CLEARANCE REQUIREMENT GUIDELINES



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Table of Contents:

1. Purpose, Scope, and Exceptions	3
2. Total Fall Distance	3
3. Free Fall Distance Factors	4
4. Deceleration Distance Factors	5
5. Additional Clearance Requirement Factors	6
6. Calculating Required Clearance	7
7. Clearance of Energy Absorbing Lanyards	8
8. Clearance of Self-retracting Devices	10
9. Clearance of Backup Systems	12
Appendix 1. Swing Fall Information	15
Appendix 2. Equations and Worksheets for Calculating Clearance Requirements	17

Notes for Use:

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

Use of the word 'shall' denotes a mandatory requirement.

Use 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.

Visit https://sprat.org for the most recent standards versions, supporting documentation, and news. Visit SPRAT's YouTube Channel for a video series supplementing these guidelines.

1. Purpose, Scope, and Exceptions

- 1.1. Purpose
 - 1.1.1. The purpose of this document is to provide the resources to estimate and calculate clearance requirements of *rope access systems* and other *fall protection systems*.
 - 1.1.2. This document is intended to be used with manufacturer instructions during work planning.
 - 1.1.2.1. Employers should determine appropriate personnel to perform clearance requirement calculations.
 - 1.1.2.2. All affected personnel should:
 - 1.1.2.2.1. Have an awareness of factors that contribute to clearance requirements.
 - 1.1.2.2.2. Use *fall protection systems* in a manner to minimize *free fall distance* and clearance requirements.
 - 1.1.2.2.3. Recognize when available clearance is less than the calculated clearance requirement.
- 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 can contact *fall protection systems* during a fall event.
 - 1.3.1.3. Calculating anchorage system strength or energy capacity requirements of fall protection systems.
 - 1.3.1.4. 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 an individual using a personal *fall protection system* can consist of three phases:
 - 2.1.1. *Free fall*, during which a falling individual accelerates due to the forces of gravity, unimpeded by forces of the *fall protection system*.
 - 2.1.2. *Swing fall*, during which a falling individual experiences a pendulum or swinging effect.
 - 2.1.2.1. A swing fall can 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 individual is stopped by the *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 Figure 1.

FIGURE 1 COMPONENTS OF TOTAL FALL DISTANCE

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

TFD = FF + SFD + 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 relative harness attachment height (H_{DA}) in relation to its connection to an *anchorage* or a *rope system*, the connection length (L_v), and additional system slack (S_A).
 - 3.1.3. *Free fall potential* is the sum of these variables, as depicted in Figure 2.



- 3.1.4. Relative harness attachment height (H_{DA})
 - 3.1.4.1. The relative harness attachment height (H_{DA}) is the vertical distance between the harness attachment and its connection via components (e.g., *lanyard*) to an *anchorage system* or *rope system*.
 - 3.1.4.1.1. This value (H_{DA}) is positive if the harness attachment is above that connection.
 - 3.1.4.1.2. This value (H_{DA}) is negative if the harness attachment is below that connection.
- 3.1.5. Connection length (L_y)
 - 3.1.5.1. The connection length (L_y) is the total length of all components (e.g., carabiners, energy absorbers, *lanyards*) connecting a harness attachment to an *anchorage system* or *rope system*.
- 3.1.6. Additional system slack (S_A)
 - 3.1.6.1. Additional system slack (S_A) can arise from several 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 (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 can 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. Obstructions
 - 3.3.1. When the harness attachment of the individual is not on the same approximate *fall line* as the *anchorage*, the *free fall distance* can be reduced.
 - 3.3.2. If the *fall protection system* can encounter an obstruction during *free fall*, the geometry of the anchorage location, individual, and any possible obstructions, should be analyzed to determine the *free fall distance*.
 - 3.3.2.1. A common example of this scenario is when an *anchorage* is selected away from an exposed edge.
 - 3.3.3. Clearance requirement examples in this document assume zero horizontal distance between the *anchorage* and the individual.

4. Deceleration Distance Factors

Mass

- 4.1. Personal energy absorber deployment (x_{PEA})
 - 4.1.1. If the average deployment force of the personal energy absorber and an individual's weight are known, deployment of an energy absorber for a given height can be calculated by the equation shown in Figure 3.

FIGURE 3 CALCULATING ENERGY ABSORBER DEPLOYMENT			
Porconal onergy absorber deployment (x)	_	Weight (W) \times Free fall distance (FF)	
Personal energy absorber deployment (x_{PEA})		Average deployment force (F_{CLR}) – Weight (W)	
x_{PEA}	=	$\frac{W \times FF}{F_{CLR} - W}$	

- 4.1.1.1. As average deployment force values published on equipment can be a maximum allowable value, any published value should be confirmed by the manufacturer prior to using 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 can provide data that provides energy absorber deployment distance as a function of an individual's weight, which can 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 MASS AND FREE FALL DISTANCE

Free Fall Distance	60 kg (132 lb)	100 kg (220 lb)	141 kg (310 lb)	Energy Absorber Deployment
0.3 m (1 ft)	7 cm (2 in)	14 cm (5 in)	24 cm (9 in)	120
0.6 m (2 ft)	14 cm (6 in)	28 cm (11 in)	48 cm (19 in)	100 -
0.9 m (3 ft)	21 cm (8 in)	41 cm (16 in)	71 cm (28 in)	80 (F)
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)*	40 - 100 kg (220 lbs)
2.1 m (7 ft)	49 cm (19 in)	96 cm (38 in)	100 cm (39 in)*	20 - 141 kg (310 lbs)
2.4 m (8 ft)	56 cm (22 in)	100 cm (39 in)*	100 cm (39 in)*	Free Fall distance (m)
2.7 m (9 ft)	63 cm (25 in)	100 cm (39 in)*	100 cm (39 in)*	0 1 2 3 4
*Ded fant i				

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

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 can be calculated through modeling.
 - 4.2.3. Alternatively, rope stretch can be estimated by measuring the stretch of a rope under the user's weight (x_{RW}), multiplying that value by the average deployment force of the energy absorber (F_{CLR}), and dividing by the user's weight (W), as depicted by the equation in Figure 5.

FIGURE	5	ESTIMATING	ROPE	STRETCH
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Rope stretch (x_R)	=	Stretch under user weight $(x_{RW}) \times$ Average deployment force (F_{CLR}) Weight (W)	
		weight (w)	

- 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. Low elongation rope: 10%
 - 4.2.4.2. High elongation rope: 35%
- 4.3. Combining *deceleration distance* factors
 - 4.3.1. All *deceleration distance* factors dissipate 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. Additional Clearance Requirement 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 can 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 individual.
 - 5.1.1.2.1. Clearance requirement examples in this document assume an appropriately fitted harness.
 - 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* factors.
 - 5.1.2. Body stretch-out
 - 5.1.2.1. During a fall, an individual's body will straighten and rotate until supported by the selected harness attachment to the *fall protection system*, which can 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 individual, 0.45 m (1.5 ft) for dorsal attachments, 0 m (0 ft) for sternal attachments.
 - 5.1.2.2.2. For a kneeling individual 0.75 m (2.5 ft) for dorsal attachments, 0.3 m (1 ft) for sternal attachments.
 - 5.1.2.2.3. For a prone individual 1.2 m (4 ft) for dorsal attachments, 0.75 m (2.5 ft) for sternal attachments.
 - 5.1.2.3. If the harness attachment cannot be ensured for a given fall, the dorsal attachment should be used as a reference in calculations.
- Version 25A Board and SOC Approved January 2025

- 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. Variability in the height of individuals using the *fall protection systems*.
 - 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 can be reduced as:
 - 5.2.3.1. A fall event is better modeled during clearance calculations.
 - 5.2.3.2. Other controls in rope access and work-at-height 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* can 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 Figure 6.



6.3. Assuming no *swing fall distance* and expressing *free fall distance* as a sum of its factors allows for the expressions in Figure 7 to be derived.

FIGURE 7 CALCULATING CLEARANCE WITH SEPARATED FREE FALL DISTANCE COMPONENTS

Free fall distance (FF)	{	Free fall potential (FF_L) Activation distance (FF_A) Deceleration distance (DD)	}	Arrest distance (AD)
		Stretch-out (x _W) + Clearance margin (CM)		
		Required clearance below platform (C_P)		
		$C_p = FF + DD + x_W + CM$ $C_p = FF_L + FF_A + DD + x_W + CM$		
		$C_p = FF_L + AD + x_W + CM$		

- 6.4. If the available clearance for a given work location is lower than the calculated required clearance, consideration should be given for:
 - 6.4.1. A more appropriate *fall protection system*.
 - 6.4.2. 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 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 8.

7.4. Final equations

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

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



FIGURE 8 CLEARANCE COMPONENTS OF ENERGY ABSORBING LANYARDS

- 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. An individual is standing on a platform and is attached to an *anchorage* 0.6 m (2 ft) above the harness attachment 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?

Relative harness attachment height (H_{DA})	-0.6 m	-2 ft
Connection length (L_y)	1.8 m	6 ft
Energy absorber deployment (x_{PEA})	1 m	3.5 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)	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) individual?

	Relative harness attachment height (H_{DA})	-0.6 m	-2 ft
	Connection length (L_y)	1.8 m	6 ft
	Energy absorber deployment (x_{PEA})	0.55 m	1.8 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)	2.65 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 individual attaches the energy absorbing *lanyard* to the height of the platform, which is located 1.5 m (5 ft) below their harness attachment. Using the energy absorber from Figure 4, what is the clearance requirement below the platform for a 100 kg (220 lb) individual? Is there any additional concern from this configuration?

Relative harness attachment height (H_{DA})	1.5 m	5 ft
Connection length (L_y)	1.8 m	6 ft
Energy absorber deployment (x_{PEA})	1 m	3.5 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)	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 individual.

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*:

$$FF = H_{DA} + L_{\nu} + FF_A$$

- 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 dependent 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 individual's harness attachment 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 can 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 can be written as:

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

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

8.3.2. If *arrest distance* is available from the manufacturer, the equation can 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. An individual 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

- 8.4.1. Example 2 Overhead self-retracting device: kneeling or crouching individual
 - 8.4.1.1. The individual from Example 1 kneels on the platform to complete a task. Assuming all other variables from Example 1 are the same, what is the clearance requirement now?

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 3 Self-retracting device attached below harness attachment
 - 8.4.2.1. A 141 kg (310 lb) individual 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 harness attachment. 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?

Relative harness attachment height (H_{DA})	0.45 m	1.5 ft
Connection 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:

$$FF = H_{DA} + L_{\gamma} + FF_A$$

- 9.1.2. Activation distance for backup systems is dependent on the backup device, and can 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 can 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* using manual *backup devices* and rope *lanyards* can 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 9.



FIGURE 9 CLEARANCE COMPONENTS OF BACKUP SYSTEMS

9.4. Final equations

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

12 Table of Contents

- 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 m (49 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's sternal attachment.
 - 9.5.1.3. The *lanyard*, which incorporates a dynamic rope, connecting the *backup device* to the rope access technician's sternal attachment 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 0.15 m (0.5 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 0.9 m (3 ft), and the dynamic rope *lanyard* is calculated to elongate 0.3 m (1 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?

Relative harness attachment height (H_{DA})	-0.3 m	-1 ft
Connection length (L_y)	0.6 m	2 ft
Activation distance (FF_A)	0.15 m	0.5 ft
Rope Stretch (x_R)	0.9 m	3 ft
Energy absorber deployment (x_{PEA})	0 m	0 ft
Lanyard stretch (x_L)	0.3 m	1 ft
Stretch-out (x_W)	0.3 m	1 ft
+ Clearance Margin (CM)	0.6 m	2 ft
Required clearance below platform (C_P)	2.55 m	8.5 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 m (50 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's sternal attachment.
- 9.5.2.3. The *lanyard*, which incorporates an energy absorber, connecting the *backup device* to the rope access technician's sternal attachment is 0.6 m (2 ft) long.
- 9.5.2.4. The ropes in use have a stretch of 5.8% 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 predicts that the energy absorber will deploy 0.15 m (0.5 ft).
- 9.5.2.7. Harness *stretch-out* is 0.3 m (1 ft).
- 9.5.2.8. How much clearance below the rope access technician is required?

Relative harness attachment height (H_{DA})	-0.3 m	-1 ft
Connection length (L_y)	0.6 m	2 ft
Activation distance (FF_A)	0.3 m	1 ft
Rope Stretch (x_R)	0.9 m	3 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)	2.55 m	8.5 ft

9.5.3. Example 3 – Low backup device

- 9.5.3.1. The rope access technician from Example 2 has their *backup device* 0.3 m (1 ft) below their sternal attachment when the main system fails.
- 9.5.3.2. Energy balance analysis predicts that the energy absorber will deploy 0.45 m (1.5 ft).
- 9.5.3.3. All other variables from Example 2 are the same.
- 9.5.3.4. How much clearance below the rope access technician is required?

Relative harness attachment height (H_{DA})	0.3 m	1 ft
Connection length (L_y)	0.6 m	2 ft
Activation distance (FF_A)	0.3 m	1 ft
Rope Stretch (x_R)	0.9 m	3 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)	3.45 m	11.5 ft

9.5.4. Example 4 – More rope in use

9.5.4.1. The rope access technician from Example 2 descends until there is 76 m (249 ft) above their *backup device*.

- 9.5.4.2. Energy balance analysis predicts that the energy absorber will not deploy, and the rope will stretch 4.4 m (14.5 ft).
- 9.5.4.3. All other variables from Example 2 are the same.
- 9.5.4.4. How much clearance below the rope access technician is required?

Relative harness attachment height (H_{DA})	-0.3 m	-1 ft
Connection length (L_y)	0.6 m	2 ft
Activation distance (FF_A)	0.3 m	1 ft
Rope Stretch (x_R)	4.4 m	14.5 ft
Energy absorber deployment (x_{PEA})	0 m	0 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)	5.9 m	19.5ft

9.5.1. Example 5 – High elongation rope

- 9.5.1.1. The rope from Example 2 is substituted with a rope with higher elongation of 35% at the average deployment force of the energy absorber.
- 9.5.1.2. Energy balance analysis predicts that the energy absorber will not deploy, and the rope will now stretch 5.3 m (17.4 ft).
- 9.5.1.3. All other variables from Example 3 are the same.
- 9.5.1.4. How much clearance below the rope access technician is required?

Relative harness attachment height (H_{DA})	-0.3 m	-1 ft
Connection length (L_y)	0.6 m	2 ft
Activation distance (FF_A)	0.3 m	1 ft
Rope Stretch (x_R)	5.3 m	17.4 ft
Energy absorber deployment (x_{PEA})	0 m	0 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)	6.8 m	22.4 ft

Appendix 1. Swing Fall Information

A.1.1. Swing Falls

- A.1.1.1. If a falling individual 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* can be added as a factor of *free fall distance* when calculating clearance requirements.
- A.1.1.3. Swing fall distance can increase activation distance of some fall arrest systems.
- A.1.1.4. 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) can be calculated if two of any of these variables are known:
 - A.1.2.1.1. Horizontal distance (d) between the individual or load to the connection to an *anchorage* or rope.
 - A.1.2.1.2. Vertical distance (H_B) of the harness attachment below the connection to an *anchorage* or rope.
 - A.1.2.1.3. Connection length (L_{y}) of connection of the individual to the *anchorage* or rope.
 - A.1.2.1.4. Pendulum angle (θ) of the connection (degrees from vertical).
 - A.1.2.2. A schematic depicting these variables in a swing fall is shown in Figure 10.

FIGURE 10 SWING FALL VARIABLES



A.1.2.3. The relation of swing fall distance to these variables is shown in Figure 11.

FIGURE 11 EQUATIONS FOR CALCULATING SWING FALL DISTANCE

$$SFD = L_y - H_B \qquad SFD = \frac{H_B}{\cos \theta - 1}$$
$$SFD = L_y \times (1 - \cos \theta) \qquad SFD = L_y - \sqrt{L_y^2 - d^2}$$
$$SFD = \sqrt{H_{DA}^2 + d^2} \pm H_{DA} \qquad SFD = \frac{d}{\sin \theta} - \frac{d}{\tan \theta}$$

- A.1.3. Swing Fall Distance Examples
 - A.1.3.1. Example 1 Swing fall distance of a rope-to-rope transfer
 - A.1.3.1.1. 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.1.3.1.2. The technician is located a vertical distance of 2 m (6.6 ft) below the *anchorages* of the rope-to-rope transfer.
 - A.1.3.1.3. The rope access technician inexplicably removed their *backup device* from their descent side.
 - A.1.3.1.4. If the main system from the descent side were to fail at this time, what would be the swing fall distance?

$$SFD = \sqrt{H_{DA}{}^2 + d^2} + H_{DA}$$
$$SFD = \sqrt{4 m^2 + 4 m^2} - 2 m = 0.82m$$

- A.1.3.2. Example 2 Swing fall distance of a shallower rope to rope transfer
- A.1.3.3. 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.1.3.4. If the main system from the descent side were to fail at this time, what would be the swing fall distance?

$$SFD = \sqrt{H_{DA}{}^2 + d^2} + H_{DA}$$
$$SFD = \sqrt{4 m^2 + 1 m^2} - 1 m = 1.23m$$

- A.1.3.5. Bonus Example Velocity of a swing fall
- A.1.3.6. 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?

$$\label{eq:v} \begin{split} v &= \sqrt{2gh} \end{split}$$
 Example 1:
$$v &= \sqrt{2\times 10m/s^2\times 0.82m} = 4 \ m/s \approx 14.4 \ km/h \approx 9 \ mph \end{split}$$
 Example 2:
$$v &= \sqrt{2\times 10m/s^2\times 1.23m} = 5 \ m/s \approx 18 \ km/h \approx 11 \ mph \end{split}$$

Appendix 2. Equations and Worksheets for Calculating Clearance Requirements

A.Z.I. Equations for Calculating Clearance Requirement	A.2.1.	Equations	for Calc	ulating (Clearance	Requiremen	its
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$C_p =$	FF	+	DD	$+ x_W + CM$
Energy absorbing lanyards	$H_{DA} + L_y$		$x_{PEA} + x_L$	
Self-retracting devices	$H_{DA} + L_y + FF_A$	+	$x_{PEA} + x_L$	$+ x_W + CM$
Backup systems	$H_{DA} + L_y + FF_A$		$x_R + x_{PEA} + x_L$	

A.2.2. Energy absorbing lanyard worksheet

Relative harness attachment height (H_{DA})
Connection 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

	Relative harness attachment height (H_{DA})
	Connection length (L_y)
Relative harness attachment height (H_{DA})	Activation distance (FF_A)
Connection length (L_y)	Energy absorber deployment (x_{PEA})
Arrest distance (AD)	Lanyard stretch (x_L)
Stretch-out (x_W)	Stretch-out (x_W)
+ Clearance margin (CM)	+ Clearance margin (CM)
Required clearance below platform (C_P)	Required clearance below platform (C_P)

A.2.4. Backup system worksheet

Relative harness attachment height (H_{DA})
Connection 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)