Capital Technical Rescue and Safety Consultants, LLC

Confined Space Rescue Technician
ITRA Confined Space Level 1 – 3

Student Manual

Capital Technical Rescue and Safety Consultants, LLC © 2025
22 Mill St., Unit 2, Albany, NY 12204 **T** 518-930-4500 **F** 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

v2025.10.8

Disclaimer

This manual is intended as a supplement for students who are enrolled or have taken our Confined Space Entry courses. The information within is not all encompassing and should never be used without proper instruction from Capital Technical Rescue and Safety Consultants, LLC instructors.

In most instances we do not get into the specific operation, use, limitations, warnings or dangers of pieces of equipment. Even when we do, you should always consult with the latest version of the manual directly from the manufacturer of the product and contact Capital Technical Rescue and Safety Consultants, LLC to receive the proper hands-on training of that device.

Most of the illustrations in this manual have been created by Capital Technical Rescue and Safety Consultants, LLC utilizing the vRigger software package. Illustrations and diagrams are not to scale. See www.vrigger.com for more details on their software.

For additional information or questions please contact us at info@capitaltechrescue.com or by phone at 518-930-4500.

The latest version of this manual may always be obtained at:

http://www.capitaltechrescue.com/downloads/csr-student-manual.pdf

Table of Contents

Pre-Course Information

What to Expect

What to Bring

- PPE
  - Helmet with chinstrap
  - Class III Confined Space Rescue Harness
  - Long pants / long sleeves or jumpsuits for certain evolutions
  - Good shoes / safety shoes / boots
  - Eye Protection
  - Gloves: Leather / mechanic style
  - Knee pads (optional - rescue classes only)
- Personal Items (optional)
  - Refillable water bottle
  - Snacks / Lunch
- Notify Us
  - Any medical problems
  - Any allergies – food, bees etc.
  - Any concerns you may have
- Winter Training
  - All training is conducted indoors and away from the elements
  - Be prepared to be working in ~ 50°- 60° temperatures

What is provided

- Additional PPE (pre-arrange)
- Coffee
- Water Bottle Fill Station
- Lunch – check with your organizer

Class at our Training Facility

Address

22 Mill Street, Unit 2
Albany, NY 12204

Directions

Directions via Google Maps: https://goo.gl/maps/r2BDuJtPeRR2

Parking

Parking is limited and we try to be good neighbors to a few businesses, so please do not block the dumpster or the loading dock as it is actively used throughout the day.

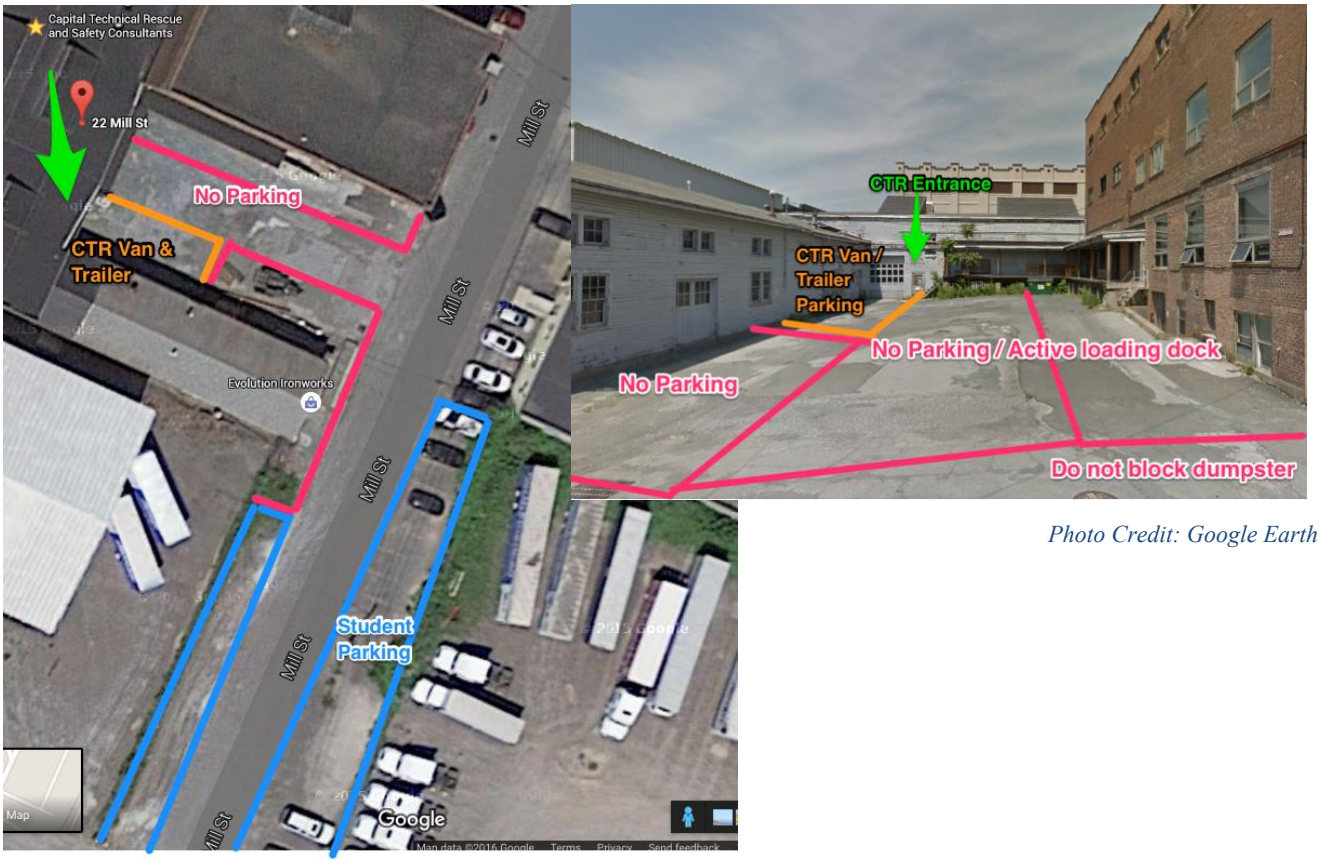


Photo Credit: Google Earth

Photo Credit: Google Earth

Facility Rules

- Tobacco / Vape Free
  - Our facility is 100% Tobacco Free
  - This includes use of smokeless tobacco

Pre-Course Study Material

- Read the Introduction, Standards and Rope Rescue Equipment Sections

- Begin learning the knots, bends and hitches from the Equipment Section. Each knot has its own information and link to videos.

NFPA Confined Space Rescue Courses – 24, 32 & 40 hour classes

- Prior to Day 1:
  - Rope Rescue Equipment
    - Rope / cordage construction features
    - Knots / Bends / Hitches
    - Rope Rescue Hardware
    - Raising and Lowering Systems
  - Definitions

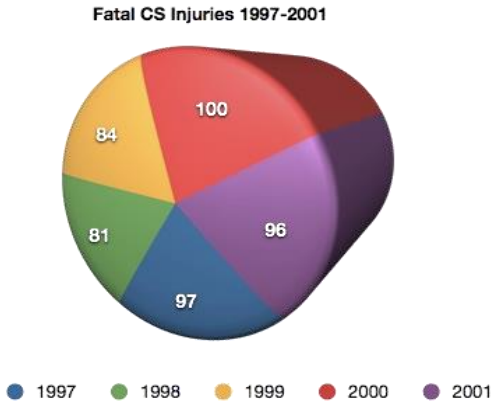
- Prior to Day 2:
  - Rope Rescue Techniques
    - Rope commands and communications
  - Confined Space Entry Equipment
    - Hazards
    - Meters, Atmospheric Monitoring and Ventilation
    - Vertical Entry Setups
    - Horizontal Entry
  - Bleeding Control / IFAK
  - Patient Packaging

- Prior to Day 3:
  - Confined Space Rescue Pre-Planning
  - Appendix Section

Introduction

The Need

Average of 67 deaths per year, 60% are would-be rescuers. General Industry statistics show there is 1 death every 4 days in confined spaces. (National Safety Council, 2008)



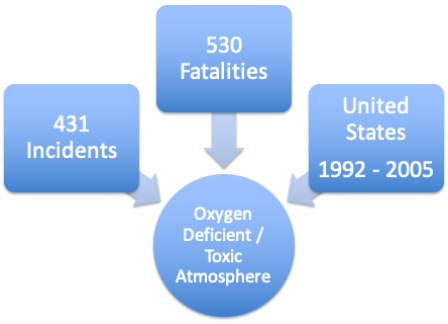
California OSHA study from 2012 showed an increase in deaths in confined space during 2011. 7 deaths, numerous injuries - many would be rescuers. All of these cases were preventable.

Pharmaceutical Plant:
January 2011 Nitrogen in large reactor vessel 1 dead, 2 injured during rescue attempt

Commercial Laundry
July 2011 Reaching in and inadvertent start up 1 dead

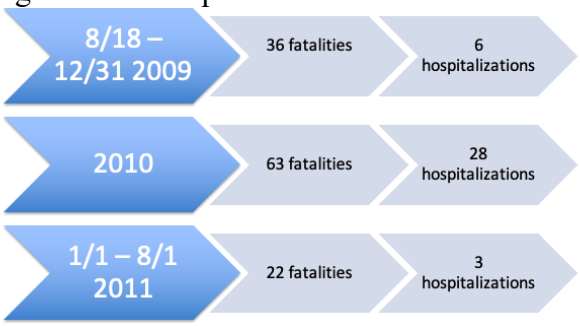
Most other incidents were atmospheric related

OSHA Statistics



There were 431 confined space incidents with 530 fatalities in the US due to oxygen deficient and/or toxic atmospheres from 1992-2005
From 08/18/2009 to 12/31/2009, there were 36 worker fatalities and 6 worker hospitalizations related to confined spaces.
In 2010, there were 63 worker fatalities and 28 hospitalizations related to confined spaces.

From 01/01/2011 to 08/01/2011, there were 22 worker fatalities and 3 worker hospitalizations related to confined spaces.
Repair & Maintenance and cleaning & inspection activities account for almost one-quarter of confined space-related fatalities.
Construction and manufacturing industries experience the most fatalities.



During a study done in 2006 by a California company, it was found that approximately one-fifth of the confined space incidents result in multiple fatalities. Data also indicated that for every fatality due to oxygen-deficient and/or toxic atmosphere, 2 non-fatal injuries occur, one of which requires hospitalization. More often than not, those additional injuries are to rescuers.
Even if properly trained, workers may forget their training and/or disregard proper entry procedures and enter a confined space without PPE because they are overcome by the natural emotion to rescue a coworker. Although companies are required to and do have written procedures and programs related to confined space entry, it does not release the company from liability due to an employee's disregard of those procedures, no matter if the employee is regular, temporary or contract. As far as OSHA is concerned, employers are responsible for the safety of ALL workers.

CTR Background

Capital Technical Rescue and Safety Consultants, LLC (CTR) was formed in 2006 to serve the needs of emergency response personnel whose job duties specifically task them with performing a variety of technical rescue disciplines. These responders have come from a variety of agency types including federal and municipal public sector emergency services as well as private industry emergency response teams and fire brigades.

The primary staff of CTR has been working and teaching together for over 10 years, prior to the formation of the company. Their backgrounds vary from volunteer to career firefighters and fire officers, emergency medical technicians to paramedics, and emergency responses from the smallest local incident to natural disasters and terrorist attacks that have had a global impact.

Previous and current CTR contracts have included teaching technical rescue courses from 6 to over 350 students, with scheduled completion ranging from a single day to over the course of several months. This flexibility has allowed our clients to minimize overtime expenses and ensure that production or response is negligibly impacted. This is also true for our industrial clients and has led us to be one of the most experienced groups of standby rescuers.

Capital Technical Rescue and Safety Consultants, LLC is a proud Petzl Technical Partner (PTP).

What is a Petzl Technical Partner (PTP)?
A PTP is a recognized expert company or individual in a vertical environment that demonstrates a thorough understanding of their respective industry, contributes to the development of best practices, and meaningfully integrates Petzl into their systems and curriculum. In return for this promotional support, Petzl endeavors to share our information, our products, our time, and our resources to ensure mutual success and sustainable growth.

Who is a Petzl Technical Partner?

Trainers & Training Organizations
Industry Leaders & Influencers
Consultants & Field Experts

PTP Mission Statement:
The Petzl Technical Partner (PTP) Program's mission is to develop a diverse network of training company partners and recognized leaders who can help Petzl promote our products and solutions to a wide variety of industries and end-users. Whereas Petzl is an expert in our products and services, we believe that front line, subject-matter experts are the best bridge to the industries we ultimately serve.
As a Petzl Technical Partner, we are part of a network of subject matter experts. There are technical partners located in 5 continents and in over 18 countries.

Capital Technical Rescue and Safety Consultants, LLC serves clients from a variety of industries. These include:

Food Service
- Ingredient Facilities
- Food processing and packaging

Paper Mills
- Fine Papers
- Recycled Paper
- Tissue Paper

Nuclear Facilities
- Nuclear research
- Nuclear training facilities

Chemical Plants
- Silicones
- Formaldehyde
- Methanol
- Pharmaceutical research and development
- Pharmaceutical production
- Biotechnology research and development, production

Industrial Plants
- Nanotechnology production
- Nanotechnology research and development
- Packaging production
- Personal Protective Equipment manufacturing
- Armament Production

Mining Operations
Cement Plants
Research Facilities
Environmental Services
Power Generation – Hydroelectric, Coal
Fire Academies
Municipal Services
Airports
Construction

CTR has a warehouse full of rescue equipment, including multiple rescue boats. Depending on the needs of the client and our hazard surveys will depend on what equipment is required. Typical CTR Confined Space Rescue Equipment list:

Atmospheric Monitors, RAE Systems	Ventilation Fan (for actual emergencies only)
Rescue Rope, variety of lengths	Supplied Air Systems (SAR) and SCBA
Mechanical Advantage Rope Systems	Pulley systems
Anchor straps	Rope winch system
Tripods, bipods and monopods	Fall arrest rescue equipment
Patient packaging gear, SKED, SPEC PAK	Intrinsically safe radios and lighting
Edge protection	Reference material, iPads, onsite phone
Ascenders & Descenders	Additional hardware and software as needed

In addition to the rescue equipment, we have our own indoor training facility for rope and confined space rescue. Our props are utilized in clients' courses as well as in testing out new and prototype equipment and techniques as well as keeping our staff up to date.

The confined space rescue simulator has multiple levels, opening types, dimensions and space configurations. These include both vertical and horizontal access points, vessels with bottom openings, top openings and more. The simulator is also located in doors and allows us to train throughout the year, regardless of weather conditions.
We are also located just minutes away from the Hudson River and the Corning Preserve boat launch. This allows us to get out on the water and train, test new equipment and get it all back in service quickly.

There are also various other training props, including cell towers, firefighter survival, and lock out tag out in house. Our warehouse area stages equipment we utilize for HAZ-MAT, trench and collapse rescue courses, as well as rigging equipment for heavy duty operations.

As this space continues to evolve, we imagine many more possibilities. These include the capability to evaluate client's issue on site and re-create it in house, so we can practice performing a potentially difficult rescue within a safe area.

You can learn more about our site at the following links:
http://capitaltechrescue.com/capital-technical-rescues-new-indoor-training-facility/

https://www.firehouse.com/rescue/article/12146756/technical-rescue-training-facility-profile-capital-technical-rescue-safety

Standards

NFPA

350 - Guide for Safe Confined Space Entry and Work

This guide provides information to protect workers from confined space hazards. It supplements existing confined space regulations, standards, and work practices by providing additional guidance for safe confined space entry and work. References are provided throughout the guide and annexes to direct the reader to other regulations and standards or other content that might be applicable. NFPA 350 bridges the gap from vague OSHA standards to industry best practices. This includes information to identify, evaluate and assess, and then eliminate, mitigate, or control hazards that are present or may occur during entry. Information is also provided regarding training, qualifications and competencies required for personnel responsible for confined spaces. It also provides information on confined space rescue best practices.

1006 - Standard for Technical Rescue Personnel Professional Qualifications

This standard identifies the minimum job performance requirements (JPRs) for fire service and other emergency response personnel who perform technical rescue operations. We utilize this standard to ensure that our training programs provide you with the knowledge and skills to meet current national standards. This standard applies directly to you, the individual rescuer.

1670 - Standard on Operations and Training for Technical Search and Rescue Incidents

This standard identifies and establishes levels of functional capability for efficiently and effectively conducting operations at technical search and rescue incidents while minimizing threats to rescuers. It is intended to help the authority having jurisdiction (AHJ) assess a technical search and rescue hazard within the response area, identify the level of operational capability, and establish operational criteria. This is known as an "organizational" standard and specifies what your organization should do and know for technical rescue incidents.

1983 - Standard on Life Safety Rope and Equipment for Emergency Services

This standard specifies requirements for life safety rope and associated equipment used to support emergency services personnel and civilians during rescue, firefighting, or other emergency operations, or during training. It is imperative to understand that this is not a "use" standard. This standard is known as a "manufacturers standard" as it defines how equipment should be made, tested, labeled and documented. Within NFPA 1983 come the terms "General Use" and "Technical Use" which relate to ratings of the specific equipment.

1858 - Standard on Selection, Care, and Maintenance of Life Safety Rope and Equipment for Emergency Services

NFPA 1858 is written for organizations that evaluate the risks faced by emergency responders and their particular needs for life safety rope and equipment. It is also written for users of life

safety rope and equipment to enable them to inspect, maintain, and care for the life safety rope and equipment they use during rescue and training operations that is compliant with NFPA 1983, *Standard on Life Safety Rope and Equipment for Emergency Services*.

NFPA 1858 applies to life safety rope, escape rope, fire escape rope, fire escape webbing, escape webbing, throwlines, moderate elongation laid lifesaving rope, life safety harnesses, belts, auxiliary equipment, litters, and victim extrication devices certified as compliant with NFPA 1983.

2500 - Standards for Operations and Training for Technical Search and Rescue Incidents and Life Safety Rope and Equipment for Emergency Services

This standard is going to be a consolidation of NFPA 1670, 1983 and 1858, and at the time of writing is not yet released.

OSHA

1910.146 - Permit Required Confined Spaces

OSHA 1910.146: Permit-required Confined Spaces, effective April 15, 1993 for general industry. Protects employees from the hazards of entry into permit-required spaces.

Confined Space Definition: 1) Is large enough and configured so someone can enter and work. 2) Has limited or restricted means for entry or exit. 3) Is not designed for continuous occupancy.

Permit-required Confined Space: Contains one or more of the following: contains or has the potential to contain a hazardous atmosphere, material with the potential for engulfment, configuration where an entrant could be trapped or asphyxiated or contains any other recognized serious safety or health hazard.

General Requirements: Employer is responsible to determine if spaces are permit-required, develop and implement a written program and inform exposed employees. In addition, employers must prevent employees from entering spaces they are not authorized to enter. A space may be reclassified as non-permit required if the only hazard is the atmosphere and continued ventilation is sufficient for safe entry, supported by monitoring and inspection data. Should a reclassified space have a hazardous atmosphere detected all employees must leave the space, re-evaluate and re-classify as permit-required if necessary. Eliminate conditions that make cover removal unsafe, promptly guard opening, perform atmospheric testing both pre-entry and periodic as well as ventilation. Contractors shall be given all information and hazards of spaces.

Permit System: Prior to entry being authorized, a permit shall be prepared and signed by the listed entry supervisor. Permits shall be posted and made available at the time of entry, at the point of entry. Terminate entry / permit when operations have been completed or conditions that are not allowed under the permit arise in or near the permit space. Retain permits for one year

and note any problems encountered on the permit. Review the permit space program using the retained permits annually and revise the program as necessary to ensure that employees are protected from permit space hazards.

Entry Permit: Contains the following information – Name / Location of space to be entered and the purpose. Entry date and authorized duration of entry. Authorized entrants, attendants and entry supervisor. Space hazards, control methods, acceptable entry conditions, test results and rescue services. Communication procedures in place, equipment used, additional information for safe entry and additional permits (such as hot work).

Training: Employer shall provide training to affected employees, before assignment of confined space duties, change in duties, change in permit program, or any deviations or inadequacies from procedures. Training shall establish employee proficiency, training certified by employer with documented names of trainees, trainers and the dates of the training. Employer must have this documentation available for inspection and provide annual training.

Entrant Duties: Know the hazards of the space, signs and symptoms of exposure, behavioral effects of hazards, proper use of equipment and communicate with the attendant when recognizing any warning sign or symptom or a prohibited condition is detected. The entrant shall exit from the space whenever an order to evacuate is given, recognizing any warning sign or symptom of exposure, or detecting a prohibited condition.

Attendant Duties: Know the hazards of the space, signs and symptoms of exposure, behavioral effects of hazards, accountability of entrants, remain outside of the space until relieved by another qualified attendant, and communicate with the entrants to monitor their status or order them to evacuate. The attendant should monitor activities inside and outside the space, and evacuate the space if they detect prohibited conditions, behavioral effects, any situation that could endanger entrants, or cannot effectively and safely perform their duties. The attendant should also summon rescue or emergency services, warn unauthorized persons to stay away from the confined space, perform non-entry rescues, and performs no other duties. The attendant should never enter the space, especially if one of the entrants has become incapacitated.

Entry Supervisor: Know the hazards of the space, signs and symptoms of exposure, behavioral effects of hazards. Verifies the permit is complete prior to allowing entry and will terminate entry and cancel the permit as appropriate. Verifies that rescue services are available. Removes unauthorized individuals. Determines that entry operations remain consistent with the entry permit and that acceptable conditions are maintained whenever responsibility is transferred, or other intervals dictated by the hazards and operations.

Rescue Services: Personnel must be trained in: Entry procedures, PPE and rescue equipment, have annual rescue training, and basic first aid and CPR. They must have access to train in permit spaces they are expected to perform rescues in, and they must be notified of the particular confined space hazards.

Rescue Personnel Requirements: The team must consist of members who meet the physical and mental requirements. Rescue is a very demanding task on both of these levels and members should train to deal with issues that may occur on these levels. There must be enough personnel to fill all the required positions to safely and effectively perform the rescue, and they must be trained to the level of response they are expected to encounter. They must also be knowledgeable about the outside resources that are available to them during a confined space rescue.

Non-Entry Rescue: Retrieval system shall be utilized unless equipment increases risk or will not contribute to the rescue. Typically, a mechanical device anchored outside of the space. Entrant shall use a full body harness and attach the retrieval line to the dorsal ring, above head, and any point the employer can prove successful rescue. Wristlets are acceptable if the employer can demonstrate that a harness is not feasible or creates a greater hazard. Applicable SDS sheets must also be available.

Employee Participation: Employers shall consult with employees to develop and implement the permit program and make available to them the information required by the standards.

1910.147 - Control of Hazardous Energy (Lockout/Tagout LOTO)

This standard covers the servicing and maintenance of machines and equipment in which the unexpected energization or startup of the machines or equipment, or release of stored energy, could harm employees. This standard establishes minimum performance requirements for the control of such hazardous energy.

Isolation Procedure: Prepare for shutdown. Notify all affected workers. Shut down equipment. Isolate equipment. Apply lockout / tag out and bleed or block. Control stored energy. Verify equipment isolation (try out).

International Technical Rescue Association (ITRA)

About ITRA

The International Technical Rescue Association is a non-profit trade association, established by technical rescue practitioners for technical rescue practitioners. We exist to provide global recognition of technical rescue practitioners including instructors. We have developed a global syllabus to compliment national standards, allowing local flexibility with global recognition.

ITRA currenty has approved and deployed curricula for the following rescue disciplines:

- Rope
- Swiftwater
- Boat

- Confined Space

CTR encourages students to take our ITRA courses and to become active members of ITRA.

As a member of ITRA you become part of a collaborative and supportive worldwide trade association that can provide instruction and assessment against global certifications across a range of disciplines and levels. It demonstrates that you are committed to excellence and high standards set by our Code of Conduct, providing external credibility and accountability.

Membership also provides opportunities to be involved in a range of association projects, from governance on the Board, to serving on committees and working groups.
We also envision numerous national and international opportunities from exchanges and conferences becoming part of the future too.

ITRA is now governed by a Board of Directors who were elected by the ITRA membership and who serve three-year terms. Previously, an interim Steering Committee was established to stand up the association and provided initial governance.

CTR has ITRA certified instructors, which means that they have been assessed in both skill and knowledge and have actually performed each of those skill sets to the ITRA standards. These are not just course attendance certificates and ITRA instructors and students can be verified for their current qualifications in the ITRA directory.

To find out more about ITRA or to become a member check out the ITRA Website

PURPOSE: WHY ITRA?

- To promote international best practices and standards for technical rescue.
- To improve the global portability and recognition of professional rescue qualifications.
- To provide local flexibility in delivering technical rescue training curriculum.

VISION, MISSION & VALUES

VISION : Our Hope

- A collaborative and professional global technical rescue industry.

MISSION : What we do

A. Recognize and document locally delivered training according to global best practice.
B. Provide Independent competency-based assessment for instructor and technical rescuers.
C. Maintain a global central database of training records for members.
D. Share safety related lessons learned from technical rescue activities to prevent harm.

VALUES : How we do it

Accountability:

1. Training and assessment systems developed by industry for industry.
2. A non-profit entity that is driven by and accountable to its membership.
3. Instructors and Practitioners maintain their currency through robust re-certification process.
4. Members acting professional and accountable under a Code of Conduct.

Transparency:

1. Meaningful and genuine consultation with members on our work.
2. Active use of social media to engage and keep members informed.
3. Annual disclosure of our activities and finances to our members.
4. Public register of qualified practitioners, instructors and assessors.

Working together:

1. To share knowledge, skills, and experiences across all disciplines of technical rescue.
2. Establish an international reporting system to highlight safety concerns within the industry.
3. To review and enhance rescue and rescue related training and assessment standards.
4. To foster collaborative interaction and professional development within the industry.
5. Membership adds value to individuals and organizations.

Legal Status

The International Technical Rescue Association is a non-profit corporation, registered in the state of Pennsylvania, USA.

Rope Rescue Equipment

NFPA 1983 Overview

As mentioned earlier, this is a manufacturing standard and not a use standard, however understanding what the certifications of NFPA 1983 mean helps guide us in the purchasing of quality products.

- NFPA G Rating - General Rating - Minimum breaking strength of 9,000 lbs
- NFPA T Rating - Technical Rating - Minimum breaking strength of 6,000 lbs
- Most hardware is good as long as it passes inspection, which should also include function tests where applicable.
- Most software is good for up to 10 years from the date of manufacture.
- NFPA 1983 also addresses:
  - Labeling on equipment
  - Record keeping and requirements

Definitions

kN – Kilonewton – The Newton is a measure of force
1 kN = 1000 Newtons
1 kN = 224.8 lbf (pounds of force)

Often, we consider 1 kN to equal the weight of 1 average person. Certainly, that can fluctuate, but in simple terms when considering how much weight or force a rope or piece of equipment can handle, if it is rated at 10 kN (2,224 lbf), that is approximately the weight of 10 people.

MBS – Minimum Breaking Strength

Carrier Count - This refers to the number of different yarns that are braided around the core of the rope to form the sheath.

Hand - The "hand" of the rope is a reference to how soft or supple the rope is. Typically, a supple rope will be considered to have a soft hand, versus a stiff rope that has a hard hand.

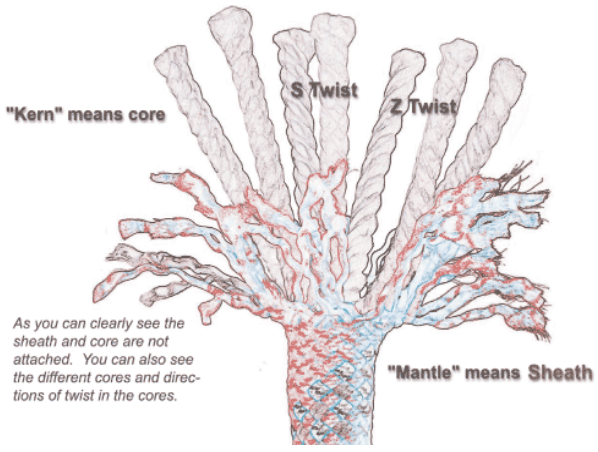


Photo Credit: NRS.com article - Know the Ropes

Kernmantle – The construction style of the rope where the "Kern" is the core, while the "Mantle" is the sheath. The core typically supports the major portion of the load, while the sheath primarily protects the core and supports a portion of the load.

Static Kernmantle Rope – A life safety rope with a maximum elongation of 6% at 10% of its minimum breaking strength. It is the primary type of rope used in technical rescue due to its low elongation, making it efficient for use in lowering and raising systems.

Dynamic Kernmantle Rope – A life safety rope with an elongation greater than 25% at 10% of the minimum breaking strength. These ropes are typically used by climbers since they help absorb the shock of a fall with their high elongation. Technical rescue teams specially trained in lead climbing, tower rescue and rescue from other structures may choose a dynamic rope over a static because they anticipate the potential of a fall.[1]

Rope / cordage construction & features

Suppleness vs. durability
The softer the hand of a rope the easier it is to knot typically. A stiff rope that has a hard hand, will be more difficult to work with and tie knots. Think about how difficult it would be to tie a knot in cable versus a softer rope. Typically, the more supple the rope the less durable it maybe. A stiffer rope will be more like cable and therefore will be more durable. Manufacturers all try to balance this with different techniques in making the ropes including coatings, treatments, fiber tensions, directions of the twists and more.

Each bobbin is a yarn that is being braided around the core of the rope to form a sheath.

High carrier count vs. low carrier count
Ropes with a higher carrier count will typically have a softer hand, while a lower carrier count will have a harder hand. Carrier counts in Static Kernmantle ropes typically range from 16 - 48 carriers. This means that there could be anywhere from 16 to 48 different yarns braided around the core of the rope to make the sheath. This will also affect how smooth or flat the surface of the rope is. The last video link below has the most in-depth explanation of all the factors of how ropes are made.

The 2 main construction characteristics that effect the performance characteristics are the number of carriers in the sheath and how much twist is in the bundles that make up the sheath and the core.

[1] Cordage Institute, Terminology for Fiber Rope

A rope with a high carrier count will have a thinner sheath and larger core, lending itself to a less durable rope with low stretch. The opposite being true of a low carrier count rope with a thicker sheath, more durability with a thinner core and more stretch. This primarily the result of a larger portion of the mass of the rope running straight in a high carrier count rope, transferring the energy in a straight line through the mass of the rope.

With a low carrier count rope there is more mass running at angles to the transfer of energy and those fibers need to straighten and bind on other fibers before holding the load, leading to more elongation.

Twisting the bundles that make up the sheath and the core adds structure, a firmness, to the body of the rope. Less twisting will typically result in a very low stretch rope, but it will feel "mushy" and tend to flatten over edges and through devices.

The amount twisting of these fibers also imparts some stretch to the rope. Adding a lot of twists to these bundles is how a dynamic rope functions as the materials are the same as the fibers used in static ropes.

Common Materials

- Nylon
  - Loses strength in water.
  - More stretch compared to polyester and aramid fibers
- Polyester
  - Unaffected by water
  - Low stretch
- Aramid (i.e. Technora)
  - Unaffected by water
  - Low Stretch
  - High Abrasion/Heat resistance
  - High strength fibers
    - 3 times stronger than nylon / polyester
  - Low resistance to shock

Videos:

How Ropes are Made
By: BlueWater Ropes

How Climbing Ropes are Made
New England Ropes

How is Climbing Rope Made?
By: Sterling Ropes

How Climbing Ropes are Made: Inside / Out
By: WeighMyRack - @Edelrid Ropes

Common Diameters / Sizes & Uses

- 10.5 - 11.5mm (7/16") Static Kernmantle Rope
  - May be NFPA T rated at 20kN - some are G rated depending on construction
  - Primarily used in industry, technical rescue teams and gaining popularity within the fire service

- 12.5mm (1/2") Static Kernmantle Rope - NFPA G rated at 40 kN - common rope diameter used in fire service.
- 6mm technora cord - used for tiebacks - rated for 21kN
- 8mm prusik cords - used as rope grabs, mini-haul systems, accessory cord, sewn cord used as anchors
    - Rated at 15 kN as a single part
    - Cords tied into a prusik loop with a double fisherman's have a theoretical rating of up to 50% less than 15 kN
    - Sewn cords in a bound prusik loop rated at 20 kN
- 1" Tubular Webbing - rated at approximately 19kN [2]
- 1" Flat Webbing - rated at approximately 26kN[3]

The practice of hand tying prusiks should be eliminated completely. Sewn bound loop prusiks offer a level of safety that far exceeds the cost savings of making your own.

Rated sewn terminations can be used as anchor straps with a degree of certainty that un-accounted for hand tied prusiks cannot.

Sewn anchor slings should be used wherever possible for the same reasons.

[2] CMC Rescue
[3] CMC Rescue

Knots / Bends / Hitches

These knots, bends and hitches are the common ones we utilize in rope, water and confined space rescue. There are many ways to tie each of these, and it is always good to know several ways to tie each.

A knot has many definitions, but for our purposes it is an intentional complication in rope, cordage or webbing which has a practical application. A bend is a type of knot that ties 2 ropes ends together, while a hitch is a knot which secures a rope, cord or webbing to another object.

A bight is a fold in a piece of rope so that the two parts lay alongside each other. This is often used to form a loop, as when we tie the "figure 8 on a bight". We make this bight, or loop sized appropriately for the task. We refer to the size of the loop or bight, as the "gain" of the knot. The gain is the overall size of the knot. The larger the gain, the larger the loop. In confined space rescue we often try to tie our knots so the gain of the knot is small enough to just clip in two carabiners. This allows us to maximize our lifting height, because if we had a knot with a large gain, and our overhead clearance was low, we could potentially not be able to get a rescuer or victim out of that space.

The working end of the rope refers to the "short" end, the part doing the knotting or the work, or the part under load. It is also referred to by some as the "running end".

The standing end of the rope is the long part of the rope, or the part not knotted, or the "free" end of the rope.

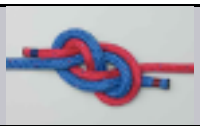
The bitter end refers to the tail end of the standing end of the rope.

Typically, regardless of the knot, bend or hitch we de-rate the breaking strength of the rope a minimum of 30% but more often de-rate it at 50%. This is because there is such a variation in the materials used in rope construction, strength loss of various knots, and condition of the rope itself – new versus used. De-rating the rope at 50% ensures that we have considered all of these factors.

Anything we tie must be easily identifiable by everyone involved. Clean and well-dressed knots, bends and hitches help us quickly inspected our system and ensure we are ready to proceed. Unless noted in the table below, we do not use "safety" knots when tying the majority of these. Instead, we follow a few rules:

- Tails in rope should be 6" or length of hand
- Tails in webbing should be 4" or width of hand
- Knots should be well dressed, set and easily identifiable

Scan the QR codes below with your camera app, or just tap on the QR Code on your mobile device and it will bring you to a video on how to tie that knot.

Rescue Knots / Bends / Hitches and their uses		
Photo / Name	**QR / Alternate Names**	**Uses**
		Stopper knot, used in the terminal end of a rope
Figure 8	Figure 8 Stopper, Flemish Knot	
		Creates a loop to anchor the end of a rope. Loop typically should only be large enough to accommodate 2 carabiners. Tail should be the length of your hand, if it is longer you can tie it off.
Figure 8 on a bight		
		Creates a loop in the end of a rope going through a ring, carabiner, harness, object, anchor point etc. Tail should be the length of your hand, if it is longer you can tie it off.
Figure 8 Follow Through		
		Joins two ropes together Tails should be the length of your hand, if it is longer you can tie it off.
Figure 8 Bend	Flemish Bend	
		Creates a loop / attachment point in the middle of a rope. Can also isolate a damaged section of rope.
Butterfly	Alpine Butterfly	
		Join two ends of ropes together. Binding knot, often used in the terminal end of patient packaging devices. It is imperative that a safety knot is tied on either side of the knot, right up against it.
Square Knot	Reef Knot	

Rescue Knots / Bends / Hitches and their uses		
Photo / Name	**QR / Alternate Names**	**Uses**
		Stopper knot, typically used up against another knot, such as the square knot.
Overhand Knot		
		Stopper knot, used in the terminal end of a rope. It is also the basis for several other knots and is used as a safety in conjunction with other knots.
Double Overhand Stopper		
		Used to place limbs as wristlets, must be backed up to ensure locking action. This knot can cause potential trauma and only should be used when other methods are not available/practical.
Handcuff Knot	Texas/California Love Knot, Hobble Knot	
		Joins two ropes of similar size together, often used to create Prusik loops.
Double Fisherman's Bend	Grapevine Bend	
		Typically a temporary holding hitch, easily adjustable. This hitch does slip and should be backed up.
Clove Hitch - Rope End		
		Two opposite hitches are created and dropped over an object to create this hitch. Typically a temporary holding hitch, easily adjustable. This hitch does slip and should be backed up.
Clove Hitch - Half Hitches	Drop Over Clove	

Rescue Knots / Bends / Hitches and their uses		
Photo / Name	**QR / Alternate Names**	**Uses**
		Anchor around a post or tree for a static rope, can be used for rappelling or a static safety line. No strength degradation of rope. Post diameter should be at least 8 times the diameter of the rope, typically at least 3 full turns around the post. Can be secured with a carabiner or a figure 8 follow through.
Tensionless Hitch		
		Can be used to tie off descenders. Attention must be paid to the tail strand to be pulled on is away from the device.
Slip Knot	Slipped Overhand Knot	
		Triple wrapped loop of cord for system loads, this creates friction on a rope and can be used as a rope grab. Double wrapped are only suitable for a single person load such as ascending, and should never be used in systems.
Prusik Knot	Triple Sliding Hitch, Prusik Hitch	
		Utility knot creating a loop in rope or webbing, either in the end or the middle. No life loads in rescue.
Overhand Knot on a Bight		
		Forms a bight in the end of the rope that will cinch down the bight. This is useful when you need a carabiner to be loaded upon the spine to keep it from easily side loading the gate or to the becket of a double pulley when using it at the dead end of a mechanical advantage system.
Poachers Knot / Double Overhand Knot	Strangle Snare	Triple wrap is known as a Scaffold Knot

22 Mill St., Unit 2, Albany, NY 12204 T 518-930-4500 F 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

Rescue Knots / Bends / Hitches and their uses		
Photo / Name	**QR / Alternate Names**	**Uses**
		Used with webbing or rope to attach a sling or loop around a bar, ring, or other attachment point. This hitch significantly weakens slings. If using to join two slings together, it maybe better to use a carabiner.
Girth Hitch		
		Attaches two ends of webbing together by rethreading one end through an overhand tied in the other side. Tails should be at least the width of your hand.
Water Knot	Ring Bend, Tape Knot, Overhand Follow Through	
		Allows for controlled descent with minimal hardware
Munter Hitch	Italian Hitch	
		Load releasing hitch, using 33' (10 meters) of 8mm static cord
Radium Release Hitch		
Photo / Video Credits: AnimatedKnots.com, REI.com, CMC.com		

Rope Rescue Hardware

Descent Control Devices

Descent control devices (DCDs) or descenders are the basis of many of our systems for both lowering and raising systems. Traditionally people have thought of simple descenders only for things such as rappelling, however over the past 25+ years more modern devices have been brought to the market and allow for many more features. These legacy type of descenders are still in use by many teams, however they don't have some the inherent safety and efficiency the modern devices offer us.

- Legacy DCDs
    - Features
        - Pros
            - Works mostly with any diameter of ropes
            - Friction based / little to no moving parts
        - Cons
            - Lighter / Cheaper
            - Used for lowering / rappelling only
            - Must be tied off to go hands free
            - Require the rope to be removed when changing over to an ascending or raising system
            - No built-in progress capture
    - Examples
        - Figure 8 with Ears (Rescue 8)
        - Brake Bar Rack
        - SCARAB

- Modern DCDs

These are the only descent control devices we utilize in our classes unless there is a specific reason / application to use a legacy device. These devices are generally known to be safer and more efficient than legacy devices.

- Features
    - Pros
        - Auto-locking devices - operator can let go and the device automatically stops any descent
        - Automatic progress capture - acts like a ratchet - and allows you to take tension off your hauling or ascending system to rest or reset without any rope sliding back through the device

- No need to remove the rope from the device during a change over to a raising system
- Some have integrated pulleys and beckets to incorporate as part of a mechanical advantage system
- Additional safety features depending on device
- Some can operate as a belay device or a "twin tensioned" device

▪ Cons

- Heavier
- Only compatible with specific diameter of ropes
- More Expensive

o Examples

			
Petzl ID'L	Petzl Maestro L	CMC / Harken Clutch	CMC MPD

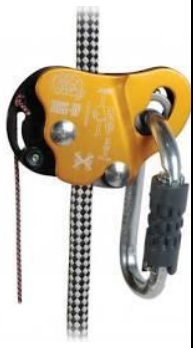
Photo Credit: Petzl & CMC Stock Photos

Backup / Safety Devices

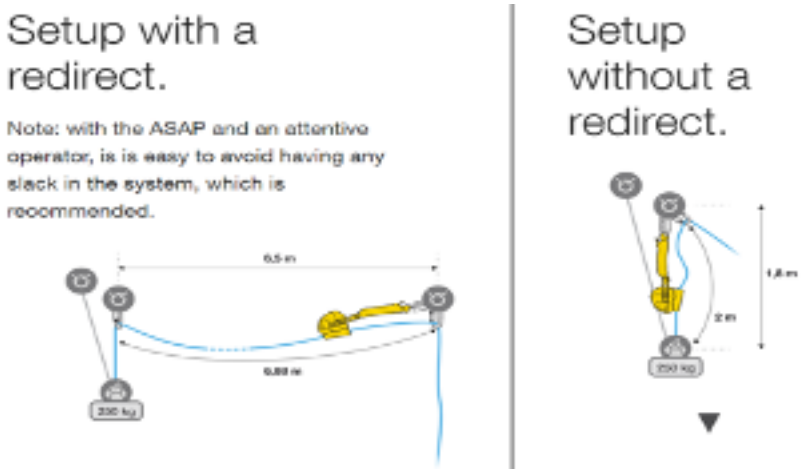
Backup devices are an option to utilize as opposed to a traditional belay or twin tensioned system that utilizes a descent control device on the second line attached to the rescuer. These devices work in a similar fashion to seat belts. The devices move freely on the rope, without the need for the rescuer to tend to them, and in the event of a shock or sudden movement the device locks up on the rope and stops the rescuer.

Most backup devices on the market are specific to rope diameter, with the exception of the Petzl ASAP and ASAP Lock. The Petzl ASAP series works with both 11mm and 12.5 mm rope, and when coupled with the proper shock absorbing lanyard, is rated for two person loads.

Video:
Petzl ASAP / ASAP Lock
By: Petzl

			
Petzl ASAP installed correctly on rope	Petzl ASAP Lock	Petzl ASAP'Sorber Axess 2 person lanyard for use with ASAPs	Kong BackUp (11mm only)
Photo Credit: Petzl and Kong stock photos			

The Petzl ASAP series can be used as a personal device (attached to the rescuer), or at the anchor as part of a system, given that there is a second carabiner at the anchor to help keep the rope oriented and feeding into the ASAP properly, and that there is at least 10' from the anchor to the edge / change of direction.



From Petzl Tech Tip web page

Rope grabs

Rope grabs are devices that do just that, grab onto the rope. We utilize them most often to help create hauling and ascending systems. There are many types of rope grabs, including both hardware and software based.

Software Rope Grabs

Prusik Cord - Traditionally we used 8mm cord for 12.5mm rope that we tied into a loop with a Double Fisherman's Bend and created a prusik hitch. These hand tied prusik loops were often tied incorrectly or at different lengths based upon who tied them. Additionally, they were not truly rated and did not allow for easy inspection. We have instead moved towards sewn prusik loops, which are manufactured and rated.

- Pros
  - Inexpensive
  - Lightweight
- Cons
  - More expensive
  - Lightweight
  - Tend to slip on wet / muddy ropes

Hardware Rope Grabs

- Styles / Features
  - Smooth cam
    - "Smooth" in that the teeth are not sharp, and are less aggressive
  - Toothed cam
    - Teeth are sharp / more aggressive
  - Captive / non-captive devices
    - Captive - rope is fully enclosed in the rope grab and can't come out
    - Non-Captive - rope is not fully enclosed in the rope grab
- Pros
  - Rated device
  - Typically, fast to install and remove from rope
- Cons
  - Can damage rope if shock loaded
  - Heavier
  - More Expensive

			
Petzl Rescuecender Smooth Cam, Captive	CMC Ascender Smooth Cam, Captive	CT Handled Ascender Tooth Cam, non-captive, captive with carabiner	Petzl Croll Tooth Cam, Non-Captive
Photo Credit: Petzl, CMC, CT stock photos			

Anchor straps

There are a variety of rescue rated anchor straps on the market, and many teams still elect to tie their own with 1" tubular webbing. A rated anchor strap can be fixed, or variable in length and may or may not have metal hardware as connection points on the ends of the straps. Fixed anchor straps typically come in a variety of lengths, while variable straps usually only have one option for the range of lengths they will handle. Metal hardware on the ends of anchor straps may be identical on each end, which will not allow a choker configuration, or may be designed with one end of the strap having a larger metal "eye" that allows you to pass the other end of the strap through the eye, creating a choker.

Anchor straps are typically used and rated in 3 configurations

Choker
- Typically, the weakest configuration
- Cinches to anchor / object

Vertical
- Inline / standard strength
- Not often used in rescue

Basket
- Strongest configuration

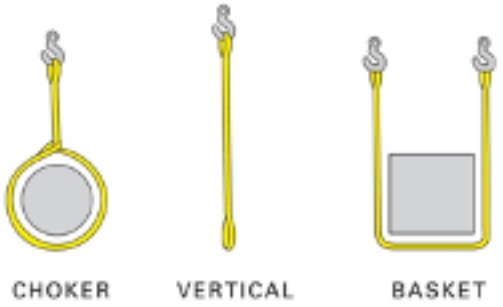


Photo Credit: Doleco-USA

		
CMC ProSeries Anchor Strap	Bluewater Rhino Sling	PMI Vari-Rigger

Photo Credit: CMC, Bluewater Ropes, PMI stock photos

Carabiners

One of the most important components of our systems is the carabiner. This allows us to connect two or more pieces of gear together. There are more options for carabiners than any other component in our systems and choosing and purchasing a compatible one is very important.

Carabiners are made either of Aluminum or Steel, with aluminum traditionally being NFPA T rated with steel holding a NFPA G rating. This however, has also evolved and there are now many lightweight aluminum and lightweight steel carabiners that are NFPA G rated.

Anatomy:

Photo Credit: Fusion Climb

The shape of a carabiner is also important, especially when it comes to device compatibility. The most common are the 4 below.

			
Oval	D	Off set D	Pear

Photo Credit: RockExotica and OmegaPacific stock photos

There are a variety of types of gates and locking mechanisms for those gates on the market. In the rescue world we typically use one of the following styles below. It is important to note that the 3 carabiners below are all made by KONG and are actually all the same style and model of carabiner, but with three different locking mechanisms.

		
Screwgate	Twist Lock	Triple Lock

Photo Credit: Kong stock photos

Nose

Most modern carabiners manufactures have changed the "nose" of the carabiner to a Key Lock style to keep the carabiner from snagging on various other items it comes into contact with. Previous designs included open hooks on either the nose of the carabiner or the top of the gate.

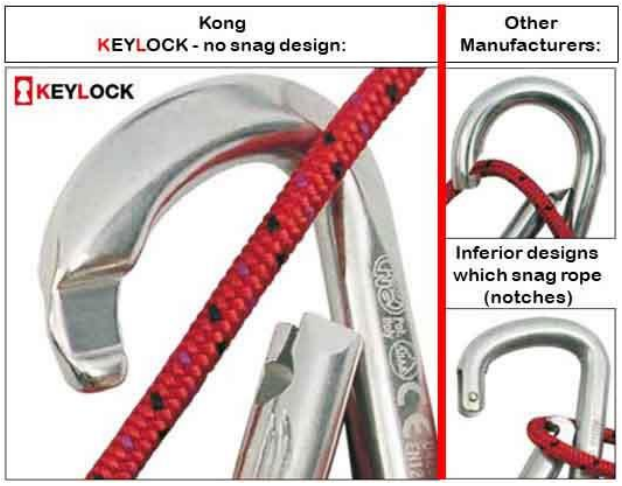


Photo Credit: Kong

Captive eye

Carabiners may also have a permanent or temporary “captive eye”. This ensures the carabiner doesn’t get side loaded but may also be utilized on systems where you don’t want the user to be able to easily remove the carabiner from that component of the system. Pre-rigged 4:1s are an example of where these maybe used.

Photo Credit: Rock Exotica stock photos

Snap Hooks

We may also utilize snap hooks in some of our systems, which have both a captive eye and typically a double or triple lock mechanism to open up the snap hook.

Photo Credit: Kong

Labeling & Inspection

Carabiners must be labeled and rated for their appropriate certifications and strengths. The numbers will be marked on the spine of the carabiner and are now rated in 3 strength categories:

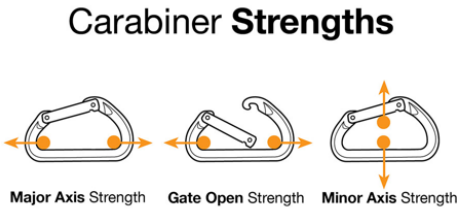


Photo Credit: Black Diamond

Inspection of the carabiner is fairly simple, examine it for any obvious damage, dirt or debris and ensure that it functions correctly by opening and closing it several times. If the carabiner does not close properly or auto lock if it is supposed to then it should be removed from service.

Harnesses

Modern rope and confined space rescue harnesses have a lot of features, with many brands available. For all industrial rescue teams and almost all fire service agencies we recommend utilizing a NFPA Class III rescue harness. There are several key features to consider when selecting a harness for team members.

The harness is considered Personal Protective Equipment (PPE) and as such what fits and works well for one team member may not work for another. Various body types, sizes and gender all play a role in harness selection. While most team members will fit in standard sizes, there are those rescuers who are outside of the standard small and large sizes. For these members a custom personal harness maybe necessary and are available from several manufacturers.

Harness Components and Considerations:

- Ventral Connection
  - Main connection at waist for descent control devices or main line attachment
- Sternal Connection
  - Back up device / belay connection point at the chest.
  - This is the preferred connection point for fall arrest systems to help prevent suspension trauma
- Dorsal Connection
  - Between the shoulder blades, traditionally used for backup / belay connections
  - Current OSHA requirements dictate to use this connection in fall arrest systems; however, the sternal connection is still our preferred connection point based upon industry research. In Europe, some manufacturers have eliminated the dorsal connection completely.
- Work Positioning Rings
  - Extra D-Rings on either side of the hips, that are used in conjunction with a work positioning strap or device to allow a rescuer to stand securely and still have their hands free to perform work. Think of a climber on a utility pole. There still must be some type of fall protection in place. This is especially useful on ladders and structural steel such as cellular and water towers.
  - You must always use both rings together, never attach to just one ring!
- Gear Loops
  - Gear loops are intended only to hang additional gear from and are not weight or load bearing
- Padding

Photo Credit: Petzl Stock Photos

- Most padding is removable and is a user preference for comfort

- Shock load indicator
  - Most modern rescue harnesses with dorsal connection points will also have a shock load indicator below the dorsal connection and is usually evident by the webbing between the chest and waist harness being folded over and stitched together. When activated a red label / flag comes out indicating the harness has seen an impact or shock load.
- Labels
  - All harnesses should have labels indicating the standards it meets, the sizes, date of manufacture as well as the ratings for the various connection points.
  - An inspection log is also included in the label.
- Inspection
  - Look for signs of excessive wear, tearing, discoloration in webbing and stitching, check hardware for any gouges and deformities. If any doubt, remove from service. Follow the manufacturers guidelines.

Photo Credit: Petzl

Photo Credit: Petzl

- Adjusting the harness
  - Tighten waist of the harness so the two straps are even with each other. You should just be able to slip in 2 fingers between the webbing and your body.
  - Adjust the chest harness so that you can reach over your shoulders and touch the dorsal connection ring. That should be positioned between your shoulder blades.

- If you are going to be suspended by the harness for any length of time, tighten the chest so you can just slip in two fingers.

Manufacturer Resources

Petzl Harness Inspection Procedure

Petzl Inspection Form

Petzl - Tips for Protecting Equipment - Harnesses

Petzl AVAO Harness Technical Notice

AZTEKs / Set of Fours / Mini-Haul

These terms are utilized interchangeably to refer to a small, pre-rigged mechanical advantage system made from small diameter rope, pulleys, and a progress capture device. Typically, these are 8mm cord, two double pulleys and prusiks, but may also incorporate a cam-based capture device, smaller cord and even triple pulleys to increase the overall potential mechanical advantage. The cord varies in length and allows for a system to extend out anywhere from 3' up to just over 10', by utilizing 30' - 50' of cord.

Photo Credit: Sterling Stock Photo

An AZTEK is the Arizona Technicians Edge Kit, which is a product name and distributed by several companies and configured with various options. A "Set of Fours" (SOFs) is also referring to the same idea as the AZTEK in that we are using rope that is weaved into two double pulleys, giving the appearance of four ropes. The AZTEK kit has over 100 documented variety of uses in rope rescue, most of which also apply to other companies "Set of Fours" or any mini-haul system, regardless of the actual mechanical advantage of the system.

			
Sterling Elite AZTEK Kit	SMC Advance Pulleys	Bluewater Ropes Mini-Haul	PMI Mini-Haul
Photo Credit: Sterling, SMC, Bluewater Ropes and PMI stock photos			

	
Petzl JAG System	ISC MiniHaul 6:1 / 7:1
Photo Credit: Petzl and ISC stock photos	

The AZTEK and various Set of Four (SOF) kits we carry have some great uses, but we also must recognize some of the limitations we encounter when utilizing the AZTEK.

The configuration of these kits typically includes either 40’ or 50’ of 8mm cord.

This allows for up to about 8' - 12’ maximum useful lifting height as we must take into account the rope around pulleys, the sewn termination and enough haul line left to be able to grip to begin a haul when fully extended.

Common Uses and Limitations of AZTEKs / Set of Fours

Primary Use	Limitations	Alternative Equipment / Considerations
Personal Travel Restraint	Must be setup, equipped and utilized properly, NOT fall protection, can fail	Grillon / work positioning lanyard
Short M:A System	Less than 10' - 12' of overall haul. Must account for anchor height, depth of confined space and clearance. Can be difficult to haul a rescue load vertically gripping 8mm cord by hand. (consider using ascenders on harness). Should only be used when other options not available, space truly dictates a small system.	Build a drop loop 5:1 system with shorter rope, build a 4:1 Maestro haul system with pull cord and length of 11mm or 12.5mm rope
Piggyback M:A System	Need to ensure progress capture by tending the rope through the progress capture device, could cause too much M:A if piggybacked onto another M:A System. Can be difficult to haul a rescue load gripping 8mm cord by hand. (consider using ascenders on harness)	Staggered 9:1 (3:1 built on a 3:1)
Adjustable Litter Bridle	Extra rope all over, consider using shorter ones, overkill if not needed, and utilizing a valuable piece of gear	Manufactured bridle, grillon / work positioning lanyards
Litter Attendant	Can be overkill, and utilizing valuable piece of gear	Petzl ID, Grillon, any descender
Adjustable / Vectored Anchors	Can be overkill, and utilizing valuable piece of gear	Petzl ID, GriGri, Grillon, TieBack Cords
Change of direction / deflections and line vectoring	Can be overkill, and utilizing valuable piece of gear	Petzl ID, GriGri, Grillon, TieBack Cords
Adjustable belay height	Can be overkill, and utilizing valuable piece of gear	Grillon / work positioning lanyard
System Knot Passing	Training and ensuring that you account for the length you will need to accommodate the knot passing	This is one of the best places for this gear. Other M:A systems can be utilized though.
Pick Off System	Heavy and can be overkill.	Grillon / work positioning lanyard / Counterbalance foot loop
Tie Back	Can be overkill, and utilizing valuable piece of gear, anchors must be close, but very fast to setup.	Petzl ID, GriGri, Grillon, TieBack Cords

Videos from Rock Exotica

AZTEK uses:
https://youtu.be/mY2EyXczDhU
Note that it shown as a replacement for a standard 4:1 system, due to the overall length limitations, especially with an overhead anchor and a confined space with additional depth.

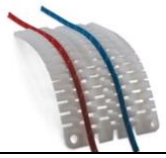
AZTEK and Mechanical Advantage:
https://youtu.be/9JszpXjcjEg
Again, it should be noted that its use for mechanical advantage is typically as an add on system, and not the primary system (although it may work)

Edge Protection

In either the natural or manmade environments, the edges our ropes run over can cause them to fail. This could be due to sharp edges, abrasive surfaces, hot surfaces and more. The edges also add friction into our system making it more difficult to haul. Ropes should be protected with edge protection wherever it is needed with the proper type of edge protection.

Edge protection should always be tied off to ensure it doesn't fall onto those working below it. The protection maybe made of soft materials such as canvass or firehose, plastic, or even metal rollers.

Edge rollers should be utilized any time moving rope goes over the first severe edge, such as a parapet wall. Canvass pads shouldn't be relied on alone in these situations, even some of the newer, heavier duty ones can't protect the rope or the edge pad itself from damage in these situations. Plastic options maybe OK to protect the rope, but there will be a loss in efficiency.

			
CMC Edge Pad	CMC Ultra-Pro Edge Protector	Petzl ProTec Plus aka Rope Snake	Petzl Roller Coaster
Photo Credit: Petzl & CMC Stock Photos			

Fall Arrest System

A fall arrest system is designed to stop a fall that has already begun. Twin lanyards for climbing structures and the Petzl ASAP with shock absorber maybe considered fall arrest systems. Once

the fall occurs those devices lock up and / or have shock absorbers that are designed to absorb the energy of the fall to minimize injury. Fall arrest systems are really a last resort since a fall may still be able to occur. Other systems maybe better suited for the application.

Edge / Travel Restraint

Edge restraint, fall restraint / travel restraint, edge restriction, travel restriction are all terms used to describe a single point anchor system that is attached to the harness and keeps the user from reaching the edge of a cliff, roof, or other fall hazard. These can be adjustable work positioning lanyards such as the Petzl Grillon, or as simple as tying a knot in the rope that won't allow you to fall off the edge.

Work positioning systems

A work positioning system is an engineering control that limits the distance of free fall to two feet or less, reducing the risk of injury due to a fall to a lower level. This type of system supports the rescuer on an elevated vertical surface, such as a tower, ladder, bridge, pole, or other structure, and allowing them to work hands free.

It must also be utilized with a personal fall arrest or belay system. This could be a backup device such as a Petzl ASAP, a traditional belay system, or a set of twin or Y fall arrest lanyards.

The system consists of an anchor, a body harness with work positioning rings, and a lanyard specifically designed for positioning.

In the example shown, the rescuer is climbing a tower, wearing a Class III rescue harness with work positioning rings at his hips, and a Petzl Grillon work positioning lanyard. This lanyard is adjustable and allows the rescuer to get in a comfortable and optimal position to accomplish a task. The rescuer can work hands free and concentrate on the tasks, while also maintaining a Petzl ASAP on the blue rope as his fall arrest system.

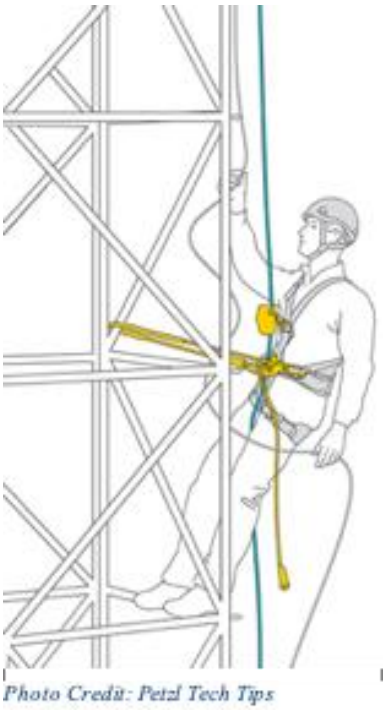


Photo Credit: Petzl Tech Tips

			
Petzl Grillon	Kong Trimmer	Petzl Connect Adjust	ISC RAD
Photo Credit: Petzl, Kong, and ISC stock photos			

Rope Rescue Techniques

Rope commands and communications

Any set designation of commands can be used as long as they are known to the entire team.

Any member can call "Stop" for any recognized safety issue. Proper sequence to ensure a team is ready for an evolution is important. As an example:

Technical Rescue Officer Asks: "Belay On?"
Belay Operator Responds: "On Belay."

Technical Rescue Officer Asks: "Main line ready?"
Main Line Operator Responds: "Main Line ready."

Technical Rescue Officer States: “Down” or “Up”

When utilizing radios, transmissions should be short and concise. Consideration should be given to operating on a designated channel to prevent cross-chatter and confusion. Radios can be difficult to use in areas of dense building materials, steel and concrete block radio transmissions.

Background noise and reverberations/ echoes can render conventional microphones ineffective; use of bone or throat microphones reduce background noise interference. Hearing protective headsets should be used in high noise environments to ensure communications can be heard as well as preventing distractions and hearing damage for rescuers.

In situations where radios or direct verbal communication cannot be used, a different system must be utilized and may include whistle signals as alternatives. Again, these communication systems should be simple commands and not be too verbose as to cause confusion to rescuers. It

is too easy to also chain words together that may have opposite meaning, and the recipient only hears the last part of the command, which may have not been the overall intent. We also want the commands utilized to be applicable across multiple disciplines of rescue. For example, if your team does rope and confined space rescue and interacts with a team that does swiftwater rescue you want to have these simple commands that will work across these disciplines.

Effective communication involves two key parties: the sender, who conveys the message, and the recipient, who receives it. To ensure that the message has been understood correctly, it is important for the recipient to repeat back the information. This practice helps confirm clarity and reduces the risk of misunderstandings.

These commands are our preferred method of communications in many rescue applications:

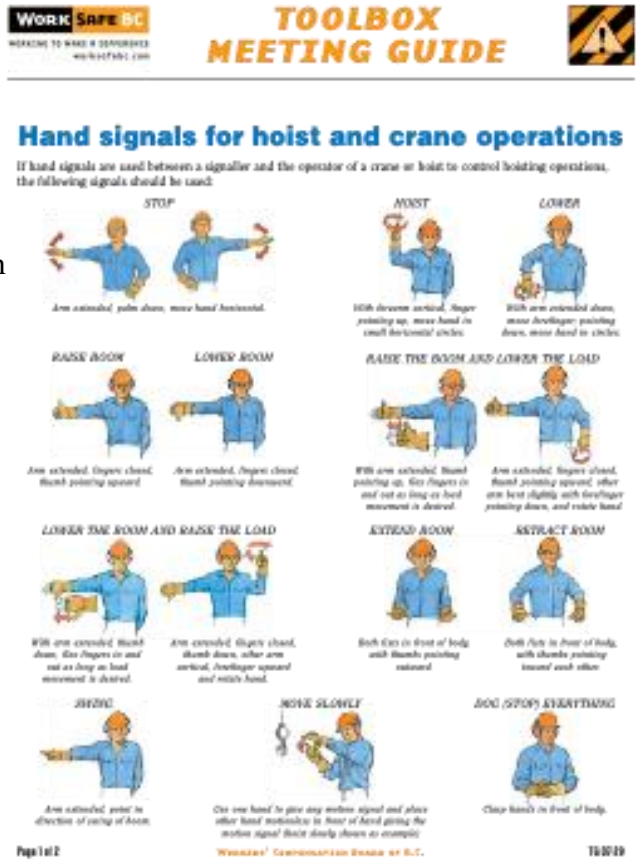
Commands	
STOP	1 Whistle Blast
UP	2 Whistle Blasts
DOWN	3 Whistle blasts
SLOW	SLOW UP / SLOW Down
TENSION	Tension by Hand
SLACK	Make Soft / Slack the line
FLOAT	Lift Up 1 meter (off ground)
AT WILL	Your discretion
RIG FOR	"Rig for raise" - next step
REPEAT COMMAND BACK Ensures they know you heard correctly	

Another method is the OATH System, which has different meaning depending on who initiates the communication. OATH can be used for communication across rope tugs pulls, whistle blasts or light flashes.

# OF TUGS	ATTENDANT / Technical Rescue Officer	ENTRANT / Rescuer
1 – **O**k:	All OK? OK / Attention / Stop	All is OK / Attention / Stop
2 – **A**dvance:	Advance / Lower	Give More / Lower
3 – **T**ake up:	Turn Back / Tension / Haul	Backing Out / Tension / Haul
4 – **H**elp:	Get Out	Send Help

Crane operator hand signals can be used when direct line of sight can be maintained and / or in high noise environments.

All operators on the team must be familiar with the signals to remain safe and effective.


WORKSAFEBC

TOOLBOX MEETING GUIDE

Hand signals for hoist and crane operations

If hand signals are used between a signaller and the operator of a crane or hoist to control hoisting operations, the following signals should be used:

STOP

HOIST

LOWER

RAISE BOOM

LOWER BOOM

RAISE THE BOOM AND LOWER THE LOAD

LOWER THE BOOM AND RAISE THE LOAD

EXTEND BOOM

RETRACT BOOM

SWING

MOVE SLOWLY

DOG (STOP) EVERYTHING

Page 1 of 2

TB-SIT-19

Photo Credit: WorkSafeBC

Other terminology maybe utilized. Some teams prefer “Up” and “Down” for rope movements instead of raise and lower. We find that using terms that cannot be confused for something else are best. For example, we have heard rescuers state: “Halt” instead of “Stop” and what the rescuers heard was “Haul”. The result is not what was intended. Therefore, terminology such as raise/lower and up/down are preferred.

Indicating a speed, or performance-based direction is often very helpful as well. “Up Slow”, “Down 2 feet”, “Good Speed”, “Down Faster” etc.

Two Rope System Overview

In all rope systems when operating in a high angle rescue environment with a live load, we will always utilize two independent and redundant connection points. This two-rope system means that one rope may be the primary support of the rescue system, while the second provides safety / backup. Each of these two systems will have its own anchor point, anchor strap, rope, rope device (descender, backup device, etc) and attachment to the rescue package.

If the need arises to remove one of the attachment points or devices in a system, we must first add another attachment point in to always maintain at least two points of independent attachment. This temporary, third attachment point, could be a fixed lanyard or rope, that will only be installed to clear a problem and does not actually offer any working purpose, other than to serve as a second point of attachment.

This will be a major principle of our operations throughout all of our rope and confined space rescue courses.

22 Mill St., Unit 2, Albany, NY 12204 T 518-930-4500 F 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

Anchoring - Basic

Anchoring is the foundation of our systems. For the purposes of this manual and course we will only be focusing on selecting single point anchors. These anchors may be substantial or could be "bombproof". A substantial anchor is one that can withstand any force that could potentially be placed upon it, intentionally or unintentionally.

The term Bombproof anchor is a term that has been used in the fire service to describe an object that is substantial enough to use for both Main and Belay/Safety lines. There is no formal definition of this term in any literature. It is subjective to the technicians doing the rigging.

We will not be discussing marginal anchors at this point, which would require tying multiple anchor points together to create an "anchor system".

Following the guidelines of "an anchor strong enough to hold the Main and/or Belay/Safety lines" will be our guiding principle and ultimate goal for this discussion.

It is important to remember that whenever possible the Belay/Safety lines should be kept independent of portable anchors that are being used to direct the main line of the systems.

Selection

Anchors are typically man-made or natural, and sometimes we combine the two to create our anchor point.

Man-made	Natural
Structural Steel / columns / standpipes	Trees
Vehicles	Large Rocks
Concrete posts / stairwell supports	

Anchors must be examined prior to use for sharp edges, corrosion, deterioration or anything else that could potentially weaken them or damage the anchor system.

When utilizing vehicles, it is important to ensure the parking brake is set, the vehicle is turned off, keys are removed and either LOTO is performed or the technical rescue officer has control of the keys. Chock wheels if appropriate, and ensure you are anchoring to clean, dry structural parts of the chassis and not just bumpers, suspension systems or areas that are coated with oil and grease. Only use tow hooks that are closed loops and do not have sharp edges.

Commercial Anchor Straps

Straight / Vertical
Basket
Choker

Double 1" webbing baskets

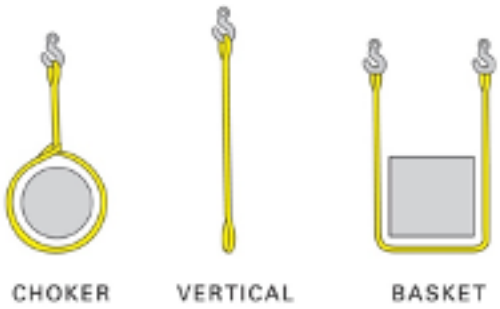


Photo Credit: Doleco-USA

When using 1" tubular webbing we tie it into a loop with a water knot and then place it around the anchor in a basket configuration. This effectively doubles the webbing as there are two parallel parts of webbing on each side of the anchor. Since webbing can be either flat or tubular, and the rating varies greatly based upon construction and manufacturer, we double the webbing basket to get the higher strengths needed to fit into our systems. Many teams will require that you have two of these webbing baskets to satisfy the strength requirements for a single anchor point.

Wrap 3 Pull 2

The wrap 3 pull 2 is considered a high strength anchor, however it can be time consuming to complete. This also uses 1" webbing and even with tubular webbing is rated at 35kN[4], with flat webbing at over 46kN[5]. Refer to the knot section on how to tie a wrap 3 pull 2.

Tensionless Hitch

A tensionless hitch is tied utilizing rope to create a rappel line or an anchor point. Because it is tensionless, it maintains 100% of the strength of the rope. The number of turns around the anchor post or tree should be at least eight times the diameter of the rope. Depending on the surface of the anchor object, more turns could be necessary. A 6" smooth post has less friction than a 6" tree, therefore it may require more wraps based solely upon the composition of the surface. Typically, there is a minimum of 3 - 4 turns around an anchor starting from the base of the anchor, working upwards without the turns crossing over each other.

Sewn Prusiks and Dyneema Slings as anchors

Newer equipment being utilized as anchor slings include sewn prusiks and dyneema slings. These are all rated in the vertical configuration, and whether used in a girth hitch or basket configuration often maintain a high enough rating to be acceptable for our uses.

Rappelling

Whenever we are going over an edge, into a confined space, or anywhere where rope is the primary means of travel getting to a victim or task, we must maintain two points of connection to our system.

Safety / Backup / Belay Line

- The first point of connection

[4] CMC Rescue
[5] CMC Rescue

- Ensures that we can't start an operation without first having a safety / backup / belay in place
- Typically attached to the sternum connection point on the harness
- Options
    - Traditional Belay System
        - Operated by another team member
        - Requires extra person and possibly more gear
        - Relies on proficiency of the belayer
        - Examples
            - Petzl ID Belay
            - Tandem Prusiks
            - Petzl Maestro Belay
    - Backup / Safety Device
        - Operated by rescuer
        - Optionally attached to anchor and tended by another rescuer
        - Automatically locks
        - Examples
            - Petzl ASAP / ASAP Lock
            - Kong Backup

Once a safety / backup / belay is in place, we have fall protection on and may now go closer to the edge. It may still be a good idea to have an edge restraint system on so you can't actually go over the edge.

Rappel Line

- The second point of connection
- Once it is connected and tested, we are ready to begin work (with safety in place)
- Typically, will attach to the ventral (waist) connection point on the harness
    - High Point
        - Rappel line and anchor are coming from above the rescuer
        - Easier and safer transition over the edge
        - General Technique
            - Keep feet wide
            - Allow rope through the descender with good brake hand positioning
            - Keep feet planted
            - Lower hips to bend to approximately 90° to feet
            - Walk down in that position, small steps
    - Low Point / Low Edge Transition
        - Rappel line and anchor are at the rescuer's feet

- Start in a sitting position at the edge
- Attach to main line
    - Rope grab with a rope ladder or etrier or foot loop
    - Place it in opposite foot
    - Stand up and pivot into it
    - Tension rope in descender
    - Weight descender
    - Remove foot from loop

- Rappelling Skills rescuer should have
    - Descent
    - Proper use of brake hand
    - Locking off
    - Working hands free
    - Understanding features of device
        - I.e., Panic Mode / Swing plate operation
    - Freeing a jammed descender
    - Ascending up to 20’

Mechanical Advantage Systems

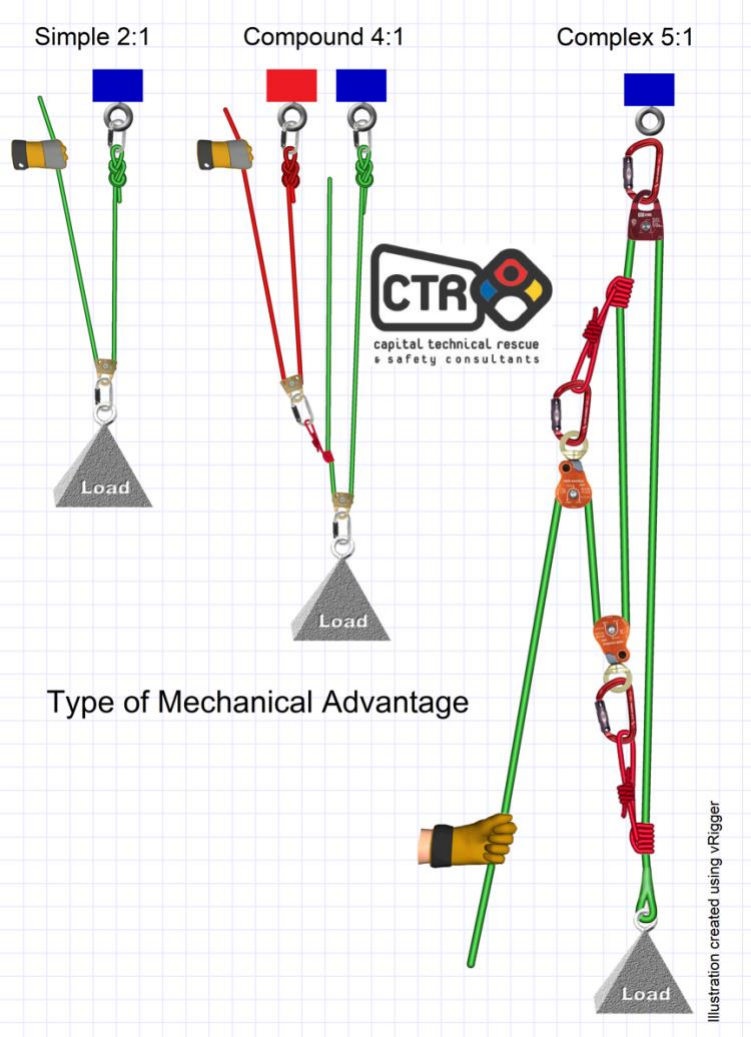
Definition

Mechanical advantage is defined by Merriam-Webster as:

> the advantage gained by the use of a mechanism in transmitting force
>
> *specifically*: the ratio of the force that performs the useful work of a machine to the force that is applied to the machine

In confined space and rope rescue we often utilize pulleys and rope grabs as our mechanisms to gain advantage to the force we transmit from hauling on our systems. There are three types of mechanical advantage systems, with the first two being the ones that we commonly utilize.

1. Simple
    - Single haul connection between the load and the load line
    - All pulleys in the system travel at the same speed towards the anchor
    - Examples: 2 to 1 mechanical advantage, integrated 3:1, piggyback 4:1
2. Compound
    - Simple mechanical advantage system pulling on the haul line of another simple mechanical advantage system
    - Collapse rates of both systems will be drastically different
    - Multiply the two systems together to give the total advantage
    - Example: 9 to 1 mechanical advantage - simple 3:1 pulling on a simple 3:1
3. Complex
    - Neither a simple nor a compound system
    - Pulleys will collapse towards each other simultaneously as the load moves
    - Determine the mechanical advantage utilizing the "T" method
    - Add the mechanical advantage of systems together to get total advantage
    - Limited practical use in rescue



Rules of Mechanical Advantage

1. Pulley at the anchor is only a change of direction
2. If the terminal knot is at the anchor, the mechanical advantage will always be an even number (eg. 2:1, 4:1, 6:1)
3. If the terminal knot is at the load, the mechanical advantage will always be an odd number (eg. 1:1, 3:1, 5:1)
4. To determine the mechanical advantage of a simple pulley system, count the ropes between the anchor and the load.
5. A simple mechanical advantage pulling on the haul line of another simple mechanical advantage is a Compound Mechanical Advantage System.

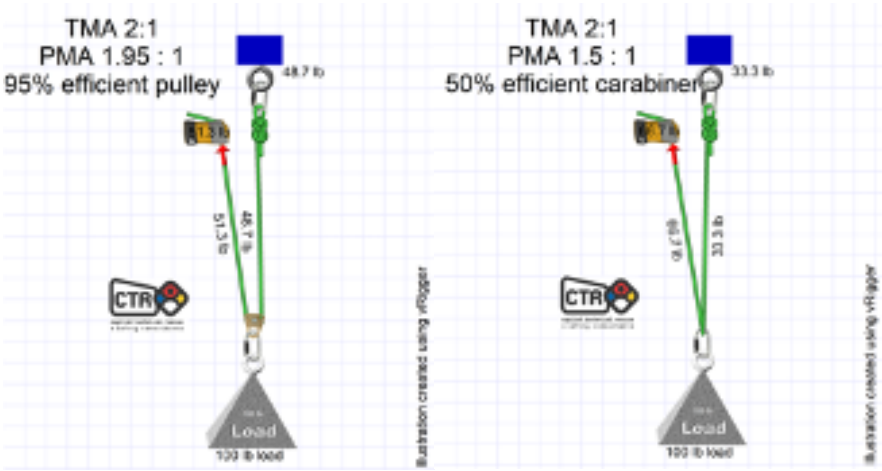
Actual versus Ideal Mechanical Advantage

Friction, rope stretch, and angles all exist in our systems. Some devices are more efficient than others, and we must understand that our mechanical advantage system's efficiencies will vary.

- Ideal or Theoretical Mechanical Advantage (IMA or TMA)
  - assumes that there are not any losses in efficiency in the systems we are building

- Actual or Practical Mechanical Advantage (AMA or PMA)
  - real world where we do have other factors such as losses in efficiency

For example, pulleys vary greatly in efficiency based on the diameter of the sheave and the diameter of the rope. One pulley could be 95% efficient while another may only be 90% efficient. If we utilized a carabiner as a change of direction instead of a pulley, we may only have 50% efficiency. Both systems below have a TMA of 2:1 but based upon the devices we select, the PMA and the amount of force we have to exert varies greatly.



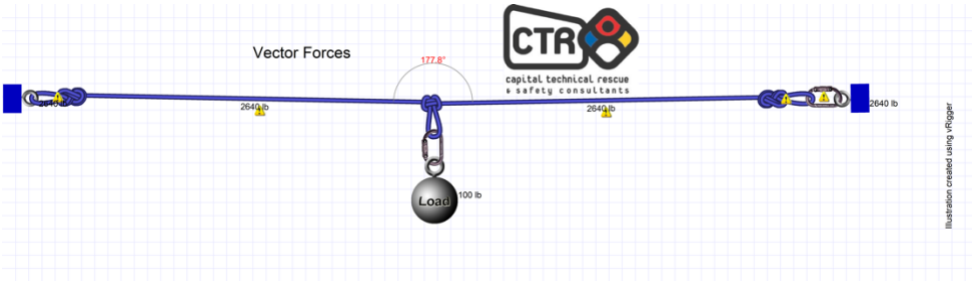
For the simplicity of learning these systems and having an easy method and naming convention we will refer to all of these systems by their Theoretical Mechanical Advantage (TMA).

Vector

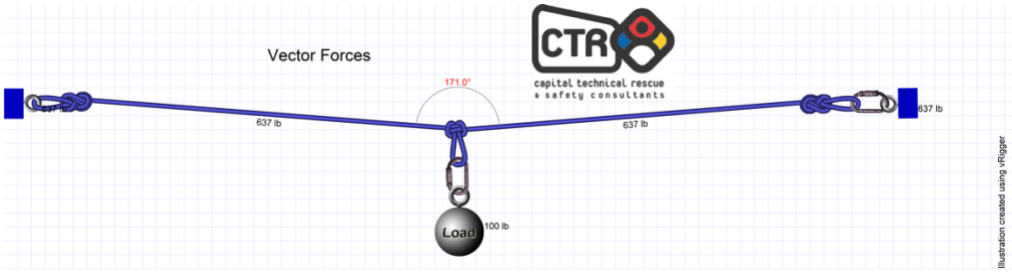
Angles between 180° and 120° create mechanical advantage as well. This is called a vector pull or vectoring. The amount of mechanical advantage created varies depending on the angle. This is good for a quick and short raise when needed and can be done by one to two rescuers with minimal effort.

The closer to 180° the more mechanical advantage will be created with minimal raise, while the closer to 120° the more raising will occur, and less mechanical advantage will exist.

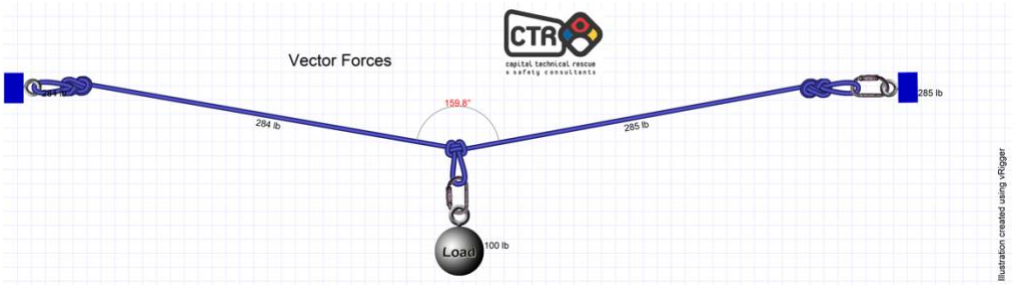
If two rescuers are pulling with 100 lbs of force on a line they can create a vector force at the anchor and the load, raising the load upwards. In the below examples we show the forces on the two anchors without the movement just to show the amount of force that can be generated.



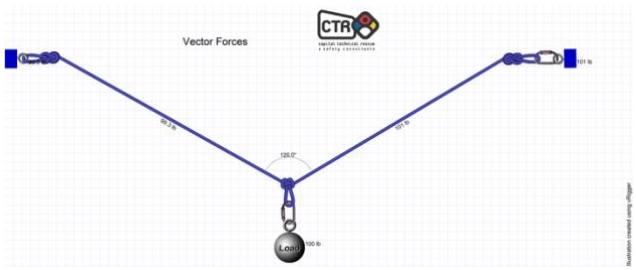
Angle: 178°



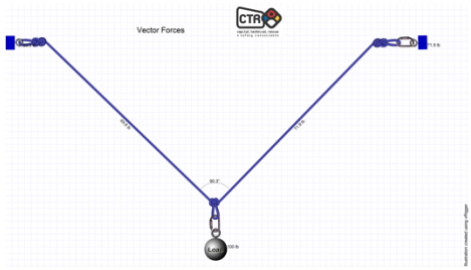
Angle:171°



Angle: 160°



Angle: 120°

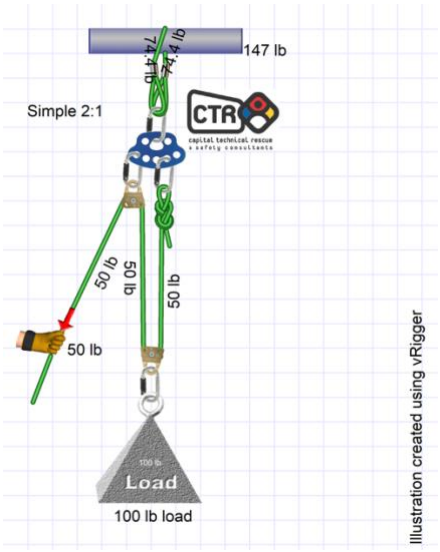


Angle: 90°

2:1

Using a 2:1 anchored to yourself or piggyback onto a rope system can be useful in a confined space where you need to move someone along a horizontal surface or minor grade.

In the picture below, the terminal knot is anchored and run through a pulley at the load. Hauling on that line creates a 2:1 mechanical advantage system. The pulley on the anchor plate is simply a change of direction and the force is unchanged on the hauler.

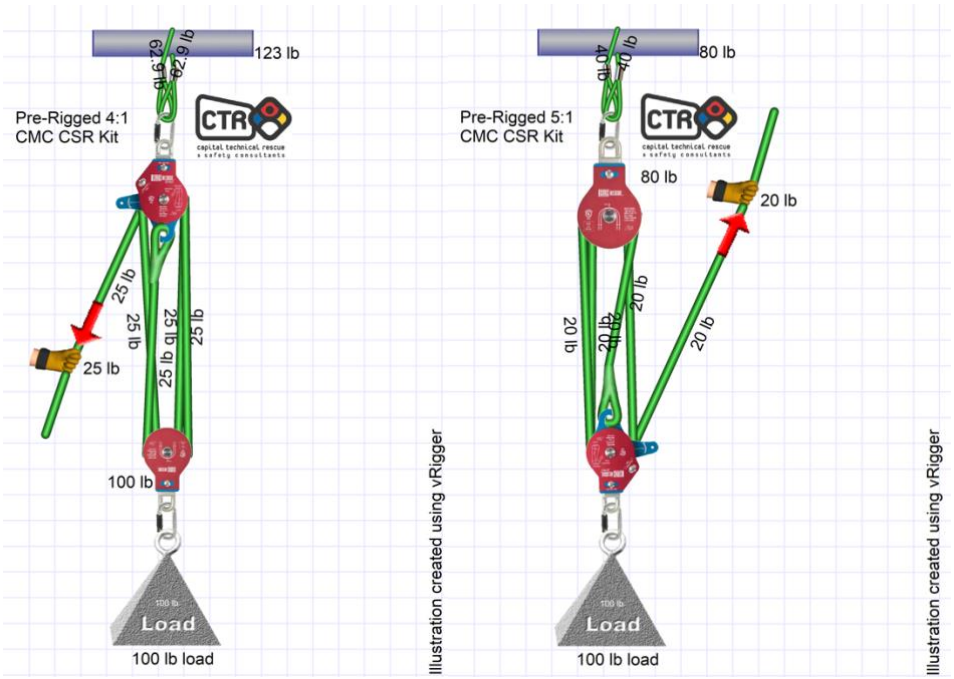


4:1 / 5:1 MA

The 4:1 and 5:1 mechanical advantage systems are built with two double pulleys and 2 or 3 carabiners, depending on how you terminate the rope into the system. It can be done with a terminal knot attached to a carabiner or screw link that is attached to the becket of one of the double pulleys. You can also put a terminal knot directly into the becket or place the terminal knot into one of the carabiners that attaches the pulley to the load or the anchor. For simplicity here, we will attach the terminal end of the rope directly into the becket.

To build the system, we typically start with the double pulleys offset 90° to each other, which allows for the system to have parallel "falls" or "legs" of the rope. Take the terminal end of the rope and attach it to one of the beckets on the double pulley, then trace the rope through the opposite pulley and take care to keep the ropes parallel. Once the rope is through all of the sheaves of both pulleys, place a carabiner on each of the pulleys and you are done.

These systems can be used as an "add-on" or "piggyback" mechanical advantage to a rope system or can use a rope grab or progress capture device to create its own main line system.



In both systems above we can utilize the rules of mechanical advantage to determine the mechanical advantage and can quickly determine if it will be an odd or even system based on the location of the terminal knot on the becket.

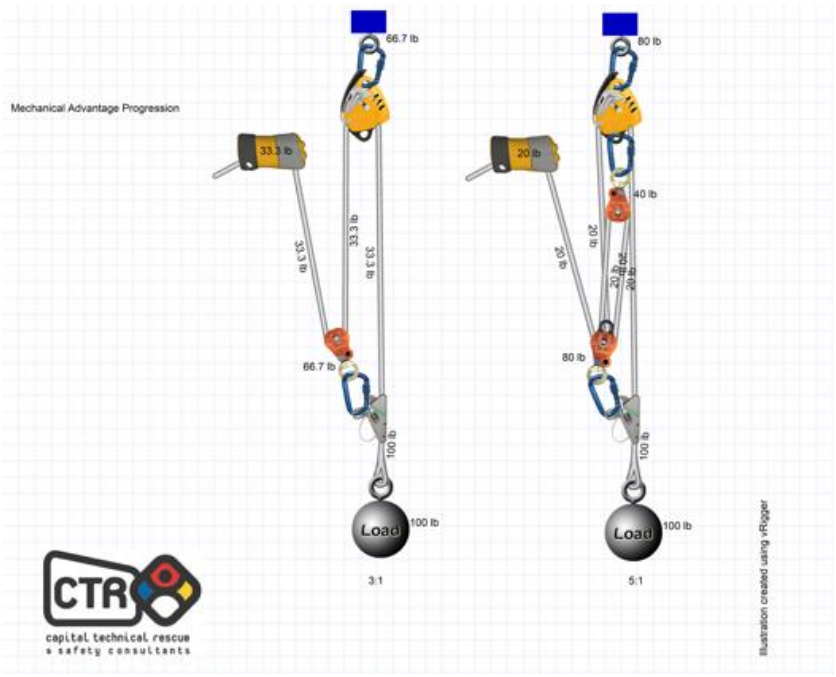
This particular system is the CMC Confined Space Rescue Kit which has progress capture built into the double pulley that has a becket. It can be used as an independent system for raising and lowering, or as an add-on mechanical advantage system to another rope.

Integrated Simple MA 3:1 / 5:1

The term integrated mechanical advantage simply means that the system is built with the load line. Using a progress capture device or a descent control device that has progress capture built in, we can utilize the tail of the rope to create our system.

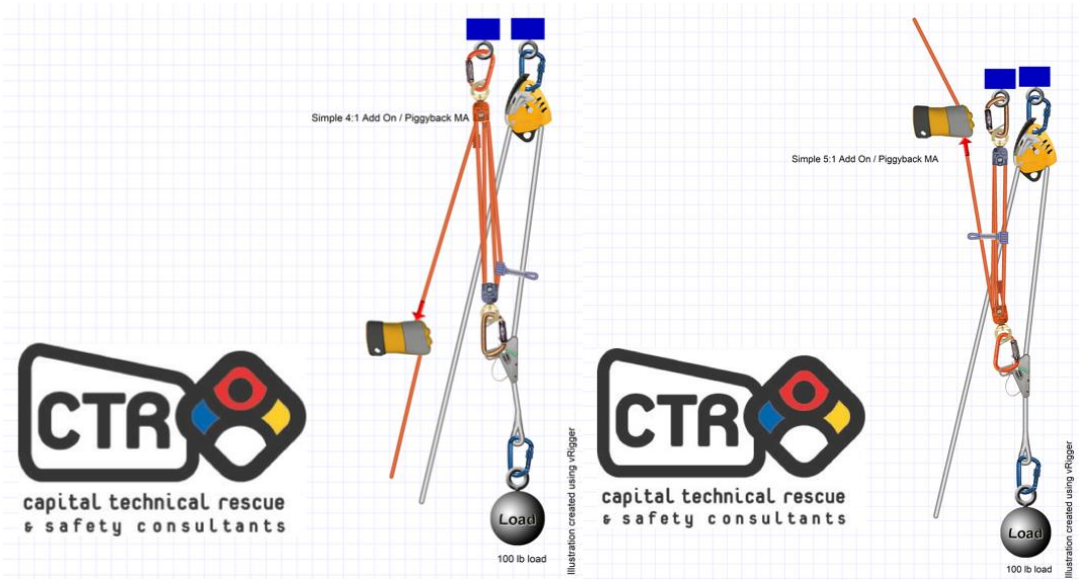
The two most common that we utilize are the integrated 3:1 and the integrated 5:1. They are quick and easy to setup and don't require a lot of gear.

- Integrated 3:1
  - 1 - Single Pulley
  - 1 - Rope Grab
  - 1 - Carabiner
- Integrated 5:1
  - 1 - Single Pulley
  - 1 - Double Pulley
  - 1 - Rope Grab
  - 2 - Carabiner



Add-On / Piggyback MA 4:1 / 5:1

An add-on or piggyback mechanical advantage system is simply putting an additional system onto the load line. In the examples below, when hauling on either the 4:1 or 5:1, a rescuer must pull on the white line, so the progress is captured of the haul.

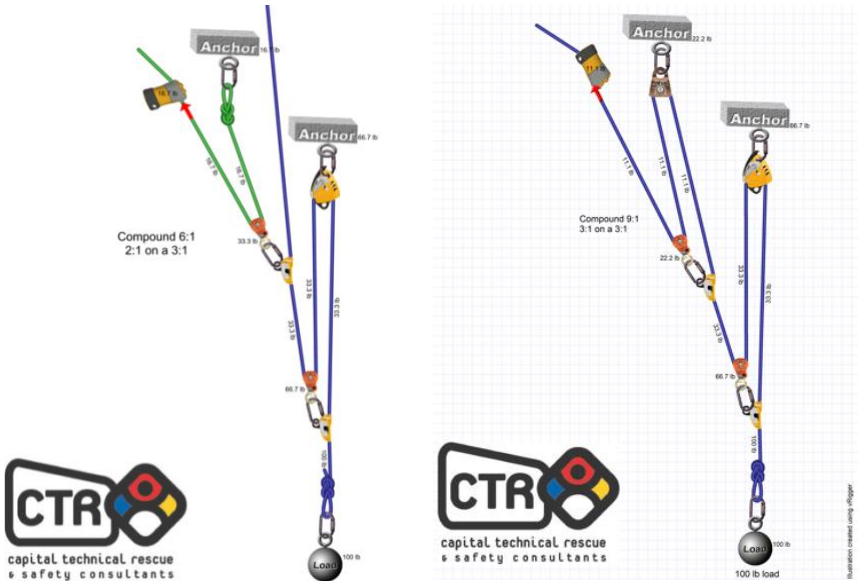


Remember, when hauling with a 4:1 or a 5:1 you are pulling through either 4 or 5 feet of rope to move the load 1 foot. Tensioning the white line for the progress capture doesn't have to be hard.

While not difficult to tend the line, this requirement also differentiates an add-on system from an integrated mechanical advantage system. With the integrated system the rope is tended through the progress capture device automatically.

Compound MA – 6:1 / 9:1

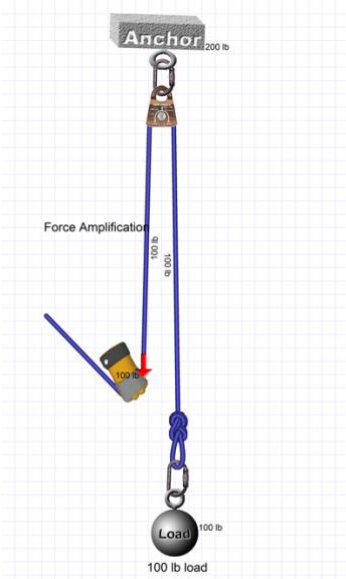
Compound is a Simple MA system pulling on the haul line of another Simple MA. Multiply the two systems together to get the total advantage. This can be either an add-on system, or an integrated system. The collapse rates of both systems will be drastically different, and it is recommended to stagger the anchors when building a compound MA to reduce the number of resets you will need.



Force amplification

In many of the above mechanical advantage examples you may notice that there is more weight on the anchor than the weight of the load. We must anticipate that our anchor will see the most force in the system, especially any time a stationary or change of direction pulley is attached to the anchor.

A change of direction pulley or other stationary pulley will amplify the forces on the anchor they are attached to. We should be careful when we are within the inside angles of that pulley, in case it were to fail.



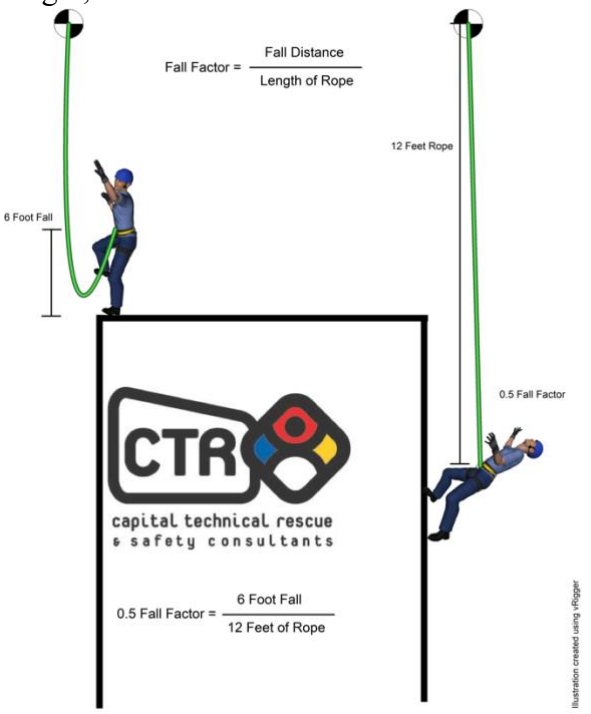
Notice that with a 100-pound load that the force on the anchor is 200 pounds. The change of direction pulley at the anchor amplifies the force because the rescuer must also pull with at least 100-pounds of force, just to keep the load from lowering. To raise the load the rescuer would need to apply more than 100 pounds of force, increasing the amount of force the change of direction pulley, carabiner and anchor would see.

Fall Factors

The fall factor is often used to quantify the severity of a fall. It can have a theoretical value between 0 and 2.

The fall factor is the ratio of fall length to rope length.

The severity of the fall does not depend on the fall length, as the longer the rope, the more energy it can absorb.



Fall Factor Calculation

F = Fall Length / Rope Length

F = Theoretical Fall Factor

Fall Length = Length of Rescuers (test mass) Fall

Rope Length = Length of rope between belay device and Rescuer (test mass)

The theoretical fall factor does not take into account the rope friction against hardware & the environment.

This friction prevents the rope from stretching over its entire length. Thus, only a part of the rope will absorb the energy of the fall: this is called effective rope length.

It is therefore useful to talk about the actual fall factor. It is clear that if a rescuer does not take the necessary steps to avoid rope drag, the actual fall factor can quickly increase.

In this case, the fall will be more severe for the rescuer.

Fa = actual fall factor

Fall length = length of the climber's fall

Effective rope length = actual length of rope in play

System Safety Factors

It is the responsibility of every Rope Rescue Operator and Technician to determine if the system they are utilizing is "safe". There has long been the misnomer that our "Safety Factors" for rope rescue in emergency services were required to be 15:1.

This is only anecdotally substantiated in the original version of NFPA 1983-1985 edition and should not be considered valid for our approach to rigging. A Safety Factor of 15:1 and even 10:1 is not possible to achieve nor do we want to carry the equipment that would be built for such a purpose.

What is achievable is a Dynamic System Safety Factor of between 2:1 and 4:1. This is in line with all of our other disciplines and more in line with industrial standards for fall protection.

Organized rescue teams should be diligent in the equipment they acquire ensuring that it serves their mission needs. All equipment, hardware and software, should be tracked and inspected regularly and after each use. Follow guidance from both the manufacturer and current edition of NFPA 1858 for the selection, care and maintenance of this equipment.

All of the systems we teach in our rope rescue operations and confined space rescue technician level courses have a Dynamic System Safety Factor between 2:1 and 4:1, with a maximum anticipated load of 6 kN.

We strive to keep the forces considerably lower than 6 kN but do recognize that it is possible to meet or exceed 6kN should a catastrophic failure of a piece of equipment, our rigging, or human error occur.

For a deeper dive into System Safety Factors, see Appendix A – Factors of Safety.

Belaying

A belay is backup or safety that is attached to the rescuer or rescue package, that will arrest a fall should the main line fail.

Our motivation for teaching safe, effective and proper belaying techniques is due to students who have gotten hurt from incorrectly operated belays (human errors) in both escape system training and also from rappelling evolutions. There is no one perfect belay system, however we are always in search of new equipment and techniques.

- Our desired belay system features:
  - Reusable
  - Safe
  - Effective
  - Easy to train on
  - Ability to lift / lower?
  - Low impact forces
  - Automatically engages
  - Provide realistic feel (minimal interference with primary system)

Some raising and lowering systems can be operated as a "twin" or "mirrored" system, and therefore do not have one of the ropes dedicated as a belay, but our two-rope principle is still in full effect. For confined space rescue especially, we rarely use a "twin" system as our main lines are often pre-rigged 4:1 system, winches or a main line setup where we can't have a belay line running through a high point such as a tripod.

- There are many factors to consider when selecting and operating a belay.
  - Rope Construction: Static vs dynamic rope
    - In confined space rescue we are only using static rope, unless you are an advanced team
  - Rope Stretch
    - Static rope can stretch from 2 - 10% under a 300lb static load
  - Fall Factors
    - Depending on where the rope is anchored and in relation to the rescue package, additional forces can be generated on both the anchor and the rescue package
    - Unwanted slack in the belay system will increase the fall factor and the additional forces
  - Distance to the Ground / next lowest level
    - Some belay / fall arrest systems have a minimum clearance distance
    - Select a belay system that will prevent a fall to the ground / next lowest level
  - Amount of rope in-service

        - The more rope in-service between the rescue package and the anchor, the more rope stretch that can occur to a point and the more the rope can absorb some of the shock force
    - Belay anchor location
        - If a belay is anchored low to ground, but operated above the anchor, the belay device will travel towards the ground if activated and increase the fall distance
        - Typically, we do not run belays through high points
    - Harness Stretch
        - Adjustments on harnesses and some harness material may stretch, increasing the overall fall distance
        - This could also happen with a bridle on a patient packaging device
    - Overall anticipated weight
        - The belay must be capable of handling the overall anticipated weight of the system and the forces generated in a fall
    - Belay Competency / Belayer Attentiveness
        - Almost all belay failures are due to human error
        - Could be because a belayer is not competent in utilizing the belay device
        - Belayer may not be paying attention to the operation and have too much slack in the system
    - Belay device slippage
        - Belay devices are typically designed to slip at a certain force to limit damage to the rope. Many are designed to slip around 6 kN.
    - Friction through change of directions - pulleys vs carabiners
        - In belay systems we typically want additional friction, as opposed to efficiency
        - Pulleys offer efficiency, and also have pin through the sheave that may not be rated for a shock load
        - Carabiners offer friction and are typically a better choice for our change of directions

The technique of belaying varies depending on the device being utilized. Some devices operate better than others for belay. There is also some personal preference to performance of belay devices, as some are easier or more comfortable to utilize based on your physical attributes.

Refer to the rappelling section for a list of common belay / backup devices.

Raising and lowering systems

With the belay line being the first point of attachment in a two-rope system, the main line is the second. The main line is typically what we utilize to create raising and lowering systems. There are a variety of systems, types of systems and equipment that can be utilized to accomplish these tasks.

For confined space rescue applications, we will be focusing on systems that utilize a main and a belay line, which some refer to as a Single Tension Rope System, as opposed to other rope rescue techniques such as the Twin Tension Rope Systems (TTRS). TTRS is not as applicable for many confined space rescues, however, could be utilized in more advanced lowering situations, such as where you need to lower someone from the top of a tank to the ground level. These techniques are covered in our rope rescue operations and advanced confined space rescue courses.

One of the fastest and widely used raising and lowering system for vertical confined space rescue is to use a pre-rigged mechanical advantage system with progress capture built in. Probably one of the most popular systems on the market is CMC's CSR2 Pulley System. This system has a lever on it that can be activated with a piece of utility cord attached to it so the operator may release or lower the system down. As soon as the operator releases tension on the utility cord the rescue package stops in place, and a haul is ready to begin. There is no additional hardware or software that needs to be integrated into this setup to switch between raising to lowering in any direction. The downside of this system is it utilizes a lot of rope. A 200' rope bag only ends up having a working length of 40 - 50', so longer descents either require longer ropes or another type of system.

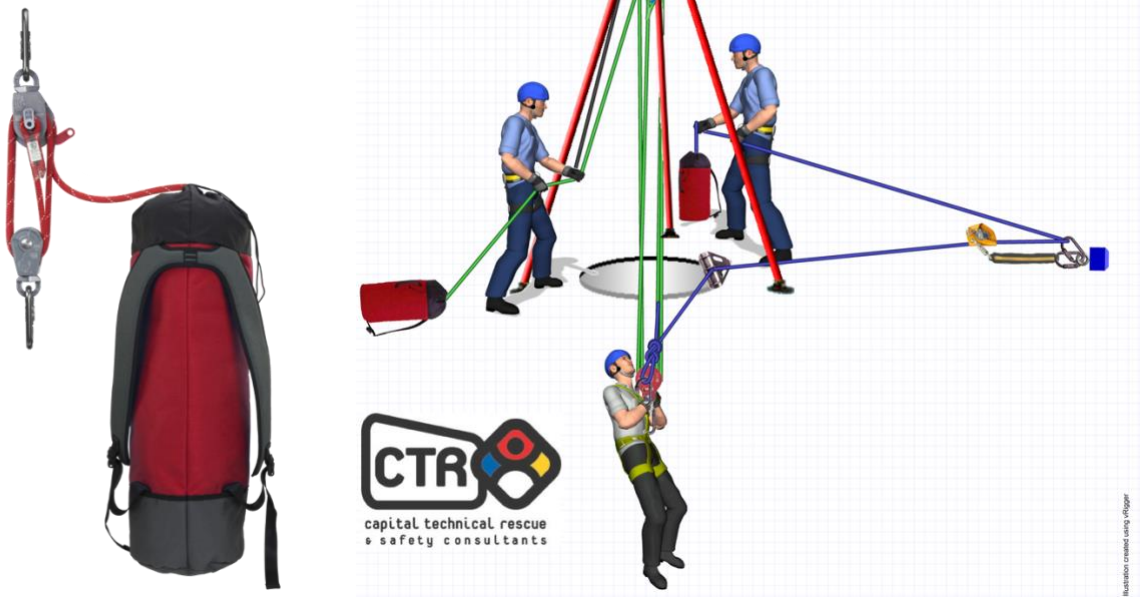


Photo Credit: CMC Stock Photo - CSR2 Pulley System

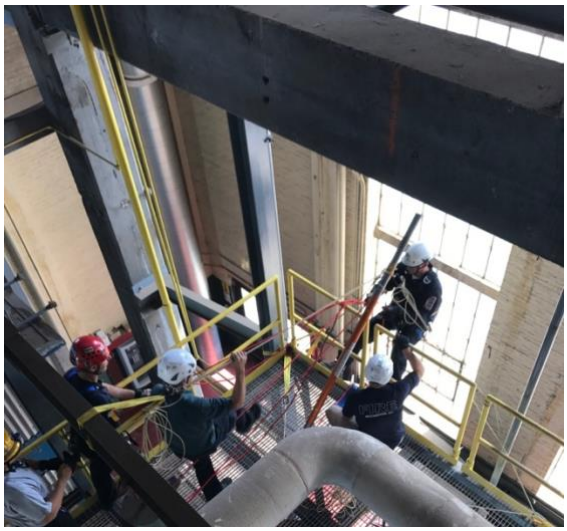
Low Angle Rescue

Low angle rescue is commonly defined by the terrain type being from 0° to 40° in steepness and may be considered non-technical since the majority of the weight is being supported by the ground. Often only one rope maybe necessary, rescuers maybe able to just carry a litter and not tie into a rope system. Of course, the condition of the terrain may still dictate a technical rope rescue regardless of how steep it is.

For example, a car down a 30° embankment in the summertime may only require a single rope to assist the rescuers with bringing the litter back up to the roadway while they are walking it up and supporting much of the load themselves. However, that same embankment after a snowstorm, or heavy rains may require a haul team to do much of the work bringing the litter up if the rescue crew is unable to maintain adequate footing to safely walk up the slope unassisted.

High Angle Rescue

A high angle rescue is anywhere the terrain is greater than 40° all the way up to 90°, and any other conditions where a two-rope system will be necessary, and the main line will be the primary means of support.



Confined space rescues utilizing a tripod are always considered a high angle rescue, as are most industrial rescues from fall protection.

These days there are a lot of references to single vs twin tension rope systems and how one is superior to the other. Often, we find that those who are saying one is the preferred way over another is doing so with one or more reasons such as a limited scope of applications, minimal real-world experience or have a financial gain in one versus the other. We utilize and teach both systems, because they each have their places and because to limit you and your team to just one of them is an unnecessary handicap.

It should be noted that both systems are “Two Rope Systems”, meaning they each have the two independent and redundant points of connection that we desire for a safe system.

Single Tension Rope System

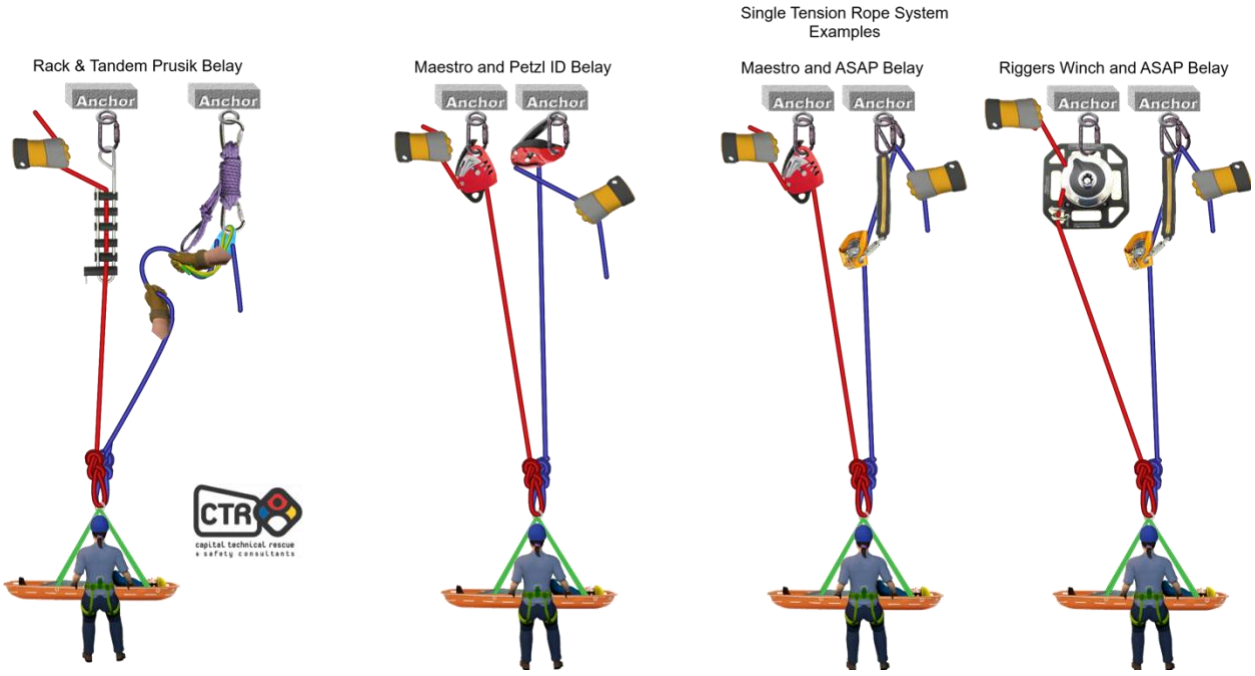
Single Tension Rope System (STRS) is a fancy name for some of the most traditional rope systems we have utilized, as well as some of the most modern and efficient systems we use.

STRS is simply the idea of a main line that supports the load under tension, while some type of belay is used with minimal slack in it so that the belay line does not support any of the load during normal operation.

Traditional systems used a rappel rack to lower on the main line, with a tandem prusik belay as the second point of connection.

A more modern version of this is using a I'D, Maestro or Clutch on the main line and a mobile fall arrester such as a Petzl ASAP on the belay (aka safety) line.

For some teams, a STRS using a capstan rope winch, such as a Skyhook or Harken LokHead on the main line and a Petzl ASAP as a belay is considered cutting edge, while others this is a basic go-to setup.



One downside to the single tension rope system is that a main line failure can result in a shock load of the belay line. It is imperative slack be managed appropriately in these systems to minimize the impact forces of a shock load. There must also be a plan to be able to transfer the load to a new main line and/or be able to raise or lower the load to a successful conclusion.

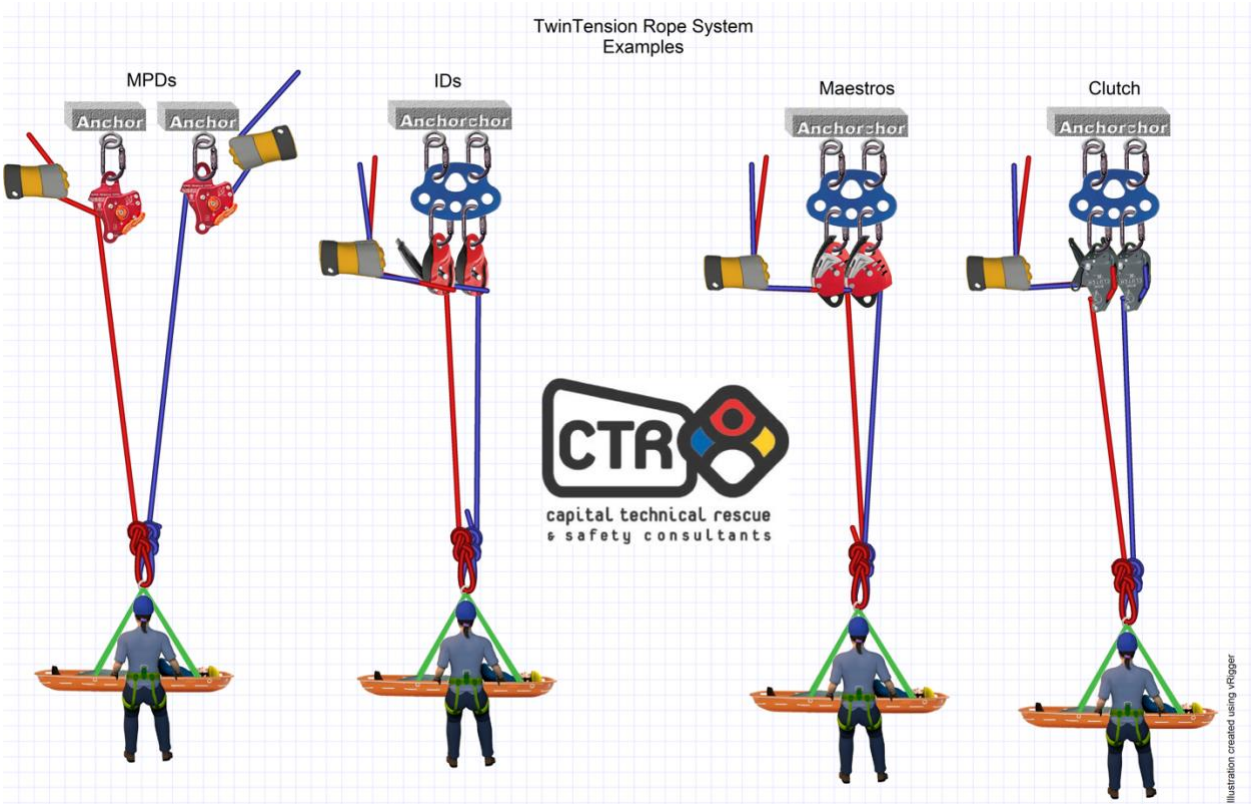
Twin Tension Rope System

A Twin Tension Rope System (TTRS) is simply where both ropes that connect to the load are sharing the tension and supporting the weight of the load. There is no slack in this system at all, and neither of the two ropes are truly just a main or just a belay line. Some teams will refer to this as a "mirrored system" since both the lines are basically mirror images of each other.

This technique is not new at all, although some manufacturers have been touting it that way. An old technique was to use two rappel racks in what was often referred to as a double line litter lower. We would be able to control the head and foot end of a litter independently while still having two points of connection to the rescue package.

The introduction of the CMC MPD brought this technique back into favor since the MPD does not, in our opinion and testing, work well as a traditional belay device.

Lowering and raising with a TTRS requires that the speed of both devices is equalized so no slack is introduced into the system. This is not a difficult task but must be monitored. One potential pitfall with this system is should a failure occur on one of the lines, the operator of the second line may not recognize that a failure has occurred. Communication and attentiveness is imperative throughout the operation.



A single operator can control a TTRS with devices such as IDs and Clutches if they can be anchored close together. Since the ID and Clutch both are handled devices, the operator can control the tails of both ropes while using a technique known as “shark finning” the handles. Due to the T-Handle on the MPD, a single operator cannot control two of them at a time.

The single operator is often preferred as they find it easier to control the tension in both sets of lines at the same time, and should one of the systems fail, the single operator is aware immediately.

22 Mill St., Unit 2, Albany, NY 12204 T 518-930-4500 F 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

Confined Space Rescue

Confined Space Entry Equipment

Tripods

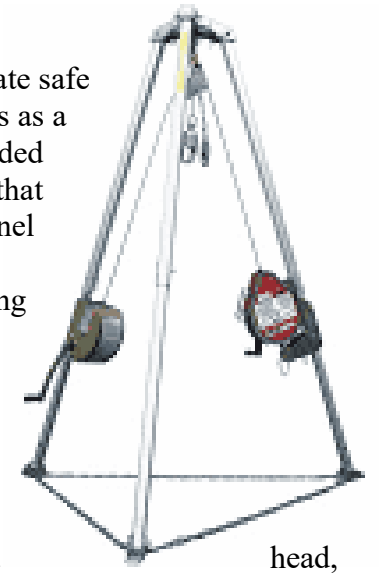


Photo Credit: 1 Honeywell Miller Stock Photo

Confined space tripods are portable anchor systems designed to facilitate safe vertical entry and rescue operations. Each of the tripod's three legs acts as a structural member, working in compression to support the load suspended from the tripod head. For maximum stability and safety, it is essential that all loads applied to the tripod—whether for raising or lowering personnel or equipment—are kept as close to axial (vertical) as possible. Axial loading ensures that the forces travel straight down each leg, minimizing the risk of tipping or structural failure.

A common and efficient setup for confined space rescue is the use of a pre-rigged 4:1 mechanical advantage system. This system, often integrated with progress capture, allows rescuers to raise or lower loads with minimal effort and rapid changeover between hauling and lowering. The pre-rigged 4:1 is typically attached directly to the tripod head, with the load line running vertically through the center of the tripod. This configuration keeps the resultant force within the tripod's footprint, ensuring that the legs remain in compression and the tripod remains stable.

When setting up a tripod, when all three legs are fully extended and the head is level the tripod has maximum stability, however the taller the tripod the lower the working load limit or weight rating it can handle. The tripod must be placed on a stable surface, and all pins or cotter pins must be securely locked. Loads should be lifted vertically and centered within the triangle formed by the legs. Pulling outside the resultant forces of the tripod can cause it to topple or collapse. If a change of direction is needed for the main line, it should be accomplished using a substantial anchor point outside the tripod, with the force redirected so that the load remains vertical relative to the tripod. Tie-backs or additional anchors may be used to further stabilize the tripod, especially when operating near the limits of its rated capacity or in challenging environments.

When using a winch or haul system, always observe the load to prevent it from catching on obstructions, which could cause injury or damage. Proper rigging, regular inspection, and adherence to manufacturer guidelines are essential for safe tripod operations. By following these principles, rescue teams can maximize the effectiveness and safety of tripod-based confined space rescue operations.

Tripod Leg Security: Hobbles and Alternative Methods
Why Secure Tripod Legs?

Tripods are designed to support loads axially—meaning the force should travel straight down through the center of each leg. This keeps the legs in compression, which is the strongest and safest way for the tripod to bear weight. If the legs are allowed to spread apart under load, the tripod can lose stability and collapse, risking injury or equipment damage. Securing the legs ensures the tripod maintains its designed footprint and that all forces remain within the triangle formed by the legs, maximizing safety and stability.

Standard Method: Hobble (Chain, Rope, or Webbing)

- **Definition:** A hobble is a chain, rope, or webbing that connects the feet of the tripod together, forming a triangle at the base.
- **Purpose:** Prevents the legs from spreading apart under load, especially when the load is not perfectly vertical or the surface is uneven.
- **Best Practice:** Always install the hobble according to manufacturer instructions before applying any load. Inspect for wear or damage before each use.

Alternative Methods to Prevent Leg Spread

While a hobble is the most common and manufacturer-recommended method, there are several alternative ways to secure tripod legs, especially in industrial or non-standard environments:

1. Lashing or Tying Legs to Open Grating or Structural Features

- **How:** Use webbing, rope, or ratchet straps to tie each foot of the tripod directly to open steel grating, anchor points, or other fixed structures on the work surface.
- **When to Use:** When the tripod is set up on a grated floor, catwalk, or near fixed anchor points.
- **Benefits:** Prevents both spreading and shifting of the legs. Can be used in addition to a hobble for extra security.

2. Bolting or Pinning the Feet

- **How:** Some tripod feet have holes or slots designed for bolts or pins. Secure each foot directly to the floor, platform, or anchor plate using appropriate hardware.
- **When to Use:** On concrete, steel, or wood surfaces where drilling or existing anchor points are available.
- **Benefits:** Provides the highest level of security against both spreading and sliding. Especially useful in permanent or semi-permanent installations.

Key Points for All Methods

- **Manufacturer Guidance:** Always follow the tripod manufacturer's recommendations for securing legs. Some methods may void warranties or certifications if not approved.
- **Inspection:** Check all securing devices (hobbles, lashings, bolts, etc.) for wear, damage, and proper installation before use.
- **Redundancy:** In critical operations, consider using more than one method (e.g., hobble plus tie-backs or bolting) for maximum safety.

22 Mill St., Unit 2, Albany, NY 12204 T 518-930-4500 F 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

Davit arms

Davit arms are also portable anchor systems, with only a single arm that can pivot and adjust for various overhead clearances. There are many various base plates available for davit arms, making them extremely flexible for a variety of jobsites. The same winch and safety systems used on tripods can often be used on davit arms with the correct mounts.

Photo Credit: Stock Honeywell Miller Davit Arm & Stock 3M DBI-Sala Davit Arm with Floor Mount

Photo Credit: Stock 3M DBI-Sala Manhole Collar and Side Entry System with Floor Mount

Personnel Winches

These are mostly manually operated winches that are designed to be used in conjunction with a fall arrest system. The winch allows you to raise and lower personnel in and out of a confined space and have mechanical advantage built in. Rope lengths are typically from 50 - 250' lengths and are made from either galvanized or stainless-steel wire rope, or Kevlar rope. Various mounts are available for winches and SRLs to allow use with tripods, davit arms and other anchors.

Photo Credit: Stock 3M DBI-Sala Confined Space Winch

Self Retracting Lifelines

These devices are for emergency evacuation only when in retrieval mode and work as a fall arrest system when climbing up and down ladders or other structures. The emergency retrieval system utilizes an internal winch that provides some mechanical advantage. They also come in similar lengths and materials as the personnel winches.

Photo Credit: Stock Honeywell / Miller MightEvac SRL

Pre-rigged 3:1 / 4:1

Some facilities are not able to utilize wire rope and may opt for a rope-based hoist system that also allows a user to position themselves where needed. These systems typically offer a 3:1 or 4:1 mechanical advantage ratio.

Photo Credit: Stock 3M / DBI-Sala

Tag lines

Tag lines are used when a horizontal entry is necessary, no fall potential exists, and a non-entry rescue maybe performed utilizing a system that doesn't require mechanical advantage. Tag lines still need to be anchored to an anchor point that meets OSHA's 5000-pound anchor requirement. The attendant should be able to control how much line an entrant can have to advance into the space. Depending on conditions, more complex systems may be necessary to facilitate a safe horizontal confined space entry such as the side entry davit system above.

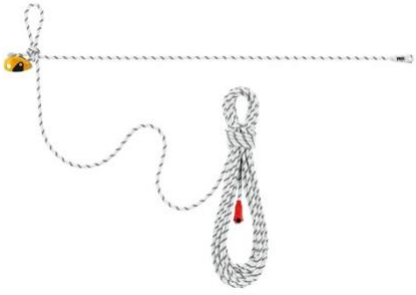


Photo Credit: Stock Petzl Grillon Photo

PPE / RPE

PPE is personal protective equipment and ranges from the types of helmets, to the shoes we wear and everything in between.

When it comes to working at height, confined space and rescuer work, it is important to consider a helmet with a chin strap. This will prevent a fall to a lower level, possibly injuring someone and possibly preventing an injury to you.

There are several levels of PPE that we address in confined spaces and the selection will be based upon the hazard identification and mitigations we are capable of doing.

- Level A
  - Fully Encapsulated
  - Positive Pressure Breathing Apparatus (SCBA/SAR)
  - Initial Entry and Monitoring
  - Most Protection Afforded
  - Unknown Scenarios
  - Known Scenarios - Very Hazardous
  - Independent of Hazard

- Level B
  - Positive Pressure Breathing Apparatus (SCBA/SAR)
  - Hooded Rain Suit / Tychem etc
  - Known Hazard

- Level C
  - Negative Pressure Respirator
  - Tyvek Suit
  - Chemical Hazard Specific
  - Cartridge Specific to Hazard

- Level D
  - Minimum protection
  - Regular work suit
  - Coveralls

RPE is respiratory protective equipment and has several different types that allow us to operate in various environments safely. All of these require that the wearer has a current respirator medical clearance and fit test for the specific equipment they will be utilizing.

- APR - Air Purifying Respirator
  - Not for IDLH Environments (immediately dangerous life hazard)

- Various respirator cartridges available such as:
  - HEPA filtration
  - Organic Vapors
  - Particulate removal
  - Specific Chemicals
  - Combination Cartridges
- Negative Pressure Respirator, can be tiring after long periods of time
- Available as half or full face
- Maybe available as a PAPR - Powered Air Purifying Respirator

Photo Credit: Stock 3M Photos

- SAR - Supplied Air Respirators
  - Unlimited air from a supplied air source
  - Small size
  - May have a small escape air bottle in case it becomes disconnected
  - Maximum hose length of 300' from last regulated source.

- SCBA - Self Contained Breathing Apparatus
  - Limited air supply on tank
  - Typically, 30, 45 or 60 minute ratings
  - Heavy and bulky
  - May have option to connect to supplied air

Photo Credit: Stock SCOTT Safety Photos

Confined spaces can amplify hazards such as noise, airborne particles, and mechanical risks, making appropriate PPE essential for rescuer safety.

Eye protection should be selected based on the environment and may include safety glasses for general protection, chemical splash goggles for liquid hazards, and face shields for tasks with flying debris or chemical exposure.

Hearing protection is critical, as confined spaces can increase the effects of noise from tools, ventilation equipment, or alarms. Options include disposable foam earplugs, reusable earplugs, earmuff-style hearing protectors, and electronic hearing protection that allows for situational awareness while reducing harmful noise levels. Many modern rescue teams also use hearing protection integrated into communication headsets (such as Con-Space or similar systems), which combine noise reduction with clear team communication.

Hand protection should be matched to the task: leather gloves offer abrasion resistance for rope work, mechanic-style gloves provide dexterity and grip, and chemical-resistant gloves (such as nitrile or neoprene) are necessary when handling hazardous substances. For cut hazards,

gloves should be selected based on their ANSI/ISEA 105 or EN 388 cut resistance rating, with higher levels (A4-A9 or EN 388 Level 4-5) recommended for sharp edges or glass. Always inspect PPE before use and ensure it is appropriate for the specific hazards present in the confined space.

Hazards

Confined Space Hazards

There are a variety of hazards that need to be recognized and mitigated prior to entry. They include atmospheric, engulfment, entrapment, mechanical, chemical, weather, slick surfaces, noise, falling objects, lighting, thermal and fall hazards. Hazards maybe liquids, vapors, gases, mists, solids, dusts, noises or an external condition or situation. Each should be mitigated with the proper techniques ranging from ventilation, to isolation to LOTO.

Psychological Aspects

Not all hazards are physical. The human mind often does not like the situations that we put ourselves in and may react with some psychological aspects that may even manifest into physiological problems. These can all attribute to workers and rescuers not being able to perform their tasks.

ANXIETY

is a distress or an uneasiness of the mind or a reaction when you feel danger from a person, object, situation or impulse.

PHOBIAS

are a persistent fear of a situation or an object in which the level of fear is not proportional to its actual seriousness. i.e., Claustrophobia...

PANIC

is a sudden terror or an unreasoning, infectious and uncontrollable fear. i.e., Hallucinations

These may arise due to biological, psychological or physiological reactions to the environment and stressors in our lives.

To help overcome these issues it is important to work with some control techniques.

- Identify problems during training
- Learn your limitations
- Develop methods to overcome / work through any anxiety related phobias
- Contextual Therapy
    - Expect, allow and accept fear

- When it comes, wait let it be
- Focus your attention on the job
- Label responses 1 through 10
- Learn to function at a level of fear
- Allow and accept it will re-appear and be prepared

Chemical Hazards

Chemicals pose hazards in multiple ways as we may be exposed to them in a variety of ways physically.

- Routes of entry into the human body from chemicals include:
  - Inhalation (breathing)
  - Skin (or eye) contact
  - Swallowing (ingestion or eating)
  - Injection

Each chemical has a defined exposure limit, symptoms of exposure and target organs affected that we must be familiar with. This information may be obtained on Safety Data Sheets (SDS), NIOSH guides or other emergency response guides. It is also important to consider a variety of physical properties that chemicals have and understand each of these. Each of these is covered in more detail in our HAZWOPER classes, or if needed in this class are addressed within the course and/or student manual.

- Potential Chemical Physical Properties
  - Solubility / Miscibility
  - Density
  - Specific Gravity
  - Vapor Density
  - Pressure
  - Boiling / melting point
  - Flash point
  - Viscosity
  - Ignition temperature
  - Flammable Range
  - Reactivity

Signs and Symptoms of Exposure Examples	
Carbon Monoxide (CO)	Acetone
Headache	Irritated eyes, nose, throat
Rapid breathing	Headache
Dizziness	Dizziness
Confusion	Central Nervous System Depression
Weakness of limbs	Dermatitis
Bright red skin	
Unconsciousness	

Chemicals may also react based on the atmosphere it is introduced to or a mixture with other substances. Reactivity is a chemical reaction that occurs under certain specific conditions. This maybe a violent or abnormal reaction when a certain chemical is in the presence of water (water reactive hazard) or normal atmospheric conditions (pyrophoric hazard).

- Examples
  - Water Reactive Hazard

        - Magnesium and water
    - Pyrophoric Hazard
        - *tert*-butyllithium ($LiC(CH_3)_3$)
        - Diphosphane (P_2H_4)

Environmental, Biological and Radiological Hazards

Additional hazards to consider are environmental, biological and radiological hazards that maybe within a confined space or associated with the equipment around it. These are covered more in depth in our HAZWOPER training programs.

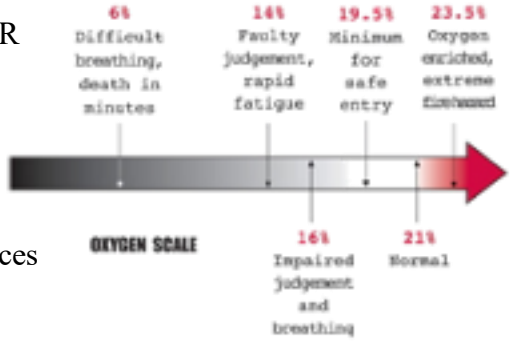
- Environmental Hazards
    - Internal or external to space
        - Extreme heat
        - Extreme cold
    - High winds
    - Lightning

- Biological Hazards
    - Viral
    - Bacterial
    - Fungal
    - Parasitic
- Radiological Hazards
    - Ionizing
    - Non-ionizing
    - Alpha Rays
    - Beta Rays
    - Gamma Rays

Atmospheric Hazards

Oxygen enrichment, deficiency, carbon monoxide, explosive hazards, hydrogen sulfide and other site-specific atmospheric hazards must be monitored for Immediately Dangerous Life Hazards (IDLH) conditions. IDLH conditions exist when your atmospheric monitor alarms. **You should ***never*** trust your senses alone to determine if the air quality is acceptable.**

Entry into an IDLH atmosphere must include SCBA/SAR and appropriate PPE, while attempts to correct the atmospheric conditions are performed.

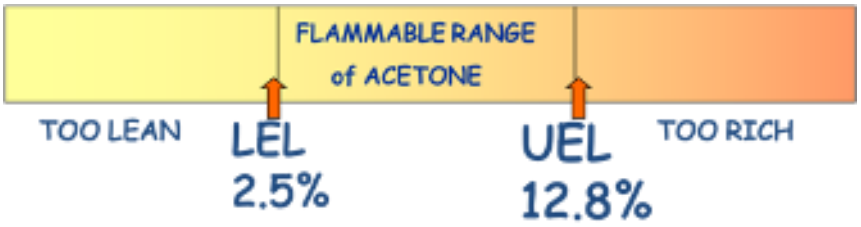


Entry and/or rescue into an atmosphere that requires SCBA or SAR can only be performed by teams that have the proper equipment, training and medical clearances based upon the OSHA standards.

If operating in the recovery mode, the incident commander may decide to not allow entry until conditions are more favorable.

Explosive or fire hazards may exist in a confined space and maybe from gas, vapors, mist or dust. These are detected in the range of Lower Explosive Limit (LEL) or the Lower Flammable Limit (LFL) to Upper Explosive Limit (UEL) or Upper Flammable Limit (UFL).

For these hazards to ignite or burn the mixture must have the right percentage of vapor in the air. This is called the flammable range. For now, let's simply think about the explosion hazard like a carbureted engine. If acetone was our engine, it would only run if the mixture of acetone to air was correct. We will get into how this works in more detail in the metering section.



Life-Threatening Effects: CO and H_2S

Effects Of Carbon Monoxide Exposure

ppm	Time	Effects & Symptoms
35	8 hours	Permissable Exposure Level
200	3 hours	Slight headache, discomfort
400	2 hours	Headache, discomfort
600	1 hours	Headache, discomfort
1000 to 2000	2 hours	Confusion, discomfort
1000 to 2000	½ to 1 hour	Tendency to stagger
1000 to 2000	30	Slight heart palpitations
2000 to 2500	30	Unconsciousness
4000	> 1 hour	Fatal

Effects Of Hydrogen Sulfide Exposure

ppm	Time	Effects & Symptoms
10	8 hour	Permissable exposure level
50 to 100	1 hour	Mild eye and respiratory irritation
200 to 300	1 hour	Marked eye and respiratory irritation
500 to 700	½ - 1 hour	Unconsciousness, death
> 1000	Minutes	Unconsciousness, death

Potential Effects of Oxygen Enriched and Deficient Atmospheres

Oxygen Content (% by Vol.)	**Effects and Symptoms** (At Atmospheric Pressure)
> 23.5%	Oxygen enriched, extreme fire hazard
20.9%	Oxygen concentration in normal air
19.5%	Minimum permissible oxygen level
15% to 19%	Decreased ability to work strenuously; may impair coordination and may cause early symptoms for persons of coronary, pulmonary or circulatory problems
10% to 12%	Respiration further increases in rate and depth; poor judgment, blue lips
8% to 10%	Mental failure, fainting, unconsciousness, ashen face, nausea, and vomiting
6% to 8%	Recovery still possible after four to five minutes. 50% fatal after six minutes. Fatal after eight minutes.
4% to 6%	Coma in 40 seconds, convulsions, respiration ceases, death

These values are approximate and vary, due to an individual's state of health and physical activity.

Source: RAE Systems, Application Note AP-206

Meters, Atmospheric Monitoring, and Ventilation

Overview

Atmospheric monitoring is typically performed utilizing portable meters which are actually calibrated instruments. We must test the conditions of the space before anyone enters, to the extent possible and then monitor conditions continuously in the area where workers or rescuers are working. This can be a challenge in certain spaces, and we must understand the ability and the limitations of our meters. It is also important to understand that metering the space will also tell us how effective our ventilation is, and that these two processes go hand in hand to ensuring safe and effective confined space entries and rescues.

Meter Anatomy

As stated, a meter is an instrument, which in the entry and rescue realm will most often be portable there are features and limitations that we must understand. When selecting a meter, we want to make sure that we have one that is:

- Reliable
  - Calibrated to specific known quantities
  - Bump tested to ensure they are working properly
- Sensitive

- Responds in a timely manner to alert workers / rescuers, typically 30 - 60 seconds
- Maybe affected by temperature, humidity and atmospheric pressure
- Pumped units may require an additional 1 - 2 seconds per foot of hose to respond

- Selective
  - Appropriate sensors are installed for the suspected hazards of the environment
  - Typically monitoring Oxygen, LEL, Hydrogen Sulfide and Carbon Monoxide
  - Many other sensors are available such as Ammonia or Chlorine
- Intrinsically Safe
  - Will not cause a fire or explosion hazard when used in a hazardous location

Most modern meters utilized for confined spaces are basically small computers that can evaluate one or multiple gases at the same time. They instantly test in order:

1. Oxygen
2. Combustible gases and vapors
3. Toxic gases and vapors

This is done as air is passed over the sensors inside the meter. These sensors are typically electrochemical sensors which contain an acid or base solution in which there are sensing and counting electrodes. Various solutions or electrode metals inside the sensor are designed to measure specific gases or vapors.

As an example, oxygen sensors use either a lead or zinc electrode with a base solution. When the oxygen in the air reacts with the electrode it produces an electrical current. Changes in concentration of oxygen will change the electrical current produced and the electronics inside the meter will relay the information gathered to the display on the meter as a percentage.

Meter calibration station where known quantities of gases are passed over the sensors to either perform bump tests or calibration.

Normal oxygen concentration is typically 20.9% in the atmosphere and the meter is programmed to alarm when certain conditions are met. If the meter detects an oxygen deficient atmosphere at 19.5% or less the meter will alarm. Conversely if the meter detects an oxygen enriched atmosphere at 23.5% or greater it will also alarm.

Internal view of sensors in a MultiRAE and QRAE 3 Meter. Two sensors are turned over to show the different electrical connections.

Electrochemical sensors have a typical service life of 1 -2 years, which could be shorter if exposed to other gases or vapors in high concentrations. As an example, Chlorine is a very corrosive gas, and typically is only utilized in a single gas meter so it does not burn out other sensors. If a Chlorine sensor is installed in a multi-gas meter and a high level of Chlorine is exposed to that meter, it will detect the chlorine without a problem, however the other sensors may not respond appropriately or remain serviceable after that use.

There are two ways for the air to get from the outside environment and into the meter. The first is called diffusion, where there are ports open on the meter that allow for air to be naturally exposed to the sensors. This works well for entrants or rescuers in a confined space who want to test the atmosphere they are actually working in.

The other way air gets into the meter is through a pump, where air is drawn from the outside and into pulled into the meter and passed over the sensors. A pump may be connected to sampling hose or a wand to extend the distance we can sample away from us. This is helpful in confined spaces so we can stay in a clean air environment and detect any hazards inside the confined space. Depending on the manufacturer, we must add at least 1 - 2 seconds of sampling time per foot of hose to the sampling time of the meter.

If a meter has a typical response time of 15 seconds and is setup as a diffusion meter, then we must wait that amount of time from our sample until we see the results on the screen of the meter. If that same meter was a pumped meter and we were using 10’ of sampling hose we may have to wait 35 seconds or more so that the air sample that is drawn into the hose has sufficient time to be pulled into the meter and evaluated in that response time.

Other types of atmospheric monitoring equipment could include colorimetric tubes which are specific to known chemicals and quantities. These are single use only and are typically only used with known hazards. There are also newer detectors that are laser based and can quickly find gases such as methane.

Methane has a LEL of 5% by volume and a UEL of 17%. That means if the atmosphere of a confined space is 5% or more methane, than an ignition can occur. If the atmosphere is less than

5% methane ignition cannot occur, as the mixture is too lean. Once the atmosphere exceeds 17% methane by volume in the confined space than once again ignition cannot occur, but this time the mixture is too rich.

This is all shown in the chart below and is more in-depth than our previous example of Acetone.

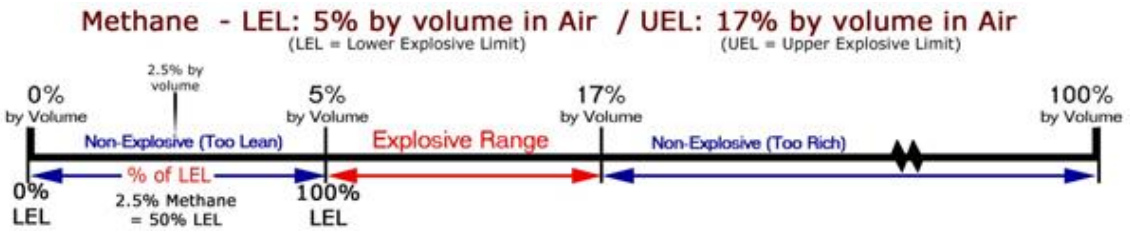


Photo Credit: Honeywell

Level of Gas Present by Volume	Meter Reading - LEL
No Methane Detected	0
0.5 % Methane	10 % LEL
2.5 % Methane	50 % LEL
5 % Methane	100 % LEL

If the level of Methane gas present is 5% by volume the LEL reading on your meter would be 100%. Most LEL sensors are calibrated to Methane, and the alarm limit is set to 10% of the LEL. This gives us a cushion to try to safely correct conditions in the atmosphere, as we are still have not come near the LEL of Methane.

Remember - The meter is measuring up to the LEL threshold and not the total amount of gas in the area or confined space.

The LEL sensor in your meter is only accurate for the gas it is calibrated to. Methane is often used because it is in the middle of many other gasses LEL by volume. So, if you know there is another gas in the area and know what it is, you can apply correction factors for more accurate results. Some meters have these functions built it.

Blackline Safety - Gas Detectors – Additional Info

CTR is a Blackline Educator Partner

Blackline Safety Advantages: Lone Worker Protection / Gas Detection / 24-7 Monitoring / Data Analytics

Used in all industries: Fire & Rescue / Biotech & Pharma, Petrochemical, Pulp and Paper, Steel Manufacturing, Water and Wastewater, Utilities, Transportation, HAZMAT and more!

Air Sampling Techniques

Various gasses that make up an atmosphere have different weights and it is therefore important to ensure we are metering at least 3 different areas or levels of the confined space. This is called stratification. Since air circulation is typically poor in a confined space, it is imperative we monitor all levels and areas possible prior to entry. It is often recommended that spaces be monitored at least 4' ahead and to the sides of rescuers or workers as they move.

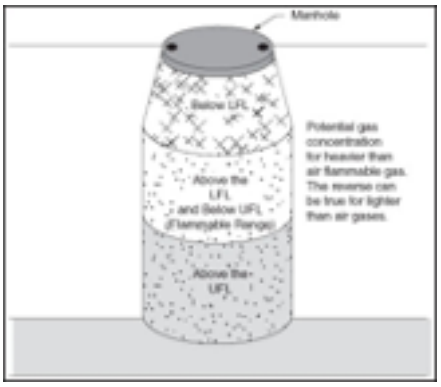


Photo Credit: Delmar Books, Confined Space Rescue

Videos by Capital Technical Rescue

https://youtu.be/cG6-1ljWAOU

Demonstration of how meters work in various atmospheres

Best Practices for Atmospheric Monitoring

Peak and Minimum Values

Understanding Meter Functions

Modern atmospheric monitors used in confined space rescue are equipped with advanced features to help keep entrants safe. Among these features are **"Peak" and "Minimum" value displays**, which record the highest and lowest readings detected for each gas since the last reset. Understanding and using these functions is critical for both real-time safety and post-entry documentation.

Why Peak and Minimum Values Matter

- **Peak values** (the highest reading detected) can reveal transient hazards—such as a brief spike in carbon monoxide (CO), hydrogen sulfide (H_2S), or explosive gases—that may not be present at the time of exit but could have endangered entrants.
- **Minimum values** (the lowest reading detected) are especially important for oxygen (O_2). A temporary drop in O_2, even if the atmosphere is safe at exit, may indicate a hazardous condition occurred during entry.
- **Regulatory and best practice standards** (NFPA 350, OSHA 1910.146) emphasize the importance of continuous monitoring and documentation of atmospheric conditions throughout entry operations.

Best Practices for Using Peak and Minimum Value Functions

Before Entry

- **Calibrate and bump test** the meter as required by the manufacturer and your organization's policy.
- **Clear (reset) all peak and minimum values** on the meter. This ensures that any values recorded during the entry are specific to that operation and not leftover from previous use.
- **Confirm the meter is set to display real-time readings** for all gases being monitored.

During Entry

- **Continuously monitor real-time readings** for oxygen, combustible gases (LEL), carbon monoxide, hydrogen sulfide, and any other site-specific hazards.
- **Periodically check the peak and minimum value screens** (if available) during entry, especially after any alarm or unexpected reading.
- **If an alarm sounds or a reading changes unexpectedly**, immediately investigate and take appropriate action (e.g., evacuate, ventilate, retest).

After Entry

- **Review and record the peak and minimum values** for all monitored gases before clearing the meter for the next use.

- **Document any readings that exceeded safe thresholds** (e.g., O_2 below 19.5%, CO above 35 ppm, LEL above 10%) even if the real-time reading is now normal.
- **Clear (reset) peak and minimum values** before the next entry or operation.

Documentation and Incident Review

- **Record peak and minimum values** on the confined space entry permit or in your entry log.
- **If a hazardous peak or minimum was detected**, document the time, location, and any actions taken (e.g., evacuation, ventilation adjustments).
- **Use this information for post-incident review** and to improve future entry procedures.

Key Points to Remember

- **Never rely solely on real-time readings.** Always check and document peak and minimum values to ensure a complete picture of atmospheric conditions.
- **Clearing values before each entry** ensures accurate tracking of hazards specific to that operation.
- **Recording values after entry** supports regulatory compliance, incident investigation, and continuous improvement of safety practices.

Why This Matters

Transient atmospheric hazards can be deadly, even if they are not present at the time of exit. By using and documenting peak and minimum values, you ensure that no hazardous condition goes unnoticed and that your team is following the highest standard of care for confined space safety.

Always refer to your meter's user manual for specific instructions on accessing and clearing peak/minimum values, and follow your organization's policies for documentation and reporting.

22 Mill St., Unit 2, Albany, NY 12204 T 518-930-4500 F 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

Sample Checklist for Atmospheric Monitoring

Before Entry:

- Calibrate and bump test meter
- Clear all peak/minimum values
- Confirm real-time display is active

During Entry:

- Monitor real-time readings continuously
- Periodically check peak/minimum screens

After Entry:

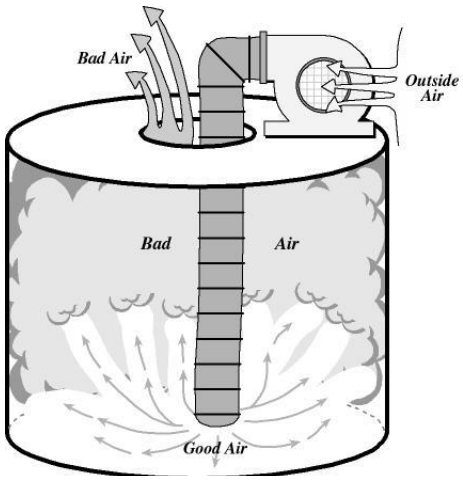
- Review and record peak/minimum values
- Document any excursions above/below safe limits
- Clear values before next use

Ventilation

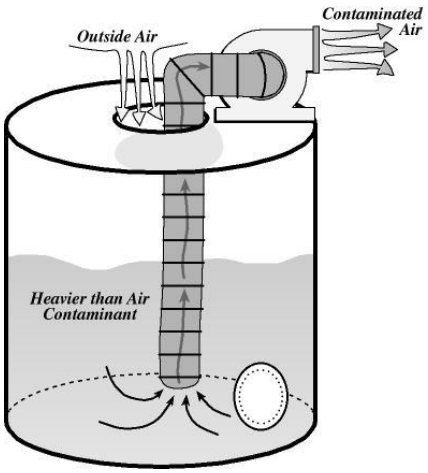
Unless you are sure there are no atmospheric hazards there should always be a ventilation system in place. Even in optimal conditions, ventilation can make the workers more comfortable and reduce psychological hazards.

Ventilation can be natural, supply or exhaust. Unless there is a reliable updraft, natural ventilation usually isn't enough. Utilize the technique that will work best for the workers.

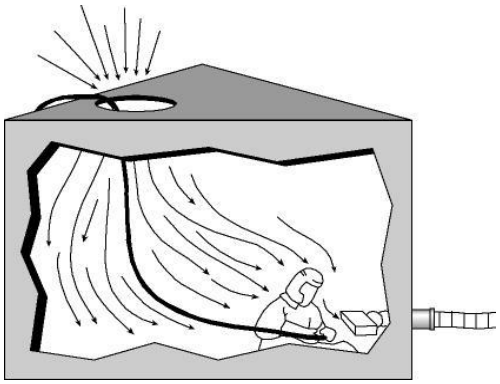
Ensure you are supplying good air, and not re-circulating the exhausted air or contaminating the work area. Monitor the space at various levels to verify effective ventilation. Adjust the duct for the desired effects.



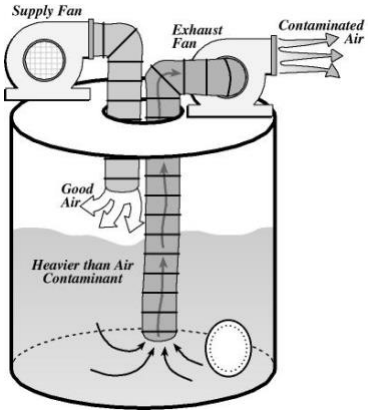
Supply Ventilation (Wiley, 2005)



Exhaust Ventilation (Wiley, 2005)

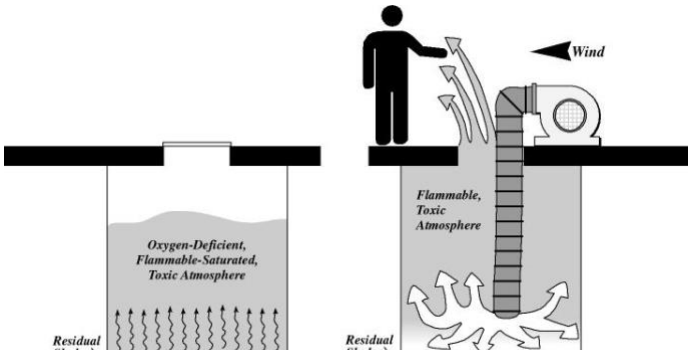


Local Exhaust Ventilation (Wiley, 2005)

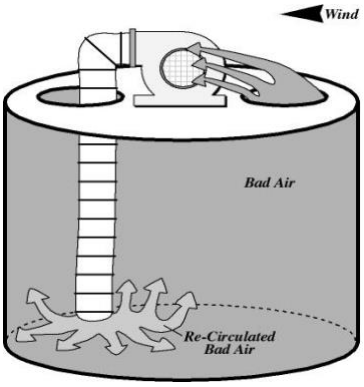


Push / Pull Ventilation (Wiley, 2005)

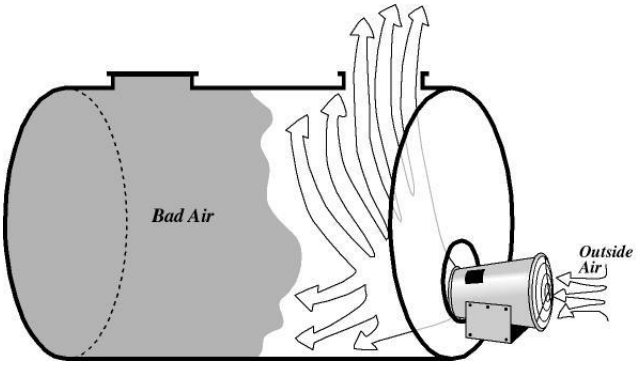
We must also be aware of some pitfalls of ventilation, that could potentially harm us or the entrants. It is also important to ensure we are periodically metering the source of our air to ensure we have good quality going into our space, and that we are sufficiently exhausting the bad air out.



Potential to be overcome by toxic atmospheres, even outside the confined space (Wiley, 2005)



Recirculation (Wiley, 2005)



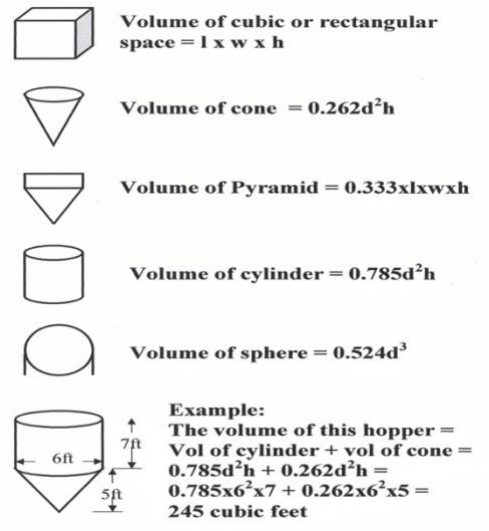
Short Circuiting (Wiley, 2005)

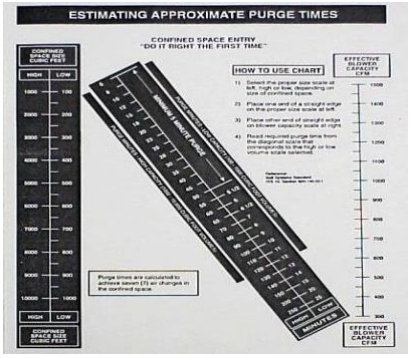
When performing ventilation, we must know the amount of air that our blower can move, and the volume of the space we are trying to ventilate. This is expressed in cubic feet per minute (CFM) and can be found in the manual or often right on the side of the blower. When using duct work, each 90° bend we place reduces the amount of CFM that the blower can move. Therefore, it is important to keep unnecessary kinks and bends out of the system.

The volume of the space maybe calculated utilizing standard mathematical formulas.

Once the effective blower capacity and the volume of the space is known, we can calculate our purge time. The purge time is the amount of time it takes to turn over the atmosphere of the entire volume of the air fully at least once, however it is recommended to be as high as 7 full exchanges of time prior to allowing entry if meter readings are within acceptable entry conditions. It is also recommended to change the air in a space at least 20 times per hour. This is all calculated by utilizing a nomograph. Regardless of the size of the space and the capacity of the blower it is always recommended to purge the space for a minimum of 5 minutes.

On one side of the nomograph is the volume of the confined space, with the opposite side having the effective blower capacity in cubic feet per minute. Utilizing a straight edge, such as a ruler connect the volume to the CFM and where it intersects the nomograph in the middle will tell you how many minutes of ventilation are required.

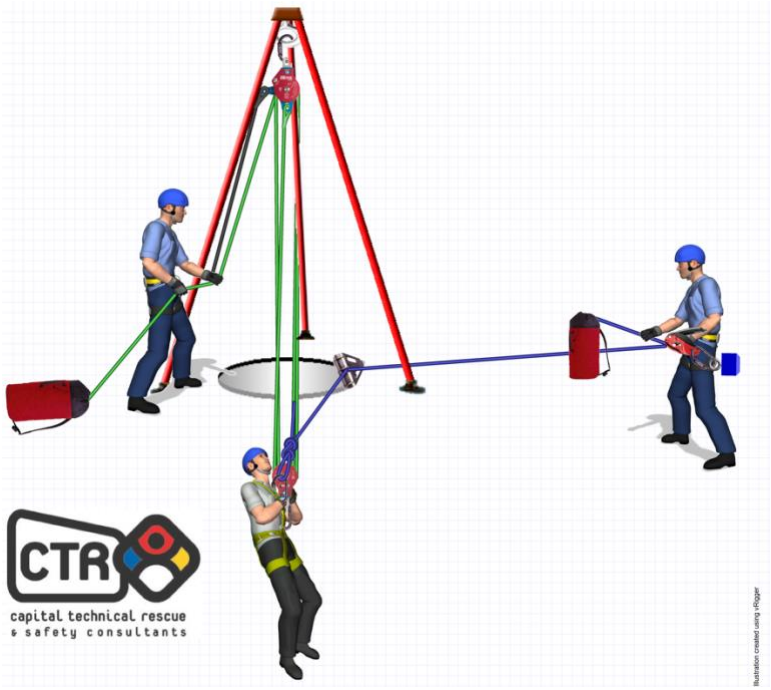




Air Systems International Manual, blower capacity plate, and nomograph.

Vertical Entry Setups

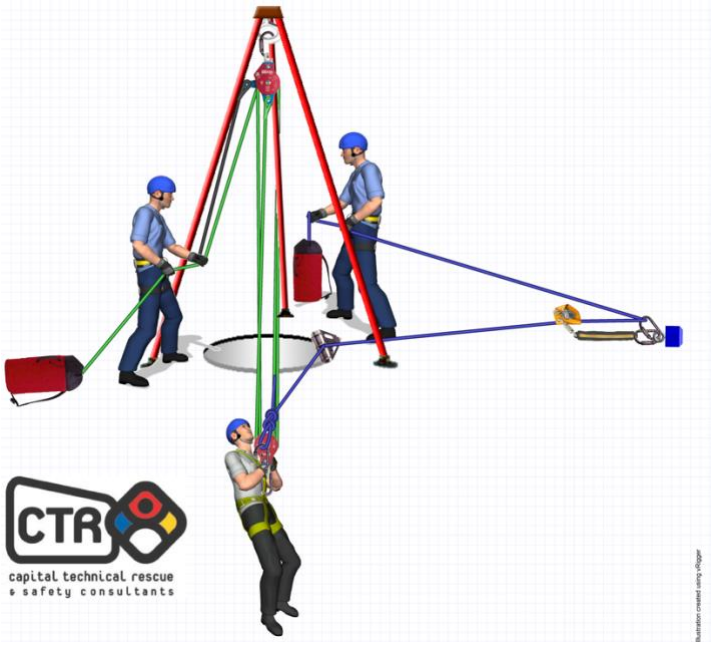
Pre-Rigged 4:1 System with Traditional



Tripod Hobble Omitted for Clarity

Features:
Fast and easy to setup using a pre-rigged 4:1 system that has integrated progress capture. Requires 2nd rescuer to run the Petzl ID belay. This is a more traditional setup, and can use other belay devices as well, including a tandem prusik belay, although we prefer setups that can be quickly converted from raising to lowering systems.

Pre-Rigged 4:1 System with Petzl ASAP Belay

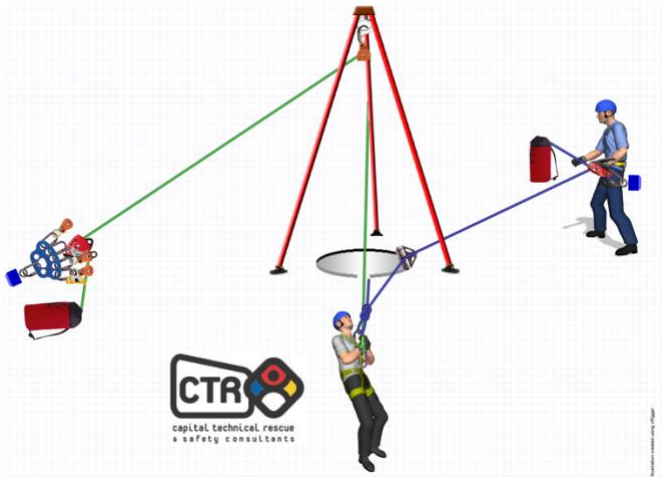


Tripod Hobble Omitted for Clarity

Features:
Fast and easy to setup using a pre-rigged 4:1 system that has integrated progress capture, and a Petzl ASAP Belay. This can be setup so that one rescuer is operating both the haul and the ASAP belay at the same time.

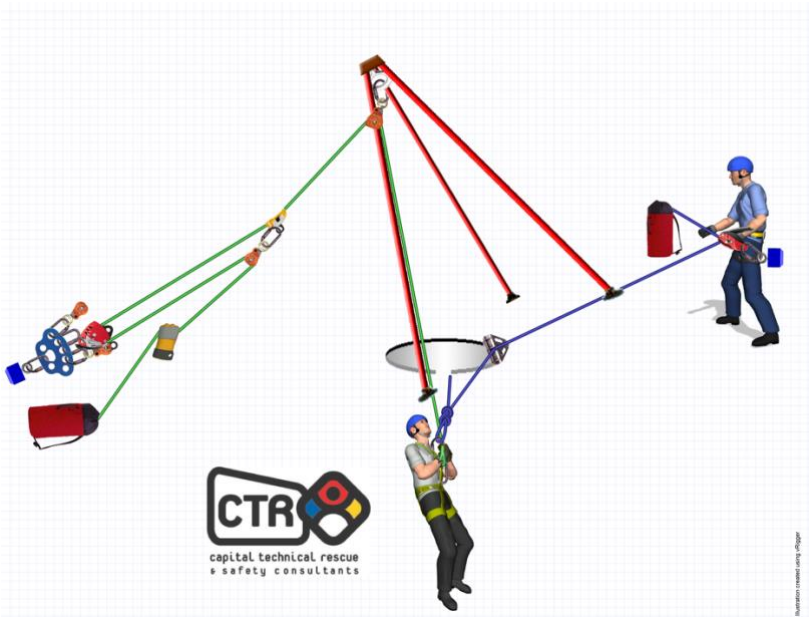
Note that when using the ASAP belay, the 2nd re-direct carabiner must be in place.

Main Line System with Traditional Belay



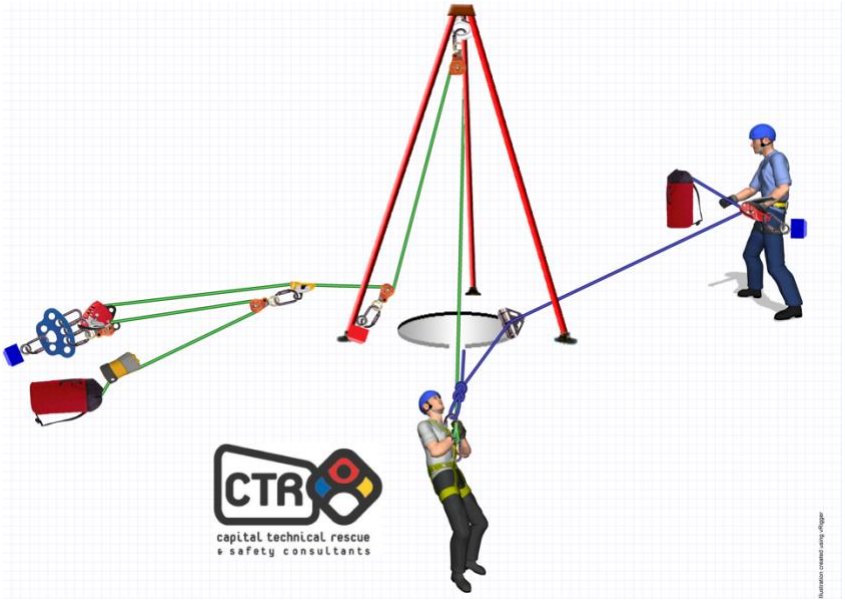
Lower Only! - Tripod Hobble Omitted for Clarity

Features: In the above scenario - this is only acceptable for lowering a rescuer quickly into a confined space. Should we try to haul on the green line, the tripod will topple over as the resultant forces will land outside the footprint of the tripod.



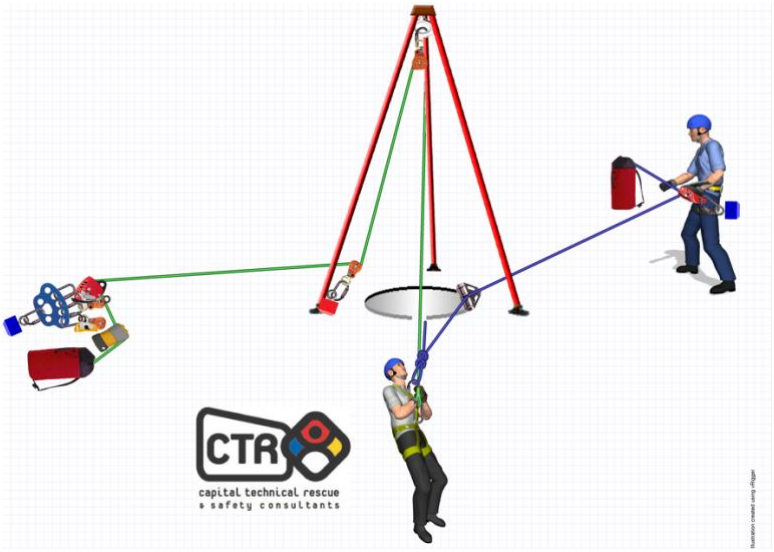
!!Hauling on Main Line topples tripod!! Tripod Hobble Omitted for Clarity

To counteract this, we must either tie back the tripod opposite the hauling force, or change direction of the main line to ensure the resultant forces remain within the footprint of the tripod.



Hauling with a Change of Direction on Main Line - Tripod Hobble Omitted for Clarity

Now that we have added the change of direction into a substantial anchor point we can haul and keep the resultant forces within the footprint of the tripod. We can also perform a lower through this setup as well.

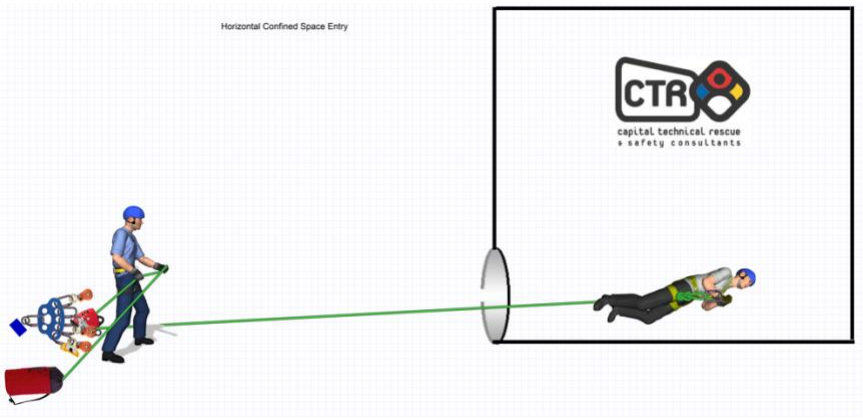


Lowering with a Change of Direction - Tripod Hobble Omitted for Clarity

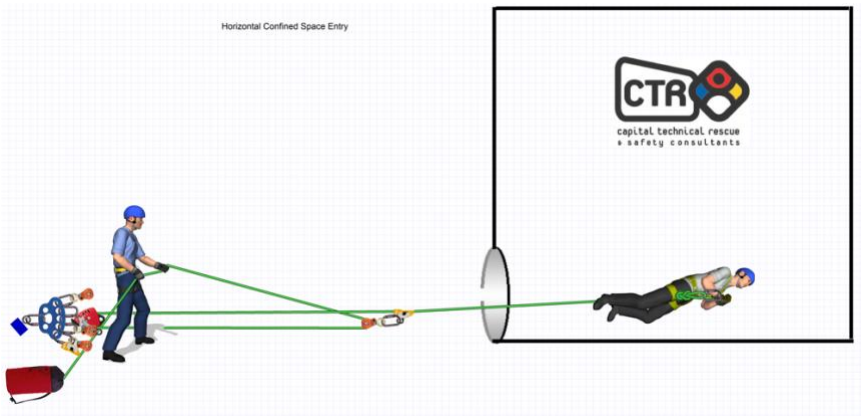
Any belay technique can be utilized, as well as any of the descent control devices. Here we have chosen a Petzl Maestro for its efficiency, safety and ability to quickly change over from raising to lowering and back to raising.

Horizontal Entry

Entries without the potential for falling



A simple system on the outside of the confined space that the attendant can control and act as a tag line to the rescuer. When no fall hazards exist, up to two rescuers per tag line can be attached by using butterfly knots or prusik hitches.



Should the need occur to try to remove the rescuer from the confined space, these types of simple systems can be quickly converted into a hauling system. Even if they can't be removed completely, if we are able to get a downed rescuer closer to the opening, we can a provide better atmosphere and possibly access, assess and treat the rescuer prior to removal.

Bleeding control / IFAK

OSHA only requires that a rescue team or an attendant who can perform a non-entry rescue to have a basic first aid and CPR class. While those are certainly important training for everyone to have, we believe it falls short of some of the life-threatening injuries that could occur within or near a confined space. In fact, you are more likely to treat someone with a major medical emergency versus having the need to perform a confined space rescue.

Modern bleeding control has changed significantly and injuries that were once a sure fatality may now be easily and rapidly addressed with the proper equipment and training. A simple IFAK or Individual First Aid Kit should be on hand at a minimum that addresses hazards such as bleeding control.

These kits are small and can be kept on the attendant's body or attached to a piece of gear close to the point of entry. Kits can be customized to your needs or be a standardized kit.

Photo Credit: Tac-Med Solutions Operator IFAK, Stock photo

- Example IFAK contents:
  - Tourniquet
  - Emergency Trauma Dressing (i.e. OLAES Modular Bandage or similar)
  - Petrolatum Gauze
  - Nasal airway
  - Surgical Tape
  - Nitrile gloves
  - Face Shield
  - Trauma Sheers
  - Casualty Card

When purchasing first aid equipment, be sure to do so from a reputable source. Many sites such as Amazon and eBay have been known to have counterfeit products that cannot hold up to the environments we work in. This is an area where trying to save a few dollars could end up costing a life.

For more information or training on IFAKs, contact us about our Stop the Bleed programs and integrated training modules.

Patient Packaging

Patient Packaging: Prioritizing the Patient

Rescuer Mindset: The Patient Comes First

In technical rescue, it's easy for rescuers to focus on the challenge, the gear, or the urgency of the situation. However, it is critical to remember that the **primary goal of patient packaging is the comfort and safety of the patient—not the convenience or speed of the rescue team**.

- **Every action taken during packaging should be guided by the question:**
  "Is this the best choice for the patient's comfort and safety?"

- **Rescuers are not the most important person in the rescue—the patient is.**
  Our role is to provide rapid, but safe, intervention that maximizes the patient's chance of survival and minimizes further harm.

Best Practices for Patient Packaging

- **Padding and Positioning:** Use padding to protect pressure points and immobilize injuries. Ensure the patient is as comfortable as possible, even if it takes extra time.

- **Communication:** Explain procedures to the patient whenever possible to reduce anxiety.

- **Gentle Handling:** Move the patient carefully, avoiding unnecessary movement or rough handling.

- **Continuous Monitoring:** Regularly check the patient's comfort, airway, breathing, and circulation throughout packaging and transport.

- **Adapt to the Patient's Needs:** If the patient has specific injuries (e.g., spinal, pelvic, or limb injuries), adjust packaging techniques accordingly—even if it means slowing down or modifying standard procedures.

Patient Comfort Kit (PACK): Practical Tools for Patient-Centered Rescue

To ensure comfort and safety, teams should deploy a **Patient Comfort Kit (PACK)** during packaging and movement. The PACK contains items specifically chosen to:

- **Protect against cold, heat, and rough surfaces:**
  Use insulated blankets ("woobie"), waterproof tarps, and folding pads to shield the patient from environmental hazards.

- **Support and cushion the patient:**
  Small pillows and pads help prevent pressure injuries and improve comfort during long or difficult extrications.
- **Maintain dignity and safety:**
  Safety / sun glasses protect eyes from debris, light; balaclavas and blankets provide warmth and privacy.

Best Practice:
Before packaging, assign a team member to deploy the PACK and ensure all comfort items are in place. Reassess comfort throughout the rescue.

Patient Comfort Kit (PACK)

- Safety / Sun Glasses/Case
- Small Pillow
- Thermorest Folding Pad
- Waterproof Thermal Tarp
- Woobie
- Balaclava

Patient Packaging Devices

There are many patient packaging devices that can be used in confined space rescue. Here we are just listing a few of the most popular ones and what we typically carry. That being said, we still carry litters or baskets, Reeves sleeves, FAST boards and other devices. A simple hasty harness may also work either alone or in conjunction with some of these devices.

Wristlets

Wristlets are typically only used either as a last resort or when you only have access to a victim's feet or wrists.

There are also times where a victim's hands inside of wristlets will help get them through very small openings.

They may cause further injury and do not fully secure the patient. Wristlets can also be used in conjunction with other patient packaging devices.

Yates Spec Pak

The Yates Spec Pak is one of our go to patient packaging devices for confined space rescue and offers a lot of flexibility. It is also rated as a spinal immobilization device.

The Spec Pak has drag and carry handles, is rated as a Class 3 harness with a maximum capacity of 400 lbs and can be utilized for both vertical and horizontal rescues.

If the victim has a harness on and/or thicker clothing / gear, remove them first, if possible.

WLCH - Acronym for securing the Spec Pak:
Waist - Legs - Chest - Head

Leg straps should be tightened before securing shoulder straps.

Should be able to get two fingers under a tightened strap.

If using a VERTICAL lift - DO NOT use chin strap. If suspension going to be more than 7 minutes you must use the spreader bar or standard lifting bridle. NEVER lift from the drag handles.

Standard Lifting Bridles - Bull ring with adjustable straps.

Spreader bar for horizontal and semi-vertical lifting is available as an accessory. It is more comfortable for longer suspension times.

Leg rest - slide from foot end down to below the knees and secure the yellow strap and tighten, put the red foot loops over the feet.

Cleaning accomplished by completely disassembling and removing the screws, head piece, back board. Front loading commercial washers should be used.

SKED

The SKED is one of the most iconic and popular confined space rescue packaging devices. This device works great for dragging and protecting victims inside of confined spaces.

The SKED is rated for both vertical and horizontal lifting however it provides no spinal immobilization and no rigidity. To get spinal immobilization it is recommended to use a short spinal device such as a KED or Oregon Spine Splint. These will also help a bit with rigidity. Some departments will also use a backboard inside of the SKED when packaging, however not all backboards fit well into the SKED, so you must be aware of this ahead of time.

Never crisscross the straps on the SKED as it will cause buckling. Never send the SKED down in the bag unless it is requested that way. Help the rescuers inside the space by having it rigged and ready for patient packaging.

CMC Drag-N-Lift

The CMC Drag-N-Lift is the newest device on the market and was designed in conjunction with SKEDCO. It is a NFPA 1983 rated Class III Victim Extrication Device, and works for both vertical lifts or horizontal drags.

It can also be used with short immobilization devices like the SKED, is easy to clean and fast to package a victim. There is padding for victim comfort, color coded straps with quick buckles that are part of the integrated harness, as well as multiple handles for dragging.

The device is easy to clean and the end user can also replace the orange drag sheet when it is worn.

A spreader bar is also available and recommended when using the device for a vertical lift.

Removal from Elevations

Once we have removed a victim from a confined space, that does not mean that the rescue is over. We still need to bring up the rest of our team and we need to get the victim to safety. This may mean lowering them from the top of a tank to ground level. There are many ways to do this, and from the start of the rescue we should be planning on how to accomplish this.

Many elevated areas and tanks that contain confined spaces do not have a big footprint to allow multiple rescuers on the top side. We may have to consider either utilizing what we have or setting up a ground based lower.

Lowering with Pre-Rigged 4:1 and Tripod Tied Back

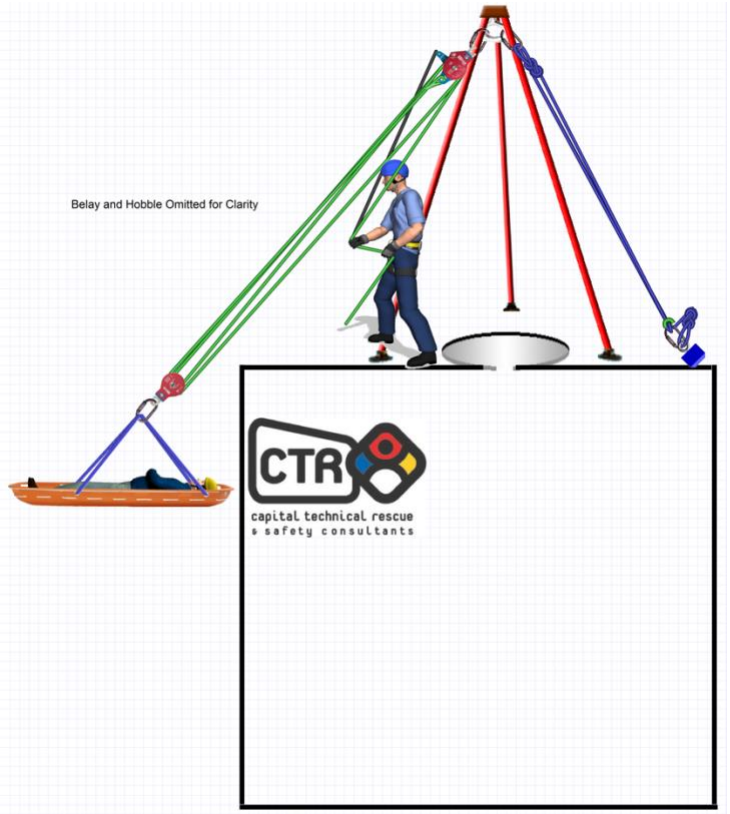
This option omits the belay line and tripod hobble for clarity, but they should always be in place. Edge protection is always an issue here and there is a lot of friction. Also, we are limited to the throw of the pre-rigged 4:1 system.

So, if it is a 200' rope, we are only going to get approximately 45 - 50' of working ability.

This setup also requires that we tie back the tripod so it does not topple over, since we will be operating way outside of the footprint of the tripod. Most tripods are not really rated for this, and other options maybe better suited.

The tie back could be an AZTEK system or a 3:1 tie back using low stretch 8mm cordage such as Sterling PowerCord or 6mm XTEC

Should the victim be critical, this maybe the fastest way to get them to the ground.



Ground Based Direct Lower

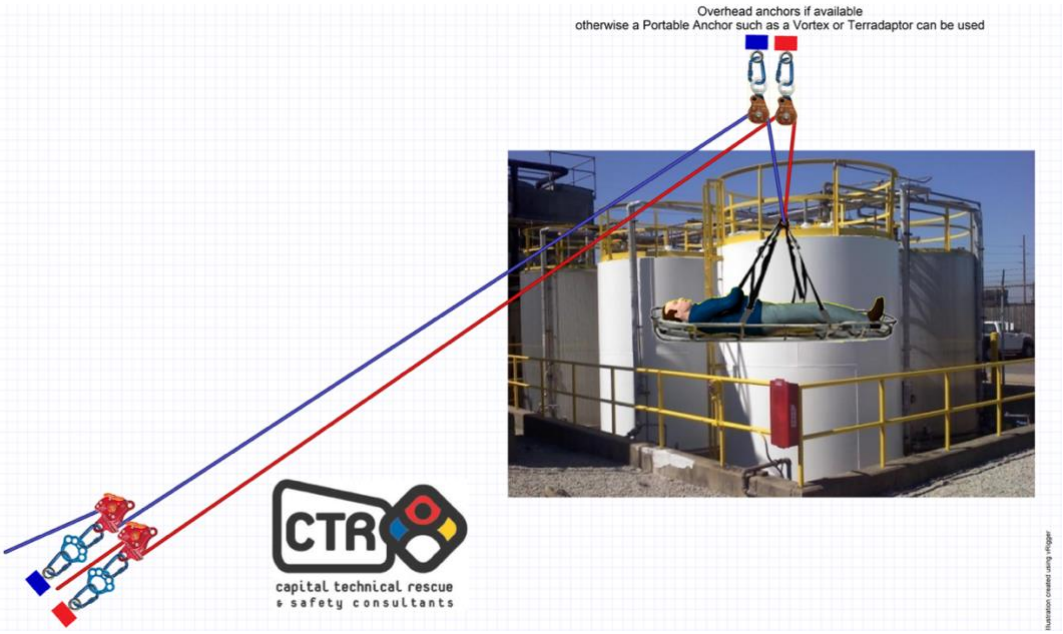
In the ground based lower we utilize either our tied back tripod or overhead anchor points and lower the victim directly to the ground with our standard raising and lowering systems. This requires rescuers to also be setup on the ground and communicating with the team on top of the tank.

The direct lower can be setup many different ways, and with various devices. This could be utilizing a single tension rope system, with both a main and belay on the ground, or the main on the ground and the belay from on top of the tank. In the diagram below, a twin tension rope system is utilized. This technique can be done with a variety of descent control devices, with the diagram showing an MPD. The MPDs will require two rescuers to operate, whereas a Petzl ID or CMC/Harken Clutch can be setup so that one rescuer is operating both devices at the same time. Regardless of the devices and the systems used, the rescue team has many options to choose from.

The major challenge for the direct lower in the industrial environment is that there are often pipes, utilities, railings and containment pits around the area.

A tag line maybe placed on the victim litter to clear these obstacles but may not always be practical due to the physical size of the area or hazards that the ropes may still come into contact with.

This will require rope that is at least twice the height of the structure to accomplish the rescue.

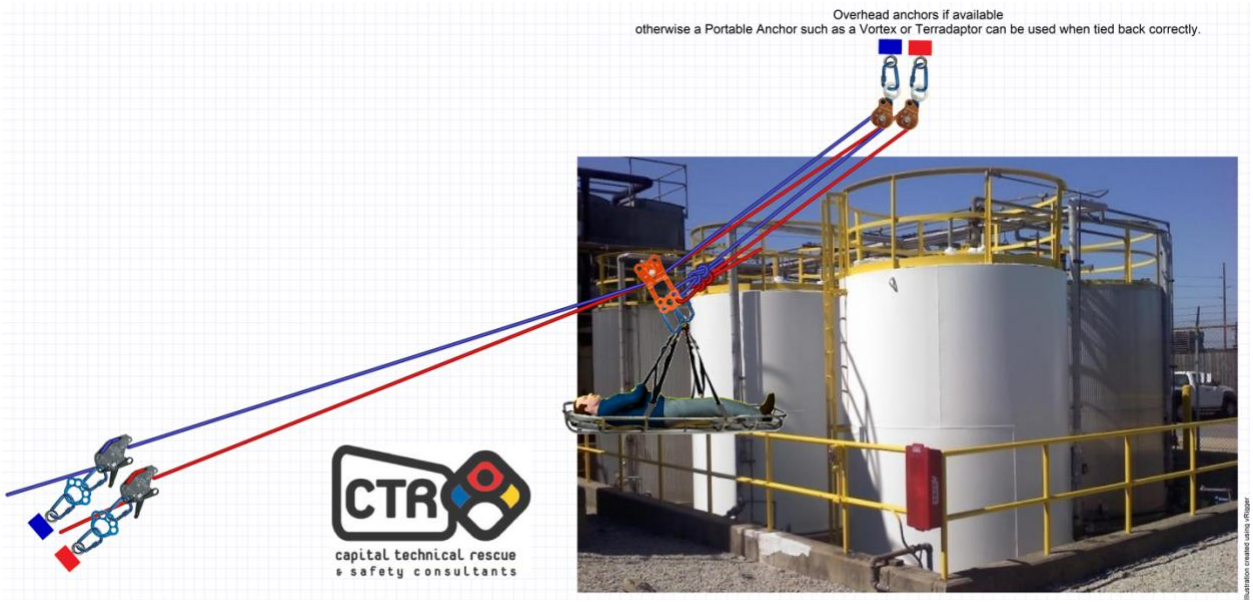


Ground Based Direct Lower

Mirrored Skate Block

A skate block system is a ground based lower where we add in an additional pulley or pulleys into the system to ride or "skate" their way down on the main and belay lines. Skate blocks require about 70' more rope than twice the height of the structure.

Typically, the rescue package will land between one-third to one-quarter the distance away from the structure between the anchor and the structure. This is highly dependent upon multiple factors, including the weight, rope stretch, height of structure and more. The further the ground anchors can be from the structure the more distance the rescue package will travel away from the structure.



Mirrored Skate Block

Pre-planning

Pre-planning is a critical component of any confined space program. It ensures that rescue operations are safe, efficient, and compliant with OSHA 1910.146 and NFPA 350. This section integrates guidance from Capital Technical Rescue, NFPA 350, and industry-standard rescue planning forms.

Objectives of Pre-Planning

- Identify and assess all confined spaces on site.
- Determine the hazards associated with each space.
- Establish rescue procedures tailored to each space.
- Ensure appropriate equipment and trained personnel are available.
- Reduce response time and increase the likelihood of a successful rescue.

Key Components of a Pre-Plan

Space Identification and Hazard Assessment

- Assign unique identifiers to each confined space.
- Document location, configuration, and access method.
- Identify atmospheric, physical, mechanical, chemical, and environmental hazards.
- Determine permit classification and reclassification potential.

Rescue Method and Equipment Planning

- Define rescue type: non-entry or entry rescue.
- Identify anchor points and pre-rigging options.
- List required rescue and medical equipment.
- Specify PPE requirements based on hazard assessment.

Personnel and Communication

- List trained rescue personnel and their roles.
- Define attendant responsibilities and communication methods.
- Address language considerations and interpreter needs.

Documentation and Permits

- Complete rescue pre-plan forms for each space.
- Review and post entry permits.
- Confirm Lockout/Tagout (LOTO) procedures.
- Specify atmospheric monitoring and ventilation plans.

Emergency Response Coordination

- Define emergency notification procedures.
- Identify EMS staging areas and patient transfer points.
- Estimate response time and equipment setup duration.
- Conduct regular drills using actual site configurations.

Rescue Team Evaluation: Assessing the Complexity of Rescue

When evaluating a rescue team's readiness or suitability for a particular confined space or technical rescue operation, it is essential to look at the **complexity of the rescue** that may be required. This assessment helps ensure that the team's training, equipment, and experience match the demands of the potential rescue scenario.

What is "Complexity of Rescue"?

The complexity of a rescue refers to how difficult, technical, or resource-intensive a rescue operation is likely to be. This includes factors such as:

- **Type of space:** Is it a simple horizontal entry, or a complex vertical shaft with multiple turns?
- **Hazards present:** Atmospheric hazards, engulfment, entrapment, mechanical hazards, etc.
- **Victim location and condition:** Easily accessible or trapped, medical needs, number of victims.
- **Required equipment:** Standard tripod and rope systems, or advanced high-directional, breathing apparatus, etc.
- **Number of rescuers needed:** Can a small team handle it, or is a large, multi-role team required?
- **Environmental conditions:** Temperature, noise, lighting, weather, etc.
- **Time constraints:** Is this a time-critical rescue (e.g., IDLH atmosphere) or can it be performed more deliberately?

Why is Complexity Important?

- **Matching Team Capability:** Teams must be trained and equipped for the level of complexity they may face. A team that is only prepared for simple rescues may not be able to safely or effectively perform a complex rescue.
- **Resource Planning:** More complex rescues require more personnel, specialized equipment, and advanced training.
- **Safety:** Underestimating complexity can lead to rescuer injury or failure of the rescue operation.

How to Evaluate Complexity

When conducting a rescue team evaluation, consider:

- The most challenging scenario that could occur in your facility or jurisdiction.
- The types of spaces and hazards present.

- The skills and certifications required (e.g., confined space technician, rope rescue technician, SCBA/SAR use).
- The need for coordination with outside agencies or mutual aid.

Incident Command System (ICS) in Confined Space Rescue

Confined space rescue incidents require a structured and scalable command approach to ensure responder safety, clear communication, and efficient operations. The Incident Command System (ICS) provides a flexible framework that can be adapted to the complexity of any confined space event. At a minimum, the ICS structure should include an **Incident Commander** responsible for overall scene management, supported by Command Staff roles such as Safety Officer, Public Information Officer, and Liaison Officer. The Operations Section typically includes a Rescue Group Supervisor, Entry Teams, Backup Teams, Rigging Teams, Attendants, and Medical Units. Logistics and Planning Sections may be activated as needed to support air supply, equipment, and resource tracking.

During a confined space rescue, the Incident Commander establishes operational priorities, assigns roles, and ensures that all personnel are briefed on hazards, entry procedures, and communication plans. The Safety Officer plays a critical role in monitoring atmospheric conditions, PPE compliance, and entry/exit protocols. Entry Teams and Backup Teams are assigned specific tasks, with clear lines of communication maintained through radio, hardwire, or visual signals. The Rescue Group Supervisor coordinates entry operations, ensures backup and medical support are available, and maintains accountability for all personnel.

Span of control is a key principle in ICS and refers to the number of individuals or resources that one supervisor can effectively manage. In technical rescue operations, maintaining an appropriate span of control is essential for safety and efficiency. The recommended span of control is typically three to seven personnel per supervisor, with five being optimal. If the number of assigned personnel exceeds this range, the Incident Commander should delegate authority by creating additional groups or divisions, such as separate entry teams or specialized units (e.g., ventilation, medical, rigging). This ensures that supervisors can maintain direct oversight, clear communication, and rapid response to changing conditions.

ICS allows for expansion or contraction of the command structure based on incident complexity. For small-scale rescues, some roles may be combined, while larger incidents may require full activation of all ICS sections. The use of standardized forms, such as the CMC Rescue ICS chart (see Appendix F) and the CTR Tactical Worksheet (Appendix G), helps document assignments, track resources, and maintain operational discipline. All personnel should reference these tools to ensure compliance with best practices and regulatory requirements.

For a visual example of a confined space ICS structure, see the CMC Rescue Incident Command System chart in Appendix F. For operational planning and documentation, refer to the CTR Tactical Worksheet in Appendix G.

Recommended Training / Continuing Education

Technical rescue, regardless of the discipline, is a perishable skill set. Without regular and consistent training, the skills taught will diminish to a point that could be harmful to yourself and your team members. This includes but is not limited to severe injuries or death due to human errors in not operating or rigging equipment properly.

We can assist in any of these skills sets, and have clients who we work with monthly, quarterly and annually to ensure they stay sharp on their skill sets.

Weekly

Recommended Minimum Time Commitment: 1 Hour

It is recommended that team members practice some type of skill at least weekly. This can be a self-guided focused review or lead by a team member who has proficiency in that particular skill.

Example topics:

- Knots
- Donning Harnesses
- Patient Packaging
- Tripod Setup
- Raising and Lowering Setups
- Equipment Inspections

Monthly

Recommended Minimum Time Commitment: 1 - 4 Hours

It is recommended that team members meet and practice some type of skill at least monthly. This can be a self-guided focused review or lead by a team member who has proficiency in that particular skill.

Example topics:

- Knots
- Patient Packaging
- Tripod Setup
- Raising and Lowering Setups
- Mechanical Advantage
- Belaying
- Pre-Planning
- Equipment Inspections

Monthly training may take place at your location or CTR's indoor training facility in Albany, NY.

Quarterly

Recommended Minimum Time Commitment: 4 Hours

It is recommended that team members meet and practice some type of simple rescue scenario at least quarterly. This should not be too complicated of a scenario but rather focus on overall team dynamics and putting together all the topics they have worked on over the past few monthly drills.

These scenarios can be guided by CTR or a team member who has shown proficiency in all systems the team uses. These should be low risk scenarios that have been pre-planned and well thought out by the team member to ensure that no one can get hurt during training.

Quarterly training may take place at your location or CTR's indoor training facility in Albany, NY.

Annual

Recommended Minimum Time Commitment: 8 - 24 Hours

Annual training is not only a great time for refresher training but also to introduce new equipment, techniques, and advancements. The minimum time is typically 8 hours, however if your team does not partake in weekly, monthly and/or quarterly training than you may need up to 24 hours of refresher training.

We recommend that you bring in a trainer such as CTR to perform this refresher training. This will allow for an independent evaluation of your team as well as ensuring that the latest techniques and/or equipment can be taught.

Our most popular option for teams that train is for a 16-hour refresher annually. This allows for time to review equipment and techniques and introduce new techniques and equipment, while still allowing plenty of time for OSHA and NFPA recommended scenarios.

Example topics:

- Knot Review
- Equipment Review
- New Equipment
- New Techniques
- Simple and more complicated scenarios

Annual training may take place at your location or CTR's indoor training facility in Albany, NY.

Other recommended training courses available

CTR has many other training courses and topics that may interest you and / or your team depending on your needs. See our website for the most up to date information.
www.capitaltechrescue.com

- Emergency Response Team Training
  - Team Evaluations
  - Site-Specific Rescue Operations
  - Stop the Bleed / Trauma Response
  - Fire Extinguisher Training
  - Structural and Industrial Live Fire Training
  - Rescue from fall protection

- Rope Rescue
  - Operations
  - Technician
  - Refresher
  - Artificial High Directional
  - Lead Climbing
  - Tower Rescue

- Industrial Escape Systems

- Confined Space
  - Entry
  - Awareness
  - Operations (non-IDLH)
  - Operations (IDLH)
  - Technician
  - Rigging Challenges
  - Small Team Operations

- sUAS (Drones)

- Water Rescue
  - Rescue Boat Operator for OSHA 1926.106
  - Ice Rescue
  - Swiftwater Rescue

Advanced rigging / small team intro

These are all topics covered in advanced classes that we offer. Contact us for more information

Tie Backs

Focused Anchors

Removable Anchors

- Removable Bolts
- Beam Clamps
- Pull Through Anchors

Split 4:1

Batwing 6:1

Capstan / Harken winches

Crane rigging

Monopods / bipods

Body Weight Anchors

Twin tension anchor systems

Ground Based Lowers

Small Team Clinics

Rescues Gone Wrong Clinic

Rigging Challenges

Skate Blocks & Hybrid Skate Blocks

22 Mill St., Unit 2, Albany, NY 12204 T 518-930-4500 F 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

Definitions

This section provides standardized terminology used throughout confined space rescue operations. Definitions are drawn from OSHA, NFPA, ANSI, and Capital Technical Rescue instructional content. Where applicable, regulatory references are included.

Confined Space

An area that: 1. Is large enough and configured so an employee can bodily enter and perform work; 2. Has limited or restricted means for entry or exit; 3. Is not designed for continuous occupancy.
Reference: OSHA 29 CFR §1910.146(b)

Permit-Required Confined Space (PRCS)

A confined space that contains one or more of the following: A hazardous atmosphere; Material with potential for engulfment; An internal configuration that could trap or asphyxiate an entrant; Any other recognized serious safety or health hazard.
Reference: OSHA 29 CFR §1910.146(b)

Lockout/Tagout (LOTO)

A procedure to control hazardous energy during servicing or maintenance of equipment.
Reference: OSHA 29 CFR §1910.147

Atmospheric Monitoring / Metering

The process of continuously assessing air quality in a confined space using calibrated instruments. Must test for: Oxygen levels, Lower Explosive Limit (LEL), Carbon Monoxide (CO), Hydrogen Sulfide (H_2S), and other site-specific gases. Meters may use diffusion or pumped sampling. Stratified sampling is required at multiple levels.
Reference: NFPA 350, OSHA 29 CFR §1910.146(d)(5)(iii)

Ventilation

The process of introducing fresh air and removing contaminated air from a confined space. Types: Supply, Exhaust, Local Exhaust, Push/Pull. Must be monitored to ensure effectiveness. Calculated using blower CFM and space volume.
Reference: NFPA 350, ANSI Z117.1

Entrant

An individual authorized to enter a permit space.
Reference: OSHA 29 CFR §1910.146(b)

22 Mill St., Unit 2, Albany, NY 12204 T 518-930-4500 F 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

Attendant

A trained individual stationed outside the confined space who monitors entrants and initiates rescue procedures if needed.
Reference: OSHA 29 CFR §1910.146(b)

Entry Supervisor

The person responsible for authorizing entry, ensuring safe conditions, and terminating entry operations.
Reference: OSHA 29 CFR §1910.146(b)

Rescue Services

Personnel designated to perform rescues from confined spaces. Must be trained in entry procedures, PPE, rescue equipment, and first aid/CPR.
Reference: OSHA 29 CFR §1910.146(k)

Non-Entry Rescue

A retrieval method using mechanical devices without entering the space.
Reference: OSHA 29 CFR §1910.146(k)(3)

Mechanical Advantage (MA)

The ratio of output force to input force in a rope system.
Simple MA: All pulleys move at the same rate.
Compound MA: One Simple MA system pulls on another. MA is Multiplied
Complex MA: Is not simple, nor is it compound.
Reference: NFPA 1006, NFPA 1670

Fall Factor

A measure of fall severity: Formula: Fall Factor = Fall Distance / Rope Length.
Reference: NFPA 1983

Minimum Breaking Strength (MBS)

The lowest force at which a component will fail under load.
Reference: NFPA 1983

Dynamic System Safety Factor (DSSF)

The ratio of the lowest-rated component's MBS to the maximum anticipated load (typically 6 kN).
Reference: NFPA 1983, NFPA 1858

kN (Kilonewton)

A unit of force. 1 kN = 224.8 pounds-force (lbf). Used to rate the strength of rescue equipment.

IDLH (Immediately Dangerous to Life or Health)

Atmospheric conditions that pose an immediate threat to life or cause irreversible health effects.
Reference: OSHA 29 CFR §1910.134

LEL (Lower Explosive Limit)

The lowest concentration of a gas or vapor in air capable of producing a flash of fire in the presence of an ignition source.
Reference: OSHA 29 CFR §1910.146

SCBA (Self-Contained Breathing Apparatus)

A respiratory protection device that provides breathable air from a tank. Required for IDLH environments.
Reference: OSHA 29 CFR §1910.134

SAR (Supplied Air Respirator)

A respirator that supplies air from a remote source via hose. May include an escape bottle.
Reference: OSHA 29 CFR §1910.134

APR (Air Purifying Respirator)

A respirator that filters contaminants from ambient air. Not suitable for IDLH conditions.
Reference: OSHA 29 CFR §1910.134

Work Positioning System

A system that supports a worker on a vertical surface, allowing hands-free work while limiting fall distance to less than 2 feet.
Reference: ANSI Z359.3

Fall Arrest System

A system designed to stop a fall in progress and minimize injury. Includes shock absorbers and locking devices.
Reference: ANSI Z359.1

Appendix

Appendix A - Factors of Safety

Factors of Safety, By Cliff Freer

Glossary of Terms

DCD - Descent Control Device

De-Rating - The act of reducing the MBS of a piece of equipment when it is not used in accordance with its intended design. (rope to 50% after knotting, carabiners to 50% for tri-loading, carabiners to 75% for wide or excessive webbing)

Dynamic System Safety Factor – The force of the Maximum Anticipated Load divided into the piece of equipment with the lowest MNS in the system.

Load Limiters - Stacked and stitched webbing intended to deploy at predictable loads to absorb and limit the energy transferred to the people using the equipment.
(Petzl ASAP Sorber Axess, Yates Rescue Load Limiter)

Maximum Anticipated Load - Estimated at 6kN based on the absorbing force of the ASAP with energy absorbing lanyard and published slip-testing data of DCDs.

MBS - Minimum Breaking Strength

Proof Loading/Testing - A load test performed by some manufacturers testing individual pieces of equipment before releasing the equipment for use. One-quarter of the MBS appears to be the common load used (Kong, Rock Exotica).

Static System Safety Factor - The force of the load at rest divided into piece of equipment with the lowest MBS in the system.

Unplanned Dynamic Event - Any event that causes a shock load or jolt force to the system.

Working Load Limit - Provided by some manufacturers and acceptable for use up to that load. Used in lieu of the Static and Dynamic safety formulas.

It is the responsibility of every Rope Rescue Operator and Technician to determine if the system they are utilizing is “safe”. There has long been the misnomer that our “Safety Factors” for rope rescue in the fire service were required to be 15:1. This is only anecdotally substantiated in the original version of NFPA 1983-1985 and should not be considered valid for our approach to rigging. A Safety Factor of 15:1 and even 10:1 is not possible to achieve nor do we want to

carry the equipment that would be built for such a purpose. What is achievable is a Dynamic System Safety Factor of between 2:1 and 4:1. This is in line with all of our other disciplines and more in line with industrial standards for fall protection.

Organized rescue teams should be diligent in the equipment they acquire ensuring that it serves their mission needs. All equipment, hardware and software, should be tracked and inspected regularly and after each use. Follow guidance from both the manufacturer and NFPA 1858-2018 for the selection, care and maintenance of this equipment. The manufacturer Kong states in their literature that a connector should be retired if it saw a load greater than one-quarter of its MBS or the load it received when Proof Loaded.

The practice of hand tying prusiks should be eliminated completely. Sewn bound loop prusiks offer a level of safety that far exceeds the cost savings of making your own. Rated sewn terminations can be used as anchor straps with a degree of certainty that un-accounted for hand tied prusiks cannot. Sewn anchor slings should be used wherever possible for the same reasons. Understanding that rigging can vary from response to response, having some bulk webbing for this purpose is warranted as a back up. The availability and low cost of various length sewn webbing loops should be considered as well.

We are going to assume that the Maximum Anticipated Load will be 6kN, which should be thought of as an injury-producing amount of force. Our training will hopefully keep the actual forces to considerably less than 6kN but we will use this number to keep our figures conservative and safe by estimating a high worst-case scenario.

We will now determine the Dynamic Factor of Safety of rigging systems of commonly used equipment. To determine a Static Factor of Safety will only engender a false sense of security, as an Unplanned Dynamic Event (UDE) will always generate more force than a static load. All modern DCDs are designed to slip when put under load to absorb some of the energy from an UDE. Unfortunately, the load at which these devices slip will not be as consistent as we would hope for. The construction and condition of the rope may not match the ropes used in the tests, the wear on the DCD and even atmospheric conditions will affect the friction and the reaction of the device to the event. Installing a Load Limiter is a safe and predictable option for any situation where a UDE is a concern. The PETZL ASAP requires the use of one at all times and the Yates Rescue Load Limiter can be installed in any system to limit the force from 6kN to 2kN if one is used or 4kN if 2 are ganged together. These load limiters do not rely on friction, which can vary considerably between component interfaces, making them more predictable.

Configuration #1
Used to lower an injured worker from the top of a water tower horizontally in a rated stokes basket.

12.5 mm rope with knots	40kN

SMC steel D x 6	40kN
Petzl I'D L x 2	22kN
anchor plates x 2	36kN
anchor straps x 2	45kN
stokes basket w/ rigging	11kN

In this configuration there is no need to de-rate any equipment other than the rope, as it is all being used properly. I put the stokes basket in there intentionally to point out that personal harnesses and patient packaging devices should not be included in the formula. These devices should only be seeing the weight of a single person and are not part of the system, they are hanging on the system. That leaves the rope as the component with the lowest MBS at 20kN after de-rating.

20kN / 6kN = 3.3:1 DSSF.

That's a considerably safe Dynamic System Factor of Safety. By purchasing ropes with sewn terminations, we can increase the strength of the rope from 50% to 85% but the DCD will keep our DSSF still under 4:1.

22kN / 6kN = 3.6:1 DSSF

This may not make our system much stronger, but it does remove some of the possibility that a knot was tied improperly and can increase the speed at which a system is installed and deployed at an emergency.

Configuration #2
Used to raise an injured hiker up a muddy hill vertically in a stokes basket.

11mm rope with knots	32kN
Rock Exotica Rock O x 6	24kN
CMC MPD	14kN
Petzl I'D S	14kN
Rock Exotica 1.5" Omni	36kN
Rock Exotica 1.5" Omni double	36kN
Petzl Basic hand ascender	5kN

In this configuration it's obvious that the Petzl Basic has the lowest MBS of any of the other equipment, but how does it fit into the system and can it be affected by an UDE? No, it can't. Because the hand ascender is only used while hauling it prevents the rope grab from seeing an impact load, which no rope grab should ever do. Even when loaded the Basic will only see 2/3 of the load. Estimating that at 2.6kN (600lbs) for a 2-person load keeps the Basic at a 1.9:1 SSSF and at no time is the load solely the

responsibility of the Basic. The MPD has the main strand of the system captive the entire operation.

The rope is at 50% making it 16kN but the DCDs still have a lower MBS at 14kN. 14kN / 6kN = 2.3kN DSSF

Many have been saying that the T rated gear isn't safe, the difference in the DSSF from a traditional G Rated system to a T Rated system is minimal and the T Rated system is still at or above all the other disciplines that we train in. The lightweight gear is not for every team and strong consideration must be given to switching or purchasing gear of that type.

Configuration #3
A high school senior while attempting to hang the school flag from a communications tower, becomes spooked as he encounters a hawk protecting its nest and freezes while climbing the tower.

11mm rope with sewn eyes	32kN
Harken Clutch x 2	22kN
Petzl William x 8	24kN
Anchor plate	36kn
Anchor straps x 4	22kN
Petzl Rescue Pulley x 4	36kN

Rescue team arrives and sets up for a mirrored skate block. Lets de-rate our gear as needed. The rope will keep 85% of its strength because of the sewn termination and no other knots are needed for the operation, 32kN becomes 27kN. All the anchor straps are being used in a basket configuration so 22kN now doubles to 44kN leaving the DCD with the lowest MBS at 22kN.

22kN / 6kN = 3.6:1 DSSF

There are a couple of G Rated 11mm ropes currently on the market, but it won't drastically change your DSSF with either sewn terminations or knots. (3.6:1 sewn as the DCD will have the lowest MBS or 3.3:1 using knots). 11mm rope with knots will produce the lowest DSSF with 32kN de-rated to 16kN for the knots, 16kN / 6kN = 2.6:1 DSSF.

With all the examples provided you can see that even when anticipating a rather large impact and worst-case scenario our gear, when used properly, is incredibly strong. This statement is supported by the reality don't read about equipment failures in our industry. We read of mistakes

made by people when they don't have the proper training, the needed practice with the skills to do the job, or all too often, fatigue and stress has played a role in the accident.

22 Mill St., Unit 2, Albany, NY 12204 T 518-930-4500 F 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

Appendix B – Reference Materials / Apps

Title: ***Technical Rescue Field Operations Guide***
Publisher: Desert Rescue Research
Author: Tom Pendley
Notes: App or Paper guide. Covers rope rescue, confined space rescue, swiftwater rescue, trench rescue, structural collapse, and helicopter operations
Link: https://www.desertrescue.com

Title: ***CMC Field Guide App***
Publisher: CMC
Author: CMC
Notes: App with charts, diagrams, videos but heavily leans towards CMC products.
Link: https://www.cmcpro.com/app/

Title: ***CMC Confined Space Forms***
Publisher: CMC
Author: CMC
Notes: PDF files of sample Permits, Rescue Permits, Preplanning documents and more
Link: https://www.cmcpro.com/forms/

Title: ***Animated Knots by Grog (Grog Knots)***
Publisher: Animated Knots
Author: Animated Knots
Notes: Easy to follow, no internet required.
Link: https://www.animatedknots.com/shop

Title: ***RigRite***
Publisher: RigRite
Author: RigRite
Notes: App to calculate complex vector forces easily.
Link: http://rigriteapp.com

Title: ***Risk: SPE, ORMA, and GAR Calculator***
Publisher: NCPTT National Park Service
Author: NCPTT National Park Service
Notes: App to calculate risk assessment scores (GAR Model)
Link: https://ncptt.nps.gov/blog/risk-spe-orma-and-gar-calculator/

Title: ***TerrAdaptor Portable Anchor System Manual***
SMC Gear

Notes: Select which version of the manual you need
Link: https://smcgear.com/terradaptor-portable-anchor-system.html

Title: ***Arizona Vortex User Manual***
CMC Rescue
Notes: Select under the Resources Drop Down for the latest version
Link: https://www.cmcpro.com/equipment/arizona-az-vortex/

Petzl Rope Systems – Second Edition

Appendix C – Regulation Resources & Case Studies

Is 911 your Confined Space Rescue Plan?

https://www.osha.gov/sites/default/files/publications/OSHA3849.pdf

OSHA – Confined Spaces (General Industry)

https://www.osha.gov/confined-spaces

OSHA – Confined Spaces in Construction

https://www.osha.gov/confined-spaces-construction

OSHA – Confined Spaces in Construction – Frequently Asked Questions

https://www.osha.gov/confined-spaces-construction/faq

OSHA FATALFacts – Asphyxiation in Sewer Line Manhole

https://www.osha.gov/sites/default/files/publications/OSHA3819.pdf

OSHA Case Study: Silent Killer in a Newly Constructed Manhole

https://www.osha.gov/sites/default/files/manhole_cs.ppt (Powerpoint)

Appendix D – Equipment Resources

Capital Technical Rescue and Safety Consultants, LLC does not sell equipment, and can help assist in determining your needs and make independent recommendations. Here we are providing a short list of links and resources you may utilize.

Honeywell / Miller Confined Space Systems

Honeywell Gas Detection

3M DBI-SALA Confined Space Systems

Allegro Industries Confined Space Equipment

Allegro Industries Blowers

Air Systems International

Blackline Safety

Blackline Safety – Additional Info

Appendix E – Manufacturer Video Links

Petzl Professional Videos

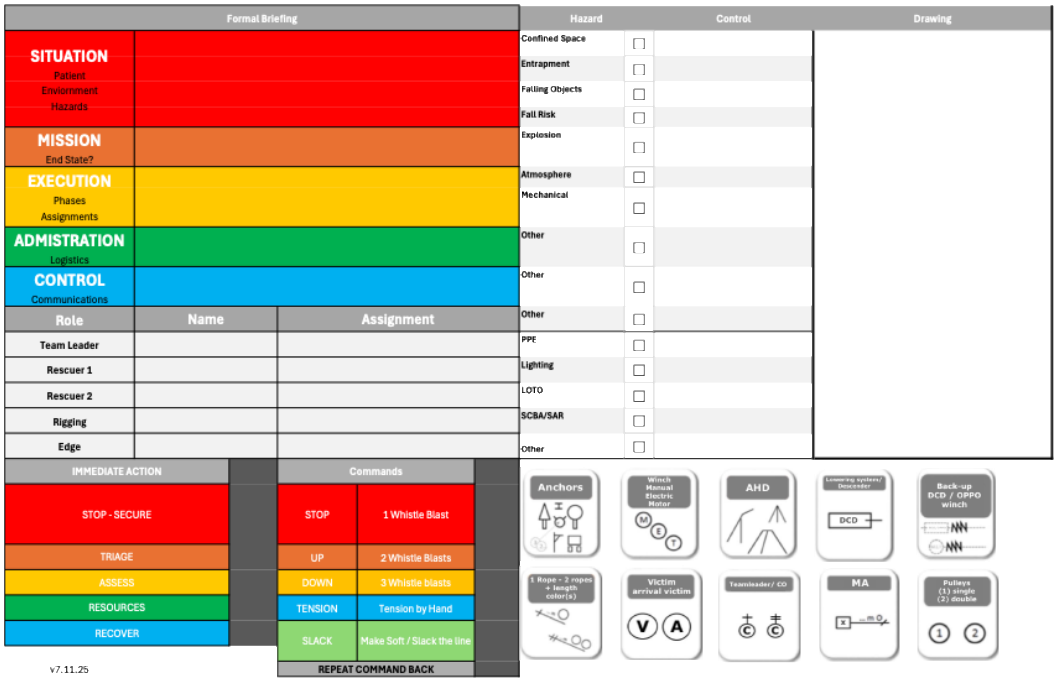
Appendix F – Inventory & Forms

CMC Forms - Rope Log, Hardware Inspection Log, Confined Space Forms Including ICS, Rescue Permits, PrePlan Survey etc

Generic Confined Space Rescue Pre-Plan Form

Scannable Inventory App

Appendix G – CTR Tactical Worksheet



[Click Here to Download Latest Version (PDF)]