



**IRATA International Code of Practice
for Industrial Rope Access
Part 3: Informative Annexes
Annex T: Tensioned Lines Guidance**

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1 SCOPE AND PURPOSE

This Annex is intended to provide informative guidance and to raise awareness of the potential risks and hazards associated with using tensioned lines in industrial rope access. It also provides information that may be applied when delivering the training and assessment of tensioned lines, in accordance with the IRATA 'Training, Assessment and Certification Scheme' (TACS) [TC-101], Section 6.4.12 - 'Tensioned Lines'.

DISCLAIMER: *The information and illustrations within this Annex are provided for informative purposes only. This document is not intended to replace appropriate training, planning, competency and job specific risk assessments.*

2 INTRODUCTION

Tensioned lines are ropes rigged between two sets of anchors (extremity or end anchors) to facilitate horizontal or diagonal movement, or to provide variable/intermediate anchor points for the working and backup lines, thereby enabling access to areas where there may be no other suitable or available option. 'Horizontal' tensioned lines are ropes tensioned between suitable anchors that are at the same or similar elevation, and 'Diagonal' tensioned lines are a set of ropes tensioned between suitable anchors which are at different elevations at each end.

Dependant on the country, region or state, tensioned lines may be referred to as Tyrolean Traverse Lines (Tyroleans), Tensioned Ropes, Highlines, Zip-Lines, Telphers and Tram Ways.

Currently no standard refers specifically to the industrial application of tensioned lines, or the application of descenders or other rope access equipment in the creation of a tensioned lines system. However, existing standards and requirements may be applicable to each component and it's use.

Using a descender or other rope access equipment as an adjustable anchor, or part of the anchor system, may not be included in the equipment's 'Instructions for Use' or 'User Manual'; as such, information regarding the suitability and use of the equipment for this purpose should be sought from the manufacturer.

Note: Tensioned lines (used in industrial rope access) differ from pre-made/off the shelf 'lifelines', as tensioned lines must meet the requirements of the 'Personal Fall Protection Systems' - EN 795 (Type C) regulation.

3 ABBREVIATIONS

MBL	Maximum Breaking Load
PFPE	Personal Fall Protection Equipment
SWL	Safe Working Load
WLL	Working Load Limit

4 APPLICATIONS OF TENSIONED LINES

Note: The applications of tensioned lines are non-exhaustive, however, the images within this Annex demonstrate some possible examples.

4.1 Horizontal and Diagonal Tensioned Lines for Work Positioning

In industrial rope access, where there are potentially no suitable or available anchor points to provide access to the work area, e.g. access to install lights in the middle of an atrium, bridge inspections, working under a ceiling etc, tensioned lines systems are commonly used to provide positioning and variable/intermediate anchor points for the working and backup lines.

4.2 Horizontal Tensioned Lines for Work Positioning (Variable Anchors)

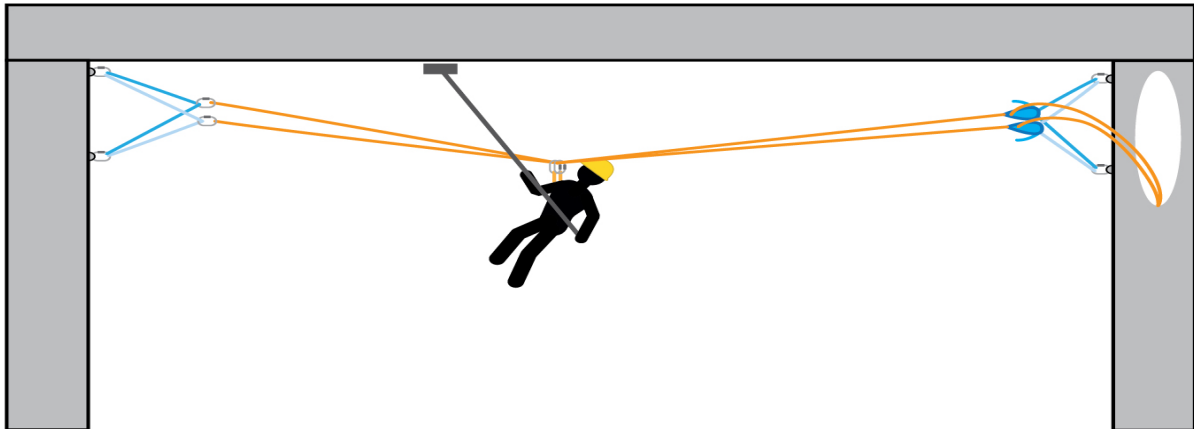


Figure 1: Horizontal Work Positioning - A simple tensioned lines system which has been installed to allow a simple connection by the technician to the system, thereby enabling them to pull themselves along the system to gain access to the working area. This example is rigged releasable to allow the technician to be lowered to an area of safety below (if required).

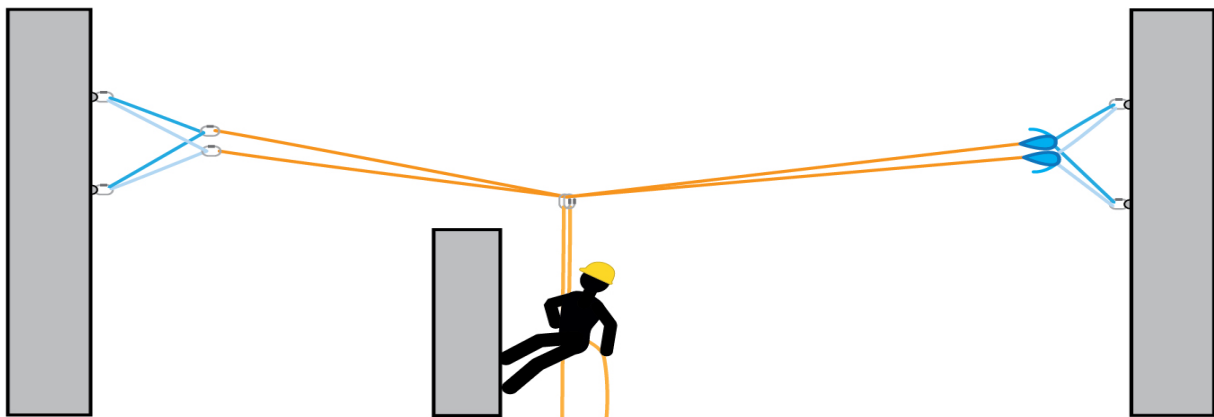


Figure 2: Horizontal with Variable/Intermediate Anchor - A simple tensioned lines system where the anchors are rigged to enable the technician to access the work location. Consideration should be given to the access techniques used to minimise any potential for shock loading. The use of tandem descending devices may be considered.

4.3 Diagonal Tensioned Lines

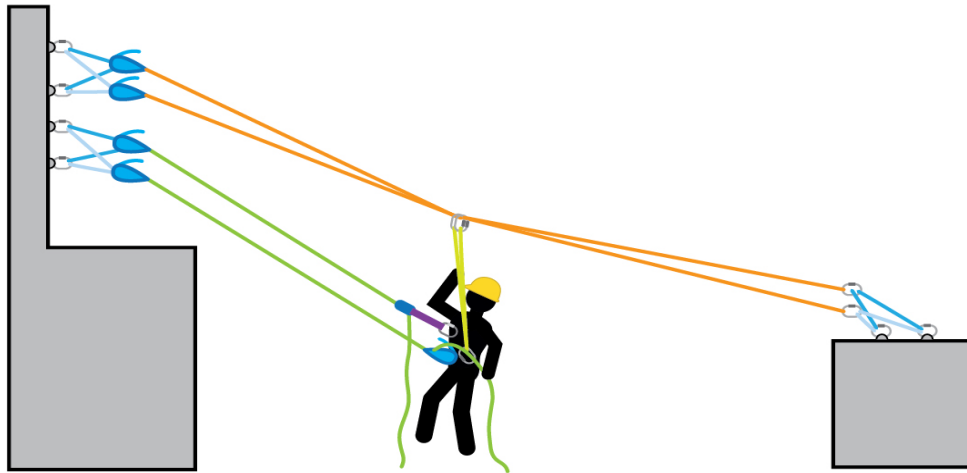


Figure 3: Diagonal Work Positioning – A diagonal tensioned lines system which includes a required control system for ascent and descent of the technician whilst they are attached. This example is rigged releasable to allow the technician to be lowered to an area of safety below (if required).

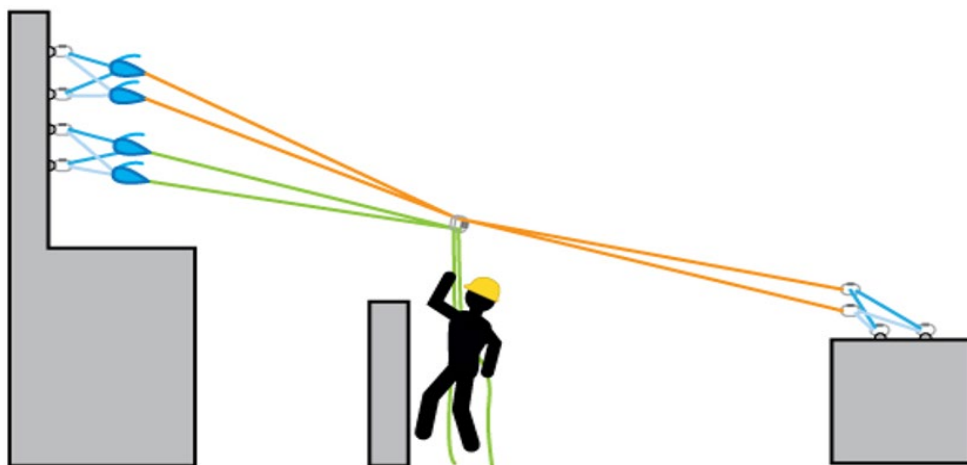


Figure 4: Diagonal with Variable/Intermediate Anchor - A diagonal tensioned lines system where the anchors are rigged to enable the technician to access the work location. Consideration should be given to the equipment and techniques used to position the anchors on the tensioned lines, to maintain the required location. This example is rigged releasable to allow the technician to be lowered to an area of safety below (if required).

4.4 Horizontal Tensioned Lines for Work Restraint

Work restraint (travel restriction) is a technique where Personal Fall Protection Equipment (PFPE) is used to prevent a technician from reaching areas where the risk of a fall from height exists.

Horizontal tensioned lines may be used to provide an anchor for work restraint equipment (e.g. fixed or adjustable lanyards), enabling safe access to the work area, e.g. the edge of a roof. A single suitable connection is acceptable when work restraint techniques and equipment are used correctly, therefore, a single tensioned line may be used as an anchor line for the work restraint of a single technician.

Horizontal tensioned lines used for work restraint should restrain the technician within a safe area where they remain supported by the structure, thereby mitigating against the possibility of a fall. Potential snagging or stretching of the line/lines should be accounted for, especially when using long work restraint lines.

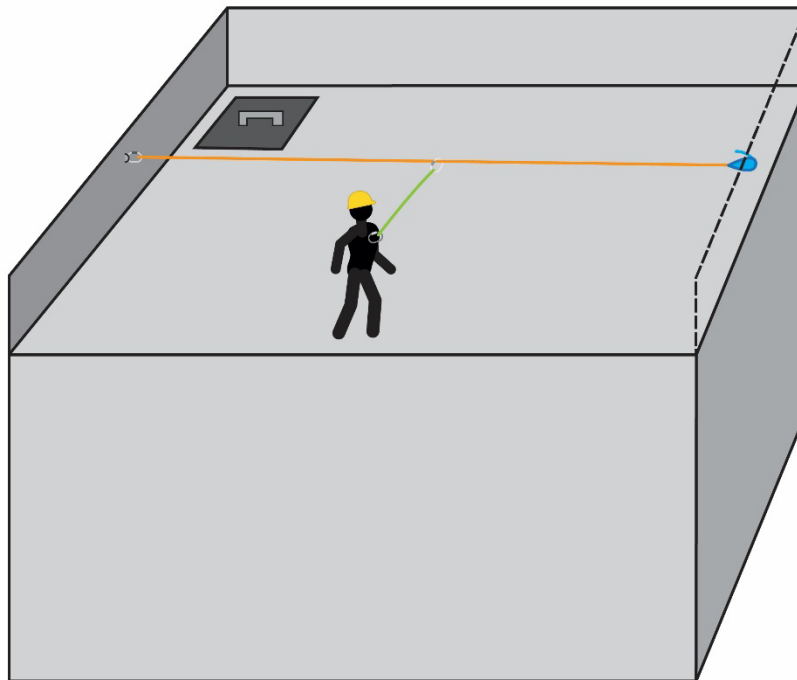


Figure 5: Horizontal Tensioned Lines for Work Restraint - A simple restraint system rigged to prevent the technician from being able to access/fall over an unprotected edge.

Note: The regulations and requirements for acceptable equipment and setup for work restraints may vary dependant on the country, region or state, e.g. manufactured temporary horizontal safety lifeline anchorage (with or without a built-in shock absorber) may be a mandatory requirement.

4.5 Horizontal Tensioned Lines for Fall Arrest

Tensioned lines used as horizontal anchor lines for fall arrest are often referred to as lifelines. Pre-made flexible horizontal lifeline systems or cable ways are available on the market and are classified under the 'Personal Fall Protection Systems' - EN 795 (Type C) regulation. A lifeline is described as a "flexible (cables or synthetic ropes) system that allows the worker to move horizontally along a structure while remaining continuously connected to the fall arrest system." Some of these systems may include a shock absorber to reduce the forces generated during a fall, whilst others require the technician to connect to the system by using fall arrest lanyards.

When ropes are rigged with the intention to be used as lifelines, the created tensioned lines system should be used with fall arrest lanyards, and be rigged at a height that is easy to reach and reduces the distance of a potential fall to a minimum.

With both the pre-made and rope-based systems, the use of appropriate anchors is key (a minimum 15 kN static load required). Some manufacturers have conducted tests on falls (shock loading) on tensioned lines and have published their findings which should be considered when planning and using tensioned lines for fall arrest.

When fall arrest techniques, equipment and systems are used, suitable clearance distances and an appropriate rescue/casualty retrieval plan must be in place. These considerations are often overlooked or neglected. The system should be designed and installed in a manner, that should a fall occur, the technician will not collide with any obstructions below. A rescue plan and fall arrest system should be in place that enables the rescuer(s) to quickly bring the casualty to a place of safety.

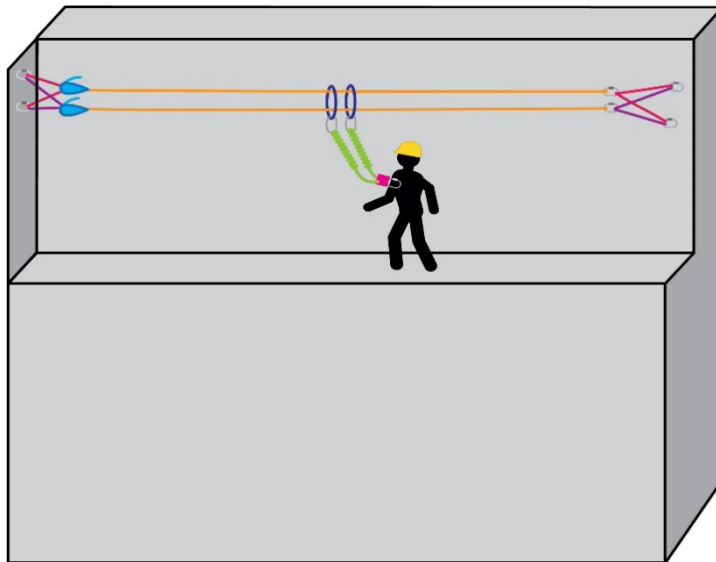


Figure 6: Horizontal Tensioned Lines for Fall Arrest - A simple fall arrest system rigged above the technician to minimise the potential fall distance. This example utilises twin fall arrest lanyards, where both connectors are attached to both tensioned lines.

The following should be considered when using a tensioned lines system for fall arrest:

- Lifelines/tensioned lines systems **with** an integrated shock absorber should **not** be used with fall arrest lanyards.
- Lifelines/tensioned lines systems **without** an integrated shock absorber **should** be used with fall arrest lanyards.

Note: The regulations and requirements for acceptable equipment and setup for work restraints may vary dependant on the country, region or state, e.g. manufactured temporary horizontal safety lifeline anchorage (with or without a built-in shock absorber) may be a mandatory requirement.

4.6 Horizontal and Diagonal Tensioned Lines for Rescue

A rescue plan may include the use of tensioned lines to retrieve/recover a casualty e.g. using a releasable tension line to lower the casualty to an area of safety or using tensioned lines as 'Tram Ways/Zip-Lines' alongside extra lines to move the casualty along the tensioned lines system.

Such rescues are classified as 'complex' and it is vital that the rescue team are trained and competent in such techniques and are familiar with the rescue plan, and their roles in a rescue situation.

When planning this type of a rescue, rope stretching, snagging and the protection of the ropes and anchors should be considered.

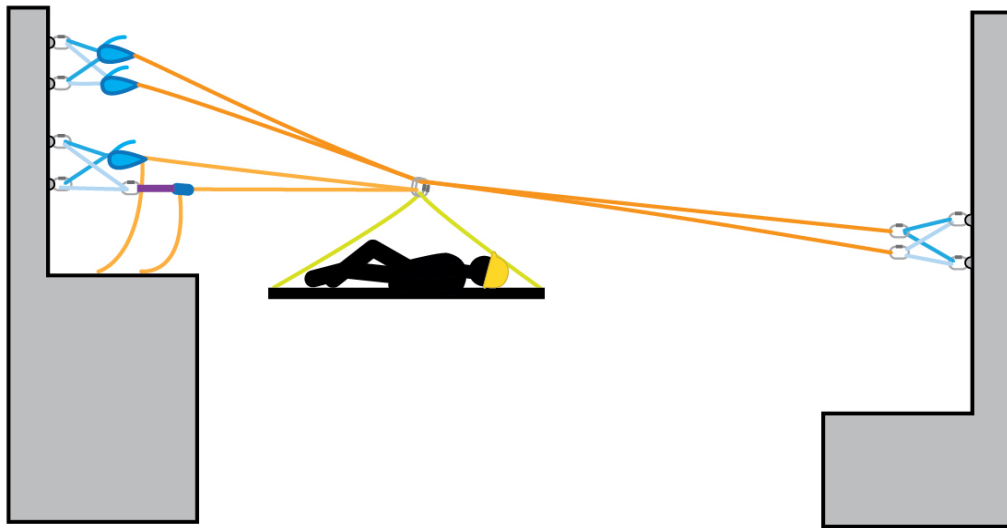


Figure 7: Diagonal Tensioned Lines System for Rescue – A system where the casualty can be raised and lowered on the tensioned lines to adjust their position using gravity.

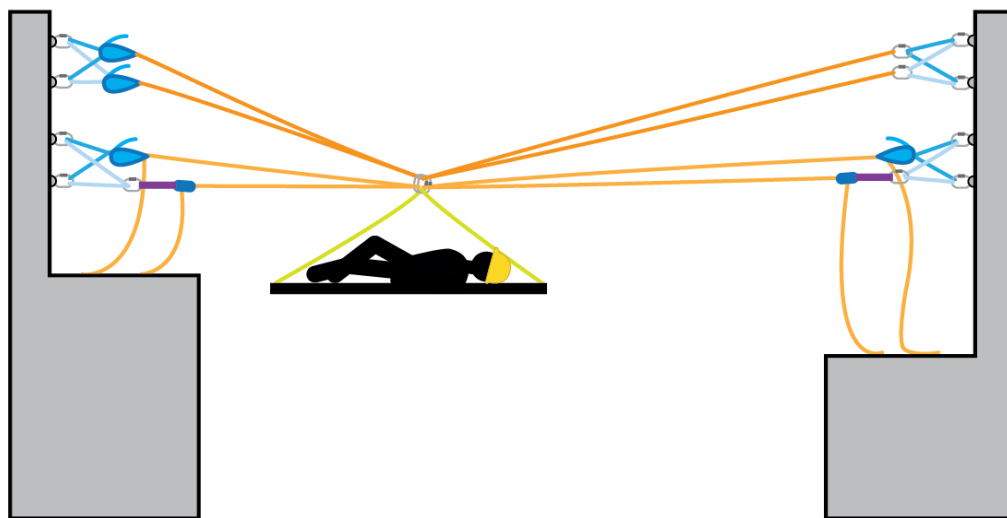


Figure 8: Horizontal Tensioned Lines System for Rescue with Multi-Directional Rigging – A horizontal system which includes hauling that is positioned at both ends to enable multi-directional positioning of the casualty.

Note: See the 'ICOP' [TC-102], 'Annex R: Rescue and Evacuation Planning, and Considerations' for additional rescue information.

4.7 Horizontal and Diagonal Tensioned Lines for Tool and Material Transportation or Positioning

Tensioned lines may be used to move or position tools or materials. The failure of tensioned lines used for this purpose can have severe consequences, e.g. tools or materials may drop causing injury or death. Therefore, the system should be designed, calculated and set-up following the same principles as those used for personnel.

5 RISKS AND HAZARDS

The primary hazard when rigging and using tensioned lines systems is excessive loading of the components by over tensioning, or shock loading the system. Increased loads in the system are inherent due to the higher rigging/loading angles created. The risk of overloading the tensioned lines system is particularly great when it is used as a safety lifeline anchor system for fall arrest.

Technicians commonly over tension the lines to minimise sagging when the system is under tension. However, tests indicate that applying high tension to the lines results in minimal change to the sag, whilst significantly increasing the load on the components of the system.

5.1 Anchor Failure

Understanding the correlation between rigging angles and the loading on the extremity anchors is important when planning and installing tensioned lines. Tensioning the lines results in a permanent load on the anchors (and all the other components of the system), and when combined with the additional weight of the technician (plus equipment and tools), and the high angle loading, this may result in unacceptably high loads at the extremity anchors. Additionally, the potential loads on the extremity anchors when subject to a fall arrest will be significantly higher than in an un-tensioned system.

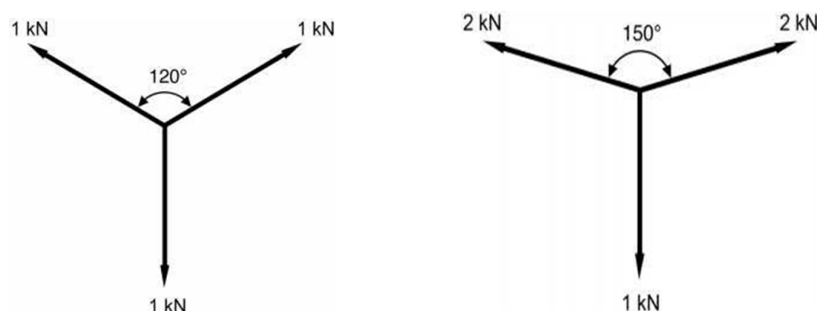
When descending devices are used for tensioning the system, consideration should be given to the Working Load Limit (WLL) and the determined Safe Working Load (SWL) of the device(s), to ensure that the loads do not exceed these limits.

Descenders may not be certified as anchor devices, however, they must still meet the requirements of the applicable standard(s). Some manufacturers have conducted tests on descenders that have been used as adjustable anchors, and have published their findings which may highlight foreseeable forces on the devices, such as different loading capacities and the applications of the devices. During testing, loads have been shown to stay below the damage threshold value. However, it is important for the person(s) designing and using the tensioned lines system to familiarise themselves with the test loading values, test scenarios, and to ensure that these are not exceeded during operations.

Equal load sharing between the anchors at each end of the tensioned lines, and across the anchor lines, is vital to avoid exceeding the WLL of the individual anchors and other components to minimise the risk of failure.

Anchor failure can be catastrophic in any situation. Due to the complexity involved in calculating potential loads when using a tensioned lines system, it is recommended that this type of system is only used when the anchors are “unquestionably reliable”, and the system is installed by a competent person(s).

The illustrations below are intended to demonstrate and raise awareness of the relationship between loading angles and the loading on the anchors, i.e. an increase in the loading angle, increases the loading on the anchors and other components of the tensioned lines system.



The above illustrations are based on a scenario where the lines do not stretch, and the loading angle remains the same. It is important to note that ropes such as low stretch ‘kernmantle’ stretch under loading, and therefore the loading angles may decrease as the downward loading on the tensioned lines increases. The illustrations should be used as a guide when calculating loading on the anchor lines and other components of a tensioned lines system.

5.2 Equipment Failure

- **Descending devices** are effective and easy to use for tensioning lines as they maintain high tension and are easy to release when needed, e.g. to lower a casualty or when the tensioned lines are no longer needed. As descenders are designed for one or two-person loads (e.g. in case of a rescue), the loading on them when used in tensioned lines systems may exceed normal working loads, resulting in physical damage or loss in functionality of the descender, for example a descender is required to be releasable in the event of a rescue but becomes stuck.
- **Ascending devices, rope grabs and pulleys** may be used to provide a mechanical advantage when tensioning lines. The SWL of these devices may be exceeded if they are not used correctly and in accordance with the manufacturer's instructions. Improper use of devices must be avoided; whilst this may not result in equipment failure, it may still cause damage to the device itself or the anchor lines e.g. an overloaded toothed ascender may cause damage to the rope.

5.3 Rope Failure

The SWL of the ropes should be considered when designing, calculating loads, rigging and using tensioned lines systems.

Note: The highest possible loading the system may be subjected to (worst case scenario) should be considered when planning and using tensioned lines systems, e.g. two-person loading, shock loading etc.

Toothed devices may start damaging the outer sheath of a rope when the loading is approximately 4kN - 6.5kN (depending on the type, diameter, age, condition etc. of the rope and the device). Depending on their position and grip on a rope, a single person can pull 20-40 Kg with a solid stance on the ground. This, combined with a 9:1 pulley system, may result in the toothed device damaging the outer sheath of the rope.

Both the path of the tensioned lines and the sag in the rope when loaded should be considered during planning and rigging to avoid sharp edges, abrasions, hot surfaces and any other hazards to the lines or the technicians. If contact between the lines and a hazard is unavoidable, appropriate rope protection should be considered and implemented.

Calculating the exact amount of sag in tensioned lines is only possible in theoretical scenarios due to multiple factors that contribute to sag in a real-life scenario. However, a 1m sag over a 10m long line (span), under a 100Kg load, is an approximation that can be used to estimate sag as illustrated below:

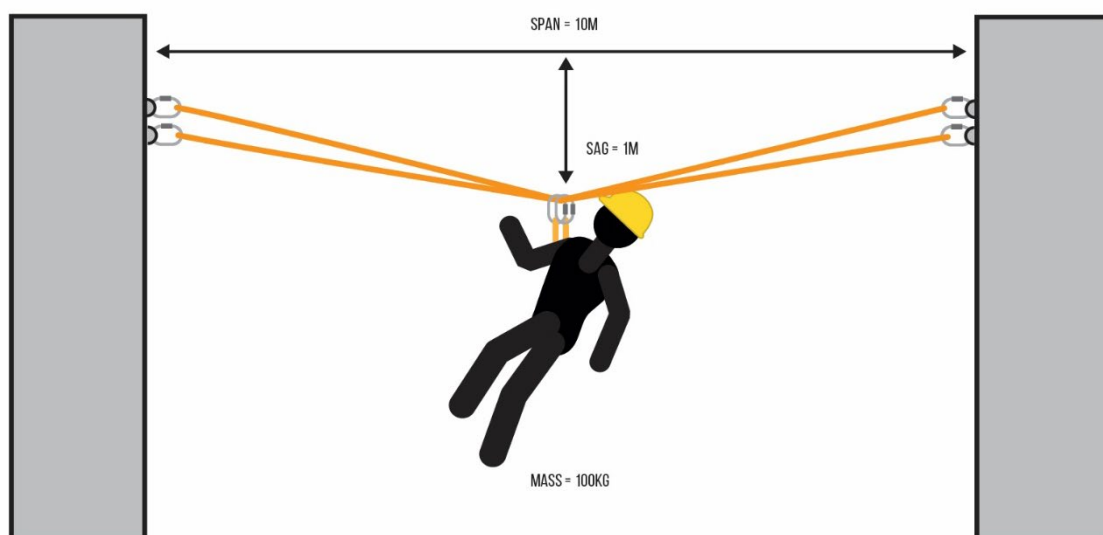


Figure 9: This illustration provides a guide to determining sag in a horizontal tensioned lines system.

Factors that affect sag in a tensioned lines system include the:

- length of the tensioned lines (span) e.g. longer lines result in more sag;
- number of lines in the system e.g. 3 lines instead of 2 lines will stretch less under the same load, therefore the sag will be reduced;
- weight of the load e.g. a heavier load will result in more sag;
- amount of tension in the system; and
- type, make and age of the ropes being used.

Note: The above list is non-exhaustive.

Excessive slack in the connecting lanyards between the tensioned lines and the technician's harness, present a substantial risk when used for work positioning or fall arrest. Dynamic or shock loading tensioned lines has the potential to overload any or all components of the system, and may result in system failure, or make it difficult or impossible to release the system by operating the descending device, as the device has become seized.

When designing and using a tensioned line system, consideration should be given to the potential for the system to be used/misused by multiple technicians simultaneously. When using or relying on the same tensioned lines system there is a risk of overloading the anchors, and/or any component, leading to system failure.

The risk of tensioned lines being damaged by a third party is often overlooked, and mitigating factors are not considered. Damage to the lines may result from:

- spilling harmful chemicals on the lines;
- unforeseen crane operations or movement;
- tools or other machinery being used in close proximity;
- high temperature objects in contact with or in close proximity of the lines; and/or
- the lines being tampered with.

6 CONTROLLING RISKS AND HAZARDS

The following non-exhaustive list includes actions and considerations which may assist in controlling the hazards associated with using tensioned lines systems:

- conducting a comprehensive risk assessment;
- appropriate planning, e.g. anchor selection, positioning, rescue provision etc.;
- competent design and installation of the system;
- appropriate testing and inspection of equipment and setup, e.g. anchor bolts etc.;
- suitable onsite management and supervision;
- appropriate checking of the system due to complexity;
- awareness of the work environment; and
- awareness of human factors that may present risk, e.g. lack of knowledge, deliberate misuse, complacency etc.

Tensioned lines should only be installed by a competent person and should be planned, calculated and adequately risk assessed prior to installation and use. The use of tensioned lines should be supervised with a comprehensive rescue plan in place.

Note: Check relevant local legislations regarding the requirements for the installation and use of tensioned lines and if there is a requirement for a third party to approve such systems in the country or region of use. Some regions have specific requirements regarding the training, use, and installation of fall arrest systems/equipment.

Effective control measures used to reduce the loading on the components of a tensioned lines system to acceptable levels, include sharing the load across the anchor lines or using load sharing rigging.

Shock loading tensioned lines must be avoided. Using two descenders may be considered when tensioned lines are used for work positioning or as an anchor system to prevent shock loading in the event of a main line failure.

The IRATA safe system of work requires the application of the 'principal of double protection', whereby there is an appropriate secondary connection to back up the technician should a single component of the system fail. With a tensioned lines system, the complexity of the rigging and techniques used may increase the potential for error, therefore increasing the importance of ensuring that double protection is implemented within the system.

7 ANCHORS

The introduction of tension into a system applies a load to the anchors before any physical load is suspended, because of this, loads are greater than those which would be applied by simply suspending the load directly from the anchor.

When selecting, fitting and using anchors, the principle of double protection applies and, therefore, at least two anchors should always be used (at each end of the tensioned lines system).

Rope access anchors should be of an adequate strength, bearing in mind the mass of the user including any equipment worn or carried and any additional forces that may occur due to high rigging angles and shock loading.

Note: Anchor strength is critical in tensioned lines systems because of the additional loads applied in these systems.

The recommended combined static strength of anchors should be at least 15 kN, and the loading should be shared between the independent anchors to reduce the likelihood of overloading.

It is important to establish foreseeable angles of loading (consider: multiplier effects caused by increase in angles) and anticipate potential loads when designing and using an anchor system, such as tools, two persons loading and shock loading. This will indicate whether any component of the tensioned lines system is going to be overloaded during operational use or rescue.

Some descenders may slip under certain loading, allowing the rope to slip through, thereby introducing slack into the system and reducing loading angles, which subsequently reduces the loading on the anchors and all other components of the system. This function of the descender may help prevent the tensioned line system from overloading. Check the manufacturers information to confirm if the device can be used in this manner and has the required characteristics.

When using anchor slings to create the anchors, they should be protected at wear points, taking into consideration a change in position when the lines are loaded. Anchor slings (both man-made fibre and wire) should be installed in such a manner so they won't slide in any direction when the tension lines are placed under loading.

Note: Anchor slings made from man-made fibres should have sewn joints and have a minimum static strength of 22 kN. Anchor slings made from wire rope should have a minimum static strength of 15 kN. Additional anchors, other than those used in the tensioned lines systems may be required to facilitate work mate retrieval.

7.1 Descenders

Some equipment manufacturers have carried out testing and published instructions and recommendations on using their descenders for tensioning tensioned lines (see Section 10). Descenders should only be used for tensioning tensioned lines if recommended for such application by the manufacturer.

Users should read the relevant documentation published by the manufacturer. Devices without available information on their use in such a manner either shouldn't be used (in tensioned lines systems) or the manufacturer should be contacted for further information and guidance.

7.2 Anchor Lines

Ropes or anchor lines are subject to increased loads when used in tensioned lines systems. The loads in these systems should be calculated by a competent person taking into consideration the SWL of the rope and the weakening effect of the anchor line terminations or knots, when implementing measures to ensure the system is safe.

Tests show that using a 3:1 mechanical advantage with a maximum of two persons pulling on it is sufficient for tensioning and should not be exceeded. Even this setup will result in constant tension in the system which applies a constant load to the components. This should not be high enough to compromise the safety of the system when it is loaded by the weight of the technician.

Too much sag in the system should be controlled by using either higher anchor points or increasing the number of lines per technician to reduce rope stretch, as opposed to increasing the tension in the system.

Backing up the lines to the anchors, behind the device used for tensioning, may be considered as a failsafe in case of the failure of the tensioning device. However, the suitability and viability of this method should be assessed in accordance with the manufacturer's instructions and take into account the potential loss of the ability to release the system should it be required.

The use of a single tensioned line system is acceptable when it is used for work restraint and the possibility of a fall (shock loading) is eliminated. For all other applications a minimum of 2 ropes are required per technician. When using a twin rope tensioned line system, always share the loading between the lines; never only load a single line.

8 IRATA TRAINING AND ASSESSMENT

The IRATA 'TACS' [TC-101] syllabus (Levels 2 and 3) includes the training and assessment on the theory, application and use of tensioned lines systems. This knowledge is the foundation for their on-site application and should provide sufficient knowledge to the candidates to enable them to set up and use such systems safely outside of the training environment.

Instructors should explain that some devices may slip when subjected to certain loading, which can be advantageous (but not without risk) when used in a tensioned lines system, as they reduce the rigging angles and the loading on the components.

Note: It is also worth noting that this may introduce other hazards e.g. if the device doesn't stop slipping after the overload, and the work is being carried out over water, hot surface etc. than an unconscious user could be lowered into a dangerous environment.

Instructors should emphasise the importance of reading, understanding, and adhering to the manufacturer's instruction(s)/publication(s), or the need to confirm with the manufacturer if the intended use of the device is not covered within these documents.

Assessors should note that only devices that have manufacture's guidance and information on their use in a tensioned lines system should be used for this purpose, and diversion (misuse) from the manufacturer's instructions of use should result in a 'Minor or Major Discrepancy'.

9 POTENTIAL APPLICATIONS, HAZARDS AND CONTROL MEASURES FOR TENSIONED LINES

The table below provides examples of potential applications, and the associated hazards and control measures of tensioned lines systems:

Application	Potential Hazard	Potential Control Measure
Anchor line system used for work positioning	Overloading the anchors, resulting in anchor failure	<ul style="list-style-type: none"> • Appropriate training and supervision of the rope access team • Correct selection of appropriate anchors (min 15kN) • Effective planning • Pre-use checks of the system
Work restraint system used for travel restrictions	The system is set-up or used in a manner that does not prevent the technician from reaching the area where a potential fall can occur <i>(accidental or deliberate misuse)</i>	<ul style="list-style-type: none"> • Using the correct length of fixed lanyards or correct use of adjustable lanyard to avoid areas where falls may occur • Effective planning – consider the stretching and snagging of ropes
Fall arrest lifelines	The anchor is overloaded resulting in anchor failure	<ul style="list-style-type: none"> • Use fall arrest lanyards to reduce the loading on the system if a fall occurs
	Fall arrest lifeline too low resulting in an impact with the ground or a structure in the event of a fall	<ul style="list-style-type: none"> • The tensioned lines should be set at shoulder level or higher to reduce the fall distance • Selection and use of appropriate PFPE which takes clearance distance into consideration
Tensioned lines used for rescues	The tensioning device becomes seized preventing the release of the rope	<ul style="list-style-type: none"> • Check the manufacturer's publication(s) about falls (shock loading) on tensioned lines systems • Avoid overloading the tensioned lines system
Directional guidelines for a technician to descend or ascend via another rope access system	Equipment failure	<ul style="list-style-type: none"> • Back up the lines of the tensioned lines systems to the anchor points
Tensioned lines used for work positioning, fall arrest, or moving tools or materials	Equipment slippage	<ul style="list-style-type: none"> • Use releasable knots in tails, if recommended /permitted by the manufacturer

10 REFERENCES

ICOP [TC-102]:

- 2.7.8.2 Device Lanyards and Anchor Lanyards
- 2.7.8.3 Anchor Slings
- 2.7.8.4 Selection Criteria for Device Lanyards, Anchor Lanyards and Anchor Slings
- 2.7.9 Anchors
- 2.11.2 The Anchor System (Anchors and Anchor Lines)
- Annex L, L.2.6.7 Horizontal Anchor Lines

TACS [TC-101]:

- 6.4.12 Tensioned Lines

11 FURTHER READING

- Skylotec publication: Sirius, Spark and Spark Tactical in Tyrolean Traverses
- Petzl publication: Tensioning a Tyrolean with Maestro, ID, Rig
- ISC Wales publication: Work and Rescue Descender User Manual
- Personal Fall Protection Systems - EN 795 (Type C)