Horizontal Fall Arrest Systems

Employee safety is a concern in any occupation. We plan for unintentional fires by having fire sprinkler systems and extinguishers available and ready to use. We wear protective clothing to guard against caustics and other harmful substances. Yet when it comes to protecting workers at height we often do not provide the needed degree of safety. Falls to lower levels fatally injure more than three times as many people annually as unintentional fires and exposure to caustics combined.

In 1997, according to the National Safety Council Accident Facts, falls to lower levels were the third leading cause of fatal occupational injuries (652 fatalities). One could argue that there always will be falls; gravity cannot be changed. However, we can limit the effect of gravity by protecting people who must work at elevations. Numerous personal fall arrest systems are available to help reduce injuries and improve productivity. One specific type of system, a horizontal fall arrest system, provides a high degree of mobility and safety if properly designed, installed, and used.

Horizontal fall arrest systems can be classified as one of two types, rigid or flexible lifeline types. There are advantages and disadvantages of each one. By understanding these systems you can make better decisions when it comes to protecting workers at height.

Flexible Horizontal Lifeline Systems

A flexible horizontal lifeline (HLL) is a pliable line rigged in a horizontal plane secured at each end to an anchorage. A worker is connected to the line using a personal fall arrest system that moves with the worker between the two anchorage points. By providing a sliding connection along the entire walkway the anchorage is kept overhead, reducing the hazard of dangerous swing falls that can occur if the worker moves to a location where the anchorage is no longer directly overhead.

Although installing a flexible horizontal lifeline may appear to be as simple as stringing a line between two supports, determining the loads that are applied to the anchorage and the clearance required below the working surface in the event of a fall can be extremely complicated. In this respect flexible horizontal lifelines are one of the most complex types of fall protection equipment.

To further complicate matters for the safety engineer, no U.S. standards currently address specific performance requirements for horizontal fall arrest systems. Consequently, designers and manufactures are able to install systems as they see fit. It also puts the responsibility of determining what constitutes a safe system in the hands of the end user. It is important for the employer or safety engineer to understand the different types of horizontal lifelines that are available and the limitations of each type in order to make an educated decision when selecting a horizontal lifeline system.

Flexible Lifeline Classification

Flexible HLL systems may be classified as either permanent or temporary. A permanent HLL becomes an integral part of the anchoring structure and should be designed to function for an extended period of time. Permanent HLL’s are usually constructed of metallic components. Most synthetic fiber ropes are not resistant to long-term UV and environmental exposure.

Temporary HLL systems are pre-engineered packaged systems that should be supplied with complete instructions for installation and use, including the number of users allowed to be connected, the maximum allowable span length, clearance requirements and anchorage requirements. They are designed for a short-period-of-time use, usually for protection during construction. When the project is complete the HLL can be removed and re-used at the next project. Both steel cable and synthetic rope are common materials used for temporary HLL systems.

Common HLL Applications

- Railcar and truck loading
- Industrial crane runways
- Building rooftops
- Structural framing
- Pipe racks
- Aircraft hangars
- Bridge construction
- Arena rigging
- Exposed walkways

HLL's can also be classified as either single span or multi-span. This classification is independent of the system being permanent or temporary. The simplest type of HLL is a single span. Single span HLL's are limited in length by their dynamic deflection. Long spans result in large deflections that may not prevent the worker from hitting the ground in most applications. Having only two anchorage points, single span HLL's are limited to a straight line.

Multi-span HLL systems are not limited in length since they are supported at intermediate anchorages. The basic method of constructing a multi-span HLL is to thread the line through eyebolts or holes in the intermediate anchorages. This requires the worker to use a double-legged lanyard to "leap frog" across the intermediate supports to remain connected at all times. An additional disadvantage of this type of system is that the line must be within reach of the workers, which is impractical for applications such as railcar loading where setback requirements would place the lifeline beyond reach.

A more sophisticated type of multi-span HLL uses a specially designed intermediate bracket that retains the cable, but allows a special connector to pass over the bracket keeping the worker connected at all times. This could either involve snaking the connector through an "S" shaped path that retains the line or a more ingenious bracket and slider arrangement that allows hands-free bypass without requiring any action from the worker. Some of the proprietary multi-span HLL systems that are available can accommodate direction changes to make corners or bend around and under obstructions such as grain loading spouts and roof stacks.

The complexity and infinite number of configurations of a multi-span HLL system requires the use of a computer simulation to accurately calculate the system performance. "Real world" testing to prove its accuracy must back up the computer model

Design Issues

Having a fall protection system in place does not necessarily mean your employees are protected in the event of a fall. When, and if, a fall occurs the employer needs to know that the fall protection system is properly anchored and will prevent the worker from hitting an obstruction or lower level before the fall has been completely arrested.

Two primary factors must be considered in designing a flexible horizontal lifeline system.

- The loads that are applied to the anchorages during a fall arrest situation must be known to design or verify the strength of the anchorages.

- The deflection of the lifeline during a fall arrest situation must be known to ensure the worker will not contact an obstruction or lower level.

The deflection and loads are closely related. They are a function of several factors including the pre-tension in the lifeline, total length of the lifeline, length of the intermediate spans, number of workers connected and the properties of the lifeline material.

Anchorage requirements

The dynamic loads at the end terminations of a flexible HLL system can be several times higher than the arresting force generated by the falling worker. This is a function of the geometry of a horizontal line during fall arrest. OSHA 29 CFR Part 1926, Subpart M, Appendix C states:

> "Horizontal lifelines may, depending on their geometry and angle of sag, be subjected to greater loads than the impact load imposed by an attached component. When the angle of horizontal lifeline sag is less than 30 degrees, the impact force imparted to the lifeline by an attached lanyard is greatly amplified. For example, with a sag angle of 15 degrees, the force amplification is about 2:1 and at 5 degrees sag, it is about 6:1. Depending on the angle of sag and the line's elasticity, the strength of the horizontal lifeline and the anchorages to which it is attached should be increased a number of times over that of the lanyard."

This statement is taken from non-mandatory guidelines for complying with the mandatory requirements of Part 1926.502. It provides an overview of the relationship between the dynamic deflection and end loads of HLL's, but is not intended to provide any strength requirements for anchorages.

OSHA Regulations for Horizontal Lifelines

- Qualified person responsible for:
  - ✓ Design
  - ✓ Installation
  - ✓ Training
- Part of a complete personal fall arrest system
- Must maintain a minimum safety factor of 2.0

The specific requirements for HLL's in Part 1926.502(d)(8) state:

"Horizontal lifelines shall be designed, installed, and used, under the supervision of a Qualified Person, as part of a complete personal fall arrest system, which maintains a safety factor of at least two."

This paragraph clearly dictates that HLL's must be designed by a qualified engineer or manufacturer that has experience designing HLL systems. It also gives the engineer guidance for designing anchorages or stanchions that will be supporting the system. It does not give quantitative values for anchorage strength. The designer or manufacturer of a HLL system must provide documentation of the loads on the system for the purpose of designing or verifying the strength of the anchorages. The designer or manufacturer must also specify what type of equipment may be used in conjunction with the HLL as a complete system.

The load requirement for HLL's is often confused with the 5,000 pound OSHA requirement for personal fall arrest systems. For example, if the maximum arresting force on a worker's lanyard was 1,800 pounds each support must sustain an 1,800 *vertical* load, but also a *horizontal* load at the end anchorages that could be much greater than 1,800 pounds. Assume the end loads were three times the load on the worker's lanyard, or 5,400 pounds, which is reasonable considering the information presented above relating the dynamic deflection to the end loads. The required anchorage strength would be 10,800 pounds applying the requisite safety factor of two. This example illustrates how a 5,000-pound requirement for end anchorages would be inadequate for most HLL installations.

Controlling Loads

Designing end anchorages for HLL's is often challenging due to heavy loads. In-line energy absorbers, which connect one or both ends of the line to the anchorage, can be used to reduce the end loads on HLL systems.

In general, in-line energy absorbers:

- Increase the deflection of the HLL.
- Require additional clearance below working surface.
- Can substantially reduce severe end loads.
- Require lighter and less costly anchorages.

If the energy absorbing capacity is used up, or the absorber has "bottomed out", the end loads may increase beyond the rating of the absorber. The manufacturer should supply instructions for proper use.

Clearance Requirements

The other primary factor that is critical to the design of HLL systems is calculating the dynamic deflection of the lifeline. Other factors that must be accounted for include freefall of the worker, the deceleration distance of the worker's shock-absorbing lanyard or retractable lifeline and any other considerations that increase the worker's fall distance. The sum of these factors must not be so great that the worker can contact an obstruction or lower level. The designer or manufacturer of a HLL system should provide a recommended minimum clearance value for permanently installed HLL systems and a method of calculating minimum clearances for temporary systems that can be installed in multiple configurations.

Rigid Horizontal Systems

A rigid horizontal fall arrest system, as the name implies, is a rigid structural shape such as a pipe, channel, or I-beam secured in a manner that provides a continuous horizontal anchor for fall arrest systems. This type of system is normally mounted at shoulder height or higher based on the particular work site perimeters. A sliding trolley arrangement freely moves along the horizontal rail as the attached worker travels parallel to the system.

Attached to the sliding mechanism is a connecting subsystem. This connecting subsystem, or lanyard, can be of a set length or a self-retracting type. The particular type of lanyard selected depends upon the required mobility; the location of the rigid horizontal anchor in reference to the user, the work environment and the basic type of work being performed (fall arrest potential or restraint system).

Classification

Rigid horizontal fall arrest systems are almost always considered permanent installations. The cost and time involved installing a rigid system dictate that the system remains in place for an extended period. Rigid systems typically are not limited in length; the structural shape can run as far as the anchoring structure does. While some more complex rigid systems can be designed to go around corners, or at least have slight bends in the rail, the majority are straight, level runs. Inclines or slopes are normally not possible because of the potential for the sliding mechanism to travel downhill should a person be freely suspended from the system.

Rigid Horizontal Fall Arrest Systems

Advantages

- Substantial structural member as anchor - Peace of mind, more resistant to damage or corrosion.
- Less clearance required arresting a fall - No deflection or sag in rail to add to fall distance, reduces potential of second worker being pulled off by first worker falling.
- Anchorage strength calculations simplified - Less complicated to determine anchoring strength requirements (no sag, deflection angles to deal with).

Disadvantages

- Initial installation costly - Large investment in material and labor to install system.
- Numerous anchoring/support members required - Long spans require a large number of supports and/or a large/heavy rigid rail system.
- More visual/architecturally less appealing - Physically larger than flexible cable system.

Design Issues

A Qualified Person must design the rigid horizontal fall arrest system. The designer involved will need to consider the distance or run length of the system, the number of workers attached to the system, the anchoring structure required to attach the rigid horizontal member to, and the position of the horizontal rail in reference to the work zone. The longer the span distance between supports the stronger the rigid horizontal structural shape must be. This results in larger and heavier horizontal members. If the rigid member is to be attached to existing structural members the overall strength of the structure must be evaluated. As an example, systems installed to the bottom side of existing roof members must be evaluated for strength based on the potential loading of falling workers, rigid rail weight, and other loads imposed by building codes.

The weight of rigid horizontal members can be substantial, ranging from 10 pounds to 100 pounds per foot or more, depending upon the number of users and the span distance. Selection of the appropriate sized rigid member must account for vertical loading as well as side loading capacity. Many structures have a high strength in a vertical plane, but may be limited in side-load capacity.

Anchoring of the rigid system can be done from existing structure or new structure specifically designed for the fall arrest system. The designer needs to determine what the anchorage strength criteria will be; a 5,000 pound anchorage requirement per person, or an engineered system providing a 2:1 safety factor minimum. Engineered systems in particular need to be designed around data from personal fall arrest system manufacturers in order to make certain appropriate safety factors are maintained. Anchorage strength calculations for rigid systems are less complicated then the calculations for flexible lifeline systems; the designer is not concerned with wire rope deflection and sag angles. Because there is no sag or deflection is the rail, the required clearance distance is also less with rigid systems when compared to flexible types.

The sliding trolley mechanism is a critical design issue. This device must move freely (even through splices or assembly joints) along the rigid horizontal member, typically trailing behind the worker a short distance. If the trolley does not freely slide, the worker is hindered from moving and could possibly be subjected to a harmful swing fall.

I-beam trolleys in particular need to be reviewed closely to make certain they are appropriate for the application. The overall strength and mobility are critical to the system performance. An I-beam trolley should be "man-rated" just like a lifting winch or anchoring hook used for personal fall protection. Man rated trolleys are designed to freely move along the rail and withstand the forces of a fallen worker. Most man rated trolleys provide adjustability to adapt to various flange widths.

Evaluating Horizontal Systems

When selecting a horizontal fall arrest system there are several issues that should be considered.

Safety. The purpose of the system is to protect people from fall injuries. Other features are irrelevant if the system can not do the job it is intended to. Look for suppliers that are experienced in the design of horizontal fall arrest system.

Ease of use. Consider the type of work being done and determine which system will be the least cumbersome for the worker. If the system makes work inefficient it's more likely that the employee will choose to work unprotected.

Length of service. The system should be appropriate to the expected term of use. Using a temporary lifeline in a permanent installation may put employees at risk. The strength of the materials may be reduced by long-term environmental exposure.

Environment. Make certain the materials are suitable for use in harsh environments if there is exposure to corrosive agents, elevated temperatures, or other severe conditions.

Adequate coverage. The primary advantage of a horizontal fall arrest system over a single point anchorage is the mobility it provides and the increased protection from swing falls. If the system ends short of the work area the worker could be at risk of a swinging collision.

Performance data. Performance data should be provided as part of any complete fall protection system.

Training. Thorough instructions and on-site training ensures the workers that will be using the equipment know how to use the equipment safely.

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*Matthew Blackford is a project engineer for SALA Engineered Systems, 3965 Pepin Ave.,
Red Wing, MN 55066; (877) 746-2672; Fax: (651) 385-8658*

*Craig Firl is Vice President of Technical Services for DBI/SALA, 3965 Pepin Ave.,
Red Wing, MN 55066; (800) 328-6146; Fax: (651) 388-5065*