leg at the anchorage attachment point, which can be very dangerous. The proper storage position of the second leg is from a small plastic ring (that looks like a D-ring) typically provided on a "higher end" harness (Figure 8).

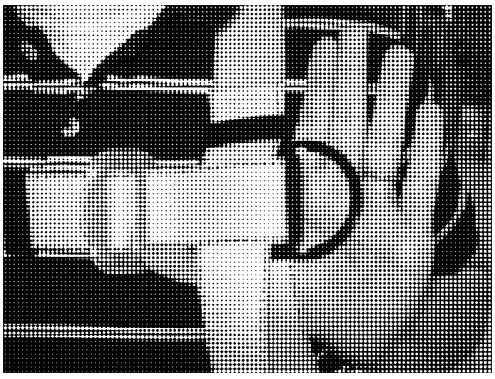


Figure 8. Proper storage position for "second leg" of double-leg lanyard (*not* for use as an anchorage)

If a 130-lb person attaches both legs to the anchorage point, the deceleration rate would exceed 10 G's: 1800 lbs/130 lbs = 13.9 G's.

Self-retracting lanyards (SRLs), although generally significantly safer than lanyards, also have limitations that can be serious. The most common misuse of the SRL is (also) the attachment of the SRL at an elevation below which they were designed. Presently we have two very common SRL designs. The most common, "SRL with brake," has a built-in braking mechanism that will engage after the user has fallen (from directly underneath the SRL) approximately eight (8) inches. A less common "SRL with shock pack" (Figure 9) has a locking mechanism that locks up solid in a free fall, and relies on a "rip-stitch" shock pack to decelerate

the fallen worker to a stop. Regardless of design, each SRL is engineered for only 24" of free fall. This then limits the proper applications of SRLs to overhead attachments only.

As SRLs are engineered specifically for overhead use only, the common misuse of the SRL is where the user incorrectly attaches his SRL to an anchorage point below his D-ring, or unwittingly climbs above the attachment point of the SRL. In this situation, the fall distance will exceed the 2-ft free fall the unit was engineered for, and the user can "tear through" the energy absorption capability of the SRL with a shock pack. Note that the SRL with shock packs are only designed with 24 inches of shock pack "extension." After the shock pack has extended fully, the user is violently snapped to a stop on the backup strap. In this case, the backup straps of the SRL with shock packs are engineered for 3000 lbs (compared to 5000 lbs for EALs) of tensile strength because of the intended shorter free-fall design. In an extreme example, if a user with a 30-ft long SRL with shock pack climbs 30 ft above his/her anchorage point, then he/she is in real danger of tearing through the 2-ft energy absorber and overloading the 3000 lb backup, and facing a potentially fatal injury, despite that fact that fall protection is being worn.

Figure 9. SRL with shock pack energy absorber, 2-ft free fall, only 2-ft payout

Compared to the SRL with shock pack, the "SRL with brake" (Figure 10) is much more forgiving. If the user does unwittingly use the SRL with brake improperly by climbing above his anchorage point, the braking mechanism inside the SRL will generally pay out well over 2 ft, normally up to the full amount of lanyard wrapped around the internal drum.

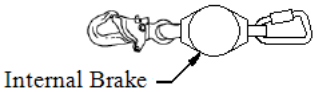


Figure 10. SRL with internal brake, 2-ft free fall, most payout more than 2 ft.

There are two other new SRL designs that will be defined in the soon-to-be-released Z359.14 ANSI standard (with a possible late 2010 release date).[8] The proposed designations are SRL-R (Figure 11) for SRLs with built-in rescue capability, and SRL-LE for SRLs that are designed specifically for leading edge work (Figure 12).

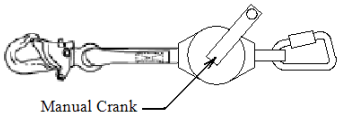


Figure 11. SRL-R Rescue capable "self-lowering" (with no crank) or "crank to rescue" (shown)

The SRL-R "rescue" SRLs commonly come in two different styles. One style automatically starts lowering the fallen worker as soon as the fall is stopped. Care must be taken with these units, as the fallen worker may not want to be lowered automatically due to hazards, such as rotating machinery, moving, temperature, or chemical hazards. Additionally, great care must be taken by the competent person in charge of all fall protection equipment to make sure that this style of SRL-R does not become mixed up with other standard (non-rescue) SRLs as this style SRL-R (without a crank handle) is almost impossible to tell apart from "plain" SRLs.

The other style of SRL-R "rescue" will not automatically start lowering the fallen worker as soon as the fall is stopped. A coworker must crank a handle to move the fallen worker to safety (Figure 11).

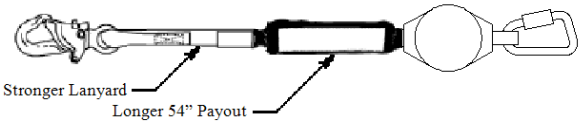


Figure 12. SRL-LE for leading edge and 5-ft maximum free fall

The SRL with the proposed designation of SRL-LE (Figure 12) is specifically designed for "leading edge" work where the SRL-LE will be hung at an elevation below the user's D-ring, as shown in Figure 13. This SRL-LE is engineered for a 5-ft maximum free fall, has a tougher lanyard to resist the cutting action of the leading edge, and also pays out a minimum of 54 inches.

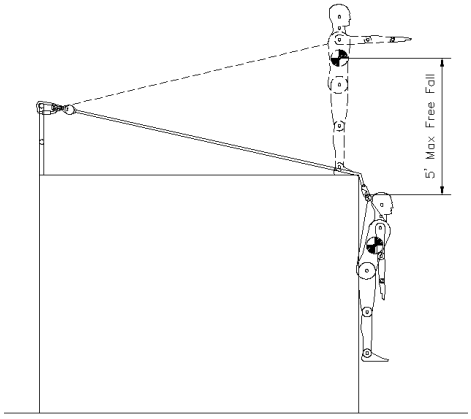


Figure 13. SRL-LE designed for 5-ft maximum free fall.

Now that we have covered some of the basic equipment and common misapplications, let's review fall hazards that are frequently overlooked.

The first fall hazard is fall distance. Fall distance calculations are absolutely critical with EALs. The commonly accepted clearance required for a 72-inch-long EAL is 18'-6" (Figure 14).

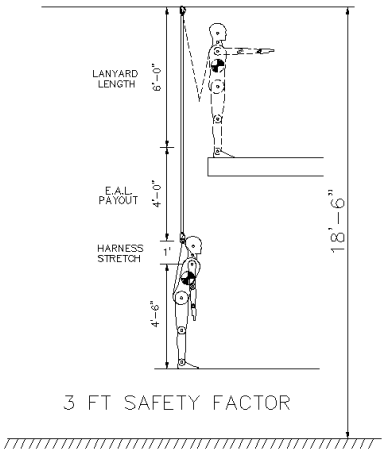


Figure 14. 18'-6" Clearance required for 72" EAL

If the EAL used was a 120" long version (4 ft longer than a 72"), then the clearance required would be 22'-6" (4 ft longer).

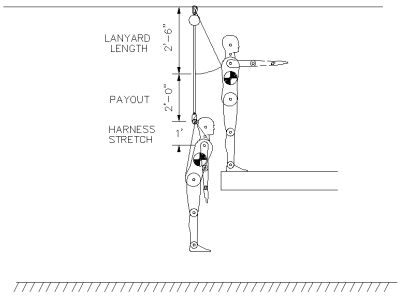


Figure 15. SRL offers the shortest fall distance

If we compare the EAL to an SRL, the SRL clearly has less fall distance due to the shorter lanyard length (self-storing capability of the lanyard) (Figure 15).

Flexible Horizontal Lifelines

Flexible horizontal lifelines, which are generally wire rope systems strung between support columns, are another area where the fall protection professional may significantly underestimate the amount of clearance required. The flexible nature of the horizontal wire rope results in significant downward deflection of the wire rope before the energy absorber engages, and additional downward deflection during the energy-absorbing part of the fall. Wire rope

deflections of eight (8) feet or more are not uncommon for long spans of wire rope. In the illustration below (Figure 16), the combination of the EAL and the flexible horizontal lifeline (wire rope), offers practically no protection to the worker using the fall protection equipment (Figure 17).

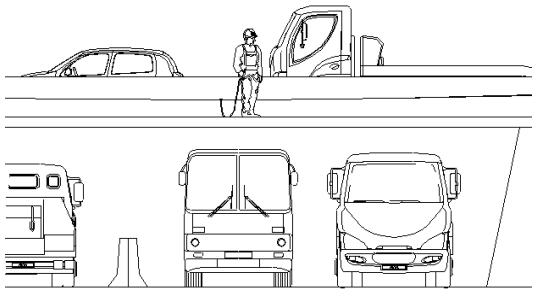


Figure 16. Worker will impact roadway before fall protection starts deceleration

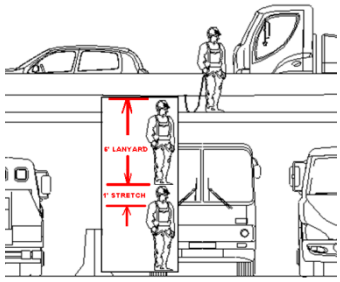


Figure 17. Rough scale of 6' EAL and harness stretch (wire rope deflection not shown)

The common argument for the system shown in Figure 16 is that all the components used by the worker comply with OSHA law; therefore, it must be safe, and it must be legal. The truth is that the combination of equipment in this system does not comply with the new ANSI *Fall Protection Code.* The new ANSI code Z359.6, just released in November of 2009, defines the requirements of custom wire rope systems.[9] It is this standard that OSHA inspectors could reference under the "general duty clause" when citing a non-compliance fine for fall protection. Additionally, there is a new ANSI standard Z359.17 (November 2010 possible release date) that will effectively outlaw "field-designed" wire rope systems.[10] The proposed new code would require that all wire rope installations be engineered and designed by a "qualified person," as defined by OSHA and ANSI.

Swing or Pendulum Falls

Swing falls (also known as pendulum falls) are probably the most commonly overlooked danger while using fall protection. Yet typical users and members of the fall protection community feel there is no way to avoid a swing fall. The bottom line is that if the attachment point of the user's lanyard is not directly over the user's head, any fall will result in the user's body "swinging" like a pendulum towards the direction of the attachment point. The greater the swing distance is, the greater the chance of injury.

In aerospace and aircraft applications, a swing fall may not only result in costly damage to aircraft, but may also result in significant physical injury.

OSHA limits the maximum off-plumb angle that the lanyard would make during a fall to 30 degrees. Any off-plumb loading can result in a swing fall into a hazard. Figure 18 shows a typical hangar fall protection system using a long SRL.

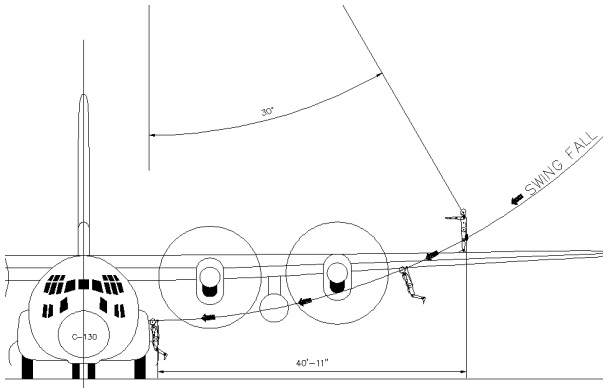


Figure 18. "OSHA legal" swing fall off the back of a C130 wing

Unfortunately, this fall will result in an impact of about 40 MPH, with significant injury to person (and plane).

To eliminate swing fall on a fixed point anchorage, the user must be limited in his/her movement away from underneath the anchor. On a horizontal lifeline monorail system, the operator can walk in a straight line, but cannot wander far from the straight line. But what if the users must cover an area? The best solution is either a traveling bridge or a swing arm system (Figures 19 and 20).

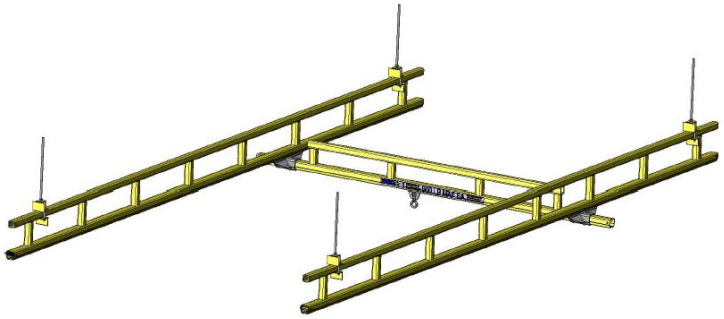


Figure 19. Traveling bridge allows almost unlimited area coverage and eliminates swing falls

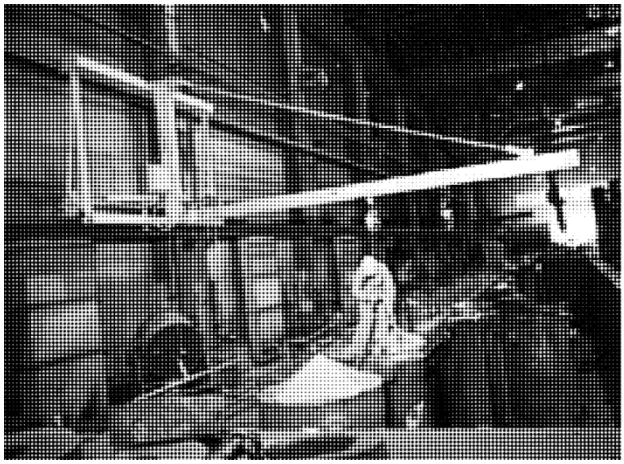
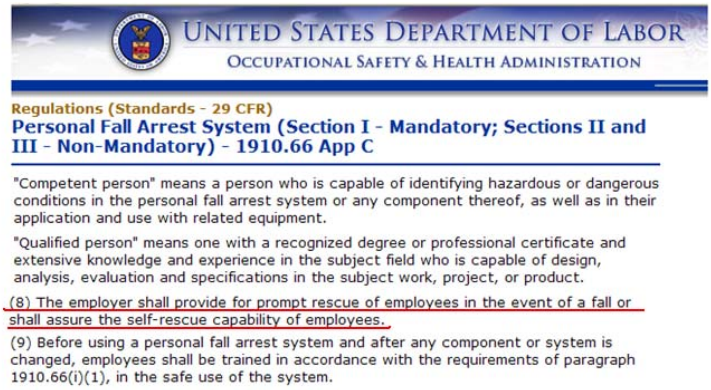


Figure 20. Swing arm allows area coverage and eliminates swing falls

Suspension Trauma

Suspension trauma (or harness trauma) can occur if the user falls and is suspended from the harness for too long. If the user is knocked unconscious during a fall, this suspension trauma can become fatal in just a few minutes.

Suspension trauma is simply the cutoff of blood flow due to the harness straps tightening around the legs during suspension from a harness. The blood is pumped into the legs through the normal heart pumping action, but is restricted from returning to the upper body. The blood then pools in the legs and the leg vessels expand like a balloon to hold the extra fluid. Because there is less blood available to flow to the brain, this can result in unconsciousness in sometimes less than 15 minutes (depending on the health of the individual). This unconsciousness then quickly becomes deadly in a few short minutes due to lack of oxygen to the brain. This is why OSHA law requires self rescue (Figure 21) or prompt rescue.


UNITED STATES DEPARTMENT OF LABOR
OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION

Regulations (Standards - 29 CFR)

Personal Fall Arrest System (Section I - Mandatory; Sections II and III - Non-Mandatory) - 1910.66 App C

"Competent person" means a person who is capable of identifying hazardous or dangerous conditions in the personal fall arrest system or any component thereof, as well as in their application and use with related equipment.

"Qualified person" means one with a recognized degree or professional certificate and extensive knowledge and experience in the subject field who is capable of design, analysis, evaluation and specifications in the subject work, project, or product.

(8) The employer shall provide for prompt rescue of employees in the event of a fall or shall assure the self-rescue capability of employees.

(9) Before using a personal fall arrest system and after any component or system is changed, employees shall be trained in accordance with the requirements of paragraph 1910.66(i)(1), in the safe use of the system.

Figure 21. OSHA requires self rescue or prompt rescue

Self Rescue or Prompt Rescue

OSHA defines prompt rescue as four minutes if there is a possibility of injury (Figure 22).

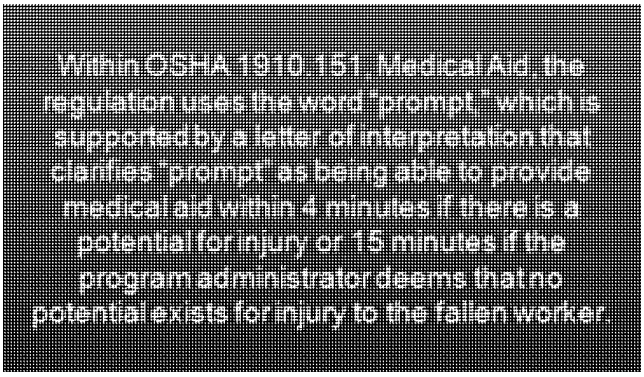


Figure 22. OSHA requires injured workers receive aid within four minutes

There are two new "self-rescue" devices available on the market today. One is the SRL-R with automatic lowering that we have already discussed. The other is a self-rescue trolley (SRT), used in conjunction with a rigid horizontal lifeline and SRL (Figure 23). If a worker were to fall away from the work surface and have no hand holds to grab onto, the rescue trolley offers an "anchorage" point on the track that the user can swing towards. Pulling on the anchorage cord allows the user to grip onto track and swing to safety. The benefit of the SRT over the SRL-R is the SRT does not need to be red tagged and sent back to the factory for reconditioning after a fall. Also, the SRT will not automatically drop the user into any hazards below.

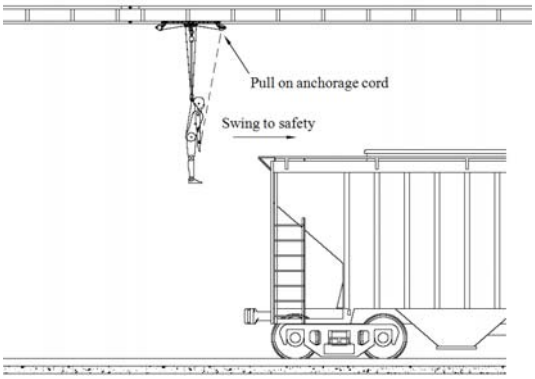
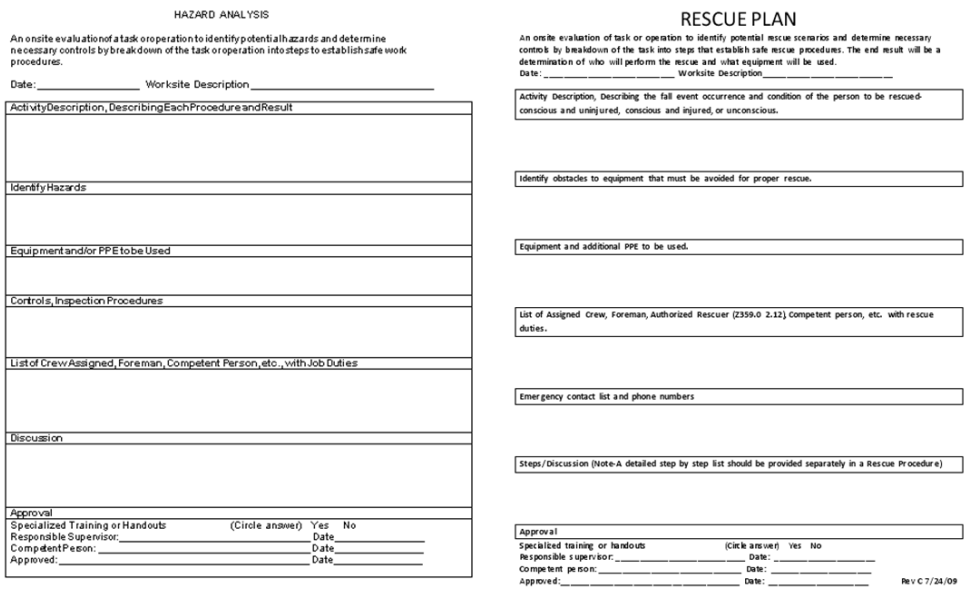


Figure 23. New self-rescue trolley (SRT) enables self rescue

Per ANSI Z359, the competent person within an organization should perform a hazard analysis and a rescue plan for every instance of fall protection (Figure 24).



HAZARD ANALYSIS

An onsite evaluation of a task or operation to identify potential hazards and determine necessary controls by breakdown of the task or operation into steps to establish safe work procedures.

Date: _____ Worksite Description _____

Activity Description, Describing Each Procedure and Result

Identify Hazards

Equipment and/or PPE to be Used

Controls, Inspection Procedures

List of Crew Assigned, Foreman, Competent Person, etc., with Job Duties

Discussion

Approval

Specialized Training or Handouts (Circle answer) Yes No
Responsible Supervisor: _____ Date _____
Competent Peson: _____ Date _____
Approved: _____ Date _____

RESCUE PLAN

An onsite evaluation of task or operation to identify potential rescue scenarios and determine necessary controls by breakdown of the task into steps that establish safe rescue procedures. The end result will be a determination of who will perform the rescue and what equipment will be used.

Date: _____ Worksite Description _____

Activity Description, Describing the fall event occurrence and condition of the person to be rescued-conscious and uninjured, conscious and injured, or unconscious.

Identify obstacles to equipment that must be avoided for proper rescue.

Equipment and additional PPE to be used.

List of Assigned Crew, Foreman, Authorized Rescuer (Z359.0 2.12) Competent person, etc. with rescue duties.

Emergency contact list and phone numbers

Steps/Discussion (Note-A detailed step by step list should be provided separately in a Rescue Procedure)

Approval

Specialized training or handouts (Circle answer) Yes No
Responsible supervisor: _____ Date: _____
Competent peson: _____ Date: _____
Approved: _____ Date: _____

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Figure 24. Sample hazard analysis and rescue plan

Figure 25 shows a perfect example of a fall hazard that should be protected against in a written hazard analysis. The best way to prevent the user from serious injury on the top of the sheet metal door is to use a rigid horizontal system to eliminate deflection of the attachment point, and use a SRL near directly overhead to minimize free fall to a few inches.

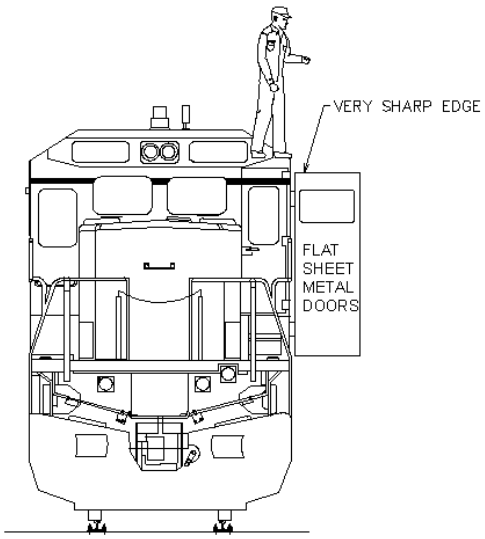

Figure 25. Solve hazards during the hazard analysis

Summary

Finally, organizations with users working at height should practice rescue drills to ensure that aid can be delivered promptly to a fallen worker. If a user falls in a very high location, in the remote regions of your plant, and is rendered unconscious, do you know with certainty you will be able to rescue the worker in four minutes? Rescue plans should be well thought out and practiced regularly to ensure self rescue or the prompt rescue, as required by OSHA.

Acknowledgements

The author wishes to thank SPANCO/Rigid Lifelines, as well as the many colleagues I have worked with over the years in the effort to provide superior, injury-free results when using fall protection systems.

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