CLEARANCE REQUIREMENT GUIDELINES

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Version 20A Board and SOC Approved February 2021
SPC-02

Registry Number:
SPC-02

Revision History:
Version 20A Board and SOC Approved February 2021

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Notes for Usage:

For the most recent standards versions, supporting documentation, and news, visit https://sprat.org.

Terminology from SPRAT's *Defined Terms* used in this document is shown in ***bold***, ***italic*** type unless written in a primary section heading.

New terminology in this document that has not received approval for inclusion in SPRAT's *Defined Terms* is shown in **bold** type unless written in a primary section heading. Interim definitions for these terms are provided in Appendix 3.

Usage of the word 'should' denotes a recommendation. The word 'should' does not connote indifference or ambivalence regarding a statement.

Approximate conversions of units are presented in parentheses. These approximations are provided as a reference and are not the standard. When a value is presented as a limit, approximations are greater than an expressed minimum or less than an expressed maximum.

1. Purpose, Scope, and Exceptions

1.1. Purpose

1.1.1. The purpose of this document is to provide rope access technicians and other individuals that work at height with the ability to estimate and calculate clearance requirements of ***rope access systems*** and other personal fall protection systems.

1.1.2. This document is intended to be used in conjunction with manufacturer supplied information during the job planning phase within rope access and fall protection programs that ensures fall protection systems are utilized in a manner to minimize ***free fall potential***.

1.2. Scope

1.2.1. This document provides:

1.2.1.1. The phases of a fall event

1.2.1.2. Contributing factors to clearance requirements within each fall event phase

1.2.1.3. Considerations for calculating clearance requirements

1.2.1.4. Examples of calculating clearance requirements for personal fall protection systems

1.3. Exceptions

1.3.1. This document does not address:

1.3.1.1. Additional clearance considerations from the sag of horizontally tensioned fall protection systems used within fall protection systems, such as tensioned rope systems or horizontal lifelines.

1.3.1.2. The effect on clearance requirements by obstructions that may contact fall protection systems during a fall event.

1.3.1.3. Calculating ***anchorage system*** strength or energy capacity requirements of fall protection systems.

1.3.2. Determining fall protection systems for a specific work environment and ensuring their appropriate use is a requirement within managed rope access and fall protection programs.

2. Total Fall Distance

2.1. A fall of a worker using a personal fall protection system may consist of three phases:

2.1.1. **Free fall**, during which a falling person or load accelerates due to the forces of gravity, unimpeded by arresting forces of the personal fall protection system.

2.1.2. **Swing fall**, during which a falling person or load experiences a pendulum or swinging effect.

2.1.2.1. A **swing fall** may occur simultaneously with the other phases of a fall.

2.1.2.2. All clearance requirement examples provided in this document assume zero **swing fall**.

2.1.2.3. Appendix 1 provides example calculations related to **swing falls**.

2.1.3. Deceleration, during which a falling person or load is brought to rest by the personal fall protection system.

2.2. The sum of the vertical distances traveled during these phases is **total fall distance**, as depicted by the equations in

2.3. Figure 1.

FIGURE 1 COMPONENTS OF TOTAL FALL DISTANCE

Free fall distance (FF)
Swing fall distance (SFD)
+ **Deceleration distance** (DD)
Total fall distance (TFD)

$$\text{TFD} = \text{FF} + \text{SFD} + \text{DD}$$

3. Free Fall Distance Factors

3.1. **Free fall potential** (FF_L)

3.1.1. **Free fall potential** can be visualized *as slack within a fall protection system prior to a fall.*

3.1.2. **Free fall potential** *is* a result of the height of the D-ring attachment to the harness in relation to the lanyard connection to an ***anchorage*** or a rope, the lanyard length, and additional system slack.

3.1.3. If all of these factors are located on the same ***fall line***, **free fall potential** is a sum of these factors, as depicted in Figure 2.

FIGURE 2 COMPONENTS OF FREE FALL POTENTIAL

Height of D-ring relative to connection (H_{DA})
Lanyard length (L_y)
+ Additional system slack (S_A)
Free fall potential (FF_L)
$FF_L = H_{DA} + L_y + S_A$

3.1.4. Height of D-ring relative to connection (H_{DA})

3.1.4.1. The height of D-ring relative to connection (H_{DA}) is the vertical distance between the harness D-ring and the connection of the lanyard to an ***anchorage system*** or rope.

3.1.4.1.1. This value (H_{DA}) is positive if the D-ring is above that connection.

3.1.4.1.2. This value (H_{DA}) is negative if the D-ring is below that connection.

3.1.5. Lanyard length (L_y)

3.1.5.1. Lanyard length includes all factors, including connectors, energy absorbers, and equipment, connecting an appropriate D-ring of a worker's harness to an ***anchorage system*** or rope.

3.1.6. Additional system slack (S_A)

3.1.6.1. Additional system slack may arise from a number of factors, such as:

3.1.6.1.1. Attachments to ***anchorages*** that allow for vertical movement of connectors prior to loading.

3.1.6.1.2. The introduction of slack in a ***rope system*** above a backup device.

3.1.6.2. As additional system slack arises only from inappropriate use of the systems analyzed in this document, clearance requirement examples assume zero additional system slack.

3.2. **Activation distance** $(\mathrm{FF_A})$

3.2.1. **Activation distance** is any vertical increase in the length of a fall protection system that does not correspond to absorption of appreciable energy of a fall.

3.2.2. **Activation distance** may vary with the **free fall potential** of a fall protection system.

3.2.3. As measuring **activation distance** is not practical in some fall protection systems, manufacturers will often provide an **arrest distance** value, which combines **activation distance** with **deceleration distance**.

3.3. Horizontal Distance Between ***Anchorage*** and Worker

3.3.1. When the D-ring attachment of the worker is not on the same approximate ***fall line*** as the ***anchorage***, the **free fall distance** may be reduced.

3.3.1.1. If the fall protection system may encounter an obstruction during **free fall**, the geometry of the anchorage location, worker, and any possible obstructions, should be analyzed to determine the **free fall distance**.

3.3.1.1.1. A common example of this scenario is when an ***anchorage*** is selected away from an exposed edge.

3.3.2. Clearance requirement examples in this document assume zero horizontal distance between the ***anchorage*** and the worker.

4. Deceleration Distance Factors

4.1. Energy absorber deployment (x_{PEA})

4.1.1. If the average deployment force of the energy absorber and the weight of a worker is known, deployment of an energy absorber for a fall from a given height can be calculated by the equation shown in Figure 3.

FIGURE 3 CALCULATING ENERGY ABSORBER DEPLOYMENT

$$\text{Energy absorber deployment } (x_{PEA}) = \frac{\text{Worker Weight (W)} \times \textbf{Free fall distance } (FF)}{\text{Average deployment force } (F_{AVG}) - \text{Worker Weight (W)}}$$

$$x_{PEA} = \frac{W \times FF}{F_{AVG} - W}$$

4.1.1.1. As average deployment force values published on equipment may be a maximum allowable value, any published value should be confirmed by the manufacturer prior to utilizing this method for calculation energy absorber deployment.

4.1.1.2. Overestimating the average energy absorber deployment force leads to underestimating deceleration distance and thus underestimating clearance requirements.

4.1.2. Manufacturers may provide data that provides energy absorber deployment distance as a function of worker mass, which may then be used to calculate clearance.

4.1.3. An example of an energy absorber with maximum deployment of 100 cm (39 in) that deploys at an average force of 3.2 kN (710 lbf) is provided in Figure 4.

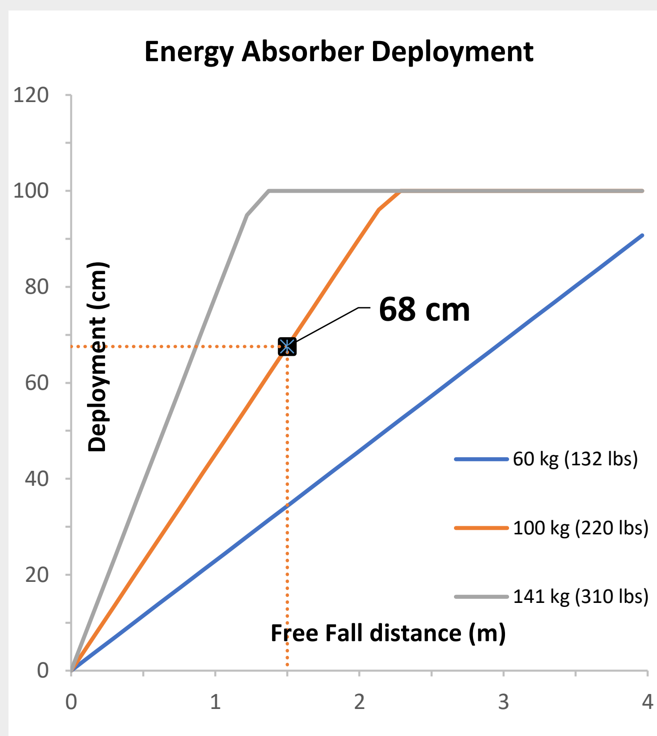
4.1.4. If no other data is available, the maximum deployment of the energy absorber should be used.

FIGURE 4 CHART AND GRAPH OF ENERGY ABSORBER DEPLOYMENT DISTANCE AS A FUNCTION OF WORKER MASS AND FREE FALL DISTANCE

Worker Mass

Free Fall Distance	**60 kg (132 lb)**	**100 kg (220 lb)**	**141 kg (310 lb)**
0.3 m (1 ft)	7 cm (2 in)	14 cm (5 in)	24 cm (9 in)
0.6 m (2 ft)	14 cm (6 in)	28 cm (11 in)	48 cm (19 in)
0.9 m (3 ft)	21 cm (8 in)	41 cm (16 in)	71 cm (28 in)
1.2 m (4 ft)	28 cm (11 in)	55 cm (22 in)	95 cm (37 in)
1.5 m (5 ft)	35 cm (14 in)	68 cm (27 in)	**100 cm (39 in)***
1.8 m (6 ft)	42 cm (17 in)	82 cm (32 in)	**100 cm (39 in)***
2.1 m (7 ft)	49 cm (19 in)	96 cm (38 in)	**100 cm (39 in)***
2.4 m (8 ft)	56 cm (22 in)	**100 cm (39 in)***	**100 cm (39 in)***
2.7 m (9 ft)	63 cm (25 in)	**100 cm (39 in)***	**100 cm (39 in)***

Example: 1.5 m (5 ft) free fall of a 100 kg (220 lb) worker



***Bold, red font** indicates maximum energy absorber deployment

4.2. Rope stretch (x_R) and Lanyard stretch (x_L)

4.2.1. The force used for calculations should be the average deployment of an energy absorber incorporated into the backup system, or the slippage force of the backup device.

4.2.2. If lanyard or rope stretch values are available from a manufacturer, rope stretch may be calculated through modeling.

4.2.3. Alternatively, rope stretch may be estimated by measuring the stretch of a rope under the user's weight, multiplying that value by the average deployment of the energy absorber, and dividing by the user's weight.

4.2.4. If manufacturer or testing data is unavailable, the following percentages should be used when calculating clearance for ***rope systems***:

4.2.4.1. ***Static rope***: 6%

4.2.4.2. ***Low-stretch rope***: 10%

4.2.4.3. ***Dynamic rope***: 35%

4.3. Combining **deceleration distance** factors

4.3.1. All **deceleration distance** factors absorb a portion of the kinetic energy created during the fall.

4.3.2. Energy balance analysis allows for accounting the multiple factors to provide a more accurate **deceleration distance**.

4.3.2.1. If energy balance analysis is not possible, each **deceleration distance** factor should be considered and added together separately.

5. Other Clearance Factors

5.1. **Stretch-out** (x_W)

5.1.1. Harness **stretch-out**

5.1.1.1. Factors affecting harness **stretch-out** under normal use may include:

5.1.1.1.1. Harness stretching

5.1.1.1.2. Flipping of the D-ring

5.1.1.1.3. Sliding of the D-ring

5.1.1.1.4. Deployment of any visual indicator

5.1.1.2. Additional ***stretch-out*** will occur from a harness not being fitted to the worker.

5.1.1.2.1. Clearance requirement examples in this document assume a harness appropriately fitted to the worker.

5.1.1.3. The manufacturer should be consulted for a harness **stretch-out** value.

5.1.1.3.1. If manufacturer or testing data is unavailable, a value of 0.45 m (1.5 ft) should be used to account for harness **stretch-out** variables.

5.1.2. Worker ***stretch*-out**

5.1.2.1. During a fall, a worker's body will straighten and rotate until supported by the selected D-ring connection to the fall protection system, which may increase the overall clearance requirement.

5.1.2.2. The following values should be added during clearance calculations as additional **stretch-out**:

5.1.2.2.1. For a seated worker, 0.45 m (1.5 ft) for dorsal D-ring, 0 m (0 ft) for sternal D-ring

5.1.2.2.2. For a kneeling worker 0.75 m (2.5 ft) for dorsal D-ring, 0.3 m (1 ft) for sternal D-ring

5.1.2.2.3. For a prone worker 1.2 m (4 ft) for dorsal D-ring, 0.75 m (2.5 ft) for sternal D-ring

5.1.2.3. If the D-ring connection for the harness cannot be ensured for a given fall, the dorsal D-ring should be used as a reference.

5.2. Clearance margin (CM)

5.2.1. A clearance margin should be added to allot for considerations that have not been accounted for in the other clearance factors, such as:

5.2.1.1. Taller workers

5.2.1.2. Elongation of ***anchorage systems*** or lanyard stretch

5.2.1.3. Underestimation of **deceleration distance** due to modeling assumptions

5.2.2. Clearance margins should not be used to account for inappropriate use of equipment.

5.2.3. Clearance margin may be reduced as:

5.2.3.1. A fall event is better modeled during clearance calculations to account for variables, such as the reduction of impact force during deceleration.

5.2.3.2. Other controls in rope access and fall protection programs are implemented.

5.2.4. For the purposes of this document, 0.6 m (2 ft) is used as a clearance margin.

6. Calculating Required Clearance

6.1. For the purposes of this document, clearance is calculated with reference to the work platform.

6.1.1. Calculating clearance using the height of the ***anchorage*** may be appropriate in some circumstances, the reference used for clearance requirements should be verified for comparing clearance calculations with other references, such as manufacturer specifications.

6.2. Required clearance below a platform (C_P) is expressed as a sum of the clearance factors, as depicted in

6.3. Figure 5.

FIGURE 5 CALCULATING CLEARANCE BELOW A WORK PLATFORM

Free fall distance (FF)
Swing Fall distance (SFD)
Deceleration distance (DD)
Stretch-out (x_W)
\+ Clearance Margin (CM)

Required clearance below platform (C_P)

$$C_p = FF + SFD + DD + x_W + CM$$

6.4. Assuming no ***swing fall distance*** and expressing ***free fall distance*** as a sum of its factors allows for the expressions in Figure 6 to be derived.

FIGURE 6 CALCULATING CLEARANCE WITH SEPARATED FREE FALL DISTANCE COMPONENTS

Free fall distance (FF) { **Free fall potential** (FF_L), **Activation distance** (FF_A)

Arrest distance (AD) } **Activation distance** (FF_A), **Deceleration distance** (DD)

Stretch-out (x_W)
\+ Clearance Margin (CM)

Required clearance below platform (C_P)

$$C_p = FF + DD + x_W + CM$$
$$C_p = FF_L + FF_A + DD + x_W + CM$$
$$C_p = FF_L + AD + x_W + CM$$

6.5. If the available clearance for a given work location is lower than the calculated required clearance, consideration should be given for one or more of the following:

6.5.1. A more appropriate fall protection system

6.5.2. A more accurate calculation of required clearance

7. Clearance of Energy Absorbing Lanyards

7.1. **Free fall distance** factors

7.1.1. With no **activation distance**, **free fall distance** is equal to **free fall potential** and can be expressed as:

$$FF = FF_L = H_{DA} + L_y$$

7.2. **Deceleration distance** factors

7.2.1. **Deceleration distance** includes deployment of the energy absorber and any lanyard stretch:

$$DD = x_{PEA} + x_L$$

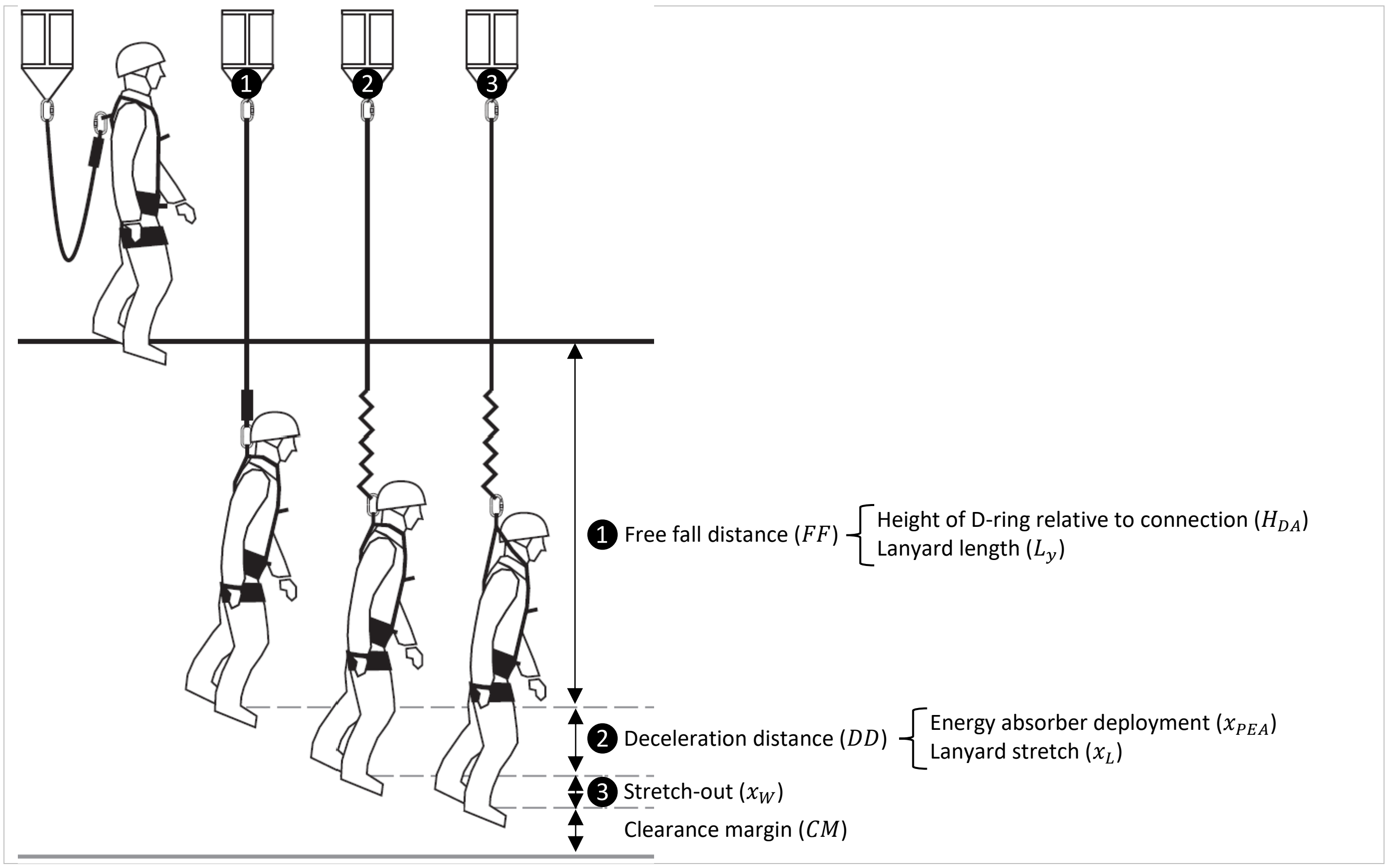
7.2.1. When an energy absorber is incorporated within a lanyard with a maximum length of 1.8 m (6 ft), the effect of lanyard stretch on **deceleration distance** is typically nominal.

7.2.1.1. Lanyard stretch is considered to be negligible in the clearance requirement examples for energy absorbing lanyards in this document.

7.3. Schematic

7.3.1. A schematic depicting the factors for calculating clearance is presented in Figure 7.

FIGURE 7 CLEARANCE COMPONENTS OF ENERGY ABSORBING LANYARDS



7.4. Final equations

$$C_p = \underbrace{FF}_{} + \underbrace{DD}_{} + x_W + CM$$

$$C_p = H_{DA} + L_y + x_{PEA} + x_L + x_W + CM$$

7.5. Clearance Requirement Examples for Energy Absorbing Lanyards

7.5.1. Example 1 – Clearance assuming full deployment of energy absorber

7.5.1.1. A worker is standing on a platform and is attached to an anchorage 0.6 m (2 ft) above the height of their D-ring with an energy absorbing lanyard that has a length of 1.8 m (6 ft) and a maximum deployment distance of 1 m (3.5 ft). Harness **stretch-out** is known to be 0.3 m (1 ft).

7.5.1.2. What is the clearance requirement below the platform assuming negligible lanyard stretch and full deployment of the energy absorber?

Height of D-ring relative to connection (H_{DA})	-0.6 m	-2 ft
Lanyard length (L_y)	1.8 m	6 ft
Lanyard stretch (x_L)	0 m	0 ft
Energy absorber deployment (x_{PEA})	1 m	3.5 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	0.6 m	2 ft
Required clearance below platform (C_P)	3.1 m	10.5 ft

7.5.2. Example 2 – Clearance using energy balance analysis

7.5.2.1. If the energy absorber in the lanyard is the same as the one in Figure 4, what is the clearance requirement below the platform for a 100 kg (220 lb) worker?

Height of D-ring relative to connection (H_{DA})	-0.6 m	-2 ft
Lanyard length (L_y)	1.8 m	6 ft
Lanyard stretch (x_L)	0 m	0 ft
Energy absorber deployment (x_{PEA})	0.55 m	1.8 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	0.6 m	2 ft
Required clearance below platform (C_P)	2.65 m	8.7 ft

7.5.3. Example 3 – Clearance from attaching energy absorbing lanyard at height of platform

7.5.3.1. Instead of attaching to a higher anchorage, the worker attaches the energy absorbing lanyard to the height of the platform, which is located 1.5 m (5 ft) below their D-ring. Using the energy absorber from Figure 4, what is the clearance requirement below the platform for a 100 kg (220 lb) worker? Is there any additional concern from this configuration?

Height of D-ring relative to connection (H_{DA})	1.5 m	5 ft
Lanyard length (L_y)	1.8 m	6 ft
Lanyard stretch (x_L)	0 m	0 ft
Energy absorber deployment (x_{PEA})	1 m	3.5 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	0.6 m	2 ft
Required clearance below platform (C_P)	5 m	21 ft

The energy absorber is expected to reach maximum deployment at *a* **free fall distance** of 2.4 m (8 ft). A **free fall distance** of 3.3 m (11 ft) exceeds this threshold and is a clear misuse of this equipment. Arrest forces can be expected to be much higher, with increased possibility of injury sustained by the worker.

8. Clearance of Self-retracting Devices

8.1. **Free fall distance** factors

8.1.1. Free fall distance for self-retracting devices is the same as that of the energy absorbing lanyard example, with the addition of **activation distance**:

$$FF = H_{DA} + L_y + FF_A$$

8.1.2. For overhead self-retracting devices, **free fall potential** is zero, with only **activation distance** contributing to **free fall distance**.

8.1.3. **Activation distance** is variable based on the type of locking mechanism of a self-retracting device and the characteristics of the arrested fall.

8.1.4. If a fall initiates when the worker's D-ring starts above the connection, unless otherwise specified by the manufacturer, no reeling in of the self-retracting device should be assumed.

8.2. **Deceleration distance** factors

8.2.1. Arresting elements of self-retracting devices may be approximated in a similar manner to the deployment of energy absorbers, and the equation is the same:

$$DD = x_{PEA} + x_L$$

8.2.2. Manufacturers typically use wire rope for longer lanyards resulting in negligible lanyard stretch.

8.3. Final equations

8.3.1. Including all terms of **total fall distance** factors, the final equation may be written as:

$$C_p = \overbrace{H_{DA} + L_y + FF_A}^{FF} + \overbrace{x_{PEA} + x_L}^{DD} + x_W + CM$$

8.3.2. If **arrest distance** is available from the manufacturer, the equation may be written as:

$$C_p = H_{DA} + L_y + AD + x_W + CM$$

8.4. Clearance Requirement Examples for Self-Retracting Devices

8.4.1. Example 1 – Overhead self-retracting device

8.4.1.1. A worker using an overhead self-retracting device with a verified **arrest distance** of 0.6 m (2 ft) and negligible lanyard stretch. Assuming a harness **stretch-out** of 0.3 m (1 ft), what is the clearance requirement?

Free fall potential (FF_L)	0 m	0 ft
Arrest Distance (AD)	0.6 m	2 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	+ 0.6 m	+ 2 ft
Required clearance below platform (C_P)	1.5 m	5 ft

8.4.2. Example 2 – Self-retracting device attached below D-ring

8.4.2.1. A 141 kg (310 lb) worker has attached their self-retracting device, which arrests a fall with the same average deployment force as in Figure 4, to an anchorage 0.45 m (1.5 ft) below their D-ring. Assuming no reeling of the self-retracting device during a fall, negligible lanyard stretch, an **activation distance** of 0.15 m (0.5 ft), and a harness **stretch-out** of 0.3 m (1 ft), what is the clearance requirement?

Height of D-ring relative to connection (H_{DA})	0.45 m	1.5 ft
Lanyard length (L_y)	0.45 m	1.5 ft
Activation distance (FF_A)	0.15 m	0.5 ft
Energy absorber deployment (x_{PEA})	0.95 m	3 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	+ 0.6 m	+ 2 ft
Required clearance below platform (C_P)	2.9 m	9.5 ft

9. Clearance of Backup Systems

9.1. **Free fall distance** factors

9.1.1. **Free fall distance** for ***backup systems*** is the same as that of self-retracting devices:

$$FF = H_{DA} + L_y + FF_A$$

9.1.2. **Activation distance** for ***backup systems*** is highly variable, and may be directly or inversely related to **free fall potential**.

9.1.2.1. If no **activation distance** value is available from a manufacturer or from testing, 30 cm (1 ft) is commonly used as an approximation in clearance calculations.

9.2. **Deceleration distance** factors

9.2.1. Deceleration distance may be written as the sum of rope stretch (x_R), energy absorber deployment (x_{PEA}), and lanyard stretch (x_L):

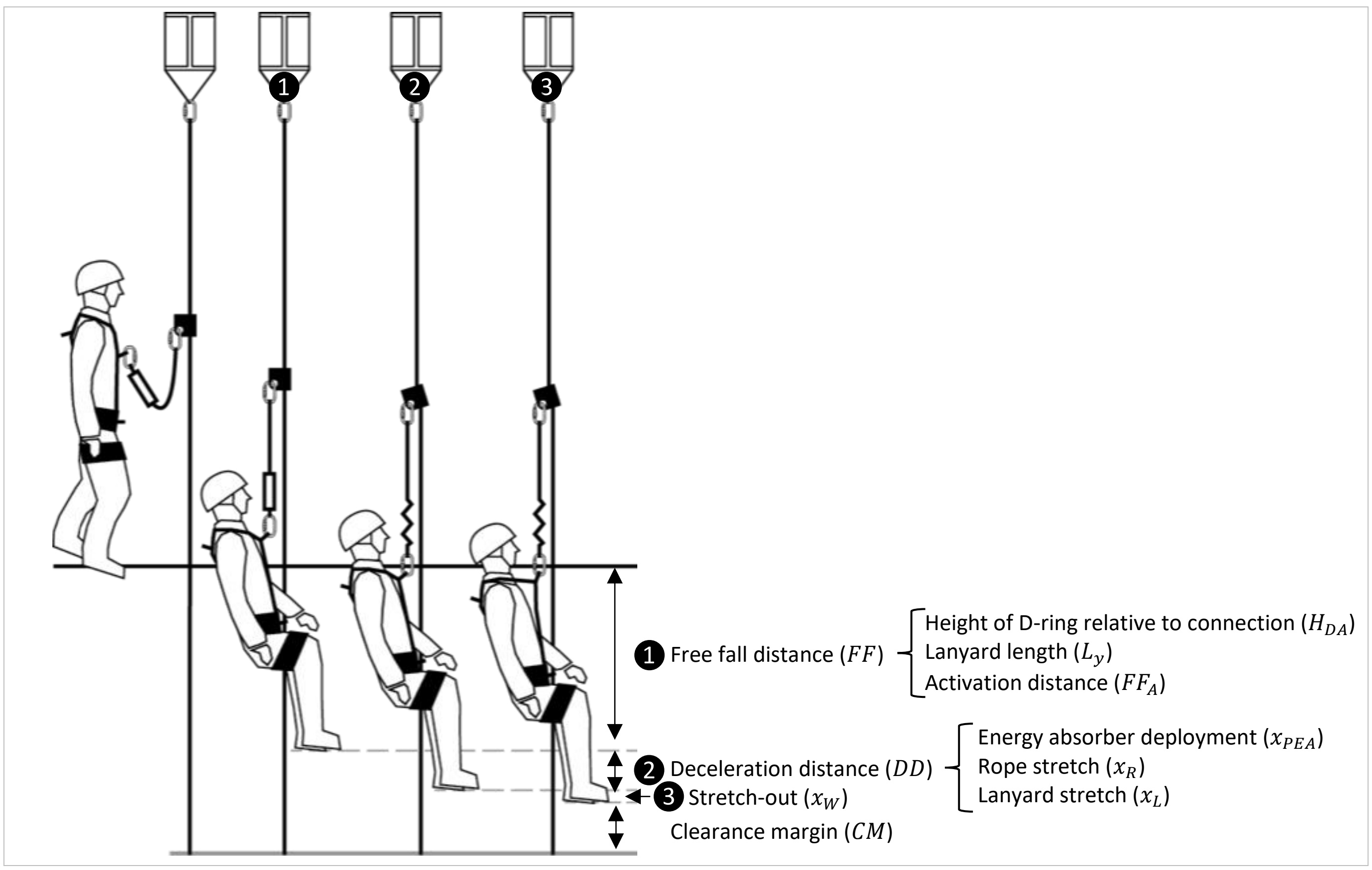
$$DD = x_R + x_{PEA} + x_L$$

9.2.2. While backup systems utilizing manual backup devices and rope lanyards may be modeled similarly to energy absorbing lanyards, clearance requirements should be calculated by treating backup device movement as **activation distance**.

9.3. Schematic

9.3.1. A schematic depicting the factors for calculating clearance is presented in Figure 8.

FIGURE 8 CLEARANCE COMPONENTS OF BACKUP SYSTEMS



9.4. Final equations

$$C_p = FF + DD + x_W + CM$$

$$C_p = \underbrace{H_{DA} + L_y + FF_A}_{FF} + \underbrace{x_R + x_{PEA} + x_L}_{DD} + x_W + CM$$

9.5. Clearance Requirement Examples for ***Backup Systems***

9.5.1. Example 1 – Manual backup device using drop test data

9.5.1.1. A rope access technician with a mass of 100 kg (220 lb) is working with 15.1 m (49.5 ft) of rope above their backup device.

9.5.1.2. The backup device is 0.3 m (1 ft) above the rope access technician.

9.5.1.3. The lanyard, which incorporates a dynamic rope, connecting the backup device to the rope access technician's sternal D-ring is 0.6 m (2 ft) long.

9.5.1.4. Drop testing using a 100 kg (220 lb) weight has shown that the backup device slides up to 0.1 m (0.3 ft) prior to engaging the rope during a fall event.

9.5.1.5. Using the arrest forces from the drop testing, the backup rope is calculated to elongate 0.3 m (1 ft), and the dynamic rope lanyard is calculated to elongate 0.2 m (0.7 ft).

9.5.1.5.1. Harness **stretch-out** is known to be 0.3 m (1 ft).

9.5.1.6. How much clearance below the rope access technician is required?

Height of D-ring relative to connection (H_{DA})	-0.3 m	-1 ft
Lanyard length (L_y)	0.6 m	2 ft
Activation distance (FF_A)	0.1 m	0.3ft
Rope Stretch (x_R)	0.3 m	1 ft
Energy absorber deployment (x_{PEA})	0 m	0 ft
Lanyard stretch (x_L)	0.2 m	0.7 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	0.6 m	2 ft
Required clearance below platform (C_P)	1.8 m	6 ft

9.5.2. Example 2 – Automatic backup device using energy balance analysis

9.5.2.1. A rope access technician with a mass of 100 kg (220 lb) is working with 15.1 m (49.5 ft) of rope above their backup device.

9.5.2.2. The backup device is 0.3 m (1 ft) above the rope access technician.

9.5.2.3. The lanyard, which incorporates an energy absorber, connecting the backup device to the rope access technician's sternal D-ring is 0.6 m (2 ft) long.

9.5.2.4. The ropes in use have a stretch of 2% at the average deployment force of the energy absorber.

9.5.2.5. Testing has shown that the backup device has a 0.3 m (1 ft) activation distance.

9.5.2.6. Energy balance analysis for this type of fall predicts that the energy absorber will deploy a distance of 0.15 m (0.5 ft).

9.5.2.7. Harness **stretch-out** is known to be 0.3 m (1 ft).

9.5.2.8. How much clearance below the rope access technician is required?

Height of D-ring relative to connection (H_{DA})	-0.3 m	-1 ft
Lanyard length (L_y)	0.6 m	2 ft
Activation distance (FF_A)	0.3 m	1 ft
Rope Stretch (x_R)	0.3 m	1 ft
Energy absorber deployment (x_{PEA})	0.15 m	0.5 ft
Lanyard stretch (x_L)	0 m	0 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	0.6 m	2 ft
Required clearance below platform (C_P)	1.95 m	6.5 ft

9.5.3. Example 3 – Substitution for a used backup device

9.5.3.1. The rope access technician from Example 2 swaps their backup device to one that has more use time.

9.5.3.2. All other variables from Example 2 are the same, except that the backup device now in use has tendency to creep down the rope and has a 0.3 m (1 ft) activation distance.

9.5.3.3. In this example, the backup device is 0.3 m (1 ft) below the rope access technician's sternal D-ring when the main system fails.

9.5.3.4. Energy balance analysis for this type of fall predicts that the energy absorber will deploy a distance of 0.45 m (1.5 ft).

9.5.3.5. How much clearance below the rope access technician is required?

Height of D-ring relative to connection (H_{DA})	0.3 m	1 ft
Lanyard length (L_y)	0.6 m	2 ft
Activation distance (FF_A)	0.15 m	1 ft
Rope Stretch (x_R)	0.3 m	1 ft
Energy absorber deployment (x_{PEA})	0.45 m	1.5 ft
Lanyard stretch (x_L)	0 m	0 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	0.6 m	2 ft
Required clearance below platform (C_P)	2.7 m	9.5 ft

9.5.4. Example 4 – Substitution for a dynamic rope

9.5.4.1. Due to the concern from this additional free fall potential, the rope access technician makes an ill-advised choice to swap the ropes from Example 3 with dynamic ropes, which have a stretch of 35% at the average deployment force of the energy absorber.

9.5.4.2. Assuming all other variables are the same, energy balance analysis predicts that the energy absorber will not deploy in this case, but the rope will now stretch 3.15 m (10.4 ft)

9.5.4.3. How much clearance below the rope access technician is required?

Height of D-ring relative to connection (H_{DA})	0.3 m	1 ft
Lanyard length (L_y)	0.6 m	2 ft
Activation distance (FF_A)	0.3 m	1 ft
Rope Stretch (x_R)	4.35 m	14.3 ft
Lanyard stretch (x_L)	0 m	0 ft
Energy absorber deployment (x_{PEA})	0 m	0 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	0.6 m	2 ft
Required clearance below platform (C_P)	6.45 m	21.3 ft

Appendix 1. Swing Fall Information

A.1.1. **Swing Falls**

A.1.1.1. If a falling worker or load is not located along the **fall line** of the ***anchorage***, and will not encounter any obstructions restricting horizontal movement during the fall, a **swing fall** will occur.

A.1.1.2. **Swing fall distance** may be added as a factor of **free fall distance** when calculating clearance requirements.

A.1.1.3. All clearance requirement examples provided in this document assume zero **swing fall**.

A.1.2. Calculating **Swing Fall Distance**

A.1.2.1. Assuming no **free fall** and no increase in length of the fall protection system during the **swing fall**, **swing fall distance** (SFD) may be calculated if two of any of these variables are known:

A.1.2.1.1. Horizontal distance (d) between the worker or load to the connection to an ***anchorage*** or rope.

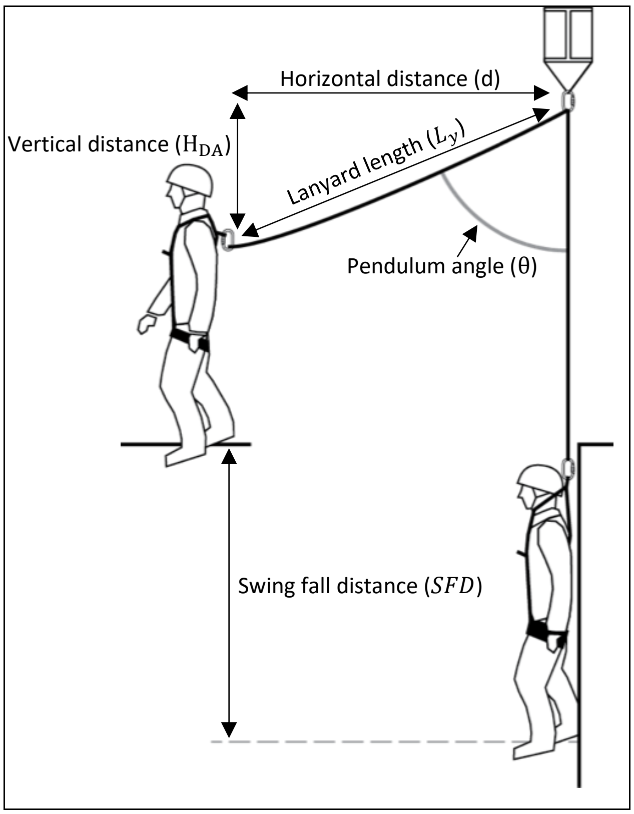
A.1.2.1.2. Vertical distance ($\mathrm{H_{DA}}$) between the worker or load to the connection to an ***anchorage*** or rope.

A.1.2.1.3. Lanyard length (L_y)of connection of the worker or load to the ***anchorage*** or rope.

A.1.2.1.4. Pendulum angle (θ) of lanyard (degrees from vertical).

A.1.2.2. A schematic depicting these variables in a swing fall is shown in Figure 9.

FIGURE 9 DEPICTION OF SWING FALL VARIABLES



A.1.2.3. The relation of **swing fall distance** to these variables is shown in Figure 10.

FIGURE 10 EQUATIONS FOR CALCULATING SWING FALL DISTANCE

$$\mathrm{SFD} = \mathrm{L_y} - \mathrm{H_{DA}}$$

$$\mathrm{SFD} = \frac{\mathrm{H_{DA}}}{\cos\theta - 1}$$

$$\mathrm{SFD} = \mathrm{L_y} \times (1 - \cos\theta)$$

$$\mathrm{SFD} = \mathrm{L_y} - \sqrt{\mathrm{L_y}^2 - \mathrm{d}^2}$$

$$\mathrm{SFD} = \sqrt{\mathrm{H_{DA}}^2 + \mathrm{d}^2 + \mathrm{H_{DA}}}$$

$$\mathrm{SFD} = \frac{\mathrm{d}}{\sin\theta} - \frac{\mathrm{d}}{\tan\theta}$$

A.1.3. **Swing Fall Distance** Examples

A.1.3.1. Example 1 – **Swing fall distance** of a rope to rope transfer

A.1.3.2. A rope access technician is in the middle of a rope to rope transfer that spans a horizontal distance of 4 m (13 ft).

A.1.3.3. The technician is located a vertical distance of 2 m (6.6 ft) below the ***anchorages*** of the rope to rope transfer.

A.1.3.4. The rope access technician inexplicably removed their backup device from their descent side.

A.1.3.5. If the main system from the descent side were to fail at this time, what would be the **swing fall distance**?

$$\mathrm{SFD} = \sqrt{\mathrm{H_{DA}}^2 + \mathrm{d}^2} + \mathrm{H_{DA}}$$

$$\mathrm{SFD} = \sqrt{4\ \mathrm{m}^2 + 4\ \mathrm{m}^2} - 2\ \mathrm{m} = 0.82\mathrm{m}$$

A.1.4. Example 2 – **Swing fall distance** of a shallower rope to rope transfer

A.1.4.1.1. While remaining in the middle of the rope to rope transfer, the rope access technician from Example 1 shortens the vertical distance below the anchorages to 1 m (3.3 ft)

A.1.4.2. If the ***main system*** from the descent side were to fail at this time, what would be the **swing fall distance**?

$$\mathrm{SFD} = \sqrt{\mathrm{H_{DA}}^2 + \mathrm{d}^2} + \mathrm{H_{DA}}$$

$$\mathrm{SFD} = \sqrt{4\ \mathrm{m}^2 + 1\ \mathrm{m}^2} - 1\ \mathrm{m} = 1.23\mathrm{m}$$

A.1.5. Bonus Example – Velocity of a **swing fall**

A.1.5.1. What would be the velocity of the rope access technician in both Examples 1 and 2 when they reach the bottom of the **swing fall**?

$$\mathrm{v} = \sqrt{2\mathrm{gh}}$$

Example 1:

$$\mathrm{v} = \sqrt{2 \times 10\mathrm{m/s}^2 \times 0.82\mathrm{m}} = 4\ \mathrm{m/s} \approx 14.4\ \mathrm{km/h} \approx 9\ \mathrm{mph}$$

Example 2:

$$\mathrm{v} = \sqrt{2 \times 10\mathrm{m/s}^2 \times 1.23\mathrm{m}} = 5\ \mathrm{m/s} \approx 18\ \mathrm{km/h} \approx 11\ \mathrm{mph}$$

Appendix 2. Equations and Worksheets for Calculating Clearance Requirements

A.2.1. Equations for Calculating Clearance Requirements

$C_p =$	FF	$+$	DD	$+ x_W + CM$
Energy absorbing lanyards	$H_{DA} + L_y$	$+$	$x_{PEA} + x_L$	$+ x_W + CM$
Self-retracting devices	$H_{DA} + L_y + FF_A$		$x_{PEA} + x_L$	
Backup systems	$H_{DA} + L_y + FF_A$		$x_R + x_{PEA} + x_L$	

A.2.2. Energy absorbing lanyard worksheet

Height of D-ring relative to connection (H_{DA})	______
Lanyard length (L_y)	______
Lanyard stretch (x_L)	______
Energy absorber deployment (x_{PEA})	______
Stretch-out (x_W)	______
+ Clearance Margin (CM)	______
Required clearance below platform (C_P)	

A.2.3. Self-retracting device worksheets

Height of D-ring relative to connection (H_{DA})	______
Lanyard length (L_y)	______
Activation distance (FF_A)	______
Energy absorber deployment (x_{PEA})	______
Lanyard stretch (x_L)	______
Stretch-out (x_W)	______
+ Clearance Margin (CM)	______
Required clearance below platform (C_P)	

	______
Height of D-ring relative to connection (H_{DA})	______
Lanyard length (L_y)	______
Arrest distance (AD)	______
Stretch-out (x_W)	______
+ Clearance Margin (CM)	______
Required clearance below platform (C_P)	

A.2.4. Backup system worksheet

Height of D-ring relative to connection (H_{DA})	______
Lanyard length (L_y)	______
Activation distance (FF_A)	______
Rope stretch (x_R)	______
Lanyard stretch (x_L)	______
Energy absorber deployment (x_{PEA})	______
Stretch-out (x_W)	______
+ Clearance Margin (CM)	______
Required clearance below platform (C_P)	

Appendix 3. New Defined Terms

A.3.1. **Activation distance** (FF_A). The increase in the length of a fall protection system before the fall protection applies appreciable force to arrest a fall.

A.3.2. **Arrest distance** (AD). The vertical distance traveled after initial interaction with a fall protection system. This distance is the sum of **activation distance** and **deceleration distance**.

A.3.3. **Deceleration distance** (DD). The vertical distance traveled during the application of force to arrest a fall.

A.3.4. **Free fall**. The act of falling before the application of forces to arrest the fall.

A.3.5. **Free fall distance** (FF). The vertical distance traveled before the application of forces to arrest a fall.

A.3.6. **Free fall potential** (FF_L). The vertical distance traveled prior to interaction with a fall protection system.

A.3.7. **Stretch-out** (x_W). Extension of the worker's body, with reference to their D-ring attachment, after a fall.

A.3.8. **Swing fall**. A pendulum-like motion that occurs during and/or after free fall.

A.3.9. **Swing fall distance** (SFD). The vertical distance traveled between the onset of and the lowest point of a swing fall.

A.3.10. **Total Fall distance** (TFD). The total vertical distance traveled from the onset of and the lowest point of a fall, with reference to a worker's D-ring attachment to a fall protection system.