Kary Environmental Services
Rescue Rigging Manual

KARY ENVIRONMENTAL SERVICES
RESCUE TECHNICIAN
SKILLS MANUAL

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Kary Environmental Services

Rescue Technician Skills Manual

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Section 1: Command and Control

Elements of a Vertical Emergency

An element of a vertical emergency is a factor, condition, or influence that can be redirected, and treated by the rescue team. A strong rescue team will draw from their “skill” toolbox and deal with these elements in a safe and expedient manner.

How does a rescue element effect the choices of the rescue team? What elements determine the manpower needed, or the amount of equipment needed at the scene? Too often rescuers make these decisions with little training and experience.

Most fire departments have the expertise to perform a low angle carryout. Most technical rescue personnel can rappel, do some basic climbing, and complete a rescue involving a non-changing fall line. But ask yourself, does your team have the skills to perform a mid-face pick-off that includes a fall line with multiple obstacles, or extricate an injured worker off the top of an electrical transmission tower.

Some elements are minor some are major. It is the accumulative effect of these elements that change the course of action. A successful rescue is the direct result of a team’s ability to recognize these elements and deal with them with confidence.

Elements of a technical rescue emergency can be divided into three major phases, Primary Assessment, Recon, and Rescue.

Primary Assessment Phase

Command – Establishment of a strong command structure starts with the first unit on the scene. This includes a complete on the scene report to the dispatch center confirming that you are on the scene, what obvious conditions, exist, and what your initial plan of action will be.

Witnesses – If possible, secure witnesses. Witnesses can offer valuable information on the location and condition of the victim. For additional reference, keep reliable witnesses close at hand to the command post.

Time of Day – Time of day may be a major element for command to consider. How much daylight is left versus the predicted length of time needed for the rescue may determine such things, as lighting needs, and the possible use of additional resources, such as helicopters.

Weather Conditions – Weather conditions or impending changes in the weather can alter the direction of a rescue operation. Weather conditions can be the primary safety concern for rescue personnel.

Vertical Type – Although all vertical rescues have similarities, different types, whether they are mountain/wilderness, urban/industrial or structural towers, can be vastly different in the resources, and skill levels needed.

Terrain – Although a true evaluation of the terrain comes from the recon sector, most of the time command can get a good idea of what kind of terrain the rescue may involve.

Resources – Based on information at hand, call for the appropriate resources early. When in doubt call for more than you need, you can always turn units around. It is always better to have too much than not enough.

Skill Level – As Command, you must have the personnel with the level of skill to bring the rescue to a safe and successful conclusion.

Vertical rescue is not unlike other rescue incidents, such as auto accidents, or structural collapse, it isn't uncommon to be treating a trapped patient, even for extended periods of time, while waiting for more advanced extrication specialists to arrive.

It is much wiser to wait for members with more advanced rigging skills to arrive, than attempt a difficult vertical extrication with members that may not be up to the task. This does not preclude treating the victim in place.

Recon Phase

Recon – Command must establish a recon sector as soon as possible. Recon is usually the first rescuers over the edge, or up the mountain. These members become the initial "eyes and ears" of command.

Victim Profile – As soon as possible command needs to know what the victim profile is. Is the operation going to be a rescue or a recovery? This element alone will dictate the speed and urgency of the operation.

Other considerations that may play into developing a victim profile are the victim's location, the victim's vertical stability, and effects of weather exposure.

Recon sector should include paramedic members with the medical equipment available to deliver advanced life support if needed.

The recon sector should be capable of evaluating any other victim/patient needs that will promote timely treatment, and extrication, including patient packaging, and litter configuration.

Terrain – Command will get its most accurate report of what kind of terrain he/she is dealing with from the recon sector.

Angle and Length of Ascent/Descent – Based initially of recon's report, the angle and length of the ascent and/or descent will determine the type of rescue profile (low, steep, or high angle), and the skill level of the personnel (non-technical, basic, intermediate, or advanced technical skills).

Horizontal and Vertical Distance from the Fall Line – Does the fall line change? Does the fall line include obstacles? Does the main line and belay line package need to be altered to affect the rescue? If so, the rescue team will need to be versed in performing any number of "offset" evolutions.

Helicopters – Is the terrain conducive to helicopter use? Helicopters are some of the most versatile and useful tools known to the rescue world, yet the use of a helicopter in a vertical rescue can be one of the most dangerous. Members must be highly trained, and command must do a complete risk assessment before a helicopter is chosen to extricate the victim.

Rescue Phase

Team Base Location, Top or Bottom – As simple as this sounds the decision on where to start the operation is one of the most important. Starting at the top and working down to the victim is most often the preferred way. But in many scenarios, such as a structural tower, there is simply not enough room to work a large team above the victim.

In the case of the "bottom" operation, a limited number of rescuers will work above the victim, setting high directional, and doing the victim packaging, while the bulk of the team is doing a support/rigging operation on the ground or below on a larger working area.

Anchor Profile, – Anchor selection, and who's building the anchor are the two biggest decisions to be made during the rescue phase.

Good *"bombproof"* anchors are single point anchors that everyone is happy with, and there is no chance that the anchor will fail. Any well-trained basic operations level rigger can manage this type of anchor.

Marginal *"multi-point"* anchors are anchor points that by themselves are questionable, but when used in combination with each other make for a very strong system anchor. This type of anchor should be handled by members with strong operations level skills and who have a full understanding in building load sharing, load distribution, back-tie, and focused anchor systems.

"Advanced anchor" construction is rare. This is developing an anchor where no apparent anchor exists. Typically this involves several advanced skills such as,

back-ties, front-ties, focused, and floating anchor systems, plus the use of bolts, cams, and wedges. Team members with advanced rigging skills should only manage these types of anchors.

Edge Profile/High Directional Needs – The number one enemy of rope is sharp edges. What resources are needed to protect the rope?

A good rescue system will keep the majority of the rope off the ground. The best way to accomplish this is by using some form of a high directional.

A high directional, in addition, to edge protection will also lessen “edge trauma” to team members going over the edge.

Rescue Vertical Direction – Down or up, or any combination of; this element requires skills in setting up and operating a lowering system, a system belay, a mechanical advantage system, and the technical skill in converting between a lowering and a haul system.

Rescue Vertical Distance – How much rope is needed? This may involve skills in combining lengths of rope in a safe and reliable manner, and the ability to pass knots through the system.

Rescue Horizontal Changes – Is there a need for *horizontal systems*, add on systems that allow the team to manipulate the mainline, and sometimes the belay line in a horizontal manner.

Long Horizontal Distance – On very rare occasions a rescue team may be called upon to build and operate a highline system that facilitates a rescue over a long expanse.

This would be that one time that the terrain would not allow the use of a helicopter, and the distance was too long to use offsets. Advanced technical rescue technicians should only attempt this type of rescue.

Hot, Warm, and Cold Zones

Zones are established by Command for the purpose of scene management.

Hot Zone

The Hot Zone is ground zero, the location of the actual rescue. No one should be allowed inside the Hot Zone who is not directly involved with the hazard entry and victim extrication. Accountability is the point of entry into the Hot Zone. Entry into the Hot Zone is strictly enforced by the *Accountability Sector*.

The diameter of the Hot Zone is established by Command based on the following key factors:

1. Type of emergency – i.e. hazmat vs. tower rescue with downed lines, a hazmat emergency may require an entire building to be designated as the

Hot Zone, whereas downed electrical lines may require a Hot Zone diameter of 500'.

2. Location – is it in an open field or a location more confining like electrical vaults or trenches?
3. Number of rescuers and equipment required to work within the Hot Zone.

Warm Zone

The Warm Zone is the emergency support area surrounding the Hot Zone. Typically, the Warm Zone extends 300' beyond the outside boundary of the Hot Zone, again, this is a command decision based on location and support needs.

The Warm Zone includes *Level One Staging* – staging of immediate needs resources.

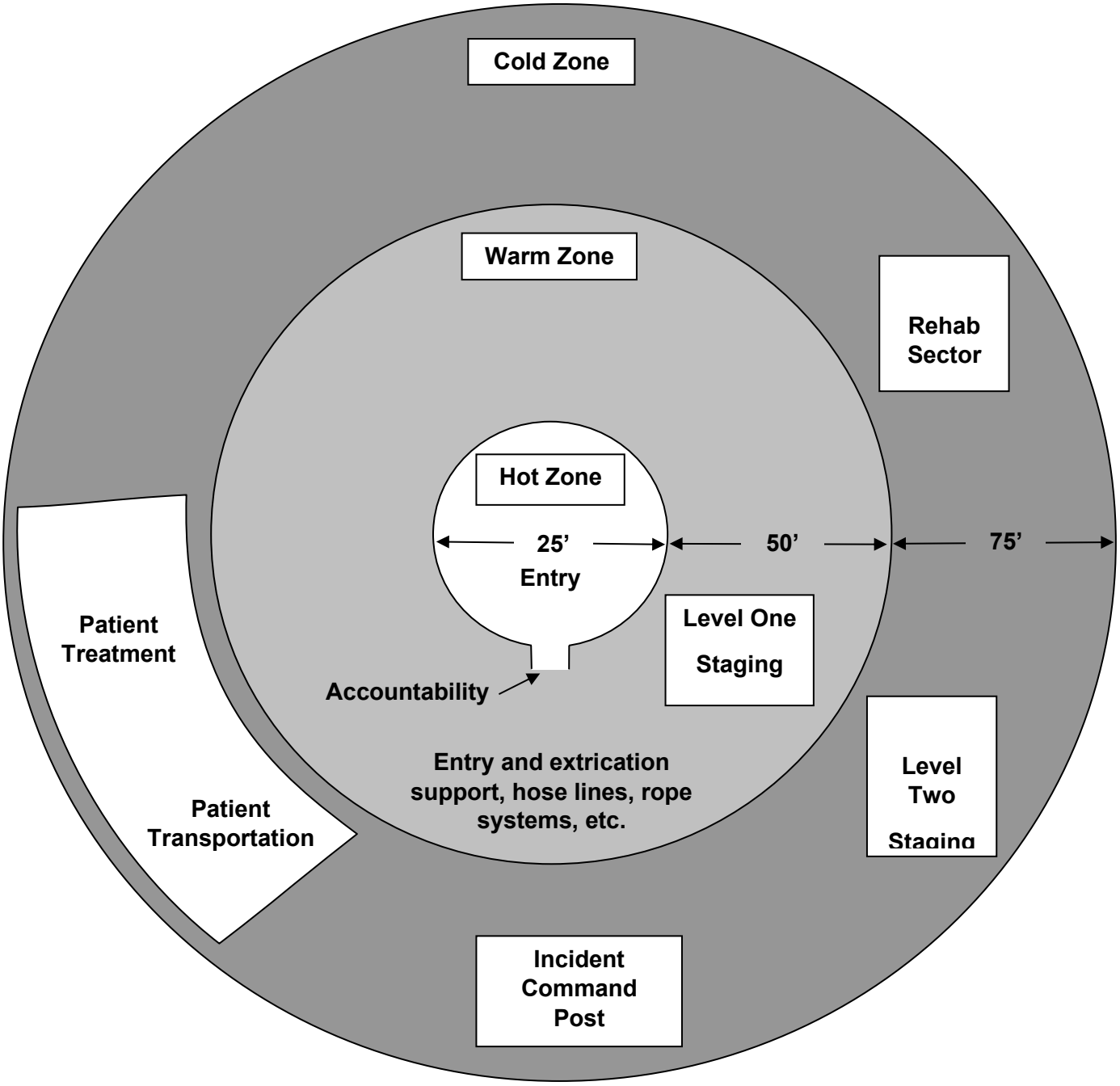
Cold Zone

The Cold Zone is the non-emergency support area surrounding the Warm Zone. Typically, the Cold Zone extends 300' beyond the outside boundary of the Warm Zone, again, this is a command decision based on needs.

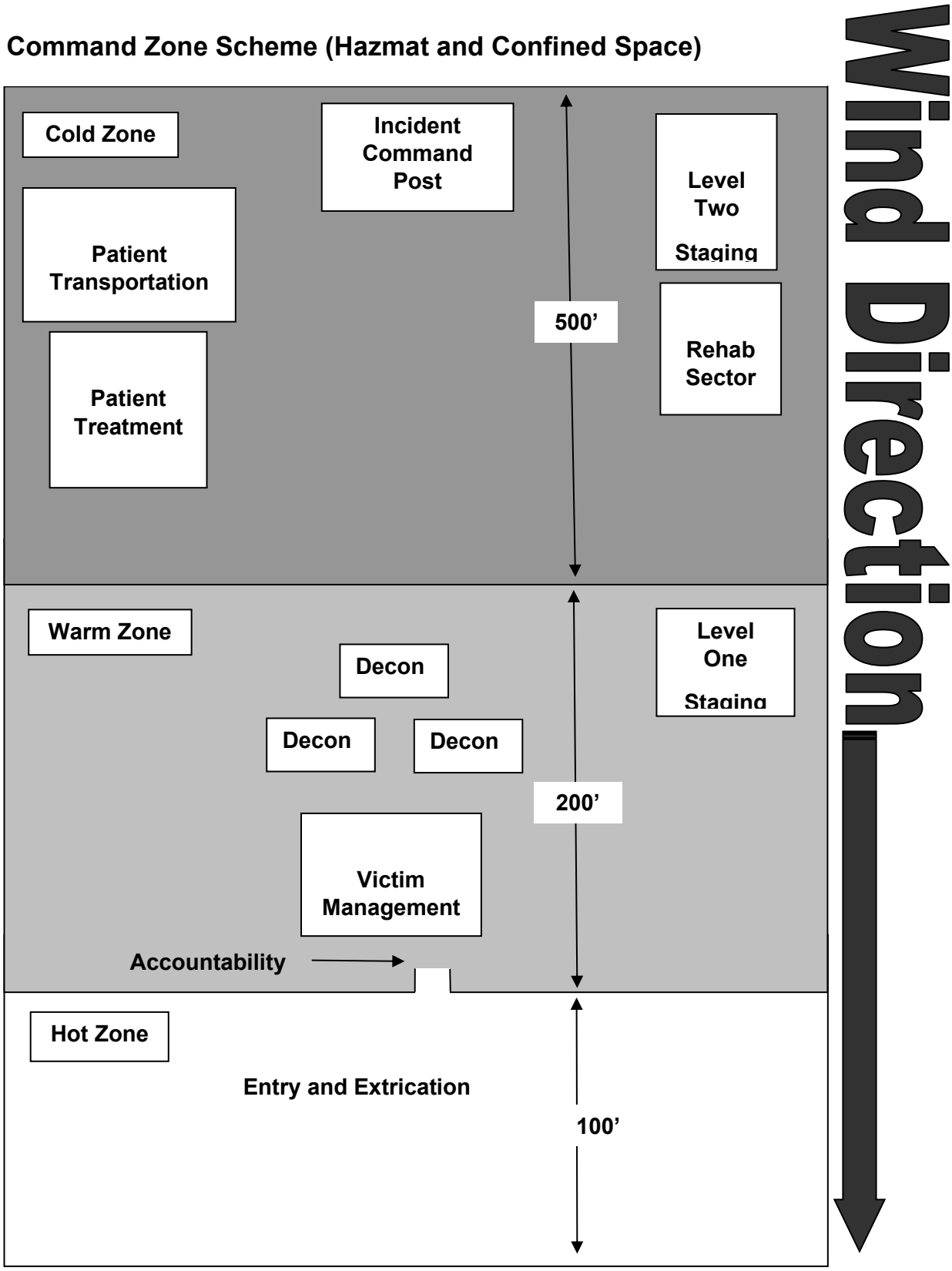
The Cold Zone includes *Level Two Staging* – staging of potential needs resources.

Note: All those not playing a role in the rescue operation, including bystanders and media must be kept outside of the Cold Zone boundary.

Command Zone Scheme (Typical)



Command Zone Scheme (Hazmat and Confined Space)



Tactical Checklist for High Angle Emergencies

Phase 1. Size up

- ☐ Primary Assessment
  - ☐ Secure witness/RP.
  - ☐ Determine location and number of victims.
  - ☐ ID immediate hazards to the public and rescuers.
  - ☐ Rescue mode or recovery mode?
- ☐ Secondary Assessment
- ☐ Type of Structure
  - ☐ Non-technical (<40º)
  - ☐ Technical (>40º)
  - ☐ Tower
- ☐ Assess the need for additional resources.

Phase 2. Pre-rescue Operations

- ☐ Make general area safe. (Cold Zone)
- ☐ Make rescue area safe. (Warm Zone, Hot Zone if possible)
  - ☐ Establish lobby control and accountability for Hot Zone.
  - ☐ Designate a safety officer.
  - ☐ Designate a Technical Rescue Officer (TRO).
    - ☐ Equipment Management
    - ☐ Technical Safety
    - ☐ Mainline
    - ☐ Belay Line
    - ☐ Qualified Climber/Lead Climber (Tower Rescue)
    - ☐ Attendant/Rescuers
    - ☐ Edge/High Directional Personnel
    - ☐ Offsets/Highlines
    - ☐ Other Personnel
  - ☐ Develop incident action plan.
- ☐ Proper personal protective equipment for the rescuers is in use.
- ☐ Appropriate rescue and patient packaging equipment is on scene.
- ☐ Personal protective equipment for the victim in on scene.
- ☐ Pre-rescue briefing.

Phase 3. Rescue Operations

- ☐ Technical Rescue Officer (TRO) commences rescue operations.
  - ☐ Complete roll call of technical rescue stations.
  - ☐ On belay!
  - ☐ Rescuer(s) into hazard zone.
  - ☐ Rescue Package out of hazard zone.
  - ☐ All stop! Rescue complete.

Phase 4. Termination

- ☐ Remove equipment.
- ☐ Personnel Accountability Report (PAR)

Incident Commander Responsibilities and Goals

- Fix the responsibility for Command on a certain individual through a standard identification system, depending on the arrival sequence of employees, rescuers, and supervisors.
- Ensure that strong, direct, and visible leadership will be established from the beginning of the rescue.
- Establish a rescue process that clearly defines the responsibilities each individual of the team.
- Provide for the ongoing safety of personnel and bystanders.
- Extricates the endangered and treats the injured.
- Stabilize the incident, and bring it to a safe and expedient conclusion.

The Incident Management System is used to facilitate an organized and controlled rescue environment. The incident commander is the conductor who drives that command process to its successful and safe conclusion. It is important that this leadership structure matches the needs of the incident to achieve the completion of all the command goals.

Establishing Command

The first rescuer to arrive at the scene of a major event requiring the extrication, victim treatment, and scene stabilization typically assumes control of the incident. This person will stay in control until such a time that a higher qualified member/rescuer takes over, or the incident is stabilized and ultimately terminated.

When possible the first arriving rescuer initiates the Command process by giving an initial radio report.

The **Radio Report** should include:

A. Identification of who is on the scene and talking.
B. A short, but concise description of scene conditions upon arrival.
C. A account of preliminary actions in progress.
D. A quick statement of obvious concerns.
E. Assumption of control.
F. Announce command location.

Incident Management[1]

Size-up

Size-up is a rapid overview of the obvious, what is observed by everyone, and what is said by witnesses.

C.A.N. report (Conditions, Actions, and Needs)

This is an ongoing communication tool between rescue personnel and Command, the focus is on simple, direct communication.

Level 1 Staging

Level 1 staging is the immediate gathering location of first arriving rescue personnel, typically in close proximity to command, (typically, close enough for voice communication)

Level 2 Staging

Level 2 staging is a location designated by command where continued arriving resources gather and await further assignment. Level 2 staging is typically positioned well outside the field of action, yet close enough to advance forward to the scene within a couple of minutes. This allows for a systematic pooling of equipment, rescue and support personnel without overwhelming the scene with congestion.

Sectors or Groups

Sectors are subdivisions of larger command events that require a manageable span of control by Command.

Sectors are named by Command, typically using their location and/or function. i.e. North Sector, West Sector, Sector 2 (2nd floor), Rescue Sector, Hazmat Sector, or Treatment Sector, etc.

Each sector will have a Sector Officer who is responsible for communicating with Command (C.A.N. report) and supervising the actions within that sector.

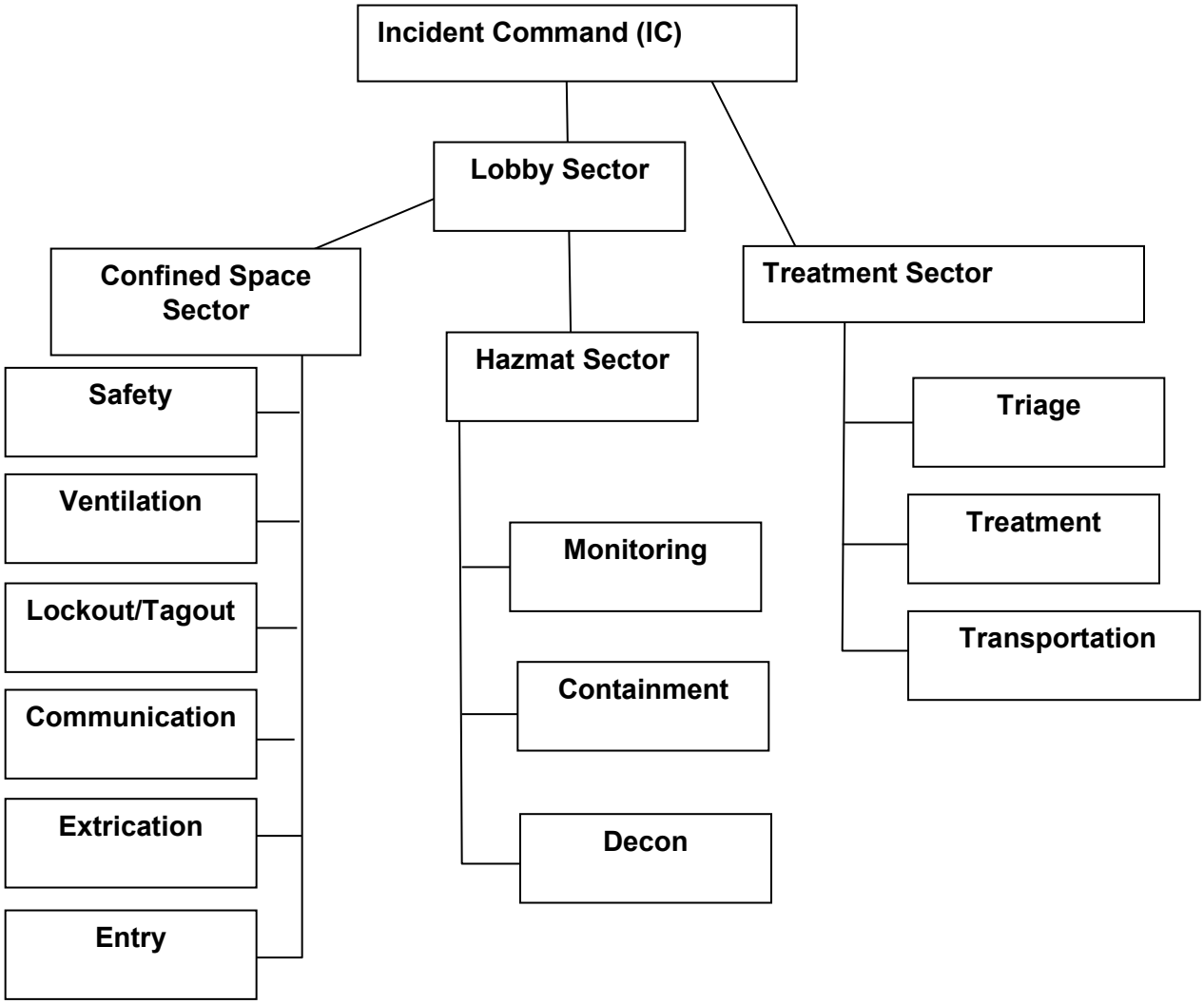
Sections and Branches

Sections and Branches are subdivisions designed for extremely large command events that require a manageable span of control by Command.

Typical Order of Command Divisions

IC → *Sections* → *Branches* → *Divisions/Groups/Sectors*

Incident Command Structure (Typical)



Section 2: Rope Rescue

Introduction and Overview

Scope

This training manual is intended for the exclusive use by Kary Environmental Services rescue members and instructors. This book is written with the intention of evolving as changes and needs are identified by Kary Environmental Services.

This reference manual addresses multiple NFPA 1670 requirements as well as OSHA Standards for rescue technician, including:

- NFPA 1670, Awareness Level,
- NFPA 1670, Operations Level,
- NFPA 1670, Technician Level.
- OSHA 1910.146 (k) Permit Required Confined Space Rescue
- OSHA 1026.1211 Confined Space in Construction Rescue Services
- OSHA 1910.134 Respiratory Protection

Additionally, most sections of this book are labeled as Level 1, and/or Level 2 Rope and are compliant with the NFPA 1006 Rope Technician requirements.

Purpose

The purpose of this manual is to provide a training resource for Kary Environmental Services rescue members and instructors specific to the rigging skills required for the technical evacuation of a person requiring assistance in an industrial environment.

It should be noted that this book is written primarily for Kary Environmental Services rescue team members and instructors, and the focus is on the safe movement of single person loads. However, there is information in this document that addresses multi-person loads. This information will assist Kary Environmental Services management in evaluating visiting contractors, and other rescue entities that may be required to come onsite.

This reference manual is appropriate for all Kary Environmental Services rescue courses. Specific topics and/or chapters are individually recommended for applicable course levels.

Ops **=Operations,** **T** **=Technician,** **Adv** **=Advanced Use**

Attention to Detail and Safety

The National Fire Protection Association (NFPA), without question, is the most recognized Firefighter/rescuer general consensus standard in the United States. Although NFPA does not have any authority to enforce or regulate the standards it has published, they do offer substantial guidance for today's technical rescue technician. To quote NFPA 1670;

"While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its codes and standards".

"Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances".

"The exercise of reasonable care in any given circumstances" is a key legal phrase in coping with our bottom line – "DON'T GET ANYONE HURT"

Don't get anyone hurt is our number one goal. A distant second place concern is, if someone does get hurt, did we do everything possible to avoid the injury? Finally, if an injury does occur, what will be the interpretation of the management and legal system?

How do we prevent death and injury in a profession that demands a high level of technical skills in moving a person? To borrow a training philosophy from the Army, keep it simple, applicable, and repetitive. Safety is everything – when it comes down to it, it is our primary rule. Lack of safety during a rescue becomes an emergency in its own right. It is the responsibility of each team member to be on guard against non-safe situations. Catastrophic failures can always be traced back to the accumulative effect of several "lesser" mess-ups, over-sights, or in many cases, simple lack of knowledge, and training. Safety is a mindset all rescuers must possess, this mindset starts with absolute attention to detail.

Equipment:

Ops

This section on equipment is based on established rope rescue practices that are commonly used by the Kary Environmental Services. Having said this, the equipment that is addressed in this section is not all inclusive of the rescue equipment that is used by the Kary Environmental Services. This section only addresses the basic rope rescue equipment that needs to be identified on a personal team member level. It is important for each member of the team to stay well-informed and up-to-date on current team equipment and related procedures.

Personal Equipment

Personal Equipment

- ***Helmet with chin strap***
- ***Gloves***
- ***Light source***
- ***Eye protection***

Photos courtesy of Glenn Speight

Harnesses

The NFPA classifies harnesses into three types:

A Class I harness fastens around the waist and thighs or under buttocks, and designed only to be used for emergency escape with one-person loads.

A Class II harness fastens around the waist and thighs or under buttocks and is designed for rescue work where two-person loads may be encountered.

A Class III harness fastens around the waist and thighs or buttocks and over the shoulders; designed for rescue where two-person loads may be encountered and inverting may occur.

Class II

Class III

Photos courtesy of Yates Gear

Rope

Kernmantle rope is the most common rope used for rescue operations. (Because of its floating properties polypropylene is sometimes used in swiftwater rescue.) Kernmantle rope is constructed of a load-bearing core, or "kern", of nylon fibers surrounded by a braided, protective outer sheath, or "mantle". The core is completely protected by the mantle and holds most of the load. It has a high strength to weight ratio, and maintains most of its strength when wet (approximately 85%). Kernmantle rope comes in two types; Dynamic and Static.

Dynamic rope consists of twisted or bundles that make up the core. This twisted core provides a high stretch quality. This allows as much as 40% stretch in the rope, depending on the manufacturer. Dynamic rope is very important in rescue work solely for the purpose of belaying a lead climber.

In contrast, static and/or low stretch kernmantle rope stretches very little, from 2-4% under load. This type of rope is made from an outer braided sheath (mantle) which is woven over straight nylon fiber core (kern). The core supports 85% of the rope's strength.

"Static" kernmantle rope is used for rigging rescue system because of its high strength, low stretch and handling characteristics.

Photo courtesy of BlueWater Rope

Rope Strength

Accessory cord rope is generally considered to be diameters 9mm and smaller. It is also of kernmantle construction and has the same characteristics as larger rope. Load Releasing Hitches should be tied with 9mm rope, system prusiks should use 8mm and personal prusiks should be tied with 6mm or 7mm.

Mainline and belay line applications use 11mm (7/16) and according to the NFPA 1983 Standard, life safety rope that is designed for technical rescue must have a minimum breaking strength of 20kN.

Typically, life safety rope varies in lengths between 100 and 600 feet. Any rope longer than 600 feet becomes a true rope management challenge; only in extremely rare rescues would longer rope be needed.

Minimum breaking strength of various rope diameters of low stretch kernmantle rope fluctuates from one manufacture to another; but in general, they are as follows:

SIZE	BREAKING STRENGTH (lbs.)
Accessory Cord, 6mm	2500
8mm	3500
9mm	4500
11mm (7/16”) rope	7500
12.7mm (1/2") rope	9000

General Rope Care

The single most important factor in rope care is good sound rigging skills.

We use rope on rope all the time in rigging applications, haul prusiks, ratchet prusiks, tandem prusik belays, and knots just to name a few. The one thing all these good applications have in common is that they are for the purpose of stopping or holding. The key question in dealing with nylon on nylon is; is there a sustained rapid motion or rubbing (even for a very short time) between two sections of rope and/or webbing. Tandem prusiks used for system belays typically involve very slow and controlled movement during normal operations; this is a safe, proven and excepted practice.
Something is dangerously wrong if there is unwanted motion in the rescue system. This principal can be applied to something as simple as tying a knot. Even a good knot will degrade a rope by as much as 35 %, a badly tied knot (leave alone the fact it could come untied) will add small amounts of movement

to the rope, usually in the area of the most server bend. What makes cut rope fibers so dangerous are the extreme pressures we operate these systems under.

Use edge protection whenever possible to avoid abrasion. Redirect rope away from sharp objects and edges. Edge rollers, edge protectors, and discarded fire hose provide effective rope padding.

Rappelling also causes abrasion. Rappelling should be slow and deliberate. Fast rappels should be avoided. Friction causes excessive heat build-up and can damage the rope. It also demonstrates poor technique and lack of control on the part of the rappeller. "Bouncy" rappels should likewise be avoided. They cause unnecessary shock loading and may cause the rope to "saw" and abrade over an unprotected edge. A cut easily propagates completely through a tensioned rope once it is initiated.

Rope should be kept away from sulfuric acid (battery acid), other strong acids, bleach, hydrogen peroxide, ultraviolet light and excessive heat. Although nylon is not damaged by gasoline, rope should be kept free of petroleum products such as gasoline, kerosene, diesel fuel and oil.

Rope Inspection

All rope should be carefully inspected when first purchased, after each use, and after cleaning. Sliding the rope through one's hands to feel for any soft spots, bulges, thin areas, or other deformities can do this. Feel for changes in rope stiffness and changes in diameter, such as an "hourglass" effect. Rope can also be examined visually for deformities. Most kernmantle rope is colored. Internal core fibers are white and easy to spot if cord damage is suspected.

When an abnormality is found, or if the rope sustains a substantial shock load, the rope should be immediately taken out of service.

It is wise to keep a rope log, documenting all use of the rope, and any changes noted. Deciding when to retire a rope is a judgment call and depends on the length of time the rope has been in service and the type of use incurred. It is a subjective appraisal of the appearance of the rope and its overall condition.

Webbing

Vertical rescue utilizes two types of 1" webbing: *tubular* and *flat*. Tubular, nylon webbing of spiral stitch construction has no seam; it is rated at approximately 4000 lbs. Flat, 1" nylon webbing is also rated at approximately 4000. Webbing is most commonly used for anchor construction and tying emergency harnesses. Flat nylon webbing in various widths is commonly utilized in the construction of factory-made runners and harnesses. Webbing should be used, inspected, and stored just as rope.

Rope and Equipment Bags

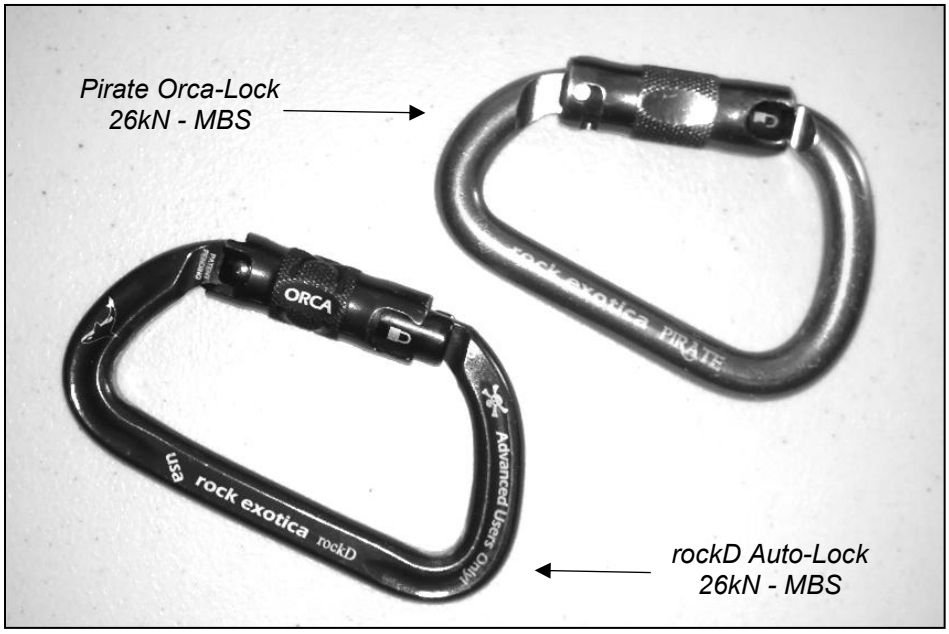
Many styles, shapes and sizes

- **Protects rope from damage**
- **Assists in keeping rope from tangling**
- **Assists in transportation and carrying of rope and other accessory rescue equipment**

Photo courtesy of Yates Gear

Carabiners

In rigging for rescue, carabiners are the most commonly used hardware component. Carabiners are used to connect other hardware and software components of the rope system. All carabiners used by the Kary Environmental Services meet NFPA 1983-Technical Use.



Maillon Rapide Quick Links typically stamps the Working Load Limit (WLL) on their products. Below is the rating of a few of the more common screw-links and tri-links:

- 7mm Oval 5kN (WLL)
- 12mm Oval 14kN (WLL)
- 10mm Delta 8kN (WLL)
- 12mm Delta 10kN (WLL)

Photo courtesy of Glenn Speight

Care of carabiners and all other rescue hardware should include:

- Avoid dropping or throwing.
- Keep clean and free of dirt.
- Do not oil.

Carabiners are rated in capacity by loading along the long axis. They have little strength when side-loaded along the short axis. Some offset carabiners, such as the modified "D" carabiner, help prevent side loading. *Make sure to always load a carabiner along it's spine (the long axis).*

It is dangerous to triple-load a carabiner, (to place a load on it in three directions), if the need arises, use a triangular screw link.

Do not use oil or grease-based lubricants on carabiners. Try using an air hose for gates that are stuck or slow to operate, if the carabiner still gives you grief, get rid of it, a small price to pay for safety.

Retire carabiners that show:

- Sharp edges or burrs.
- Cracks.
- Weak gate spring.
- Loose or bent gate rivets.
- Deformity.
- Or if it is known to have been shock loaded.

Know your equipment, especially carabiners, hand-me-down equipment should be avoided.

Pre-rigged Mini Haul Systems

The mini haul system is often referred to as the Set-of-fours, or simply SOFs.[2] Pre-packaged mini haul systems are enormously useful in rope access and rescue. Indeed, they've been in use for decades. Like any pre-rigged system, it is the responsibility of the end user to fully understand the application and method in rigging and re-assembling the system when needed.

Petzl ID

The ID (Industrial Descender) has been available for several years now, and it has only recently become somewhat acceptable in the US fire service. This is a bit hard to understand because the ID has proven beyond any doubt to be a simple and cost effective solution for mainline descent control. Even though it introduces friction into the system, the ID, given an adequate haul team and proper understanding of rigging physics, makes changing from a lower to a raise incredibly simple. As a rescue system belay device, the ID comes very close to eliminating the number one cause of belay line failures – the human factor. In addition, the shock absorption qualities exceed tandem prusiks and the 540.[3] It is through the formalization of rope access into the industrial working at height culture that the ID has made great strides in acceptance as the premier “must have” tool.

Petzl Ascension with the Metolious Easy Aider Foot Loops (Technician Use Only)

The Petzl Ascension hand ascender combined with the Metolious Easy Aider foot loop is a favorite preferred by many rope access technicians as an ascending system for vertical mobility.

However, there are several manufacturers that produce hand ascenders and foot loops and any number of them may prove to be more preferable to the end user than these particular examples. The Petzl ascender is a little more efficient in receiving carabiners in the upper hole and when capturing the host rope, i.e. 3:1 pulley systems for vertical hauling and ascending.

The Metolious Easy Aider foot loops is very efficient when adjusting the length while in use.

The Petzl ASAP

The Petzl ASAP is another favorite auto belay device. The ASAP is bulkier than the Kong Backup. However, the ASAP is the smoothest device during descents. This tool is extremely effective when belaying on tensioned rope systems like the trackline of a sloping highline system.

Pulleys

There are several manufactured types of rescue pulleys that will accomplish various functions during the course of a rescue.

Pulleys typically come in one of two different axle types; bushings, and sealed ball bearings. Ball bearing pulleys are approximately 90% efficient verses the bushing type which is only about 75% efficient.

Photo courtesy of Glenn Speight

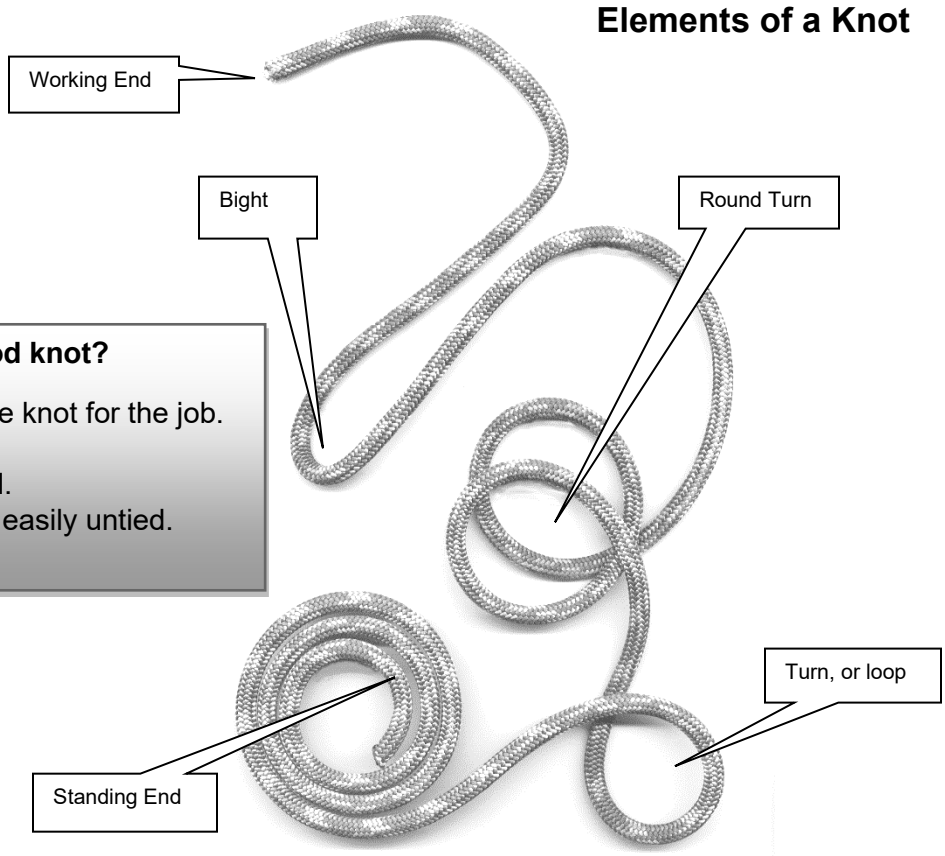
Rock Exotica Omni Block Pulleys

The Omni Block pulleys are simple a work of art for a strong (36kN MBS) rescue and rope access pulley. What makes this pulley so attractive is the ability to insert the rope, or remove it from the sheave via the slide and lock side plate. For rope access and rescue, this feature is invaluable for improved efficiency.

Knot Craft:

Ops

Elements of a Knot



What makes a good knot?

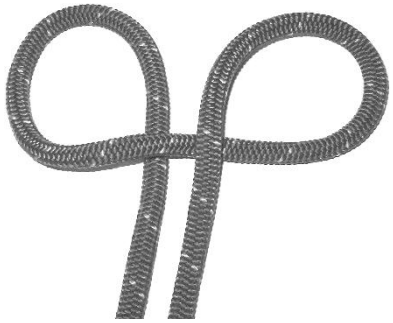
- Most appropriate knot for the job.
- Recognizable
- Cleanly dressed.
- When required, easily untied.

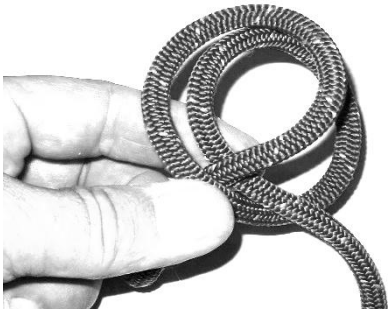
Single Hitch Family

Hitches are a type of knot that, for the most part, is dependent on a host object for maintaining its form and function. When the host object is removed from the hitch, or the hitch is removed from the object, the hitch will come apart.

Clove Hitch

T





Clove Hitch Tied Around an Object

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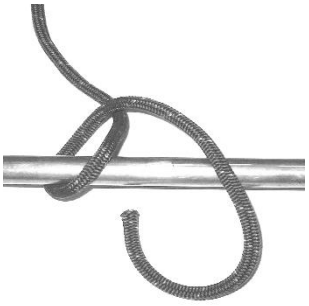
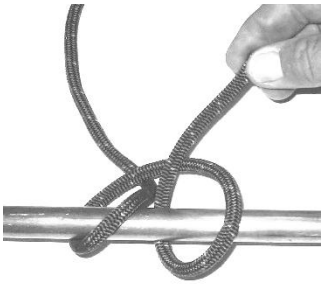
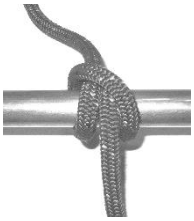


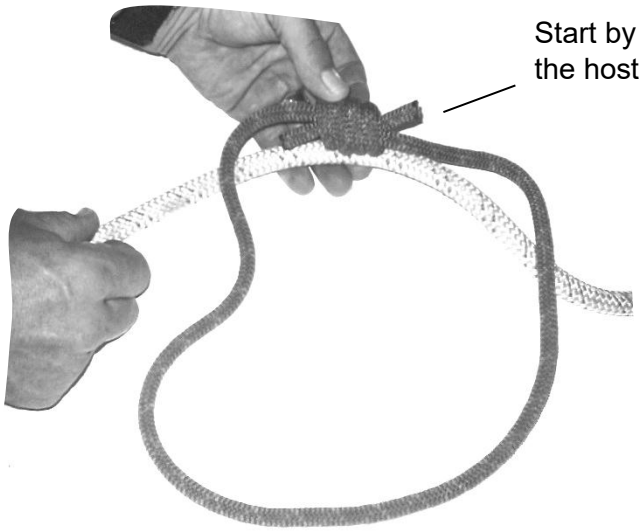




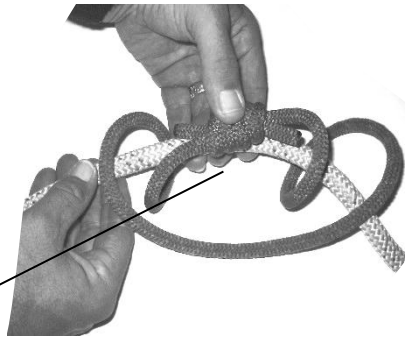
Prusiks

The Prusik is used in everything from personal attachment points for ascending, to system uses such as Tandem Prusik Belays, and Haul Prusiks for mechanical advantages. The ability to tie the prusik correctly is a must for all rope rescue personnel.

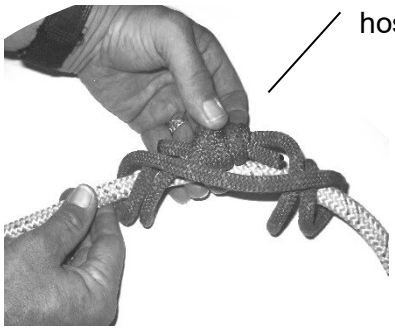
Ops

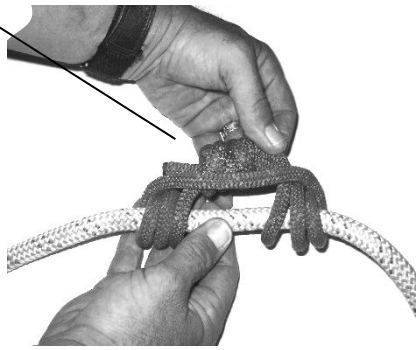


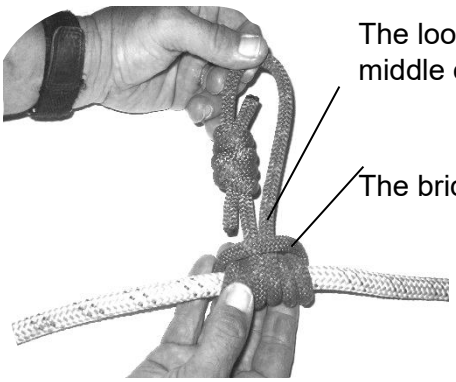
Start by placing the bend on the host rope.



Roll the bend around the host rope three times.







The loop should originate from the middle of the knot.

The bridge should run end to end.

Dress the prusik and offset the bend to one side of the loop.

Overhand Bend (Using Webbing)

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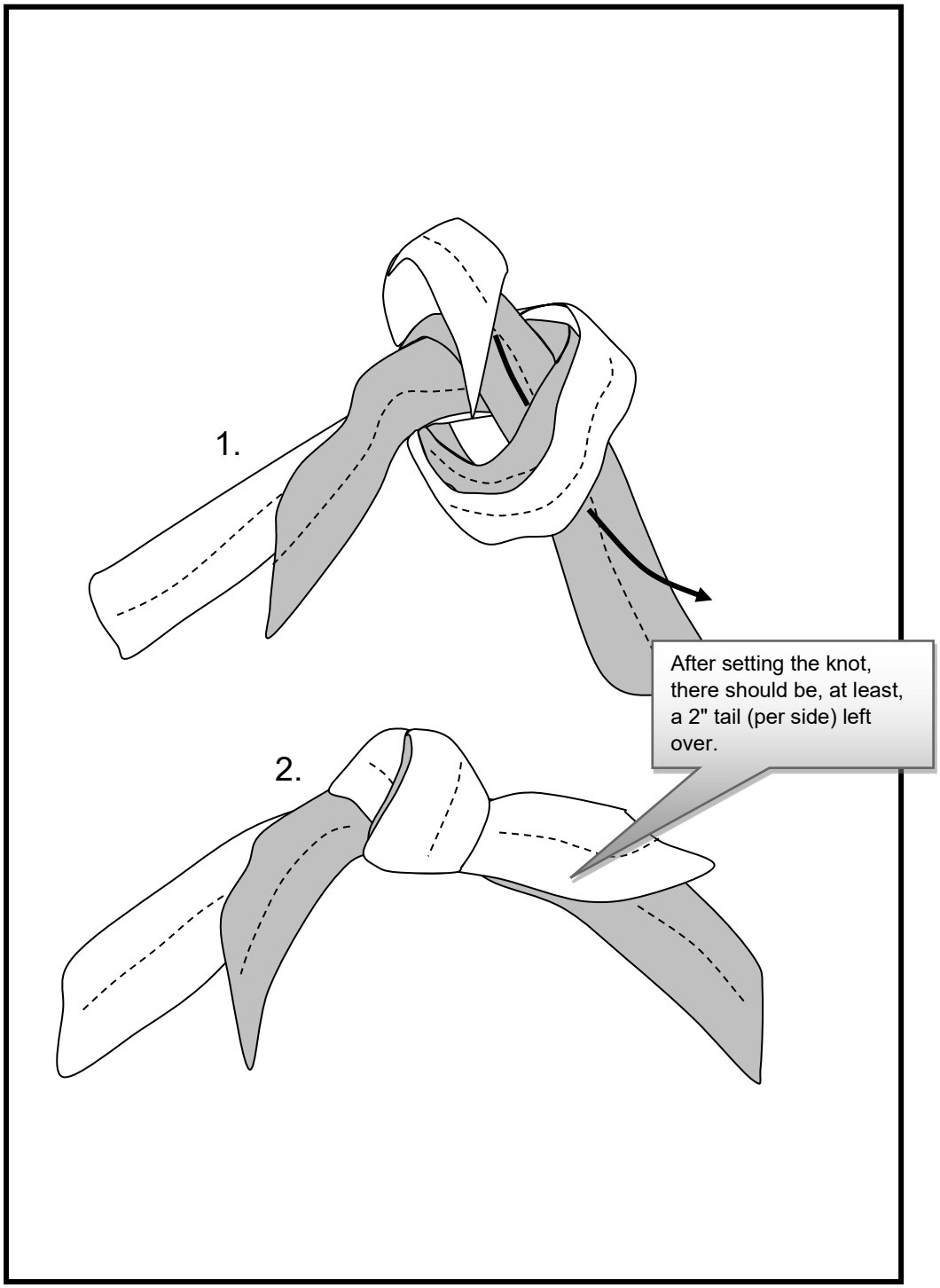
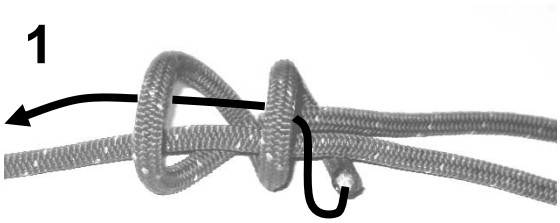


The Double Overhand and Follow-through Bend

T

This Bend is used to combine two working ends of rope, i.e. extending a line, or for making accessory cord loops. Some teams advocate a triple overhand bend. 3 overhands is over-kill, 2 will more than do the job.

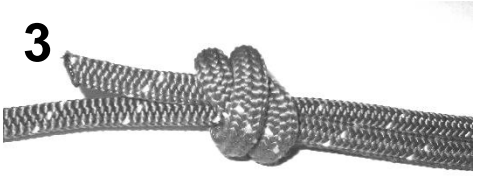
1



2

After the first Double Overhand is tied, rotate the entire ensemble clockwise and repeat the first three steps.

3



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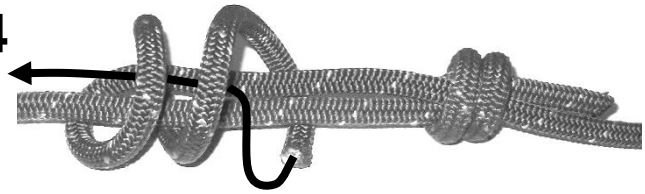

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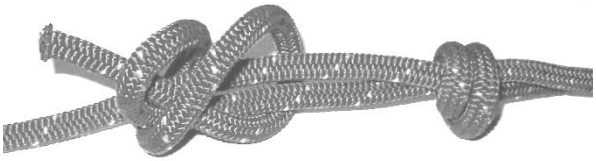

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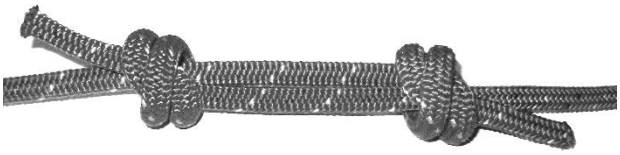

After the two Double Overhands are tied and the tails are pre-tensioned about 1 ½ " long (the tails will tension to about 1" in length when the bend is set), pull on the standing parts so that the two knots slide together as shown below in steps 7 and 8. When this bend is tied correctly, two inter-locking Xs will form on one side (7) and the other side will look parallel.

7

8

Butterfly

The Butterfly is the most versatile mid-line loop. This knot is very fast to tie, quick to untie, and easily recognized.

In addition to its mid-line qualities, the Butterfly has three distinct loops, when the knot is opened up, can be loaded in three different directions.

It is considered part of the overhand family, and it is a close cousin to the “Ashley Bend”, the Striate Bend and the “Hunters Bend”.

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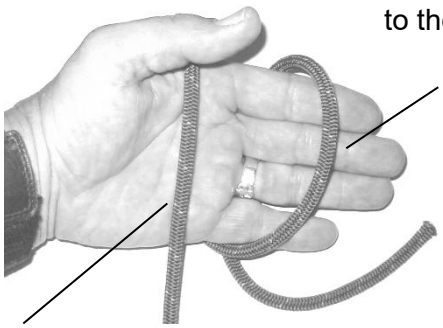

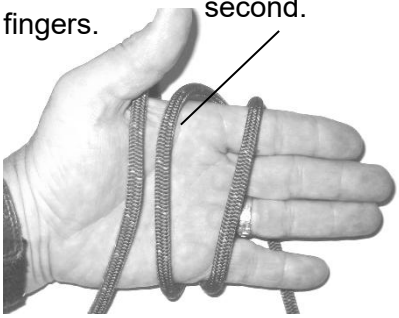

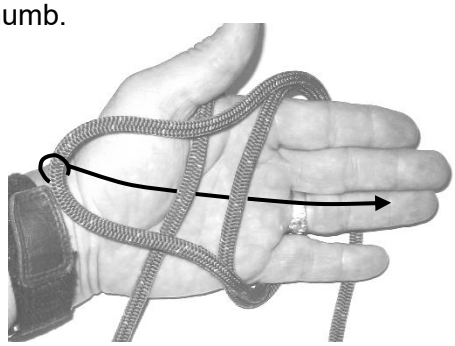

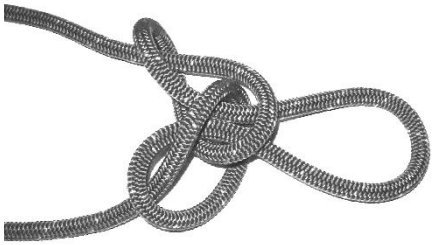

Butterfly Tied From a Bight (Twist Method)

Many time it is preferable to tie the butterfly from a bight, this technique allows for a precise location of the final loop. This is a valuable tool when rigging multiple tensioned back-tie anchors as shown in the bottom photos.

T

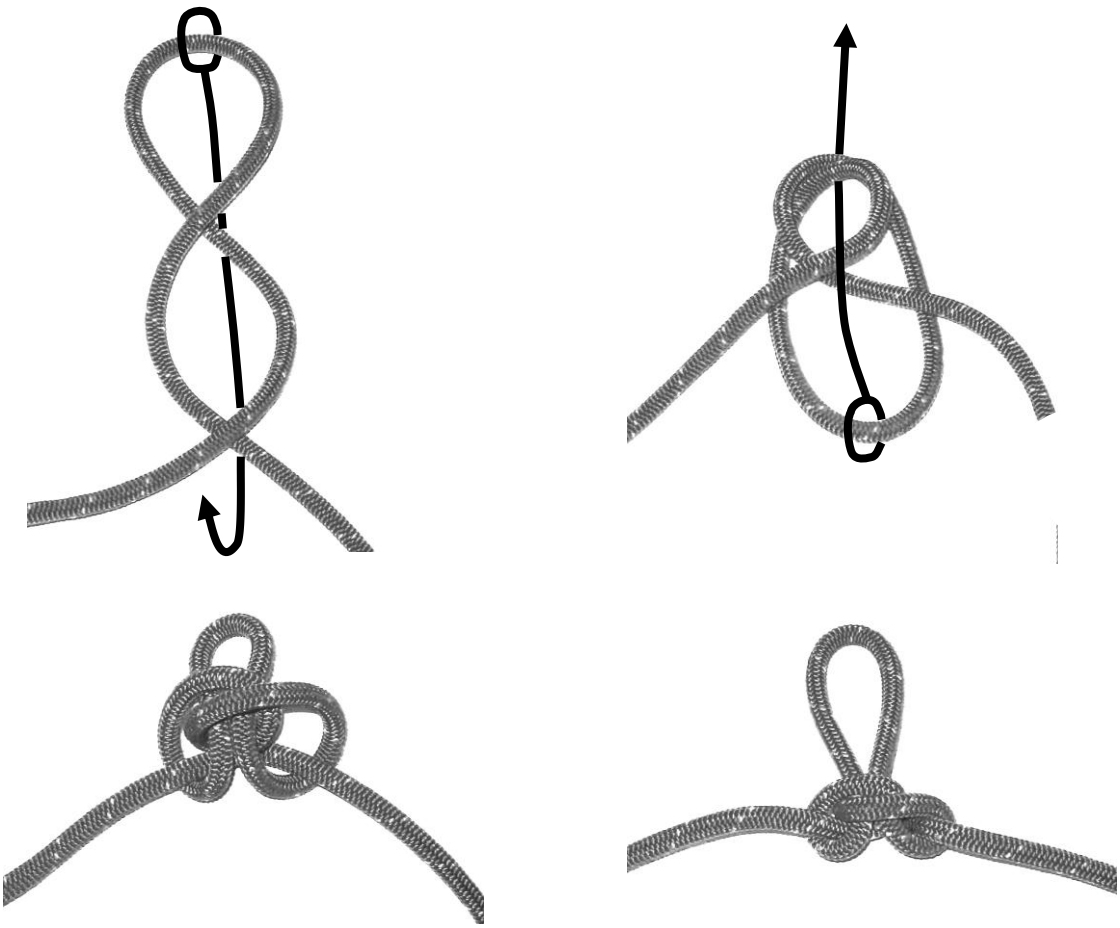

Figure Eight Family

Figure Eight, and the Figure Eight on a Bight

The *Figure Eight* is the base knot for the entire figure eight family of knots. The figure *Eight on a Bight* is one of the two most used knots (the other being the Bowline) for rescue anchoring.

Some notable advantages with the *Figure Eight*, and the *Figure Eight on a Bight* is that they are very recognizable, which makes mistakes in tying these knots obvious. In addition, the Figure Eight and the Figure Eight on a Bight are easy to learn and remember.

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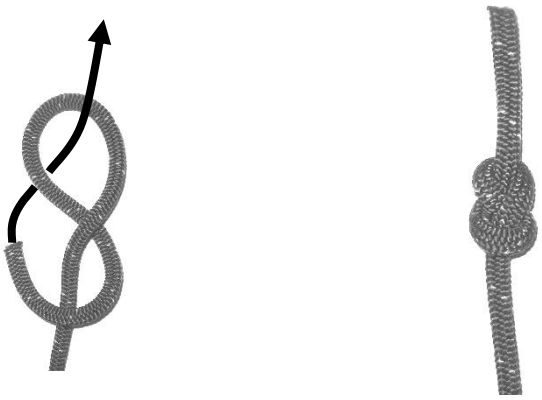

Although the *Figure Eight on a Bight* is a slightly stronger knot than the Bowline, the tradeoff is that the *Figure Eight on a Bight* is definitely harder to untie after being subjected to a heavy load. In addition, given equal loops, the gain of the Figure Eight on a Bight is double the size of the Bowline. Sometimes this is not a huge issue, but when working under a high directional, using ½" rope, every bit of working space counts.

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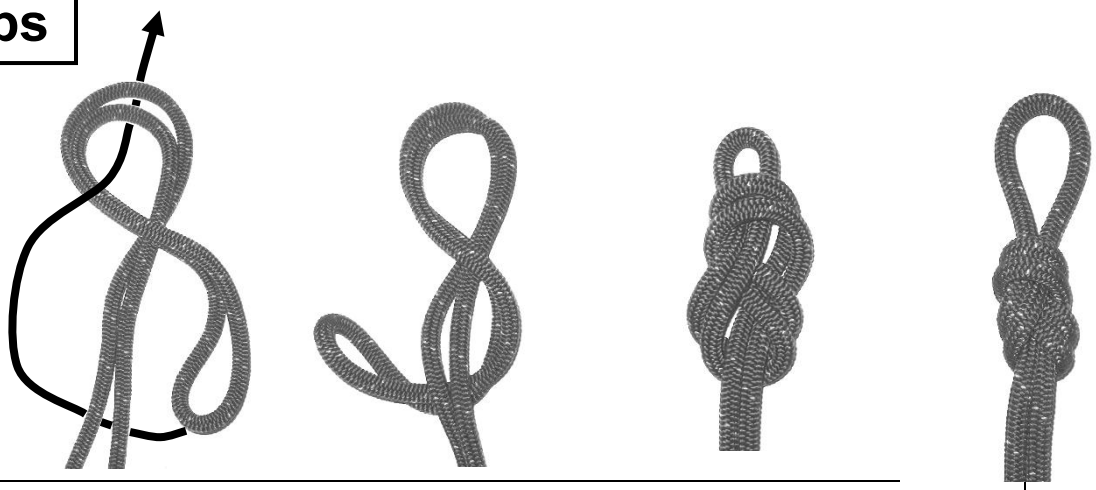
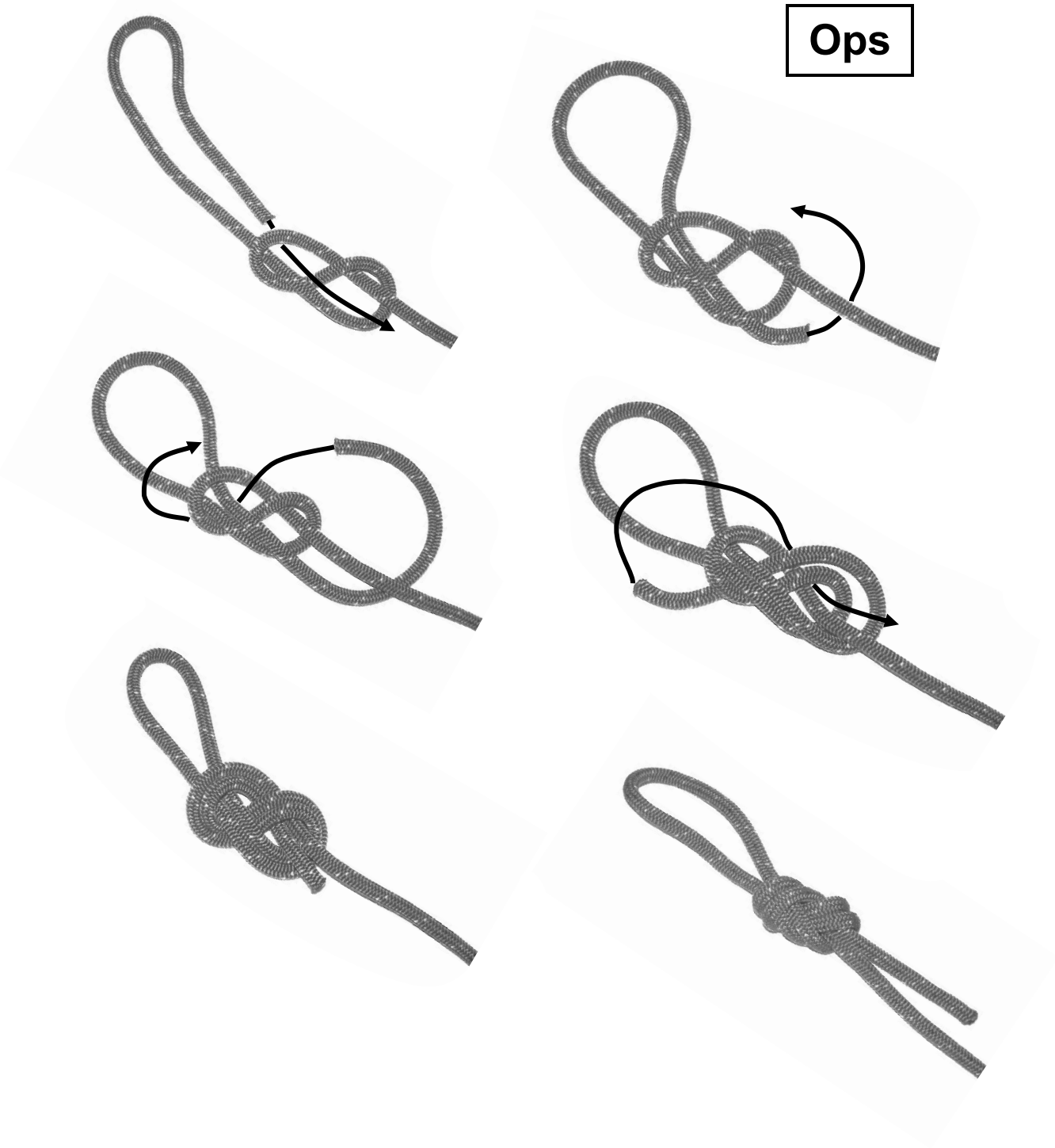


Figure Eight Follow Through

Although the end result of this knot is the same as the Figure Eight On a Bight, the way it is tied and it's function is much different. This knot is typically used when the need is to tie around an object. Care must be taken to correctly retrace the original Figure Eight. As with most knots, this knot is very susceptible to failure if it is not tied correctly.



The Bowline Family

The *Bowline* is the most versatile knot in rope rescue. It has received a bad rap for being a weak knot…it would serve well to study the history of this knot. The Bowline is historically the knot used to secure the bow line of a ship while in port, if it is strong enough for that job, it more than meets the task of rescue rigging. The *Bowline* does have three main advantages over other knots in that it is substantially easier to untie, it is self-dressing, and it has a small gain.

The *Bowline* is strong under tension, and susceptible to “self-untying” when in a relaxed position, because of this fact, Kary Environmental Services utilizes the Yosemite back-up (see next page).

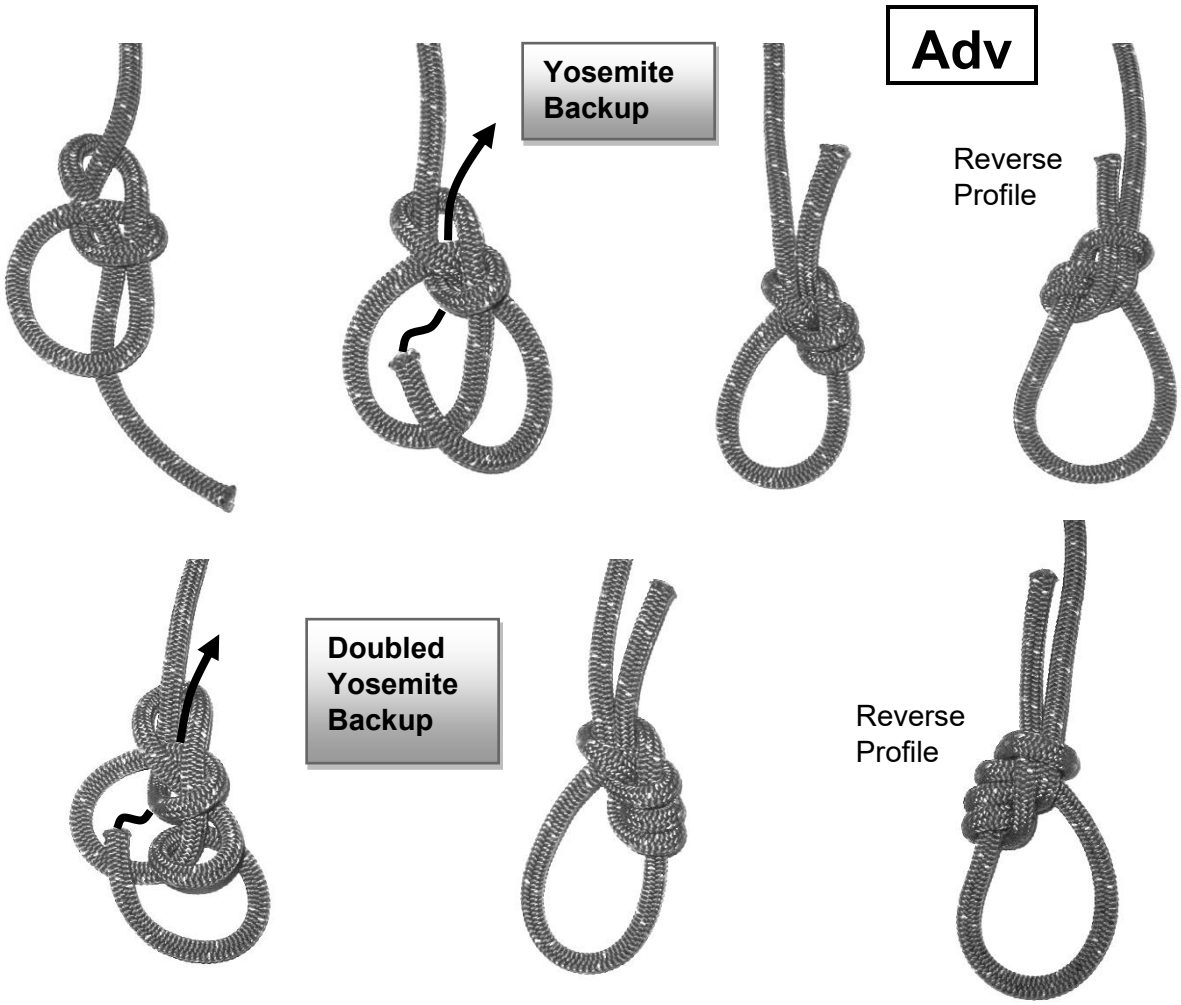
T

The Double
Overhand backup.

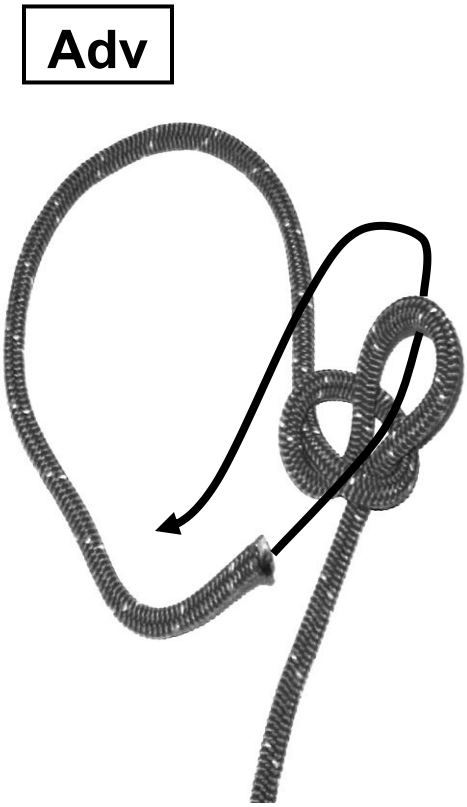
Yosemite backup to the Bowline (NFAP 1006, Level 2 Rope)

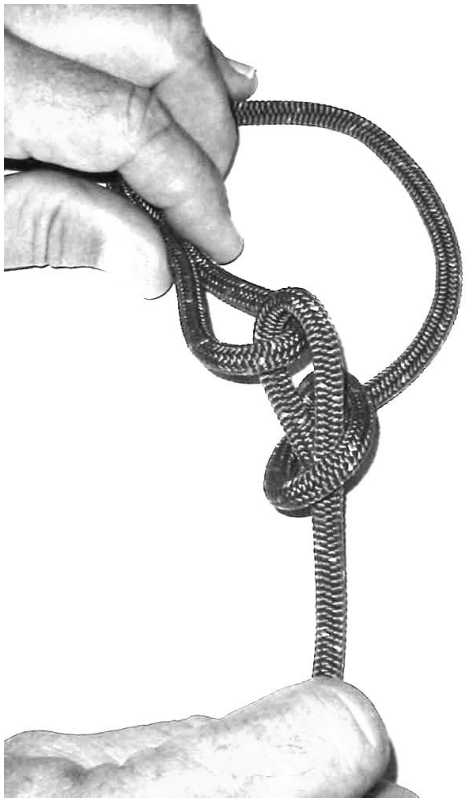
As we stated earlier, the Bowline needs a backup knot. Under tension there are no problems with the Bowline (even with dynamic rope). It is during those times when the Bowline is in a relaxed position that it becomes susceptible to coming undone, mandating a backup. Note, the Double Long Tail Bowline does not require a backup because the long tails that are used as secondary attachments for the rescue package keep the knot from undoing.

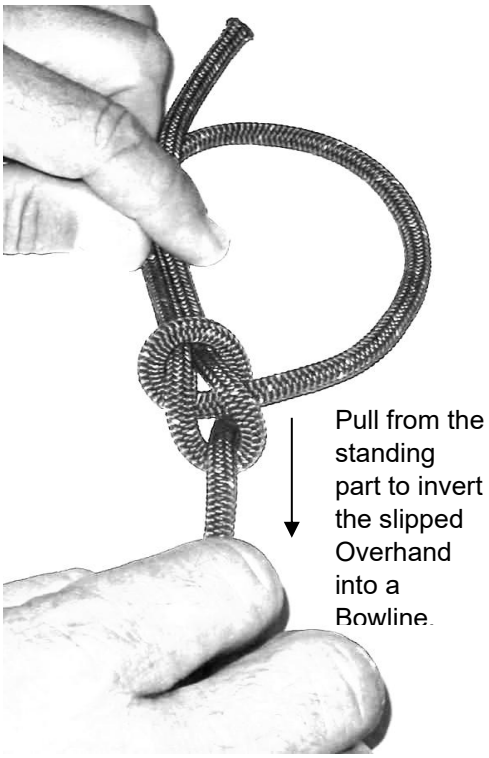
The Double Over-hand Backup is a very secure backup (shown on the previous page). However the Double Over-hand Backup adds more bulk to the loop of the Bowline; this is what makes the Yosemite backup so popular. It is much cleaner, keeping the loop free, and it is also very reliable.



Snap Bowline/Climber's Bowline







Snap Bowline/Climber's Bowline

The Snap Bowline, also known as the Climber's Bowline, is nothing more than a nick name that defines a specific way to tie the knot.

This is a graphic example of how the Bowline is an inverted slipped Overhand. Indeed, this method of tying the Bowline takes advantage of this fact.

This technique works well when facing an anchor or an object that you must be tie the Bowline to. It is extremely quick, and makes the initial adjustment of the loop very easy.

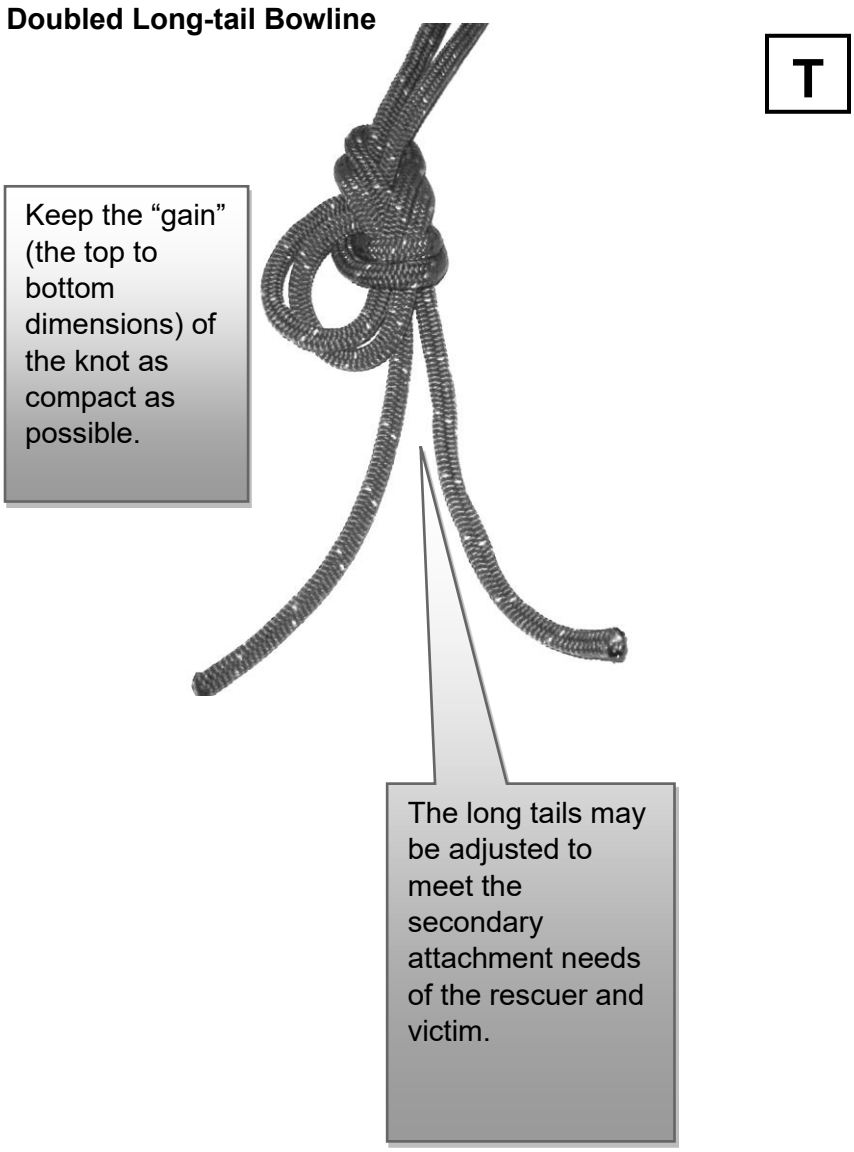
Doubled Long Tail Bowline

The *Doubled Long Tail Bowline* is used in creating the yoke, the culmination point at the rescue end of the mainline and the belay line.

The yoke is the point of attachment for the rescue adjunct, i.e. high angle/steep angle litter attachment, and team based pick-off rescue package attachment.

The doubled bowline is the adjunct attachment point, and the long tails are secondary attachment points for the rescuer and victim. The long tails may be tied at any length to meet the need of the type of adjunct used.

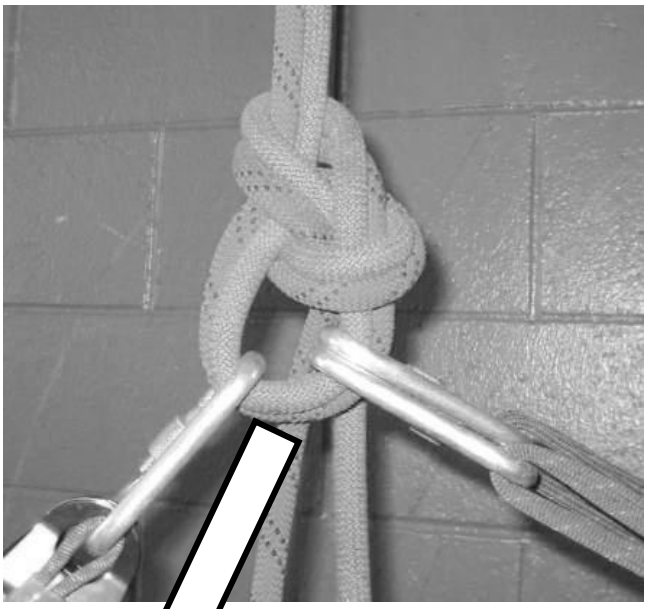
Doubled Long-tail Bowline

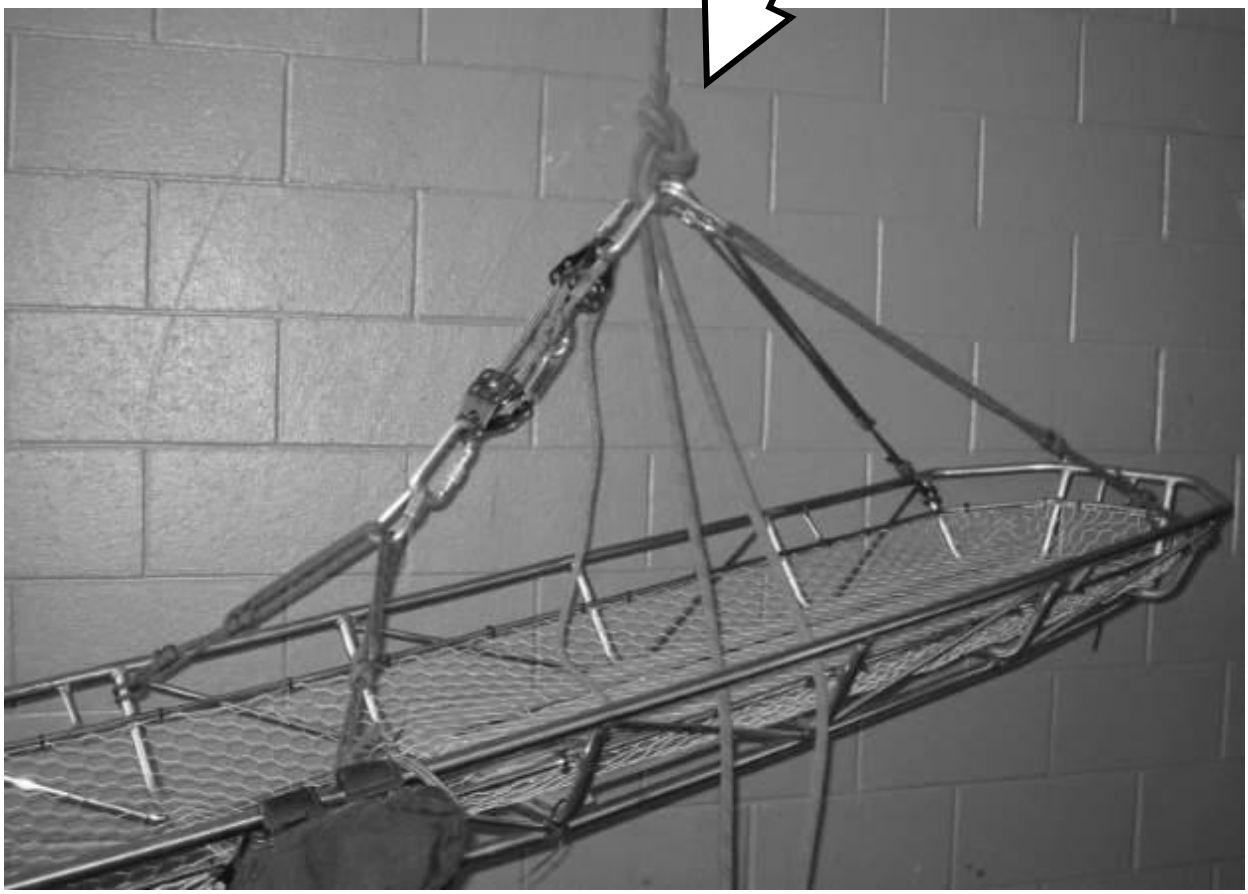


The Doubled Long-tail Bowline is the perfect knot for a collection point for team based rescue adjuncts, easily and safely loaded in multiple directions.

This knot is half the gain of a Figure Eight on a Bight, allowing for added space under a high directional anchor system.

The Bowline is substantially easier than the Figure Eight on a Bight to untie after it has been used for system loads.





Single Point Anchors:

Ops

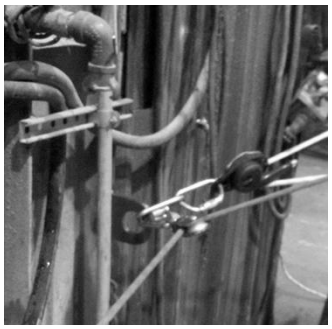
Single Point Anchors

Single Point Anchors are typically rated to a minimum breaking strength of no less than 5000 lbs, or to a 10:1 safety margin for the intended load, whichever is the greatest. Anchors are the most critical component of any rope rescue system. The entire rescue is in jeopardy if the anchors are not reliable. Anchor systems are made up of two major elements; 1-choosing the best anchor (i.e. boulders, vehicles, trees, and bolts), and 2-rigging the anchor. Building an anchor system requires much practice and experience.

When dealing with structures, chose anchor points which are part of the inherent structure of the building. This includes columns, beams, anchors for window cleaning equipment, and elevator housings. Avoid corroded metal, weathered stonework, and deteriorated mortar. Avoid using vents, flashing, gutters, and chimneys.

Often a desirable anchor is off to the side of a needed direction of pull. Ideally, they should be directly above and close to the fall line. When this is not possible (which seems to be more times than not) advanced anchor rigging skills come into play, namely, focusing the direction of the main anchor to a viable position.

Engineered Rescue Anchors



Engineered Rescue Anchor

As industrial rescue teams develops rescue plans, more engineered rescue anchors are being established. This action greatly enhances the safety and controlled speed of the rescue operation.

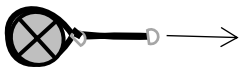
Anchor Straps

Anchor Straps come in a variety of shapes, sizes, and lengths. These rigging tools are commonly used by the Kary Environmental Services. Anchor straps promote rapid attachments with minimal rigging knowledge required.

Anchor straps are typically rigged with three basic configurations:

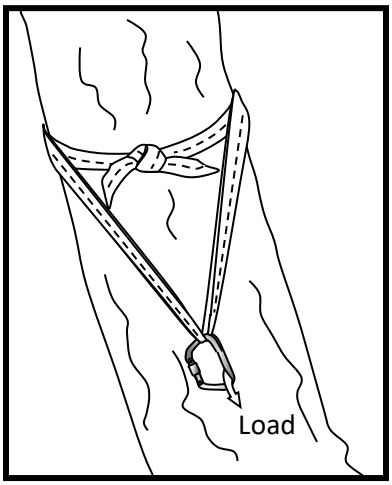
Inline – 100% of the manufacturer's rating.

Choker – Approximately 60% to 70% of the manufacturer's rating.



Basket – Approximately 200% of the manufacturer's rating.

Wrap 3, Pull 2



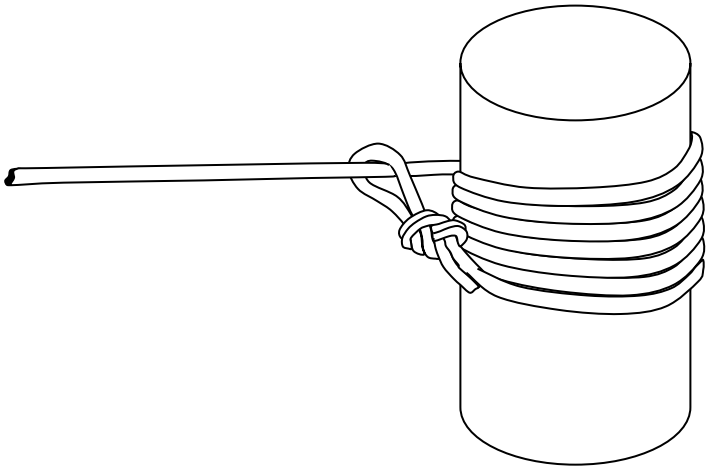
Based on the diameter of the anchor, select an appropriate length of webbing, wrap the webbing around the anchor 3 times, and tie an overhand follow through bend with its ends. Dress the wraps in a way that will position the bend on the first wrap and next to the anchor, pull the remaining two wraps and attach a steel carabiner (with the gate pointing downhill from the anchor). Attach the next link of the system to this carabiner.

Rope may be used in place of webbing when wrapping very large anchors, i.e. a boulder ten feet in diameter.

Tensionless Hitch

A high strength tie-off is used when maximum strength of the rope is needed, i.e. highline operations. The two most common high strength tie-offs are the wrap 3/pull 2, and the tensionless Hitch.

The Tensionless Hitch is made by wrapping the line enough times around a “bombproof” anchor to take the tension off the knot on the last wrap. The smaller the diameter of the anchor the more wraps of the rope is needed.



Tie a "figure 8 on a bight" or a “bowline” on the working end of the rope, and connect this knot to the standing rope just in front of the first wrap by using a steel carabiner

As a rule of thumb for a high strength tie-off, avoid using anchors that are less than 3 inches in diameter.

Advanced Anchor Skills:

T

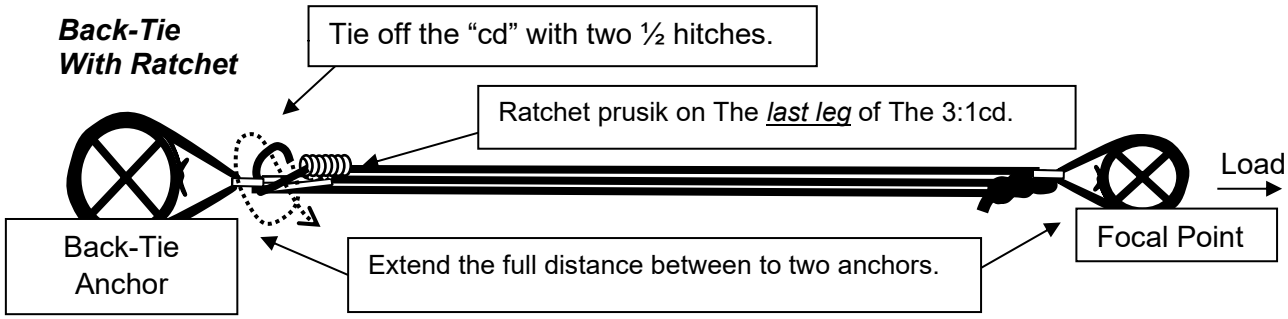
Back-ties

Quality back-tie skills require management of the elongation of the back-tie rope. In other words, doubling, tripling, and even sometimes with smaller diameter cordage, quadrupling the legs of rope between the back-tie anchor and the point being supported greatly helps in mitigating the elongation of the back-tie.

Sometimes a questionable anchor that has a preferable location to the fall line may be employed by backing it up to a bombproof anchor. Back-ties typically connect the two anchors (focal point and backup) by using a 3:1cd MA. Again, addressing the issue of rope elongation, the 3 legs of the MA should extend the full distance between the front anchor and the back anchor. Note in the diagram below that the ratchet prusik is applied to the last leg of the MA. (in a normal MA setup, the ratchet be would on the first leg, closest to the load) By doing this, all three legs of the MA are tensioned for greater strength and minimal rope stretch. *In addition, because this is a "non-hauling" MA, carabiners should be used in place of pulleys.*

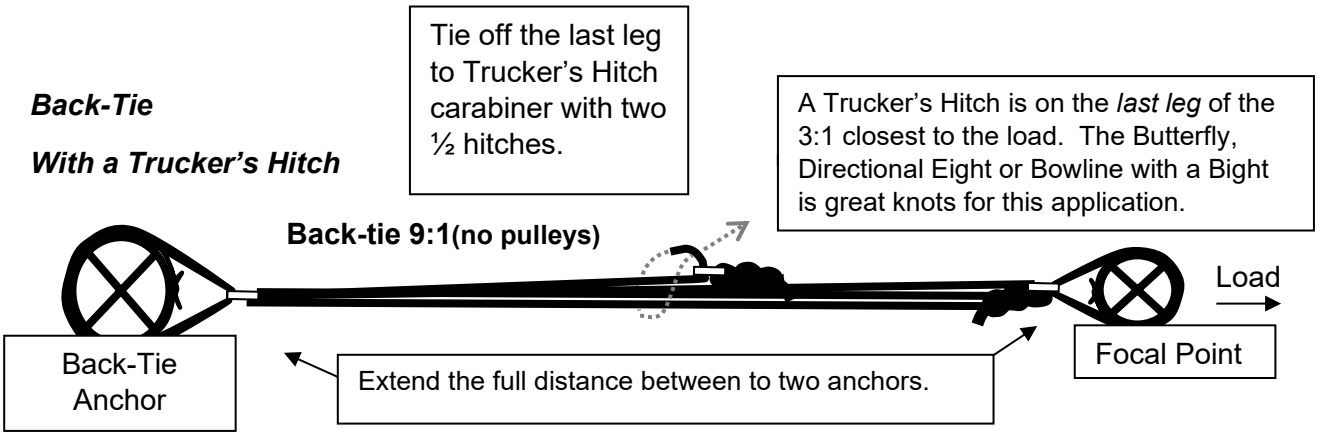
Back-tie 3:1 (no pulleys)

Back-Tie With Ratchet



Back-Tie With a Trucker's Hitch

Back-tie 9:1(no pulleys)



Mainline Lowering:

Ops

Petzl I'D

The Petzl ID

An excellent descender for working on rope, the Petzl I'D's auto-locking feature combines with a locking position for the handle. Additional safety features include an anti-panic function that stops the descent if the handle is pulled too far and an anti-error safety catch that reduces the risk of an accident from incorrect rigging on the rope. The Light Use model has a safety clip on the swinging side plate that reduces the risk of dropping the device when removed from the rope, such as when passing intermediate anchors.

Maximum descent distance: 660 ft. (200 m).

Mainline Operations with the ID

When building a mainline system, consider the possibility of the need to convert from a lowering system to a raising system. There are numerous hidden factors that have caught many teams by surprise. By predicting these factors and pre-planning the Mainline, life becomes much easier and safer when the time comes to convert to the raising system.

Typically, lowering systems are safer then raising systems because we are cooperating with gravity. As soon as we go to a raising system gravity becomes our prime enemy, and gravity's most powerful accomplice is friction. What we are talking about mostly is the friction coefficient or mainline contact with the surface between the mainline anchor and the rescue package. Yes, friction is working in our favor during the lowering process, and if we are going down only, then ground friction isn't that big of a deal (although we still keep a sharp eye out for rope abrasion, and damage), but when it is known that a raising system is going to be employed, we must mitigate rope contact with the surface before the lowering system is put into action. This is best accomplished by the use of a high directional.

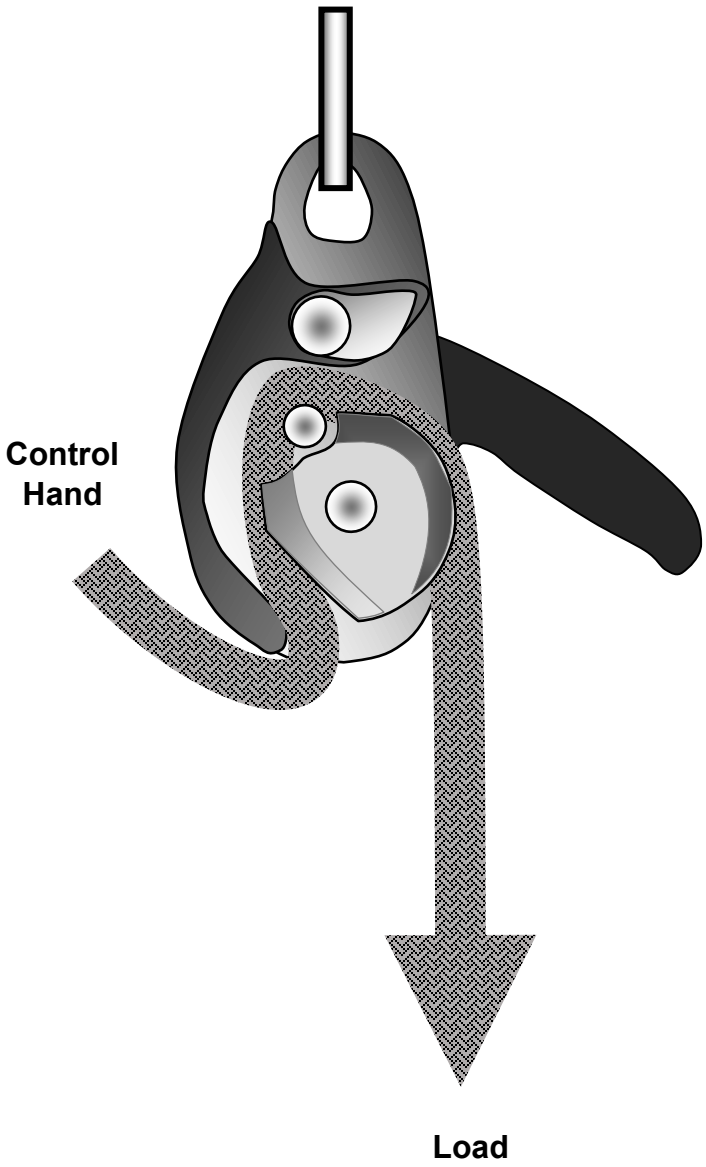
The Ideal Load Weight (ILW) is the weight of the load during a static state; the Practical Load Weight (PLW) is the actual weight of the load plus the effects of the friction in the system, especially at the edge. Unfortunately, this fact is many times overlooked by many teams. During a lowering with approximately 20 feet of rope contact with the surface, the PLW of a 450 pound two person load may be only 150 pounds. During a raising with the same 20 feet of rope drag, the PLW will skyrocket to about 1100 pounds!

What does this mean to our anchor selection? With the use of a high directional the unwanted friction is all but eliminated. Without the use of a high directional, our anchor system is very susceptible to this hidden weight and possibly prone to failure. Control of all the many aspects of friction during a rope rescue operation is a must.

The Petzl ID is quickly becoming the mainstay for the operation of the mainline system. Pulley systems may be built off of the ID and utilizing the ID as the

progress capture.To lock the ID simply pull the handle all the way down (towards the connecting carabiner). A hard tie-off may be accomplished by tying two half hitches around the mainline directly above the ID, and setting the hitches tight to the ID.

Handle in locked position



Belay Systems:

Ops

Tandem Prusik Belay

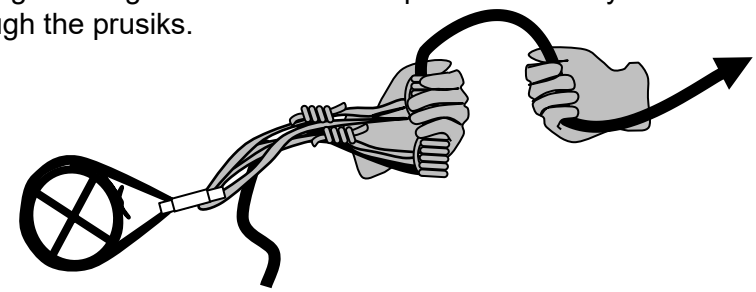
We no longer advocate the use of a pulley behind tandem prusiks as part of a system belay. This decision is based on numerous studies and test that prove the likely hood of tandem prusik belay failures due to the tendency of the belayer's normal reaction of applying tension behind the pulley while the rescue operation is in a hauling mode. Similar failures have also occurred during lowering modes when the belayer is using the old "Z" turn. The "Bubble Turn" as shown below is the preferred method for operating a tandem prusik belay system.

During hauling or lowering modes, it is critical the tandem prusiks are allowed to lock. When the belayer puts the panic/death grip on the prusiks during a lowering failure, or behind the belay pulley during a hauling failure this critical lock is impaired. Panic gripping of the belay line is an extremely high probability anytime human reaction is put into the equation.

Proper Technique for the Tandem Prusik Belay, *the Bubble Turn.*

The tandem prusiks should be tight enough around the host rope that the belayer can hear the belay rope going through the prusiks.

Note: The belay line must have the least amount of slack as possible for the safest operation.



The tandem prusiks must be held back from accidental locking and at the same time, quickly lock if a system failure occurs. The best way to accomplish this is through using the *Bubble Turn* technique. Note that the hand manning the prusiks is bending the prusiks perpendicular to the rope; this will facilitate a much quicker grab of the prusiks when needed. The other hand will feel the weight of the load; as the bubble (the length of rope between the hands) gets smaller, the belay simply pulls a section of the rope through the prusiks (the hand movement should be approximately shoulder width) and creates a new bubble. Also note that the thumbs do not grab the rope; we want the system to be snapped from the belayer's hands if a failure happens.

This technique works equally well going up or down. It is simply a matter switching hands and pulling the belay rope through the prusiks either one direction or the other.

Belaying with the Petzl ID

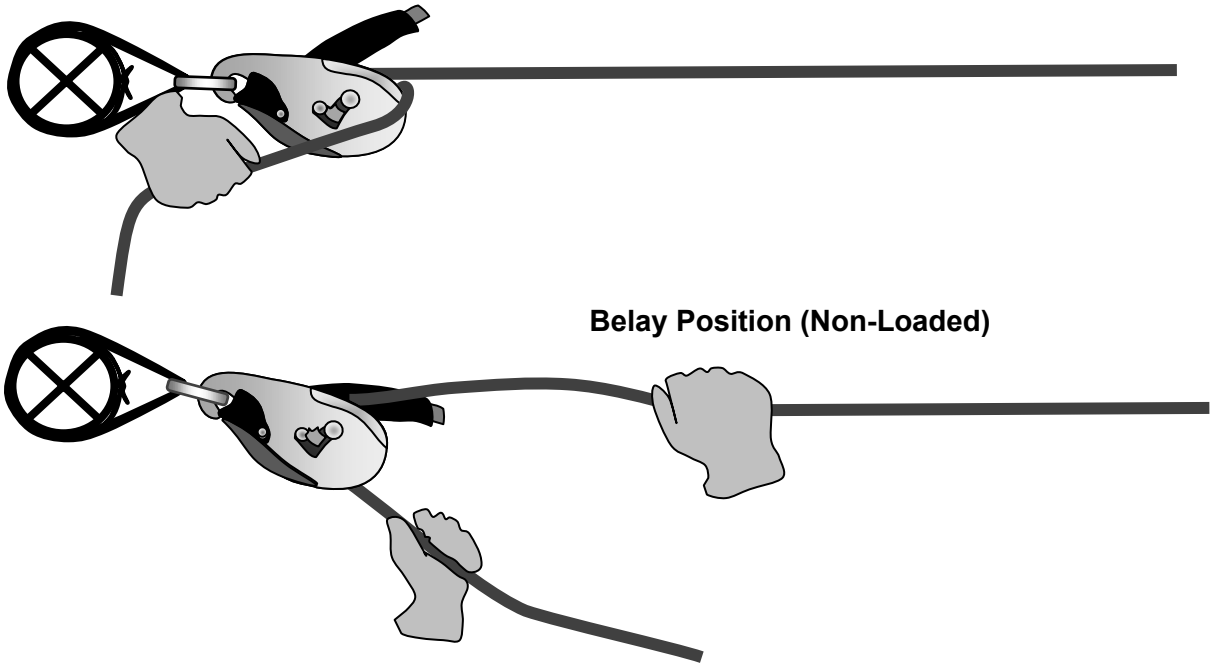
The Petzl ID provides an excellent option for system belays, especially for industrial applications. The ID truly passes all fail safe testing criteria. Rig the ID in accordance to the Petzl User Manual. Manage the slack by pulling the rope connected to the load back towards the ID *(See Non-loaded Position below)*.

Petzl shows in their instructions that one hand should always hold the component of rope opposite the component of rope connected to the load. Following this technique of Petzl there is a tendency for two conditions to happen; the belayer can potentially introduce too much slack into longer systems, or the Petzl ID simply locks up and the need to release tension with the handle is required.

During the belaying of raising systems; simply pull the standing end of the rope through the ID with one hand, and with the other hand introduce the component of rope from the load side into the ID. During all *non-loaded* belay applications, the handle stays in the neutral position. When leaving the belay station, rotate the handle to the locked position.

Loaded Position

(Mirrored System)

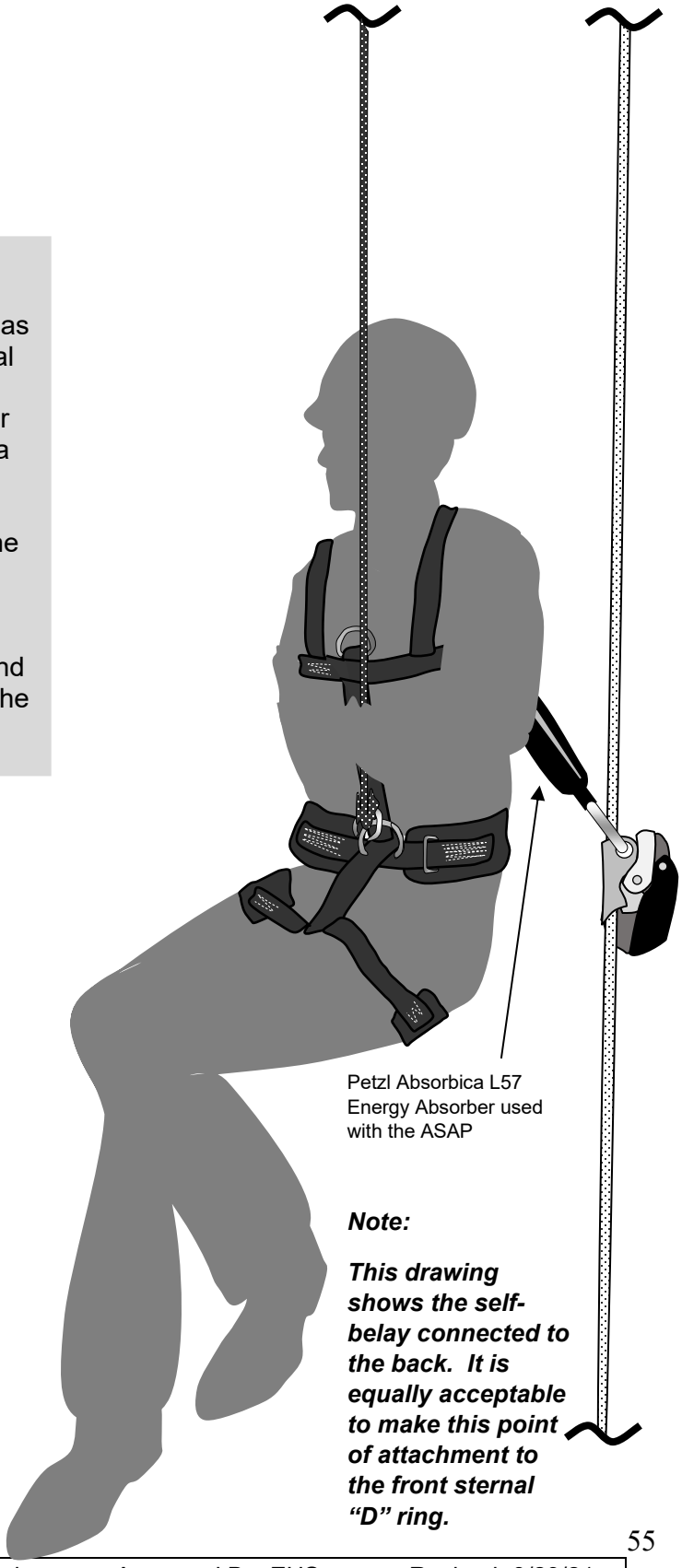


Petzl ASAP Belay (Traveling Position)

Note on the ASAP

The ASAP is easily adapted as a belay device for any vertical rescue. This is particularly useful when only one rescuer is performing a rescue from a crane.

The ASAP is connected to the victim's dorsal "D" ring and follows a fixed belay rope to the ground while the rescuer lowers the victim to the ground with the Petzl ID controlling the mainline.



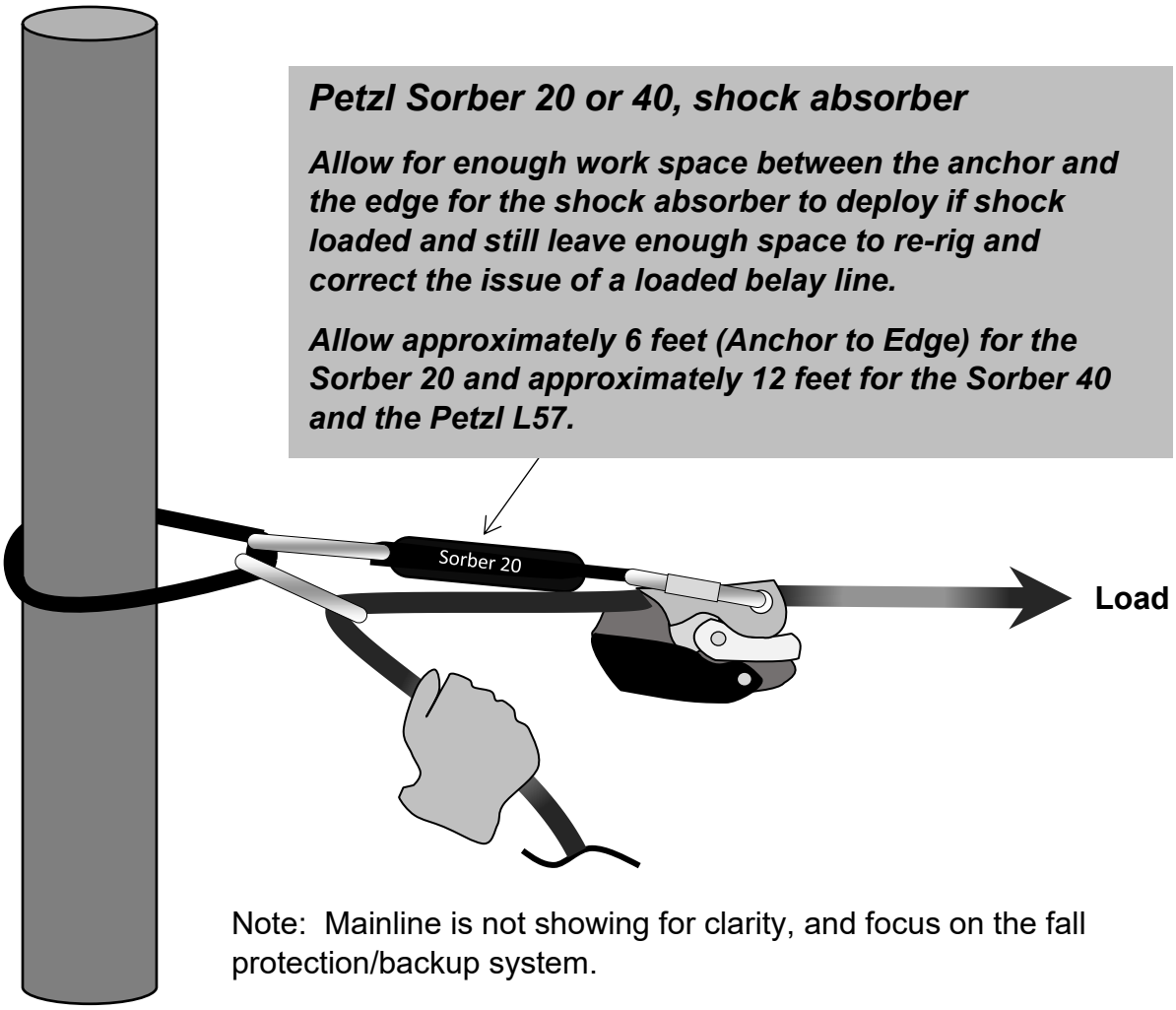
Note:

This drawing shows the self-belay connected to the back. It is equally acceptable to make this point of attachment to the front sternal "D" ring.

The Petzl ASAP Used as a Fall Arrest/Belay Rigged to an Anchor

The ASAP is extremely easy to use as a fall protection system that is attached to an anchor approved by the team leader. The fall arrest (Belay) rope is, simply allowed to run through the ASAP as the load is lowered via the primary rope system. ***Care must be taken to eliminate any buildup of slack in the belay rope between the ASAP and the load.***

This drawing is an approved belay method for a single person load. When belaying a two person load with the ASAP rig the Petzl L57 Energy absorber between the anchor connection and the ASAP.



Note: Mainline is not showing for clarity, and focus on the fall protection/backup system.

This is only a reference drawing that is to be used as a follow-up to detailed hands on training. For more detail information on the Sorber 20, 40, L-57 and the ASAP go to the Petzl website.

Pulley Systems:

There are three categories of mechanical advantages using pulleys; Simple, Compound, and complex. A Simple MA consists of a pulley system that has a single haul connection between the load and the haul team. A Compound MA is a simple mechanical advantage system pulling on the haul line of another simple mechanical advantage. Multiplying the two systems will give the total advantage.

Here are five rules that can be used to determine simple and compound mechanical advantage systems:

1. If the rope used in the pulley system is tied to the load, the theoretical mechanical advantage (TMA) will be ODD (i.e., 1:1, 3:1. 5:1, etc.)

2. If the rope used in the pulley system is tied to the anchor, the theoretical mechanical advantage (TMA) will be EVEN (i.e., 2:1, 4:1. 6:1, etc.)

3. To determine the TMA of a simple pulley system, count the ropes between the anchor and the load. Do not count the ropes between two anchors.

4. If the pulley closest to the haul team on the anchor, the pulley is only considered a change of direction (cd). Same rule applies to ANY pulley system.

5. A simple MA pulling on the haul line of another simple MA is called a compound MA system.

A Complex MA system is neither simple nor compound, and the above rules will not work in determining the system. The only way in determining the mechanical advantage of a complex MA system is by calculating the "tension units". The combinations of pulleys that can be incorporated in an MA system are infinite. With this in mind, how many pulleys are needed, and what are the characteristics of a quality haul system?

In general, the theoretical mechanical advantage (TMA) is the ratio between the distance the load moves and distances the haul team moves. In a 2:1 system the load will move 1' to every 2' of haul. However, this does not mean that lifting the load is twice as easy. The practical mechanical advantage (PMA), or simply put, the efficiency of the system, is the actual physical advantage the haul team ends up with. In short, based on the size of the haul team, try to build the MA system as small as possible. More pulleys create more friction, resulting in efficiency loss.

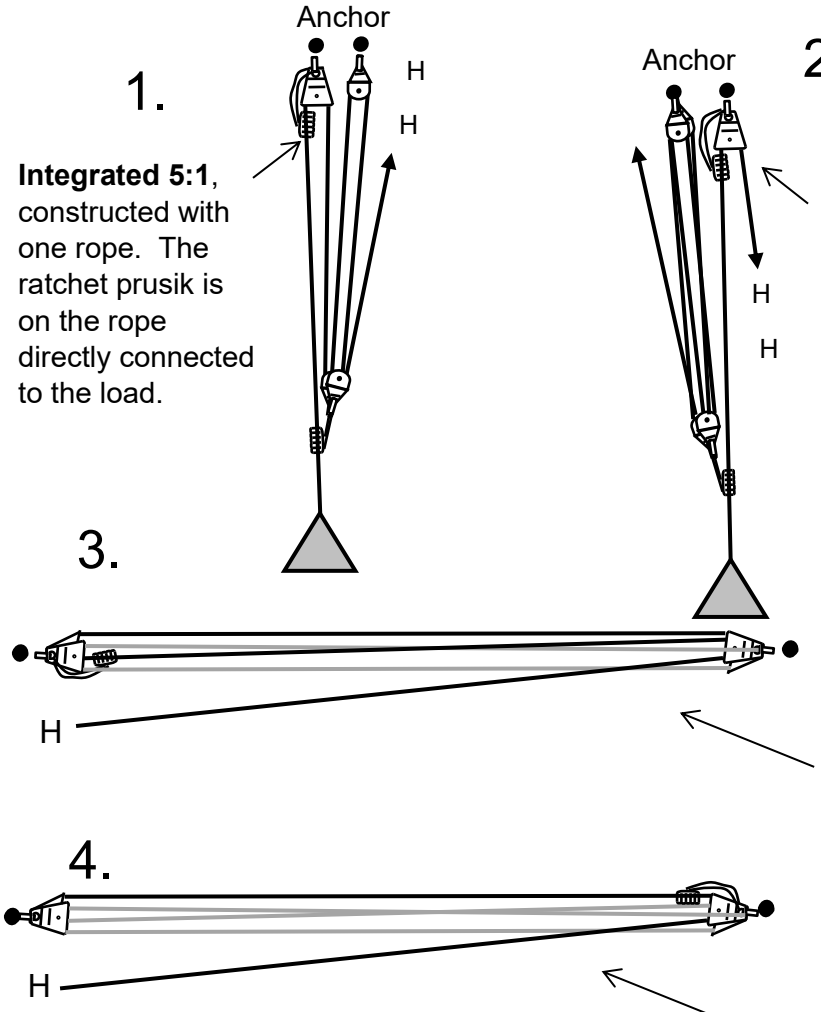
Consider the hauling field; that is to say, configure the MA system in a way that maximizes that amount of ground area the haul team can operate. This will also minimize the number of re-sets of the haul system. Build the MA system clean. Avoid crossed or twisted lines, as this will add unwanted friction in the system.

When the haul prusik slips this is an indication that something is not right. Do not add an additional prusik, correct the problem. A slipping haul prusik as like having a pressure relief device in the system, the haul prusik typically slips between 800 and 1200 pounds. Putting tandem haul prusiks in the MA is like replacing a 15-amp fuse with a 30-amp fuse, something could very well fail.

Placement of the Progress Capture (ratchet prusik)

Typically for the purpose of hauling and the ability to perform multiple resets of the pulley system we would rig the ratchet prusik on the leg of rope directly connected to the load as seen in examples 1 and 2. Example 1 is an integrated system (rigged with one rope) while example 2 is a ganged on system (rigged with a different rope from the mainline).

Examples are all variation of a simple 5:1(or 4:1cd)



Integrated 5:1, constructed with one rope. The ratchet prusik is on the rope directly connected to the load.

Ganged 5:1, rigged with a separate rope from the mainline.

The ratchet prusik is still on the leg of rope directly connected to the load but in this example it is the mainline and not the pulley system.

Mini Haul 5:1/4:1cd, is a variable direction system in that is readily used to go up and down. There are two options for the ratchet that is dependent on the location of the operator.

Example 3 is typically used for personal rigging, i.e. a solo pick-off or rope access when the operator is lowering/raising himself/herself. In this example the ratchet is rigged on the 3rd leg in from the haul.

Example 4 might be rigged on a tripod and operated from the top; this ratchet is placed directly off the cd of this 4:1.

Other MA Factors

Equipment

Lack of proper equipment, namely, ropes and pulleys and the assorted adjuncts such as rope grabs, carabiners, anchor material, progress captures, haul prusiks and ratchet prusiks for starters, is like going into battle against a powerful opponent who is vastly superior. The answer is straightforward; know the challenge at hand and make sure your team is properly equipment to get the job done.

Power

How many people do you have to haul versus the hauling power of the pulley system? With pulley system mechanical advantages (MA), horsepower equals the number of haulers plus the size of the MA system. With a small team of one or two haulers, a 9:1 may be in order. However, with the 9:1 the load will move very slowly, only about 1 foot for every 9 feet of haul. A 9:1 with a very large haul team could be so powerful as to actually break something if the load were to hang up.

On the flip side of this coin, a 3:1 is going to be more effective with a large haul team of six as the load will move much faster than the 9:1 and the large number of haulers will more than compensate for the smaller system.

What about a 1:1 with a super team of haulers? This is a risky proposition in that the load could move so fast that it creates a trip hazard or a greater hang up potential for the rescue package. The 3:1 seems to be a good speed control for the larger haul team.

Anchorage

We've addressed anchor issues quite a bit so far (with more anchor physics to follow later in this book); due to the overwhelming importance and relationship of the anchor with a successful outcome, we will add a little more to the subject as it pertains to hauling systems.

When we create a hauling system we will magnify the hit on the anchor system by a substantial amount. An anchor that was chosen and rigged strictly for a lowering system may not be capable of absorbing the physical increase of a haul system. This is highly predictable. When we know we will be converting a lowering system to a hauling system, we must pre-engineer our anchor to meet

our time of greatest stress to the system. This time of greatest stress will always be during the initial onset of the hauling process.

Work Space

Pretty simple; how much space have you been afforded to complete the job? We typically think of two issues with work space for hauling; 1) the amount of space the haul team has to move, walk, and/or work; 2) the amount of space the pulley system has to contract before a re-set is needed. Obviously more space is a good thing, however, sometimes the hand we're dealt is not always what we were hoping for. Maybe you're working on the confines of a structural tower, or in an enclosed space and your ideal space requirements are simply not available. Consider the use of change of direction (cd) pulleys to maximize your operating space. Small spaces usually equate to small haul teams. Can the haul line be re-directed to another location that could accommodate a larger team, i.e. on the ground of the tower, or outside of the enclosed space?

Clarification of MA Terms

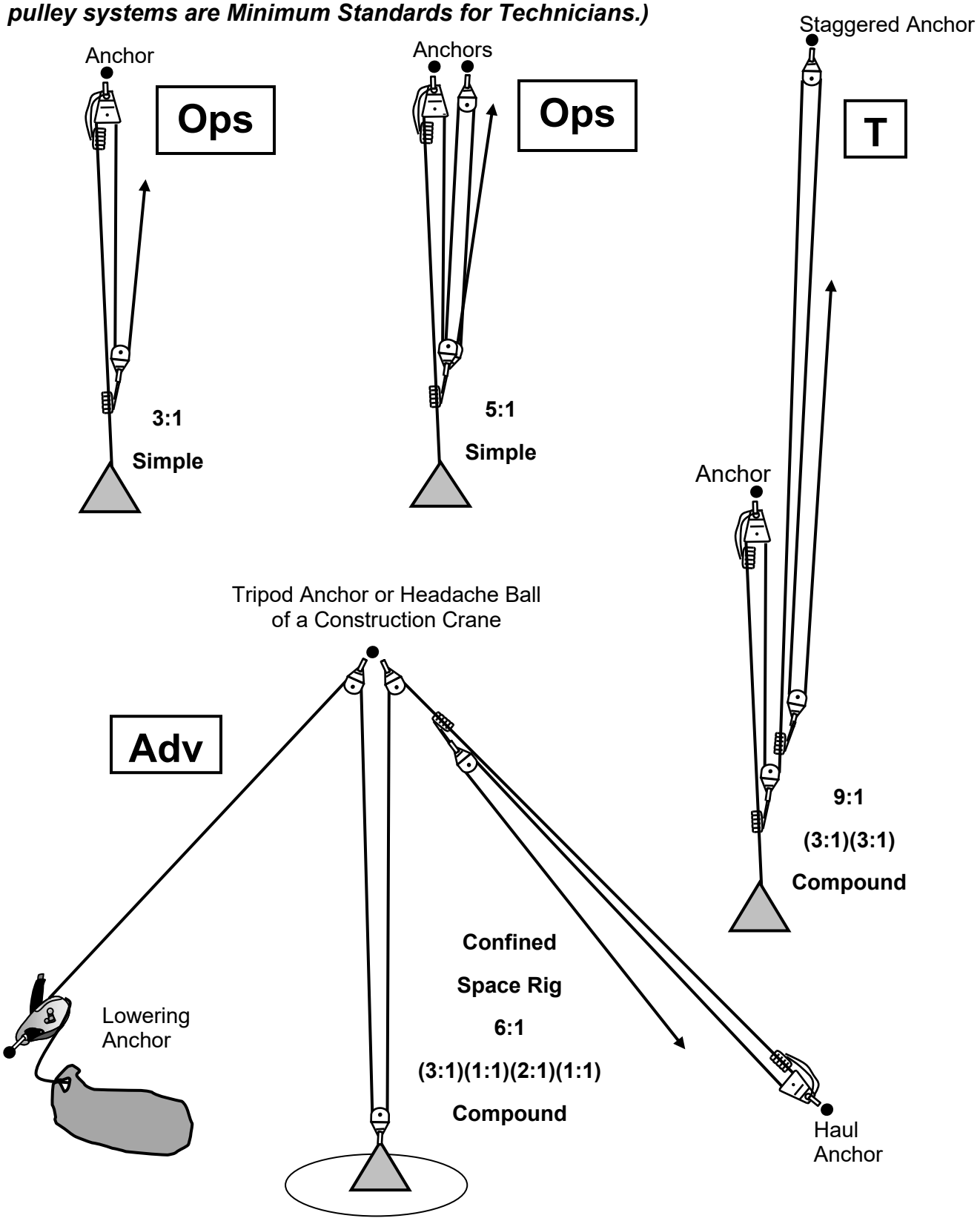
Integrated Versus Ganged On; Plain and simple, if its built with the one rope that is connected to the load it is an integrated system, this may be a simple, compound, or a complex system. A ganged system is an MA which is built with a separate rope that is attached to the working rope.

Ganged on Versus Piggyback; A piggyback system is a compound MA that is made up of two or more *identical* simple MA's. i.e. a compound 4:1 (2:1)(2:1). A Ganged MA system is attached by a haul grab to a second main rope for the purpose of lifting or lowering a load.

Change of Direction Versus Directional; A change of direction is a pulley on the anchor closest to the haulers, notated (cd). A cd adds no mechanical advantage to the system. A directional is a pulley or pulleys between the pulley system and the load to be raised, notated (d) or (1:1)

Useful Hauling System Schematics

(3:1 and 5:1 are Minimum Standards for Operations Level, the rest of these pulley systems are Minimum Standards for Technicians.)

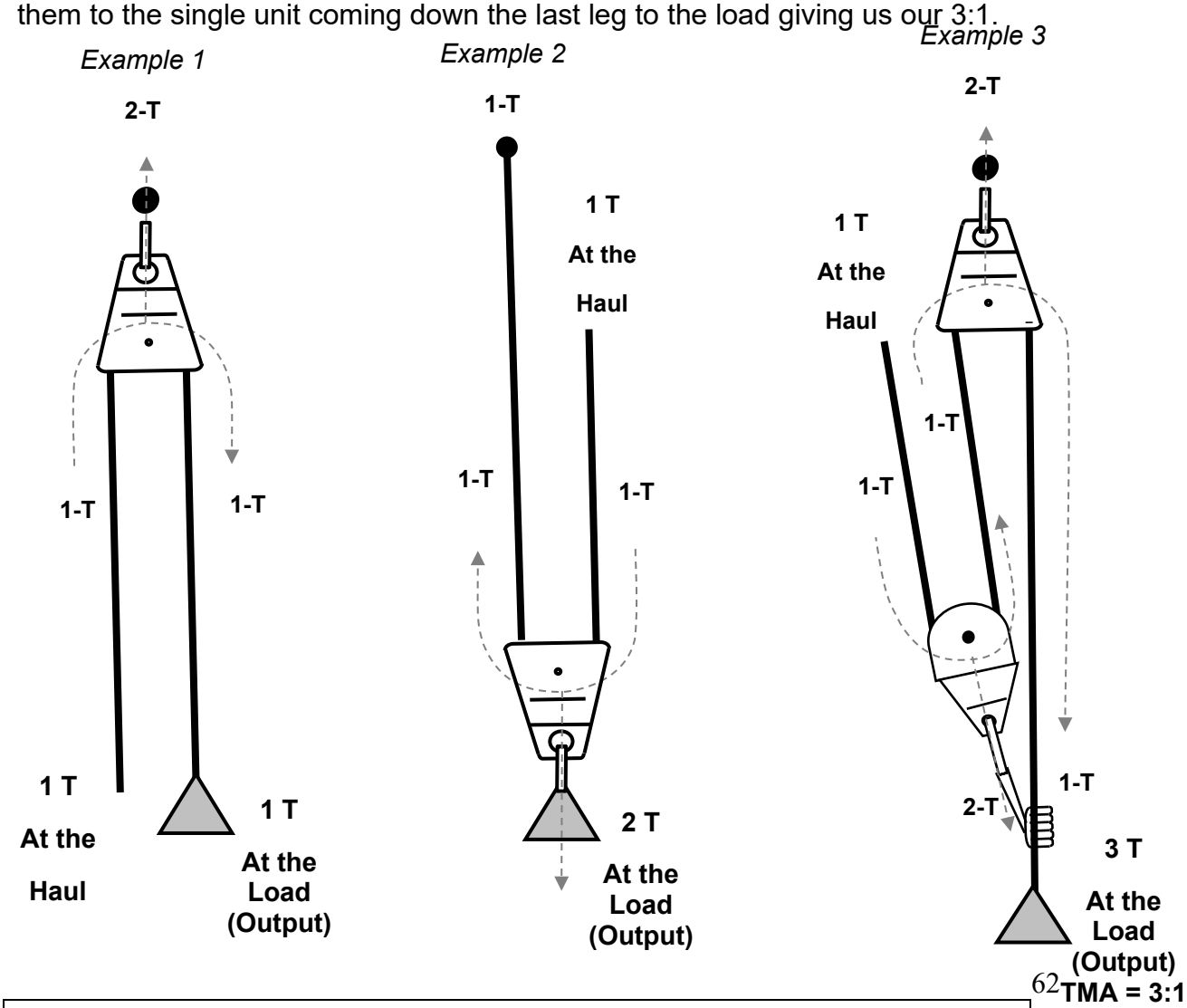


T

Tension Units – Theoretical Mechanical Advantage (TMA)

When calculating units of tension as they relate to pulleys, we are addressing a tensioned leg of rope on the input side of the pulley and a tensioned leg on the output side as well. Setting aside the efficiency of the pulley for the moment; for a pulley to be in an operating state, it must have close to equal tension on both sides coming and going. This is the Theoretical Mechanical Advantage (TMA).*Always* starting at the input of power (the haul team) we start our count with a single unit of tension (1) and continue following the rope until it reaches the output of power (the load) adding units in and units out of each pulley on our journey through the pulley system. As you can easily see in *example 1;* we end up with one unit of tension at the load (output) giving us a 1:1. Simply by flipping our 1:1 upside down as seen in example 2; with two units of tension at the load we've created a 2:1.

Looking at example 3; with the two units at the haul prusik, we now must add them to the single unit coming down the last leg to the load giving us our 3:1.

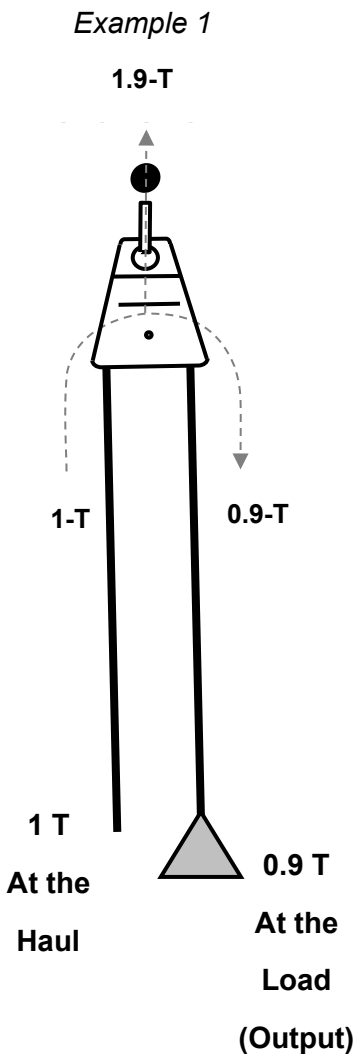


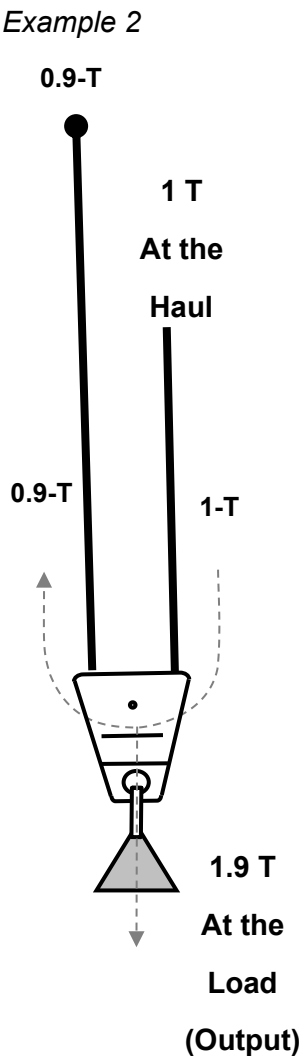
Tension Units – Practical Mechanical Advantage (PMA)

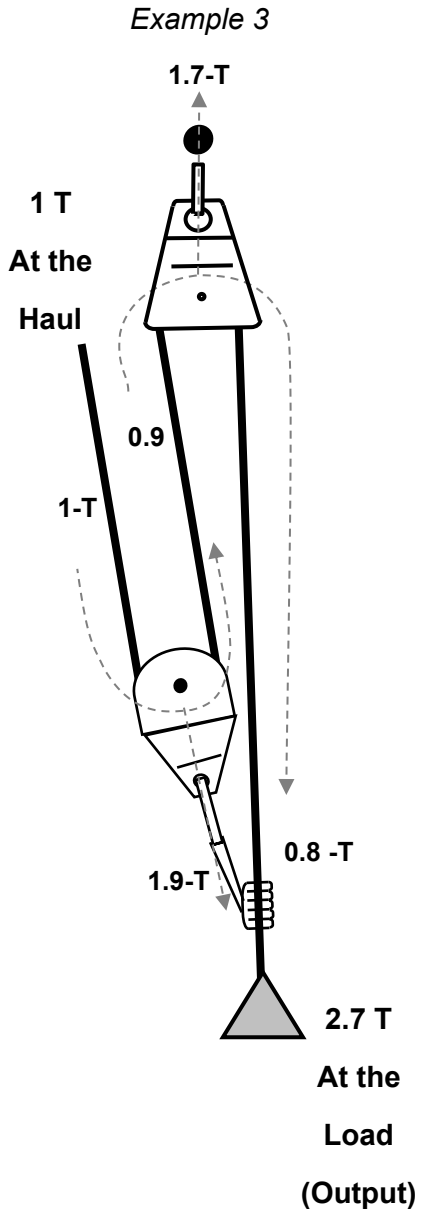
Let take the examples from the previous page and analysis the practical MA, in other words, what do we really have in terms of hauling efficiency? Most of our good rescue pulleys that have ball bearing axles are around 90% efficient. Therefore we lose 10% of our hauling efficiency each time the rope passes through a pulley.

In example 1; our PMA is a 0.9:1 disadvantage…so to lift a 100kg load we would have to pull approximately 111kg.In example 2; our 2:1 is really a 1.9:1 (PMA)…we would have to lift around 52.5kg to haul our 100kg load.

In example 3; our 3:1 is really a 2.73:1 (PMA)…we would be lifting around 36.5 kg to haul the 100kg load.







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Petzl ID Ascend and Petzl ASAP Belay:

(Technician Only)

Ascending Rope with the RAD System

(Rapid Ascend and Descend)

Rope may be ascended by using your hand ascender/foot loop and the Petzl ID. As with all aspects of rope access, the user must be on a separate belay line (Shown in the drawing is the Petzl ASAP).

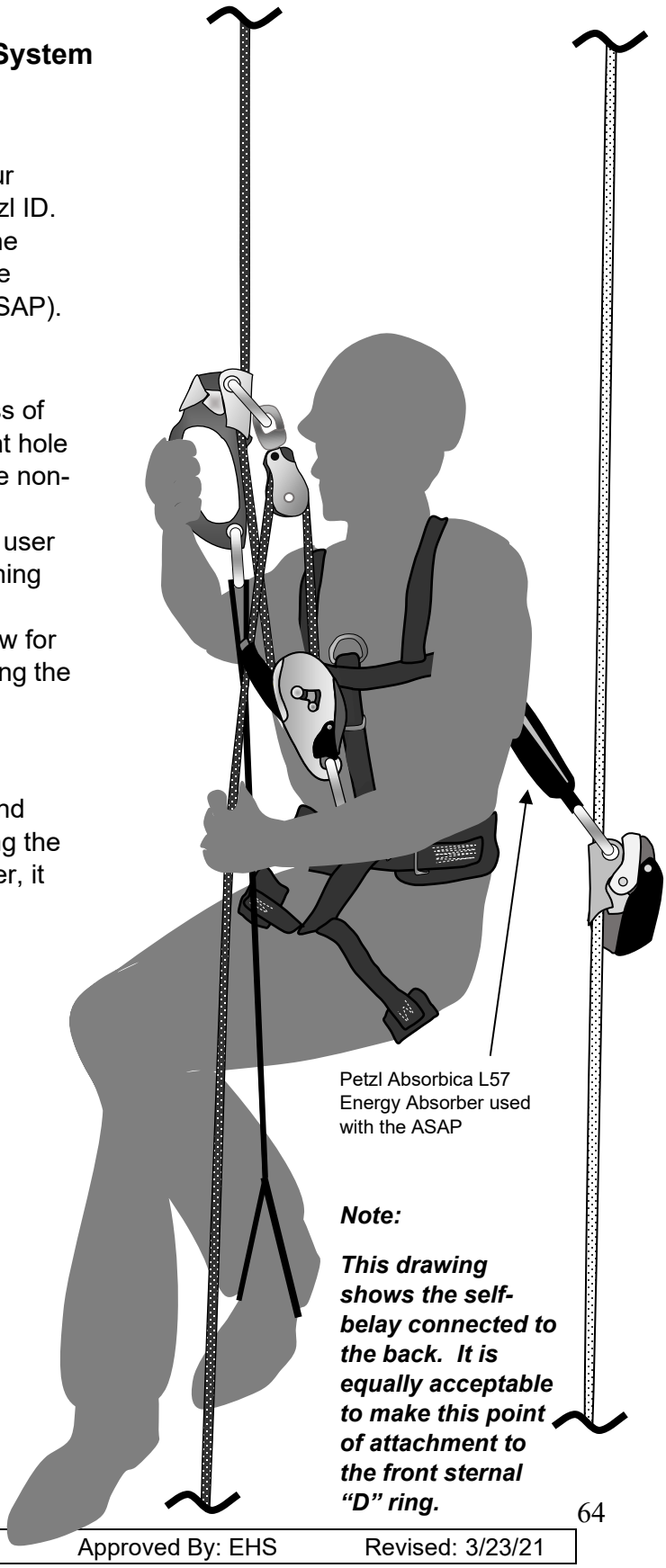
The RAD systems is a simple process of rigging a pulley on the top attachment hole of the hand ascender and running the non-loaded leg of the rappel rope up and through the pulley. This will give the user a 3:1 mechanical advantage. Combining the foot loop which is attached to the bottom of the hand ascender will allow for easy step and pull action for ascending the rope.

For a faster response, omit the 3:1 and simply pull slack through the ID during the step-up move. Although this is quicker, it does require more effort and timing.

Note on the ASAP

The ASAP is easily adapted as a belay device for any vertical rescue. This is particularly useful when only one rescuer is performing a rescue from a crane.

The ASAP is connected to the victim's dorsal "D" ring and follows a fixed belay rope to the ground while the rescuer lowers the victim to the ground with the Petzl ID controlling the mainline.



Note:

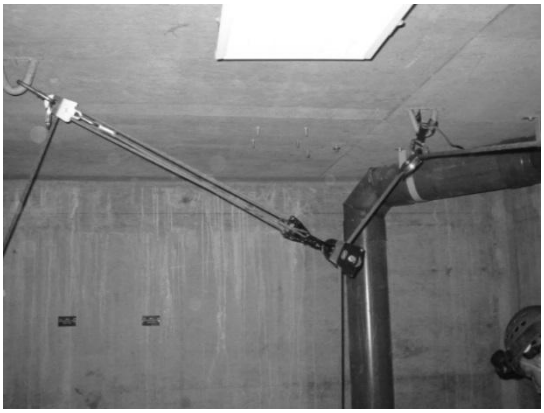
This drawing shows the self-belay connected to the back. It is equally acceptable to make this point of attachment to the front sternal "D" ring.

The Set of Fours (SOFs) Rigging Kit:

T

The “Set of Fours” mini-haul system as it is depicted in this module is a highly advanced rope rescue/rigging tool.

A key professional theme of rope rescue rigging and equipment use should be *“keep it simple and efficient”*. With the personal equipment every rope rescue technician should carry on the side of their harness, plus the addition of a working line and a belay line, *most* rope rescues may be safely accomplished in an expedient, highly professional fashion



Mechanical Advantage System

This 5:1 pulley system uses two mini double sheave pulleys rigged on the 38 feet of 9mm rope at the opposite end from the travel restraint/fall arrest system.

Remember our simplicity/efficiency theme on the use of equipment? The Kary Environmental Services program believes, when possible, *“use gear that provides multiple uses”*. The *Set of Fours* exemplifies this theme. The rescuer/rigger can deploy this mini 5:1 (SOFs) in a multitude of rigging applications, including hauling systems, tensioned back-ties, tensioned guying for artificial high directionals, dynamic lowering systems, and dynamic directionals (approximately an 8’ throw when using the full 38’).

The *SOFs* is the perfect primary attachment device for a litter attendant, allowing very rapid and easy vertical adjustments. By repositioning the 6mm ratchet, the personal *SOFs* can be transformed into a 4:1cd scoop line for the foot end of the litter.

Assembling the Set of Fours

Although the *Expanded edge kit* is made up of very simple components, the assembly method and knot craft is highly evolved. It is extremely important that the user fully understand this process.

Components of the Set of Fours

The central component of the SOFs is a *38' of 9mm rope*. We would highly recommend a rope that utilizes a factory sewn attachment point loop. This sewn version is somewhat stronger than tying a knot, and knots tied to the becket can sometimes get in the way of the ratchet prusik.

Two Mini Double Sheave Pulleys with a minimum rating of 22kN should be used.

The carabiner at the fall arrest end of the kit should be an *auto-lock* type that allows for quick attachment.

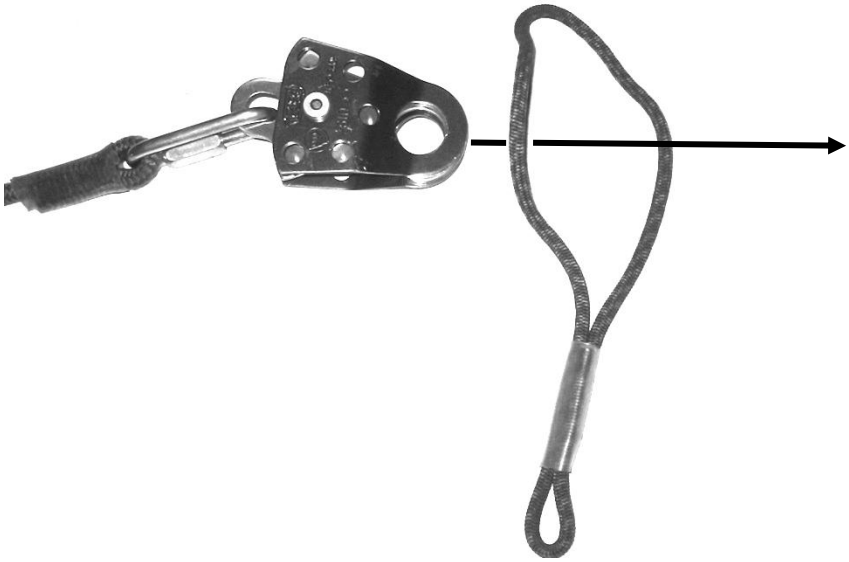
One 7mm Maillon Rapide Screw-link are used, one for the attachment point at the becket of the pulley.

The ratchet for the SOFs is made from approximately 32” of 6mm accessory cord. Again, a factory sewn version is highly recommended.

3/2 Ratchet Prusik

This hitch is used at 3 different positions, the SOFs ratchet, the shock absorber 9mm attachment point, and the shock absorber adjustable loop.

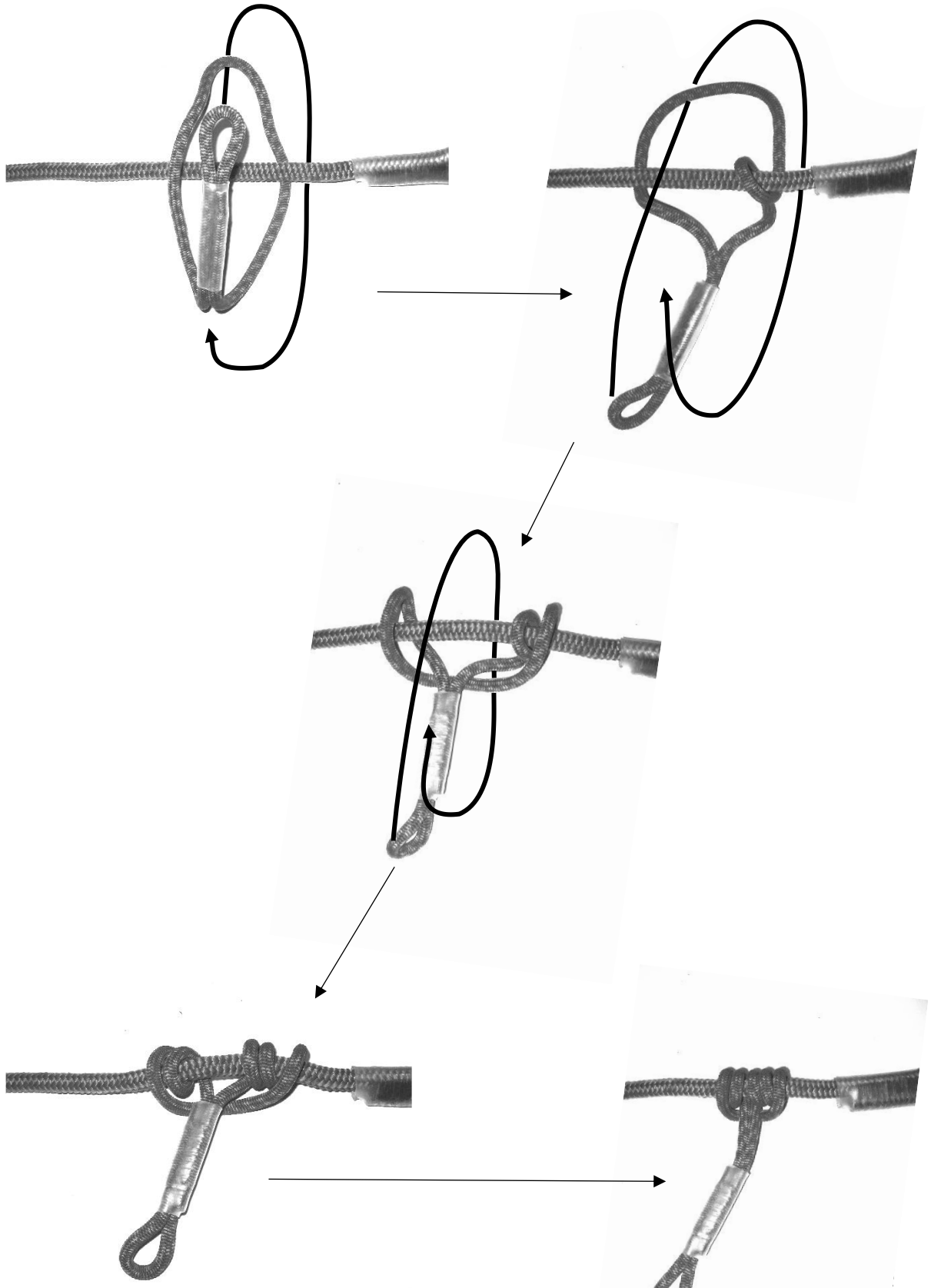
By sliding the host rope through the original loop of the hitch an uneven potential is created for a typically wrapped prusik hitch.



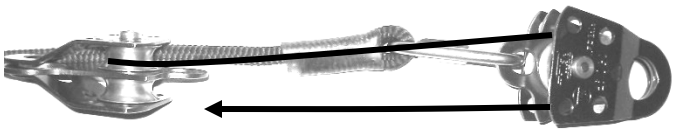
It is essential that the 3 wraps of this prusik always be towards the load bearing end of the host rope. This positioning is easily made possible by orientating the prusik loop with the host rope as shown in step 2.

Again, by arranging the 3 wraps towards the connecting becket of the pulley, the ratchet will always point in the right direction without detaching it from the host rope, regardless if it is repositioned to meet any number of different applications.

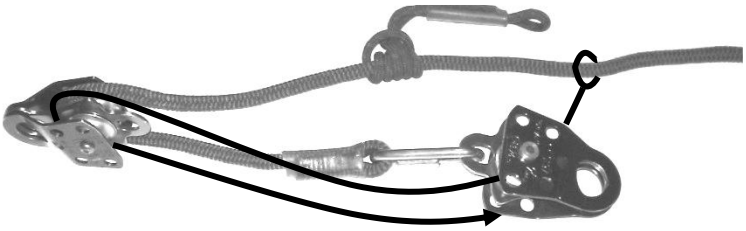
Simply follow the remaining steps on the next page to complete the ratchet.



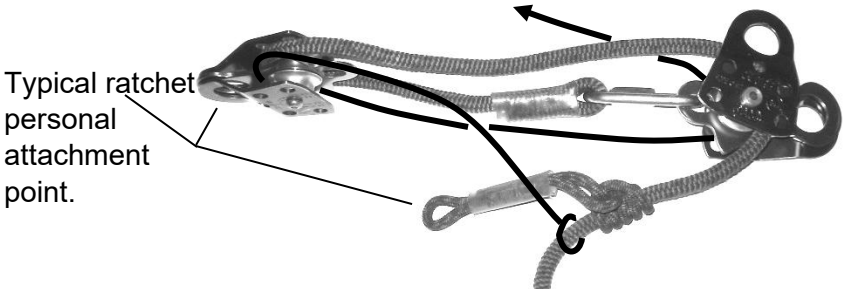
Assembling the "Set of Fours"

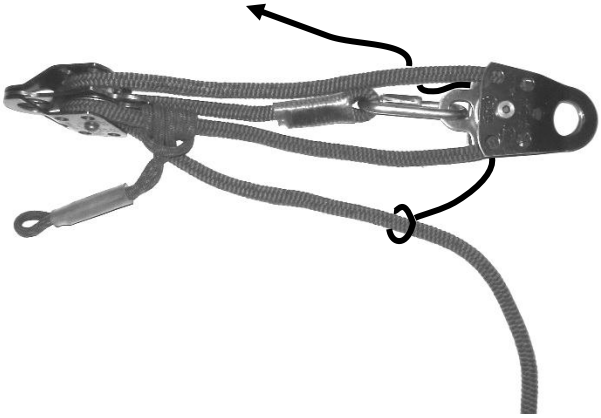


We have found that the best way to build any ganged 5:1 MA, in this application, the "Set of Fours", is best accomplished in the following manner shown on this page and the next. Note that one double sheave pulley is lying vertical and the other is horizontal, it makes no difference which is which. Start by connecting the 9mm to the becket of one pulley via a 7mm screw link.

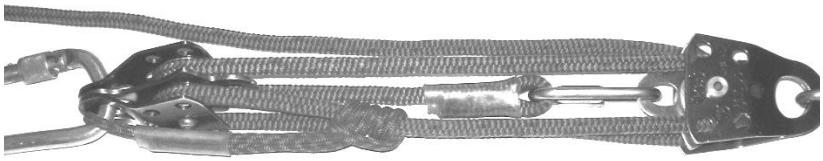


The rope can now be worked in an organized manner, alternating from pulley to pulley with no crossing of any legs. The 3/2 ratchet prusik of the *edge kit* is used in one of two easily changed positions. For most applications, including personal attachments, i.e. litter attendant's primary attachment point, the ratchet is positioned on the 3rd leg in, on the pulley opposite of the initial connecting pulley.

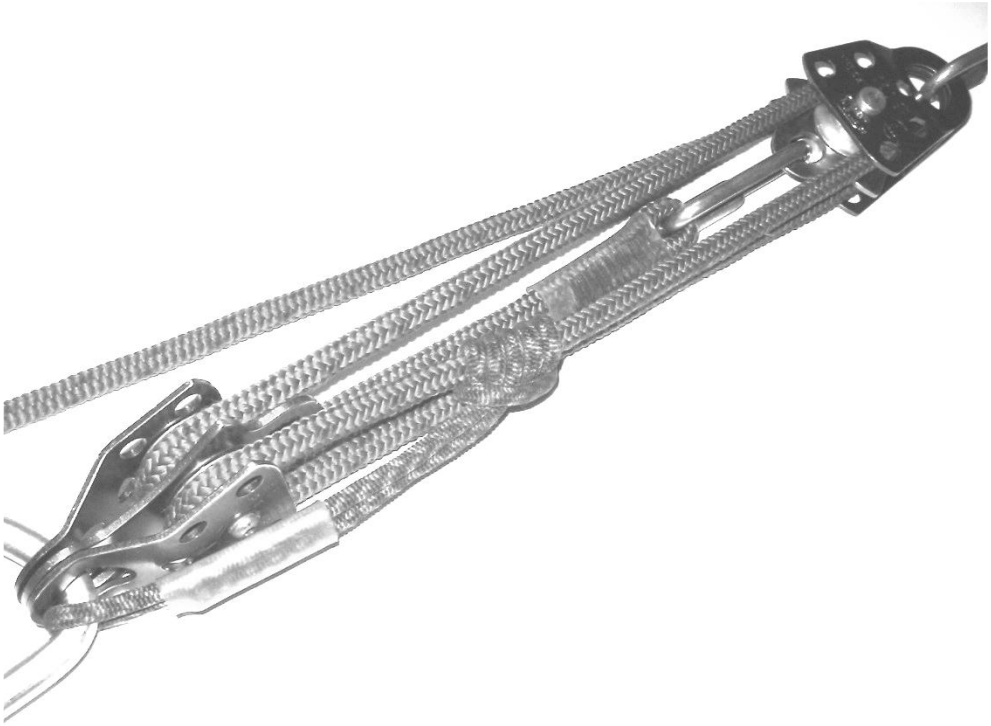




By using this prescribed method of rigging the double pulleys, the rope follows the natural path that is directed by each sheave.



Each leg of rope alternating from sheave to sheave should end up extremely clean with no crossing of any legs.



Resultants:

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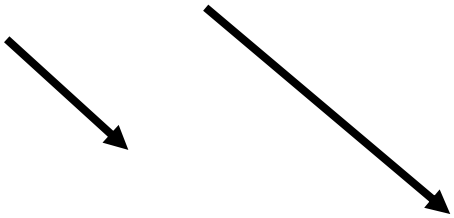
Force Vectors[4]

To have a better understanding on how force acts upon any anchor at least some aspects of trigonometry and vector physics is desirable. The knowledge of angles, components, and resultants is synonymous to quality rope rigging. To study vectors is to study the physical qualities of force that has both direction and magnitude.

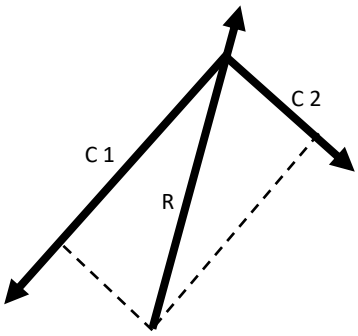
A force vector may be graphed or represented as a simple arrow, also more commonly referred to in math as a component. This component will always indicate the direction of the force.



When we compare the length of one force vector component to the length of another force vector component, we not only have the direction of each vector, but we now can compare their magnitude relative to each other.

Therefore, the component that is the longest has a greater magnitude. In fact, simply by comparing the two components we could deduce that the second component (above) is about 2 times more powerful or stronger than the first.

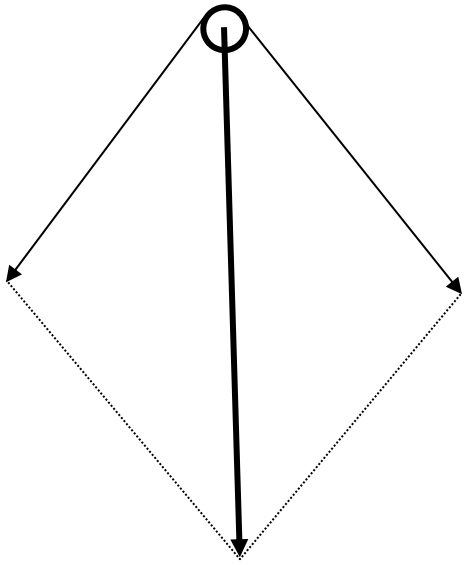
The force of any resultant/ vector acting upon any two components of an angle can be realized by drawing a parallelogram that matches the components and is bisected by the vector component. *Within the boundaries of the parallelogram* we can simply measure each of the three components (C1, C2, and R) and based on the known magnitude of the resultant (R) we can then assign a value to C1 and C2.



When a rope runs through a pulley to create an angle, the pulley equalizes the components of that angle and renders them equal. The resultant (in this case, the pulley) will always seek the location halfway between the two rope components.

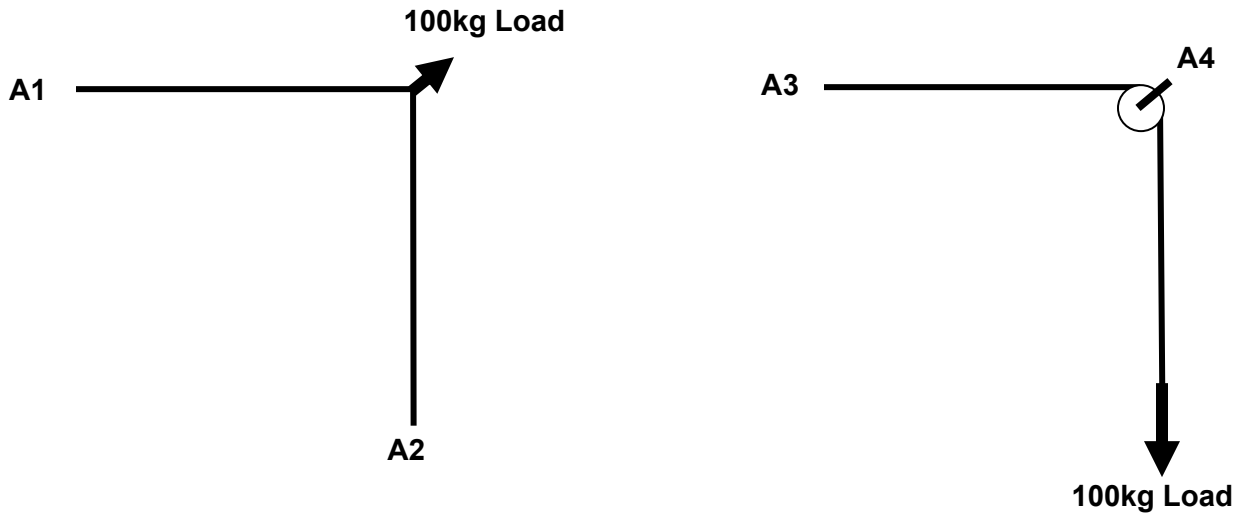
The center of any tensioned pulley will always point to the exact location and direction of the resultant force at work on the associated anchor.[5]

The use of the parallelogram still works well in determining the resultant force, its direction and magnitude. Once again, the resultant of any pulley will find the middle point between the legs of rope going in and coming out of the pulley.



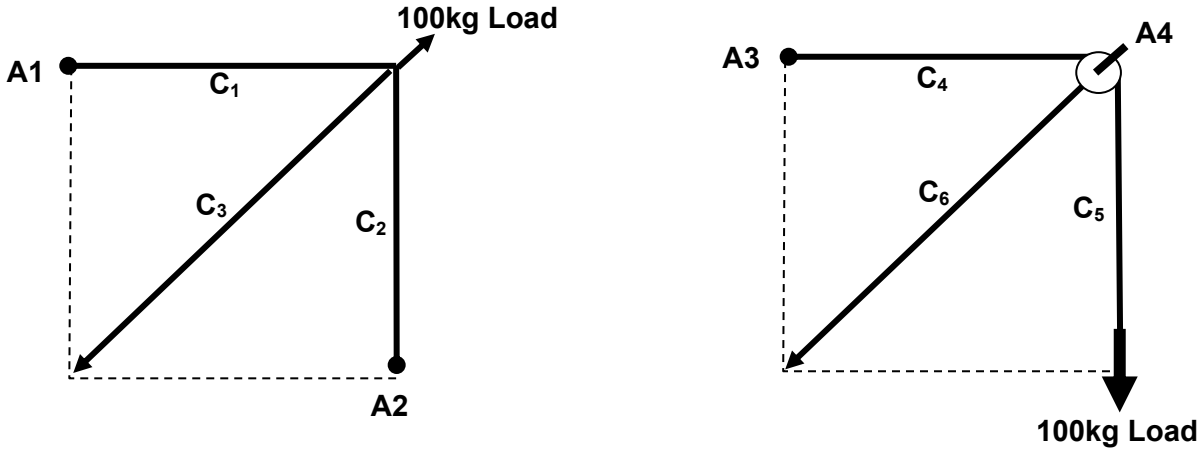
The resultant of an equalized pulley is the absolute indicator of where the force of that pulley is directed.

Study the two right angle rope systems below; both have two anchors and both support a 100kg load. What percentage of the load is each anchor receiving?



If you said A1 and A2 receive 71kg; A3 receives 100kg; and A4 receives 141kg you would be correct.

Let's look at these right angles again and apply our parallelogram/resultant analysis:



The 100kg load is our known value, whatever component the load is in line with represents 100% of that load; the remaining two components may now be assigned a value simply by comparing their length. C3 = 100%, therefore C_1 and C_2 are 71% of C_3. C_5 = 100%, therefore C_4 = 100% of C_5 and C_6 = 141% of C_5.

Although using parallelograms as mentioned above to determine the resultant of any given angle is a good rule of thumb method, ultimately, for field application we must commit to rote memory the recognition of angles as they apply to either, 1) multipoint anchor systems, or 2) directional pulley anchors.

Force Vector Formula for Directional Pulley Anchors

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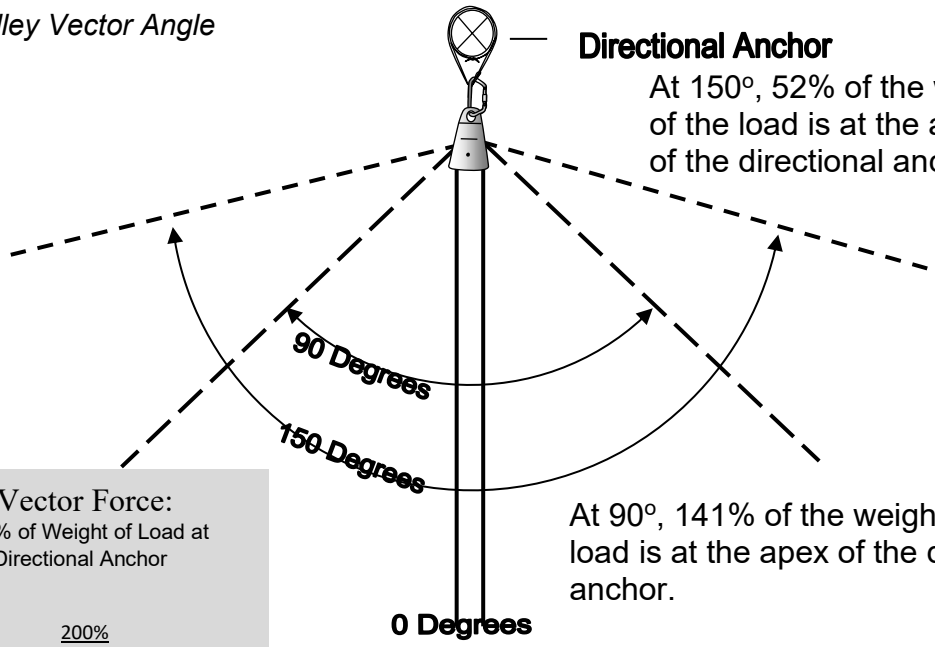
% of Load on Pulley Anchor = cos{<(0.5)} (2)

< = Pulley Vector Angle



Directional Anchor

At 150°, 52% of the weight of the load is at the apex of the directional anchor.

At 90°, 141% of the weight of the load is at the apex of the directional anchor.

At 0°, 200% of the weight of the load is

at the apex of the high directional.

High Directional Vector Force:

Degree of Angle	% of Weight of Load at Directional Anchor
0	200%
5	199.9%
10	199%
15	198%
20	197%
25	195%
30	193%
35	191%
40	188%
45	185%
50	181%
60	173%
65	169%
70	164%
75	159%
80	153%
85	147%
90	141%
95	135%
100	129%
105	122%
110	115%
115	107%
120	100%
125	92%
130	85%
135	77%
140	68%
145	60%
150	52%
155	43%
160	35%
165	26%
170	17%
175	8%
180	0%

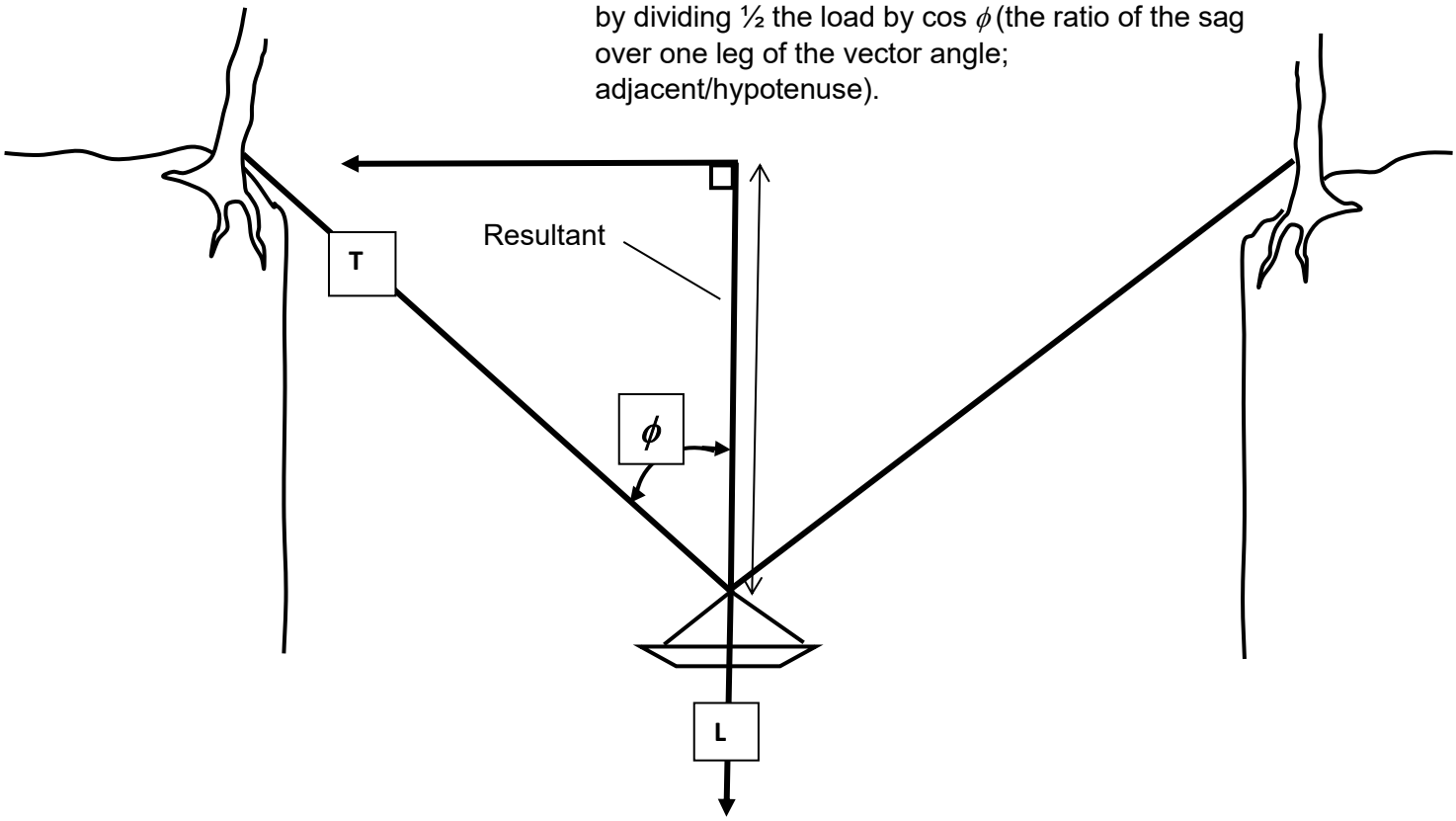
Force Vector Formula for Multipoint Anchors

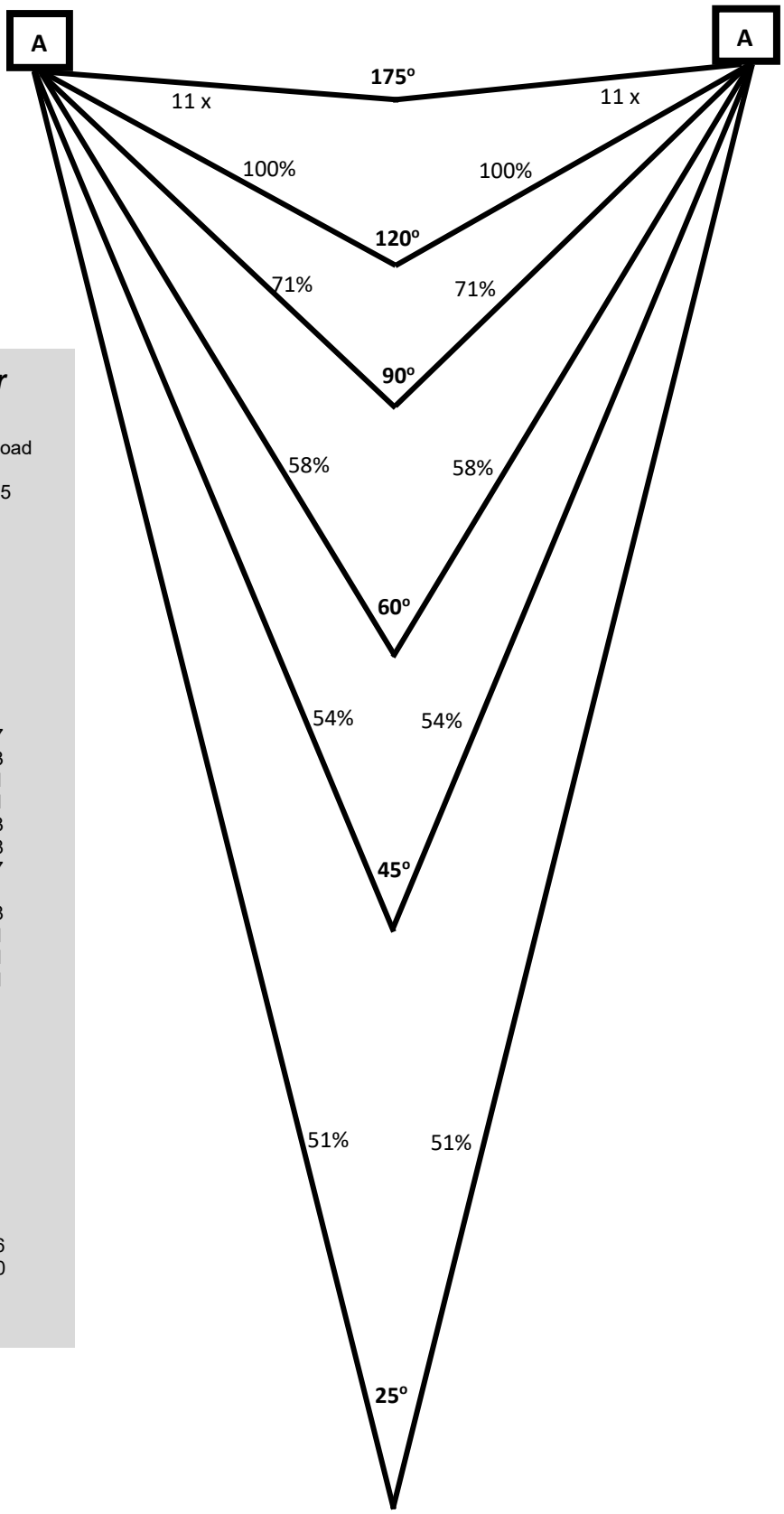
T

$$T = \frac{(L)(.5)}{\cos \phi}$$

By using this basic trigonometry function we are able to look at ½ of the entire system. Doing so, we can derive the amount of tension at one anchor by creating a right angle between the resultant component of the load and one leg of the system.

The tension of one leg of the vector angle is realized by dividing ½ the load by cos ϕ (the ratio of the sag over one leg of the vector angle; adjacent/hypotenuse).





Anchor Vector Forces

Degree	% of Load
0	50
5	50.05
10	50.2
15	50.4
20	50.8
25	51.2
30	51.8
35	52.4
40	53.2
45	54.1
50	55.2
55	56.4
60	57.7
65	59.3
70	61.1
75	63.1
80	65.3
85	67.8
90	70.7
95	74
100	77.8
105	82.1
110	87.1
115	93.1
120	100
125	108
130	118
135	131
140	146
145	166
150	193
155	231
160	287
165	382
170	575
175	1136
179	5600

T

Elevated Anchors

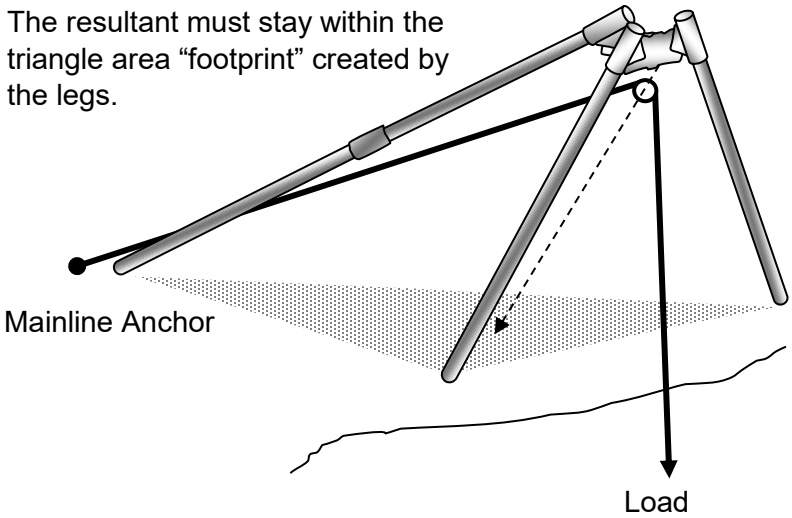
Tensile and Compression Force

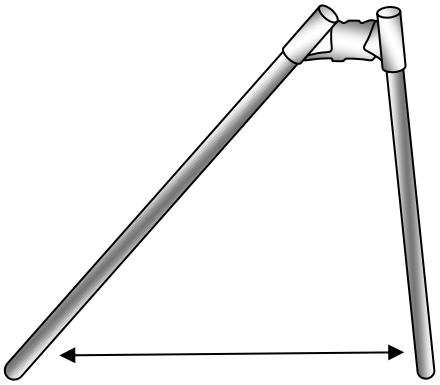
Footprints – a prelude to understanding compression

What is meant by the *"footprint"* of a tripod? Most rescue techs understand this term when using a tripod…but what about other forms of anchors, especially elevated anchor systems?

The footprint is exactly what it says. The footprint you make in the sand is created by the compression of your body weight on your leg and down to your feet. Therefore we can say the footprint represents compression. The same criterion applies to all artificial high directionals (AHDs) such as tripods, bi-pods, and mono-pods. The footprint defines the area of compression between the legs of these anchors.

Tri-pods





The footprint of an "A" Frame is a single line between the legs.

The tripod is a very visual triangle…but what about an "A" frame (bi-pod); the area of compression between the two legs is now limited to a single line between the legs. The gin pole's (mono-pod) footprint is rendered down to a single point

Stand up and take a look at your feet…why do you not fall over? The answer is that the resultant force of your body is perfectly focused on that invisible line that defines the area of compression between your feet (footprint). The moment that you lean your body backwards you focus your body weight (resultant force) backwards and you start to fall, thus the need for something to grab a hold of to prevent the fall (a back-tie). In a hypothetical perfect world of balance, we would be able to keep our high directional pulley focused right on that single line defining the footprint of an "A" frame and it would never tip over, or we could keep our gin pole from falling simply by focusing the high directional pulley straight down the pole on its single footprint.

Of course we know this is virtually impossible. We will always have some movement due to elongation of the ropes in the back-ties, and inefficiencies of the pulleys. Therefore, the ability to rig quality back-ties and accurately engineer the resultant of the pulleys to maximize the compression of the legs is vital for advance use of AHDs.

In the application of rigging, we must address tension and compression at the same time. Most of us associate units of tension with the study of pulleys and mechanical advantage systems. While this is indeed a critical factor of pulley systems, it is important to remember that the same physics that characterize tension in the study of pulley systems is also applicable to every single act of rope rigging. The instant a single piece of rope is tied and loaded, units of tension become a factor.

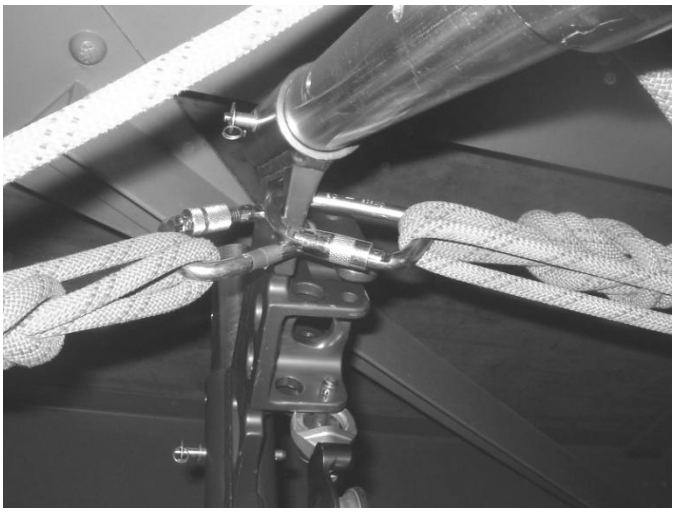
Compressive and tensile forces are symbiotic. As with all forms of construction, (rope rigging included) one cannot exist without the other. Not only must harmony exist between tension and compression, there must be equal synchronization with all aspects of rigging physics. The bottom line revolves around the anchors. Will they hold, or won't they? What is the exact force vector being applied to the anchor? What is the resultant on the anchor? Is there an adequate amount of tension/compression at work to guarantee the integrity of the anchor?

Back-tie Schematics for Elevated Anchor Guying Systems

Most rope rescue personnel who experiment with all these variations of elevated anchors usually agree on one thing….Sideways A Frame *(SA)* Frame is by far the safest, user-friendly, and resultant accommodating of the whole lot. Because of this, we feel compelled to talk a bit more about some additional rigging tips concerning the SA frame.

To the right; as seen in this photo of a challenging industrial enclosed space extrication, the SA frame can fit in extremely tight locations such as industrial catwalks. The rules still apply when choosing the guying anchors for the tension back-ties. When eyeing from one back-tie anchor to the other, this visual straight edge should bisect the middle of the plane created by the front and back legs of the SA frame.

Many times when the back-tie anchors don't quite line up, the SA frame may be rotated to make the plane of the legs accommodate the back-tie anchors.



Note the photo to the left. Although this is a Vortex Multi-pod system, this rigging example still applies to the TerrAdaptor.

This is a view looking up at the head of a SA Frame; this is a good example showing the tensioned guying system pulling opposite directions. Note that they are connected to the same location on the head; unwanted torque will arise if one back-tie is forward on the head and the opposite back-tie is rigged to the back end of the head. In addition, when more radical HD (High Directional) pulley resultants are predicted, the HD pulley should be rigged as close as possible to the same location on the head as the guying system.

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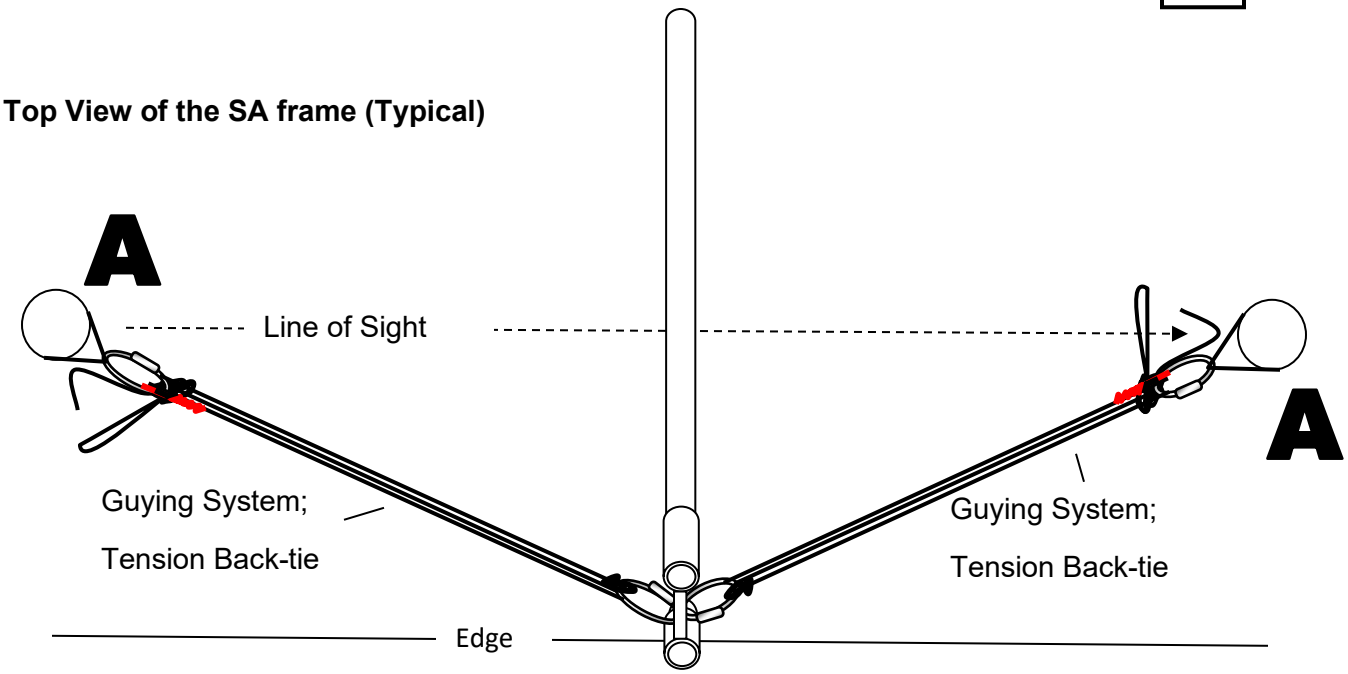
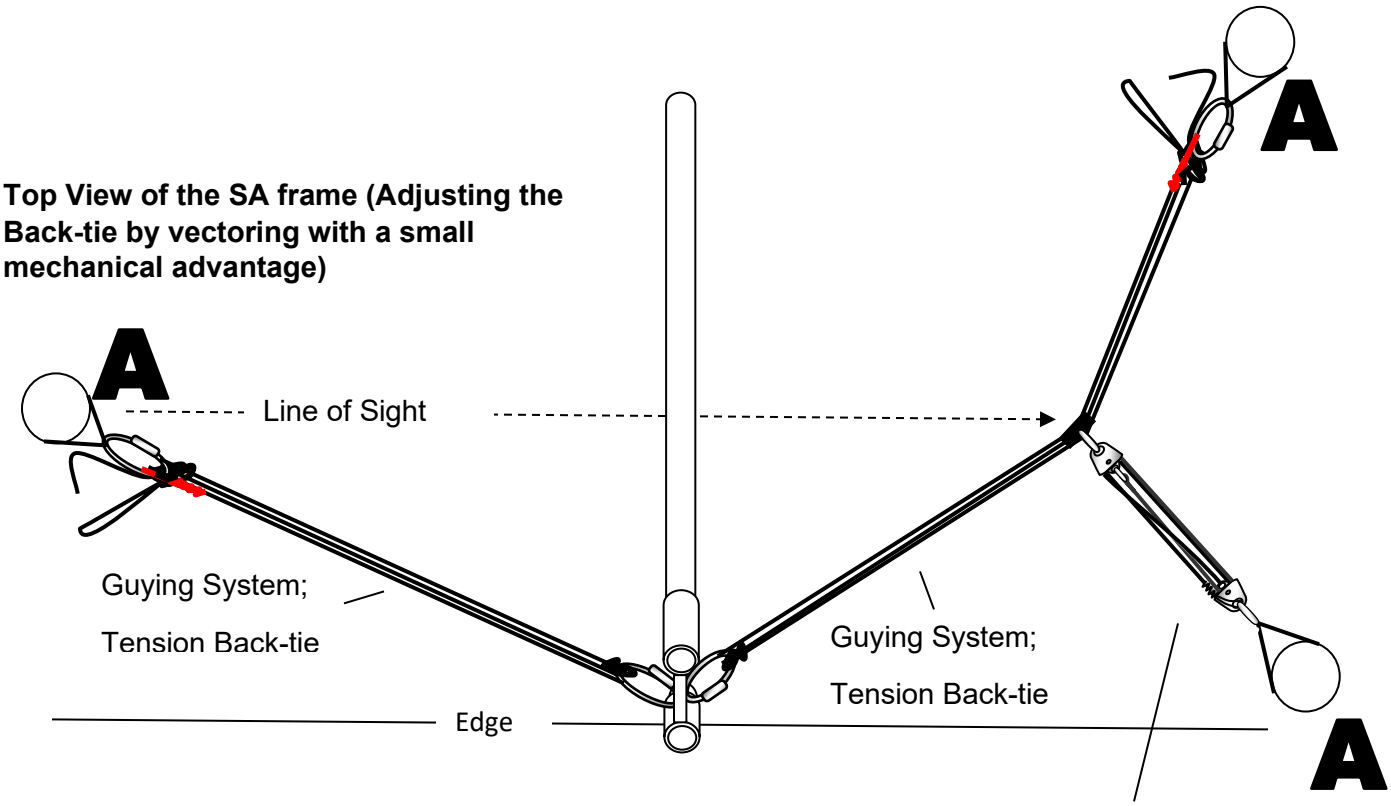
Top View of the SA frame (Typical)



Top View of the SA frame (Adjusting the Back-tie by vectoring with a small mechanical advantage)



Small MA, typically a personal mini-haul will work for vectoring the back-tie into a usable position.

Dynamic Directionals (controlled anchor dynamics)[6]

Dynamic Directional Anchors are adjustable pulleys/anchors. Being able to have a stable anchor and simultaneously move that anchor is only allowed when doing so under an extremely controlled and calculated manner. Many times the interface of a simple 5:1 between a stable anchor and the directional pulley works well for smaller gaps. Larger gaps may require rigging that provides a somewhat larger amount of horsepower; at least a 6:1 or 9:1 compound system.

For short deviations, minor dynamic directional anchors may not require a belay for the point of horizontal influence; however the belay option may be put into use based on the decision that the dynamic directional is indeed a critical safety element of the overall operation. The key question you must ask is, if the dynamic directional were to fail, would the pendulum effect of mainline cause serious injury to the rescue load?

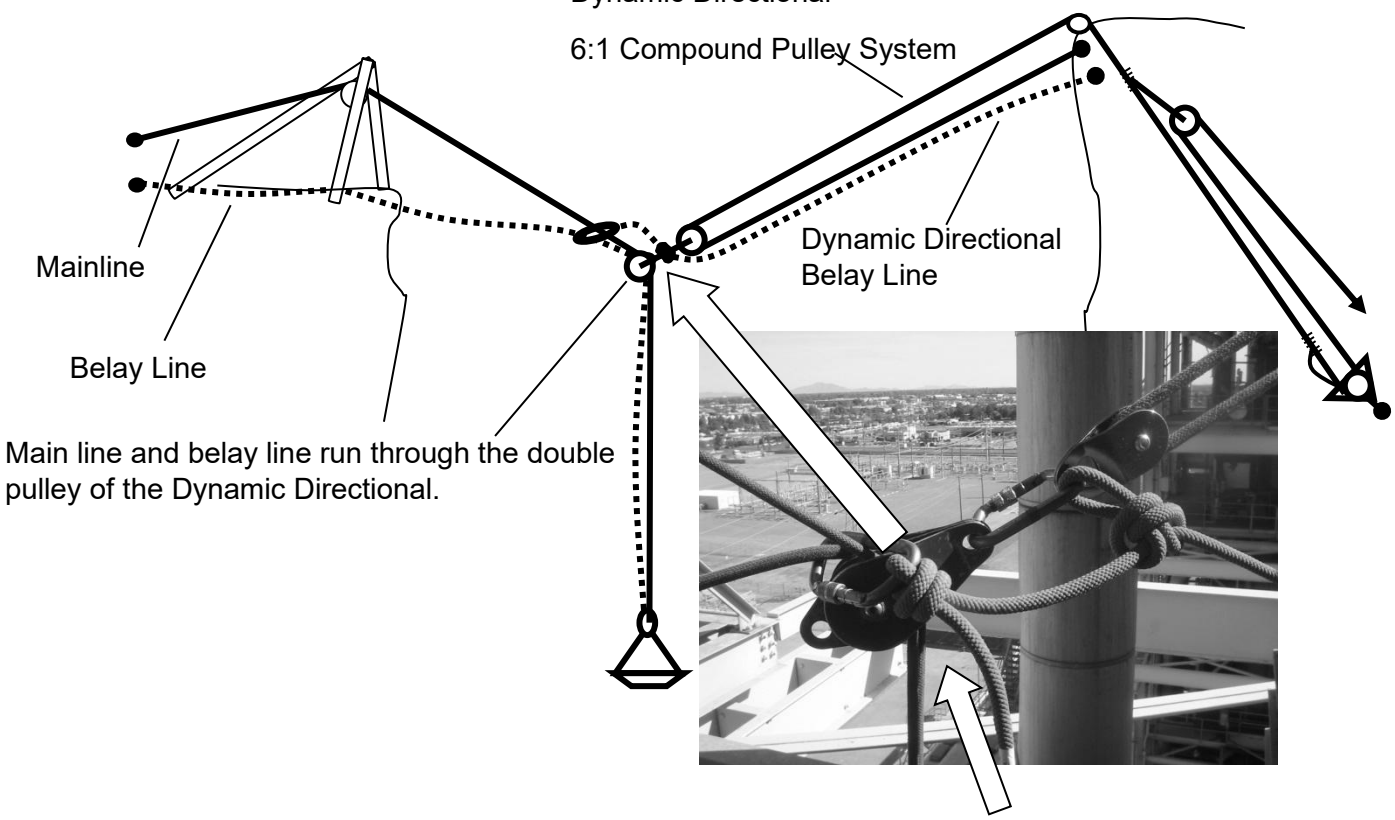
Low or high directional on the deflected offset side should be relatively parallel to the high directional on the mainline.

Dynamic Directional Anchor

High directional on the mainline side.

Dynamic Directional

6:1 Compound Pulley System



Main line and belay line run through the double pulley of the Dynamic Directional.

The Dynamic Directional belay is tied in to the pulley carabiner with a “butterfly”. A one foot tail from the butterfly goes to a steel carabiner that encompasses the main line and belay line just above the double pulley.

Friction and Torque

Rigging is the use of tension and compression to either move something or to keep something in place. Whether we are moving or holding something, friction is always there, working for us or against us. This section on friction is a basic treatment of coefficients of friction with a specific focus on how it will multiply the weight of the actual load during a hauling.

It is common practice in rope rescue to use a friction device such as a Petzl ID for the addition of friction during a lowering. When the mainline come in contact with the edge during a lowering it is as if an additional brake rack has been added. Aside from any rope wear and tear of continual edge contact, this edge friction is working in our favor.

Now let's convert our lowering to a raising system; the same edge contact that was working in our favor on the way down is now playing tug-of-war with the haul team! A matter of fact, a good rule-of-thumb measurement is about 3 times the weight of the load is really what the haul team has to overcome when the rope is being pulled over a rock ledge. This is arguably the single most important reason for the use of elevated anchor systems (the Vortex Multipod, or TerrAdpapter, natural or structural) over difficult edges.

Traditionally, we have always perform a Static System Safety Factor (SSSF) prior to the implementation of a rope rescue; we analyzed our rigging and made a judgment of the weakest link and whether or not it was within the parameters of our safety margin, usually a 10:1. The Dynamic System Safety Factor (DSSF) on the other hand, judges the rigging system during its operation, and predicts the weakest link during the greatest moment of system stress? This moment of greatest stress will always be during the transition between a static state to a state of hauling, or put into physical terms; the *transition from static friction to dynamic friction (sliding friction).*

Friction Law

Friction is a force of resistance between two objects that tends to oppose any motion. Friction may be further defined as being either static friction (force that tends to counter motion of an object that is in a state of rest, and kinetic friction (force wanting to slow an object in motion).

Dynamic Friction

After the initial spike of needed force to move the object from a state of rest, the dynamic friction (sliding friction) is the force needed to sustain movement over the surface.

Although we have performed multiple *Rope Test Lab*[7] slow pull test of a 200kg load over a sandstone edge and steel structures at a 90° contact surface, we have found an effective and simple way to prove this point in the classroom is through the use of tabletop demonstrations by raising a 5 pound weight over a brick or metal pipe on the edge of the table. We usually use 6mm rope connected to the 50 pound rated dynamometer (fish scale). Going down, the 5 pound weight will register around 1.5 to 2 pounds on the scale; coming up the same 5 pound weight will register around 18 plus pounds on the scale. The results of these small scale classroom demonstrations are remarkably close to the test we performed with 200kg loads over a sandstone edge; a magnification of the load by approximately 3 times during the hauling process. Rounded steel proved little relief with an increase of the true load of about twice as much.

Torque

Torque has been included in this part because of the importance it plays in the use of high directional anchor systems. Nowhere is this physical factor more evident than in the use of aerial ladder/platforms employed by fire service rope rescue teams as elevated anchor points.

A bad assumption in the use of aerials for rope rescue is relying on the manufacturer's ratings of maximum dynamic loads under *firefighting operations*. Firefighting ratings are assuming water flow and the weight of water in the ladder pipe distributed along the full length of the aerial. In addition, when the master stream is in operation there is a reverse thrust that is actually reducing the potential torque. Rope systems on the other hand, create a singular force of torque on the aerial towards the ground.

Here are some basic rules for using aerial ladders for elevated anchors in rope rescue:

1. Minimize the load; victim only whenever possible.
2. Maximize the degree of aerial elevation
3. Minimize aerial extension

4. Minimize vertical torque by rigging the mainline resultant as close as possible to the compression of the aerial.
5. Minimize horizontal torque by rigging the mainline in line with the aerial.
6. Never rig the belay line at the tip of the aerial. Either operate the belay from the structure the victim is being extricated from, or consider using a single rope technique when no other belay option is practical. A dynamic event causing the deployment of the belay system rigged through the tip of the aerial could be catastrophic.
7. Use larger haul teams; this will promote smoother control of the mainline and much less shock loading that is typically seen by a small number of haulers that are forced to use jerking pulls.

A good lesson may be learned from simply observing construction cranes. This is in essence exactly what we are doing when we use aerial ladders for our elevated anchor points in rope rescue. As with all cranes, aerial ladders are huge class one levers…not tripods. As with any elevated anchor system, the resultant of the mainline system at the tip of the high directional is the most critical element in maintaining the integrity of the system.

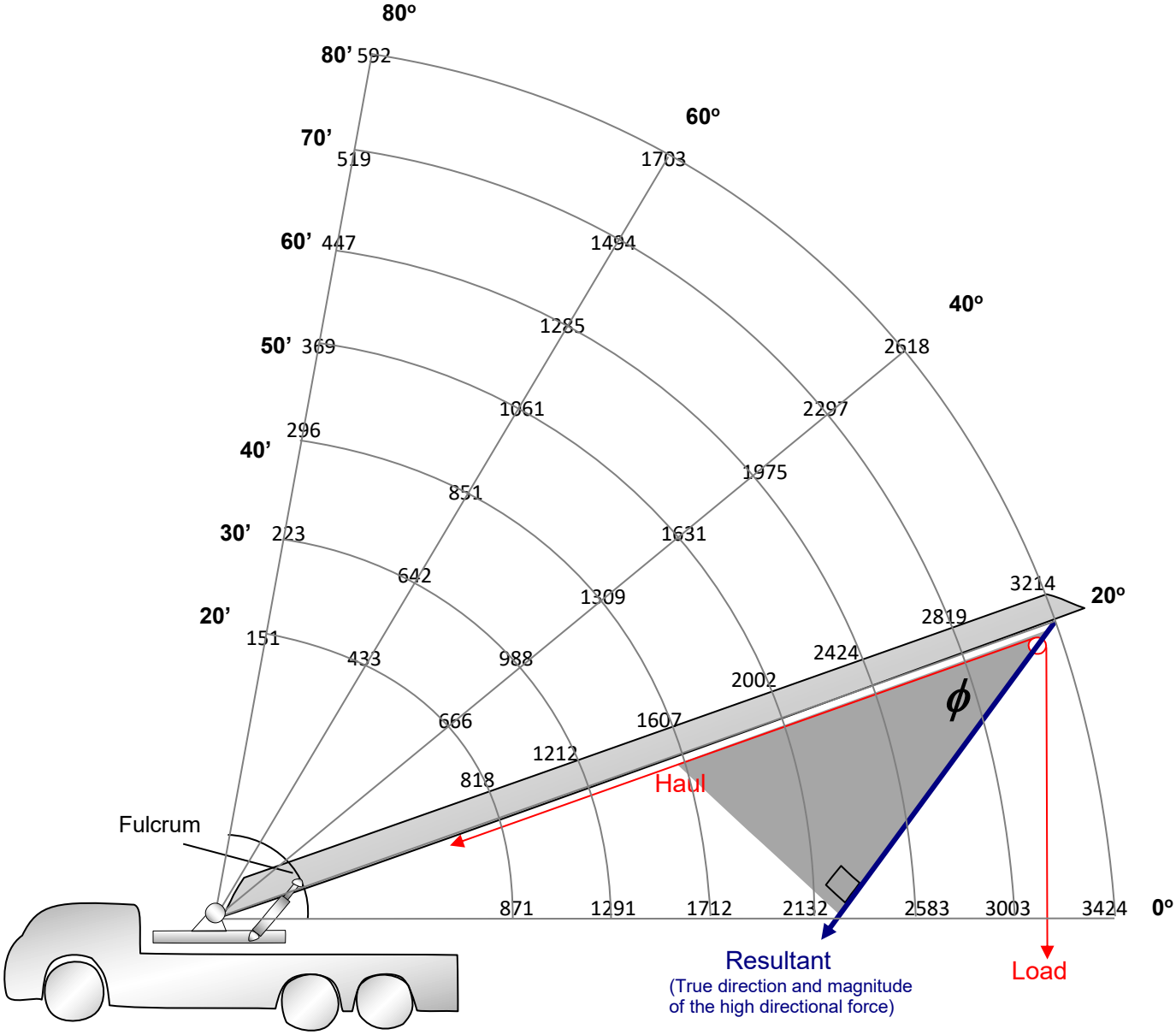
The basic theory of crane operation is to keep the resultant of the mainline system at the tip of the HD as close as possible to the compression of the crane, or in our case, as close as possible to the compression of the aerial. The closer the mainline resultant of the HD pulley gets to 90° with the aerial, the more the torque there is at the pedestal and the more bending moment there is along the length of the aerial itself.

Unfortunately there are some publications on the market that are incorrect and actually show diagrams that are depicting the use of aerials at close to a worst case scenario for maximum torque. Aerial ladders should also minimize torque through the manipulation of the mainline resultant at the HD pulley.

The next two pages contain torque calculations based on the rigging of the mainline through a high directional pulley versus the rigging of a 4:1cd at the tip.

It should also be noted that these are static calculations. The only way we have been able to get a true dynamic representation of the actual load during the raising process is through the use of factory integrated overload systems that come with newer models of aerial ladder trucks. Through limited testing, we confirm our suspicions that when the MA is operated on the ground, a larger haul team may be used therefore promoting a smoother haul and substantially less shock force to the aerial. Conversely, when using the 4:1cd at the tip of the aerial, only one or two haulers at the most are typically used because of limited space around the hole; this promotes shock loads as much as five time higher due to the jerking motions of the limited number of haulers.

Torque on the Fulcrum or the Weakest Link of an Aerial Ladder
(4:1cd versus Single Directional Pulley)



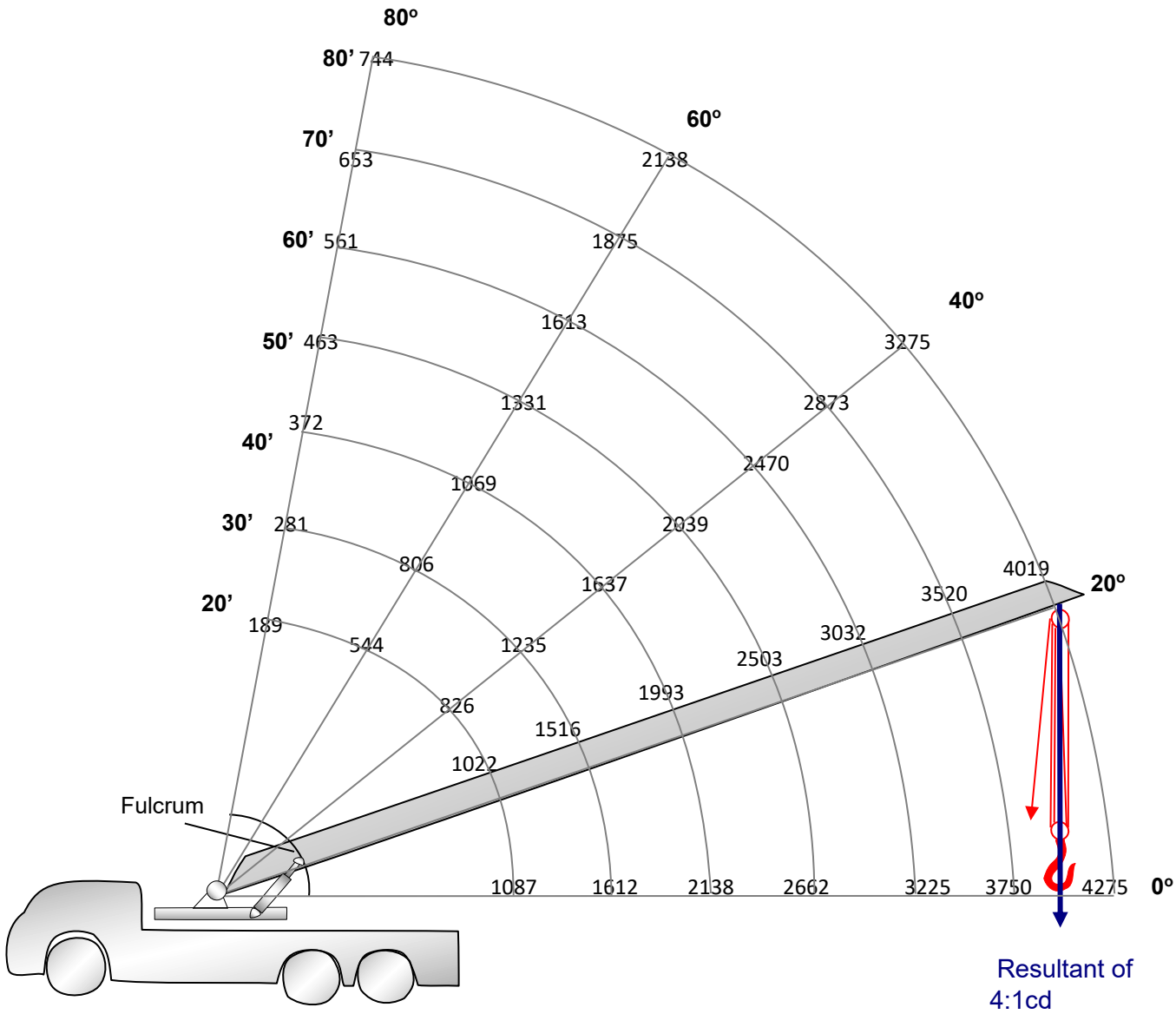
- Calculate the resultant of the HD for the weight at the tip.
- Calculate the leverage ratio on the fulcrum (ram) using:

Length of aerial above fulcrum / 7 feet

- Create an adjusted right triangle, using the resultant as the opposite and the aerial as the hypotenuse.
- Formula is: *(Tip Load)(Leverage Ratio)(sinϕ)*

The Load in this example is 300 lbs.

Avoid this practice (shown below) when rigging to aerial ladders. This will create excessive force that is beyond the capabilities of many ladder trucks.

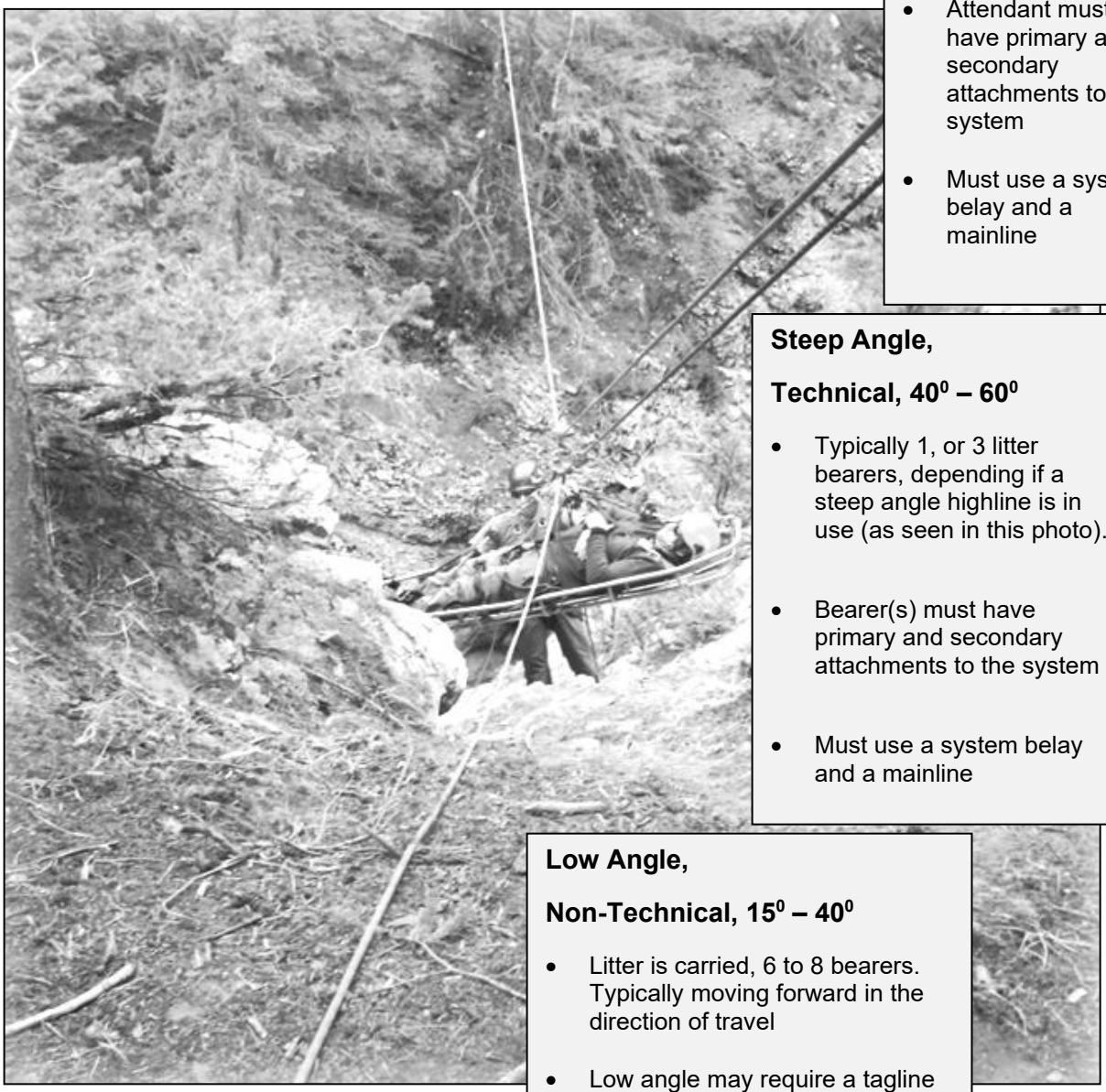


Litter Rigging:

T

As with all aspects of rope rescue, depending of which school you adhere to, there are many ways to rig the litter package. In an attempt to stay consistent with the underlying theme of this book*, keep it simple and applicable*, we will focus on one type of connection for the litter, namely, the use of the *Doubled Long Tail Bowline.* This will be the connecting loop, or *yoke,* for high angle vertical configurations as well as steep angle horizontal configurations.

The Type of Terrain Determines the Litter Configuration



High Angle, Technical, 60^0 – 90^0

- 1 – litter attendant
- Attendant must have primary and secondary attachments to the system
- Must use a system belay and a mainline

Steep Angle,

Technical, 40^0 – 60^0

- Typically 1, or 3 litter bearers, depending if a steep angle highline is in use (as seen in this photo).
- Bearer(s) must have primary and secondary attachments to the system
- Must use a system belay and a mainline

Low Angle,

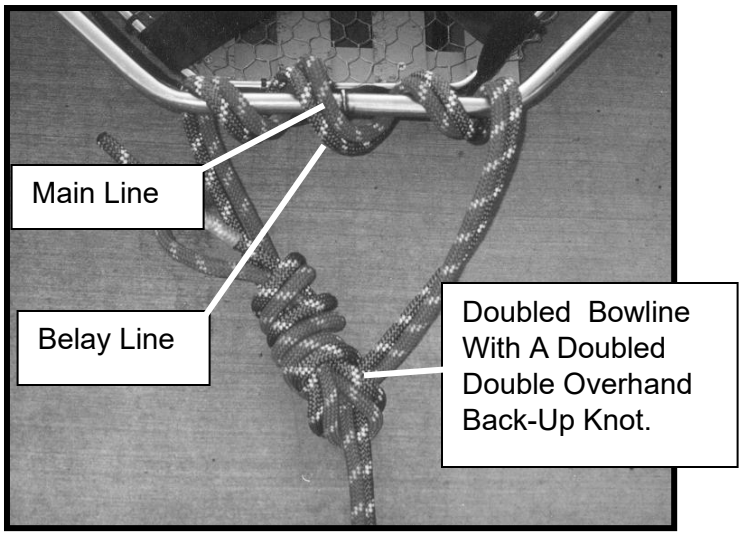
Non-Technical, 15^0 – 40^0

- Litter is carried, 6 to 8 bearers. Typically moving forward in the direction of travel
- Low angle may require a tagline

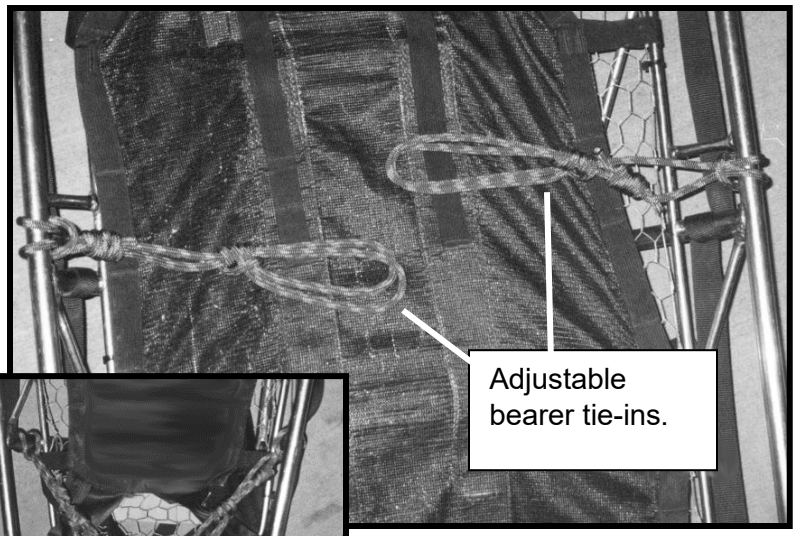
Steep Angle Litter Configuration

Steep angle extrications that are of a lesser exposure may be rigged according to the photo to the right. This is the time when you know you must use, at least, a tag line but the question arises, is a tag line alone secure enough to safely do the job?

If there is any doubt about the use of a tag line, go with a steep angle operation.



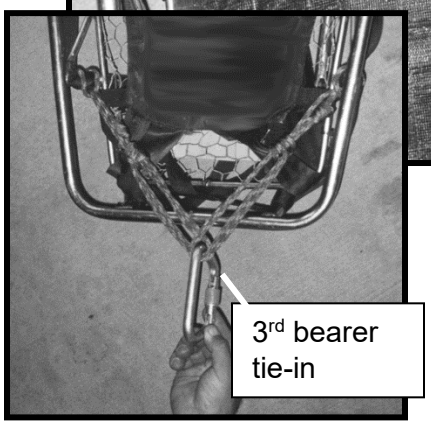
The doubled bowline is the best knot at the yoke for a low exposure steep angle operation. It is easy to tie and inspect. The main line and the belay line are connected, via the doubled bowline, to the bottom litter struts, and candy striped to the litter rails. The resulting loop should form approximately, an equal-sided triangle that captures the litter at its strongest point.



Adjustable bearer tie-ins:

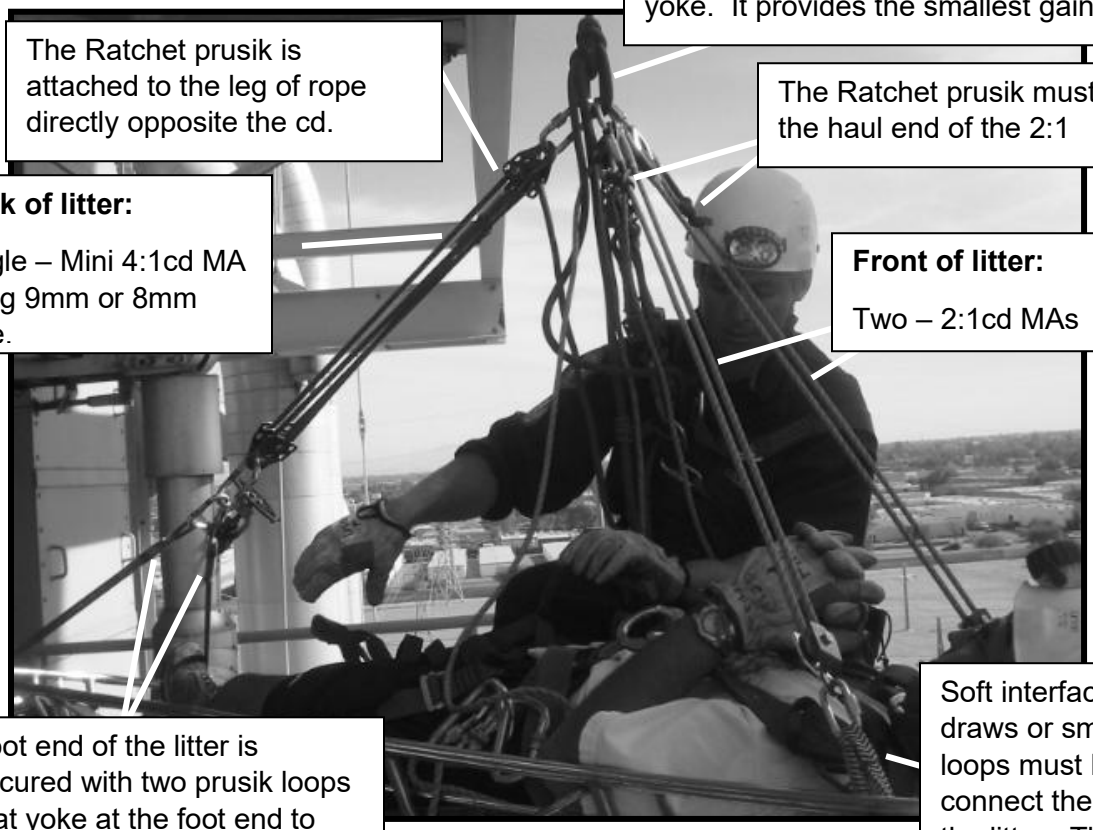
Constructed from approximately 77” of 8mm accessory cord. A loop is formed by tying a double overhand bend. The adjustable loop is formed by a 3-2 prusik hitch on itself. (3 wraps on the top, and 2 wraps on the bottom) The tie-in is attached to the top rail of the litter with a girth hitch.

When using 4 bearers, two are attached towards the top, and two are attached near the bottom.



With a 3 bearer configuration, 2 bearers are towards the top of the litter, and the 3rd bearer will tie-in at the very back of the litter using two adjustable tie-ins, forming a “V” off of the back two struts of the litter. In all steep angle configurations, the bearers will connect the tie-ins to the waist “D” ring of their harness.

High Angle Litter Configuration Using the RescueRig Litter System



The Double Long Tail Bowline is used for the yoke. It provides the smallest gain.

The Ratchet prusik is attached to the leg of rope directly opposite the cd.

The Ratchet prusik must secure the haul end of the 2:1

Back of litter:

Single – Mini 4:1cd MA using 9mm or 8mm rope.

Front of litter:

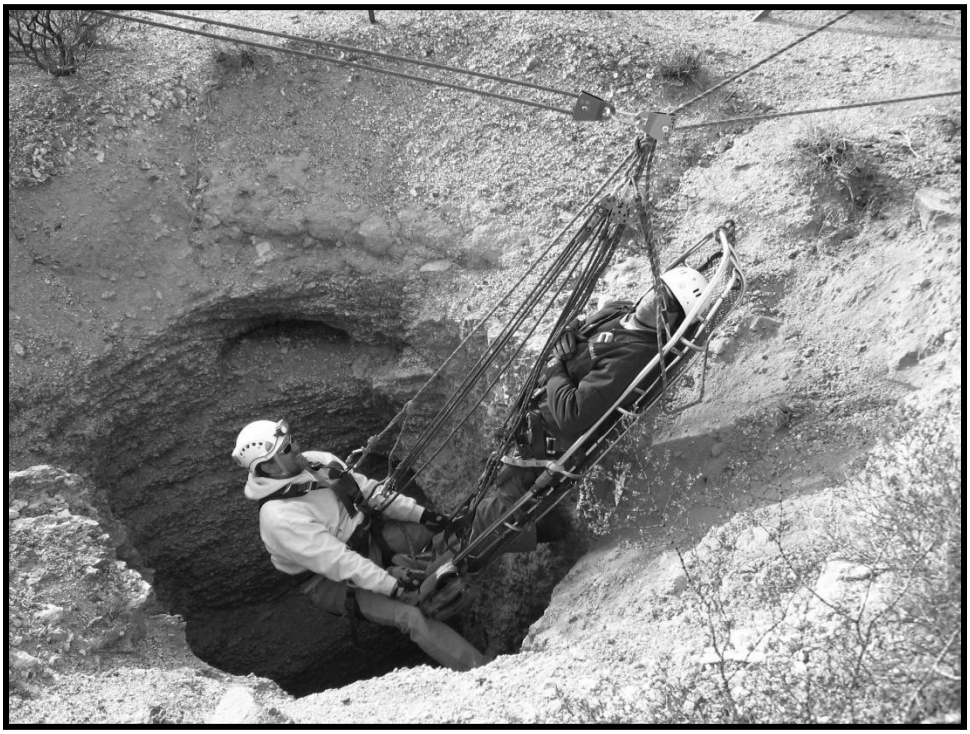
Two – 2:1cd MAs

Foot end of the litter is secured with two prusik loops that yoke at the foot end to the mini 4:1cd.

Soft interface like quick-draws or small prusik loops must be used to connect the 2:1 MAs to the litter. This will allow for radical and quick movement of the litter system. Hard connectors tend to side load and bind in awkward position.

The RescueRig Litter System will allow quick up and down configurations to meet extremely tight situations.

The RescueRig Litter System allows for an endless array of configuration possibilities that can safely, quickly, and easily be manipulated by a single attendant.



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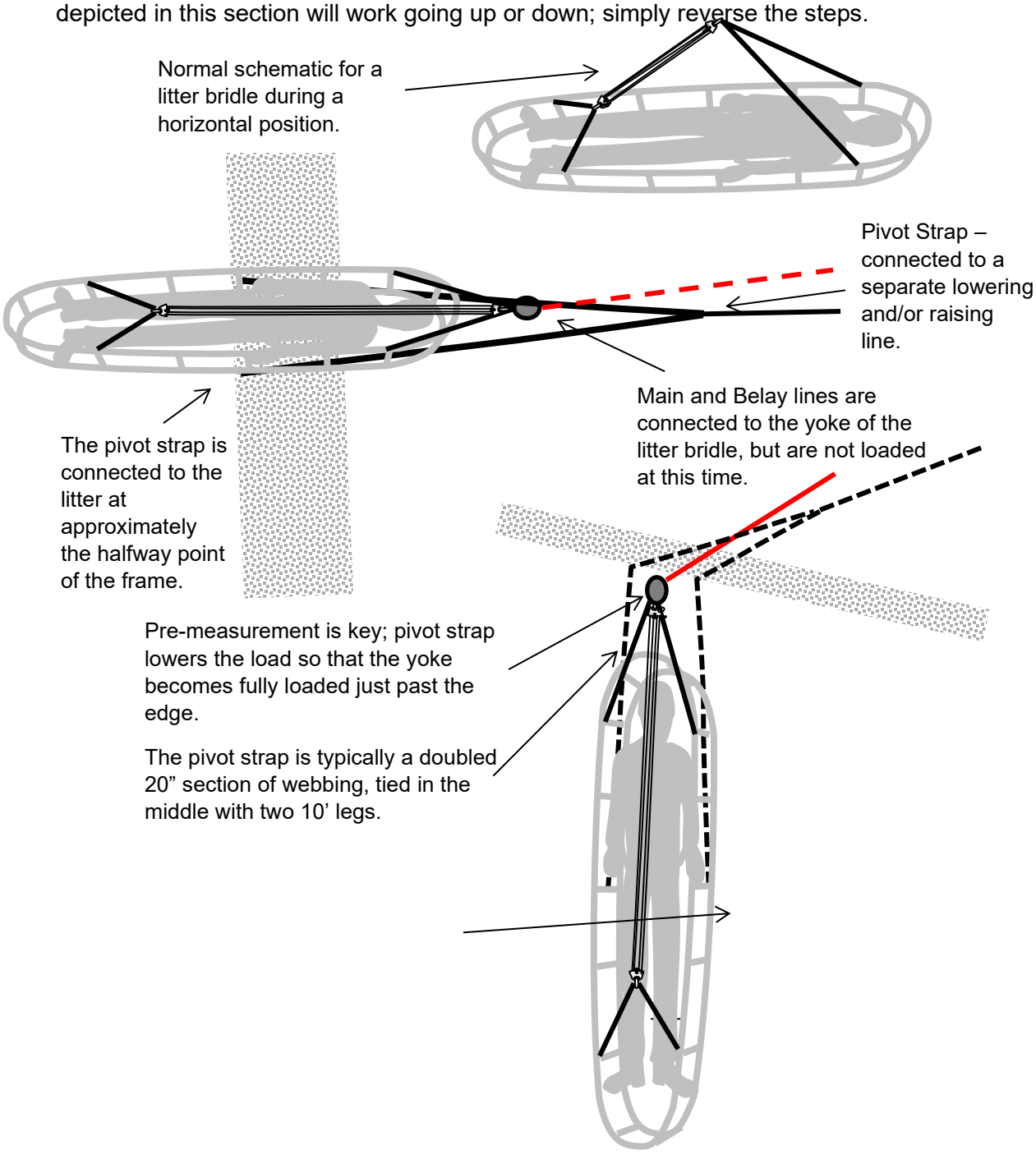
Pike and Pivot

The concept of the Pike and Pivot Rescue has predominately revolved around the use of the litter basket. The key factor is in the rigging of a pivot point at the middle of the basket that allows the basket to hinge at the edge. However, although most practitioners have focused on the use of the litter basket, the pike and pivot technique is equally valuable as a tool when used with other patient adjuncts like the Yate's Spec-pak. The ability to rig a pivot point is also useful with elevated anchors (i.e. Vortex or TerrAdpator) while negotiating handrails and other obstacles at the edge. The process depicted in this section will work going up or down; simply reverse the steps.



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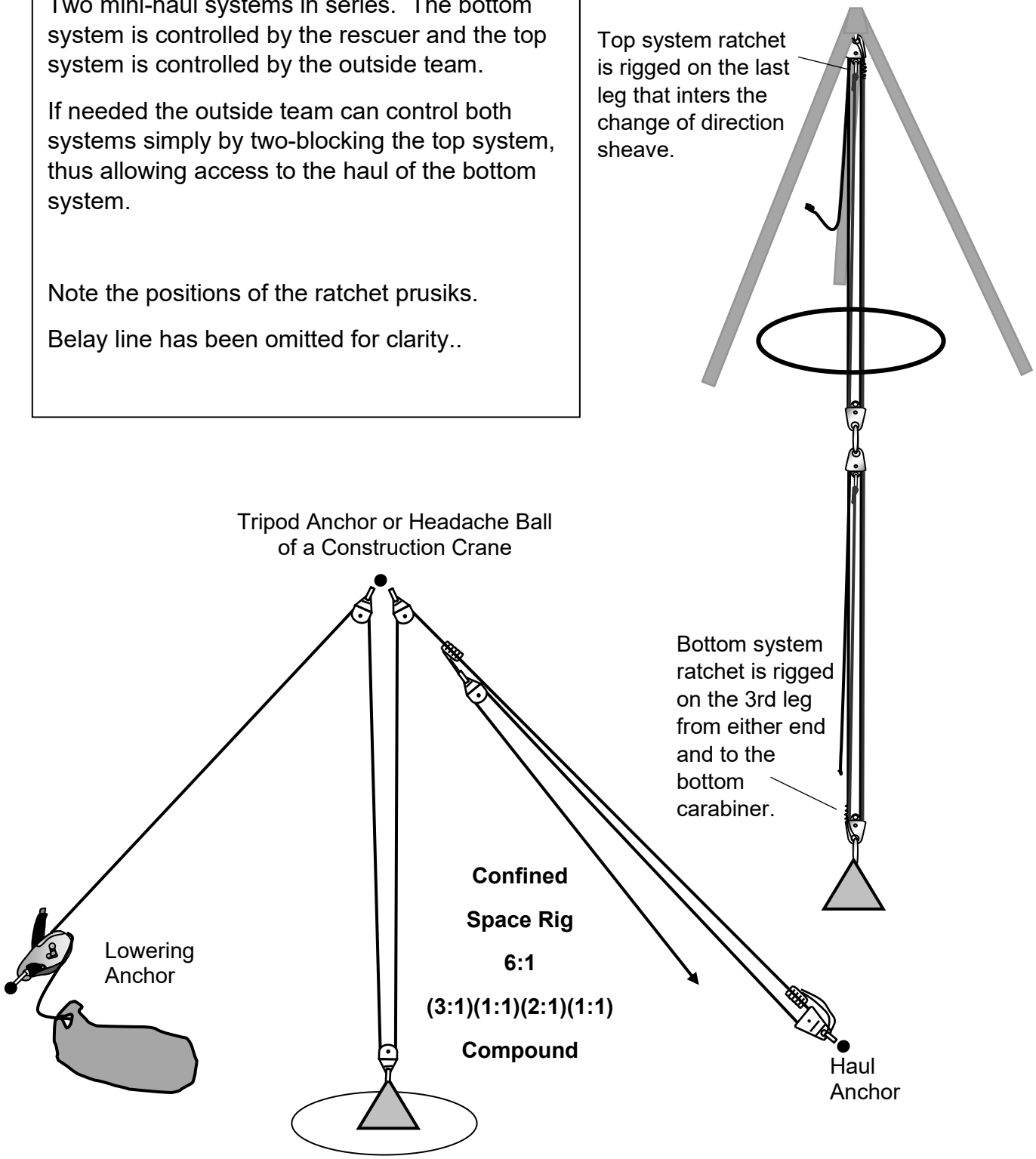
Confined Space Rigging:

Two mini-haul systems in series. The bottom system is controlled by the rescuer and the top system is controlled by the outside team.

If needed the outside team can control both systems simply by two-blocking the top system, thus allowing access to the haul of the bottom system.

Note the positions of the ratchet prusiks.

Belay line has been omitted for clarity..



Dynamic Anchors Lowering System (DALS):

T

The Dynamic Anchor Lowering System (DALS) is a proven rescue practice of the Kary Environmental Services. This technique is commonly used on many of the cranes to extricate a sick or injured crane operator from the cab; most notably, the gantry cranes, and many of the bridge cranes in use on the property. This technique is equally valuable with many potential confined space rescues, such as booster fan housings.

Anchor Profile

As with many cranes, good high point improvised anchor options are abundant. However, the best practice is to have engineered rescue anchor points installed above and just outside the cab.

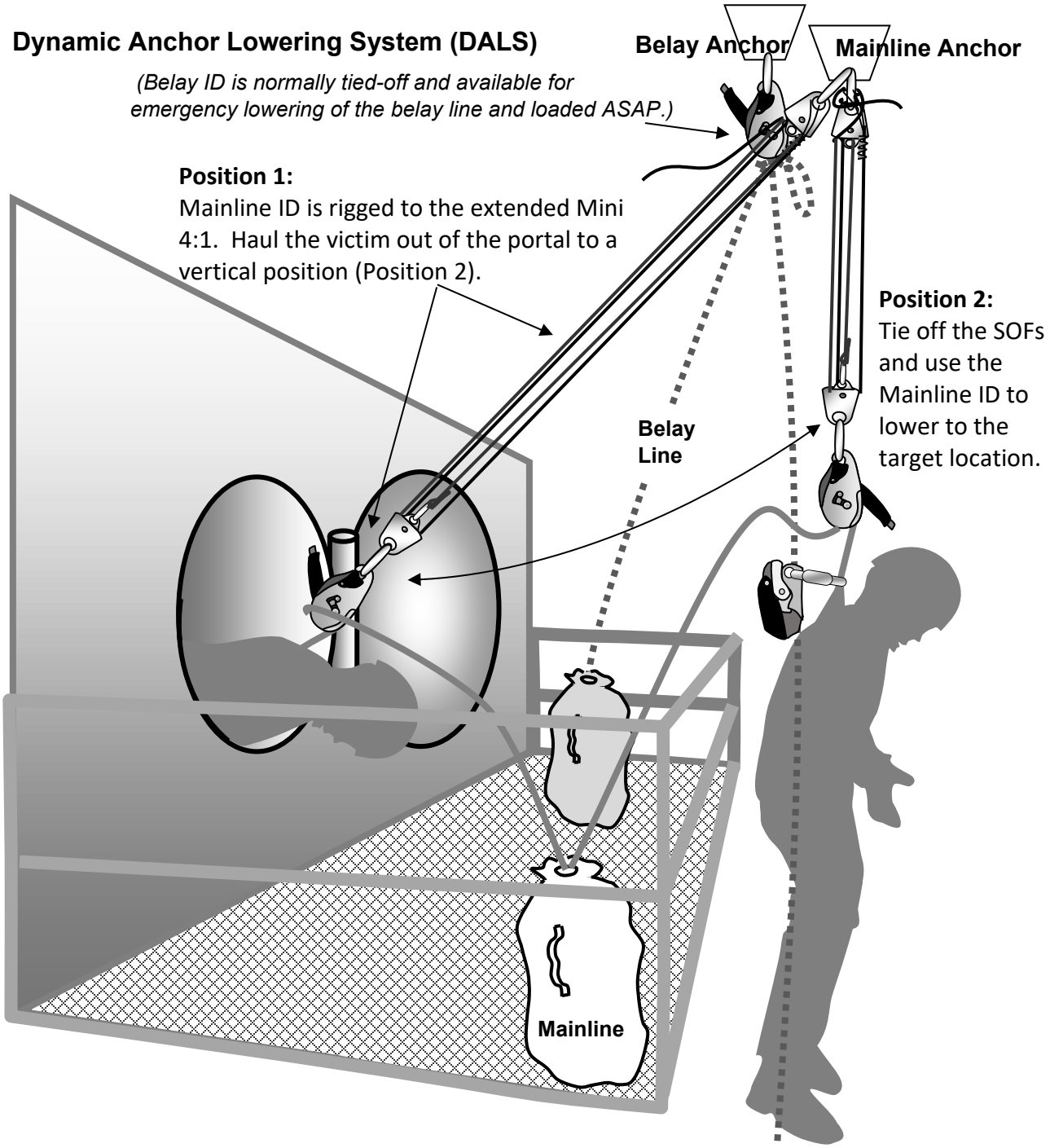
Most of the confined space openings will require some form of improvised anchor. It should be an ongoing process of industrial rescue teams to identify these conditions and determine the best rescue anchor options for the rescue plan.

Prior to any confined space entry of the workers, attempt to identify structural elevated anchors outside the opening that a haul system may be operated from to assist in moving a potential victim through the portal.

Vertical movement after the portal or crane cab evacuation

There are several potentials during this type of rescue for the need to lift from the crane cab and then immediately lower to the ground or the next level. Many times simply the use of the Set-of-Fours (SOFs) haul system to go both up and down with the victim is all that may be required. However, some locations present greater vertical challenges and obstacles to weave around during the descent of the victim. During these instances the sole use of a full anchor-to-victim pulley system would be dysfunctional rigging and a single mainline lowering system would be more practical.

Consider using the DALS. The DALS is a descent device (typically the Petzl ID) pre-rigged to the load end of a SOFs haul system. Once lifted out and away from the portal/crane structure, the victim can quickly be lowered via the attached Petzl ID to the next level. ***See next page.***



The belay shown in the diagram above is an auto belay using the Petzl ASAP. This system works well with limited manpower. However, a second rescuer may provide a man operated belay with the Petzl ID. In this example the ASAP belay is attached to the victim after exiting the confined space, but before being placed in vertical exposure.

Note:
The belay line is tied off through a Petzl ID connected to the belay anchor. The ID handle is in the locked position. In the event of the ASAP engaging (mainline failure or accidental loading), This ID located at the belay anchor can be used to complete the lowering of the victim with the belay line. There must be enough belay line in the belay bag to complete this function.

Highlines:

Highline operations are some of the most demanding rigging challenges a team may be called upon to perform. Highline rescues invoke the use of advanced rigging skills, performed by advanced technicians. Under no circumstances should a highline be attempted solely on the instruction of this book. Anyone interested in performing a highline must have solid rigging skills, and seek advanced training through an accredited school of rope rescue and/or a seasoned lead instructor who has a full grasp of the physics involved.

Ninety-nine percent of the time most high angle rescues can be accomplished through the use of helicopters, and/or a mainline/belay line system combined with various forms of taglines. It is that rare 1% of the time that a highline might be needed. Typically, highlines are incorporated where a long expanse must be negotiated and/or a long term search and rescue campaign over extreme terrain is required, such a building collapse, rubble pile, or a flood plain.

Highlines are almost always a last resort option. The good side of highlines is that it is a viable option; the bad side is that there are numerous reasons why not to do one. If over tensioning and rope abrasion are the archenemies of rope rescue operations, than consider these two evils the devil incarnate to a highline.

By its very nature, highlines go against most conventional rules of safe anchor building. In most cases, we try to keep the angle between multi-point anchors 90% or less, at 120 degrees the force at each anchor equals the weight of the load. With highlines, you are looking at a vector angle of 150 degrees and up. This alone will multiply (with the rescue load in the middle of the trackline) the weight of the load anywhere from 2 times at 150 degrees to 11 times at 175 degrees at each anchor!

Because of this tremendous stress highlines put on the anchors, here are some key principles that must be included in the construction of highlines:

- Anchors must be bombproof.
- Full strength of the trackline must be utilized by eliminating all knots, and all sharp bends.
- All knots on the control lines must be bypassed.
- Maintaining a pulley tension system to the highlines utilizing a “slipping clutch” (or safety fuse) in the form of system prusiks. (8mm, 3-wrap) or stitched shock absorbers.
- Incorporate a carriage system supporting the load.

Highline Definitions

Highline: A highly tensioned horizontal or diagonal rope system drawn tightly between two points to assist the access of rescuers, patient and/or equipment.

Trackline: The trackline is the main support rope that the carriage system will travel on.

Control Lines: Ropes rigged on both ends of a highline system and used to control the movement of the carriage system. The control lines also double as the secondary/belay system in the event of a trackline failure.

Span: The straight-line distance from side to side.

Control Line Hangers: Control line hangers are loops approximately 0.5m long, typically tied from 3mm to 6mm cordage. These loops are used to support the control lines on longer systems. The hangers are affixed to the trackline via a carabiner, and to the control line using a girth hitch. Control line hangers should be placed approximately 15m to 25m apart.

Deflection: Deflection is the sag of the load creating the vector angle typically represented as a percentage of the length of the span, i.e. a single rope trackline 150m long should deflect approximately 10% or 15m when the load is in the middle of the system.

Carriage: A carriage is the traveling support vehicle for the load rigged with pulleys.

Pilot Line: The pilot line is the very small first line, light enough to spool from a line gun or throw across the gap.

Messenger Cord: The messenger chord is the second delivery line light enough to be pulled across by the pilot line yet strong enough to pull the first system rope across without breaking. The messenger cord is typically a 3mm cord.

Construction and Tensioning of the Highline

There are immense forces generated at each end the highline, because of this it is imperative that all knots be eliminated from the highline, and that the highline not be over tensioned.

The highline must be one continuous rope and the opposite side must be anchored with a high strength tie-off.

The control side of the highline is *typically* finished off with an integrated 3:1 MA. (Ganged systems are sometimes used, especially for bundled 2 and 4 rope highline systems.) This MA should include a single ratchet prusik at anchor pulley. Once tensioning is complete, the second leg of the 3:1 will be tied off at the anchor (behind the ratchet prusik); it is at this point that the ratchet prusik now becomes a prusik bypass.

When pre-tensioning the highline, use only one person to pull on the equivalent of a 3:1 MA. Post tensioning of the highline the maximum number of haulers is dependent on the weight of the rescue load, the length of the highline, and the amount of desired percentage of sag.

Multiple Bundle Highlines/2 Rope, and 4 Rope Highlines

As stated earlier, one of the most critical points of a highline operation is the amount of tension at each anchor created by the vector force of the load. In pre-tensioning a single highline we would use a single person pulling on the 3:1 MA, this would allow for approximately 10% sag with the load at the middle.

There may situations that will not allow for this much sag i.e., swiftwater highline rescues, or long term operations over a building collapse rubble pile. For these types of highlines where little sag is wanted, it would be very dangerous trying to remove the sag by increasing the tension. This problem is solved by the deployment of additional rope in the trackline, also known as bundles.

Typically seen are 2-rope, and 4-rope bundled tracklines. Keep in mind, that the sag is lessened by the addition of more ropes to the bundle, the tension on each individual

rope in the bundle is still going to be about the same as a single rope trackline. The 2-rope bundle will allow for 5% sag, and the 4-rope will allow 2.5% sag.

Highline, Floating “A” Frame

The use of high directionals is a very important aspect in the construction of highlines, especially on the side the rescue package will be brought to.

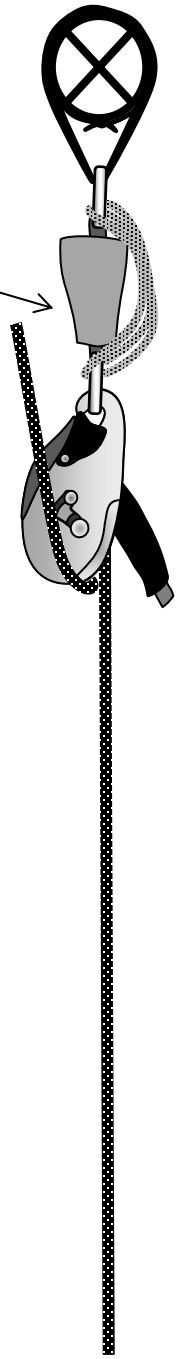
The first option would be for a “natural” high directional, usually a tree, if this is not possible, the “A” frame makes a quick and easy to set-up alternative.

When used in this application, the “A” frame does not need to be guyed in the traditional manner as shown earlier. After the trackline is constructed, lash the “A” frame together, hook a pulley to the trackline and connect it to the apex of the “A” frame while the “A” frame assembly is flat on the ground. The “A” frame can easily be vectored into place prior to the pre-tensioning of the trackline.

Once the “A” frame is upright, it is then guyed into place by employing two opposing system prusiks connected to the trackline on both sides of the pulley.

Floating “A” Frame on a twin bundle trackline; note the prusiks front and back on the trackline facilitating the guying of the high directional.

Control Line with ID and the Yates Shorty



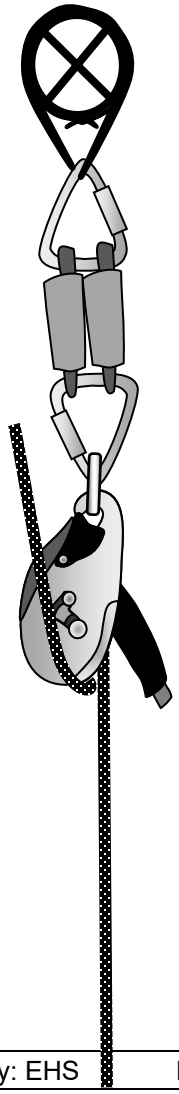
These configurations are somewhat different from the traditional brake-rack/tandem prusik control line rig. Our tests have shown the Petzl ID to work very well for control line operations. Combined with a single Yate's Shorty and a basket hitch (typically a doubled 8mm prusik loop) the ID will provide the needed shock absorption in the event of a trackline failure.

Note on Highline Failures and Shock Absorption:

Recent studies suggest that the shock force produced during a highline failure and resulting in the capture of the load by the control lines is not a single location event. It is believed that a wave emits from the source (usually the carriage) and travels to each control anchor then back again, repeating shock waves until completely dissipated. This concept suggest that shock absorbers at the carriage and the anchors will help dissipate this wave.

Option 1: Basket Hitch; doubled long 8mm prusik; the load is on the "Shorty", during a trackline failure the "Shorty" will deploy stitches and gently transfer the load to the basket hitch. The rating of the 8mm basket hitch configuration is considered a high strength anchor ≥ 36kN.

Option 2: Instead of the Basket Hitch, we may choose to simply employ two Shorties as shown below working in conjunction with an ID.



Either of these combinations of the Yates Shorty will work well.

Option 1 will deploy at 2 kN and safely load the basket hitch, whereas *Option 2* will deploy at 4kN and suffice as the sole anchor interface. *Option 1* works well with added absorbers rigged into the carriage system, while *Option 2* arguably eliminates the need for additional shock absorbers at the carriage.

Rope Access Highline (Team Controlled)

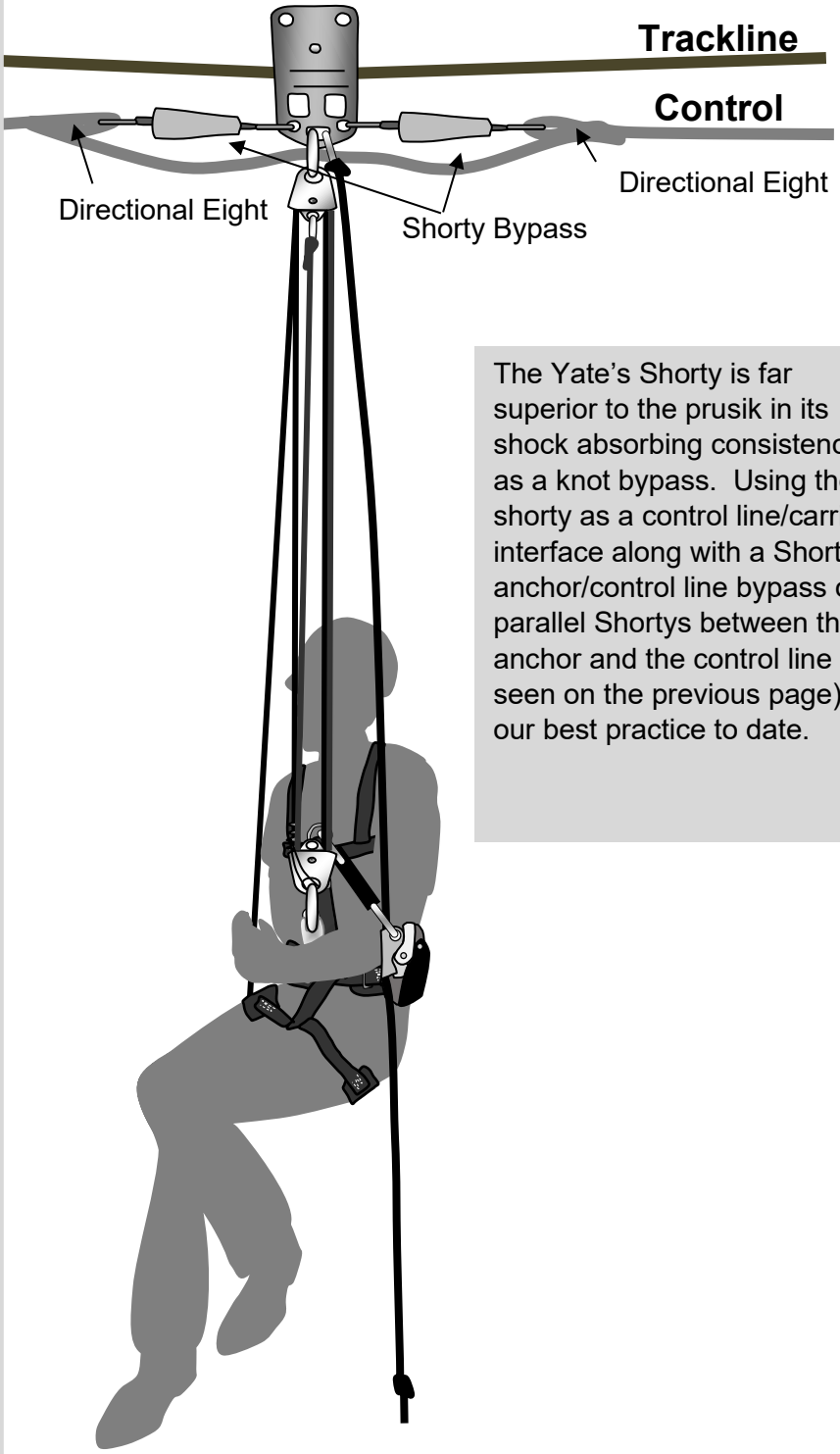
Why Highlines?

Whereas extensive highlines combined with elaborate reeving systems have very little use in rope rescue, a strong argument can be made for this type of rigging in the realm of rope access and work positioning. The key factors shown here are shock mitigation in the form of legitimate manufactured shock absorbers. The old technique of prusik bypasses should only be used as a last resort.

Reeving Systems:

Any number of reeving systems can be employed from the portable carriage anchor.

Maintaining a reliable belay system is mandatory for any rope access event. The old technique of opposing prusiks for a reeve system is highly questionable given the propensity of failure of prusik belays on tensioned rope…the jury is still in deliberation on the use of prusiks for reeve system belays. Employing proven belay devices like the Petzl ASAP is currently the best practice.



The Yate's Shorty is far superior to the prusik in its shock absorbing consistency as a knot bypass. Using the shorty as a control line/carriage interface along with a Shorty anchor/control line bypass or 2 parallel Shortys between the anchor and the control line (as seen on the previous page) is our best practice to date.

Basic Highline Tensioning Formula[8]

I have found this basic formula taken from the cable yarding industry to be more rule-of-thumb, nonetheless, very practical and reliable for quick field use.

$$T = \frac{(\text{Load})(\text{Span})}{(4)(\text{Deflection})}$$

Example:

Rig a transportation (personnel shuttle) highline across a rubble pile of a large collapsed building brought down during an earthquake.

The load is potentially 200kg and the span (the line-of-sight distance between each side) is 300 feet; based on the height of the anchors on each side, the load will have no more than 18 feet of clearance when it is mid-span, so we'll make our maximum deflection 15 feet mid-span.

$$\text{Tension} = \frac{(200)(300) = 60{,}000}{(4)(15) = 60} = 1000\text{kg}$$

We would take a 1000kg hit at each anchor and our rope system would have to withstand this high tension.

Given that a 12.5mm rope has a tensile MBS of approximately 4000kg and 11mm rope has a tensile MBS of approximately 3500kg how many ropes would need to bundle in the trackline to give us approximately a 7:1 to 10:1 safety margin?

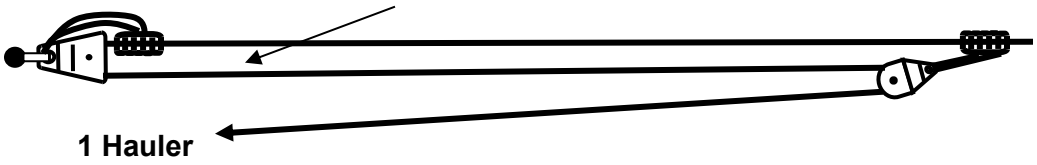
2 – 12.5mm ropes would give us approximately an 8:1 safety margin.

2 – 11mm ropes would give us a 7:1 safety margin.

4 – 11mm ropes would give us a 14:1 safety margin.

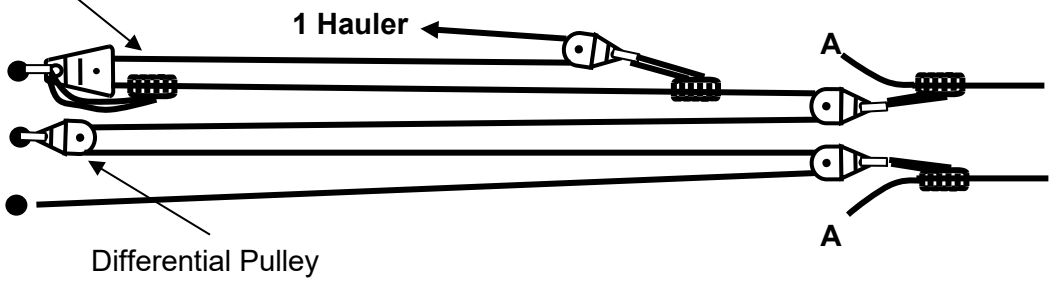
Single Trackline, 3:1 Tensioning System [9]

After tensioning is complete, tie-off this leg to the anchor creating a prusik bypass. Minimize the slack between the tie-off and the progress capture prusik.

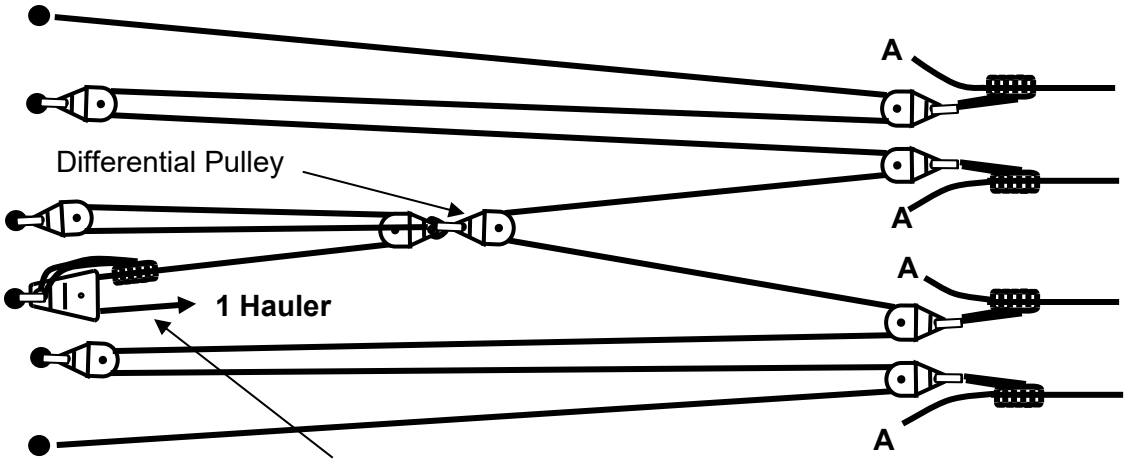


Twin Bundle Trackline, Parallel 6:1 Tensioning System

After tensioning is complete tie-off this leg to the anchor creating a prusik bypass. Minimize the slack between the tie-off and the progress capture prusik.



Quad Bundle Trackline, Four Parallel 3:1 Tensioning System



After tensioning is complete tie-off this leg to the anchor creating a prusik bypass. Minimize the slack between the tie-off and the progress capture prusik.

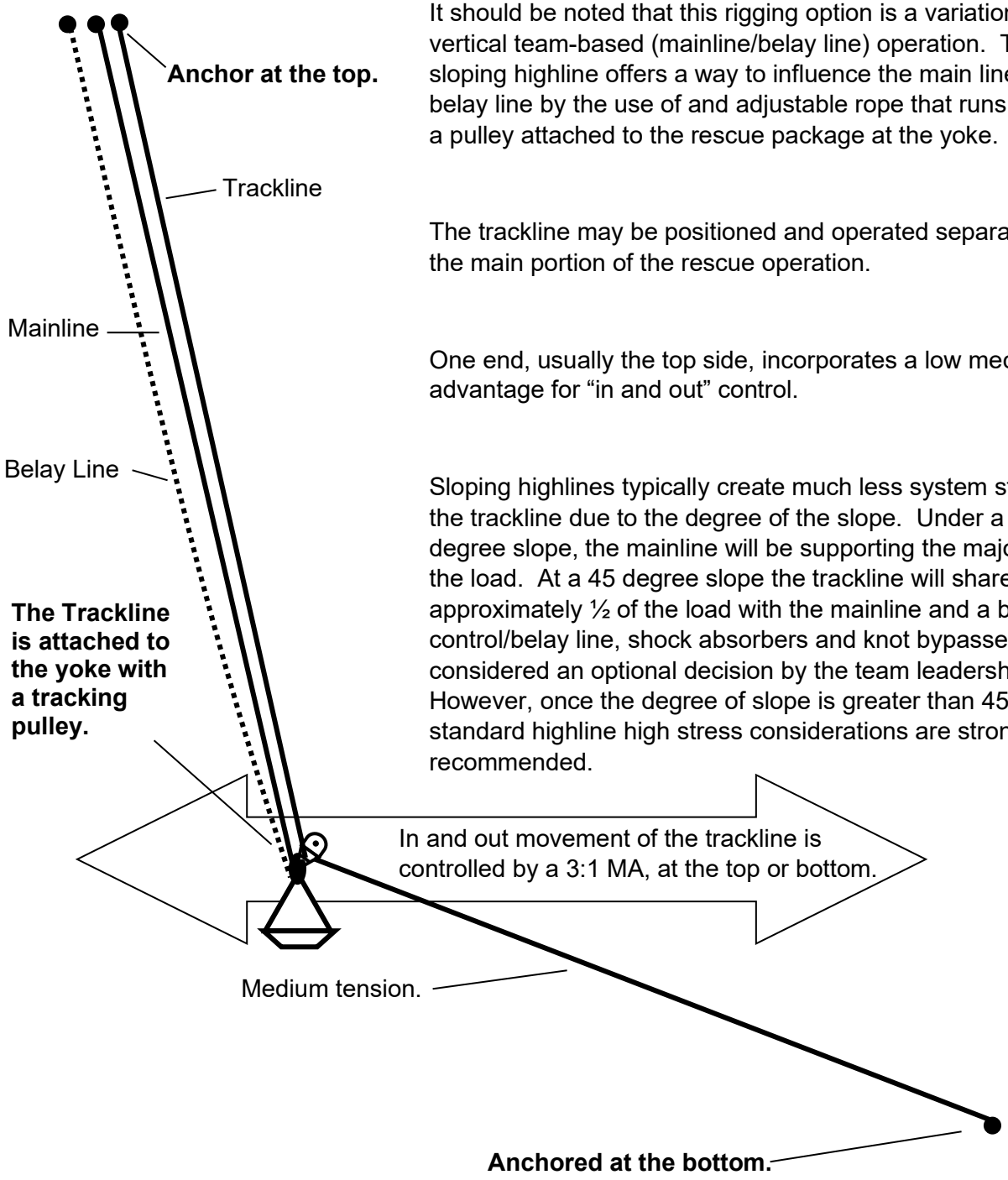
Sloping Highlines (Adjustable Trackline)

It should be noted that this rigging option is a variation of a vertical team-based (mainline/belay line) operation. The sloping highline offers a way to influence the main line and belay line by the use of and adjustable rope that runs through a pulley attached to the rescue package at the yoke.

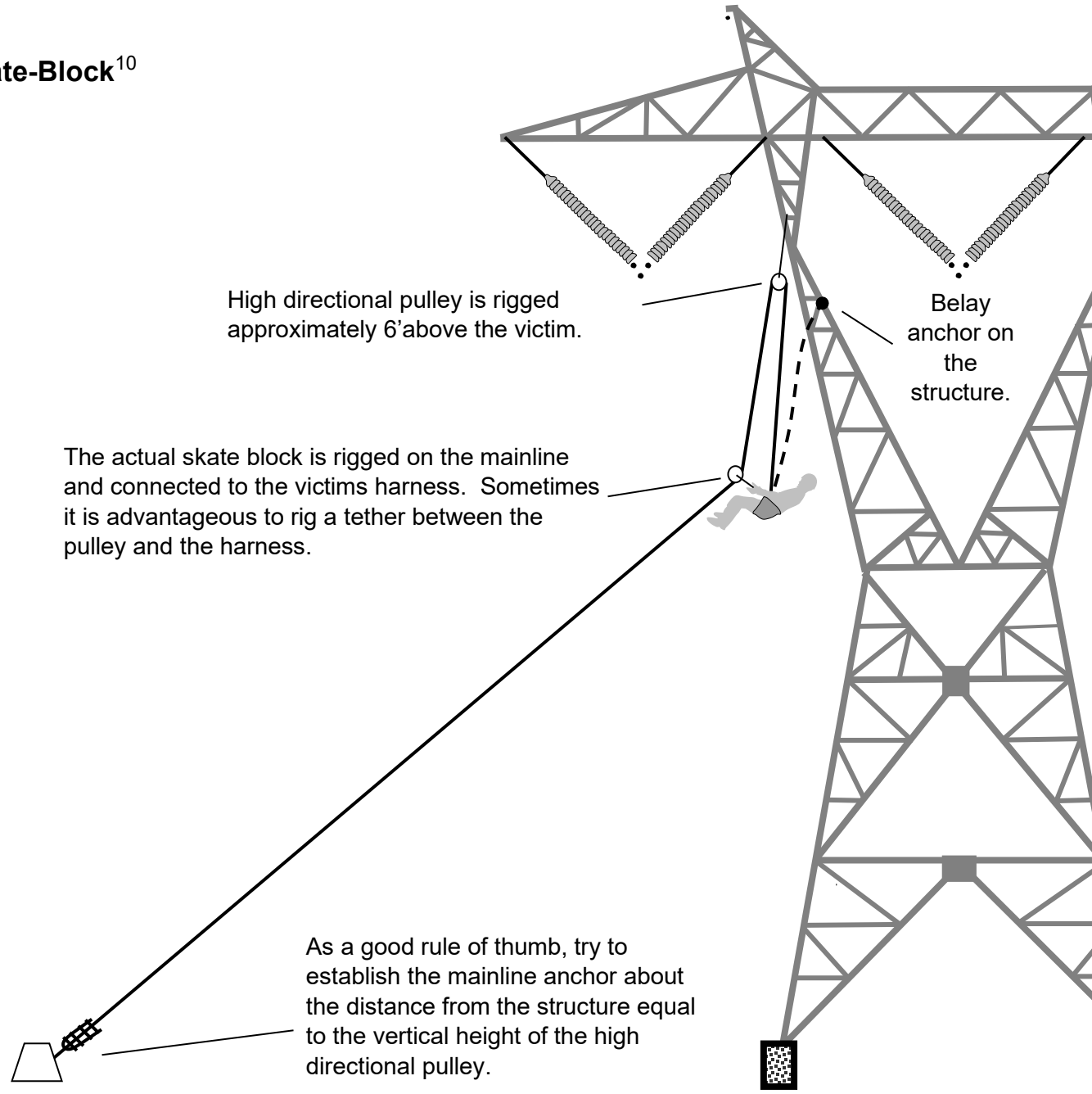
The trackline may be positioned and operated separately from the main portion of the rescue operation.

One end, usually the top side, incorporates a low mechanical advantage for “in and out” control.

Sloping highlines typically create much less system stress to the trackline due to the degree of the slope. Under a 45 degree slope, the mainline will be supporting the majority of the load. At a 45 degree slope the trackline will share approximately ½ of the load with the mainline and a bottom control/belay line, shock absorbers and knot bypasses may be considered an optional decision by the team leadership. However, once the degree of slope is greater than 45 degrees standard highline high stress considerations are strongly recommended.



Skate-Block[10]



The Skate Block is extremely useful for extrications from structural towers, industrial settings, and even tree rescues. This offset is easy to rig, and controls excessive tension. The victim should gently touch down several feet in front of the mainline anchor.

T

Mid-Wall Rescues:

Mid-wall rescues can run the full gamut of rescue complexities. It can include almost everything from one or two people coming to the rescue of a fellow climber, to a fully orchestrated team-based rescue. Because of this we have divided pick-offs into two major divisions 1) Solo Rescue, and 2) Team Based. These two divisions can be further subdivided A) Clinging, and B) Hanging, depending if the victim was simply free climbing, or if the victim was using a harness and rope.

Vertical Mobility

Keep in mind: Solo v. Team Based is not a black and white issue. In many cases a vertical rescue may indeed require skill and techniques from both disciplines. A rope rescue technician must be vertically mobile when needed. This is to say, the tech needs to be proficient in descending and ascending a rope system.

Patient contact is usually considered an early benchmark for any vertical rescue. Any delays in early patient contact due to the setup of a team-based system should be viewed as an ill-advised practice. This early contact is quickly and safely completed by descending and/or ascending as a solo rope access technique. In addition, most victim extrications do not require a two-person load (victim plus attendant); this is a paradigm shift in rope rescue that is heavily influenced by the evolution of rope access techniques worldwide.

A litter basket does not always require an (attached) attendant. Any victim/patient packaging adjunct can quickly be sent down to an awaiting rope technician who is already tending the victim; if hauling is required, it may be easier and safer for the team to haul the victim only and allow the vertically mobile rescuer to ascend on his/her independent rope system. This does require additional rope resources, but the tradeoff is almost always a much lighter load for the haul team and an overall safer operation.

This combination approach is not always possible; however it is a viable option…an important tool in our rigging skills toolbox that should never be discounted.

Solo Rescue

Solo rescues are rappel operations, two rescuers from start to finish is preferred whenever possible. One rescuer will rappel to the victim and perform the pick-off, and the second rescuer will stay topside and belay.

Team Based

A team-based rescue is done with a system lowering. It is designed for three or more team members and because it is a lowering (not a rappel) the attendant's

hands are free for a quicker capture of the victim. This type of pick-off will also allow for the option of a system raising should the need arise.

Clinging rescues of the Non-Injured or Slightly Injured Victim

A clinging victim pick-off is rescuing a climber or hiker from a vertical hazard. This person has no harness; rope or any other fall arrest system, and is almost always inexperienced.

Because of this person's inexperience and probable fear, the rescuer should be prepared to capture the victim as quickly as possible. This can be best accomplished by using a pick-off harness, and having it and all other pick-off equipment pre-rigged before the rescuer's descent to the victim.

The rescuer should be talking to the victim as soon as possible, offering assurance of safety, and explaining what will take place. Do not make any sudden or hard pulls or jerks on the victim. Remember, this person is deathly afraid of falling, and not unlike a drowning person, he may see you as the life preserver---something that will keep him from going down. Reassurance, confidence, and professionalism are paramount in keeping this victim calm.

Pick-Off Harness Made From Webbing, (The Diaper Sling)

There are numerous victim harnesses on the market that are very good. A great deal of efficiency may be afforded to the rescue process as a whole when these manufactured harnesses are used in accordance to the recommendations of the manufacturer. We will not explore these various manufactured harnesses, instead, let's pretend as though we only have webbing to fashion a victim's harness. This concept is also consistent with our general theme of this book in that rescuers should think light and that most rescues should be completed with the equipment typically carried on their own rescue harness: "Rescue from the hip". When manufactured rescue harnesses are available they should be used, but consider a diaper sling made with a 15' piece of webbing as a viable back-up to the manufactured versions.

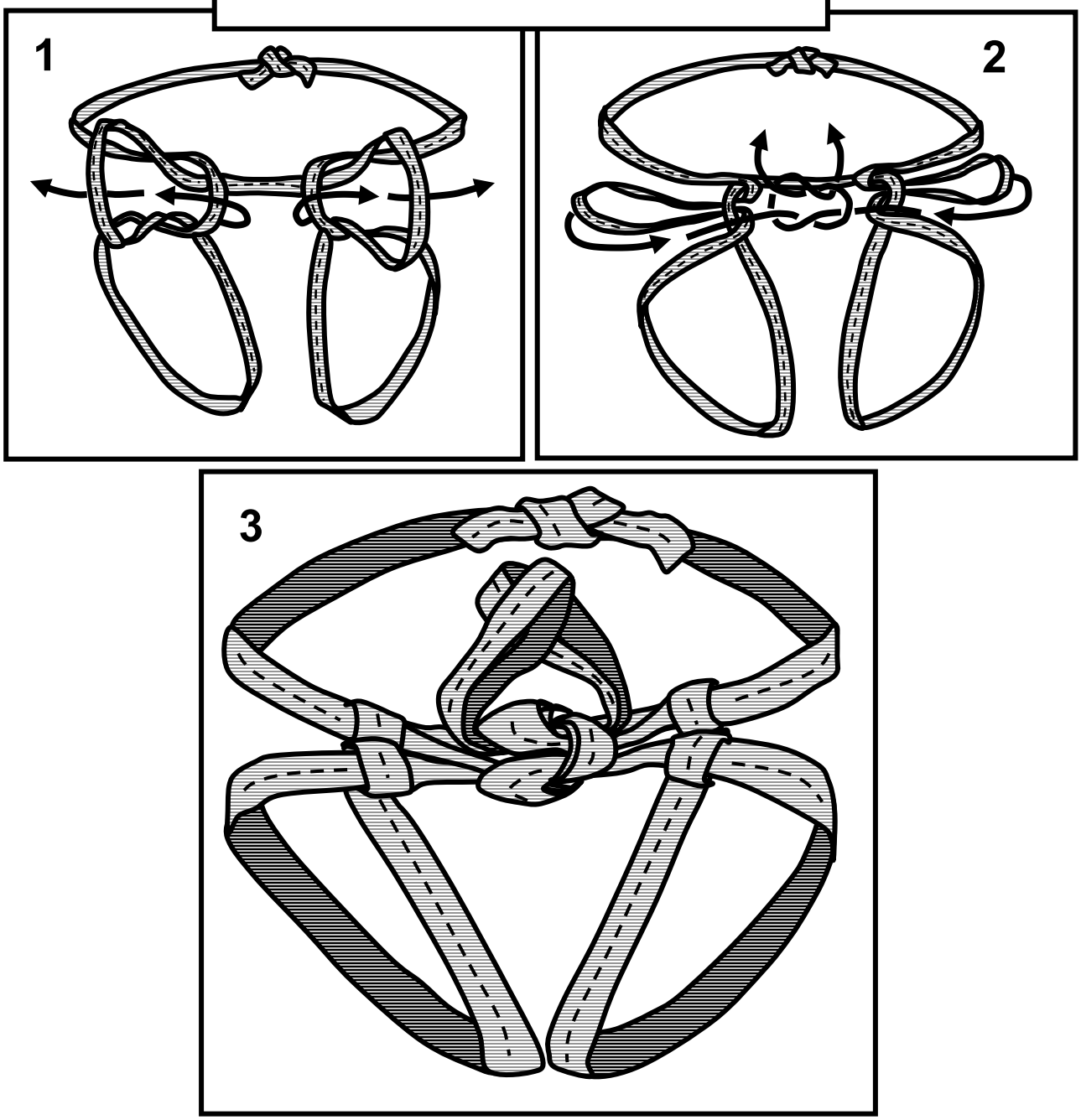
For most adults, the diaper sling is best made using 15' of webbing. Tie the webbing into one large loop using an "Overhand Follow-through Bend" (Water Knot). With the rescuer behind the victim, this loop may be draped over the victim's shoulders from the backside (keep the water knot of the loop next to the victim's neck). With both hands at each side of the victim's body, the rescuer should reach through the loop and down and in front of the victim's legs and grab the bottom of the loop. Care should be given pulling the bottom of the loop up between the legs, and back out and around the side of the victim. The rescuer can finish the "diaper sling" by dressing all loose ends of the webbing, bringing the ends around and to the front of the victim's waist, and tying a square knot.

After a pick-off strap and the belay line have secured the victim, the rescuer may choose to secure the chest and shoulder by tying a 12" to 15' webbing loop. The webbing should be pre-tied into a loop using an "Overhand Follow-through Bend". This loop can then be tied to the victim with a "Double Girth Hitch" around the chest, and slipping one

of the top sections of webbing over one shoulder. The remaining tail of the chest loop should be tied to the diaper sling.

Note: On smaller body sizes excess webbing (prior to putting the finishing knot and carabiner on), should be wrapped either around itself, or around the victim's waist. The final tail should not be over 6" to 8" in length.

Unsupported Pick-Off, Diaper Sling Schematic



Hanging Pick-Offs of the Non-Injured or Slightly Injured Victim

A hanging pick-off is the rescue of a victim who is still on rope. That is to say he is in a harness, or he has some form of support from a fall arrest system.

Any number of things can cause a person to become stuck on a rope. The great majority of the time it involves a jammed rappel device. The rappel device is usually fouled by the victim's own hair or some bulky article of clothing. Once again, because this person was unable to perform a "self-rescue", he probably lacks experience, and you can count on him being scared.

Because this victim is supported, you do have time on your side, and if resources are available, a ***Team Based*** pick-off should be the first option. Any serious injuries to the victim, especially any kind of neurological compromise, a more involved rescue possibly utilizing a litter for the patient adjunct may be called for.

Evaluate the victim's rappel line. What is the quality of the anchor, and the victim's rope? The victim may want to rappel down on his own system after being freed from the jammed rappel device*, this option requires extreme vetting.* This person is probably in a "shaky" state of mind in the first place, and once the rescuer assumes control, it is the responsibility of rescuer to maintain control until the victim is safely on the ground.

Once contact has been made with the victim, and the rescue connections have been made (the pick-off strap, and one of the long tails from the "Double Long Tail Bowline"), the victim must be taken off of his system. When all else fails, and the need to cut the victim's rope is deemed necessary, boot scissors are one of the best tools for this job. An open knife is extremely hazardous around tensioned rope, especially if the knife accidentally touches any part of the rescuer's support system.

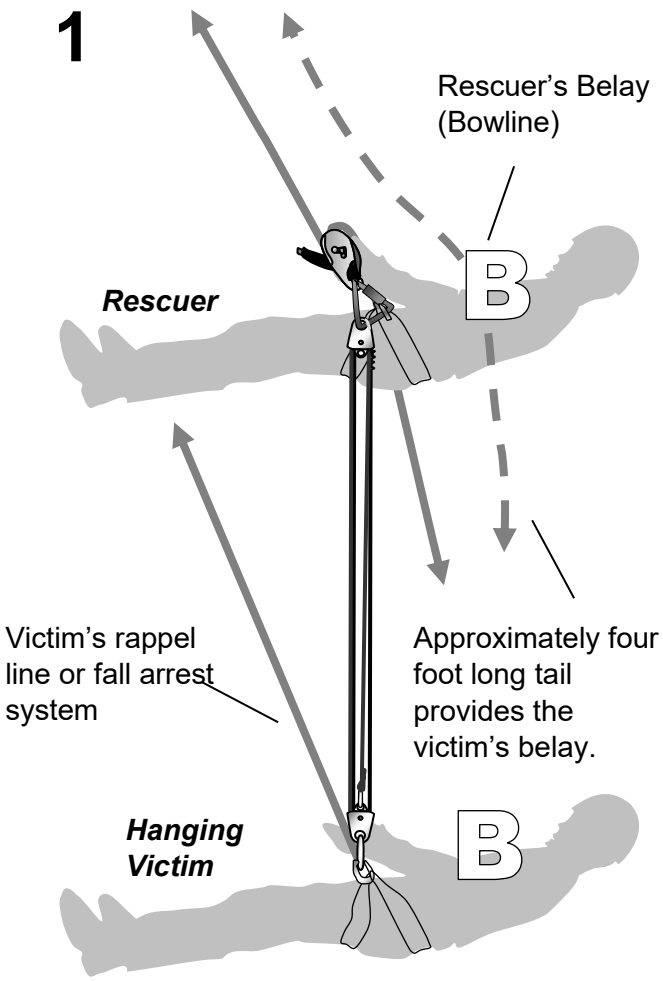
To remove the victim from his rope, his weight must be raised off of his rappel device by using a mechanical advantage.

For a ***Team Based*** pick-off, the MA is rigged at the top by the team; usually a ganged-on system is needed to raise the load. Once the victim has been freed the team based MA lowers the victim onto the pick-off strap.

For a ***Solo Rescue*** pick-off, This MA must be rigged by the rescuer. There are a number of ways to use this tool. Two double mini-PMP pulleys is recommend. This pulley system is not only used to un-weight the victim from his/her system, but also doubles as the primary attachment to the victim.

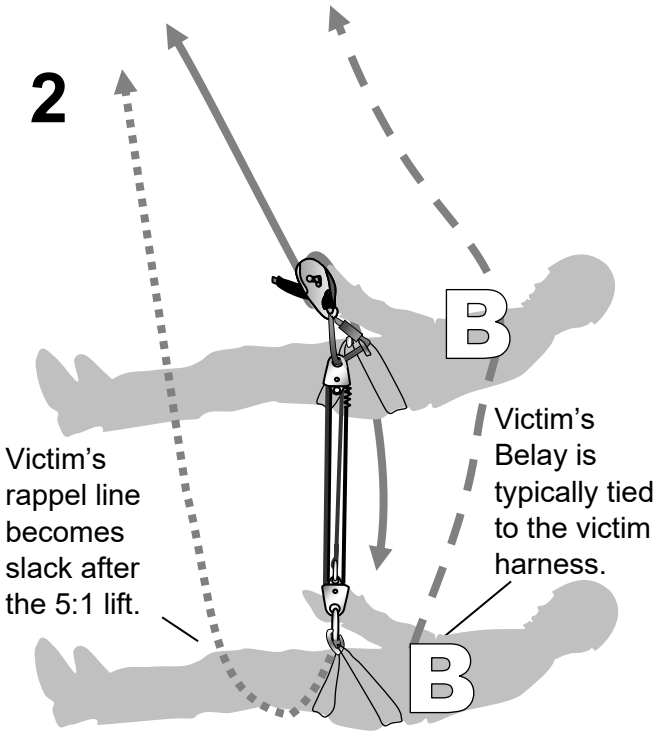
Solo Mid-wall Pickoffs, *Hanging Victim*

Utilizes a Mini 5:1 and a Petzl ID on Rappel



Step 1 – Rescuer pre-rigs the mini 5:1 to the needed length. The ratchet prusik and haul end (shock absorber) must be accessible to the rescuer at all times. The lengthened mini 5:1 is typically draped over the rescuer's shoulder during his/her rappel.

Step 2 – Rescuer stops approximately 5 to 7 feet from the victim, ties off the descent device, hands the victim's end of the mini 5:1 to the victim and closely monitors the victim's self-connection. For a victim that is unable to assist, the rescuer must be prepared to invert to make an unassisted victim connection.



Step 3 – Using the 5:1 MA, the rescuer hauls the victim up until the victim's rappel line becomes slack and the rescue belay line can be attached to the victim.

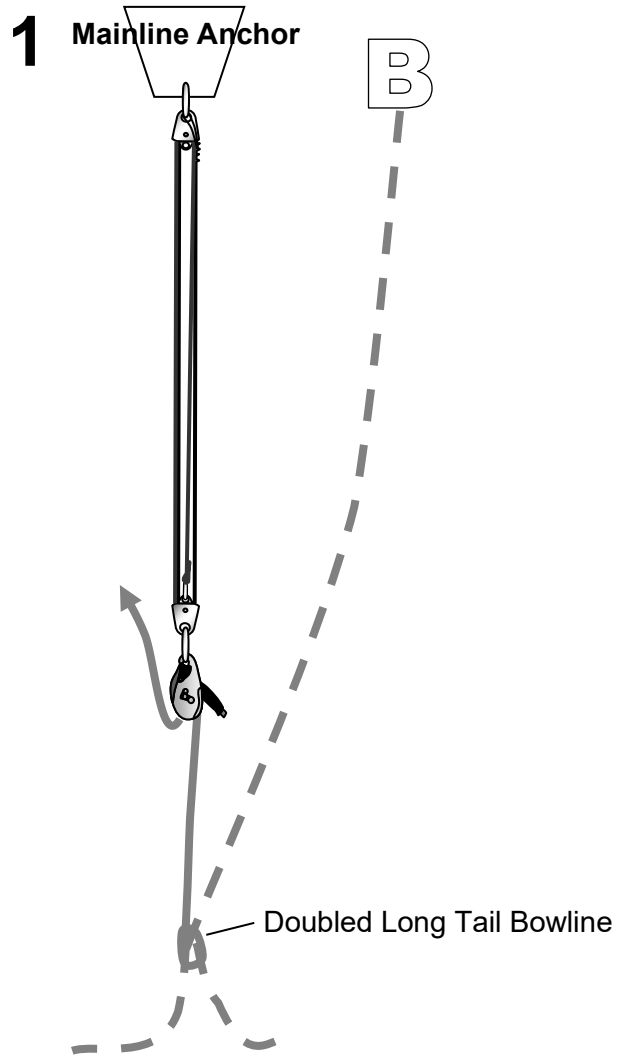
Step 4 – The rescuer ties off the MA/victim's primary attachment, connects the victim's belay, detaches the victim's rappel line and descends to safety.

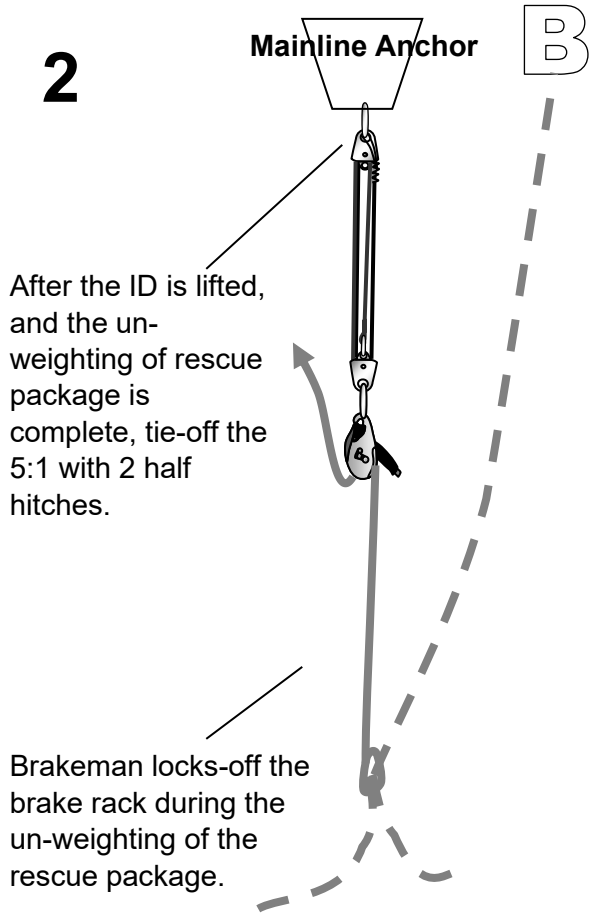
Belay Line Connections

Belay line is attached to the rescuer by employing a bowline with a four foot tail to the chest "D" ring of the rescuer's class III harness. The long tail of the bowline is used to tie the end of the belay line to the victim. A bowline is the perfect knot for the rescuer's attachment point because it facilitates the adjustment of the slack between the two parties without disconnecting it from the rescuer.

Team-based Mid-wall Pickoffs, *Hanging Victim*

Utilizes a Mini 5:1 and a Petzl ID





Mainline and Belay line Operations

Step 1 – Rig the Petzl ID to an extended mini 5:1 which is rigged to the mainline anchor.

Step 2 – Rig a system belay.

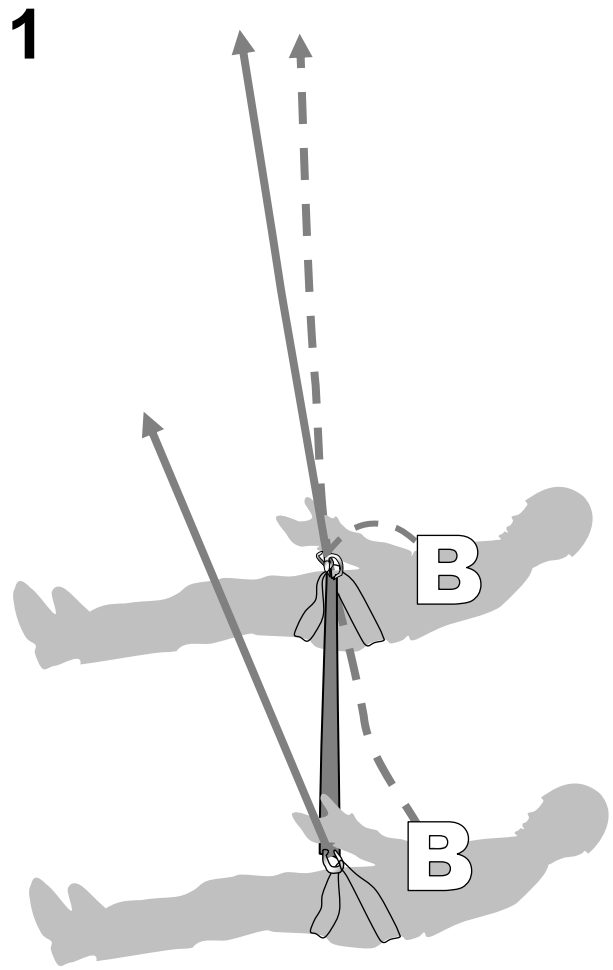
Step 3 – Rig a Doubled Long Tail Bowline to the rescue end of the mainline and belay line, and connect the rescuer's harness waist "D" ring to the Doubled Long Tail Bowline. Tie one of the long tails of the bowline a second point of attachment on the rescuer's harness.

Step 4 – After the rescuer has reached the victim, and the victim connections have been made, the victim's rappel line must be un-weighted by hauling the locked off ID using the 5:1.

Step 5 – Once the victim's rappel line is un-weighted, tie-off the 5:1 with two half-hitches and resume the lowering with the ID.

Team-based Mid-wall Pickoffs, *Hanging Victim*

Rescuer Considerations

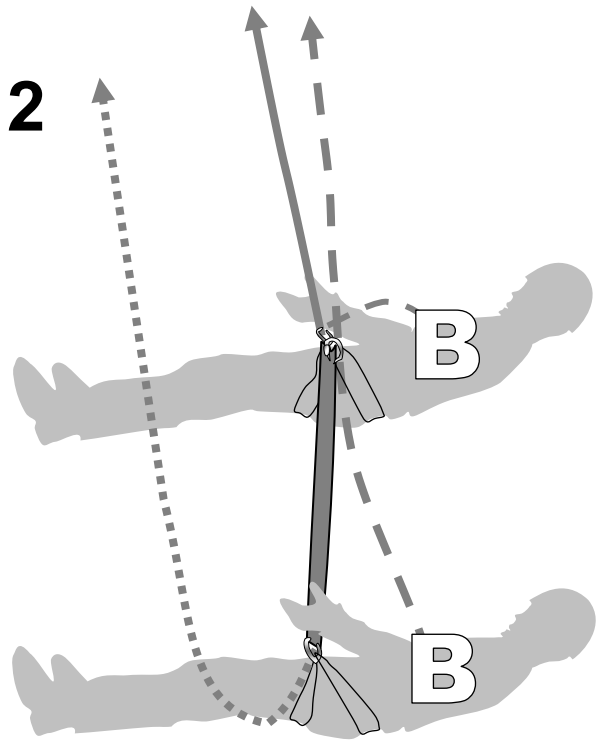


Rescuer Considerations

Step 1 – Once the rescuer has been lowered to a position even with, or slightly above the victim call for a “Stop”.

Step 2 – Make a connection between the Doubled Long Tail Bowline and the Victim using a pick-off strap or short webbing loop.

Another good option for the victim’s primary connection can be accomplished by using a short purcell which is prusiked onto the mainline just above the Doubled Long Tail Bowline. Tension this primary victim connection as much as possible before the command to haul.



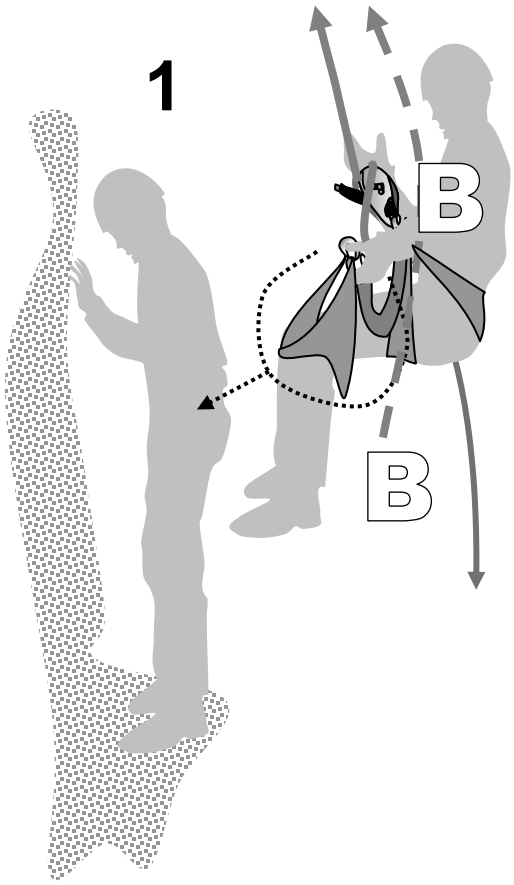
Step 3 – Tie the remaining long tail of the bowline to a second point on the victim’s harness.

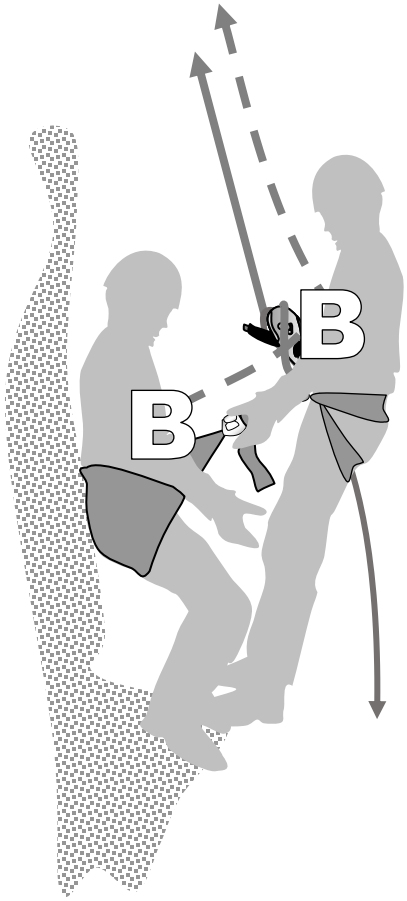
Step 4 – Once these victim connections are complete call for an “Up Rope”.

Step 5 – The top team will haul the mainline now supporting rescuer and the victim by using the pre-rigged 5:1. Once the victim’s rappel line/fall arrest system becomes slack, the rescuer will call for “Stop”, and then “Down Rope”.

Suggestion *– Attach all the victim connections and rescue adjuncts to the Mainline prior to the start of the operation. This will facilitate a faster and safer pick-off for the rescuer and victim.*

Solo Mid-wall Pickoffs, Clinging Victim





Rescuer's Considerations

Step 1 – Rescuer pre-rigs the victim's harness and pick-off strap.

Step 2 – Rescuer stops approximately eye level to the victim, ties off the descent device, pre-rigged for maximum friction, applies the victim's harness to the victim and connects the end of the belay line to the victim, either by tying the belay rope directly to the victim's harness or clipping it onto the victim's harness via a screw-link (avoid using carabiners for the belay connection).

Step 3 – Once the victim's connections are made, take up as much slack as possible in the pick-off strap then tie-off the pick-off strap using an Overhand Stopper.

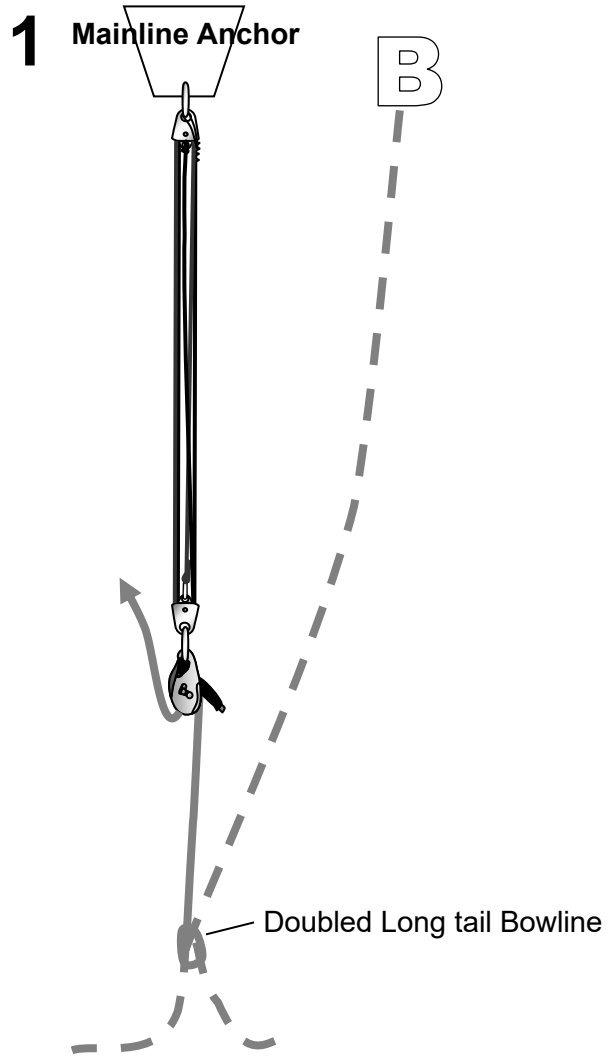
Step 4 – Have the victim gently weight his/her connection by totally sitting in the victim's harness. Once the victim is completely on the rescuer's system, the rescuer may then unlock the ID, and rappel to safety.

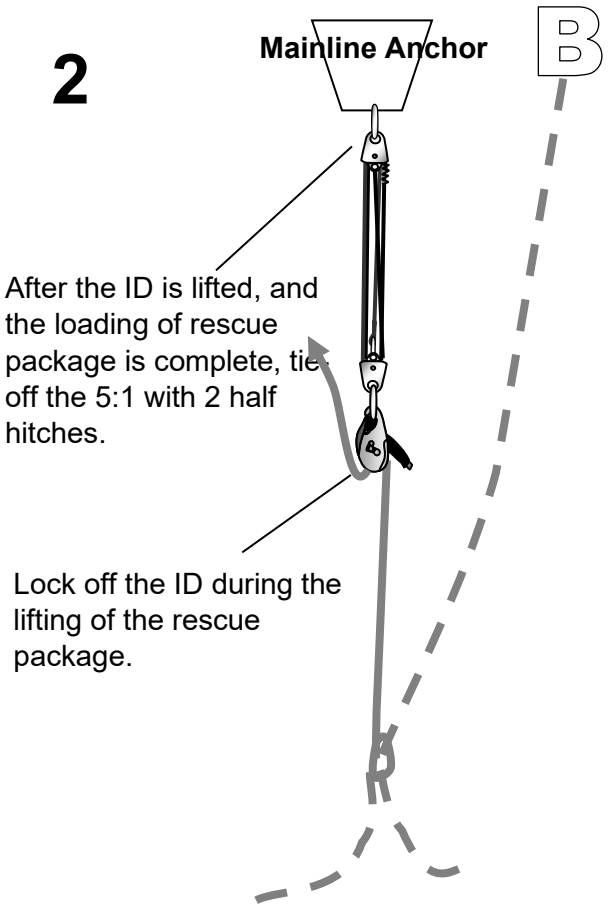
Belay Line Connections

Belay line is attached to the rescuer by employing a bowline with a four foot tail to the chest "D" ring of the rescuer's class III harness. The long tail of the bowline is used to tie the end of the belay line to the victim. As stated before, the bowline is the perfect knot for the rescuer's attachment point because it facilitates the adjustment of the slack between the two parties without disconnecting it from the rescuer.

Team-based Mid-wall Pickoffs, Clinging Victim

Utilizes a Mini 5:1 and a Petzl ID





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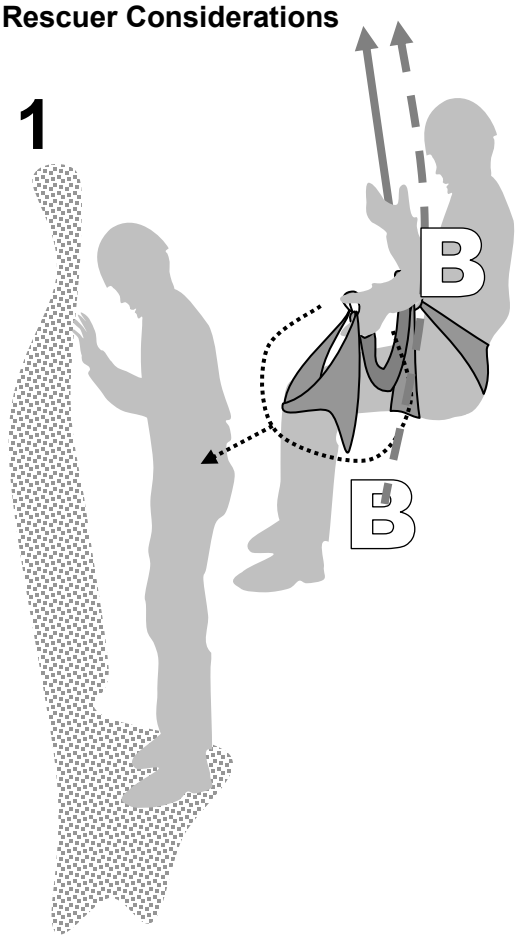
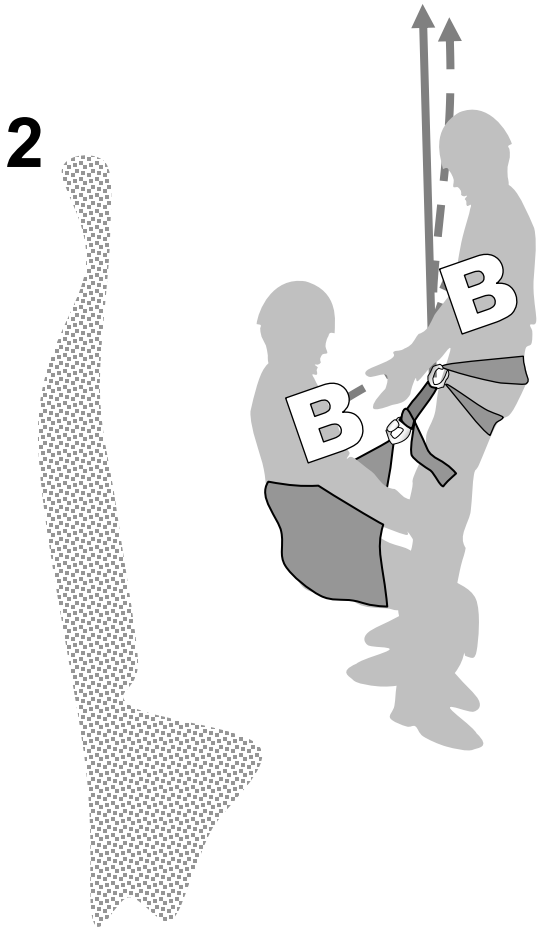
Step 4 – After the rescuer has reached the victim, and the victim's connections have been made, the victim and rescuer may have to be lifted off the victim's perch by hauling the locked off ID using the fixed 5:1.

Step 5 – Once the victim and rescuer is lifted from the victim's perch, tie-off the 5:1 with two half-hitches, and resume the lowering with the ID.

Team-based Mid-wall Pickoffs, Clinging Victim

Rescuer Considerations





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Step 2 – Apply the victim’s harness. Make a connection between the Doubled Long Tail Bowline and the Victim using a pick-off strap or short webbing loop.

Another good option for the victim’s primary connection can be accomplished by using a short purcell which is prusiked onto the mainline just above the Doubled Long Tail Bowline. Tension this primary victim connection as much as possible before the command to haul.

Step 3 – Tie the remaining long tail of the bowline to a second point on the victim’s harness (remember, one of the two long tails of the Double Long Tail Bowline is attached to the rescuer).

Step 4 – Once these victim connections are complete call for an “Up Rope”.

Step 5 – The top team will haul the mainline (now supporting rescuer and the victim) by using the pre-rigged 5:1. Once the victim and rescuer are lifted from the victim’s perch, the rescuer will call for “Stop”, and then “Down Rope”.

Suggestion *– Attach all the victim connections and rescue adjuncts to the Mainline prior to the start of the operation. This will facilitate a faster and safer pick-off for the rescuer and victim.*

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System Design Considerations:

Fall Line

As simple as this may sound, it is possibly one of the most over looked conditions during the early setup of a rope rescue system. This singular factor sets the stage for everything from anchor selection in the rear of the rescue arena to high directional anchors at the edge, to placement of horizontal systems on an opposing side.

Anchor Considerations

Anchors selection is highly dependent on establishing the fall line, however, nothing is written in stone. Many time we can fudge on the fall line to accommodate a more lucrative anchor, as opposed to the creation of some very elaborate and time consuming anchor system work of art.

Recon/Early Patient Contact

If there is a common theme to this course, early patient contact is probably right up there with the most important. This task requires not only quick recon anchor selection, but also a selection that is going to enhance, or at the least stay out of the way of the future main and belay line operations.

Whoever command sends over the edge for recon/patient contact needs to be pretty squared away with their vertical mobility skills. In addition, this person must possess the appropriate medical skills to make EMS judgment calls over the edge.

Most times command will have enough preliminary information to initiate pre-anchor selection and construction for the mainline, and belay line operations while the recon phase is in progress. A well-oiled rescue team with sound leadership will know how to multitask and avoid stepping on each other's toes.

Mainline Construction

After the establishment of anchors and possibly a report from recon, command will need to determine the direction of travel for the victim. They're either going to go to the ground, or they're coming back up to the original edge.

- Down Systems
  Down systems are typically easier and safer due to the fact that friction is working with us. In addition, many times, the need for a high directional is

diminished as long as edge management is properly addressed. A down system can typically operate from a smaller work platform, i.e. a structural tower.

- Up Systems
  Up systems require some form of a hauling component. This usually means that command must plan for the proper size pulley system based on the available manpower (haul team).

  Another critical aspect of designing the haul system is the size of the haul field; is it a large parking lot with tons of running room, or is it a factory catwalk that might require multiple changes in the direction of pull. Equally important, the edge must be made as efficient as possible by using a high directional anchor, or at the least, a low directional edge roller.

Belay Line Construction

The belay line is the most important consideration of any rope rescue. We typically will always look for a belay anchor the s bombproof. Try to keep the belay rope in close proximity to the mainline; in the event of a mainline failure this will help avoid wild and out-of-control pendulums as the belay is catching the load. Many times a simple re-direct anchor will assist in keeping the belay in line.

Offsets/Horizontal Systems

Sometimes when matching the fall line with the system is difficult some form of a horizontal influence may be needed. This can range from a simple tagline to extremely complex multi-bundled, reeving highlines. Keep in mind, the more complex the horizontal adjunct rigging is, the longer the rescue is going to take. Rope rescue is a game of safe and efficient speed. System design is about rigging what is needed to accomplish this goal…nothing more.

Edge Management/High Directional Anchors

When we address the topic of edge management, we are really talking about overcoming the effects of friction. Friction contributes to heat buildup, and abrasion to rope and webbing; this is especially dangerous if the rope is stationary (rappel rope) versus a rope that is moving over an edge.

During down operations consider some form of padding or cover for edge protection…remember, the added friction is working with us while going down.

Coming up is another story altogether, edge friction is a major enemy now. The effects of unmanaged friction during a hauling operation can and will increase our true load by as much as three times! In the event of this scenario, we must have an efficient edge;

which means, at the best, the Vortex (or something similar), or at the least, an edge roller.

Critical angles

The ability to fully understand and immediately visualize the effects of angles during a rigging event takes much practice and experience. However, there are a couple of simple tips for new rope technicians that have not had the luxury of time.
1) Avoid real tight angles that run through a pulley; tight angles, 0 to 60 degrees are very dependent on the strength of the connecting anchor.

2) Avoid wide angles between two anchors; the wider the angle the greater the hit on each side when the load is vectoring in the middle. This constitutes an advance form of highline rigging that requires shock force mitigation, and a full understanding vector force analysis.

Appendix A: The TerrAdaptor – Parts and Assembly [1]

The TerrAdaptor System

Multiple configurations of the TerrAdaptor Portable Anchor System can be built from various standard system components. The primary system revolves around the TerrAdaptor Tripod System (Part number NFPA230100). This system includes all of the necessary parts to assemble a standard symmetric tripod that provides the ability to reach a height of approximately10-feet. The system comes packaged in three compact packable bags to make it easy to "grab your bags and go" as well as store the System together in an organized manner. The individual component pieces included in the TerrAdaptor Tripod System are listed in Section 4 of the user's manual.

To transition your Tripod to a Quadpod System, you can purchase the TerrAdaptor Quadpod Attachment Kit (Part Number 230105). This kit provides the fourth leg and attachment pieces necessary to transition your tripod into a quadpod. The individual component pieces included in the TerrAdaptor Quadpod are listed in Section 4 of the user's manual.

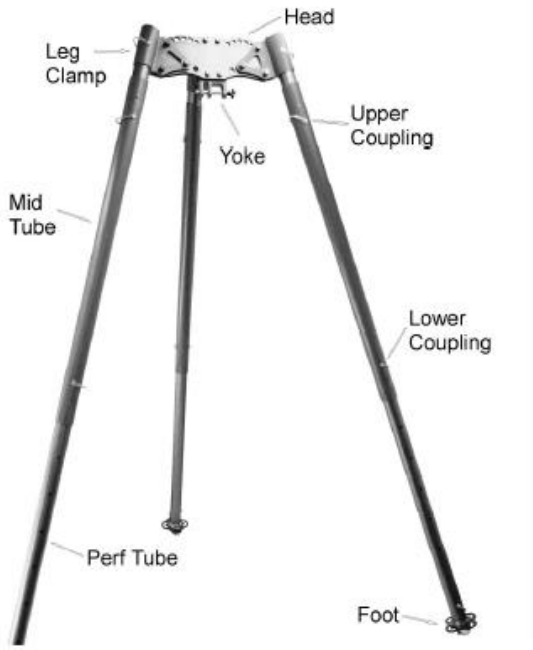
If your needs are fairly simple and a single gin pole is the best solution for your situation, you can purchase the TerrAdaptor Gin Pole Kit (Part number 230106). This kit includes a full leg kit to reach approximately 10 feet in height adjustability. The individual component pieces for this kit are listed in Section 4 of the user's manual.

For those who typically encounter environments that require more than 10 feet of height, additional leg extension pieces (appropriately 4 feet in length) can be individually purchased for this use. This piece can also be used to provide one extra long leg if a tall "lazy leg" configuration is desired. Other replacement parts and options are available for the TerrAdaptor system and are listed in Section 4 of the user's manual.

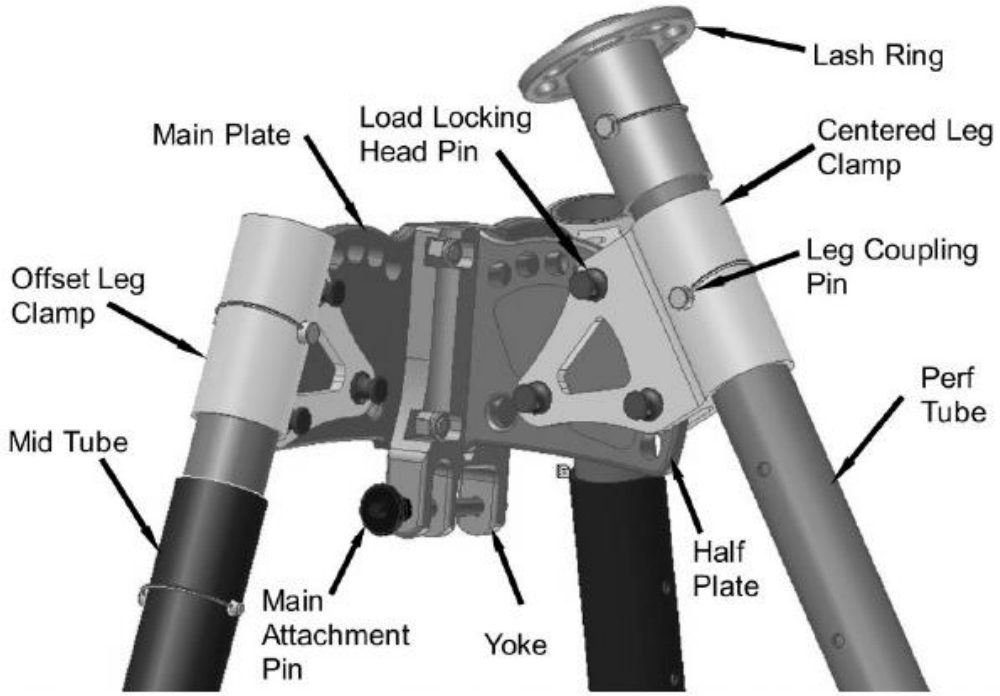
[1] The content of Appendix A is taken directly from the TerrAdaptor User Manual and is intended solely for the in-house use of Kary Environmental employees.

Major component Overview

The images below are an overview of a tripod set-up.



An overview of the head section along with the correct names of each component is presented below. Please refer to this image while learning how to assemble the TerrAdaptor as outline in Section 2.



Testing Applied to the TerrAdaptor

The TerrAdaptor system has been tested extensively in both lab and field environments. As a result, the TerrAdaptor Portable Anchor system in the standard symmetric tripod and quadpod configurations are the only systems of their kind to be certified by UL to NFPA 1983 (2006 ed.) Other useful configurations were also tested and have been included in this manual (Section 3) for reference purposes. Each rescue situation is unique and the ultimate safety of the TerrAdaptor system rests in the knowledge and training of those setting up the system.

Warnings

Technical work and rescue, mountaineering and other rope assess activities are inherently dangerous. Any person or team using a portable anchor system must obtain qualified instruction prior to using such equipment in any manner. If you are not extremely versed in the understanding of resultant forces, high directional concepts and other basic issues regarding portable anchor systems theory, you are not qualified to use this device until adequately trained. Any person or team using the TerrAdaptor Portable Anchor System is responsible for their own decisions and actions. Failure to heed this warning can cause serious Injury or Death.

Breaking Strengths listed in the configuration section are the maximum load sustained prior to system collapse. During testing, the typical system failure mode was the failure to sustain a load. This was due primarily to flexing and yielding of components, rather than the components themselves fracturing and releasing the load, as is typical in other rescue systems. Bent or warped components are the symptom of a system that has been overloaded. Continuing to use bent or warped components will unpredictably alter the system strength, possibly resulting in injury or death. If bent or distorted components of any kind are discovered, immediately discontinue use of the TerrAdaptor system until components are replaced, a safety analysis of the system has been performed, and corrective action implemented. Hardware item such as nuts, bolts, pins, etc, are specified by the manufacturer for strength and other characteristics which make them suitable for use in the TerrAdaptor system. Substituting with commonly available hardware store items may result in injury or death.

As mentioned above, the breaking strengths presented represent the load prior to system collapse, not the working load of the system. The user is responsible for determining the proper working load required given the specific situation and the safety margins required to provide a safe environment for the circumstance.

Assembly instructions

The TerrAdaptor is the most versatile and configurable portable anchor system on the market. This section will provide detailed information about each component in the system and how these components are assembled with one another. See Section 3 for instructions on setting up various configurations.

Leg Tube Connections

The height of the TerrAdaptor is easily adjusted by means of telescoping leg sections. Adjustment holes in small diameter leg sections (referred to as **Perf Tubes**) are labeled 1 through 9 and adjustment holes for the larger diameter mid section tubes (**Mid Tubes**) are labeled X and Y (fig1). Configuration charts assume legs are oriented with 1 at the bottom and 9 at top. A setting of X7 would indicate that the pin is to be used at the mid tube X hole and go through hole 7 on the perf tube. (Please note that the 7 will be covered up by the mid tube in this process).

Fig 1 Leg Markings

Leg connections and connections to various accessories are made by sliding the small diameter perf tube into the large diameter mid tube or other components and securing the connection with a **Leg Coupling Pin**. Leg coupling pins provide a secure connection when the pin is fully inserted and the bail is properly secured (fig 2).

Fig 2 Properly Secured Leg Coupling Pin

Fig 3 Improperly Secured Leg Coupling Pin

Height Adjustability – Leg Assembly Configurations

The TerrAdaptor can be used with as few as one leg section and is extendable up to a total of 4 sections per leg. The shortest leg configuration consists of just one perf tube attached to the head. Longer legs are assembled by alternating mid and perf tubes to reach the desired height as follows:

1. The perf tube is the initial starting point (this tube section will always be used to attach to the head)
2. Position and connect any lash rings where they might be needed
3. Orient and attach leg clamps, either offset or centered
4. Attach a mid tube as close to the leg clamp as possible. This connection is referred to as the **Upper Leg Coupling** in configuration charts
5. A second perf tube can be added by connecting it to the bottom of the mid tube at whatever setting achieves your desired leg length. This

connection is referred to as the **Lower Leg Coupling** in configuration charts

6. For maximum length legs, an optional mid tube section (the 4th section) can be connected to the bottom of the perf tube. This connection is referred to as the **Optional Leg Coupling** in configuration charts
7. Any variety of foot options can be attached to the last leg section
8. No additional sections can be attached beyond the four mentioned above

Best Practice:
When raising the height of a tripod, fully extend the lower leg section before extending the upper leg section. The legs are strongest when the most amount of tube overlap is near the head section. All configurations used should follow this practice.

Care & Maintenance:
File small dents and burrs from surface of leg sections. Clean parts with a water rinse and wipe dry. Clean parts last longer and assemble easier.

Legs can be bent under severe loading. Retire leg sections that won't fully slide into or over another leg section. Due to the potential causes of bent legs, they are not automatically replaceable. See the warranty section to determine the process of replacing bent legs.

Leg coupling pins (Part number 230301) should be replaced when worn or bent.

Warnings:

- Do not tie into the leg coupling pin bail for any reason and avoid snagging with ropes and other rigging
- **Do not** substitute leg coupling pins (or other hardware) with "like-kind" from your local hardware store as they may not meet the necessary strength requirements. Replacement leg coupling pins can be purchased from your dealer.

Head Angle Adjustments

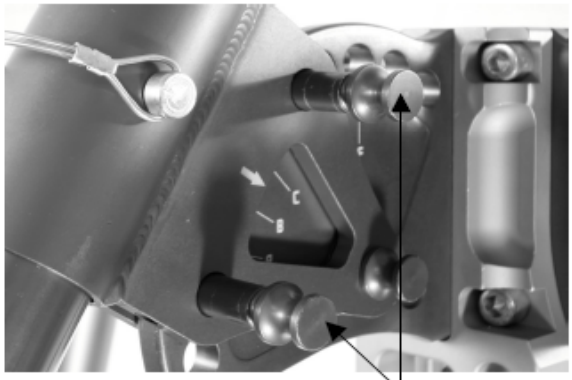


Fig 4 Load Locking Head Pins (Parked position)

Entirely unique to the TerrAdaptor is the ability to adjust the head angle in multiple directions. This allows the head to remain level even when the terrain is not. A level head means that rigging attached is clean, safe, and organized.

The main head and the half plate each have 10 oval shaped holes on the outside curve which serve as adjustment holes. The inner 6 holes are marked A through F for angle reference purposes. Head angle adjustments are achieved by pivoting leg clamps to desired angles A through F and locking in place by using three **Load Locking Head Pins**.

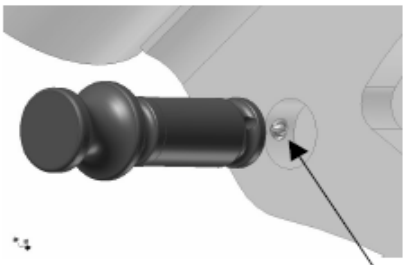


Fig 5 Detent Pin used to "lock" the Load Locking Pin in place. Insert this way

The Load locking head pins are designed to "lock" in place with the inclusion of a detent pin (fig 5) inserted into the leg clamp. Please note that the detent pin is only included on one side of each of the leg clamp assembly. The load locking pin must be inserted from the side which includes the detent pin. The load locking head pin can be locked in either the "parked" position as shown in figure 4 or the fully inserted position as shown in figure 6.

As the load locking head pins are designed to resist movement under loads, the head must be unloaded to adjust the leg angle. To adjust the angle, pull the two outer pins to the parked position, leaving the inner pin for the leg to pivot on (as configured in fig 4). Adjust to the desired or recommended angle and return the 2 parked pins to their fully installed positions (fig 6). Cotter pins are supplied for the load locking head pin if additional security is desired or if the pins could be subjected to inadvertent force which may push them out of position.

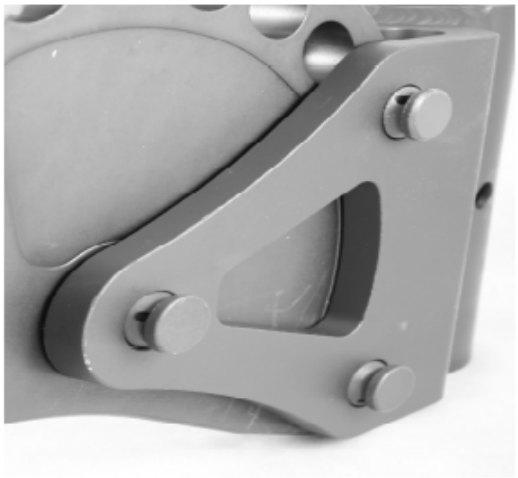


Fig 6 Fully inserted pins properly protruding from leg clamp

Best Practice:
Head angle adjustments are easiest to make when the TerrAdaptor is unloaded and laying flat on ground prior to final installation. Use Configuration Tables in section 3 for recommended angles.

Care & Maintenance:
Clean parts with water rinse and wipe dry. Clean parts last longer and adjust easier.

Check for excessive wear on the load locking head pin as indicated by wearing through of the hardcoat anodizing. Load locking head pins can be re-ordered as replacement parts (Part number 230260) when worn or lost.

Warnings:
- Do not use the device if the load locking head pins cannot be fully inserted. This may be an indication that the device is not properly configured or excessive loads have caused some distortion beyond safe use
- Check configuration tables for proper and safe angles (see section 3)
- Retire load locking head pins when wear through of the hardcoat anodizing is evident

Leg Clamps

Leg Clamps are the means of attaching leg sections to the main head of the TerrAdaptor. Two types of clamps, **Centered** and **Offset**, are used in the tripod configuration.

Although the different style leg clamps are safe to use in any position, the centered clamp is most commonly used on the rear leg (fig 8), while the offset clamps are used in the side legs. For the typical tripod setup the offset clamps

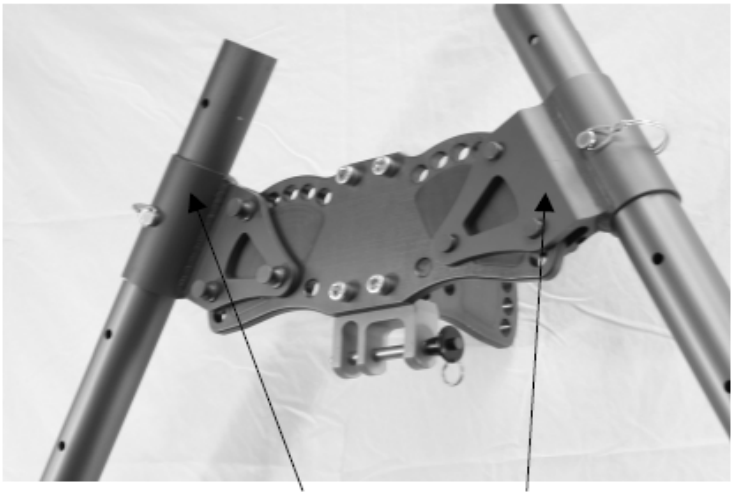


Fig 7 Offset Leg Clamps (left-facing forward; right-facing backwards) for illustrative purposes. Best practices has both offset leg clamps facing forward in a typical tripod configuration set up

Fig 8 Rear leg with centered leg clamp. Legs are able to by-pass each other due to offset leg clamp orientation

are oriented with the offset leg tubes facing forward (away from the rear leg) providing the most stable and symmetric configuration.

In some setups, for space or rigging considerations, it may be desirable for both side legs to extend through the head. In this case, set one side leg clamp facing forward and the other backwards so that leg tubes may bypass each other without interference (fig 8). This alternating forward and backward leg clamp arrangement is also ideal for rigging sideways A-Frames with greater stability and a greater working area under the head.

The perf leg tubes slide through the leg clamps and are secured in position by using the leg coupling pin. Leg clamps are attached to the head by means of 3 load locking head pins as shown in figure 6.

Best Practice:
Use centered leg clamp on the rear leg and set both offset leg clamps facing forward when configuring as a standard tripod.

For symmetric or edge-A tripods use centered leg clamp on the rear leg and set both offset leg clamps facing forward on the side legs.

For sideways A-frames use alternating forward and backward facing leg clamps.

Care & Maintenance:
Clean parts with water rinse and wipe dry. Clean parts last longer and assemble easier. Check for excessive wear of load locking head pin.

Check leg clamps for warping. If leg clamps have been warped, the entire system may be at risk. Refer to warranty section for information on replacing the leg clamps.

Warnings:

- Do not use device if any of the load locking head pins cannot be fully inserted
- Check configurations tables for proper and safe angles to be used
- Retire pins when worn or bent
- Do not use the system if leg clamps are warped or damaged such that they do not move freely with mating parts

Feet

The TerrAdaptor comes standard with aluminum half round **Ball Feet** that are suitable for most leg angles and surfaces from hardpack dirt to most industrial surfaces. Wide leg angles and slick surfaces are a dangerous combination and in this situation the standard ball foot can be rotated so that its hardened steel spike will bite into the surface (fig 9).

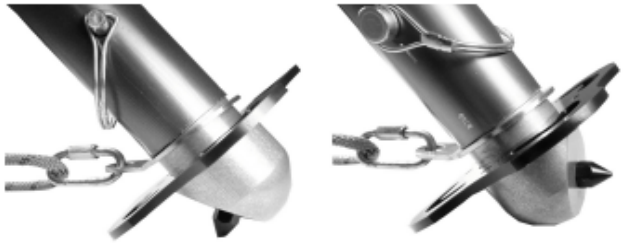


Fig 9 Ball Foot with hobble ring, basket and quick link (left –spike rotated into ground, right – round surface on ground)

The standard ball feet are designed to accept a ring for attaching leg hobbles and **Baskets** whose large surfaces resist penetration of the legs into snow, sand, mud and other soft surfaces.

The optional **Articulating Foot Assembly** (Part number 230400) is available for the TerrAdaptor. Articulating feet swivel on a stainless ball and have a rubber pad for use on hard surfaces such as concrete or other flooring surfaces. Additionally, there are holes for attaching the foot by means of screws, bolts, or driven spikes. Three large holes are also available for clipping and lashing the foot to other objects. For extreme wide leg angles or other special circumstances the articulating foot can rotate 90 degrees to the flat position.

Fig 10 Articulating Foot with Hobble Plate and Quick link

All feet are easily attached to either the large or small diameter leg tubes by means of a leg coupling pin. Generous clearances between the feet and leg tubes allow mud, rocks and debris to not interfere with foot attachment.

Best Practice:
Select the feet option (use of ball foot, spike or optional articulating foot) and feet position before setting up tripod. Feet are not easily exchanged when the TerrAdaptor is loaded or hobble is tight.

Care & Maintenance:
Standard ball foot, articulating foot, hobble plate and quick link can be cleaned with a water rinse and simple wipe dry.

On all types of feet, check for bent or loose components before use. Ball foot replacement kits are available (Part number 230217) when retirement is needed.

If the spike becomes dull and rounded from use, the point can be lightly filed with a common file until sharpened.

Warnings:
- Using the TerrAdaptor without feet is not advisable. Contact of leg ends on hard surfaces will permanently damage the legs
- Carabiners clipped into articulating feet should be properly positioned to avoid cross or side loading of the carabiners
- Do not clip into the basket

Leg Hobble

Leg Hobbles are an important structural element for the TerrAdaptor. It is important to understand that the ultimate strength of any configuration depends on the ability to secure the feet against movement by either hobbling the legs together or direct attachment of the feet (or legs) through bolts, lashing, or other means of eliminating the possibility of movement of the legs.

Fig 11 Rope Hobble attachment by Quick Link

The **Rope Hobble** provided with each TerrAdaptor is light, versatile, and much easier to use than a standard chain hobble. The rope and prussic cord used in the hobble is specially designed for low stretch and high strength. (If chain is used, the chain is attached to the hobble plate in a similar manner as the rope hobble (fig 11)).

After positioning and adjusting other elements of the TerrAdaptor, attach the rope hobble with a quick link on each rotating **Hobble Ring**. When attaching the rope hobble, clip the small sewn loop into the quick link on one foot. Slip the prussic to create a large loop of rope as seen in figure 12 and attach this loop to the quick link at the foot of the second leg. Grasp prussic and pull

Fig 12 Rope Hobble Loop with Prussic. Sewn loop connected to quick link; large loop connected to 2nd leg quick link.

on tail of rope to take most of the slack out of loop. Repeat this with all three of the rope hobbles and fully close the quick links. To do final adjustments, tighten the rope hobble, one at a time, until each leg flexes in slightly, or in the case of an NFPA configuration, until the correct hobble length is reached. Tables included in Section 3 of this manual include the ideal hobble adjustment for the various configurations.

Best Practice:
Adjust the head angle, leg length and leg heights before the hobble is attached and tightened. Even a lightly tightened hobble can make other adjustments difficult to accomplish.

Care & Maintenance:
Check the rope hobble for cuts and worn areas and replace as necessary (Part number 230307).

Check the prussics for proper operation.

Make sure quick links are able to close completely and are free from burrs and sharp edges that may harm rope. File or sand if needed.

Check lashing holes in articulating feet for sharp edges or burrs and file or sand to remove as needed.

Warnings:
- Do not use the TerrAdaptor without feet hobbled, lashed or somehow secured into position
- Rope hobbles may deteriorate with prolonged exposure to the elements
- Sharp edges may cut ropes and webbing. Do not tie directly into holes and quick links which have sharp edges
- Use chain rather than rope when hobbling in an environment where chemicals are present that may damage or harm the rope

Main attachment point

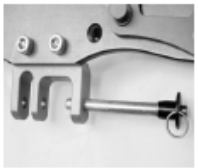


Fig 13 Main Attachment Yoke

The main load bearing attachment point on the TerrAdaptor is a two position yoke located at the bottom of the main head. Items are attached to the head with the use of the **Main Attachment Pin**, which is a quick release ball lock pin (fig 13). Insert the main attachment pin into the yoke while holding the release button in. Once the main attachment pin is in place, the release button will "pop" back out (fig 15) and the ball lock detent pins will engage and prevent the pin from being pulled back through the yoke.

Figure 14

- The narrow portion of the yoke is designed for an auxiliary sheave but is also suitable for a rescue carabiner or other gear (fig 14).

- The wide portion of the yoke is designed for bulky gear

such as swivels or multi-sheave pulleys, but again, is suitable for all types of rescue gear. The wide yoke is also preferred for use with pulleys when shifting loads may side load a pulley restricted by the narrow yoke (fig 14).

Best Practice:
When changing out gear there is no need to fully remove the main attachment pin from the yoke as it can be temporarily parked in the last attachment hole. This facilitates the ease of using both hands to maneuver the gear into the yoke and then sliding the pin back through the entire yoke area.

Fig 15 Release Button

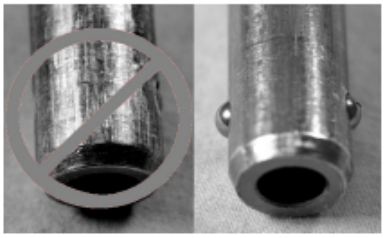


Fig 16 Left pin – retired due to wear and detent pins not properly working; Right pin – in good working condition

Care & Maintenance:
Clean parts with water rinse and wipe dry. Clean parts last longer and assemble easier.

Check that release button moves freely (fig 15) and that locking detent pins move in and out with release button (fig 16).

Check proper pin engagement in yoke by attempting to pull the main attachment pin out of the yoke without depressing the release button; if removable without depressing button, **do not use** and retire pin immediately (Part number 230311)

Check that pin is not bent or dented by installing pin into yoke; it should move freely in and out when release button is depressed.

Warnings:
- Do not run a moving rope directly over the main attachment pin. This may cause excessive wear on the pin and/or cause the pin to roll and potentially cause wear damage in the yoke attachment holes
- Retire main attachment pin if button or ball detents do not return to "popped" out position once released
- Do not use load attachment pin that is bent or does not function properly

Auxiliary Attachment Points

There are three **Auxiliary Attachment Points** on a tripod head that are suitable for clipping carabiners and other rigging gear into (fig 17). Do not clip into the head angle adjustment holes as these are not designed as load bearing connection points.

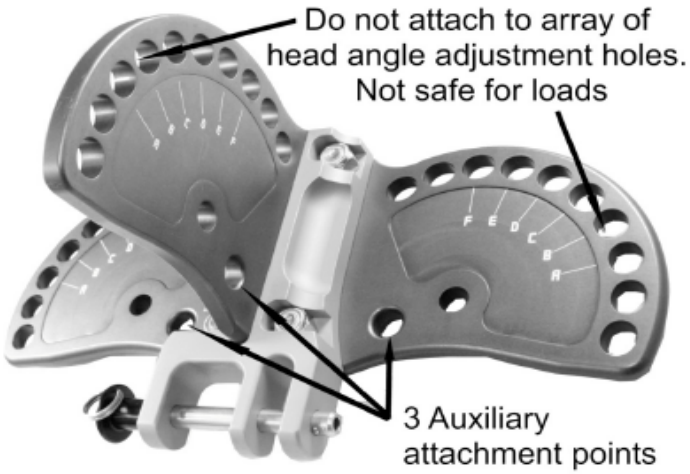


Fig 17 Head Auxiliary attachment points

Care & Maintenance:
Clean parts with water rinse and wipe dry. Clean parts last longer and assemble easier.

Warnings:
- Do not clip into head angle adjustment holes

Head Assembly – Tripod, Quadpod, A-Frame/Bi-Pod

The TerrAdaptor Tripod head consists of a **Main Plate** with a single attached **Half Plate**. A Quadpod head consists of a main plate with two half plates. Half plates can remain attached to the main plate even if they are not used in the configuration.

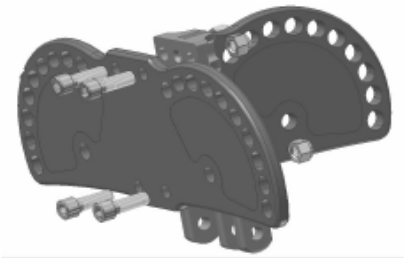


Fig 18 Half Plate attachment to Main Plate

Half plates are attached to the main plate with the **Yoke** facing down. Attach the half plate to the main plate with 4 socket head bolts (1-1/4" long for tripod configuration and 1-3/4" long for a quadpod configuration). To remove half plates, loosen and remove all 4 bolts, then separate half plates from main plate.

To attach half plates, clean all parts (including nuts and bolts) then select bolts (long for quadpod or short for tripod) and insert all 4 bolts and hand tighten into nylon locking nuts. Then tighten all 4 bolts to 450 in/lbs and check that assembly is tightly mated and that the bolt protrudes beyond flush on all four bolts.

Fig 19 Bolt protrudes just beyond flush

Best Practice:
Leaving the half plate on while using as an A-Frame allows for quicker setup times and more available lash and load points.

Care & Maintenance:
Check attachment holes for sharp edges and burrs. File or sand to remove sharp edges.

Check main and half plates for bends and/or warping. This could indicate over loading of the head. See the warranty section for the replacement policy on these component parts.

Check to make sure all 4 bolts are tight before each use. Any small gap between the head plates and half plates may cause significant instability when the system is loaded.

Fig 20 Do not remove these screws

Warnings:

- The three screws attaching the half plate to yoke plate as shown in figure 20 are not user serviceable. **Do not remove**
- Do not lash or attach other gear to the array of holes intended for the load locking head pins. Damage in this area will disrupt normal adjustment of head angle (fig 17)
- **Do not** substitute nuts or bolts (or other hardware) with "like-kind" from your local hardware store as they may not meet the necessary strength requirements. Replacement bolt kits can be purchased from your dealer (Part number 230326)

Lash Ring

The TerrAdaptor **Lash Ring** is designed to provide multiple attach points for stabilizing the tripod. Each TerrAdaptor tripod comes with 2 lash rings and additional accessory lash rings are available for purchase, if desired. Lash rings can be installed in any position, in any quantity and in any orientation along the perf tubes (small diameter leg). For lighter loads, especially in a MonoPod configuration, the lash ring may serve as an auxiliary main attachment point.

Fig 21 Lash ring on tripod

Best Practice:
When a tieback could be subjected to a load over 5,000 lbs (22 kN), consider clipping directly into the stronger holes on the head plate rather than the lash

Care & Maintenance:
Check for bending and warping which could indicate overloading.

Because the lash ring is both tied into and clipped into, pay careful attention to sharp edges or burrs that may have developed. Lightly file or sand off burrs before use. Additional lash rings may be purchased (Part number 230230)

Fig 22 Lash Ring used near foot section for increased stability

Fig 23 Lash Ring atop of gin pole as main attachment

Warning:
- Carabiners clipped into lash rings should be positioned to avoid cross or side loading.

Final Assembly – How to put it all together

The fastest and safest way to set up any configuration of the TerrAdaptor system is to start with it lying on the ground, if possible. **Each situation is different and users are responsible for ensuring their own safety while erecting and using this product.** Erecting a typical Tripod configuration can be done by laying it out on the ground as follows:

1. First set all legs to target height
2. Attach leg clamps and feet to the legs
3. Attach front legs to the main plate, setting leg angles at this time
4. Still leaving the TerrAdaptor flat on the ground, attach the rear leg to the half plate pivot point, and lock in angle, if desired
5. Rig safety ropes, lines or webbing; also installing rigging in the yoke at this time may be desirable especially when the yoke may be out of reach once tripod is standing
6. Raise the TerrAdaptor upright by lifting front legs and tilting towards the rear leg
7. Recheck all connections before continuing to rig tripod
8. Carefully and with all necessary safety measures, move unit into position before attaching hobbles or securing feet

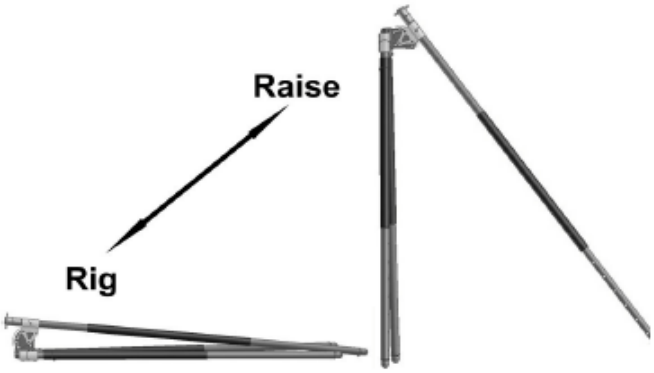


Fig 24 Final Assembly Steps

Configurations and Set-up Tables

Standard Configurations

The TerrAdaptor is both very modular and highly adjustable, lending itself to an almost unimaginable number of configurations. We have identified and tested a core group of configurations that we feel addresses a broad range of rope rescue applications. By providing this information we hope that users will find configurations that fit their needs as well as provide a basis for developing new configurations. **As with any piece of rope rescue gear, the user is ultimately responsible for ensuring that it meets their safety and performance requirements.**

The following section outlines the core group of configurations and provides the TerrAdaptor settings used to achieve the configurations. Each table includes the required setting for head angles, leg height adjustment references, and hobble lengths to achieve various heights. The table also identifies the manufacturers tested breaking strength of the system at the acquired height.

The height indicated on the table is the height from the ground to the main attachment point and is expressed in feet. If there is "N/A" in the leg section, then the third or fourth leg is not needed to achieve the designated height. For example, to achieve the 5-foot height, only the first two legs are needed and they are joined at Y4. If a 7-foot height were desired three tubes would be required.

Also note that the main plate head angle settings are expressed with 2 listings for both the left and right hand side of the head. In all of the examples listed below, the angles are the same on both sides of the head, but this may not always be the case in the field.

I. Symmetric Tripod (includes NFPA configuration)

Symmetric Tripods are typically used for straight vertical access such as above manholes or access hatches. When straddling a manhole or access hatch, a symmetric tripod's feet are equal distance from the center of the manhole or hatch. All three legs are equally loaded. This is most often the strongest tripod configuration.

Table 1

Symmetric Tripod			Main Plate Head Angle Settings - **A/A**			
			Half Plate Head Angle Settings - **B**			
Height	Upper Section Coupling	Lower Section Coupling	Optional Section Coupling	Hobble Length	Breaking Strength	Applicable Standards
4	X7	n/a	n/a	42"	12,200	NFPA, ASTM
5	Y4	n/a	n/a	54"	12,000	NFPA, ASTM
6	X2	n/a	n/a	60"	9,300	NFPA, ASTM
7	Y7	X9	n/a	69"	12,100	NFPA, ASTM
8	X5	X9	n/a	77"	9,400	NFPA, ASTM
9	Y2	X9	n/a	78"	9,300	NFPA, ASTM
10	X1	X9	n/a	70"	7,800	ASTM
11	X6	X9	X1	78"	8,200	ASTM
12	Y3	X9	X1	78"	5,600	ASTM
13	X1	X9	X1	78"	4,600	

How Head angles affect tripod strength

There are many factors that go into the proper set-up and stability of a tripod system, which is why intensive personal training is required with the TerrAdaptor. Two of the main factors affecting the total strength and safety of a placement are the head angle used and the overall height of the system. As a guideline, for a given height, the wider the head angles the lower the strength. For example, the following table shows how a 7-foot tripod breaking strength declines from 12,100 lbf. to 7,700 lbf. just by slightly increasing the head angle.

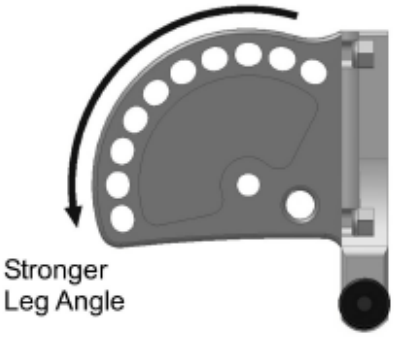


Table 2

Symmetric Tripod setup angle comparison							
Height	Main Plate Head Angle setting	Half Plate Head Angle setting	Upper Section Coupling	Lower Section Coupling	Hobble Length	Breaking Strength	Applicable Standards
7'	A/A	B	Y7	X9	Tight	12,100	NFPA, ASTM
7'	B/B	C	Front – X5 Rear – Y6	Front – X9 Rear – X9	Tight	10,100	ASTM
7'	C/C	D	Front – Y2 Rear – X6	Front – X9 Rear – X9	Tight	7,700	ASTM

Wide Tripod Configurations

In many cases a wide and more stable configuration is desirable even at the expense of breaking strength. Wide configurations also offer a larger work area under the tripod. The following table shows strength of a few wide stable configurations which have very large work areas.

Table 3

Symmetric Tripod – Wide setup							
Height	Main Plate Head Angle setting	Half Plate Head Angle setting	Upper Section Coupling	Upper Section Coupling	Hobble Length	Breaking Strength	Applicable Standards
7'	B/B	C	Front – X5 Rear – Y6	Front – X9 Rear – X9	Tight	10,100	ASTM
8'	B/B	C	Front – Y2 Rear – Y4	Front – X9 Rear – X9	Tight	9,600	ASTM
8 ½'	B/B	C	Front – X1 Rear – X3	Front – X9 Rear – X9	Tight	8,300	ASTM

II. Symmetric Quadpod (includes NFPA configuration)

Symmetric Quadpods fill the same role as symmetric tripods, but with added strength and stability of a fourth leg.

Table 4

Symmetric Quadpod			Main Plate Head Angle Settings - **A/A**			
			Half Plate Head Angle Settings - **A/A**			
Height	Upper Section Coupling	Lower Section Coupling	Optional Section Coupling	Hobble Length	Breaking Strength	Applicable Standards
4	Y7	n/a	n/a	29"	13,000	NFPA, ASTM
5	X5	n/a	n/a	33"	12,100	NFPA, ASTM
6	Y2	n/a	n/a	36"	12,100	NFPA, ASTM
7	Y7	X9	n/a	38"	12,200	NFPA, ASTM
8	Y5	X9	n/a	40"	12,600	NFPA, ASTM
9	Y3	X9	n/a	42"	11,500	NFPA, ASTM
10	X1	X9	n/a	46"	8,500	ASTM
11	Y7	X9	X1	46"	8,100	ASTM
12	Y4	X9	X1	46"	7,100	ASTM
13	X1	X9	X1	46"	5,100	ASTM

III. Edge-A Tripod

Probably the most popular configuration for an over the edge rescue, the Edge-A Tripod is essentially an A-Frame with the added stability of a third leg. Edge A configurations are popular for their large work areas, high strength and the ability to configure the A leaning either over or away from the edge. The TerrAdaptor's rear leg can be left to hinge (unsecured) or can be pinned in place for added stability.

Table 5

Edge A Tripod			Main Plate Head Angle Settings - **B/B**			
Height	Half Plate Head Angle	Upper Section Coupling	Lower Section Coupling	Hobble Length	Breaking Strength	Applicable Standards
6'	D	Front - Y7 Rear – X1	Front – X9 Rear – X9	Front – 112" Side – 136"	9,100	ASTM
7'	C	Front – X5 Rear – X1	Front – X9 Rear – X9	Front – 116" Side – 122"	9,600	ASTM

IV. A-Frame/Bi-Pod

The TerrAdaptor is easily configured as a standard A-Frame or a Sideways A-Frame often used in narrow areas like catwalks. The half plate can be removed to eliminate weight and opportunities for it to be in the way, or it may remain attached.

Table 6

A-Frame			Main Plate Head Angle Settings - **B/B**		
Height	Upper Leg	Lower Leg	Hobble Length	Breaking Strength	Applicable Standards
7'	X5	X9	120"	5,600	ASTM

V. Gin Pole/Monopod

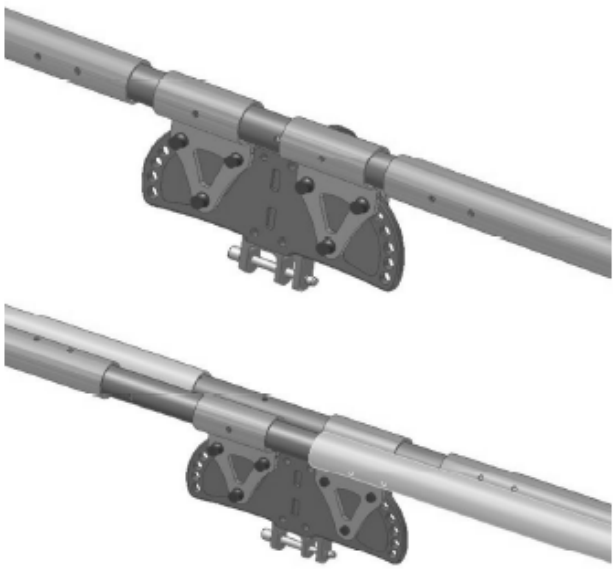
The Gin Pole or Monopod is the TerrAdaptor's lightest high anchor configuration. A properly rigged gin pole/monopod can support several thousand pounds while remaining a lightweight, single leg assembly. The Gin Pole is also ideal for close quarters where there is not enough room for multi-leg configurations.

Table 7

Monopod					
Height	Upper Leg	Lower Leg	Hobble Length	Breaking Strength	Applicable Standards
8'	Y6	Y9	n/a	4,500	

VI. Horizontal Span

Unlike other tripods, the TerrAdaptor can be configured to span horizontal voids such as trenches, catwalks, pits or small streams. As shown in this figure a void can be spanned by using either 1 or 2-leg assembly depending on the span length and strength required.



Warning

The horizontal span can be one of the weakest configurations and should be used with great caution.

Table 8

Horizontal Beam		
Span	Leg Tubes	Breaking Strength
4'	Single	5,600
4'	Double	8,200
6'	Single	3,500
6'	Double	5,900
8'	Double	4,000

Appendix B: Rope Rescue Operations Level Skills Check List

Complete basic knots, including:

- ☐ Figure 8 on a Bight
- ☐ Figure 8 Follow Through
- ☐ Bowline
- ☐ Double Long-tail Bowline
- ☐ Butterfly
- ☐ Clove Hitch
- ☐ Prusik Hitch
- ☐ Munter Hitch
- ☐ Becket Bend (Sheet Bend)
- ☐ Double Overhand Bend (Double Fisherman's Bend)
- ☐ Single Overhand Bend (Water Knot) using webbing

Anchor rigging concepts including:

- ☐ Single Point Anchors
- ☐ Multipoint Anchors
- ☐ Wrap 3 Pull 2 with Webbing
- ☐ High Strength Tie-Off (Tensionless Hitch)
- ☐ Back-Tie Techniques

Mainline concepts including:

- ☐ Lowering Operations
- ☐ Changeovers
- ☐ Raising Operations
- ☐ Simple and Compound Mechanical Advantage Systems

Belay concepts, including:

- ☐ Petzl ID
- ☐ Petzl ASAP

Additional concepts, including:

- ☐ Rappel and Ascend a Fixed Rope (Instructor's Discretion)
- ☐ Patient Packaging; including the Spec Pak, and Sked system
- ☐ Participate in a Steep and/or High Angle Evacuation

Participant's Name: _____

Participant's Signature:_____ Date: _____

Instructor's Name: _____

Instructor's Signature: _____ Date:_____

Appendix C: Rope Rescue Technician Level Skills Check List

- ☐ Participate in classroom lecture/discussion on concepts and summary of NFPA 1670, 1006, and 1983
- ☐ Participate in classroom lecture/discussion on incident management of rope rescue emergencies
- ☐ Participate in classroom lecture/discussion on force multipliers including resultants, effects of friction at the edge, static system safety factors, dynamic system safety factors, fall factor, impact forces and calculation of compression and tension.

Perform knots including:

- ☐ Figure 8
- ☐ Figure 8 on a Bight
- ☐ Figure 8 Follow Through
- ☐ Bowline
- ☐ Double Long-tail Bowline
- ☐ Butterfly
- ☐ Clove Hitch
- ☐ Prusik Hitch
- ☐ Munter Hitch
- ☐ Single Overhand Bend (Water Knot) using webbing
- ☐ Double Overhand Bend
- ☐ High Strength Tie-off (Tensionless Hitch)

Perform anchor rigging concepts including:

- ☐ Single Point Anchors
- ☐ Focus Floating Anchors
- ☐ CRAS (Controlled Release Anchor System)
- ☐ Back-tie Techniques (tension and multi-point)
- ☐ A Frames
- ☐ SA Frames
- ☐ Gin Poles

Mainline concepts including:

- ☐ Loaded Changeovers
- ☐ Knot Passing
- ☐ Simple and Compound Mechanical Advantage Systems

Belay concepts including:

- ☐ Management of Elongation of the Belay Line

Additional concepts including:

- ☐ Rappel and Ascend a Fixed Rope (Instructor's Discretion)
- ☐ Patient Packaging
- ☐ Complete a Vertical Team-based Pick-off
- ☐ Participate in a Litter Pike & Pivot
- ☐ Complete a Vertical Solo Pick-off
- ☐ Participate in a Vertical Litter Scoop
- ☐ Participate in a rescue scenario evolution that encompasses major taglines
- ☐ Participate in a rescue scenario evolution that encompasses a minor highline
- ☐ Participate in a rescue scenario evolution that encompasses a major highline
- ☐ Participate in a rescue scenario evolution that encompasses dynamic directionals

Participant's Name: _____

Participant's Signature:_____ Date: _____

Instructor's Name: _____

Instructor's Signature: _____ Date:_____

Section 3: Respiratory Protection

Respiratory Protection

Scope and Purpose

In the control of occupational diseases caused by breathing air contaminants, Kary Environmental Services, Inc. primary objective is to prevent air contamination. This shall be accomplished by effective engineering controls such as ventilation, confinement, etc. When these controls are not feasible or while they are being initiated, appropriate respirators shall be used.

Safety/Environmental

Kary Environmental Services, Inc. is committed to reducing the impacts on the environment from our manufacturing and related processes. The procedure contains instructions where appropriate on proper disposal of waste, reduction of emissions, opportunities for recycling, water conservation and energy efficiency, conservation of raw materials and protection of site's environmental control/abatement equipment.

Applicable Standards:

This document shall comply with the Occupational Safety and Health Act (OSHA), Code of Federal Regulations, Title 29, Part 1910.134 regarding respiratory protection. When other governmental regulations are more stringent, then they will apply.

Management Responsibility:

It is the responsibility of the section manager and/or supervisor of the department to notify the Environmental Health and Safety Coordinator (EHS) of questionable atmospheres which may be unnecessarily exposing employees to hazardous concentrations of contaminants.

When an atmosphere has been deemed hazardous for inhalation by EHS and respiratory protection is the chosen control, then it is the responsibility of the section manager of the department to ensure that their employees are in strict adherence to this standard.

Where respirator usage is mandatory, the section manager will not obtain respirators for, or allow the use of respirators by, employees who have not met the requirements of this standard.

Employee Responsibility:

It is the responsibility of the employee to report to supervision or EHS any questionable atmospheres, which may be unnecessarily exposing employees to hazardous concentrations of contaminants.

It is the responsibility of the employee who wears the respirator to abide by the instructions he/she received regarding fitting, usage, and care.

The employee shall guard against damage to the respirator. The employee shall report any malfunction of the respirator to their supervisor or EHS. The employee shall field inspect, clean, and store their respirator pursuant to paragraphs set forth in this document.

Violation of this Procedure:

Improper use of respiratory equipment: use of respiratory equipment by personnel who are not certified will be considered to be a major infraction of safety procedures and as such will have a Safety Incident report filed with the Human Resources Department with a request for disciplinary action.

Respiratory Procedures:

Physiological Limitations for Respirator Wearers

All employees who are to be included in the respirator program shall me medically qualified. The EHS will determine whether or not an individual is qualified. This determination will be repeated annually, or as directed by the EHS.

Approved Respirators

- Respirators which have obtained proper NIOSH/MSHA approvals will be used.
- Respirators, when required, shall be full-face piece unit.
- All respirators used on the site shall be approved by EHS.

Respirator Selection Criteria and Classification
The selection of the proper type of respirator shall be made solely be EHS and be based on the following:

- The operation, frequency, and duration of exposure.
- The type of respiratory hazards (physiological effects on the body, concentration of toxic material).
- The physical characteristics and functional capabilities and limitations of the various types of respirators.

Respirator Protection Factors
Respirators are classed by two major categories: air purifying and atmosphere supplying. Air purifying respirators cleanse the air by removing particulates and/or vapors and gases. They consist of either a filter and/or absorption medial to provide protection against specific agents. These have saturation points and are therefore limited by concentration and time. They do no supply atmospheres. Atmosphere supplying respirators provide respirable air from a source other than the surrounding atmosphere.

This class of respirators includes self-contained breathing apparatus (SCBA) (Scott Air Pack) or supplied air (SA) (hoseline) or a combination of both. The use of SCBA and/or SA equipment will fall under the 2-Man Rule safety requirement.

Appendix A contains a listing of the types of respirators and appropriate uses.

Mandatory Respirator Usage
EHS will determine and maintain a list of mandatory respirator wearers.

Dangerous atmospheres
In areas that may be immediately dangerous to life and health such as a highly toxic gas, at least one additional person shall be present (2-Man Rule). Communications (visual, voice, or signal line) shall be maintained between the individuals present. Self-contained breathing apparatus will be worn or a combination of supplied air and SCBA will be worn in IDLH atmospheres and during emergency responses.

EHS or supervisory personnel shall train employees on respirator usage. This training will include air purifying and air supplied respirators.

Instructions for respirator usage

For safe use of any respirator, it is essential that the user be instructed in its selection, use, and maintenance. The instructor and training program must be approved by the EHS. The employee will be instructed in the following:

- Purpose of wearing the respirator.
- Selection of respirators for the particular hazardous agent.
- Limitations of respirators.
- Care, cleaning, and storage of respirators.
- How to put on the respirator (a demonstration will be given.) Employee will practice.
- Contents of this standard

Respirator Fit Test

Each respirator wearer who is required to wear a respirator shall receive a qualitative fit test to assure proper protection. Each respirator wearer shall be required to check the seal by the manufacturer's recommendations (which they will learn how to do during the fitting instructions) prior to entering a harmful atmosphere.

Facial hair, contact lenses, and eyeglasses – an employee who is required by the Safety Department to wear a respirator shall not be permitted to wear it when:

- Facial hair comes between the sealing periphery of the face piece and the face.
- Temple bars or eyeglasses extend through the sealing edge of a full-face piece.
- Contact lenses will not be permitted wearing a respirator.

Monitoring Respirator Use

Supervisory personnel shall periodically monitor the use of respirators to ensure they are worn properly.

Respirator Inspections

Non-emergency use respirators (air purifying) shall be "field" inspected by wearer before and after each use for defects. This procedure will include, but not be limited to, the following:

- Tightness of connections.

- Cracks, tears, excessive dirt, distortion.
- Scratches (face piece).
- Head strap slippage and loss of elasticity.
- Valves, inhalations, and exhalation.
- Correct air-purifying cartridges.
- Suspension (air hood).

Emergency-use respirators (SCBA or SCBA/SA) shall be inspected monthly by EHS. In addition, each emergency-use respirator shall be inspected by the wearer after each use for the following:

- Tight fitting face piece.
- Scratches, cracks, elasticity.
- Integrity of air supply lines, hoses, and fittings.
- Correct operations of all regulators and valves.
- Amount of air left in the bottle (refill if less than 25% full).

Cleaning

When a respirator is not assigned to an individual, the respirator shall be cleaned by washing in detergent in warm water, rinsing in clean water, then disinfecting with alcohol wipes or other approved means by the employee using the respirator after each use.

When a respirator is assigned to an individual, the employee must clean his/her own respirator by washing with detergent in warm water, thoroughly rinsing in clean water, and air drying in a clean place after each use.

Storage

Respirators must be stored to protect against dust, sunlight, heat, extreme cold, chemicals and excessive moisture, and mechanical damage (such as leaving it on the work bench, etc.).

Air purifying respirators should be stored in a cabinet and clearly marked as to its contents so as to be ready for routine and emergency use.

Air purifying respirators must be stored in sealed plastic bags after each use so that the filter and/or chemical absorbent will be prolonged.

SCBA's must be stored in a wall-mounted case or a chest as purchased from the manufacturer. The locations must be well known and clearly marked and must be in an area that will remain uncontaminated.

Maintenance and Repair
Supervisors who find respirators to be unacceptable, as determined by the filed inspections, must notify EHS in order that replacement or repairs can be performed.

Record Keeping
EHS will keep all records pertaining to training and inspections.

Records will be kept of the dates and findings of each emergency-use respirator that undergoes an inspection.

Non-Mandatory (Voluntary Respirator Usage)
Employees who want to wear a particular respirator for a given substance, although they are not exposed in excess of any governing limits, may do so if they obtain EHS authorization.

When respirators are worn on a voluntary basis, this program must be followed.

RESPIRATORY PROTECTION, APPENDIX A

RESPIRATOR TYPE	LIMITATIONS ON USE
Air Purifying	
A. Particulate Removing	
- Half mask dust (disposable)	Up to 5X PEL*
- Half mask high efficiency	Up to 10X PEL
- Full face piece high efficiency when eye and/or skin irritation exists	Up to 50X PEL
B. Gas and Vapor Removing	
- Half mask	Up to 10X PEL
- Full face piece	Up to 50X PEL when eye and/or skin irritation exists
Supplied Air Devices	
A. Supplied Air (SA)	
- Pressure demand full face piece	Up to 2000X PEL
- Continuous flow hood	Up to 2000X PEL
B. Self Contained Breathing Apparatus (SCBA)	
- Open circuit pressure demand full Face piece emergency egress, IDLH atmospheres.	Up to 10,000X PEL,
Combination Respirator	
- Any SA and an SCBA: Refer to II, A and B above, for extended work periods with toxic materials when IDLH potential.	

NOTE: * PEL is Permissible Exposure Limit as established by OSHA

Section 4: Confined Space Rescue Factors

A.I.R. Assessment, Isolation, Resources

The Role of the First Responder
The role of the first responder is one of paramount importance; the actions of this person will most likely determine the success, or failure of a confined space emergency. There are two major concerns the first responder will affect in a positive manner by using sound judgement, and a strong command presence.

Safety of fire department members.
Overall efficiency of an event that will be brought to a successful conclusion.

It is essential, that we recognize a confined space environment when we are not expecting one. WE MUST TAKE THE BLINDERS OFF AN LOOK AT THE BIG PICTURE!
The first responder, and his/her crew must deal with three areas of action, and it must happen, for the most part, at the same time. These three areas are:
A complete and accurate ***assessment*** of what happened, who is in charge, and what are the hazards.
Isolation of the area, and all hazards, anything that may cause harm to the public, the victims, and to our own people.
Identify and call for the appropriate ***resources***.

The Confined Space Environment
According to O.S.H.A., confined spaces account for over **60 deaths and 12,000 injuries** every year. Many of these deaths are would-be rescuers, including fellow employees, by-standers, and emergency services members.
Confined spaces come in many forms, they can be found in petroleum processing, food industry, utility vaults, underground communication, electrical tunnels, various liquid storage facilities, and in many other forms of industry, just to name a few.
A confined space is defined as an area that is large enough to enter and perform work, has restricted means of access and egress, but is not designed for continuous occupancy.
A permit-required confined space is defined as a confined space that has one or more of the following:
An atmospheric hazard:
An engulfment hazard:
A configuration hazard; or
Any other recognized serious hazard.
Fatalities and injuries are common occurrences among workers in confined spaces. Workers are exposed to multiple hazards which may cause injury, illness, or death. According to NIOSH, toxic, oxygen-deficient, and explosive atmospheres are responsible for most reported fatalities and injuries in confined spaces. Many injuries and fatalities resulting from energy sources, such as steam, electricity, and mechanical equipment go unreported as confined space accidents.

Hazards of Confined Spaces

The cardinal rule for anyone planning to enter a confined space or area is **"Never trust your senses."**

What may look like a harmless situation may be a potential threat. What may smell strange at first can impair your senses and make you careless. Indeed, some of the deadliest gases and vapors have no odor at all.

The three most common atmospheric conditions that constitute hazards are:

Oxygen Deficiency

Normal fresh air contains 20.8% oxygen. OSHA states the any atmosphere containing less than 19.5% oxygen is considered to have an oxygen deficiency.

Oxygen deficiency occurs in confined spaces where the level of oxygen has been reduced below the level to support life. Common causes are oxidation of metals, bacterial action, combustion and displacement by other gases. Gases that are physiologically inert when they exist in sufficient quantities to exclude or displace an adequate oxygen supply may also cause oxygen deficiency. Substances such as nitrogen are used for inerting operations and as a medium for purging vessels. Carbon dioxide is widely used as a fire-extinguishing medium in refrigerated trucks and ships. Carbon dioxide is heavier than air and often forms pockets at the bottom of confined areas. It not only displaces oxygen, but also causes an increase in the acidity of the blood. Concentration as low as 6% carbon dioxide can be fatal in less than one hour.

Combustible Gas and Vapors

Atmospheres may ignite or explode if a source of ignition is present or introduced into the environment. This category of atmospheric hazards includes naturally occurring gases and the vapors of a large group of liquids that are used as fuels and solvents. Some of these liquids evaporate easily. Both gases and vapors, when mixed with the required amount of air and a source of ignition, will burn and explode.

Many flammable gases or vapors are heavier than air. If they flow into a pit, a tank opening, or other confined space, they will present a serious fire or explosion hazard. Disposal of flammable liquids into sewers presents municipal workers with many potentially explosive situations. Gasoline, cleaning fluid vapors, and other natural gases are often found in sewers.

Toxic Gases or Vapors

Atmospheres containing contaminants, even in low concentrations, can cause injury or death. This category includes **asphyxiant** and **irritants**.

One should always anticipate that anyone or combination of the above atmospheric conditions might exist in tunnels, utility manholes, vaults, sewers, excavations, railroad tank cars, sump pits, silos, open tanks, rooftop mechanical penthouses, cold storage facilities, ship holds, stacks and chimneys, duct work, brewer's vats, mine tunnels, etc. In addition, hazards sometimes appear unexpectedly in normal situations due to inappropriate industrial waste disposal or leakage of toxic substances into earth strata and conduits.

Toxic substances are commonly found in industry as well as being generated by natural processes. Included are all gases and vapors that are known to provide disease, acute discomfort, bodily injury, or death.

Some gases, in very low concentrations, are mildly irritating to the respiratory and nervous systems. At higher levels they cause death.

Carbon monoxide is one of the common asphyxiant encountered in industry. It is formed by incomplete combustion whenever fuel-containing carbon is burned. In addition to being a by-product of many industrial operations, it is produced in large amounts by internal combustion engines such as automobiles, diesel powered compressors, and forklifts. Substances that render the body incapable of utilizing an adequate oxygen supply are called chemical asphyxiant.

Hydrogen sulfide is even more toxic than carbon monoxide. Air containing as little as 100 PPM. or 0.01% hydrogen sulfide may cause death i a few hours. Death is due to asphyxiation resulting from paralysis of the muscles that control breathing. In low concentration it is classified as an irritant because it inflames the mucous membranes and results in the lungs filling with fluid. Hydrogen sulfide has a characteristic rotten egg odor. Since the gas renders the olfactory nerve (which controls the sense of smell) ineffective, a worker may be lulled into a false sense of security, not realizing a toxic concentration of gas may be present.

Hydrogen sulfide is a hazard in many industries not only because of its use in manufacturing, but also because of its accidental occurrences. It is recognized as a major hazard in the oil refining industry, in sewage treatment, and wherever organic matter containing sulfur decomposes.

Temperature Extremes:

Extremely hot or cold temperatures can present problems for workers. For example, if the space has been steamed, it should be allowed to cool before any entry is made. If temperatures exceed 100 degrees, crew rotation on a regular basis is a must.

Engulfment:

Loose, granular material stored in bins and hoppers such as grain, sand, water, coal, or similar material, can engulf and suffocate a worker.

Noise:

Noise within a confined space can be amplified because of design and acoustic properties of the space. Excessive noise can not only damage hearing, but can also affect communication, such as causing a shouted warning to go unheard.

Slick/Wet Surfaces:

Slips and falls can occur on a wet surface causing injury or death to workers. Also, a wet surface will increase the likelihood of an electric shock in areas where electric circuits, equipment, and tools are used.

Falling Objects

Workers in confined spaces should be mindful of the possibility of falling objects, particularly in spaces that have topside openings for entry, and where work is being done above the worker.

Claustrophobia

Claustrophobia is the abnormal fear of closed or confined spaces.

Assessment

Two Most Common Pitfalls

Rarely are they reported as a confined space emergency. As we said earlier, 911 callers usually don't tell the Alarm Room that the emergency they are reporting is in a confined space. Who knows the reason why, maybe they don't see past their co-worker lying on the floor of a storage tank, or a trench, or maybe, they feel if they don't report it as a confined space incident they won't get in trouble. Whatever the case, we must recognize the presence of a confined space.

They look safe. Most confined spaces people get injured in or die in simply look safe. That's probably the reason the victim went inside the space in the first place, and the same reason the would-be rescuer entered to save his buddy! If the confined space was filled with boiling oil, or had rattlesnakes in it no one would go in.

The victim is down for a reason, don't become another victim by making an ill thought out rescue, even for a fellow firefighter. If it got him/her, it will get you. ***Do not trust your senses, what you don't see may kill you.***

What happened?

Competent Person/Supervisor, Responsible Party, Witnesses.

What happened? The first responder must find out who is the responsible person, if the space is located on a construction site, road project, or excavation, there will most likely be a "Competent Person", or Entry Supervisor close at hand. *Keep that person with you at all times!* He/she can provide valuable information on what happened, what hazards have been identified, the possible location of the victim, and the layout of the confined space.

Other witnesses, co-workers, and friends may also provide needed information as to what happened.

What are the hazards?

Onsite Entry Permit.

If the confined space is a work site of a reputable company, they will most likely have a Entry Permit. The Entry Permit will provide such information as: What is the purpose of the entry,

what work was being done, what was the atmospheric readings prior and during entry, what they did for lockout and tagout of electrical, mechanical, and other hazards.

The Entry Permit should also name the workers who entered the space, these will probably be the victims we will rescue.

Victim Profile

Rescue or Recovery?

The first responder should determine how many victims have been affected.

We should try to determine how long the victims have been down, the mechanism of injury, and the survivability profile of the victim.

An early decision must be made as to whether the operation will be run in the **rescue or recovery mode.**

Isolation

Control access to the area.

People of good intention will try their best to squeeze in as close as possible to the opening of the space, to get a peek, to help, or whatever. Do whatever it takes to get them back at least 300 feet. Call P.D. early for crowd control, ***Use fire line tape, it works!***

Sectors are a must. Create a 50' hot zone, a 150' warm zone, a 300' cold zone

Atmospheric Monitoring.

Atmospheric hazards are the number one killer in confined space emergencies. Because of this, confined space emergencies are as much a Hazmat incident as it is a TRT incident.

Technical rescue units should be equipped with atmospheric monitors, hazmat units will have the same, plus many other specialized atmospheric monitoring equipment.

For the first responder the **onsite entry permit** may be the best early clue to the condition of the atmosphere of the space.

If you don't have immediate access to a atmospheric monitor, your best action might be, sectorize, and keep a safe distance from the space.

Lockout, Tagout.

Atmospheric Controls such as gas valves, and air handling systems may provide great use for isolating atmospheric conditions. Utilities, including electrical, gas and water should be secured

and locked out. If it is not possible to lock/tagout/blankout, Safety Sector shall post a guard to assure the utilities are secured and not turned on during the operation.

Any product that is in or flowing in the confined space must be secured and blanked off if possible. It may be determined that the space must be drained of any product prior to entry.

Any manufacturing or processing equipment must be shut down prior to entry. If possible, **all equipment should be locked/tagged out and brought to a zero energy state.**

Remember: Tags alone do not restrain! Padlocks and other physical restraints should always be used.

Resources

Call for Technical Rescue and Hazmat early.

Determine if there is an adequate number of trained personnel on scene to do the rescue/recovery, (a minimum of eight (8) trained personnel).

Command should consider the effect of temperature extremes on personnel, and consider early rotation of personnel operating on scene, approximately every 15 to 20 minutes, 30 minutes in the winter.

TRT, and Hazmat units will provide the proper equipment to complete the operation. This
includes, but is not limited to:

1. Atmospheric monitoring equipment.
2. Explosion proof lighting.
3. Explosion proof communications.
4. Supplied air breathing apparatus or remote air.
5. Cascade system.
6. Victim removal systems/equipment.
7. Ventilation equipment with the necessary duct work.

Call for P.D. early for traffic and crowd control.

Personal Equipment

All entry and back-up personnel should wear the proper level of personal protective equipment. This should include helmet, gloves, proper footwear, goggles, Nomex or PBI jumpsuits, "brush turnouts", and a Class III harness.

Breathing Apparatus:

All entry and back-up personnel should wear SABA (supplied air breathing apparatus) or SCBA when making entry into the confined space. SABA is the most preferred.

If entry personnel use an SCBA, they shall enter no farther than one half the amount of supplied air minus 500 lbs. EXAMPLE: 2000 PSI tank gauge pressure--1/2 = 1000 PSI minus 500 PSI = 500.

Air Monitoring:

Entry personnel shall use personal air monitoring devices that monitor O_2, flammability, and toxicity as a minimum.

Communications:

Entry personnel shall have a minimum of one portable radio and/or be equipped with a hard wire intercom system, CSI-2000, (see section on Confine Space Communications). The first entry team member should be equipped with hard wire communication and a air monitoring meter, the second member should have the tag line and a portable radio, this way the portable radio is less likely to accidentally key the air monitor.

Managing the Point of Entry

One of the key elements of a successful confined space rescue is quality management of entry point of the space. It is not uncommon for the entry team to tag in several different types of support lines, such as the supplied air hose, hard-wire communication lines, and taglines. All this is in addition to the needed extrication and medical equipment for the patient. So how do we avoid a situation that looks more like a "spaghetti dinner" than a confined space rescue?

A quality command structure and sectors is a must; a hot zone of at least a 10' to 20' radius should be established around the opening of the confined space. This hot zone should have a "lobby" entrance, monitored by a lobby control officer. This person is responsible for the accountability of all members within the "hot" zone. In most cases, only the entry team, line management support personnel, hard-line communications control officer, the safety officer, ventilation/air monitoring, supplied-air cart, and the technical sector officer, should be allowed into the "hot" zone.

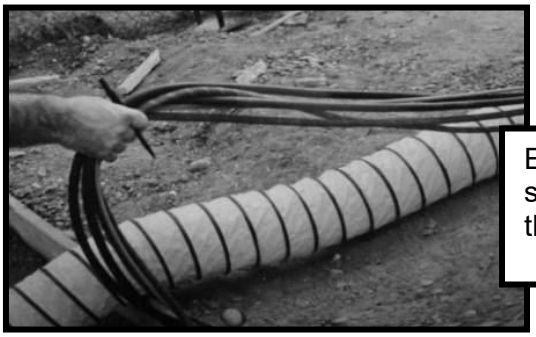
A "warm" zone is established and extends approximately 50' past the radius of the hot zone. The warm zone is where the backup entry team should be staged. Also, the warm zone is an ideal area to flake out and manage the various lines that will make their way into the space. Rope systems for victim and rescuer extrications should typically operate from the warm zone, although, this is not an absolute, and it is not a black and white issue. An astute technical rescue officer (TSO) will keep an eye on the big picture and know when to cross the hot zone boundary with systems such as haul lines, belays, and air hoses.

The "cold" zone should extend 300' from the theoretical radius of the warm zone. This is where command should establish general staging, rehab, treatment, and transportation. In addition, all spectators, and media should not be allowed past the cold zone.

Management of the many lines needed inside the space is a practiced skill, requiring the use of technician level personnel. Communication between the entry team and the line support personnel must be continuous; entanglement outside of the space becomes a time consuming, embarrassing issue that puts the entry team at risk. Entanglement inside the space can spell disaster.

Sometimes there is simply not enough room to flake-out large bights of lines. An alternative is to pre-place the lines/hoses in large “figure eight” stacks. Teams have also had great success with portable reels customized for air hose and communication lines. Some teams combine the hose line and the communication line by using various forms of cable ties or “zip” ties. Also Velcro straps work good in this application. It is not recommended to combine taglines to the air hose and communications line. The entry team needs to have the capability of using the taglines as an independent tool. The reality is, taglines offer little help when trying to extricate someone from a confined space that involves multiple turns. Taglines are very useful to the entry team in rigging and moving the victim and/or equipment inside the space.

Use a large staging area to flake the “umbilicals”. Do what ever it takes to avoid entanglement of the entry team.



Each rescuer inside the confined space should have one attendant on the outside just to manage the lines.

The questions must always be asked, what am I going to get tangled up in and what is going to come undone if my body, or the victims body holds it down? Do what ever it takes to mitigate a “birds nest” of the umbilicals.

End Notes:

[2] This reference/nick-name "Set-of-fours is taken directly from the electrical lineman profession. Linemen have been using SOFs since the advent of electrical distribution.

[3] These tests were performed in 2010 during a Pat Rhodes rigging physic course at the Ultra-safe lab in Phoenix, Arizona.

[4] References:
College Physics Enhanced 7th ed. ©2006 Raymond A. Serway
Chapter 3, Vectors and Two Dimensional Motion

Schaum's A-Z Physics, © 1997, 2000, 2003, Michael Chapple
Vector Addition
Parallelogram Law

[5] It should be noted that this statement is correct most of the time. However, when the end of the rope (opposite the load end) is connected to the same anchor that the directional pulley is connected to, the primary force acting on the anchor is now represented by the leg of rope connected to the load. This is commonly seen when a capstan wench is mounted to the leg of a tripod. With the haul end of the rope connected directly to a leg, the resultant of the directional pulley attached to the top of the tripod does not indicate the forces at play on the tripod. Given this scenario, if the load does shift outside of the footprint, the tripod will tip over.

[6] We will use the term Dynamic Directional to reflect any directional pulley that requires extremely controlled adjustability. This can be as simple as a mini-haul system used to adjust the height of the belay line at the edge, or something more grandiose as seen in this drawing. This particular example of rigging is also commonly known as a Deflection Offset. I first learned this rigging technique while working with Reed Thorne and Ropes That Rescue.

[7] Rope Test Lab, Safety Access and Rescue, Lawson, Australia, Richard Delaney

[8] I was inspired to employ this very basic formula after studying the Cable Yarding Systems Handbook, from Work Safe BC. I have found it to be not only simple to remember but applicable and accurate, especially for shorter systems where we might not be too concerned about the weight of the rope.

[9] I first learned about the tensioning and bundling of highline systems under the guidance of Reed Thorne during my tenure with Ropes That Rescue. Several years later, these techniques are still pretty much the same, with some minor changes such as evolving from tandem prusiks as the tensioning system connection to the tracklines, to a single prusik connection combined with the anchoring of the end of each trackline behind the connecting prusik, thus creating a prusik bypass effect.

[10] My first introduction to the Skate-block came from transmission maintenance linemen with Salt River Project. This was a common rigging skill they would use in hoisting various equipment to the arm of the structure.