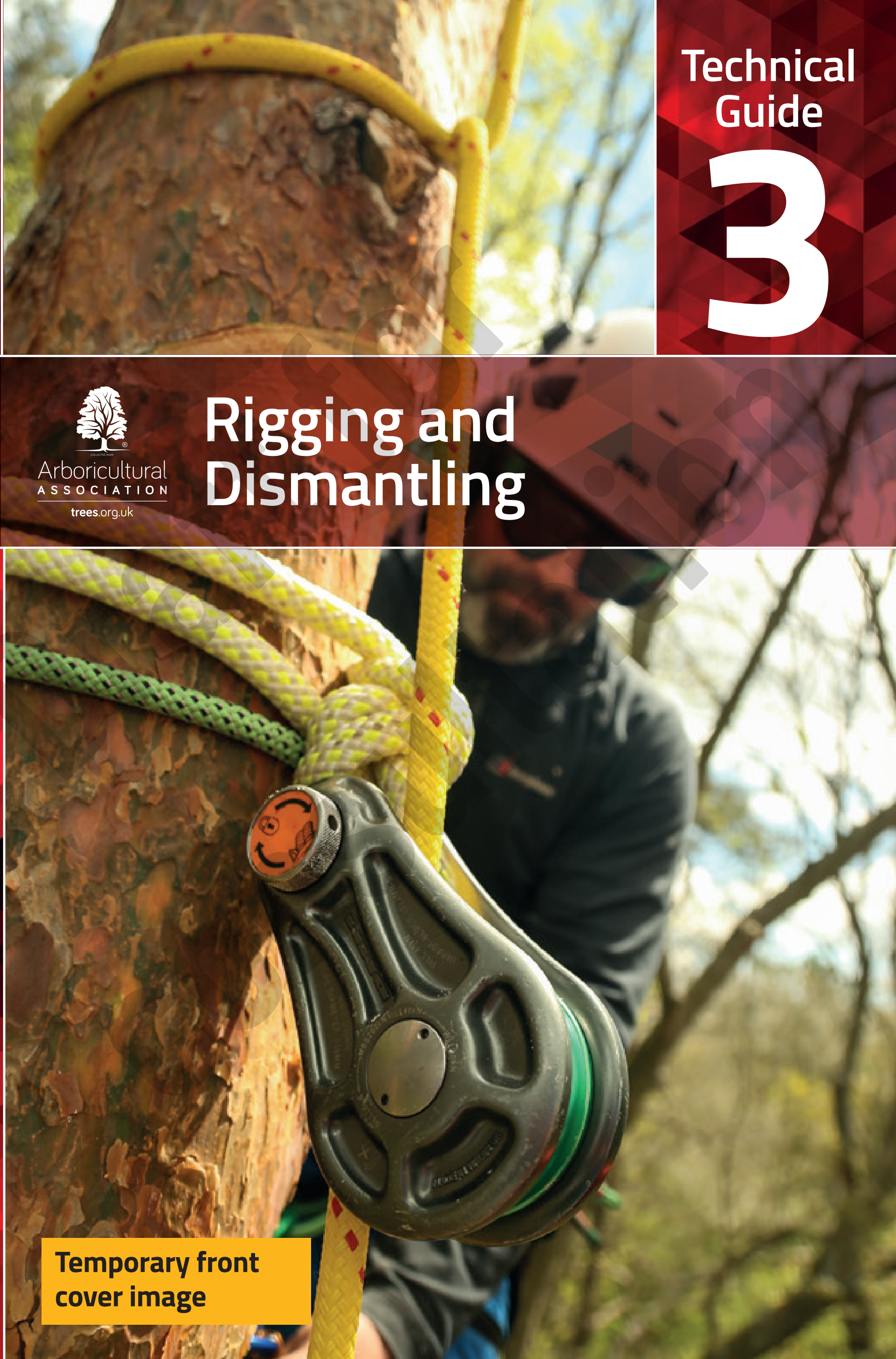
Technical Guide

3

Arboricultural Association

trees.org.uk

Rigging and Dismantling



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Published in the UK by
Arboricultural Association,
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First published in XXXXXX 2021.
ISBN XXX-0-XXXXXX-XX-X

Background to the Arboricultural Association

Founded in 1964, the Arboricultural Association is the largest and longest-established UK body and authority for the amenity tree care profession. It has a base of circa 3,000 members in central and local government, commercial and educational employment, at craft, technical, supervisory, managerial, tutor and consultancy level.

The Arboricultural Association is regarded by central government departments, the Royal Horticultural Society and local government as the focal point for good practice in arboriculture, for certification and regulation of the industry, for information, education and research. It is unique in the profession in that its body of knowledge extends across the full spectrum of arboricultural issues. The Association can represent and advise a wide range of members, from small operators to large corporate bodies and local and central government, as well as engaging with national and international partners and the general public.

The Association publishes a range of technical leaflets, guidance notes and other publications concerning arboriculture, the quarterly *ARB Magazine* and the quarterly *Arboricultural Journal*. In its function as voluntary regulator for the arboricultural industry, the Association produces an online directory of Registered Consultants and Approved Contractors, all of whom have reached standards of excellence in arboriculture. The Association offers training through a varied programme of topical workshops, seminars and online learning, and holds events such as an annual trade show (the ARB Show), an annual Amenity Conference and webinars which attract a global audience. Various grades of membership exist for professional arboriculturists, those in related disciplines and enthusiasts.

This Technical Guide is part of a series of guidance documents published by the Arboricultural Association with support from STIHL, City & Guilds/NPTC and the Scottish Forestry Trust.

Foreword

This Technical Guide has been developed as part of a comprehensive review of industry guidance relating to arboricultural tree work at height. It represents the culmination of several years of work involving hundreds of days of study, research, practical workshop exercises, demonstrations, drafting and industry consultation.

The document sits within a national framework of guidance for planning, managing and delivering safe and effective arboricultural operations.

The overall principles for planning and management are set out in the *Industry Code of Practice for Arboriculture – Tree Work at Height* (ICoP), which provides an organisation's Responsible Person with the information needed to implement appropriate structures, systems and controls.

This Technical Guide is the third in a series of five guides which provide practical guidance to operators carrying out tree work.

Technical Guide 1: *Tree Climbing and Aerial Rescue*
Technical Guide 2: *Use of Tools in the Tree*
Technical Guide 3: *Rigging and Dismantling*
Technical Guide 4: *Use of Mobile Cranes in Tree Work*
Technical Guide 5: *Use of Mobile Elevating Work Platforms in Tree Work*

They are designed to be read sequentially, thus avoiding excessive duplication between guides.

In each Technical Guide, picture captions begin with the number of the paragraph to which the image relates.

At the beginning of each technical section in the guide, there is a checklist of key safety points related to that subject area. This serves to highlight good practice for the operator and to assist the competent person in supervising the work. All the checklists in this guide are compiled into a separate, free-to-download Safety Guide, available from the Association's website: **www.trees.org.uk/safety-guides**. The Safety Guide provides a useful collation of all the key safety points and can be used to audit safe operations on a work site.

Acknowledgements

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This Technical Guide has drawn significant inspiration, influence and data from the HSE-commissioned Rigging Research document, *Evaluation of current rigging and dismantling practices used in arboriculture* (HSE, 2008). We are indebted to its authors along with the many arborists and others who have also contributed valuable insight, ideas, facts and figures to this guide. We would particularly like to thank Adam Davies, Ben Daniel, Ben Rose, Chris Wyatt, Marcus Undery and Terry Banyard.

The Arboricultural Association has consulted with the Health and Safety Executive in the production of this technical guidance.

1

Introduction

1.0 Introduction

1.1 This document, Technical Guide 3, provides technical guidance for anyone who is required to carry out tree rigging and dismantling.

1.2 This Technical Guide is not a substitute for adequate training but sets out current industry good practice relating to rigging and dismantling.

1.3 Everyone involved in rigging and dismantling operations can use this document:

a. to help make rigging and dismantling safer;

b. to help ensure the correct use of components in a rigging system;

c. to identify suitable techniques for rigging and dismantling operations;

d. as the basis of a safe system of work to avoid or reduce risk; *and*

e. as guidance, to ensure health and safety legislation is complied with.

1.4 In accordance with the Industry Code of Practice for Arboriculture, the key principles of tree work at height must be adopted when using this Technical Guide.

It is essential that:

a. all work at height is properly planned, organised, supervised and managed;

b. tree climbing should only be undertaken when it is not reasonably practicable to do the work from ground level or from a platform;

c. everyone engaged in a rigging and dismantling operation has the appropriate training and experience to be proficient in the tasks they are required to undertake;

d. lifting (and lowering) systems are properly designed, including the compatibility and correct configuration of components within each system; *and*

e. any equipment used is suitable for the task and subject to periodic inspection, examination and maintenance to confirm it remains safe for use.

1.5 **Warning:** Tree work and related operations at height can be inherently dangerous. It is the responsibility of any proficient operator to learn, understand and practise the proper techniques for working in such environments. While it is not possible for this technical guide to cover all methods used to carry out tree rigging and dismantling, it aims to set out the principal considerations, some of the more common techniques used and their correct application.

2

Key Terms and Definitions used in this Technical Guide

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2.1 Terms and Definitions

Anchor force (AF): The force at the anchor derived from the combined force applied to each leg of rope which enters and exits the anchor.

Bend ratio: The ratio between the diameter of the rope and the diameter of the object around which it is bending.

Dismantling: The process by which trees or parts of trees are taken down in sections. This can be done using free-fall techniques or with the aid of ropes, pulleys and/or friction devices, or mechanised systems such as cranes, tree shears/grapple saws, etc.

Dynamic load: Forces generated by arresting a falling or swinging mass. Measured in kilonewtons (kN) or decanewtons (daN).

Fairlead: A device or component which facilitates the unimpeded routing of a rope into another component.

ICoP: *Industry Code of Practice for Arboriculture: Tree Work at Height* 2nd edition (Arboricultural Association, May 2020)

Mass: The amount of matter in an object, measured in kilograms (kg).

Mechanical advantage (MA): The process by which a force is multiplied by using equipment such as winches or component assemblies such as fiddle blocks.

Minimum breaking strength (MBS): The load above which an item of equipment might fail when it is new, as determined by the manufacturer.

Peak load (PL): The maximum force experienced during the cycle of a fall. Measured in kN or daN.

Pre-loading: Removing slack and tensioning a rope in preparation for lifting or to help reduce the potential for high dynamic loading.

Rigging: The process of dismantling trees or parts of trees using systems and/or techniques to control the falling sections.

Safe working load (SWL): The load that an item of equipment can safely lift, lower or suspend based on particular working conditions.

Safety factor (SF): The relationship between the MBS and the WLL/SWL, often expressed as a ratio.

Snubbing off: Where the lowering rope is held (either deliberately or inadvertently) causing the falling section to stop suddenly, resulting in potentially high peak loads.

Units of force and mass:
newton (N): unit of force
decanewton (daN): 10 newtons
kilonewton (kN): 1000 newtons
gram (g): unit of mass
kilogram (kg): 1000 grams

Vectors: A quantity that has both magnitude and direction.

Weight: A force, measured in newtons (N).

Working load limit (WLL): The load that an item of equipment can safely lift, lower or suspend when it is new, as specified by a manufacturer. This does not account for particular service conditions.

Worst-case scenario: The scenario where all possible variables have conspired to produce the least favourable conditions and situation.

2.2 How kN Values are Used in Arboriculture

2.2.1 Arborists may be familiar with marks on equipment which indicate the item's minimum breaking strength (MBS), expressed in kilonewtons (kN).

2.2.2 The unit in use is the newton (N). One newton is the force that would have to be exerted on a 1kg mass to make it accelerate at a rate of 1 metre per second per second (expressed as $1m/s^2$, $1m{\cdot}s^{-2}$ or $1m\ s^{-2}$, or less commonly, 1m/s/s).

2.2.3 Force = mass × acceleration, so 1N is also equal to the force exerted by stopping a 1kg mass which is accelerating at $1m/s^2$ ($1N = 1kg \times 1m/s^2$).

2.2.4 Acceleration due to gravity is $9.8m/s^2$, and therefore the arrest force required to stop 1kg falling due to gravity would be $1kg \times 9.8m/s^2$, i.e. 9.8N. Where larger forces are involved, the kilonewton (kN) is the unit used (1kN = 1000N).

For example, a karabiner stated as having an MBS of 25kN is rated at 25,000N, which represents a force equivalent to 2551kg acted upon by gravity (i.e. 25,000 ÷ 9.8).

Expressed the other way round,
$2551kg \times 9.8m/s^2 = 25{,}000N$ or 25kN.

For simple conversion, the number of kN × 100 is approximately equal to the kilogram rating of equipment.

Draft for consultation

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3

Planning Rigging Operations

Checklist:

- **Are the proficient operators on site aware of who the competent person is?**
- **Is there a suitable and sufficient site-specific risk assessment?**
- **Has the risk assessment been communicated and agreed by all parties?**
- **Do operators have clearly defined roles and responsibilities, and do they understand them?**
- **Do the operators have the necessary level of proficiency to carry out their allocated tasks?**
- **Are operators aware of the actions to be taken if they have concerns about unsafe work practices?**
- **Have appropriate drop, work and exclusion zones been identified and are all operators aware of them?**
- **Has an adequate tree condition assessment been carried out?**

Have you checked?

3.1 Introduction

3.1.1 As stated in the ICoP, all tree work at height operations, including rigging, need to be planned by an individual who is competent and has adequate knowledge of the task to be undertaken.

3.1.2 Proficient operators should have no doubt about who the competent person is during any rigging operation. That individual, who will have been nominated by the responsible person in a company and may, for example, be a team leader, is accountable for ensuring that the rigging operation is managed and undertaken safely, and the work environment (the work site) is controlled.

3.1.3 Anyone involved in a rigging operation should be aware that no two jobs will be the same. The techniques used, the sequence of operations and the site considerations, amongst other things, will vary from site to site and job to job. Because every job is different, proficient operators and the competent person will be required to make decisions about how work progresses as the task is carried out.

3.1.4 As the competent person will oversee the task and ensure it is done safely, no one should take on this role unless they have the required knowledge, training and experience to do so.

3.1.5 If at any point during the rigging operation any operator considers that the planning or organisation of the task has been inadequate, they must immediately bring this to the attention of the competent person who should temporarily halt work to address the operator's concerns.

3.1.6 The competent person must ensure that the following four requirements have been addressed in the planning of the operation and that suitable and sufficient measures are in place:

a. risk assessments including emergency procedures;
b. personnel and supervision including roles and responsibilities;
c. equipment and resources; *and*
d. communication.

Responsible person:
an individual who is ultimately legally responsible for all activities under their control.

Competent person:
individual(s) responsible for ensuring operations are managed and undertaken safely and that the work environment is controlled.

Proficient operator:
a skilled, knowledgeable and experienced operator able to perform specific tasks.

3.1.1 Definitions for the responsible person, competent person and proficient operator taken from the Industry Code of Practice for Arboriculture: Tree Work at Height.

3.2 Risk Assessment

3.2.1 Published industry good practice (the ICoP and Technical Guides) sets out the requirements for producing a suitable and sufficient site-specific risk assessment for the competent person and proficient operators. Due to the potentially complex nature of rigging operations, and the risks associated with tree or component failure, the site-specific risk assessment must form part of the overall risk control system for the task and work site, including adequate emergency planning. Proficient operators should be aware that a suitable risk assessment will allow all potential hazards to be identified, and the control measures required to manage the risks arising from those hazards should be included as part of the overall work plan.

3.2.2 It is important that any risk assessment carried out for dismantling operations identifies the nature and level of the risks associated with the task. The competent person is responsible for ensuring that, as a minimum, the following factors are included in the process of drawing up a suitable and sufficient assessment:

a. type of load being lifted, its mass and shape/form;
b. risk of a load falling, moving, breaking up or striking a person or object and the consequences;
c. risk of the equipment striking a person or an object and the consequences;
d. risk of the equipment failing while in use and the consequences; *and*
e. risk of damage to the equipment that could result in failure.

3.2.3 Everyone involved in rigging operations must be aware that risk assessment must continue throughout the task. The nature of rigging operations means anchor points may move, equipment requirements may change and the rigging set up may be adjusted. In any of these scenarios, the work team may encounter additional hazards. Therefore, the site-specific risk assessment should be under constant review with input from proficient operators, particularly at key moments such as:

a. an alteration to the work method, for example, moving from free-fall to rigged sections;
b. introduction of new equipment in the rigging system; *or*
c. significant change in how equipment is being used, e.g. moving from a load positioned beneath a pulley to above the pulley.

3.3 Planning

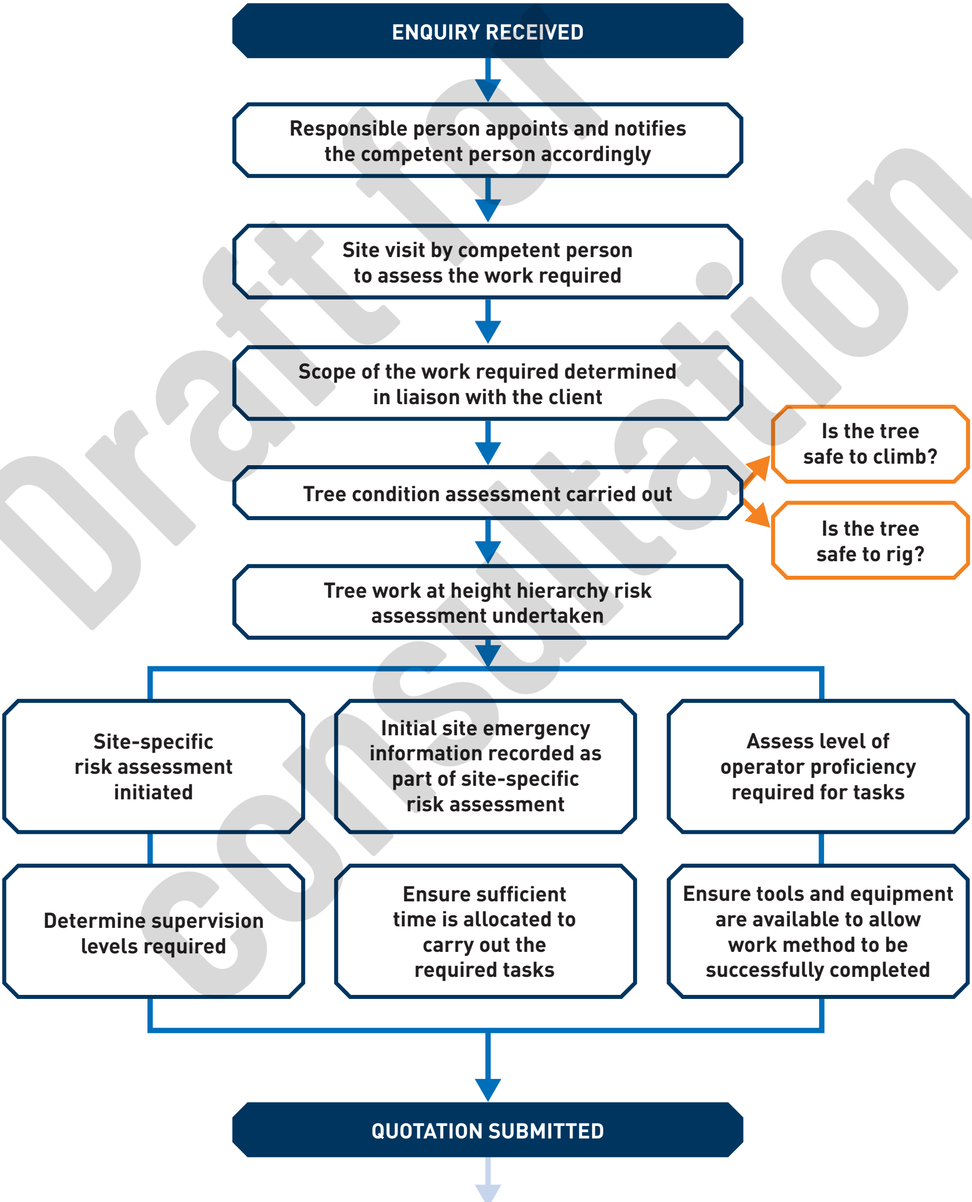
3.3.1 In the same way that a competent person may use a checklist to ensure work is being carried out to an agreed standard, operators are actively encouraged to question as part of their pre-work briefing whether the following factors have been considered and implemented during planning for the rigging operation:

a. Is there a generic risk assessment in place which covers both the hazards relating to rigging operations and the control measures required for safe working?
b. Has a site-specific risk assessment been produced that is specific to the actual work site, the nature of the task and the equipment to be used?
c. Has emergency contact and access information been recorded as part of the site-specific risk assessment, and is there a rescue plan in place?
d. Is the weather suitable for the work to be undertaken, or does it present a significant hazard which means work should be delayed?
e. Has adequate time been allocated for the work? Under no circumstances should anyone attempt to take short cuts or jeopardise their or others' health and safety because insufficient time has been allocated to complete a task.
f. Are enough operators available to carry out the work safely and effectively, including people to manage the work site, operate lowering systems and implement any emergency procedures if required?
g. Has sufficient equipment been provided to allow the work to be carried out safely?

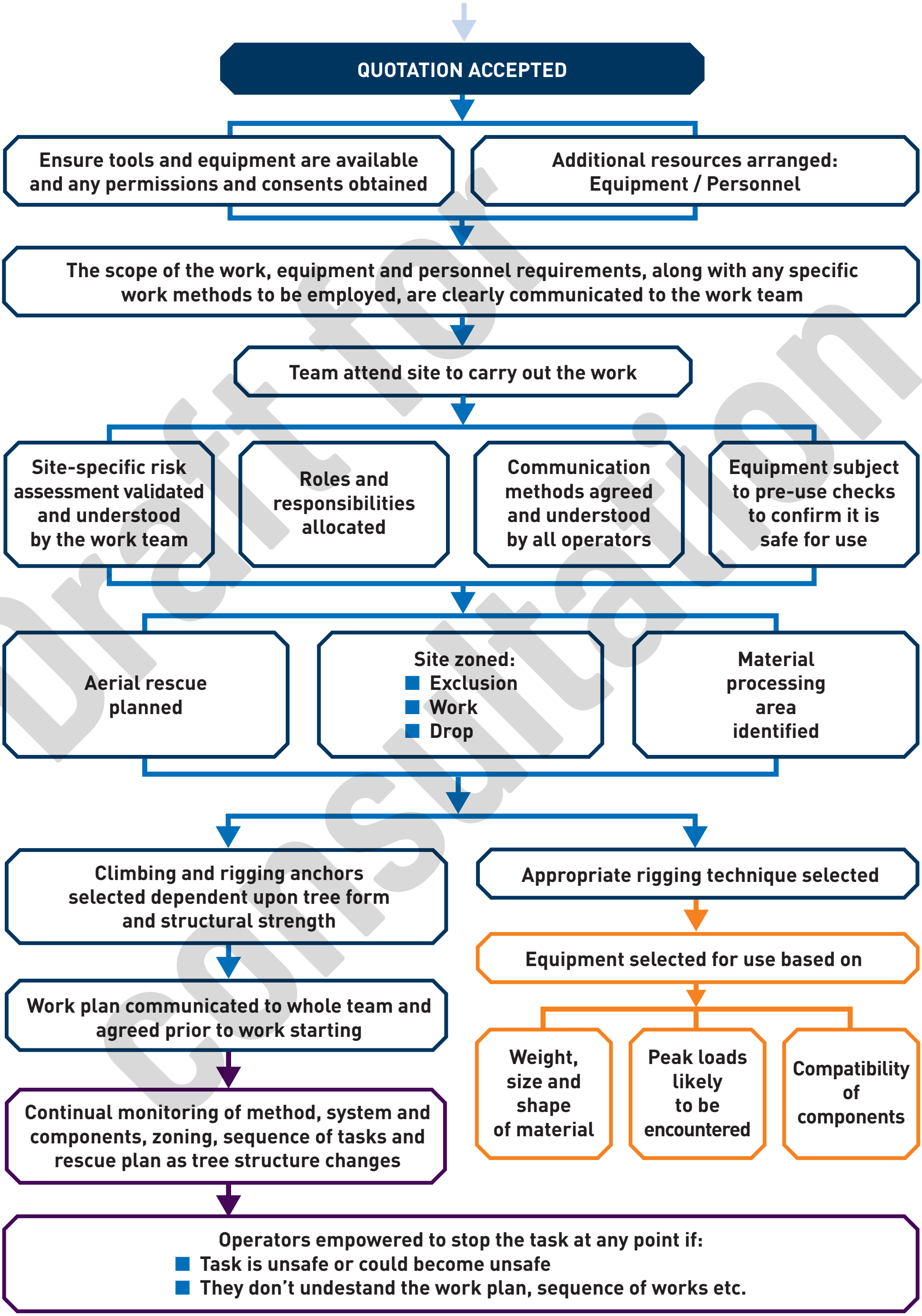
The competent person who is managing and controlling the work site is responsible for ensuring the factors listed above have been adequately addressed.

3.3.2 The planning process should follow a logical sequence so that it covers all of the key factors which are critical to the efficiency or safety of the operation.

The flow diagram below suggests some way-markers in the process of planning a tree-removal operation which may involve rigging. The planning process begins with the initial enquiry, which in this example is a client asking for a quote.



3.3.2 Checklist for planning rigging operations.


QUOTATION ACCEPTED
Ensure tools and equipment are available and any permissions and consents obtained
Additional resources arranged: Equipment / Personnel
The scope of the work, equipment and personnel requirements, along with any specific work methods to be employed, are clearly communicated to the work team
Team attend site to carry out the work
Site-specific risk assessment validated and understood by the work team
Roles and responsibilities allocated
Communication methods agreed and understood by all operators
Equipment subject to pre-use checks to confirm it is safe for use
Aerial rescue planned
Site zoned:
Exclusion
Work
Drop
Material processing area identified
Climbing and rigging anchors selected dependent upon tree form and structural strength
Appropriate rigging technique selected
Equipment selected for use based on
Work plan communicated to whole team and agreed prior to work starting
Weight, size and shape of material
Peak loads likely to be encountered
Compatibility of components
Continual monitoring of method, system and components, zoning, sequence of tasks and rescue plan as tree structure changes
Operators empowered to stop the task at any point if:
Task is unsafe or could become unsafe
They don’t undestand the work plan, sequence of works etc.

3.4 Roles and Responsibilities

3.4.1 *Technical Guide 1: Tree Climbing and Aerial Rescue* establishes the principle that for any tree work operation, clear and correctly defined roles and responsibilities must be established from the outset to ensure a consistent approach to the planning, management and completion of tree work at height.

3.4.2 As part of the planning for a tree dismantling operation, each person on site must understand what their role is and what their responsibilities are.

3.4.3 A dismantling operation is a team task. Aerial tree work operators and ground staff must respect each other's roles, and if either party has any concerns about safe work practices, work should immediately be called to a halt.

3.4.4 General points:

a. Any form of instruction given by an aerial operator or ground person should always be acknowledged.
b. Work at a speed respectful of each other's tasks.
c. Never walk or work beneath suspended loads.
d. Maintain visual contact between operators, and where this is not possible adopt controls such as using radios to ensure effective communication is maintained.
e. Safeguard your own health and safety by using machinery and PPE correctly, including gloves for ground staff when they are handling ropes and controlling friction.
f. Work together to help determine appropriate friction levels to maintain control and efficiency when using lowering devices.
g. Constantly be aware of drop zones, ensuring material is not dropped and no one enters a drop zone without clear command-and-response communication.

3.5 Operator Competency

3.5.1 A decision about whether tree climbing is the most appropriate method for carrying out the work, and whether it is safe to carry out operations using rope and harness techniques, should be based on a preliminary work site assessment. This decision must be undertaken by the responsible person and/or competent person, prior to works taking place.

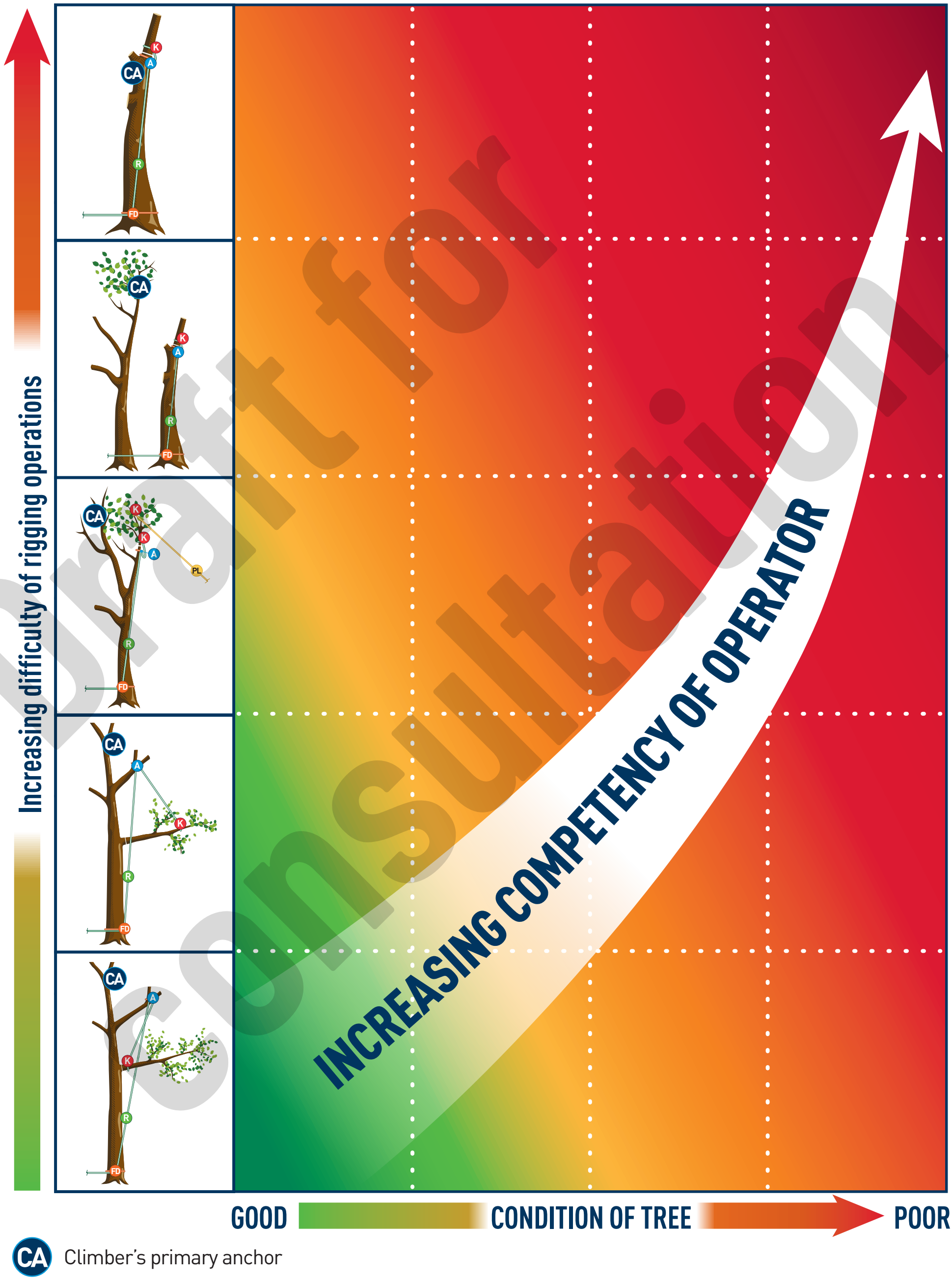
3.5.2 As part of planning a rigging operation, the competent person must ensure that sufficient personnel are available to carry out the work safely and effectively and that they are proficient in the tasks required.

3.5.3 A proficient operator is 'a skilled, knowledgeable and experienced operator able to perform specific tasks' (ICoP).

3.5.4 Rigging operations can be complex in terms of the equipment required. They may also pose an increased level of risk to the operator because of the forces applied to the structure and the confined areas where the operator may be required to work, e.g. when dismantling vertical timber with no overhead anchor point from spikes.

3.5.5 When evaluating the competency of anyone who will be involved in a rigging operation, the competent person must consider the tree's condition and the degree of difficulty involved in the rigging. This will indicate the level of experience and training required from the operator.

3.5.6 Operators who are not adequately trained in the tools, equipment or techniques required must not proceed with the work. In the first instance they should speak to the competent person to determine if it is appropriate for the work to continue or whether alternative work methods, sequencing or equipment are required.



3.5.5 Operator competency vs the rigging scenario.

3.6 Site Layout

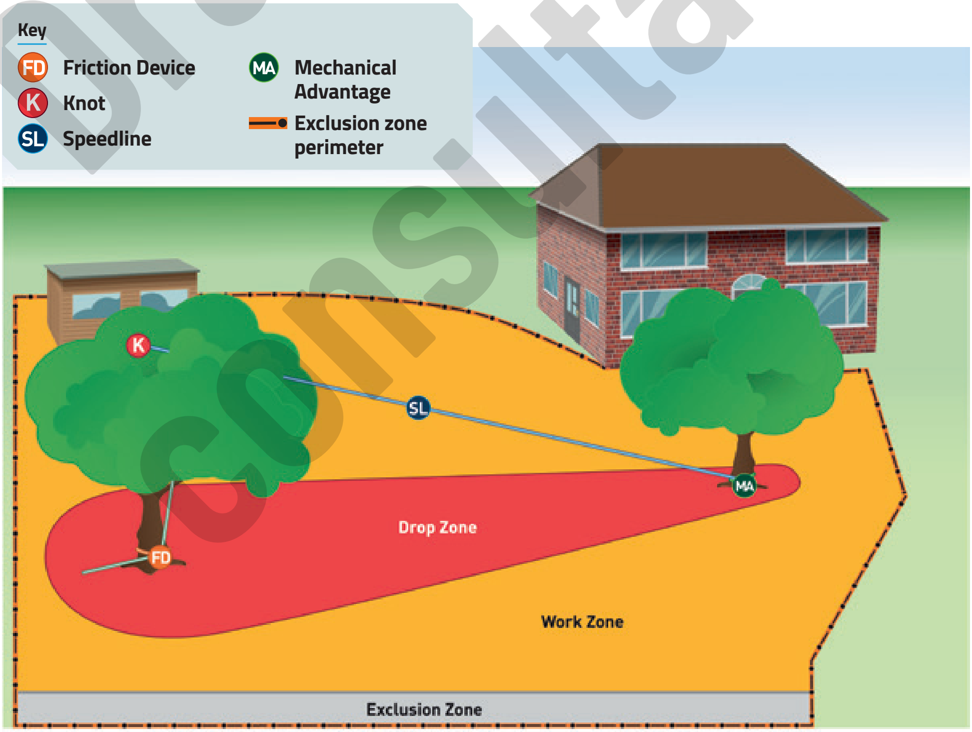
3.6.1 A well-planned work site layout is key to establishing a safe and efficient workflow. Jobs will often comprise a series of operations, each requiring equipment and/or machinery, which will place demands on the space available. The operations will often need to be undertaken simultaneously and the site should be planned so that one operation does not hinder another. For example, branches might be lowered to the ground during rigging whilst brash is being dragged away to an area for processing. If the area for chipping is located directly within the drop zone, managing these two separate operations will prevent a constant flow of work.

3.6.2 When planning the site layout, take into consideration buildings and structures and any overground or underground hazards such as powerlines, telephone lines, drainage and pipework.

The following may be required to make the work site safe:

a. power – shutdown or isolation;
b. power/telephone – temporary removal of the lines;
c. ground protection – boarding or matting to spread the load created by pedestrian or vehicular traffic; *and*
d. buildings/structures – boarding or sheeting to protect fragile surfaces such as windows and rendered brickwork (boards can also be used to cover hazards such as ponds and drain covers).

3.6.3 It is important that each operator on site is clear about how the work site is to be laid out, particularly the locations of exclusion, working and drop zones. To assist with this, the competent person may draw up a sketch map or site plan as part of producing the site-specific risk assessment, to provide guidance to operators on how the site is to be laid out.



3.6.4.7 Site layout including drop, work and exclusion zones.

3.6.4 Site Zoning

3.6.4.1 During any work at height task, operators – particularly those working on the ground – can be injured by falling tools, equipment or debris. When the layout of a work site is planned, the risk associated with falling objects must be considered and appropriate drop and work zones must be set up. These zones must be established, communicated and maintained by everyone involved in the work as part of the risk control system for the site.

3.6.4.2 **Drop Zone**: This is the area where it is anticipated materials may fall and therefore where people or property would be at significant risk from falling objects.

a. The factors that will influence the dimensions of a drop zone include, but are not limited to:
   i. wind conditions and direction;
   ii. size, weight, shape and type of material being dropped;
   iii. the technique being used;
   iv. the accuracy (experience) of the person dropping the material;
   v. the potential for contact with other objects (e.g. lower branches);
   vi. the height of the fall; *and*
   vii. the surface onto which the material will fall and its topography.
b. Specific controls must be in place to manage entry to this zone. It is expected that as a minimum these will include verbal confirmation from the climber to ground staff and vice versa that it is safe to proceed, and demarcation, for example physical barriers, signs, floor indicators, physical features (e.g. canopy dripline).

NB: A drop zone need not necessarily be physically marked, e.g. with barriers. However, the limits of any drop zone must be agreed and all those engaged in the task (climbers and ground staff) must know the extent of those limits.

3.6.4.3 **Work Zone**: An area where hazards could be encountered or created.

a. The risk that items from the drop zone could enter the work zone must be considered and control measures may be needed, such as extended drop zones and work practices to minimise the chance of falling objects, e.g. branch-lowering techniques.
b. Unauthorised persons must not be able to access the work site. Appropriate signage and guarding must be established and maintained at the perimeter of exclusion zones.

3.6.4.4 The size of each zone should be assessed and determined individually. Changes to the dimensions of any zone must only be made following a reassessment of the factors that determined the original zone size and only after carefully considering why a change is to be made. If a zone's size or location is to be changed, the details of the alteration must be made clear to everyone involved in the operation.

3.6.4.5 Any operator entering a drop or work zone must wear PPE in accordance with current good practice. This requirement must be strictly enforced by the competent person on site, e.g. the foreman or team leader.

3.6.4.6 The aerial operator must make it clear when equipment is being handled in the tree, e.g. during the installation of pulley blocks or other items, in case it is dropped. Before installing the equipment, the aerial operator must ensure the areas below are clear and must give a verbal warning. The aerial operator must have received a positive reply to the warning before proceeding.

3.6.4.7 When the operation involves the use of techniques such as speedlining (see section 4.4c), it may be necessary to extend the drop zone over a greater area to encompass the full span of the speedline.

3.7 Tree Condition Assessment

3.7.1 A tree condition assessment is an essential prerequisite for any tree work operation. It involves a thorough examination of the tree's structure to identify the presence of hazards or defects which could compromise the safety of any proposed work.

3.7.2 The person carrying out the condition assessment must:

a. be competent and able to identify existing and potential defects;
b. evaluate the severity of defects in relation to the proposed operation; *and*
c. advise on suitable control measures to address any risks posed by the defects or hazards.

3.7 Tree condition assessment.

Previous works:
Any previous works could have resulted in:

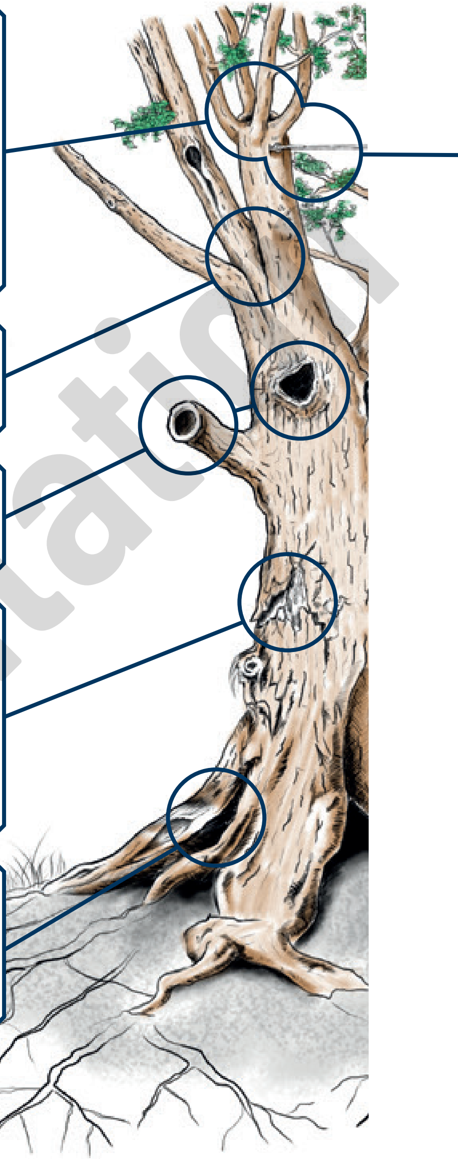
- wounds being inflicted to the tree which could have created cavities and weak points;
- destabilisation of the structure by creating an imbalance;
- the presence of foreign objects like bracing which constitute obstacles to running lines and swinging loads. Fixed rod braces or tensioned steel wire which are holding or restraining significant loads may be especially problematic when the tension is released during rigging, potentially causing structural failure.

Branch attachments:
Poor branch attachments, such as V-shaped or included unions, present hazards during rigging due to their diminished bearing capacity when used as anchor points.

Cavities:
Cavities will indicate the absence of material cross-section in the stem or limb and as a result should not be excessively loaded in either tension or compression.

Loose/dead/flaking bark:
These signs could indicate the presence of something more significant which is affecting the tree such as decay fungi. (This may only be established following further investigation by a competent person who is knowledgeable in tree-related pathogens.) However, they may also be a characteristic of the species. Dead or flaking bark may be an impediment to grip for both the climber and/or any equipment such as slings used to secure components to the structure.

Buttress roots:
Absence of, or damage to, buttress roots will significantly impede the tree's ability to deal with lateral forces. Such forces are a common aspect of rigging operations and, in some cases, can be very high. As a result the absence of buttress roots could cause the tree to fail during rigging.



Deadwood:
The presence of deadwood does not always indicate significant issues with the tree, nor does it always constitute a significant hazard. However, it is vitally important during rigging operations to consider the stability and security of deadwood, as the sudden, high forces generated during rigging could cause deadwood to become dislodged and fall.

Cracks:
Whether these are horizontal (perpendicular to the grain) or vertical (parallel to the grain), they represent a delamination of fibres which will be a source of weakness.

Wood decay fungi/decay/rot:
The effects of wood decay fungi can vary between species of fungi and species of tree. Some fungi produce a cubicle brown rot which can contend with compressive forces far better than tensile ones. Equally, a white rot may tolerate some degree of flexibility but be unable to deal with any form of compression. For this reason, the presence of any fungal fruit body should be treated with caution and the advice of a competent person who is knowledgeable in tree-related pathogens should be sought.

Soil cracks:
Soil cracks around the rooting area could indicate root plate instability.

Root system:
If a significant proportion of roots are damaged, lost or decayed, this could destabilise the tree. This would be particularly hazardous during rigging when lateral loads are applied to the stem.

3.7.3 Whilst the initial tree condition assessment may be undertaken by an individual other than the proficient operator, it is vitally important that the proficient operator builds on the initial assessment. They should do so during access into the tree and throughout the rigging operation.

3.7.4 If, during this continuing assessment, the operator identifies tree features or characteristics which may compromise the safety of the operation, they should stop work. It may then be necessary to undertake a further tree condition assessment, and work should continue only when it is deemed safe to do so.

3.7.5 Methods used for carrying out tree condition assessments will vary and are dependent on the hazard(s) identified. Usually, the assessment will be a visual check carried out from ground level. However, if this is not sufficient to establish the significance of any identified hazard(s), then diagnostic tools and/or aerial inspection may be required.

3.7.6 If diagnostic tools are used, the person operating them must fully understand how to do so and be able to interpret the results as data which can then be used to inform suitable control measures. Diagnostic tools include:

a. increment borer;
b. fractometer;
c. resistograph; *and*
d. PiCUS Sonic Tomograph.

3.7.7 Once the extent of the hazard(s) has been evaluated, suitable control measures must be implemented to reduce or eliminate the potential for harm to occur. Which measures are put in place will depend on the nature and severity of the defect and also the proposed work. Some options could include:

a. guying a weak structure to the ground or an adjacent tree;
b. bolting or cabling split or weak stems or junctions;
c. strapping a fractured stem to avoid splitting; *and*
d. loading weak unions in compression as opposed to tension.

4

Rigging Techniques

Checklist:

- Is the selected technique going to achieve the intended objective safely and efficiently?
- Is there enough suitable equipment to undertake the selected technique?
- Are there enough competent operators to undertake the selected rigging technique, both aerial and ground based?
- Will the technique facilitate the safe and effective removal of the intended section?
- Is there sufficient suitable equipment to preload lines or generate mechanical advantage where required?

Have you checked?

4.1 Introduction

4.1.2 Selecting the appropriate rigging technique(s) is vitally important to the safety and efficiency of the work being carried out. It may be that more than one technique must be used (possibly simultaneously) to complete the operation. Operator competence will also have significant bearing on which techniques are selected and must be carefully considered before any operation begins because of the inherent risks presented by lack of knowledge, ability, training or experience.

4.1.3 Each of the techniques described in this section can be implemented using a range of equipment and as a result there is no definitive configuration for any of the systems described. However, it is important to ensure that all components used are compatible with each other and configured for optimum efficiency.

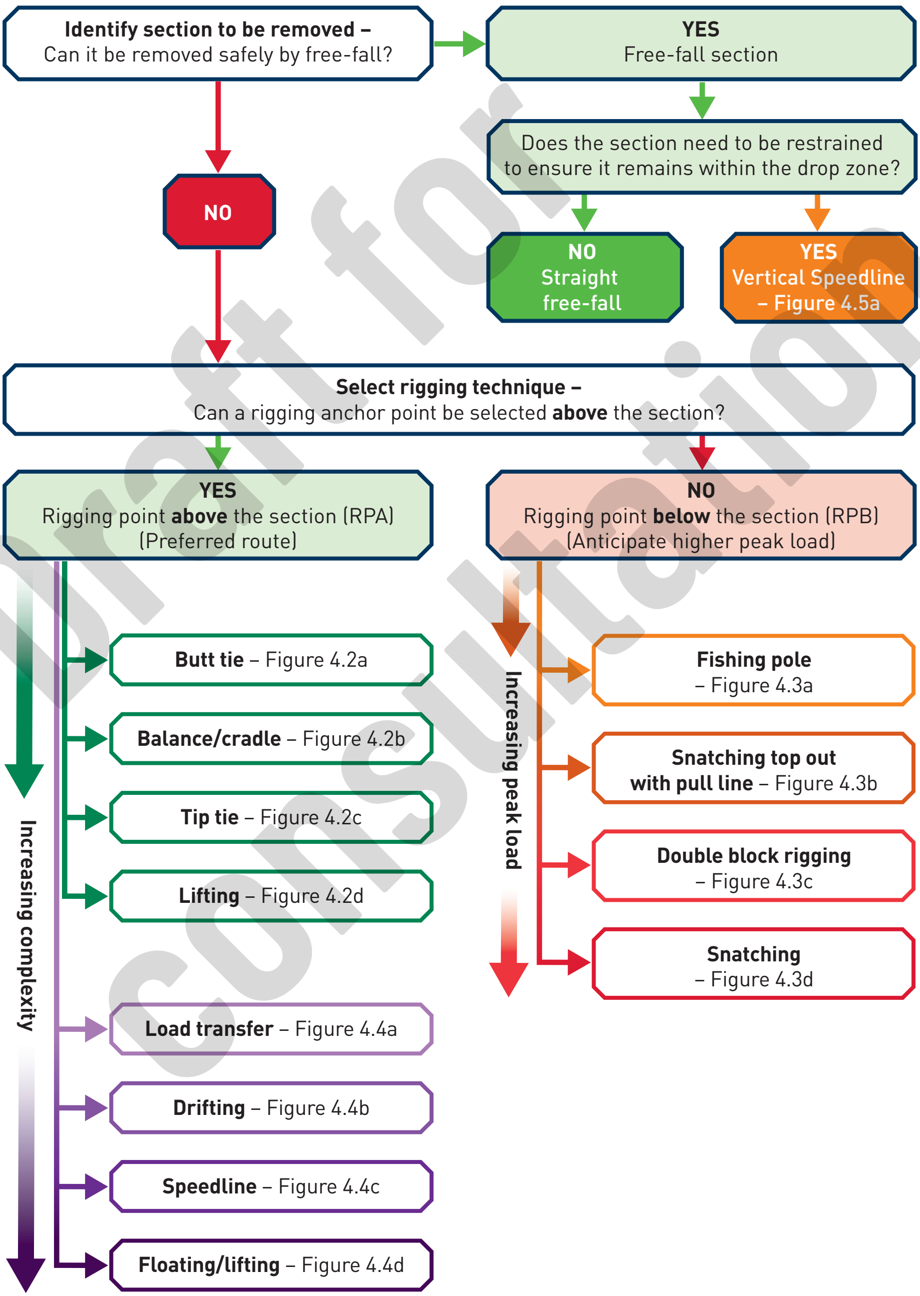
4.1.4 In the flowchart opposite and the descriptions of the configurations in the pages that follow, the term 'section' is used to describe branches, limbs, stem or trunk sections of a tree.

4.1.5 The illustrations on pages 28–40 show different types of rigging configuration. The configurations are set out in order of increasing complexity and potential peak loads generated. The positions of the main components are indicated by letters in a coloured disc. The key to the letters appears below and also provides examples of each component's purpose. Each technique illustration also has its own key.

Key to letter discs in rigging illustrations on pages 28–40

- **A** **Anchor:** rigging anchor point, e.g. pulley block, anchor ring, natural crotch
- **R** **Rope:** to control the load
- **FD** **Friction Device:** to control the load – e.g. rope brake, winch, wraps around the stem
- **K** **Knot:** as appropriate to the application
- **MA** **Mechanical Advantage:** e.g. bollard with integrated winch, fiddle block compression system, carter's hitch
- **PL** **Pull Line:** to guide the controlled section
- **PB** **Pulley Block:** e.g. when used to increase mechanical advantage or reduce peak loads
- **SL** **Speedline:** rope used for transferring load in speedline scenario
- **T** **Trolley:** supporting the load in speedline scenario
- **Ka** **Karabiner:** to connect components of the system
- **CS** **Compression System:** to achieve mechanical advantage
- **S** **Sling:** Used to connect section to rigging system or to support anchor

4.1.4 Selecting an appropriate rigging technique.

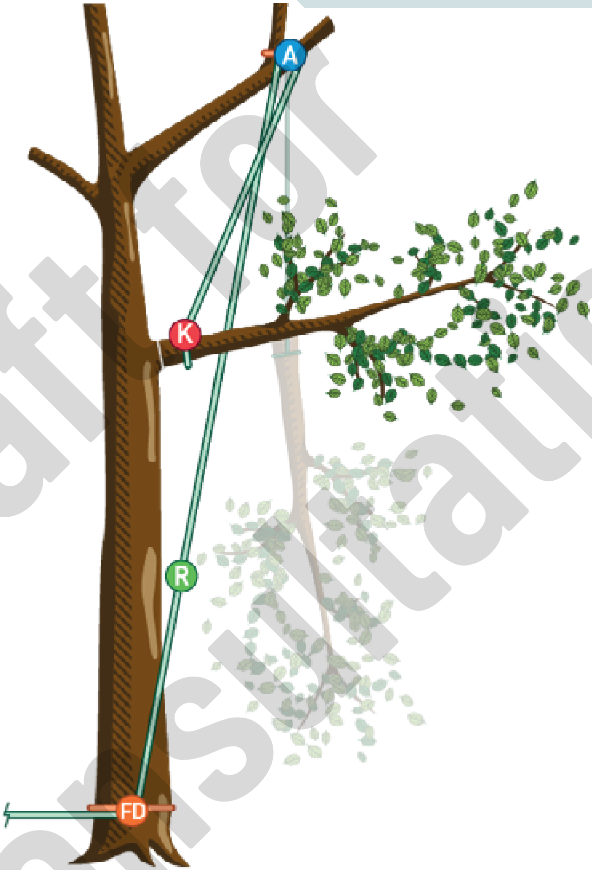


4.2 Rigging Point Above

4.2a Butt tie

Key

- A Anchor
- K Knot
- R Rope
- FD Friction Device



Description

The line is attached to the base of the section so that the tip falls first.

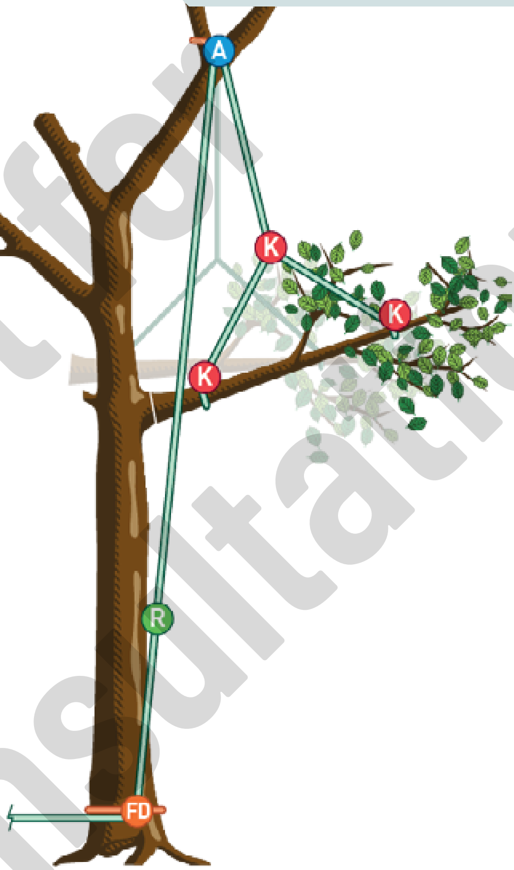
Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure attachment point on section is to the butt side of its centre of gravity and a secure connection is made.
4. Pre-load line.
5. Include ancillary equipment such as pull/control lines to minimise swing and impact.

Key

A Anchor
R Rope
K Knot
FD Friction Device

4.2b Balance/cradle



Description

A technique used to remove horizontal or near horizontal sections which keeps them supported in their original orientation during their removal.

Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure attachment points on section are positioned on either side of its centre of gravity and a secure connection is made.
4. Pre-load line.
5. Include ancillary equipment such as pull/control lines to minimise swing and impact.

Key

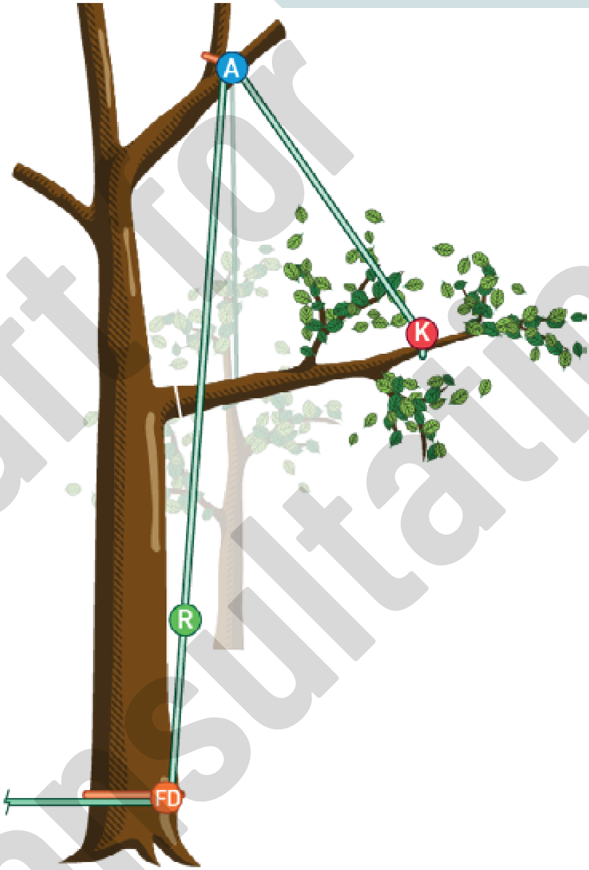
A Anchor

R Rope

K Knot

FD Friction Device

4.2c Tip tie



Description

The line is attached to the tip of the section. This can be used to lift limbs or to allow the base of the section to swing away.

Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure attachment point on section is to the tip side of its centre of gravity and a secure connection is made.
4. Pre-load line.
5. Include ancillary equipment such as pull/control lines to minimise swing and impact.

Key

A Anchor
K Knot
R Rope
MA Mechanical Advantage

4.2d Lifting

Description

Can be used with any of techniques 4.2a–c to facilitate the section being lifted away from the point of cut. The lift can be achieved in a number of ways, from the ground operator pulling on the line to more complex systems which require the integration of winching bollards or other mechanical advantage.

Principal Considerations

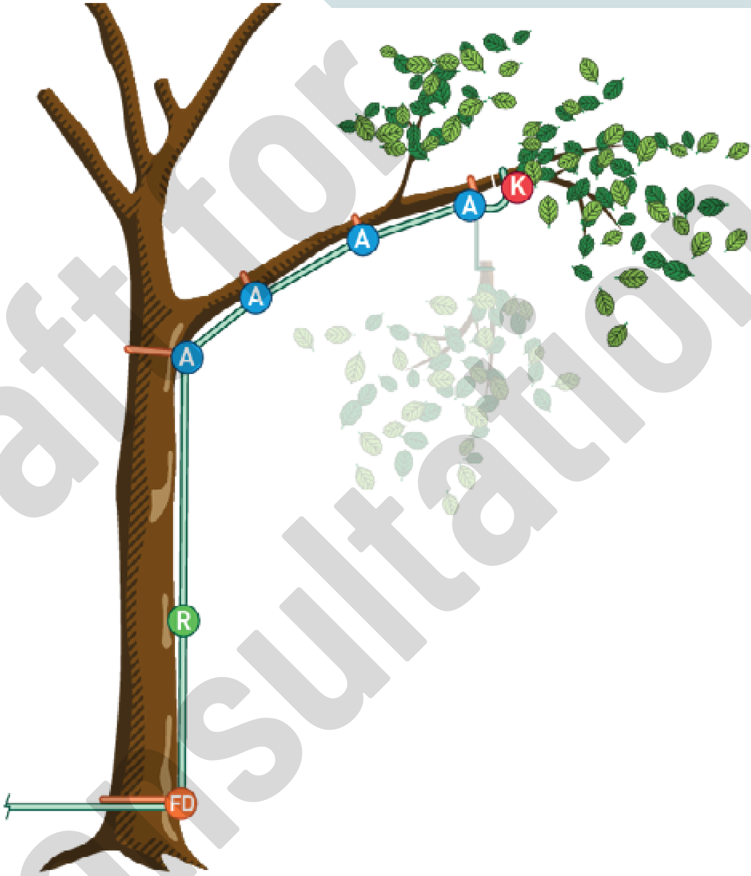
1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure attachment point on section is to the tip side of its centre of gravity and a secure connection is made.
4. Pre-load line to eliminate the potential for section to sit back.
5. Lift section to break hinge and raise to desired position.
6. Include ancillary equipment such as pull/control lines to minimise swing and impact.

Key

- (A) Anchor
- (K) Knot
- (R) Rope
- (FD) Friction Device

4.3 Rigging Point Below

4.3a Fishing pole



Description

Can be particularly useful on over-extended lateral/ horizontal limbs where overhead anchors are either not available or are located in a position which would result in a significant pendulum swing when the cut section is removed.

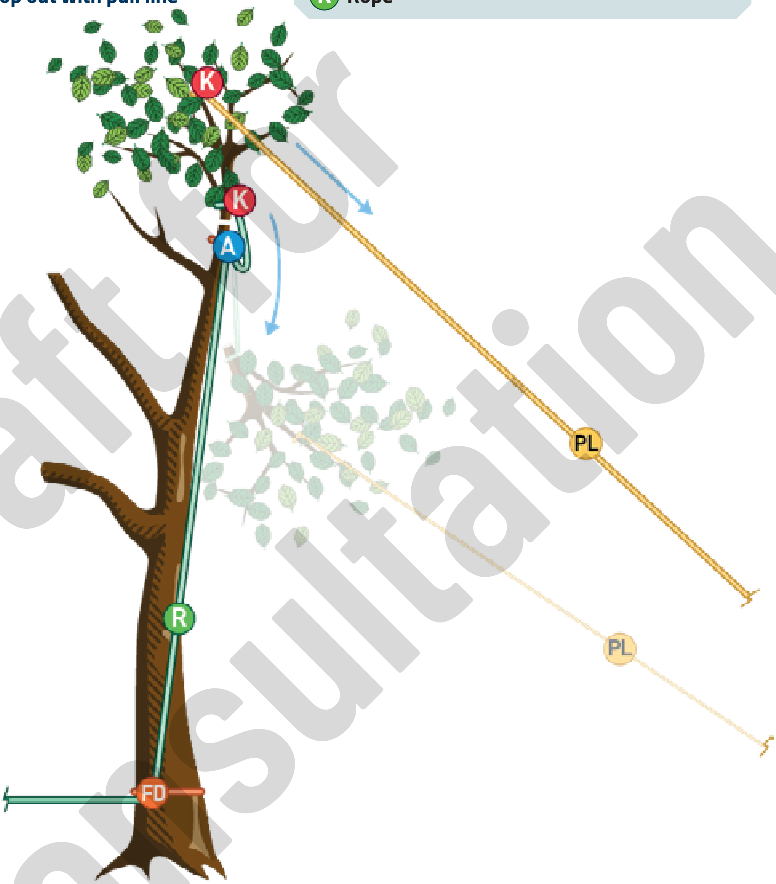
Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure a secure connection is made.
4. Pre-load line to minimise fall distance and reduce peak loads.
5. Plan to minimise impact and lateral forces placed on stem.

Key

- (A) Anchor
- (K) Knot
- (R) Rope
- (FD) Friction Device
- (PL) Pull Line

4.3b Snatching top out with pull line



Description

The rigging point is located directly below the section to be removed. This technique will most frequently be used on upright stems when there are no suitable overhead anchor points.

In this scenario, a pull line has been added to control the direction of fall.

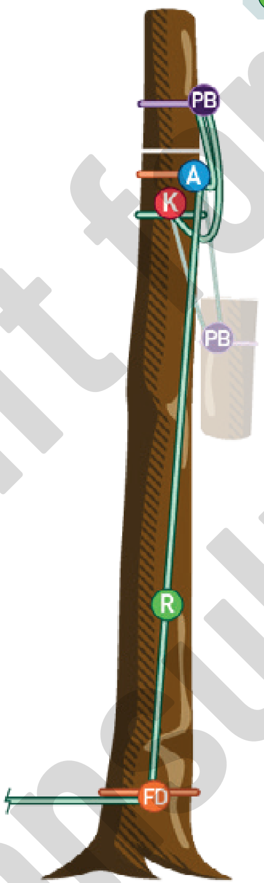
Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure primary attachment on section is positioned below its centre of gravity and a secure connection is made.
4. Pre-load line to minimise fall distance and reduce peak loads.
5. Plan to minimise impact and lateral forces placed on stem.
6. Force on pull line should only be applied when directed by the aerial operator.

Key

- A Anchor
- K Knot
- R Rope
- FD Friction Device
- PB Pulley Block

4.3c Double block rigging



Description

Similar to snatching, where the rigging point is located directly below the section to be removed and there are no suitable overhead anchor points. However, an additional block is incorporated into the system on the section being removed, thus potentially reducing peak loads. This technique could be used in a rigging-point-above situation due to the inbuilt mechanical advantage.

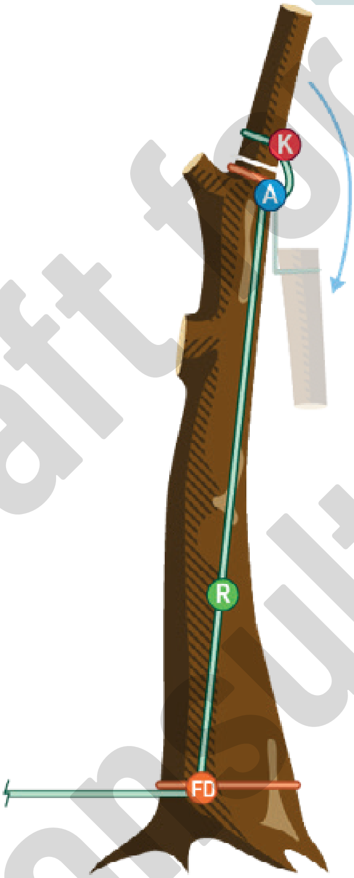
Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure primary attachment on section is positioned below its centre of gravity and a secure connection is made.
4. Pre-load line to minimise fall distance and reduce peak loads.
5. Plan to minimise impact and lateral forces placed on stem.

Key

- **A** Anchor
- **K** Knot
- **R** Rope
- **FD** Friction Device

4.3d Snatching



Description

The rigging point is located directly below the section to be removed. This technique will most frequently be used on upright stems when there are no suitable overhead anchor points.

Principal Considerations

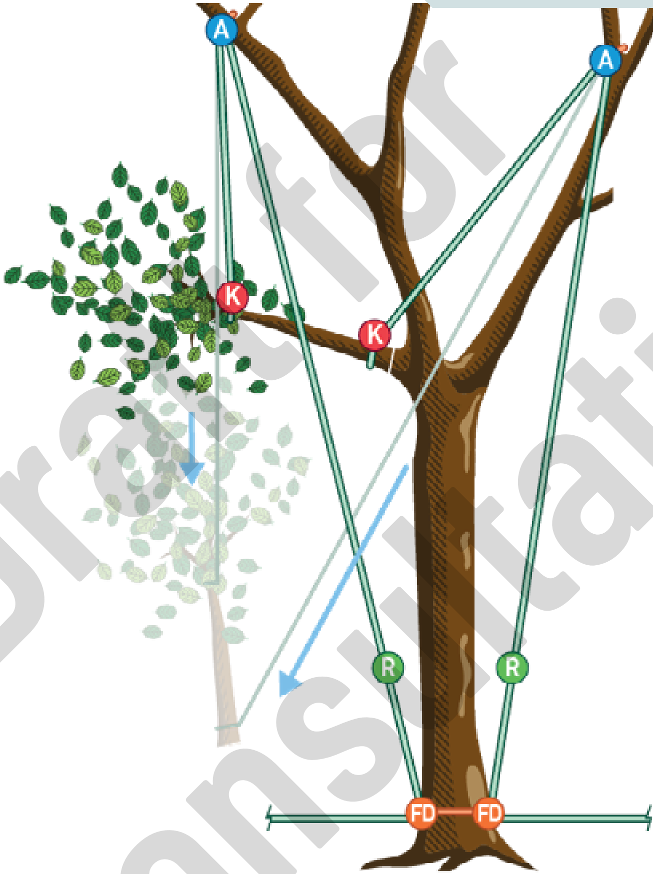
1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure primary attachment on section is positioned below its centre of gravity and a secure connection is made.
4. Pre-load line to minimise fall distance and reduce peak loads.
5. Plan to minimise impact and lateral forces placed on stem.

Key

- A Anchor
- R Rope
- K Knot
- FD Friction Device

4.4 Additional Rigging Scenarios

4.4a Load transfer line



Description

Facilitates the movement of sections laterally, by employing a second line running through an appropriately positioned anchor point and connected to the cut section. This technique involves the use of a second load-bearing anchor point.

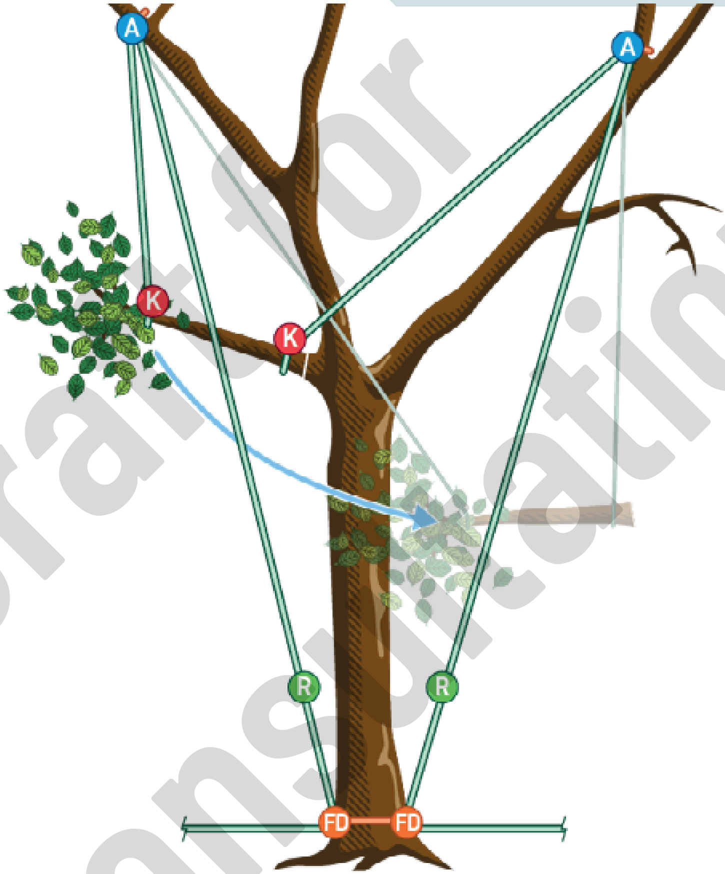
Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure centre of gravity is between anchor points.
4. Ensure secure connections are made.
5. Pre-load both lines to support mass of section.
6. Include ancillary equipment such as pull/control lines to minimise swing and impact.
7. Transfer section to drop zone.

Key

- A Anchor
- K Knot
- R Rope
- FD Friction Device

4.4b Driftline



Description

Similar to a load transfer line in that the system and components are the same. The principal difference with this system is that the section being lowered can be moved, or drifted, into an alternative drop zone. This may be useful, e.g. where multiple drop zones are necessary or beneficial to the operation.

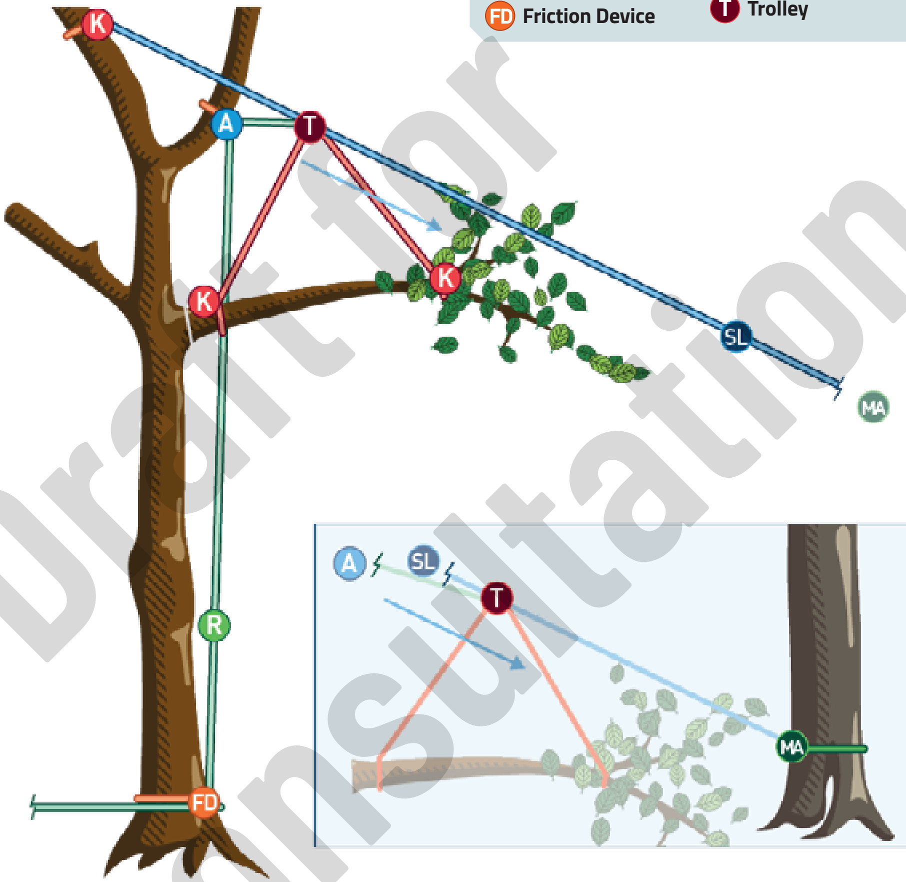
Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure centre of gravity is between anchor points.
4. Ensure secure connections are made.
5. Pre-load both lines to support mass of sections.
6. Include ancillary equipment such as pull/control lines to minimise swing and impact.
7. Transfer section to drop zone.

Key

- **A** Anchor
- **K** Knot
- **R** Rope
- **FD** Friction Device
- **MA** Mechanical Advantage
- **SL** Speedline
- **T** Trolley

4.4c Speedline



Description

Speedlining is most commonly used where the section being removed needs to be moved from the tree to a designated drop zone. Like all of the techniques described in this guide, speedlining can be basic or complex and should be carried out in a way that is commensurate with the abilities of the operators and equipment available.

Principal Considerations

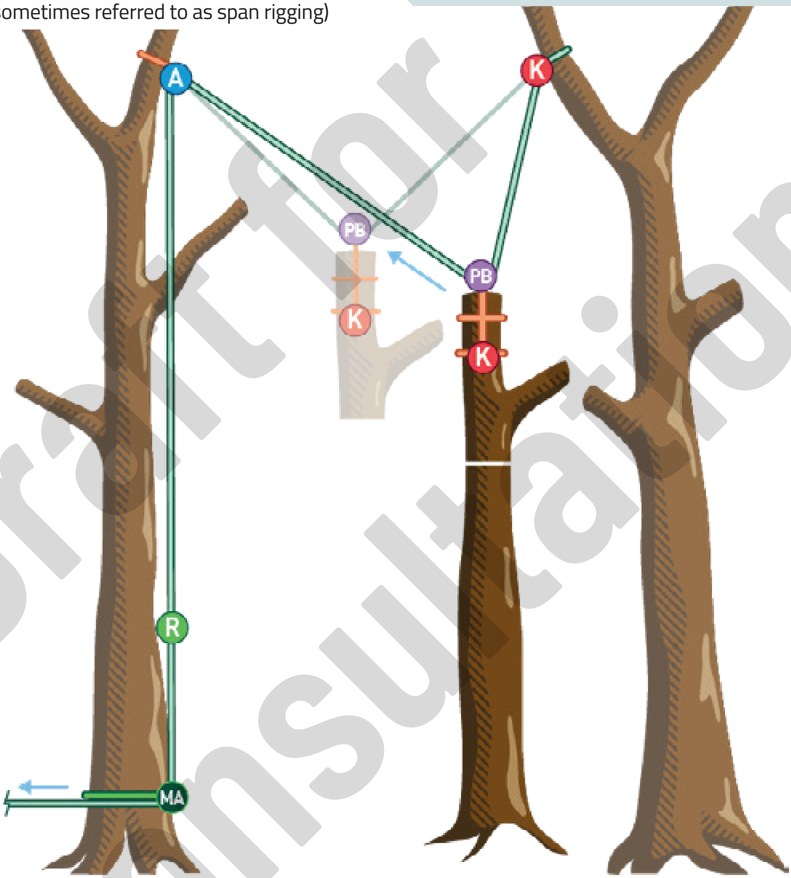
1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure a secure connection is made to the section.
4. Pre-load both speedline and lowering line to lift/move section to desired location.
5. Do not snatch onto a tensioned line.
6. Manage speed of descent.
7. Include ancillary equipment such as pull/control lines to minimise swing and impact.
8. Transfer section to drop zone.

Key

- A Anchor
- K Knot
- R Rope
- MA Mechanical Advantage
- PB Pulley Block

4.4d Floating/lifting

(sometimes referred to as span rigging)



Description

Can be employed where it would be advantageous to lift sections prior to lowering them. It is reliant upon suitably positioned anchor points above the tree which is being removed.

Principal Considerations

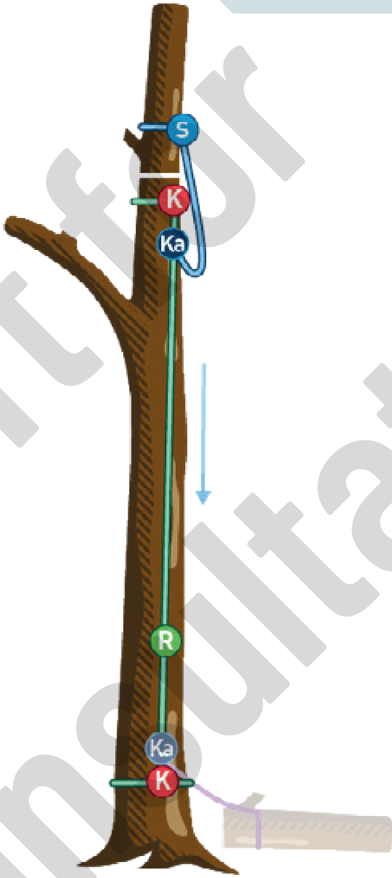
1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure attachment on section is positioned above its centre of gravity and secure connections are made.
4. Pre-load line being aware of significant forces due to angles created between the lines.
5. Lift section to desired position.
6. Include ancillary equipment such as pull/control lines to minimise swing and impact.
7. Transfer section to drop zone.

Key

K Knot
R Rope
S Sling
Ka Karabiner

4.5 Assisted Dismantling Techniques

4.5a Vertical speedline



Description

A speedline set vertically, often running parallel to the stem of the tree. While this is not strictly a rigging technique, the principle is to allow the cut section to free-fall whilst preventing it from travelling away from the stem of the tree, both when it is falling and when it comes into contact with the ground. The key merit in this technique is that it allows some degree of control over the falling piece while significantly reducing the forces that are exerted on the stem.

Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Consider method of attachment to ensure that it will not catch resulting in a sudden stop.
4. Consider the fall of the line, ensuring that there will be an uninterrupted descent.

4.5b Pull line

Description

A line attached to a section of timber which is used to aid removal by introducing a force to ensure the cut section will fall in the intended direction (see illustration 4.3b). This technique will commonly be used on vertical or horizontal limbs where they are weighted or biased away from the desired direction of fall by lean or wind loading. A pull line is also used to control pendulum swing and to position a section as it is being lowered.

Principal Considerations

1. Identify section to be removed.
2. Estimate mass and centre of gravity.
3. Ensure a secure connection is made.
4. Apply force to line, under the direction of the aerial operator, until section begins to move in the desired direction.
5. Once section is being lowered, use pull line to guide section to desired landing place.

4.6 Pre-loading Lines

4.6.1 Pre-loading lines means removing slack and tensioning a rope in preparation for lifting or to help reduce the potential for high dynamic loading. This can be achieved simply by pulling on the rope manually or by using equipment to maximise the pre-load.

4.6.2 Pre-loading lines when lifting and lowering provides a number of benefits:

a. removes slack and reduces the distance a section will free-fall before being fully supported by the rigging system, e.g. when snatching;
b. creates a load bias towards the intended fall direction to prevent sections being misdirected, particularly when the section is backward leaning or wind-loaded against the direction of fall;
c. when lifting, it ensures the section will not drop before it is lifted – a drop could lead to the saw becoming trapped or the operator being struck; *and*
d. when lowering it can serve to hold a cut section stationary while other operations are carried out, such as the climber repositioning.

4.6.3 How does it work?

4.6.3.1 Pre-loading 'charges' the line with an opposing force to offset the weight of the section being removed.

4.6.3.2 In simple terms it is like a set of scales with the section on one side and the pre-load on the other. If the pre-load is equal to the mass of the severed section and the forces acting upon it, the scales will remain balanced. However, if the pre-load is greater than the mass and its forces, the scales will tip and the section will move. If the mass and its forces are greater, the rope will stretch.

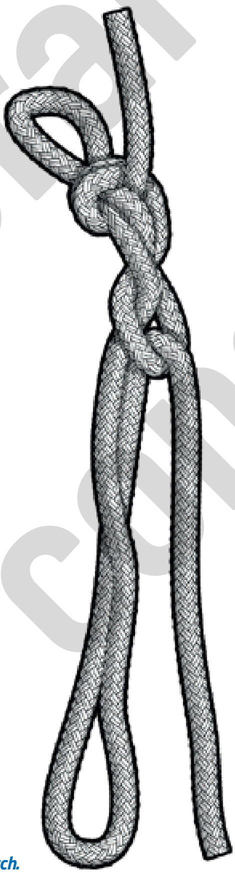
4.6.3.3 When applying a pre-load to a line, consider the following:

a. What is the desired objective – lift, pull, swing, remove slack or a combination of these?
b. What is the mass of the section?
   This will inform the amount of pre-load applied, e.g. if lifting or pulling, the pre-load will need to be greater than the mass and any forces acting upon it; if removing slack, the pre-load will need to be enough to offset the slack.
c. What method will be used to pre-load?
   A manual pull may be enough to swing a section or take up slack but it has limited capabilities when lifting, in which case mechanical advantage may need to be incorporated in the form of winches or pulley systems.
d. What type of rope is being used?
   Some ropes will have more elastic stretch than others and will require greater pre-loading before the mass of the section will move.

4.7 Mechanical Advantage (MA)

4.7.1 In tree rigging, mechanical advantage (MA) is the process by which a force is multiplied by using equipment such as winches or component assemblies such as fiddle blocks. MA is either incorporated within a rigging system or added to it. MA is particularly helpful when a pull or lift is required and there is limited force available, e.g. where one person is required to lift a mass which is greater than them.

4.7.2 MA systems are often rated using a ratio to express the load increase, such as 2:1, 3:1, 4:1 etc. Each of these ratios shows the load multiplication which is afforded by the system, e.g. a 2:1 system produces 2× the force which is put into it.



4.7.3 Carter's hitch.

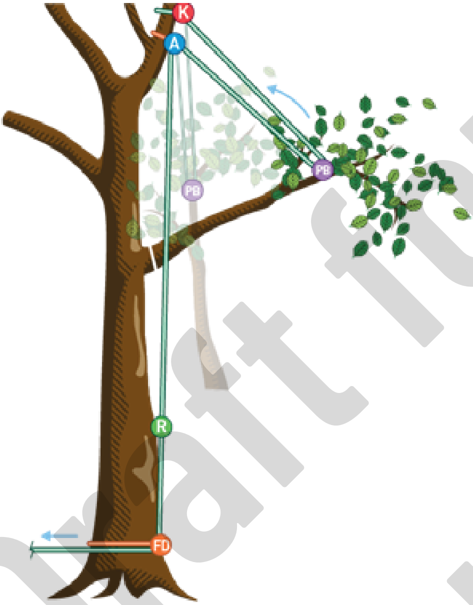
4.7.3 The most basic method of generating MA can be seen in the carter's or wagoner's hitch. This type of hitch can generate a very simple 2:1 increase in load without the need for additional components to be added. The MA can be worked out by counting the legs of rope that support the load. In the carter's hitch there are two legs of rope supporting the load which results in a force multiplication of 2×.

4.7.4 Component assemblies such as fiddle block sets or compression systems are more advanced systems which build on the principle of the carter's hitch. These systems are an assembly of pulleys through which a rope passes multiple times. Each time the rope passes through and creates a running leg of the system, the MA increases.

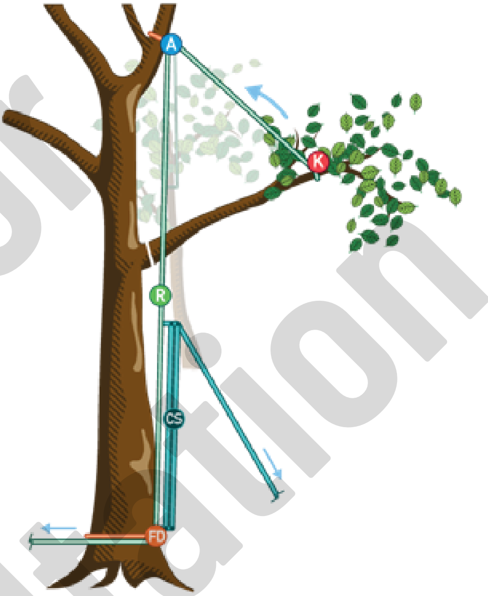
Image to come

4.7.4 Fiddle blocks.

4.7.5 The diagrams below show two common examples of when MA is used in rigging systems:



4.7.5.1 A pulley is attached to the section to incorporate mechanical advantage into the rigging system. The rope runs through both the anchor pulley and the section pulley and is terminated at or near the anchor.



4.7.5.2 Compression system attached to the rigging line to add mechanical advantage and help lift the limb.

4.7.6 Before using MA, operators should consider the following points:

a. **What is the maximum mass that needs to be moved?**
Knowing the mass of the section you intend to move will help inform the type of MA system or components used. For example, a rope-tensioning device built into a rope brake (i.e. a winch) can produce significantly more force than fiddle blocks on a rope.

b. **Can the system, its components and the anchors to which it is connected withstand the additional forces?**
Increasing the force using MA will help to provide additional 'power'. However, it will also increase the loads on other parts of the system. Always ensure that the components used and anchors in the structure are strong enough to withstand the anticipated loads.

c. **Will the section be lifted or pulled?**
If the section is lifted the system may be required to produce a smooth, consistent lift for longer than if the section is pulled, which may simply involve tipping it towards the intended fall direction.

d. **Will MA be required repeatedly in the rigging operation?**
If several lifts are to be done in succession, a system with incorporated MA, e.g. a rope brake with a built-in winch, may be preferable to a system which requires fiddle blocks to be clipped to the rope each time a lift or pull is needed.

e. **Will the load remain under control if the mechanical advantage is released?**
Should a control prusik or cam cleat be used? Can the speed of control ropes be maintained by the operator? Has all equipment been subject to function tests prior to be being fully relied upon?

Filler image to come

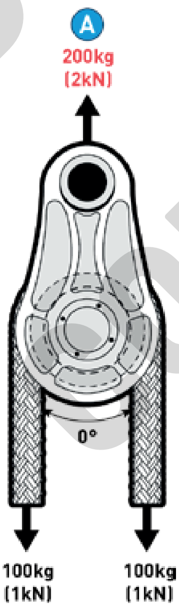
5

Anchor Forces

Checklist:

- **Has the system been configured to minimise potential anchor forces?**
- **Have appropriate measures been taken to manage friction within the system?**
- **Are redirects used to reduce potential anchor force where appropriate?**

Have you checked?



5.1.2 The anchor force created when the rope enters and exits a pulley at 0°.

5.1 Introduction

5.1.1 When a rope bends around a block or pulley, the forces in each leg add together to create the anchor force. For example, if two legs of rope are hanging straight down from a pulley or block, each with a force of 1kN, the anchor force would be 2kN.

5.1.2 The drawing below illustrates how, when a rigging system is supporting a timber section, the force applied to the top anchor point can be double that produced by the mass of the cut section. This must be taken into account to ensure appropriately rated equipment is selected for the system.

- If a timber section of 100kg mass is suspended by a rope directly from an anchor, the force of gravity exerted on the mass will result in an anchor force of approximately 1kN.
- If the same mass is suspended from one leg of a pulley, with the other leg anchored vertically below, the line force in the rope leg is the same as above, i.e. 1kN. The holding anchor below continues to sustain 1kN, **but the pulley must sustain the sum of both**.
- Force at pulley (2kN) = the force created by gravity acting on the mass (1kN) + the reaction force required to maintain the mass in suspension (1kN).

5.1.3 The multiplication of load on an anchor can vary depending upon:

a. how the system is anchored;
b. the angles at which rope will run into and out from the anchor;
c. friction within the system;
d. type of rigging system used;
e. peak loads generated; *and*
f. the amount of rope in the system.

5.2 Friction

5.2.1 Where a rope runs around an object, whether that is a branch or an item of anchor equipment, friction will be created between the two surfaces.

5.2.2 During dismantling operations ropes are generally required to slide around a smooth surface which may either rotate, such as a pulley, or remain static, such as a branch or a ring-to-ring-type device.

5.2.3 If anchor equipment other than a pulley is selected for a lowering operation, the tension will be different in the two sides of the rope (entering and exiting the anchor) because of friction.

5.2.4 Whilst it is possible to calculate the value of the friction at the anchor, in general terms the friction present means that ground staff are likely to feel that the mass on the end of the rope is lighter during lowering.

5.2.5 Considerations:

a. Friction introduced at the anchor does not automatically result in reduced peak load forces.
b. Additional friction introduced will require ground staff to be more vigilant in terms of letting sections run, avoiding a snubbing off* scenario.

* Snubbing off is where the lowering rope is held (either deliberately or inadvertently) causing the falling section to stop suddenly, resulting in potentially high peak loads.

5.3 Vectors

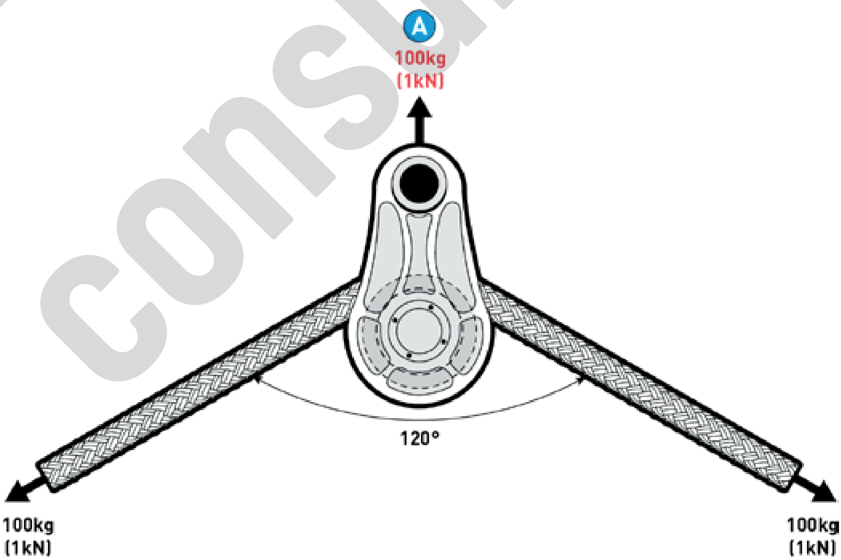
5.3.1 A vector is a force that has direction and magnitude (size). In rigging systems, the rope which is supporting the load will indicate which way the force is acting. If a rope runs through an anchor, a block or a pulley, the force will now be acting in two directions – that of each leg of rope. The resulting anchor force now depends on these two forces and the angle created by the ropes as they enter and exit the pulley.

5.3.2 If a rope enters and exits a pulley at a broad angle, the resulting force at the anchor will be less than two times the force in the rope.

5.4 Anchor Forces Varying with Rope Angle

Table of anchor force in relation to angle between the legs of the rope.

Angle between the two legs of rope	Anchor force
0°	2.00
30°	1.93
60°	1.81
90°	1.53
120°	1.00
150°	0.52
180°	0.00



5.3.2 The anchor force created when the rope enters and exits a pulley at 120°.

5.5 Redirects

5.5.1 A redirect is a deviation in the route of the rope which can be created using the natural features of the tree or with components such as pulleys, blocks and rings. Redirects are extremely useful in a rigging system because they can help to improve safety and efficiency.

5.5.2 Redirects may be used:

a. **To reduce the forces exerted on the structure by the rigging system.** A redirect can be used either before or after a main rigging anchor point to open the rope angle as it enters and exits the pulley. In this way the force at the main rigging anchor point can be reduced, helping to reduce the stress on the structure.

b. **To create a low friction route for a rope.** A rope routed through the canopy can make contact with the tree at a number of points. Using pulleys, blocks or rings at the contact points can help to reduce abrasion caused by friction, avoid damage to parts of the tree which are being retained and maintain a more consistent level of friction for more predictable lowering.

c. **To divert the fall of the rope to move the intended drop zone.** The fall of the rope as it exits a pulley may not always result in the load being directed towards the drop zone. By using a redirect, the fall of the rope can be diverted, allowing the load to be brought down into the preferred location. (See also fishing pole rigging – 4.3a.)

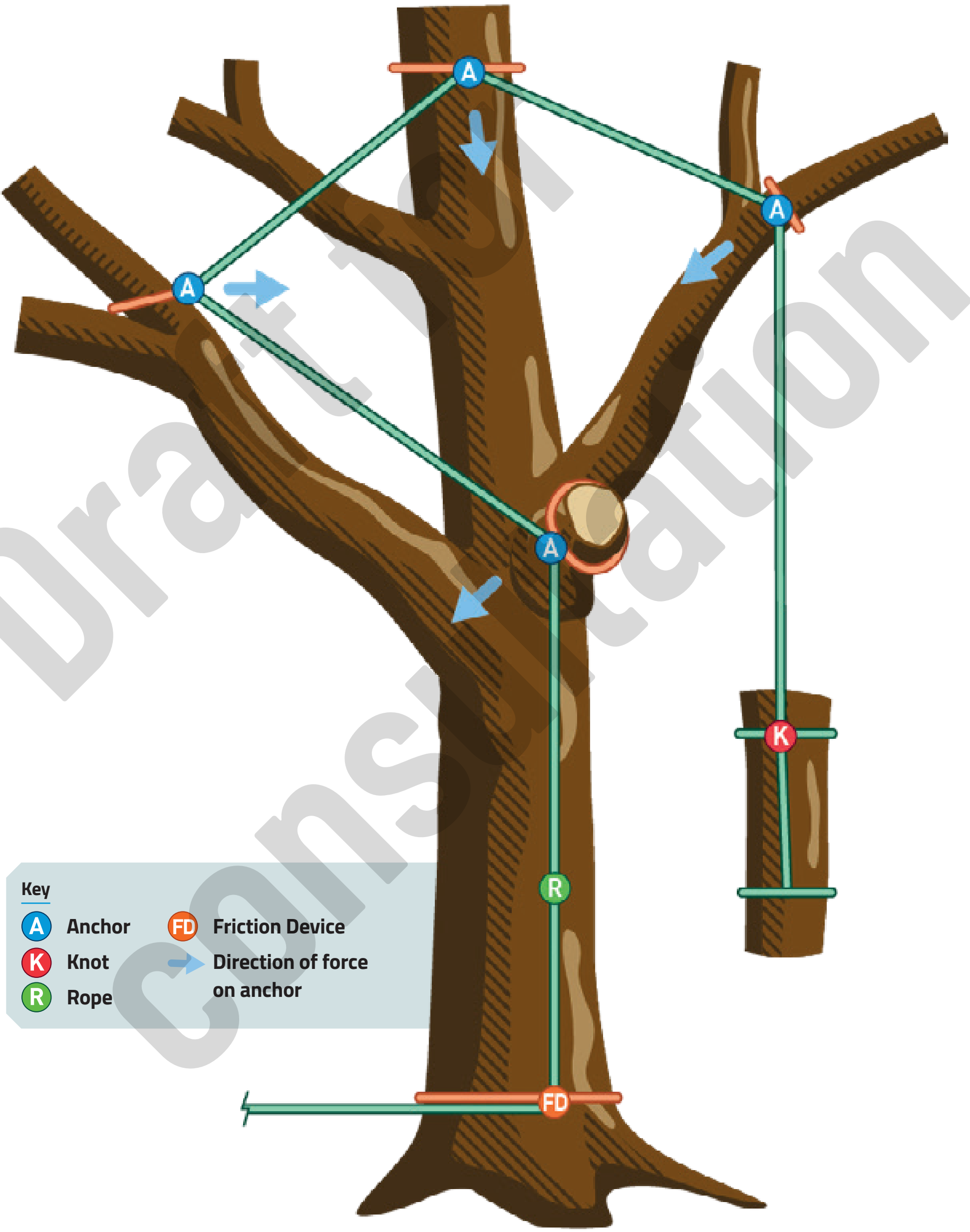
d. **To reduce or eliminate the potential for a pendulum swing.** In much the same way as a redirect can be used to move a load into a drop zone, it can also be used to reduce or eliminate a pendulum swing which could occur when a section is cut from a long lateral limb where the rigging point is located more centrally within the tree. (See also fishing pole rigging – 4.3a.)

e. **To act as a fairlead for the rigging rope.** If the rope enters a pulley or friction device at an unfavourable angle, i.e. where the rope is not being fed directly into the pulley and is rubbing on the cheek plates or misaligned as it enters the friction device, a redirect can fairlead the rope in the required direction and reduce potentially harmful effects such as increased friction, rope distortion, heat build-up and component misconfiguration.

5.5.3 Principal safety considerations

Redirects can provide a range of benefits in a rigging system, as set out in 5.5.2. However, caution must be exercised because they can also introduce unexpected forces to parts of the tree structure. Redirects may often be located away from the main structural parts of the tree in order to serve their intended function, often along lateral limbs. In these circumstances, the load placed on the limb will be acting in both tension and compression. The tension will be acting on the top of the limb and the compression will be acting both on the underside of the limb and axially down it.

5.5.2–5.5.3 Redirects – spreading the load.



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6

Operator Positioning

Checklist:

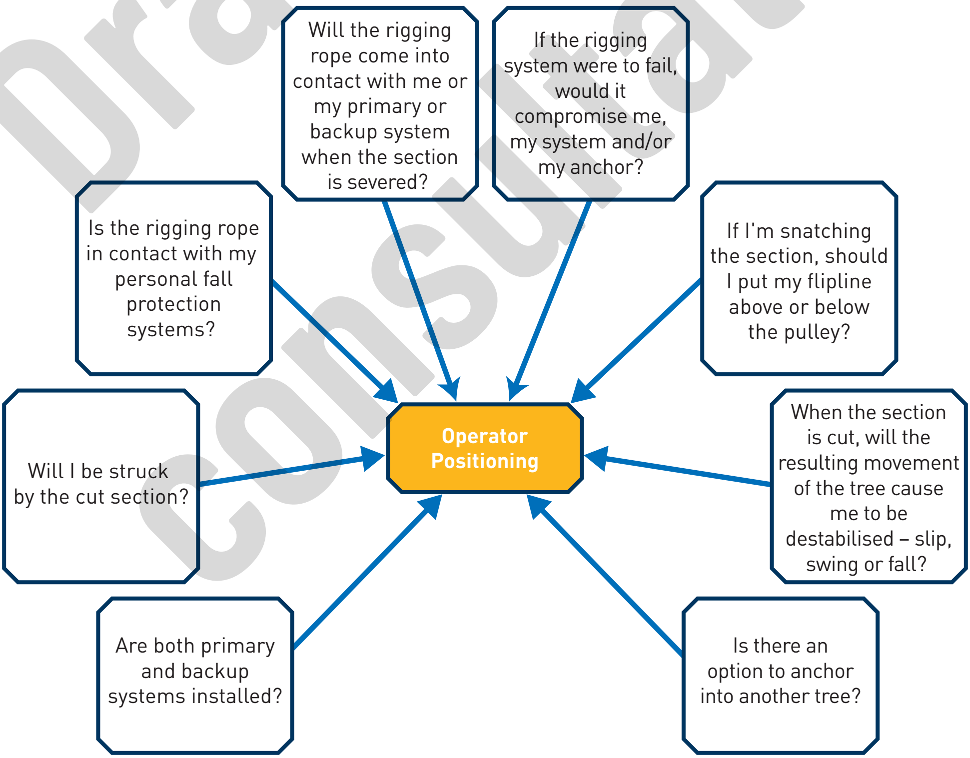
- **Is the operator positioned so as to avoid being struck by the cut section?**
- **Has the operator achieved the best position to make accurate cuts?**
- **Is the operator's personal fall protection system positioned so as to avoid being cut?**
- **Are the operator's primary and backup systems positioned so as to avoid being struck by the rigging rope or cut section?**

Have you checked?

6.1 General

During any aerial tree work at height operation, the position of the operator relative to the work being undertaken is crucial to their safety. This is never more important than during cutting, and especially when rigging the cut sections, because of the many different factors which must be considered in order to maintain safety.

The diagram below sets out a number of the factors to consider in relation to operator positioning and safety.



6.1 Considerations for operator positioning.

6.2 Cutting Techniques

6.2.1 The cutting technique selected must be safe and effective. For guidance on the type of cut and the preparation of the equipment prior to work, see *Technical Guide 2: Use of Tools in the Tree*. However, as a result of increased technical complexity, rigging scenarios can present a more challenging work environment, with an increased number and variety of hazards.

6.2.2 Operators must ensure that all appropriate measures are implemented to prevent, or reduce the consequences of, inadvertently cutting the primary and/or backup system:

a. correct use of primary and backup systems;
b. correctly positioning systems prior to cutting;
c. ensuring that the operator has a stable posture;
d. using equipment such as cut-resistant lanyards*;
e. using chainsaws with appropriate bar length;
f. opting to use a handsaw as opposed to a chainsaw where applicable; *and*
g. anchoring within an alternative structure.

* Whilst a cut-resistant lanyard can reduce risk in the event of the chainsaw striking the system, operators are not specifically required to use one.

6.2.3 An operator using a chainsaw must decide whether a pulling or pushing chain is more appropriate. This will often be determined by:

a. the size of chainsaw being used;
b. the diameter of the section being cut;
c. the operator's position relative to the stem (whether it is on their left or right side); *and*
d. which method provides the operator with the best view of the cut and therefore the greatest level of accuracy.

6.2.4 When an operator is positioned on a stem during snatching, they will also have to decide the optimum placement of their lanyard relative to the anchor block/pulley. The two main options are lanyard above the pulley or lanyard below the pulley. Both are acceptable but they have different advantages and disadvantages, some of which are shown in the table below.

6.2.4 Lanyard position relative to anchor block/pulley.

Lanyard position relative to the anchor block/ pulley	Advantages	Disadvantages
Lanyard above	■ Lanyard is clear of the pulley and the running rope. ■ Lanyard will not become trapped after section has been cut and rigging system is under tension. ■ Potential for improved levels of support because lanyard is positioned higher.	■ Lanyard is closer to the cut being made and therefore at greater risk of being cut. ■ Distance between cut and rigging point is increased to accommodate lanyard. ■ Potential for lanyard to flip off the top of the stem if significant movement is generated after the section is cut.
Lanyard below	■ Lanyard is further away from the cut. ■ Very low likelihood of lanyard flipping off the top of the stem if significant movement is generated after the section is cut. ■ Rigging point can be closer to the cut being made, helping to reduce potential reaction forces.	■ Lanyard may become trapped after the section is cut and rigging system is under tension. ■ Lanyard may come into contact with running rope and be damaged. ■ Potential for reduced levels of support because lanyard is positioned lower.

6.2.4 *Operator positioned on a stem with lanyard above rigging point.*

6.2.4 *Operator positioned on a stem with lanyard below rigging point.*

6.2.5 Whilst working on a stem, climbers must ensure they always have a secure connection to the stem by means of a system which allows them an uninterrupted descent to the ground without the need to re-anchor. There are a wide variety of ways that this can be achieved. Two examples are shown below.

6.2.5a *Cinched climbing system using a running bowline. The ring is used to reduce rope-on-rope contact. The climber would need to install additional friction before descending on this system.*

6.2.5b *Operator positioned on a pole using a cinching false anchor. The major benefit of this type of system is that an operator does not need to incorporate additional friction prior to descent.*

Filler image to come

7

System Components

Checklist:

- Are components suitable for the chosen application?
- Are components being used in accordance with manufacturers' guidance?
- Are the components compatible with their neighbouring components?
- Are components being loaded correctly?
- Have components been configured to prevent overloading of individual elements and/or the entire system?
- When assembled as a system, are the components within it correctly configured?
- Have measures been taken to avoid misconfiguration?

Have you checked?

7.1 General

7.1.1 A component of a system is any single part or adjoined parts functioning as a whole (such as a friction device with integrated ratchet system). Components are constructed of either hardware or textile or a combination of the two (referred to as a modular components).

7.1.2 Every component, regardless of its composition, must be suitable for the chosen application. There will often be a wide range of equipment available for a single application and the selection process should, at the very least, consider:

a. the load that the component could be exposed to, factoring in worst-case scenario loading;
b. the consequences of component failure and the effect it would have on other parts of the rigging system and the tree structure;
c. the position/location that the component will be used in;
d. the possibility of misconfiguration when the system is loaded and unloaded; *and*
e. the construction materials of the component and the environmental stresses they will be subjected to whilst installed in the rigging system.

7.2 Hardware Components

Hardware components are made principally of metal or a composite material. They are generally more robust than textile components and have greater environmental resilience. Examples:

a. blocks, pulleys, and rings;
b. trolleys;
c. friction devices and lowering bollards with integrated winches;
d. connectors – open and closed;
e. rigging plates, hubs, backbones;
f. rigging wrench.

7.3 Textile Components

Textile components are made principally of cordage and/or webbing. They are generally less resilient than hardware components because of the materials used and their lower tolerance of environmental conditions. Examples:

a. rope;
b. slings – endless;
c. slings – soft-eyes;
d. slings – eye-to-eyes;
e. slings – adjustable e.g. whoopie, loopie.

7.4 Modular Components

7.4.1 A modular component is anything which has both hardware and textile elements. Modular components range from Ploopie slings (a looped sling with a pulley integrated into it) to rope brakes with an integral winching function.

7.4.2 The hardware and textile elements of any modular component will respond differently to the environmental stresses presented in a tree rigging scenario. This must be taken into account when a decision is made to use the component in a specific context and when carrying out an inspection for functionality and safety.

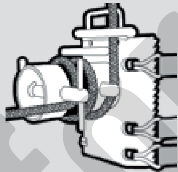
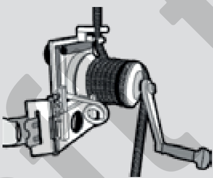
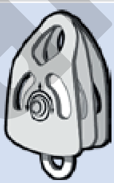
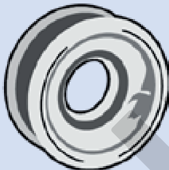
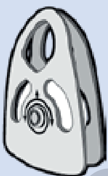
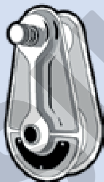
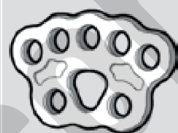
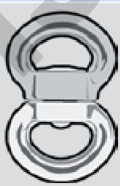
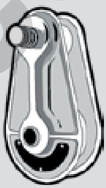
7.5 Connectors

7.5.1 Connectors are components used to connect elements of a rigging system. Operators building a system need to ensure that all connecting elements are compatible with neighbouring components and correctly configured. Refer to manufacturer's guidance to ensure that the application for which the connector is to be used meets the specifications.

7.5.2 General safe practice:

a. Only use connectors where they can be configured to ensure they are loaded correctly. Captive accessories or cinching techniques between hardware and textile components may help to ensure components remain aligned correctly.
b. Ensure a connector is not exposed to a load that exceeds its stated safe working load (SWL). (See section 8.1 for definition of SWL.) Worst-case-scenario peak load calculations will allow an operator to select suitable components. Equipment selected with a higher SWL, such as steel connectors for rigging, may also help provide a greater margin of safety.
c. Where applicable, select a locking mechanism that prevents the connector opening inadvertently and reduces the risk of rope roll out, e.g. autolocking gate mechanisms.
d. Ensure that hardware items designated for rigging operations are not used as part of personal fall protection systems.
e. Monitor the position of connectors within the system throughout the task, ensuring alignment and correct configuration are maintained.

7.6 Summary of Component Types

Component type	Image	Scope of use
Rope brakes	  	■ Used to add friction within a rigging system to allow greater control of the section being lowered. ■ Devices with integrated mechanical advantage which can facilitate lifting as well as lowering.
Pulleys and blocks	   	■ Used to create a low friction point through which the rigging rope can run. ■ Enables lifting and lowering of sections whilst removing harmful levels of friction. ■ Can be set in rigging systems as the principal rigging anchor point or as redirects to change the path of the rope. ■ Can be configured in series to create mechanical advantage.
Anchors	  	■ Provide an attachment interface between the structure and rigging system. ■ Can facilitate attachment of multiple pieces of equipment. ■ Can be used to prevent misconfigurations in use (swivels). ■ Can help to accommodate multi-directional loads.

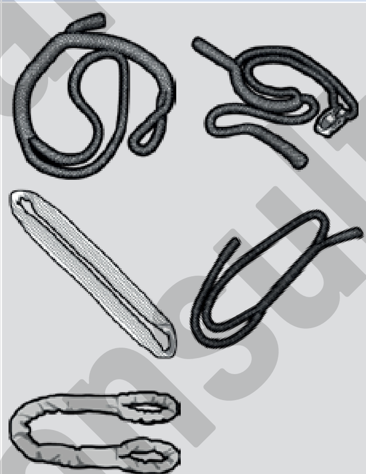
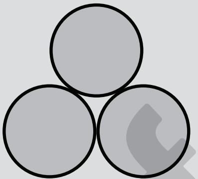
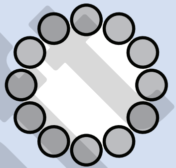
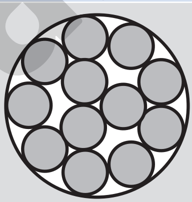
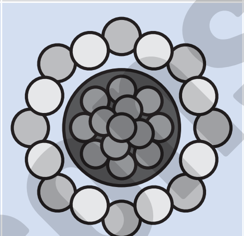
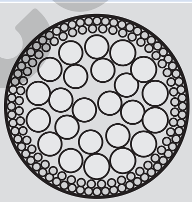
Component type	Image	Scope of use
Connectors		■ Provide a secure connection between other elements of the system or anchors connected to the structure.
Slings		■ Come in a wide variety of configurations and sizes which facilitate connections between the system and the structure or between neighbouring components. ■ Can be chokered on timber to minimise slipping. ■ Some slings are of modular design incorporating rings or pulleys which can provide an attachment to the structure as well as a rigging point through which the rope can run.

Table continues over page.

Ropes

Construction	Cross-section image	Scope of use
Twisted/plaited 3, 6, 8 (multi-plait) strand		■ The most basic rope construction. Has a multitude of applications. Most commonly used as a pulling rope but could be used for rigging operations where an operator may wish to use a natural crotch method.
Hollow braid 12 strand		■ This type of rope construction is often used for making rope tools such as whoopie, loopie and ultra slings which constrict when under tension. This is due to its simple construction which also facilitates splicing.
Solid braid 12 strand		■ A simple but robust construction suitable for most rigging situations, with or without the use of blocks and pulleys. ■ Solid braids tend to have greater strength, lower stretch and overall better handling characteristics than twisted or multi-plait ropes. ■ No outer sheath, so this type of rope is also suitable for natural crotch rigging.
Single braid 16 strand		■ A rope type associated more with PPE applications than rigging. It bears the majority of any load on its outer sheath, whilst the core preserves the profile of the rope when under load. ■ A good all-rounder suited to a wide variety of rigging applications from pull-lines to main rigging ropes.
Braid on braid/ double braid		■ Possibly the most common rope construction associated with rigging operations, due principally to its handling characteristics, knot-ability and size-to-strength ratio. ■ Load is shared between the inner core and outer sheath, giving it superior strength properties. ■ Best suited to rigging situations with low-friction rigging points because of the load share between the inner core and outer sheath.

8

Working Loads

Checklist:

- What is the Safe Working Load (SWL) of the equipment to be used?
- Is the SWL adequate for the intended load or could the SWL be exceeded?
- What safety factor is being used to calculate the SWL and does it allow for age/wear and tear?

Have you checked?

8.1 Terms and Definitions

Minimum breaking strength (MBS): The load above which an item of equipment might fail when it is new, as determined by the manufacturer.

Working load limit (WLL): The load that an item of equipment can safely lift, lower or suspend when it is new, as specified by a manufacturer. This does not account for particular service conditions.

Safe working load (SWL): The load that an item of equipment can safely lift, lower or suspend based on particular working conditions, as specified by a competent person. The SWL may be lower than the WLL.

Safety factor (SF): The relationship between the MBS and the WLL/SWL, often expressed as a ratio.

8.2 Why do we Need a Safe Working Load?

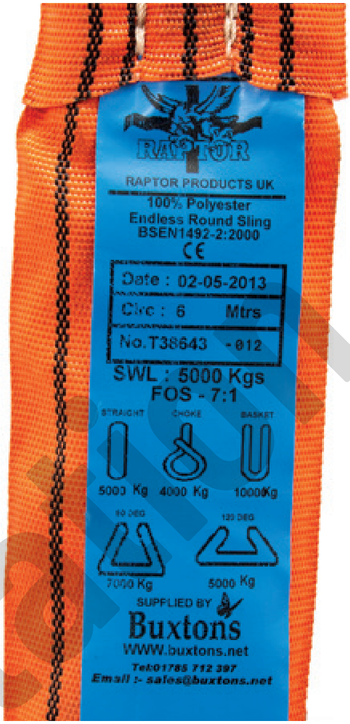
8.2.1 All equipment used in a system for dismantling operations must have a stated SWL, i.e. the load that an item of equipment can safely lift, lower or suspend based on particular working conditions, as specified by a competent person.

8.2.2 In order to guarantee its safe use for the duration of its determined service life, lifting equipment should not be loaded in excess of its SWL. Rope is given a higher factor of safety than metal components due to deterioration, wear over time and configured strength, e.g. when knotted. The strength of a rope may be significantly below its original MBS.

8.2.3 Using a high safety factor when loading rope will ensure that it is suitable for the next lifting/lowering operation. For rope constructions and fibres that elongate when loaded, recovery of stretch is quicker with higher safety factors.

8.2.2a *Loading parameters of the equipment as marked by the manufacturer – MBS.*

8.2.2b *Loading parameters of the equipment as marked by the manufacturer – MBS and WLL.*



8.2.2c *Loading parameters of the equipment as marked by the manufacturer – SWL and Factor of Safety.*

8.3 Cycles to Failure (CtF)

8.3.1 The principle of cycles to failure recognises that every time an item of equipment is used (a cycle) it gets closer to the point at which it may fail. In practice, the potential for failure is avoided by carrying out regular pre-use inspections and thorough examinations and following the manufacturer's guidance on use, maintenance, repair, storage and dates for withdrawal from service.

8.3.2 The number of cycles to failure is rarely stated because it is dependent upon a number of variables, some of which are listed in section 8.3.1. Exceeding an item's SWL is one of the most common occurrences which can cause a significant reduction in the number of CtF.

8.3.3 CtF are based on the assumption that an item of equipment is used within the parameters of its stated SWL. For example, a karabiner has an MBS of 25kN and the resulting SWL is given as 500kg (a 5:1 safety factor, or 20% of the load at which it may fail). Using the karabiner at 20% of its MBS allows multiple cycles of use before it may need to be withdrawn from service due to age or wear and tear.

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9

Compatibility and Configuration

Checklist:

- Is the component intended for use compatible with its neighbouring components?
- When configured within the system, will the component function as intended by the manufacturer?
- When configured and in use, will the component remain compatible with its neighbouring components?
- Is the component made from materials which will be compatible with its intended use?
- When in use, will textile components be subject to movement causing a bend, and if so, will that bend create a significant strength loss?

Have you checked?

9.1 Introduction

9.1.1 To optimise performance and ensure any rigging system functions safely, all components must not only be compatible with one another but also be correctly configured in accordance with their design and construction.

Compatibility: The ability of components to function together, without detriment to any element.

Configuration: A collection of parts where the relative organisation of components is defined.

9.1.2 The principle which underpins compatibility and correct configuration is that the function of an individual component should not hinder or adversely affect the operation of the system as a whole or any of the parts within it.

9.1.3 There are a number of elements to consider when selecting components and incorporating them into rigging systems. Some are generic and others apply only to certain types of components.

9.2 Generic Points to Consider when Selecting Components

9.2.1 Application: where and how the item is to be used:

a. only use the component in the manner for which it has been designed; *and*
b. follow the manufacturer's guidance on safe use.

9.2.2 Construction, design and materials:

a. abrasion and heat resistance – polyester ropes have far better abrasion and heat resistance than high modulus polyethylene (HMPE) ropes, whereas an HMPE rope of the same size will often be significantly stronger;
b. elongation – low-stretch components will be well suited to lifting or winching scenarios, whereas components with greater elongation will be better where dynamic loads may be encountered;
c. fixings – when under load, any fixing or method of attachment must not be able to open inadvertently or loosen, e.g. a remotely tied timber hitch may be more likely to untie when slack, whereas a running bowline may be more secure in the same conditions;
d. materials – a steel karabiner connected to an aluminium swing cheek pulley will, during use, cause deformation in the pulley because the steel is harder than the aluminium.

9.2.3 Alignment: reduce the risk that components could become incorrectly configured. For example, a karabiner may be correctly orientated when not loaded, but it could become three-way loaded when under load. This can be avoided by using a karabiner with a different profile or a cinching attachment.

9.2.4 Functionality: friction control and overall dimensions. Size will often be a deciding factor when selecting components, and operator's preference may tend towards smaller and lighter items of equipment. However, sometimes this can be detrimental, particularly in the case of rope brakes, as a small-diameter bollard used with a large-diameter rope can result in rope damage and strength loss.

9.2.5 Strength and loading: Strength is one of the most significant selection criteria and should be considered in relation to the component's application and also its location within the system, e.g. a soft-eye sling used to connect at a main rigging anchor point during snatching operations will be subject to far greater loads than if it is used only for rigging-point-above operations.

9.2.6 Mode of attachment to structure, device or system:

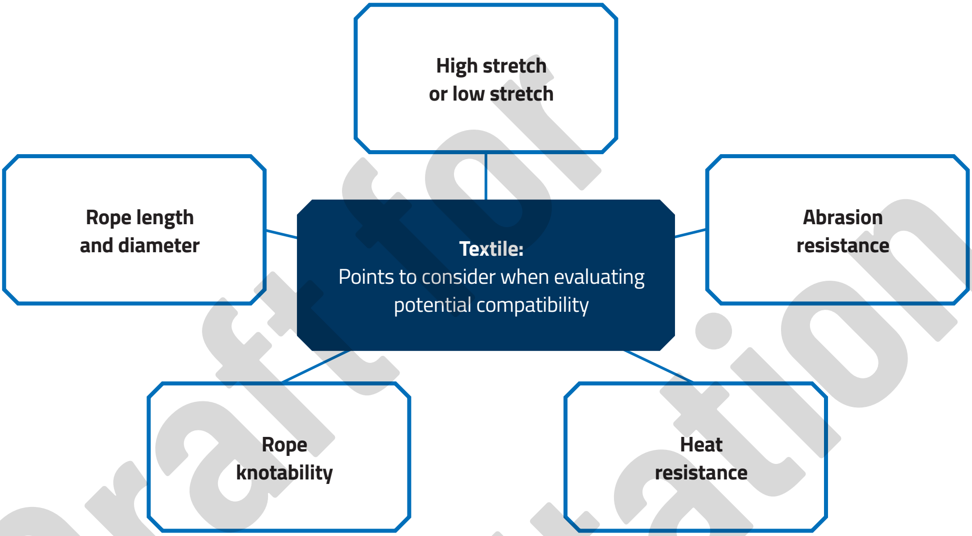
a. When connections are to be made in a system, consider the type of loading the component will be subject to. Hardware components may be stronger but will often be less tolerant of dynamic loading than textile ones.
b. Selecting the most appropriate knot will have a direct impact on the security of the attachment to the structure/section and also on the strength losses the knot will cause, e.g. a timber hitch may provide a secure connection to the stem but a cow hitch will most likely cause less strength loss and have greater gripping capabilities.

9.2.7 Type: a single component or an assembly of components. Lifting systems can be created using multiple pulleys and connectors. However, a rope brake with integrated mechanical advantage capabilities may be more appropriate for rigging operations when a series of branches need to be lifted as part of a sequence of lowering operations.

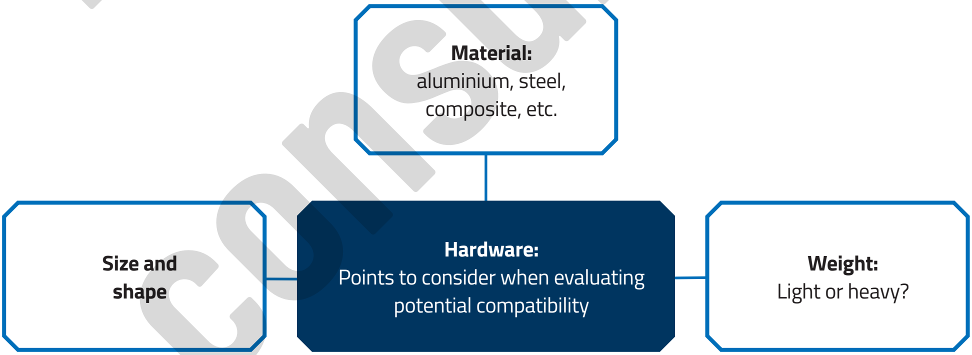
9.2.8 Duration of use: When a rigging system is configured and the potential peak loads are calculated, it may be that the rope will be subject to loads within its capabilities and less than its MBS. However, because the stated SWL is calculated using a 10:1 safety factor, the rope may be deemed unsuitable for the system because the loads will exceed the SWL. If the safety factor is reduced to 5:1, this increases the SWL, enabling the rope to be used within its safety parameters. If the safety factor is reduced in this way, the rope's lifespan must be shortened to reflect the increased loading it will experience. (See section 11.1)

9.2.9 Ergonomic constraints: Operator efficiency and comfort have a direct effect on safety. For example, in situations where rigging components are frequently moved during the course of an operation, an operator may wish to choose smaller, more lightweight components, particularly if they are being transported on the harness.

9.3 Points to Consider when Selecting Textile Components



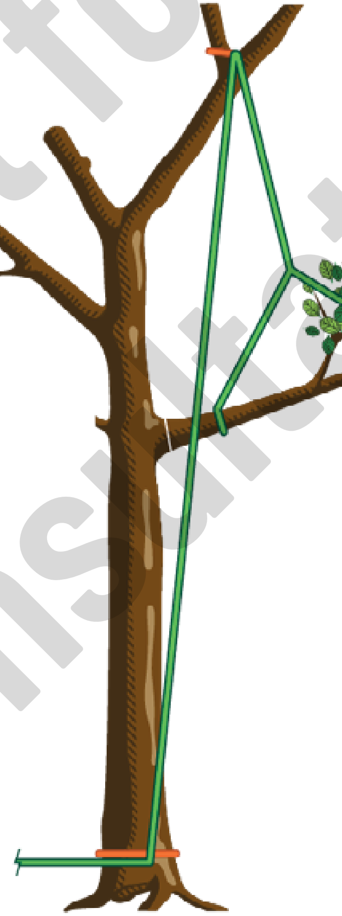
9.4 Points to Consider when Selecting Hardware Components



9.5 Incompatibility and Incorrect Configuration

Incorrect: Sling chokered to pulley cheek plates.

Incorrect: Oversized rope running through small pulley.



Incorrect: Chokered karabiner.

Incorrect: Three-way loaded karabiner at branch attachment.

Incorrect: Oversize rope running through small diameter friction device.

Incorrect: Three-way loaded karabiner at friction device.

9.6 Bend Ratios

9.6.1 Introduction

In the context of ropes and textiles within rigging systems, a bend ratio is the relationship between the diameter of the rope/textile and the diameter of the surface around which it will turn.

It is important to understand that any bend or twist that occurs in a textile component like a rope or a sling can create strength loss. The tighter the bend, the greater the strength loss will be; the opposite is true of a wider bend. Therefore, when assembling a system, operators must be aware of the nature and frequency of the bends in any textile component, particularly ropes which are running.

In rigging systems, bends can occur whenever a rope is:

a. knotted;
b. attached to a pulley or block;
c. running through a pulley or block;
d. running around a rope brake; *or*
e. travelling around a stem or branch.

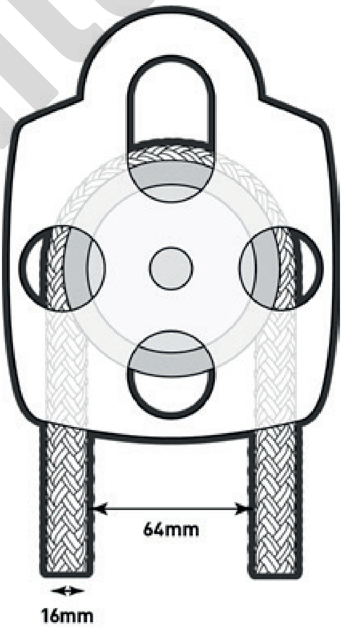
In textiles such as slings, bends occur most often when the component is attached to a stem or branch by knots or chokers.

9.6.2 Preferable bend ratios

Bends in ropes and textiles are unavoidable in rigging systems, so preferable bend ratios should be adopted to minimise any strength loss.

Preferable bend ratios can be applied in two different circumstances:

a. **Stationary – 3:1:** that is, when the rope or textile does not run around or over the bend, e.g. when it is in a knot or fixed to a pulley or block. In practice this would mean that the diameter of the surface around which the rope or textile is bending would be 3× the diameter of the rope, e.g. a 16mm-diameter rope would be around a 48mm-diameter pulley sheave.
b. **Running – 4:1:** that is, when the rope or textile runs around or over the bend. In practice this would mean that the diameter of the surface around which the rope or textile is running would be 4× the diameter of the rope, e.g. a 16mm-diameter rope would run around a 64mm-diameter pulley sheave.



9.6.3c Preferred ratio of 4:1 in a running pulley.

The reason for the difference between the two ratios is that when the rope is running around or over a bend there is friction between the fibres which increases the detrimental effects.

9.6.3 Avoiding bad bend ratios

Bad bend ratios are where ropes or textiles take tight turns around an object. They are particularly detrimental when the rope is required to move or run around the bend.

To avoid bad bend ratios, follow these basic steps when configuring a rigging system:

a. Identify where bad bends could occur (see examples below).
b. If a rope is involved, identify whether it will be running or stationary.
c. If the rope is running, apply a minimum ratio of 4:1.
d. If the rope is stationary, apply a minimum ratio of 3:1.

9.6.3a *Bad bends: example 1 – large diameter rope running round a small capstan.*

9.6.3a *Bad bends: example 2 – large diameter rope running through a karabiner.*

Filler image to come

10

Using Knots and Slings

Checklist:

- Are appropriate knots being used to ensure the security of the load?
- Have the knots been tied, dressed, and set correctly?
- Are the knots and slings being used appropriately given the application?
- Are slings configured to minimise strength loss and ensure the security of the load?

Have you checked?

10.1 Introduction

10.1.1 Knots and slings are most often used to form attachments or connections, either within the rigging system or from the system to the structure or section of timber to be removed. Common uses for knots and slings:

a. knots
   i. to create terminations in ropes into which components such as karabiners can be attached;
   ii. to attach a rope to the cut section, e.g. running bowline tied around a branch to be lowered;
   iii. to attach a rope when pulling or drifting sections;
   iv. to terminate a rope to prevent it slipping through a device or knot, e.g. figure of 8 stopper behind a bowline; *or*
   v. to create a midline loop for attaching tools and equipment, e.g. a marline spike hitch or a midline loop such as an alpine butterfly for additional connections such as spider leg slings when cradling limbs.

b. slings
   i. to attach components to the structure, e.g. a whoopie sling attaching a rope brake to the base of the tree;
   ii. to form a connection between the rope and the section being removed, e.g. chokered around a branch and clipped into a karabiner in the end of the rigging line; *or*
   iii. to create a midline attachment in the form a friction hitch when cradling or balancing.

10.1.2 Timber sections or branches will most often be attached to the rigging system using either a direct rope attachment, where a knot or series of knots is used, or a component which acts as an interface, such as a sling. Where a sling is used some type of opening connector is needed between the two parts. This will commonly be a karabiner.

10.2 Knots and Hitches

Primary knots: A primary knot requires no secondary hitch in order to retain its integrity or grip against an object, e.g. a running bowline.

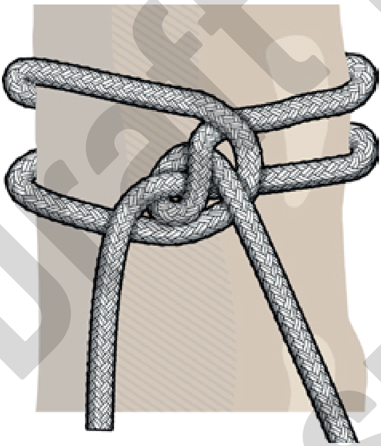
Primary hitch: A primary hitch requires a secondary hitch in order to retain its integrity or grip against an object, e.g. a clove hitch or a cow hitch.

Secondary hitches: A secondary hitch is used in addition to a primary knot or hitch to create extra security and/or to spread the load when a rope is attached to an object, e.g. a half hitch or marline hitch.

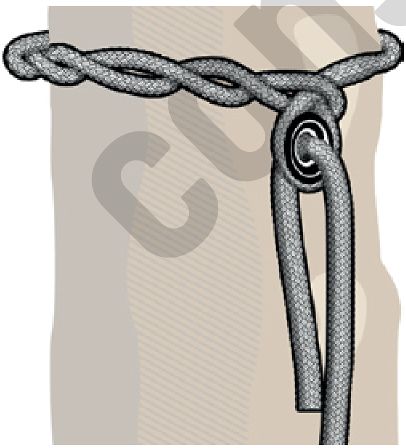
Whatever method is chosen to connect the parts of the system, the parts must not be able to accidentally disconnect or misconfigure during the operation. For example, it is better to use certain knots and slings only where the system remains under tension throughout the operation.

The method chosen will depend upon the rigging technique, system components and the limitations of the equipment available.

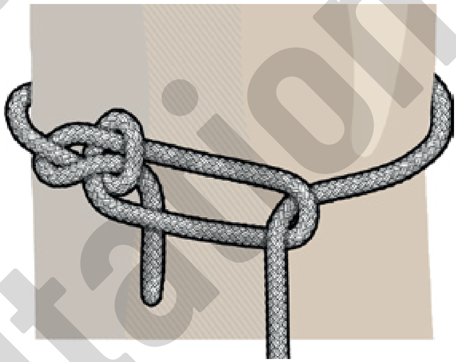
10.2.1 Direct rope attachment: primary knots and hitches



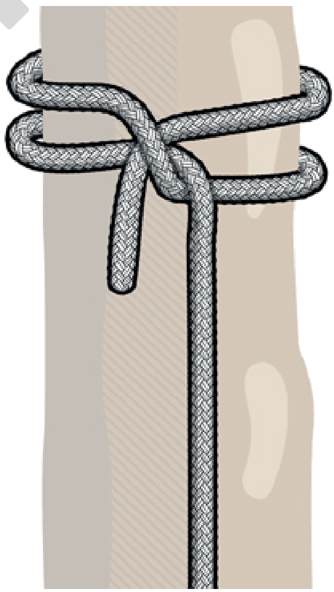
10.2.1a Cow hitch with half hitch.



10.2.1b Timber hitch.



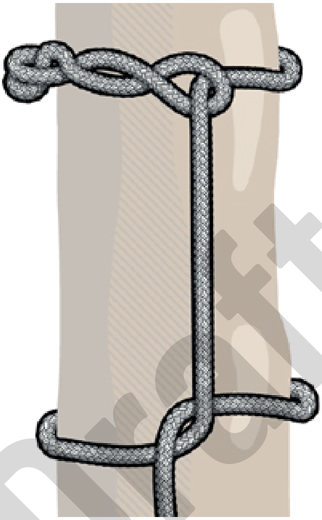
10.2.1c Running bowline.



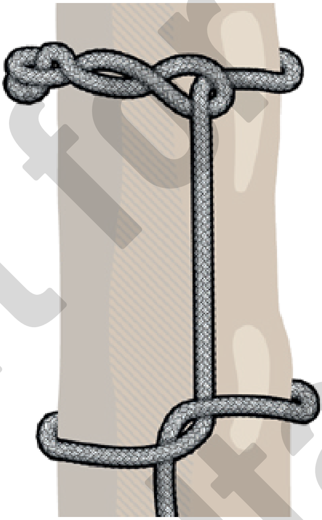
10.2.1d Clove hitch.

10.2.2 Secondary hitches

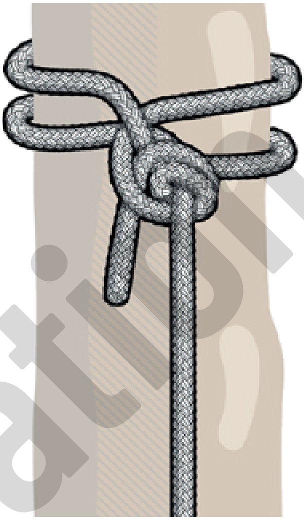
These hitches can be used in conjunction with one of the knots or hitches listed in 10.2.1 to provide extra security to the primary attachment point and can be set directly to the log section or incorporated into the primary knot/hitch itself as in the case of the clove hitch with two half hitches.



10.2.2a *Timber hitch with half hitch.*



10.2.2b *Timber hitch with marline hitch.*

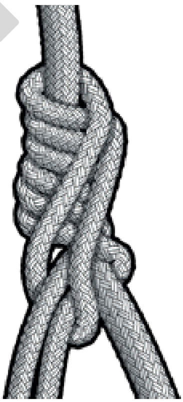


10.2.2c *Clove hitch with two half hitches.*

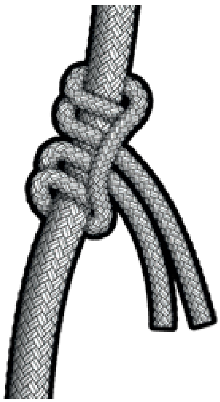
10.2.3 Midline attachment

Midline knots can be used where it is necessary to create a loop to attach a component to a line (such as a progress capture when lifting or hauling) or where the end of the line is required to form an independent connection to a section of timber (such as in a cradle/balance).

10.2.3a *Butterfly knot.*



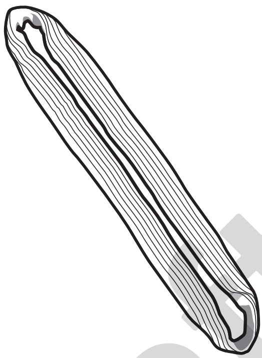
10.2.3b *Klemheist hitch.*



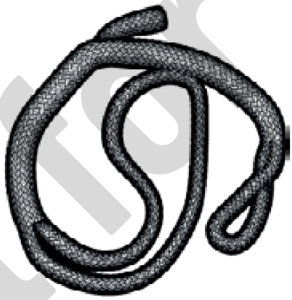
10.2.3c *Prusik hitch.*

10.3 Slings

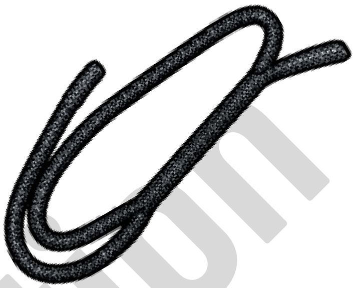
Slings are versatile and can be used in a variety of situations. Depending upon their construction, they can be attached to the structure or tree section in different ways.



10.3.1a Endless sling.



10.3.1b Whoopie sling.



10.3.1c Loopie sling.

10.3.1 Types of sling

Type of sling	Common use	Modes of connection
Endless	Attaching the rigging rope to the section being removed.	Choker Basket
Soft-eye	Creating false anchors for attaching components to the tree such as pulleys, blocks and rope brakes.	Choker
Loopie	Creating false anchors, attaching components to the tree or attaching the rigging rope to the section being removed.	Choker Basket
Ploopie	Creating a rigging point or attaching to the section being removed.	Choker Basket
Whoopie	Creating false anchors for attaching components to the tree such as pulleys, blocks and rope brakes.	Choker Basket
Ultra	Creating false anchors for attaching components to the tree such as pulleys, blocks and rope brakes.	Choker

10.3.2 Sling construction

Slings are constructed using a variety of different materials and sometimes combinations of materials. The selection process must consider the type of material they are made from in relation to their application. The table below sets out common materials used for sling construction and their characteristics.

Material(s)	Also known as	Characteristics
PES	Polyester	Strong. Low stretch. Low water absorption and shrinkage when wet. Very good abrasion and UV resistance.
PA	Polyamide, Nylon	High strength-to-weight ratio. Good energy absorption. Good resistance to abrasion and most chemicals. Prone to water absorption, shrinkage and strength loss when wet.
HMPE – high modulus polyethylene	Dyneema, Spectra	Very strong. Low stretch. Does not absorb water, shrink or lose strength when wet. Good UV resistance. Relatively low melting point compared to other fibres which means it does not deal well with high friction settings.
High modulus polyamide	Aramid, Technora, Kevlar	High strength. Low stretch. Good tolerance of heat and greater ability to deal with friction than HMPE fibres.
High modulus polyester	Vectran	High strength. Low stretch. Good heat and chemical resistance. Low UV resistance and a tendency to snag due to fine fibres so works best with a protective sheath.

11

Strength Loss in Rigging Components

Checklist:

- **Have the system and its components been configured to minimise strength losses?**
- **Has the most appropriate method of strength loss calculation been used?**

Have you checked?

11.1 Introduction

Factoring in strength loss is particularly important when assembling a rigging system because the way in which a component is configured can significantly affect its residual strength. Strength loss relative to configuration can often be most easily identified in textiles, particularly ropes and slings.

11.2 Strength Loss – Rope

11.2.1 Whenever a bend is made in a rope, the strength of the rope will be reduced. Where a knot creates a very tight bend, the strength loss will be even greater. A knot or series of knots will cause strength loss and therefore must be accounted for.

11.2.2 Strength loss is a factor which is used to calculate the safe working load (SWL) of an item of equipment, and its magnitude is dependent on the way and the environment in which the item is used.

11.2.3 The principle of strength loss should be applied to inform the SWL when the item is brand new. This ensures that the item will not have been exposed to any circumstances or environments which could have already adversely affected its SWL.

11.2.4 A strength loss calculation must take into consideration:

a. type of material – textile, hardware, or a combination of both;

b. configuration – if the item could be used in many different ways, it is prudent to consider a worst-case scenario based on the weakest configuration;

c. age – ideally factored in when the item is brand-new, age is related to lifespan and must be considered in order to enable the application of a consistent SWL for the duration of the item's service; *and*

d. wear and tear – like age, this may not appear to be relevant for a brand-new item. However, because the working environment will affect the item's condition, and therefore its strength, this must be anticipated from the point of its introduction into service.

11.2.4.1 Calculating strength loss: method A

This is the most basic method for calculating strength loss. Using this method, the MBS is divided by an appropriate safety factor which in turn produces an SWL.

Example 1.
MBS = 55kN; SF = 10:1
SWL = 5.5kN or 550kg (approx.)

11.2.4.2 Calculating strength loss: method B

Method B involves more steps but the result is more accurate. The greater level of accuracy can be derived by factoring in elements such as age, wear and knots. In this calculation, a safety factor is still applied and here it is 3.

Example 2.
MBS = 55kN - 20% (age and wear) - 40% (knots) ÷ 3 (safety or design factor = 3:1)

SWL = 8.8kN or 880kg (approx.)

11.2.4.3 Method A and method B produce slightly different SWLs. Method B may be preferable because the SWL is greater.

11.3 Adjusting the Safety Factor to Increase the Safe Working Load

11.3.1 The most effective way to maximise the SWL of an item is to adjust the safety factor of the item. However, if this is done, it is critical that it is reflected in the anticipated service life of the product – more plainly put, the number of times the item is used before it is withdrawn from service must be reduced.

11.3.2 The following example shows the SWL calculated using method A.

a. A rope with a SWL of 540kg is rated using a safety factor of 10:1. This is based on the premise that if the rope is used at a 10th of its MBS for the duration of its working life, it will be possible to use it in this way until it is retired due to age. The purpose of this safety factor is to help ensure that the rope will be safe from the potential of failure in use due to excessive loading. Excessive loading means exposing the rope to loads up to and beyond the MBS. Given that the rope has an MBS of 5400kg, it is clearly capable of far greater loads than its 10:1 rating would suggest.
b. With this in mind, the manipulation of the safety factor from 10:1 to 5:1 or even 3:1 would significantly increase the SWL of the item whilst remaining below the MBS.
c. As a consequence, the rope could be used up to an SWL of 1800kg (3:1) and remain safe to use.
d. It is important to remember that whenever the SWL is increased, the service life (or number of cycles of use) must be shortened to reflect this, because the product cannot be used like this up until its retirement due to age.
e. **The most difficult aspect to judge is how long to keep an item in service.** For the purpose of this example, it is assumed that a rope's service life is 5 years. If the convention is to rate it at a 10:1 then it would seem reasonable that if it was rated at 5:1 this would shorten its service life by half, e.g. 2 years 6 months. If a safety factor of 3:1 is used, the rope would be operational for a third of its service life, e.g. just over 18 months.

11.4 Strength Loss due to Configuration

11.4.1 Knots and methods of attachment lead to strength losses within a system. The tables below show some of the common knots, hitches and methods used for creating attachments, along with the potential strength losses they cause.

NB: The maximum potential strength losses are shown and will vary depending upon the diameter and construction of the ropes used. However, they provide a useful guide for calculating the configured strength of rigging systems.

11.4.1a Potential strength loss in rope when tied to a log using one of the following techniques.

Type of attachment	Potential strength loss
Clove hitch	up to 44%
Cow hitch	up to 43%
Half hitch with running bowline	up to 43%
Marline hitch with running bowline	up to 41%
Running bowline	up to 36%

11.4.1b ***Potential strength loss in ropes when knots are tied using one of the following methods.***

Type of attachment	Potential strength loss
Bowline knot	up to 45%
Clove hitch	up to 47%
Butterfly knot	up to 55%
Double fisherman's knot	up to 43%
Figure of 8 on a bight	up to 34%

11.4.2 **A worked example:** Using the information in the tables above, the strength loss in a rigging system resulting from using a knot or hitch can be calculated as follows:

A rope with an MBS of 1000kg when tied to a log with a half hitch and running bowline will have an effective working strength of approximately 570kg (i.e. 1000kg – 43% = 570kg).

11.5 Strength Loss – Slings

11.5.1 Slings come in a number of different configurations and constructions, each with potentially different uses. Because of this, there are also a variety of ways to attach them to stems, branches and other components. Each method of attaching the sling will cause a different level of strength loss and this must be considered before the sling is put into use.

11.5.2 For example, an endless sling can be attached using two methods, the choker or the basket hitch. When tied using a choker, the sling has the potential to lose up to 50% of its strength, whereas when tied as a basket hitch, the sling's strength is effectively doubled. However, caution must be adopted when using the basket hitch as it does not tighten, even under load. For this reason, it would be prudent to only use this technique where the natural features of the tree accommodate this mode of attachment and the system is under constant tension during the removal of the section.

11.5.3 The tables below provide information on common sling types and attachments along with corresponding potential strength losses.

NB: The maximum potential strength losses are shown and will vary depending upon the diameter and construction of the slings used.

11.5.3a ***Potential strength loss in soft-eye slings tied to a log.***

Type of attachment	Potential strength loss
Timber hitch	up to 30%
Cow hitch	up to 40%

11.5.3b ***Potential strength loss in adjustable slings when chokered to a log.***

Type of sling	Potential strength loss
Loopie	up to 16%
Whoopie	up to 26%

11.5.4 **A worked example:** Using the information above, the strength loss in a rigging system resulting from using a sling can be calculated as follows:

A loopie sling with an MBS of 1000kg when chokered to a log will have an effective working strength of approximately 840kg (i.e. 1000kg – 16% = 840kg).

12

Mass of Sections

Checklist:

- Has the mass of the section been estimated?
- Has due consideration been given to the variables of the section being removed? (mass/dimensions/foliage/taper/decay/moisture)
- Does the operator's estimate of mass seem accurate?

Have you checked?

12.1 Terms and Definitions

12.1.1 The terms mass and weight are frequently used interchangeably to describe sections of timber and the forces experienced during rigging operations. When discussing weight, it has become common to refer to something in kilograms. However, this is not correct because **weight is a force** that a **mass affected by gravity** exerts on a surface and it is measured in **newtons**.

12.1.2 The authors of this technical guide acknowledge that when stating a weight, operators will frequently describe it in kilograms. However, for accuracy the following definitions and example illustrate the difference:

Mass: mass is the amount of matter in an object and is measured in kilograms (kg).

Weight: weight is a force and is measured in newtons (N) or kilonewtons (kN).

So, what's the difference? The mass of an object is the same everywhere but weight depends on the effect of gravity.*

*Gravity is measured in metres per second per second (m/s^2). On Earth it is $9.8m/s^2$ and on the surface of the Moon it is $1.62m/s^2$.

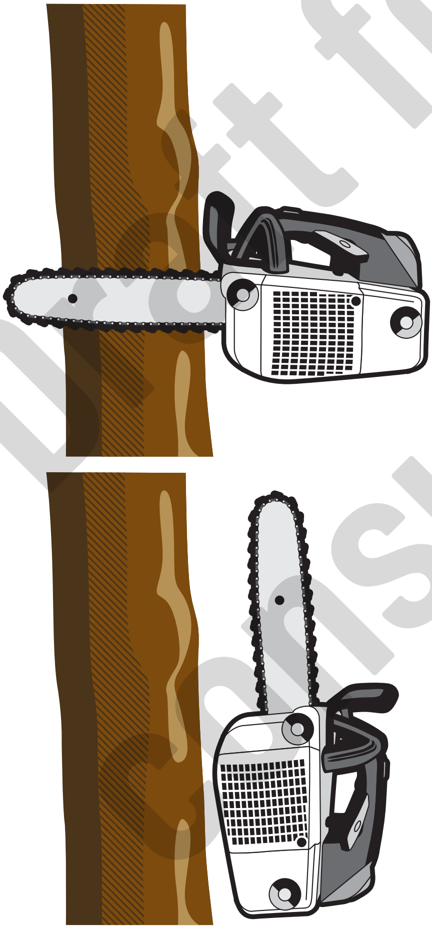
A silly example:

A branch with a mass of 100kg has a weight of 980N (0.98kN) whilst it is lying on the ground next to the tree that it has been cut from. If that same log were (somehow) on the surface of the Moon, it would still have a mass of 100kg but its weight would be 162N (0.162kN) because of the lower gravity on the Moon.

12.2 Estimating Log Mass

12.2.1 When estimating the mass of a log, the operator must first estimate its dimensions, i.e its length and diameter. These dimensions can be cross-referenced to a log mass chart which will provide an initial value for the mass of the piece.

12.2.2 A chainsaw can be a useful quick reference to help estimate length and diameter.



12.2.2 A chainsaw can be used to measure the length and diameter of a piece of timber.

12.2.3 The mass chart on page 88 indicates what the initial value for the mass of the section will be if it is green hornbeam (*Carpinus betulus*). The term 'green' here means live and healthy, as freshly cut from the tree. Hornbeam has been chosen as the initial base value as its specific gravity is the same as water.

Example calculation:

100cm (length) × 30cm (diameter) = 70kg (mass of hornbeam)

12.2.4 Identifying the tree species is an important factor in achieving a more accurate estimate of mass and is particularly important where the species is likely to be denser and heavier than hornbeam.

Species-specific correction factors (SSCF) for calculating the mass of a section more accurately are given in the second table on page 88. The numerical value for green timber of each species in the table is its SSCF (e.g. hornbeam 1.0, English oak 1.20, common beech 1.27, black poplar 0.85). The SSCF can be incorporated into a simple calculation to achieve a more accurate estimate of log mass.

Example calculation:

a. a piece of common beech is measured as 100cm long by 30cm diameter;
b. using the log mass chart, the dimensions show that the mass would be 70kg if it were green hornbeam; *and*
c. using the SSCF of 1.27 for common beech and multiplying this by the 70kg, the result shows that the mass of the section is more like 88.9kg.

Expressed as calculation, it looks like this:

a. mass × SSCF = accurate mass of section; *or*
b. 70kg × 1.27 = 88.9kg

This shows a piece of green beech is heavier than a piece of green hornbeam with the same dimensions.

12.2.3 Reference log mass chart: green hornbeam is used as the basis for all log mass calculations.

Length in cm	Diameter in cm: 15	30	40	50	60	70	80	100
50	8.8	35	65	100	140	190	250	395
80	14	55	100	155	225	310	400	630
100	18	70	125	195	285	385	505	785
150	25	105	190	295	425	575	755	1180
200	35	140	250	395	565	770	1005	1570
250	45	175	315	490	705	960	1255	1965
300	55	210	375	590	850	1155	1510	2355
Mass in kg								

12.2.4 Species-specific correction factors (SSCF) for calculating the mass of a section of green timber. Hornbeam (Carpinus betula) is the reference species with a correction factor of 1.00.

Species	Correction factor
Alder, common	0.85
Ash, common	0.89
Beech, common	1.27
Birch	0.93
Black poplar	0.85
Coast redwood	1.01
Douglas fir	0.84
Elm, English	1.03
Elm, wych	1.11
Eucalyptus – blue gum	1.15
Hornbeam	1.00
Horse chestnut	1.04
Larch, European	0.90
Lawson's cypress	0.80
Lime, European	0.80
Liquidambar	0.99
Locust, black	0.95
Locust, honey	1.10

Species	Correction factor
London plane	1.11
Oak, English	1.20
Oak, red	1.05
Oak, Turkey	1.04
Pine, lodgepole	0.73
Pine, Scots	0.96
Silver fir	0.94
Spruce, Norway	0.85
Spruce, Sitka	0.68
Sugar maple	0.95
Sweet chestnut	1.06
Sycamore	1.04
Tulip tree	0.79
Walnut, English	0.95
Western red cedar	0.87
Willow, white	0.87
Yew	1.16

12.3 Increasing the Accuracy of Log Mass Estimates

12.3.1 Tapered logs

12.3.1.1 Operators can calculate the mass of a regularly tapered log by working out the mass of a cylinder that has a diameter equal to the average diameter of the section to be removed.

$$\text{Average diameter} = \frac{\text{diameter at base} + \text{diameter at tip}}{2}$$

12.3.1.2 It may not be possible to assess the average diameter of an irregular-shaped section. In these circumstances it is recommended that operators either:

a. choose a representative diameter; *or*

b. assess the position of the centre of gravity of the section and measure the diameter at this position.

When the log mass is calculated, the species-specific correction factor should be used, especially where the diameter of the section does not change gradually over its length, e.g. where a sudden diameter change occurs at a branch junction.

12.3.2 Decay

12.3.2.1 The presence of decay will generally result in lower density wood and therefore lower mass. However, particular fungus and tree combinations or rotten material which may be soaked with water can contribute to an increase in the density or mass of timber sections.

12.3.2.2 Sections that are hollow to varying degrees or have areas of decay may have lost mass. An operator may be able to calculate any loss by assessing the thickness of residual walls or by comparing the extent of cavities with standard shapes.

12.3.2.3 Any reduction in estimated mass must always be arrived at with extreme care as the actual extent of decay may not be reliably predicted during the tree condition assessment process and might only be truly realised during the dismantling. A reduction factor of 20% for decay of unknown extent could be applied.

12.3.2.4 Assessing the mass of deadwood is virtually impossible due to the potential presence of rot that is exposed to the natural environment resulting in potential extremes of either water absorption or reduction of mass. Operators can assume that deadwood will be roughly 20–30% lighter than living green wood.

12.3.3 Moisture

12.3.3.1 Changes in the moisture content of timber will result in changes to its density. Seasonal changes and the biological processes of trees such as, but not limited to, transpiration and photosynthesis will also have a direct effect on moisture content and therefore mass.

12.3.3.2 Operators should use the relevant species correction factor value as a precaution. This will provide a margin of safety that accounts for an unpredictable moisture content.

12.4 Estimating Crown Section Mass

To estimate the mass of a crown section or branch, the operator must take into consideration not only the potential for a taper but also the added twigs and foliage. Because there are extensive variations in form, both within and between species, in foliage types, season and in timber densities, it is advisable to overestimate the dimensions where there is any doubt.

How to estimate the mass of a crown section or branch:

a. measure/estimate the length of the section from the point of cut to the tip;
b. measure/estimate the diameter of the section at the point of cut;
c. estimate the mass of the section based on these dimensions as if the piece were a cylindrical section;
d. apply the necessary SSCF for the timber;
e. multiply by the formfactor of 0.8, which accounts for the taper and foliage of the section.

A worked example:

a. a branch section of Scots pine measures 300cm from point of cut to the tip of the branch;
b. the diameter of the branch at the point of cut is 15cm;
c. the mass of this section if it were a cylinder would be 55kg (based on the green hornbeam from the log mass chart in section 12.2);
d. multiply 55kg by the SSCF for Scots pine which is 0.96;
e. multiply the resulting value of 52.8kg by the form factor of 0.8.

Expressed as a calculation (starting with the log mass chart result), it looks like this:
(55kg × 0.96) × 0.8 = 42.24kg.

13

Anchor Selection

Checklist:

- Has the operator correctly identified the species of tree being worked on?
- Is the species of the tree capable of supporting the potential load?
- Is the selected anchor point(s) strong enough?
- Has consideration been given to the consequences of anchor failure?
- Has appropriate equipment been selected for the type of anchor(s) being used, e.g. natural crotch rigging?
- Are components correctly secured to anchors?
- Are PPE and rigging anchors suitably independent?
- Are redirects being used appropriately to avoid causing adverse loading to anchors?

Have you checked?

13.1 Strength of Living Trees

13.1.1 The strength of the tree has a significant bearing on the ultimate safety of the rigging operation and must be carefully considered in relation to the planned works.

13.1.2 A number of factors influence a tree's strength, some of which can be visually assessed while others require greater levels of investigation using diagnostic tools (see section 3.7).

13.1.3 A tree's strength can be quantified in two ways:

a. Yield strength: the point at which primary failure occurs. This may be externally apparent when cracks and deformation occur. However, these frequently occur internally and will not necessarily be obvious.

b. Ultimate strength: the point at which complete failure occurs and the maximum load, i.e. the load required to cause fracture.

13.1.4 When the strength of the tree is considered before a rigging operation, it is important to appreciate that yield strength and ultimate strength are different for different tree species and also vary between points in the structure of the same tree.

13.1.5 Whilst the ultimate strength of a tree can only be determined by destructive testing, certain characteristics can help operators evaluate its ability to deal with the forces exerted during rigging operations.

One of the key characteristics to take into account is the tree's rigidity (stiffness). The following table includes some common tree species and a ranking between 5 and 10 which indicates each species' rigidity, 5 being the lower level of rigidity and 10 being the highest.

13.1.5 *Rigidity ranking for common tree species from highest to lowest.*

Tree species	Rank
Silver fir	10
Douglas fir	10
Sycamore	9
Hornbeam	9
Common beech	9
Norway spruce	9
Common alder	8
White willow	8
Small leaf lime	8
Lime	8
Birch	7
European oak	7
Red oak	7
Black locust	7
Sugar maple	6
Sweet chestnut	6
Common ash	6
Scots pine	6
London plane	6
Black poplar	6
Wych elm	6
Horse chestnut	5
Walnut	5
European larch	5
Liquidambar	5
Tulip tree	5

13.1.6 How to use tree species rigidity rankings

Rigidity rankings can help operators better understand the characteristics of the species being worked on so they can tailor the rigging system or technique accordingly.

Rankings can be interpreted as follows:

a. **Rank 8–10:** Trees with a high degree of rigidity – These trees will not cope well with suddenly applied shock loads and may be more prone to failure in such circumstances. However, when slender featureless stems with few or no side branches are rigged from, high rigidity can be beneficial in reducing excessive sway which could lead to failure.

   Actions to be taken: Avoid sudden shock loads and apply loads more gradually using techniques where the rigging anchor point is above the section to be removed. Where the rigging anchor point is below the section, cut sections small and let them run to allow the load to be applied gradually.

b. **Rank 5–7:** These trees display moderate levels of rigidity. They may be more flexible so they have a greater ability to dissipate shock loads because their branches bend further as the load is applied.

   Actions to be taken: Although these types of trees may be better at dissipating sudden shock loads, avoid excessive shock loading. This is particularly important when working on a slender, featureless stem.

13.2 Natural Crotch Rigging

13.2.1 In this basic technique the rigging rope runs through natural crotches (branch unions/forks) instead of components such as pulleys or blocks. This type of rigging provides operators with a simple option requiring minimal equipment.

13.2.2 If the objective is to keep kit to a minimum, operators may choose to use trunk wraps (wrapping the rigging line around the stem of the tree) to add friction during lowering. However, it is not necessary to omit all components to use natural crotch rigging.

13.2.3 Natural crotch rigging creates higher levels of friction and relies on there being suitable forks or stubs to position anchor points where they are needed. Direct rope contact with stems and forks can also cause friction and compression damage, which may be unacceptable if the tree is being retained.

13.2.4 Factors to consider when deciding whether to use natural crotch rigging:

a. **Is the tree being removed completely or just some sections?**
   Direct contact between the rope and the surface of the tree will cause friction and compression-related damage, which will be particularly concentrated in the forks. If the tree is to be retained this may cause unacceptable damage, so the technique may be better suited to trees which are being removed completely.

b. **Does the structure of the tree allow for the suitable positioning of the rigging line?**
   Components can often be used to create false anchor points, sometimes on featureless stems. This is not an option with this technique, so an absence of appropriate crotch features may prevent safe and effective rigging.

c. **Is the rope appropriate for the operation?**
   Many of the ropes used for rigging are of a double-braid construction. Large amounts of friction on the outer sheath will render the core largely ineffective, causing a reduction in strength. Therefore, a twisted, solid or single braid would be more appropriate.

13.3 Selecting Anchor Points

13.3.1 Whatever rigging technique is used, anchor points must be carefully selected, inspected for suitability and load tested where applicable before use. Poorly selected anchor points could fail, resulting in an inadvertent release of the load and also the potential for personal injury. When anchor points for a rigging operation are selected, consideration must be given to the loads they will bear and the direction that the load will be applied to the anchor(s).

13.3.2 Anyone selecting anchor points must be able to demonstrate an understanding of:

a. the timber characteristics of the tree species involved;
b. branch form – diameter, length and the relevance of angle attachment to the stem;
c. tree health and the potential effects of any decay, damage or defect present on the tree; *and*
d. the potential forces on the anchor.

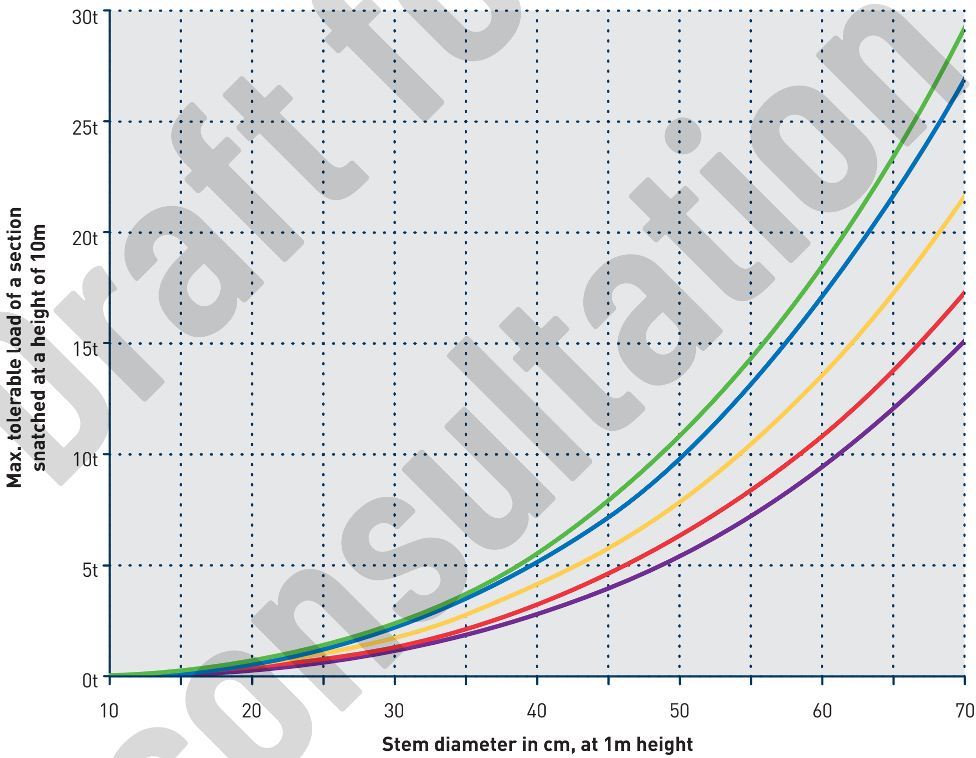
13.3.3 Aerial operators installing any anchor should consider the following points:

a. the equipment to be used, its suitability and how it will be attached to the anchor;
b. when installed, the anchor and its components will not allow the rope to slip down the stem;
c. any spread in the rope as it passes over an anchor and the effect this may have on the rigging technique and equipment in use during the operation;
d. the position of the anchor in relation to the branch(es) to be lowered and the features present in, on, around or beneath the tree; *and*
e. the weather (especially the wind) expected during the work and how this may increase loading on an anchor.

13.4 Bearing Capacities of Anchor Points

13.4.1 Snatching

The graph below shows the bearing capacity of a stem used as an anchor during snatching scenarios. This information can be used to help decide which technique is appropriate and what size of section can be tolerated during a snatching operation at a height of 10m. The bearing capacity can be taken as the maximum tolerable load which the stem could withstand during a snatching operation. For example, the red line represents a Scots pine (amongst other species). As the graph shows, a tree of this species with a stem diameter of 45cm at 1m height has a maximum tolerable load of 5 tonnes.



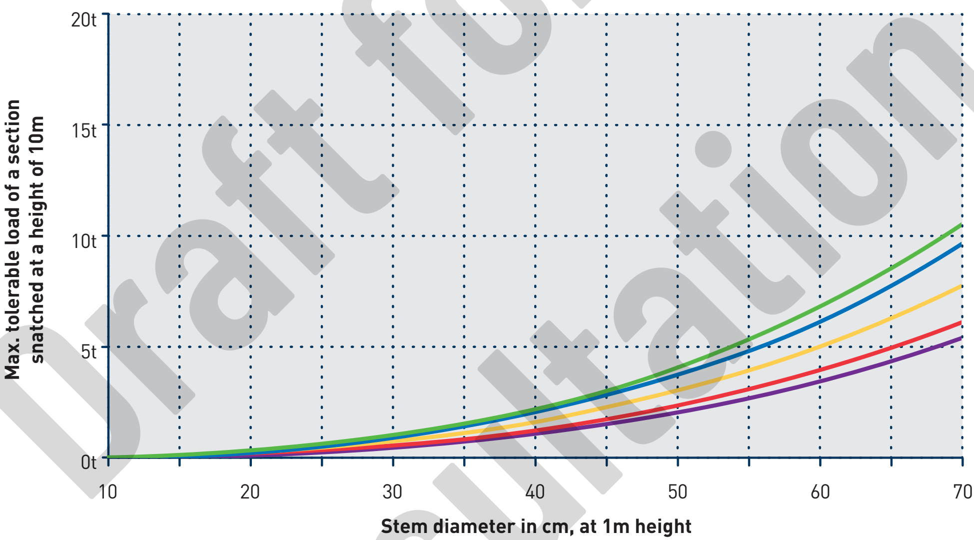
13.4.1 Bearing capacities of anchor points by species.

Key to tree species

- English oak, Norway maple, London plane
- Sycamore, sweet chestnut, beech, ash
- Sugar maple, alder, birch, Lawson cypress, poplar, red oak, robinia, lime
- Hornbeam, larch, tulip tree, Scots pine, willow, redwood
- Silver fir, horse chestnut

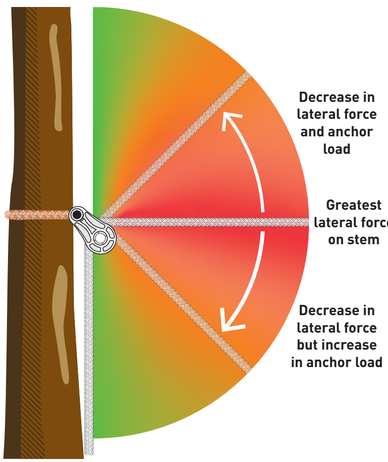
13.4.2 Redirected rigging

13.4.2.1 Incorporating a redirect into a rigging system immediately changes the load to which the anchor is subjected. The loading can either increase or decrease depending on the position of the redirect relative to the main anchor. In graph 13.4.2.1, the red line depicts a significantly lower bearing capacity due to the presence of a redirect pulley installed perpendicular to the position of the main anchor pulley as this represents the worst-case scenario. It has caused a reduction in bearing capacity of about 3 tonnes, i.e. without the redirect the bearing capacity is approx. 5 tonnes but when the redirect is installed this has dropped to 2 tonnes.



13.4.2.1 Worst-case effect on bearing capacity of installing a redirect.

13.4.2.2 The presence of a redirect will change the rope angle as it enters and exits the main anchor pulley. This alters the loads experienced at both the main anchor and the redirect. The image on the right shows how the rope angle at the pulley can either increase or decrease the load which is experienced. This basic principle can be applied to any point where the rope takes a deviation through the tree structure, i.e. through or around a piece of installed hardware or a natural crotch/branch.



13.4.2.2 The effect of rope angle on the load on a pulley.

14

Peak Loads

Checklist:

- Has the potential for a high peak load been considered?
- Has the potential peak load been calculated?
- Have measures been taken to reduce potential peak loads?
- Has the system been configured appropriately to contend with the potential peak loads?

Have you checked?

14.1 General

14.1.1 Peak Loads (PLs) will always occur in rigging system during a lowering or lifting operation. However, it is dynamic loads, often called shock loads, which are potentially harmful and need to be controlled.

14.1.2 The greatest loading will occur around the main anchor point and the lead of the rope where it exits the pulley or block and attaches to the falling section, at the moment when the falling section comes to bear on the rigging line and the rope begins to take the strain.

14.1.3 The peak load is the point when the rigging system is under the maximum load during a lifting or lowering cycle and it can be made significantly worse by the following factors:

a. **removing excessively large sections of wood:** the greater the weight of the section, the greater the resultant peak load will be; *and*

b. **sudden stops:** when the fall of a piece is suddenly stopped, the change in inertia transfers significant forces into the system and structure.

14.1.4 The problem with high peak loads is the potential for harm to occur, both to the tree and the operator, often with one leading to the other. The damage inflicted on the tree, such as internal fractures or root movement, may not immediately be obvious but it could compromise the tree's ability to sustain further loads.

If the tree's structure is compromised, this will have a direct impact on the safety of the operator, particularly if they are secured to the tree with a personal fall protection system. This is clearly not acceptable and is the fundamental reason to avoid high peak loads.

14.2 Worst-case Scenario

14.2.1 Operators undertaking any rigging operation must understand and be able to estimate the anticipated worst-case scenario in relation to peak load – that is, the maximum foreseeable load which could be experienced during a cycle of the rigging operation.

14.2.2 A correctly planned rigging system can be assembled using components which are capable of withstanding the worst-case-scenario load, or an alternative system of work or rigging system/technique can be selected which will lower it.

14.2.3 The worst-case scenario is an essential starting point when considering:

a. whether or not to undertake rigging;
b. the structural integrity of the tree and/or available anchor points;
c. what rigging technique should be used;
d. which components should be incorporated in the system;
e. the configuration of the system and its components; *and*
f. the competence of the operators involved, both ground based and aerial.

14.2.4 If the aerial operator is secured by a personal fall protection system within the tree structure which is being rigged and/or dismantled, careful consideration should be given to the effects that the selected techniques, systems and removal of sections will have on the tree's structure and the climber.

14.2.5 It is also important to consider what will happen at each stage of the operation. The tree will undergo constant changes as sections are removed. These changes will influence and alter the distribution of forces throughout the tree because the oscillations created by the dismantling operation will be conducted through a structure which is continually decreasing in size.

14.3 How to Reduce the Potential for High Peak Loads

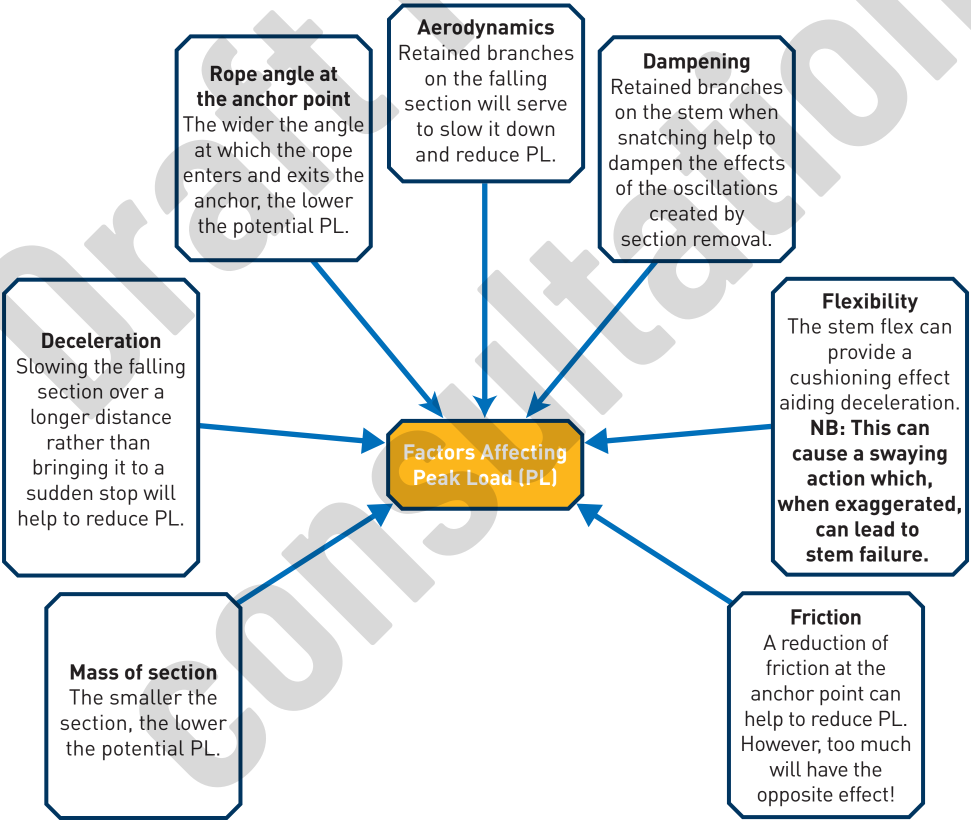
14.3.1 Several factors affect peak loads, some of which can be controlled or directly influenced by the operators involved in the operation:

a. **Rigging technique selected:** e.g. if the pulley is below the load, snatching will cause the greatest peak loads because the section of wood will momentarily free-fall before being caught by the system, which means there will be an inevitable 'impact' on the system.
b. **Size of section being removed:** Cutting a smaller section will immediately reduce the potential of a high peak load because the smaller the mass of the piece, the smaller the peak load. **NB:** Small sections can still cause dangerously high peak loads.
c. **Snubbing off and too many wraps:** Too much friction will stop the section suddenly and cause a high peak load.
d. **Distance of fall:** The further the section is allowed to fall, the greater the speed it will gain. If the falling section is then stopped suddenly by the system (snubbed off) the resulting peak load will be high.
e. **Rope characteristics – elongation, elasticity, age:** If the rope has a high level of elongation and elasticity, it will be able to 'absorb' the peak load, causing the load at the anchor to be reduced. If the rope does not elongate or have any elasticity (which can often diminish with age), it will not be able to absorb peak load particularly well.
f. **Height and slenderness of the stem:** A tall slender stem will often have high levels of flexibility which can aid in the absorption of the peak loads. However, in some cases this can also be hazardous due to the stem's propensity to oscillate, which in turn leads to exaggerated bending and ultimately possible stem failure.
g. **The retention of side branches (on the stem and cut section):** The retention of side branches serves to dampen the effects of the oscillations created and reduce the violence of any stem flexing.
h. **System configuration:** A poorly configured system where the cut sections are allowed to fall further than is necessary before being 'caught' by the rope, or which prevents the free running and gradual slowing of the piece, or which has little or no flexibility/elasticity built in will result in potentially high peak loads.
i. **Components used – types of hardware and textiles:** Systems with significant amounts of hardware will invariably be less flexible than systems which incorporate more textile items.
j. **Competency of operators – both ground based and aerial:** Where operator competence is lacking, errors such as incorrect component configuration, inaccurate cutting and poor system operation will result in a number of hazardous situations, one of which will be the generation of high peak loads.
k. **Friction in the system:** Excessive levels of friction within a system or poor application of friction could cause the falling section to build up excessive speed and/or stop suddenly.

14.3.2 Cutting a smaller section is the simplest way to minimise peak load as it does not involve modifying the system or integrating additional components. The easiest way to demonstrate this is to alter the first value in the peak load calculation (see section 14.4): it has a direct influence on the final number.

14.3.3 Sometimes, however, reducing the size of the section is not feasible because of factors such as tree form, the security of the fixing between the rigging line and the section, the availability of appropriate work positions and overall effectiveness and efficiency.

14.3.4 The diagram below shows some of the factors that can affect peak load and some ways in which it can be avoided.



14.4 Estimating Peak Loads

14.4.1 An estimate of the PL will only be accurate if it is based on as much quantifiable data about the planned operation as possible. The more information and understanding that can be applied to the calculation and estimate, the more accurate it will be and the safer the operation.

14.4.2 Estimating the PL begins with an accurate estimate of the mass of the section which is to be removed. This is covered in section 12: Mass of Sections.

14.4.3 The most influential factor affecting the PL is the rigging technique used, in particular the position of the rigging point relative to the cut section. The two most common set-ups are referred to in this guide as rigging point above (RPA) and rigging point below (RPB).

- RPA is where the section being severed is below the rigging point. Generally, this means that the rigging rope can be pre-tensioned, immediately reducing any potential peak loads.
- RPB is where the section being severed is above the rigging point, which results in an element of free-fall (albeit brief) prior to the section being arrested by the rigging rope. This free-fall causes a significant increase in the potential PL which can be many times greater than the PL experienced in RPA.

14.4.4 The equation illustrated below can be used to calculate a worst-case scenario when estimating the potential peak load for RPA or RPB. The key difference between them is the anchor force (AF), which is much greater value for estimating RPB.

- Rigging point above: anchor force = 2
- Rigging point below: anchor force = 11

Mass
This is the mass of the piece based on its length and diameter and derived from the reference log mass chart for green hornbeam (see 12.2.3).
This **does not** account for species.

Safety Factor
A conventional safety factor which increases the log mass value by 30% to allow for potential misjudgements when working out log mass.

NB: Be aware that this **does not** fully account for an underestimation of diameter!

$$(70\text{kg} \times 1.27) \times 1.3 \times 11 = 1271.27\text{kg } (13\text{kN})$$

Species-Specific Correction Factor
This is a value based on the specific gravity of the actual species of the tree being worked upon.

Anchor Force
The amount by which you will multiply the 'true' log mass based on whether the rigging point is above or below the load.

Peak Load
This is load experienced at the anchor point, based on the assumption that all circumstances are conspiring to create the worst-case scenario.

14.4.4 Equation for calculating worst-case scenario peak load. This example is a rigging point below set-up.

14.4.5 A worked example.

This example provides practical guidance for how an operator might select the correct components, based on an understanding of calculated strength loss and the worst-case scenario peak load which might occur during a snatching operation*. It begins with an explanation of the equation illustrated in 14.4.4 and then takes the process further to determine whether the equipment selected for the operation can withstand the force to which it may be subject.

*Snatching is the rigging operation that produces the greatest peak load, so if the components selected can withstand these forces with a suitable margin of safety, it is assumed any other rigging operation will be well within the capabilities of the system.

The first stage is to work out the forces encountered in the rigging system.

Part 1: Calculation of the mass of the section (see also section 12):

a. A piece of common beech is measured at 100cm long by 30cm diameter.
b. The log mass chart shows that the mass would be 70kg if it were green hornbeam.
c. Using the SSCF of 1.27 for common beech and multiplying this by the 70kg, the result shows that the actual mass of the section is more like **88.9kg**.

Part 2: Worst-case scenario peak load that a mass of 88.9kg could generate:

a. The common beech log has a mass of **88.9kg**.
b. **88.9kg** (actual mass of section)
   × 1.3 (safety factor)
   × 11 (anchor force for snatching)
   = 1271.27kg

Part 3: Line force

a. The force on the line is calculated by dividing **1271.27kg** by **1.8** (this accounts for unequal loading on the lead and the fall of the rope as it runs through the pulley).
b. **1271.27kg**
   ÷ 1.8
   = 706.26kg

The second stage is to calculate the capability of the two components which will be subject to the greatest load, the rope and the sling which supports the pulley/block:

Rope:

a. A 16mm double braid rope has an MBS of **6300kg**
b. – 20% (age and wear)
   6300 × 20% = 1260kg »
   6300kg - 1260kg = 5040kg
c. – 40% (knots)
   5040 × 40% = 2016kg »
   5040kg - 2016kg = 3024kg
d. ÷ 3 (safety factor)
   3024kg ÷ 3 = SWL: 1008kg

Sling:

a. A 22mm loopie sling has an MBS of **16,600kg**
b. – 20% (age and wear)
   16,600 x 20% = 3320kg »
   16,600kg - 3320kg = 13,280kg
c. – 16% (chokered)
   13,280 × 16% = 2124.80kg »
   13,280kg - 2124.80kg = 11,155.20kg
d. ÷ 3 (safety factor)
   11,155.20 ÷ 3 = SWL: 3718.40kg

The forces on the rigging and the capabilities of the two components which are subject to the greatest load have now been calculated. The outcome shows that the equipment is capable of withstanding the force to which it may be subjected. Put simply, the forces must be less than the SWL of the equipment in order to be suitable for use:

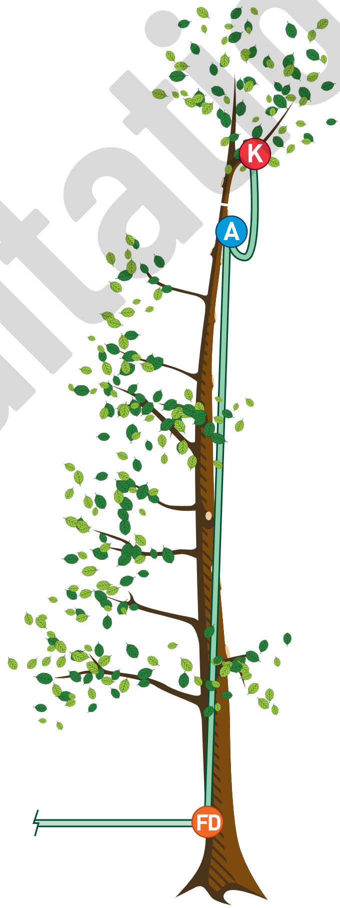
- The 16mm double-braid rope has a configured SWL of **1008kg** and the line force will be **706.26kg** (worst-case scenario). This equates to a safety factor of approximately **4.3** (**3024kg ÷ 706.26kg**).
- The 22mm loopie sling has a configured SWL of **3718.40kg** and the worst-case scenario peak load at the anchor will be **1271.27kg**. This equates to a safety factor of approximately **8.8** (**11,155.20kg ÷ 1271.27kg**).

14.5 Slender Stems

14.5.1 Trees with slender stems, or trees which have been dismantled to the point that there is a single slender stem, are particularly prone to stem oscillation. This will be much more acute if the stem is top heavy, i.e. if all the lower branches have been removed and the top remains (see image below).

14.5.2 This is a very common scenario during a dismantling operation where an operator has removed all lower branches on ascent and is left with a top which is then often removed in a single section. This is a hazardous situation because the oscillations created by removing the top could be significant enough to cause stem or entire tree failure. This effect can be avoided by retaining a number of lower branches which will help to dissipate the oscillations and reduce the potential for failure. The retained branches need to be relatively close to the point that the top is cut to mitigate the effects of the slender stem (see image below).

14.5.1 Slender stem with lower branches removed: vulnerable to oscillation.



14.5.2 Lower branches retained to dissipate oscillations when the top is removed.

Filler image to come

15

Inspection and Maintenance

See also *Technical Guide 1: Tree Climbing and Aerial Rescue*, section 15

Checklist:

- **Has all equipment been subject to pre-use checks?**
- **Is the equipment on site in a serviceable condition?**
- **Has relevant equipment been subject to thorough examination?**
- **Are thorough examination records available?**
- **Has equipment been stored, transported and maintained correctly?**
- **When equipment has been found to be defective, have operators removed it from service?**

Have you checked?

15.1 Introduction

15.1.1 All operators undertaking rigging and dismantling operations must be adequately trained and able to carry out pre-use equipment checks. Operators must have practical experience of using the equipment they plan to check and they must understand the standard to which the equipment should be inspected, as defined by the arboricultural industry and the manufacturer's recommendations. Arboricultural lifting equipment must undergo thorough examination at recommended intervals to ensure it remains safe to use. Rigging equipment should be thoroughly examined by a competent person at least every 12 months. Anyone who carries out thorough examinations must be sufficiently independent and impartial to make objective decisions.

15.1.2 All in-service rigging equipment must be subject to a pre-use check by the user. The competent person must ensure it is demonstrably clear that anyone carrying out a pre-use check is proficient to do so, which should include:

a. end users have access to manufacturers' product data and user instructions;
b. end users are trained in how to carry out pre-use checks of equipment; *and*
c. periodic auditing to ensure the standard of pre-use checks is satisfactory.

15.2 Equipment Inspection

15.2.1 Equipment must be given a close visual and tactile (touch) inspection to look for:

a. cuts;
b. frays;
c. glazing;
d. condition of rope terminations;
e. functionality of moving parts;
f. contamination;
g. condition of attachment points;
h. burrs;
i. cracks;
j. deformity;
k. corrosion;*and*
l. any other defects.

Glazed fibres.

Damage to stitching on sewn tape sling.

Diameter changes such as thinning of ropes or slings.

Loss of whipping and/or thrapping bars around spliced eye.

Discolouration - the lightening of colours which may appear like fading.

Clean rope" emanating from the throat of an eye splice.

15.2 Examples of damaged textile items.

Deformed rope brake.

Corroded karabiner.

Cracked pulley block.

Burr on pulley.

15.2 Examples of damaged hardware items.

15.2.2 Other key elements that must be inspected include:

a. the condition of and stitching on any textile elements;
b. the condition of the ropes to be used, particularly splices or knots and areas that are subject to high levels of wear; *and*
c. connector condition and function.

15.2.3 The inspection of karabiners must include the gate mechanism, looking for signs of abrasion, cuts, deformity and sharp edges. The nose of the karabiner and hinge rivet must also be inspected for condition and correct alignment. Gate action tests must be carried out without applying bias or influence to any of the actions and as a minimum must include:

a. a fully open gate test;
b. a test that is carried out close to the nose; *and*
c. a test carried out over the nose.

The gate action must close positively and reliably in order to be safe for use. Cleaning and lubrication must be done in accordance with specific manufacturer's guidance. (See Technical Guide 1: *Tree Climbing and Aerial Rescue* – 15.3)

15.2.4 Textile elements must be subject to visual and tactile checks, which include the operator running the item through their hands and making a rope loop to ensure a constant curve along its entire length, looking out for damaged fibres, inconsistent diameter etc.

15.2.5 Hardware items must be checked for proper operational function on the correct rope type and diameter.

15.2.6 Any protective parts that cover splices or stitching should, where practical and possible, be pushed back or slid away to ensure the integrity of the item.

15.2.7 If the operator is unsure about the serviceability of a component at any point, it should be removed from service immediately and thoroughly examined.

15.3 Equipment Lifespan

The lifespan of an item is impossible to quantify precisely because of the many factors involved. However, some information is included here for guidance only.

15.3.1 Metal lifespan

a. Most items age naturally, even under perfect storage conditions. For metal items, ageing may result in slight strength loss. This is insignificant compared with the wear incurred during normal use.

b. In general, metal items can be used until they exceed acceptable levels of wear or are otherwise damaged. Refer to manufacturer's guidance on maximum lifespan from date of manufacture.

15.3.2 Textile lifespan

a. Textiles deteriorate with age. The fibres degrade naturally even under perfect storage conditions.

b. All textile equipment is subject to wear and tear with use. Ropes and rope tools are particularly subject to high levels of wear and tear.

c. Individual manufacturer's guidance should be followed to help determine the point of retirement, paying particular attention to guidance about lifespan from date of manufacture or from date into service. See also section 11.

15.4 Maintenance

15.4.1 Repairs, alterations or modifications should normally only be carried out by the manufacturer. However, components in some products can be replaced by the operator, such as the bridge on sliding D harnesses and the cam on some rope adjusters. The manufacturer's instructions about maintenance and replacement parts must be followed.

15.4.2 Operators are encouraged to have equipment and materials available on site to allow mechanisms such as karabiner gates to be cleaned and lubricated.

15.5 Storage and Transport

15.5.1 Equipment should be maintained, stored and transported by operators in accordance with the manufacturer's instructions.

15.5.2 Consideration should be given to the total weight of a portable storage device containing equipment, particularly when wet, and how ergonomically it can be manoeuvred. Bags or boxes with carrying straps, handles or wheels may be preferable.

15.5.3 Wet equipment should be thoroughly dried before storage, e.g. in a well-ventilated environment away from any direct heat source.

15.5.4 Storage bags or buckets that are breathable and permeable to moisture and water will help equipment dry out more efficiently.

15.6 Marking and Traceability

15.6.1 For traceability, individual products must be uniquely identifiable. Any marking must ensure that the item can be traced back to its records. Marking must, therefore, remain legible and form part of the checking process and thorough examination of equipment.

15.6.2 For all product groups, it may be necessary to contact the manufacturer to ensure that items are marked correctly, and where re-marking of an item is required, manufacturers may stipulate criteria to prevent the structural integrity of the equipment being compromised. Always follow manufacturer's recommendations regarding modification or alteration of a product, which may include ID marking it.

15.7 Records

15.7.1 Equipment must be used and maintained within a controlled system. The system should start with a purchase record, enabling traceability to the manufacturer and a production batch.

15.7.2 Additional records for any item of equipment should also be maintained, including:

a. manufacturer's instructions; *and*

b. any evidence of conformity (which should be filed and retained for as long as the equipment is in use).

15.7.3 In addition to pre-use checks, interim inspections on items subject to high wear and tear are required and these must be recorded. It is essential that interim inspections are taken seriously and carried out by someone who has the necessary experience and authority.

15.7.4 Rigging equipment must be thoroughly examined by a competent person at least every 12 months and records kept for as long as the items are in service.

15.8 Equipment Withdrawal

15.8.1 All equipment must be regularly inspected. Any defective equipment must be withdrawn from use and the details recorded.

15.8.2 Operators should be aware of the quarantine processes in place. Such processes may include the removal from service, repair and/or maintenance of equipment, then its return to service or destruction, as applicable.

Technical Guide 3

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ISBN XXX-X-XXXXXX-XX-X
Printed XXXXXXX 2021