Performance Evaluation of Select Fall Arrest Equipment to 420 lb Capacity

Background

Equipment Selection

Evaluation Criteria

Results & Conclusions

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Capital Safety
What is Capacity?

**ANSI Z359.1:**
- The combined weight for which the component is designed to be used. Combined weight includes the user’s body weight and clothing, tools, and any other objects carried or borne by the user.

**OSHA:**
- Capacity is not defined however, test protocols provided apply to “combined person and tool weight”
Why is capacity important?

Key to defining equipment limitations:

- Capacity influences the design and testing of each system component.
- System performance can be compromised if the capacity limit is exceeded: MAF, fall clearance, FOS.
- Research indicates that deceleration rates for heavier people may be too great for lighter people. Equipment capacity rating provides guidelines for proper selection.
- Standards developers are considering “classifying” equipment according to total energy limits i.e. free fall x capacity.
Why 420 lbs (191Kg)?

There is a need:
• Historically test criteria found in fall protection regulations and standards are based around a capacity limit of 310 lbs (141kg) – Result is that most equipment designed to this level only

• Safety directors: “We know we have workers that are greater than 310 pounds and we want them to have the right equipment”

• Looking at the fully equipped worker:
  - Clothing + PPE $\geq 15$ lbs (7 kg)
  - Tools and other $\geq 50$ lbs (23 kg)
  - Body weight $\geq 245$ lbs (111 kg)
  - Total $\geq 310$ lbs (Our target 420 lbs)
Equipment Selection

System components:

- Body support component
  - Full Body Harness (FBH), three base types
- Connecting subsystems
  - Energy Absorber + Lanyard (EA+L), one type
  - Self Retracting Lanyard (SRL), two types
  - Fall Arrestor + Lanyard + Lifeline (FACSS), one type
  - Work positioning lanyard (WPL), two types
- Ladder safety subsystem (LSS), one type
- Connectors (CON), as required by system
# Full Body Harness

## Twelve models representative of series:

<table>
<thead>
<tr>
<th>AE Type</th>
<th>Fall Arrest (dorsal)</th>
<th>Work Positioning (hip level)</th>
<th>Ladder Climbing (front)</th>
<th>Work Seat (pair)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vest</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>X-Over</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Step-in</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*Capital Safety*
Adjuster Buckles

- Tongue Buckle
- Pass-Through
- Quick Connect
Vest type with front and dorsal D-rings, QC buckles
Vest type with work seat and dorsal D-rings, TB buckles
Vest type with front, dorsal, and hip level D-rings, PT buckles
X-over type with front and dorsal D-ring, QC buckles
X-over type with front, dorsal, and hip level D-rings, PT buckles
Step-in type with front, dorsal, and hip level D-rings, TB buckles
Energy Absorber + Lanyard

Arrest Force vs Increasing Capacity
900 lb (4KN) Design

Capacity (lbs)

- 1800 lb Limit
- Measured Force

Arrest Force (lbf)

0 500 1000 1500 2000 2500

0 310 335 365 390 420

Capital Safety
Energy Absorber + Lanyard

- Type selected: Tear-ply high capacity energy absorber, “CE type” designed to maintain MAF to 6 kN (1350 lb) or less.

Standard 900 lb (4kN)  High capacity 1350 lb (6kN)
Two “internal brake” SRL models selected:

- 50 ft (15m) length wire rope lanyard portion
- 11 ft (3.3m) length synthetic webbing lanyard portion
Fall Arrester and Lifeline

- Mobile fall arrestor with 5/8” (16mm) 3-strand synthetic rope lifeline
Work Positioning Lanyards

- Webbing construction
  Y-lanyard and single leg lanyard
Ladder Safety Subsystem

- Fixed ladder cable based system with traveling sleeve
Evaluation Criteria

Fall arrest:

• Dynamic performance criteria (OSHA system)
  – A maximum arresting force of 1800 lbs (8 kN)
  – A maximum deceleration distance of 3.5 ft (1.1m)
  – Maximum free fall 6 ft (1.8m)

• Test method
  – Apply OSHA Subpart M “Force Test” methods modified by proportionally increasing test weight:

  \[
  220 \text{ lb test weight} = \text{Increase test weight} = 300 \text{ lb (136 kg)}
  \]

  \[
  310 \text{ lb Capacity} \quad 420 \text{ lb Capacity}
  \]
Evaluation Criteria

Fall arrest (continued):

• Dynamic strength criteria (OSHA system)
  – Must not release test weight/torso
• Test method
  – Apply OSHA Subpart M “strength test” methods modified by proportionally increasing test weight: 300lb (136kg) to 420 lbs (191 kg)
  – Test as system: 4 ft (1.2m) or 7.5 ft (2.3m) free fall
• Static strength
  – Components must meet OSHA minimums
Evaluation Criteria

Work positioning:

- Dynamic strength criteria (OSHA system)
  - Must not release test torso, no MAF limit
- Test method
  - Apply OSHA Subpart M “positioning device system” methods modified by proportionally increasing test weight:
    
    \[
    \text{250 lb test weight} = \text{Increase test weight} = 340 \text{ lb (155 kg)} \\
    \text{310 lb Capacity} \quad 420 \text{ lb Capacity}
    \]
- Test using “stiff” work positioning lanyard and 4ft (1.2m) free fall connected to single or D-ring pair
- Static strength criteria
  - Must comply with OSHA Subpart minimums
Evaluation Criteria

Ladder climbing:

• Dynamic performance criteria (system)
  – Must arrest within 6 inches (152mm), no MAF limit
• Test method
  – Test method from ANSI A14.3 standard on fixed ladders
    proportionally increase test weight: Test weight of 220 lb (100kg)
    increased to 300 lb (136 kg)
• Dynamic strength
  – No change from ANSI A14.3, 500 lb (227kg) x 1.5 ft (free fall)
• Dynamic strength criteria (harness component)
  – Must not release test torso
• Test method
  – Test method from ANSI A14.3 standard on Fixed ladders
    proportionally increased test weight: Test weight of 220 lb
    (100kg) increased to 300 lb (136 kg)
  – Free fall 1.3 ft (.4m) with wire rope lanyard
# Results

## FBH+L+EA System:

<table>
<thead>
<tr>
<th>FBH Type</th>
<th>FBH Description</th>
<th>Con. Point</th>
<th>EA+ Lanyard</th>
<th>Wt (lbs)</th>
<th>FF (ft)</th>
<th>MAF (lbf)</th>
<th>AD (in)</th>
<th>P/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vest</td>
<td>TB/PT/QC Buckles</td>
<td>Dorsal</td>
<td>Wire rope +EA</td>
<td>420</td>
<td>7.5</td>
<td>N/A</td>
<td>N/A</td>
<td>P</td>
</tr>
<tr>
<td>X-over</td>
<td>QC Buckles</td>
<td>Dorsal</td>
<td>Wire rope +EA</td>
<td>420</td>
<td>7.5</td>
<td>N/A</td>
<td>N/A</td>
<td>P</td>
</tr>
<tr>
<td>Step-in</td>
<td>TB Buckles</td>
<td>Dorsal</td>
<td>Wire rope +EA</td>
<td>420</td>
<td>7.5</td>
<td>N/A</td>
<td>N/A</td>
<td>P</td>
</tr>
<tr>
<td>X-over</td>
<td>PT Buckles</td>
<td>Dorsal</td>
<td>Wire rope +EA</td>
<td>300</td>
<td>6.0</td>
<td>860 to 1146</td>
<td>42 to 46</td>
<td>*P</td>
</tr>
</tbody>
</table>

*Note: EB = Eye Bolt, PT = Prong Tool, QC = Quick Connect, TB = Tubular Buckle, AD = Adjusting Device, MAF = Maximum Applied Force, FF = Fall Factor, P/F = Pass/Fail, FBH = Fall Arrest Harness*
Conclusions

FBH+EA+L System:

• Sufficient strength to withstand twice the potential impact energy of fall permitted by system - No damage to system
• MAF < 1800 lbs
• DD > than 42” limit?
  – OSHA Subpart M clarification:
    • De minimis violation provided,
    • MAF < 1800 LBS (FBH)
    • Worker cannot contact lower level
    • Sufficient strength to withstand twice the potential impact energy.
• Special EA markings
  – Maximum DD = 65 inch (1.6 m)
  – MAF = 1350 lbf (6 kN)
  – Capacity: 130 lbs to 420 lbs
## Results

### FBH+SRL System:

<table>
<thead>
<tr>
<th>FBH Type</th>
<th>FBH Description</th>
<th>Con. Point</th>
<th>SRL Type</th>
<th>Wt (lbs)</th>
<th>FF (ft)</th>
<th>MAF (lbf)</th>
<th>AD (in)</th>
<th>P/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vest</td>
<td>PT Buckles</td>
<td>Dorsal</td>
<td>Wire rope 50 ft</td>
<td>420</td>
<td>4.0</td>
<td>N/A</td>
<td>N/A</td>
<td>P</td>
</tr>
<tr>
<td>Vest</td>
<td>PT Buckles</td>
<td>Dorsal</td>
<td>Wire rope 50 ft</td>
<td>300</td>
<td>“0”</td>
<td>915 to 1180</td>
<td>15 to 34</td>
<td>P</td>
</tr>
<tr>
<td>Vest</td>
<td>PT Buckles</td>
<td>Dorsal</td>
<td>Webbing 11 ft</td>
<td>420</td>
<td>4.0</td>
<td>N/A</td>
<td>N/A</td>
<td>P</td>
</tr>
<tr>
<td>Vest</td>
<td>PT Buckles</td>
<td>Dorsal</td>
<td>Webbing 11 ft</td>
<td>300</td>
<td>“0”</td>
<td>744 to 925</td>
<td>21 to 33</td>
<td>P</td>
</tr>
</tbody>
</table>
Conclusions

**FBH + SRL SYSTEM:**

- No damage to system
- Sufficient strength to withstand twice the potential impact energy of fall permitted by system.
- MAF < 1800 lbs
- DD < 42 inches
- Special markings: Capacity: 420 lbs
## Results

### FBH+FACSS System:

<table>
<thead>
<tr>
<th>FBH Type</th>
<th>FBH Description</th>
<th>Con. Point</th>
<th>FACSS+ Lanyard</th>
<th>Wt (lbs)</th>
<th>FF (ft)</th>
<th>MAF (lbf)</th>
<th>AD (in)</th>
<th>P/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vest</td>
<td>PT Buckles</td>
<td>Dorsal</td>
<td>FA+VLL+ Wire rope lanyard</td>
<td>420</td>
<td>7.5</td>
<td>N/A</td>
<td>N/A</td>
<td>P</td>
</tr>
<tr>
<td>Vest</td>
<td>PT Buckles</td>
<td>Dorsal</td>
<td>FA+VLL+ Wire rope lanyard</td>
<td>300</td>
<td>6</td>
<td>1371 to 1566</td>
<td>25 to 28</td>
<td>P</td>
</tr>
</tbody>
</table>

Capital Safety
Conclusions

FBH + FACSS SYSTEM:

- No damage to system
- Sufficient strength to withstand twice the potential impact energy of fall permitted by system.
- MAF <1800 lbs
- DD < 42 inches
- Special markings: Capacity: 420 lbs
## Results

**FBH+LSS System:**

<table>
<thead>
<tr>
<th>FBH Type</th>
<th>FBH Description</th>
<th>Con. Point</th>
<th>LSS Description</th>
<th>Wt (lbs)</th>
<th>FF (ft)</th>
<th>AD (in)</th>
<th>P/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>TB/PT/QC Buckles</td>
<td>Front</td>
<td>Wire rope lanyard</td>
<td>300</td>
<td>1.3</td>
<td>N/A</td>
<td>P</td>
</tr>
<tr>
<td>Vest</td>
<td>PT Buckles</td>
<td>Front</td>
<td>Cable carrier w/sleeve</td>
<td>300</td>
<td>System 9 in max.</td>
<td>2.3</td>
<td>P</td>
</tr>
</tbody>
</table>

Capital Safety
Conclusions

FBH + LSS SYSTEM:

• Dynamic performance
  – Arrest < 6 in (152mm)

• Dynamic Strength (harness component)
  – No release of torso

• Special markings:
  – Capacity: 420 lbs
  – One user per system
## Results

### FBH+WPL System:

<table>
<thead>
<tr>
<th>FBH Type</th>
<th>FBH Description</th>
<th>Con. Point</th>
<th>Lanyard</th>
<th>Wt (lbs)</th>
<th>FF (ft)</th>
<th>P/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vest</td>
<td>TB/PT/QC</td>
<td>Hip</td>
<td>Web</td>
<td>340</td>
<td>4.0</td>
<td>P</td>
</tr>
<tr>
<td>Vest</td>
<td>TB/QC</td>
<td>Seat</td>
<td>Y-Web</td>
<td>340</td>
<td>4.0</td>
<td>P</td>
</tr>
<tr>
<td>X-over</td>
<td>PT</td>
<td>Hip</td>
<td>Web</td>
<td>340</td>
<td>4.0</td>
<td>P</td>
</tr>
<tr>
<td>Step-in</td>
<td>TB</td>
<td>Hip</td>
<td>Web</td>
<td>340</td>
<td>4.0</td>
<td>P</td>
</tr>
</tbody>
</table>
Conclusions

FBH + WPL SYSTEM:

• No damage to system
• Sufficient strength to withstand twice the potential impact energy of fall permitted by system.
• Special markings:
  Capacity: 420 lbs
Conclusions

FBH Component:

- In each case harness sufficient strength to withstand impact – No release of the torso.
- Little or no damage to webbing or harness stitching. No slippage of adjusters.
- Special markings:
  - Warning: Do not exceed capacity of other system components
  - Capacity definition
  - Capacity: 420 lbs
Conclusions

Other system components:

• Connectors
• Anchorage
• Anchorage Connectors
• Anchorage
• These system components maintain FOS since $\text{MAF} \leq 1800 \text{ lb (8kN)}$
Conclusions

Final Comments:

• Results illustrate the capacity rating is a key guideline for equipment selection and system performance.
• Systems selected meet 420lb capacity evaluation criteria!
• Is this the correct test criteria?
## Final Comments

### Testing at 1.1 and 1.0 human weight / rigid weight:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Con. Point</th>
<th>Test Lanyard</th>
<th>Wt (lbs)</th>
<th>FF (ft)</th>
<th>MAF (lbf)</th>
<th>AD (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBH+L+EA</td>
<td>Dorsal</td>
<td>Wire rope</td>
<td>420</td>
<td>6.0</td>
<td>2075 / 2065</td>
<td>68/68</td>
</tr>
<tr>
<td>FBH+L+EA</td>
<td>Dorsal</td>
<td>Wire rope</td>
<td>380</td>
<td>6.0</td>
<td>1546 / 1581</td>
<td>65/66</td>
</tr>
<tr>
<td>FBH+SRL</td>
<td>Dorsal</td>
<td>50 ft cable</td>
<td>420 “0”</td>
<td>1267 / 1183</td>
<td>27/20</td>
<td></td>
</tr>
<tr>
<td>FBH+SRL</td>
<td>Dorsal</td>
<td>11 ft web</td>
<td>420 “0”</td>
<td>1009 / 1042</td>
<td>36/43</td>
<td></td>
</tr>
<tr>
<td>FBH+FACSS</td>
<td>Dorsal</td>
<td>Wire rope</td>
<td>420</td>
<td>6.0</td>
<td>1442</td>
<td>40</td>
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<tr>
<td>FBH +LSS</td>
<td>Front</td>
<td>N/A</td>
<td>420</td>
<td>System 9 in max</td>
<td>N/A</td>
<td>4.5 to 6.8</td>
</tr>
</tbody>
</table>
Thank you!

Questions?