Fall Protection for safety at heights

Dave Dickinson
MSA Senior Territory Sales Manager
Mobile: 925-783-0539
Dave.Dickinson@MSA Safety.com

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Workers connect a link in a cantilever section during construction in 1936. It took less than six years to design and build the entire bridge.

2: Years to choose, design, award bid
3.6: Years of construction
24: Deaths during construction
148,000: Tons of structural steel
8.2: Miles of bridge
$1.3B*: Cost to construct the bridge
Ironworkers on the bridge’s new eastern span are dwarfed by a cable saddle. Construction alone, still ongoing, has taken nearly 11 years.

5: Years to choose, design, award bid
11: Years of construction
0: Deaths during construction
250,000: Tons of structural steel
2.2: Miles of bridge
$550,964: Cost per foot to build
Fall protection safety at heights

• Training Objectives:
  – Physics of fall arrest
  – Fall Protection Hierarchy of controls
  – Fall Protection PPE
    • ANSI Manufacturing Updates
  – Rescue Concerns / Considerations
Physics of falling & suspension

5 phases of a fall

1. Onset of fall
   - Accidental fall starts when you first experience the fall hazard and ends the instant you lose control over your stability.
   - Likely to be only a few tenths of a second
   - Time period of onset may be affected by your posture at the instant you encounter the fall hazard
Physics of falling & suspension

2. **Free fall.**
   - Subjected to the forces of gravity
   - Body will accelerate until such time you strike an object
   - Mass x acceleration
   - Body cannot move in a coordinated way
3. Deceleration

- If you are not protected by a PFAS and you strike a concrete floor that has very little “give”, you will undoubtedly be severely or fatally injured
- Energy absorbing lanyard permits the dissipation of built up energy over time and distance
Physics of falling & suspension

4. **Rebound**

Some or all of the parts of a personal fall arrest system have a degree of elasticity - *elastic deformation* - *temporary*.

- Some components will stretch and nearly return to its original form.
- Part of the stretch may be what is called *plastic deformation* - *permanent*.
- Bounce in the system could cause additional forces & injury.
Physics of falling & suspension

5. **Suspension**

- You will remain suspended until rescued during the suspension phase.
- You will not be able to perform a self-rescue in all cases.
- During suspension in such a condition, your swift rescue is extremely important.
## What Happens in a Fall with a 1.8 m (6 ft) lanyard?

<table>
<thead>
<tr>
<th>Time</th>
<th>Physical Response</th>
<th>Free-Fall Distance</th>
<th>Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 sec</td>
<td>Unaware</td>
<td>5.1 cm (2 in)</td>
<td>1.0 m/s (3.3 ft/s)</td>
</tr>
<tr>
<td>0.2 sec</td>
<td>Aware</td>
<td>20.3 cm (8 in)</td>
<td>2.13 m/s (7 ft/s)</td>
</tr>
<tr>
<td>0.5 sec</td>
<td>Start to Move</td>
<td>1.22 m (4 ft)</td>
<td>4.88 m/s (16 ft/s)</td>
</tr>
<tr>
<td>0.61 sec</td>
<td>Slight Movement</td>
<td>1.83 m (6 ft)</td>
<td>5.97 m/s (19.6 ft/s)</td>
</tr>
<tr>
<td>0.7 sec</td>
<td>Impact</td>
<td>2.41 m (7.9 ft)</td>
<td>7.01 m/s (23 ft/s)</td>
</tr>
<tr>
<td>0.9 sec</td>
<td>Rebound</td>
<td>3.96 m (13 ft)</td>
<td>8.84 m/s (29 ft/s)</td>
</tr>
<tr>
<td>1.0 sec</td>
<td>Suspend</td>
<td>4.9 m (16 ft)</td>
<td>9.75 m/s (32 ft/s)</td>
</tr>
</tbody>
</table>
How High Can You Go Before You are Afraid of Falling?

<table>
<thead>
<tr>
<th>Height</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 m</td>
<td></td>
</tr>
<tr>
<td>2.0 m</td>
<td></td>
</tr>
<tr>
<td>2.5 m</td>
<td></td>
</tr>
<tr>
<td>3.0 m</td>
<td></td>
</tr>
<tr>
<td>3.5 m</td>
<td></td>
</tr>
<tr>
<td>4.0 m</td>
<td></td>
</tr>
<tr>
<td>&gt; 4.0 m</td>
<td></td>
</tr>
</tbody>
</table>

___% of people who fall from > 3.4 m (11 ft) die .....
Fall Hazard Assessments/Analysis

• Use Site Fall Hazard Assessments to understand the fall hazards of an identified area.
  – Job Site Assessment
  – Job Hazard Assessment
  – Tool box / tailgate talk
# Hazard Assessment Exercise

## Fall Protection Program

### Fall Hazard Assessment

<table>
<thead>
<tr>
<th>Designation:</th>
<th>Location:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Assessed:</td>
<td>199</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Related Operating Procedures</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewed:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location Marked and Entry</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### FALL HAZARD ASSESSMENT CHECKLIST

1. Can an employee enter the area without restriction and perform work? □ Yes □ No
2. Are fall prevention systems such as cages, guardrails, toeboards, manlifts in place? □ Yes □ No
3. Have slipping and tripping hazards been removed or controlled? □ Yes □ No
4. Have visual warnings of fall hazards been installed? □ Yes □ No
5. Can the distance a worker could fall be reduced by installing platforms, sets etc.? □ Yes □ No
6. Are any permanently installed floor coverings, gratings, hatches, or doors missing? □ Yes □ No
7. Does the location contain any other recognized safety and health hazards? □ Yes □ No
8. Is the space designated as a Permit Required Confined Space? □ Yes □ No
9. Have anchor points been designated and lost tested? □ Yes □ No

### Assessment Information:

- (indicate specifics with initials)

<table>
<thead>
<tr>
<th>Initials</th>
<th>Hazard</th>
<th>Remarks/Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Initials</th>
<th>Total potential fall distance:</th>
<th>Number of workers involved:</th>
<th>Frequency of task:</th>
<th>Obtainable anchor point strength:</th>
<th>Required anchor point strength: (not less than 5000 lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

### Additional Requirements:

- Potential environmental conditions that could impact safety:

<table>
<thead>
<tr>
<th>Initials</th>
<th>Condition</th>
<th>Remarks/Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- Possible required structural alterations:

<table>
<thead>
<tr>
<th>Initials</th>
<th>Alteration</th>
<th>Remarks/Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Possible task modification that may be required:

<table>
<thead>
<tr>
<th>Initials</th>
<th>Task</th>
<th>Remarks/Recommendations</th>
</tr>
</thead>
<tbody>
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</table>
Solution Choices

• Use the Hierarchy of Control
  – 1. Elimination or substitution
  – 2. Passive fall protection
  – 3. Fall restraint (travel restraint)
  – 4. Fall arrest
  – 5. Administrative Controls

• Each choice has its place and time
Fall Protection Hierarchy of Controls

1. **Elimination or substitution**
   Removing the hazard or hazardous work practices.

**Examples**: Elevated work platforms, remote tools, lowering the work or task to the ground. Change a process, sequence or procedure such that a worker does not approach the fall hazard.
2. Passive fall protection

Isolating or separating the hazard or hazardous work practice from the worker.

Examples: Installing guard rails, Stairways, netting – vertical and cantilevered
3. **Fall restraint (travel restraint)**

Securing the worker to an approved anchorage using a lanyard short enough to prevent the person’s center of gravity from reaching the fall hazard.

**Examples:** Restraint Lanyard or energy absorbing Lanyard anchored above the worker over head and behind or on the walking surface.
Fall Protection Hierarchy of Controls

4. **Fall arrest (PFAS)**

A system designed to stop a worker after the onset of a fall.

**Example:** An energy absorbing lanyard connected to an approved anchor connector and connected to full body harness
5. Administrative Controls

Work practices or procedures that signal or warn workers to avoid approaching a fall hazard.

**Examples:** Flat or sloped roof control zones, warning lines, training, lights, sounds and/or a monitor who’s sole function it is to watch and warn when anyone is approaching unguarded leading edge or lines.
Fall Prevention Options – Fall Restraint

• Fall Restraint System
  – Used with a fully body harness and anchorage
  – 1000 lbs anchor per person attached
Fall Protection Options –
Personal Protective Equipment

• Full Body Harness
• Connectors
• Energy Absorbing Lanyard
• Self-Retracting Lanyard
• Vertical Lifelines
• Ladder climbing systems
• Anchor connectors
• Horizontal Lifeline
• Anchorage point

• These all have specific design and performance requirements – some are established, and some must be engineered.
Personal Protective Equipment – Full Body Harness

• Materials
  • Nylon, Polyester, Nomex/Kevlar

Buckles
  • Secure-Fit, Qwik-Fit, Tongue buckle

Accessories
  • Shoulder, Back Pads
  • RFID
  • Waist Belts, Saddle
Personal Protective Equipment – Full Body Harness

• D rings
  – Back D-ring for fall arrest
  – Front D-ring for rescue/evacuation
  – Side D-ring for positioning / restraint
  – Shoulder D-ring personnel riding
  – Kevlar for hot work/welding
  – ASTM 887 for Electrical

• What about Body Belts?
Full body harness

Permanent visual load indicator (Pucker Stitching)

- Fall arrest indicator activates to give a permanent, readily visible warning
- Tears at approximately 2kN or 450 lbs-F
Full Body Harness

Permanent visual load indicator (Pucker Stitching)

- Located below dorsal D-Ring
- 1-2 may be present
- Must be removed from service if deployed
Personal Protective Equipment – Connectors

- Connectors --
  - Double locking snap hooks
  - Double locking Carabiners
  - Self Closing
  - Self Locking
Connectors

- **ANSI Z359.12 - 2009**

- Gate strength must be 16kN / 3600 lbs.

- Must be 22.2 kN / 5000 lbs. static load strength
Connectors

Roll Out

• A process by which a snap hook or carabiner “unintentionally” disengages from another connector or object to which it is coupled.
Incorrect Connector Application
Energy Absorbing Lanyard

- Energy Absorbing Lanyard
  - Energy absorber pack / Internal energy absorber
  - Fixed / Adjustable length
  - Webbing / Cable / Rope
  - Tie back connectors
  - 6’ free fall
  - 12’ free fall
Energy Absorbing Lanyards

• A system of approved connectors, the lanyard itself & and integral energy absorber
• Can be single leg, twin leg
• Wire rope, webbing or braided rope
• Adjustable in length
• Can be used as travel restraint
Energy Absorbing Lanyards

- Never connect two lanyards together
- Never tie a knot in the lanyard
- Properly stow an unused leg of a twin leg lanyard
- Twin-leg use has the potential for high fall arrest forces when both lanyard legs are connected simultaneously
Energy Absorbing Lanyards
Allowing 12 ft Free Fall

What does ANSI Z359.13 – 2009 state?

Personal energy absorbers are divided into two distinct classes:

– 6 foot free fall
– 12 foot free fall

• The capacity for both classes of personal energy absorbers remains within the range of 130 to 310 lbs.
Fall Protection Background – Forces

• Maximum Average Arresting Force
  – Force on the body caused by stopping a fall
  – Maximum peak arresting force is 1,800 lbs by law (OSHA)
  – Force causing serious body damage 2,700+ lbs

• 6 foot free fall lanyards
  – MAAf 900 lbs / 1,125 lbs (tested wet/cold)
  – Max deceleration distance 48”
    *(Increased from 42”, older ANSI Z359.1)*

• 12 foot free fall lanyards
  – MAAf 1,350 lbs / Max 1,575 lbs (tested wet/cold)
  – Max deceleration distance 60”
Self-Retracting Lanyard

- Minimizes free fall distance
- Allows vertical mobility
- Contains visual load/Fall indicator
- Wire rope or Nylon webbing
- MAF of 900-1800lbs with integral shock absorber
- SRL’s with rescue capabilities
Self-Retracting Lanyard

• ANSI Z359.14 – 2012
  • Class A SRL
    – Maximum deceleration 24”
  • Class B SRL
    – Maximum deceleration 54”
• Leading Edge (LE-SRL)
  – Inline shock absorber next to user
• Factory Recertification
  – Based on frequency of use from first date of service
## Appendix A: Inspection Requirements

<table>
<thead>
<tr>
<th>Type Of Use</th>
<th>Application Examples</th>
<th>Conditions Of Use</th>
<th>Inspection Frequency Competent Person</th>
<th>Factory Authorized Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrequent to Light</td>
<td>Rescue and confined space, factory maintenance</td>
<td>Good storage conditions, indoor or infrequent outdoor use, room temperature, clean environments</td>
<td>Annually</td>
<td>At least every 2-5 years, but not longer than intervals required by the manufacturer</td>
</tr>
<tr>
<td>Moderate to Heavy</td>
<td>Transportation, residential construction, utilities, warehouse</td>
<td>Fair storage conditions, indoor and extended outdoor use, all temperatures, clean or dusty environments</td>
<td>Semi-annually to annually</td>
<td>At least every 1-2 years, but not longer than intervals required by the manufacturer</td>
</tr>
<tr>
<td>Severe to Continuous</td>
<td>Commercial construction, oil and gas, mining</td>
<td>Harsh storage conditions, prolonged or continuous outdoor use, all temperatures, dirty environment</td>
<td>Quarterly to semi-annually</td>
<td>At least annually, but not longer than intervals required by the manufacturer</td>
</tr>
</tbody>
</table>
Personal Protective Equipment – Vertical Lifeline

• Vertical Lifelines
• Rope Grabs / Fall Arrestors
Vertical Lifeline – Fall Arrester

(Rope grabs)

• Engages a vertical lifeline in vertical or sloped plane
• Can be moved along the lifeline in accordance with the position of the worker; and
• Automatically engages on the lifeline in the event of a fall in order to arrest the fall.
Vertical Lifeline
- Manual Fall Arrester

- Locked on a synthetic lifeline line
- Requires a manual action by the worker to displace it along the line
- Connected to the dorsal attachment point of a harness
- Remains engaged on the lifeline if released or held beyond its non-engaged position (panic grab feature).
Fixed Ladder Climbing Device

• Ladder climbing devices are the preferred system to protect permanent ladders.

• Rigid Rail and Flexible Cable Systems

• A minimum length connection is attached to the D ring

• Limiting free fall distances to < .6 m (2 ft) reducing your impact forces
Anchorage Connectors

• Characteristics
  – Temporary
  – Permanent
  – Available for routine work
  – Easy to use

• Mobility Requirements
• Capture/Couple the Anchoring structure
Anchorage Connector

- Compatible with PFAS 22kN (5000 lbs)
- Eye bolts
- Tripods
- Beam trolleys
- Fixed and travelling beam clamps
- Tie-off adaptors
- Concrete anchorage connectors
- Wedge anchorage connectors
Anchorage Connector

- Penetrating & non-Penetrating
- Friction anchor connectors
- Ballast Anchor Connector
Anchorage Connectors

• Horizontal Lifelines
  – Requires a Qualified Person for engineering or anchorage certification
Horizontal Lifelines - Temporary

– Synthetic Rope with Tensioner
– Wire Rope with turn buckle & thimble eye clamp
Horizontal Lifelines

Purpose

• Improves user horizontal mobility
• Use for fall arrest, positioning or restraint
• 100% continuous fall protection
• Provides additional vertical mobility
• Generally have an inline energy absorber
  – Use with energy absorbing lanyard
  – Use with Self Retracting Lifeline (SRL)
Horizontal Lifelines

Applied Forces

• Forces generated in HLL sub system tend to be large
• They are generated on the vertical and horizontal axis
• Generate maximum deflection at the point of Maximum Arresting Force (MAF) generation
• In line energy absorbers reduce anchorage requirements to below 22 kNs (5000 lb)
Horizontal Lifelines

-Tension

• Follow instructions regarding lifeline tension
• Most systems require hand tensioning and adjustment by turnbuckle
• Over tightening results in:
  – Energy absorber deployment
  – Higher end anchor loads
  – Higher MAF
  – Greater rebound after fall
Anchorage

A fixed structural member such as a post, stanchion, beam, girder, column, floor or wall required for the stability and other purposes of the structure itself.
Fall Protection Background – Anchorage Points

• Who specifies the anchorage point?
  – Competent person
    – Non-certified anchorage point
    – 22 kN (5000 lbs), per person attached
  – Qualified person
    – Certified anchorage point
    – Designed with a safety factor of at least two (MAF), per person attached
Fall Protection Background – Personal Protective Equipment

- What all do we consider before using PPE?
  - Free-Fall Distance
  - Maximum Arresting Force
  - Anchorage Point Strength and Location
  - Total fall distance / Clearance calculation

Strength and Location
Type of PPE Desired

Best combination for the Work at Heights task
Total Fall Distance Calculation

How to calculate Total Fall Distance

- 6 ft Length of lanyard
- 4 ft Extension of energy absorber
- 6 ft Height of person to attachment
- 2 ft Safety factor

Total Fall Distance required = 18 ft

Distance to next surface

Drawing only representational. NOT TO SCALE.
Fall Protection -- Rescue Plan

• Each time PPE is used, there must be a rescue plan!
  – You must be able to rescue someone in a minimum amount of time.
  – Define the plan during the Hazard and Risk Prediction.
Suspension Trauma

Orthostatic incompetence (intolerance)

*John Doe on parade*

- Blood pools in the legs
- Venus pooling
- Brain detects low O2
- Cardiac output increases
- Brain O2 still falls
- Emergency response:
  - Pulse drops
  - Loss of consciousness
  - John falls over
  - Blood flows back to brain
- John wakes up.

*John Doe in suspension*

- Blood pools in the legs
- Venus pooling
- Brain detects low O2
- Cardiac output increases
- Brain O2 still falls
- Emergency response:
  - Pulse drops
  - Loss of consciousness
  - John CANNOT fall over
  - Brain function decreases
- John never wakes up.
Fall Protection - Emergency Rescue Plan

- How many people who may need rescue or evacuation?
- What is the elevations from which rescue or evacuation will be needed?
- Which direction (up or down) must be used for rescue or evacuation?
- What anchorages for personal fall arrest systems may be used for rescue or evacuation?
- What independent anchorages for a rescue or evacuation may be used?
Rescue Equipment

• Full Body Harness
  – Designed for Rescue
  – Allows longer suspension
Rescue Equipment

- SRL’s
  - Emergency Retrieval capabilities
  - Reset from Retrieval to Fall Arrest

- Hoists
  - Lifting, Lowering, Positioning of personnel and equipment
Pre-Rigged haul System

- Use the rescue utility kit
- Telescopic remote pole
- 4:1 mechanical advantage pulley system
- Remote Connector
Rescue Equipment - Escape

• MSA Anthron
  – Self-Rescue
  – Great in a panic
  – Manual device
  – Non integrated rope
  – Operator control descent speed with friction
Rescue Anchorage

- Anchorage should be a rigid structure, such as a beam, column or large truss above the casualty.
- Anchorage for rescue and decent control needs to be rated for at least 3,000 lbs. (16kN)(1406 kg).
- Select an anchorage other than what may have been used to arrest the fall of the casualty.
- A separate (independent) anchor system should be set up for each fall arrest system and each lowering or raising system required.
Review

• Fall Hazard scenarios have options
• Use the Hierarchy of controls
• Must choose which solution works best for your work situation
• Fall Protection
  – ANSI Product updates
  – Additional training requirements
  – Rescue concerns and considerations