I. INTRODUCTION

A. Purpose: To provide Department personnel with information and instruction for constructing raising systems and for utilizing mechanical advantage in these systems.

B. Scope: This instruction applies to all sworn personnel.

C. Author: The Deputy Chief of the Special Operations Bureau is responsible for the content, revision, and periodic review of this instruction.

D. Objectives: To assist Department personnel in identifying raising systems and mechanical advantage and maintaining uniformity Departmentwide.

E. Definitions: See glossary.

II. RESPONSIBILITY

A. All sworn personnel are responsible for the information contained in this section.

B. Company officers/training captains are responsible for training personnel and ensuring proficiency with the information contained in this article.

III. POLICY

A. All raising systems shall be constructed with both a main and belay lifeline.

B. All sworn personnel shall be able to construct a raising system using both a main and belay lifeline.

C. Commands: The following commands and whistle signals shall be used on all raising systems.

1. All stop* (one long whistle blast)

2. Raise (two whistle blasts)

3. Lower (three whistle blasts)

4. Belay line ready

5. Main line ready

6. Rescuer(s) ready

7. On belay line

8. Off belay line

9. On main line

10. Off main line

*If at any time during a raising system operation it is felt that something is not correct with the system being used or the procedures being applied, a rescuer should loudly state, “ALL STOP”! All personnel shall stop their actions immediately until the suspected problem(s) can be resolved.

D. Raising systems

1. Raising systems are used to raise personnel from over the side type rescues, underground vaults, confined spaces, etc.

2. Raising systems shall include both a main and belay lifeline. The belay is a back-up to the main lifeline and is the only means of protection should a fall or failure of the main lifeline occur.

3. Separate anchor points shall be used for the main and belay lifelines. At no time should both lifelines be attached to the same anchor point.

E. Mechanical advantage

1. Many rescue situations require raising a victim and/or rescuers from an accident site. To do this, a knowledge of mechanical advantage (MA) or pulley systems is required so the rescue can be accomplished more safely and easily.

2. The ability to raise loads with a rope is increased when the rope is used in conjunction with a pulley or pulleys. Combinations of fixed and moving pulleys create systems that multiply the force that rescuers are able to apply. Making use of MA to reduce required strength, at a trade-off of increased endurance. Said another way, MA enables a rescuer to lift a load applying less force than the load itself, but over a longer distance.

IV. PROCEDURES

A. Standard raising system, manpower raise

MAIN LINE

1. Ensure that the brake bar rack or figure 8 descender is tied off.

2. Attack a prusik (the longer prusik if available) using three wraps to the tension side of the main lifeline and attach it to the anchor webbing with a second carabiner.

   If the brake bar rack has been used, a sling made from green webbing can be used to extend the prusik from the anchor.

3. Slide the prusik as far as possible towards the load to remove the slack.

4. Advise the rescuer(s) that slack is coming. Slowly untie the brake bar rack or figure 8 descender and transfer the load to the prusik. Insure that the prusik sets.

5. Remove the brake bar rack or figure 8 descender from the anchor and disengage the lifeline.

6. Set the lifeline into a pulley and attach the pulley to the anchor carabiner.

   Note: A prusik minding pulley may be used in this position with a ratchet prusik, eliminating the need for a rescuer to mind the prusik. The rope must make a 180° bend around the prusik minding pulley for this to function properly.

7. A haul team is ready and awaiting the command to retrieve the main lifeline.

BELAY LINE

1. No equipment changes are necessary on the belay lifeline. The lifeline will be pulled up instead of being fed out.

   Note: A prusik minding pulley may be used on the belay lifeline, set the belay lifeline into the prusik minding pulley and attach the prusik minding pulley to the carabiner holding the tandem prusiks. The belay lifeline shall make a 180° bend around the prusik minding pulley for this to function properly.

2. The belayer must always be attentive and never leave the belay system unattended.

3. Always have an extra set of tandem prusiks and a webbing load releasing hitch or a radium release hitch ready for knot passing or tandem prusik change out, should a fall occur.

B. Operation

1. The rescuer(s) will advise the control person when they are ready.

2. The control person will confirm that a safety inspection has been completed and that all systems and personnel are ready by asking:

   a. Belay line ready?

   b. Main line ready?

   c. Rescuer(s) ready?

3. Answering ready means that all systems are ready to operate immediately. If there is a delay at any position the response should be “stand by” and indicate how long it will take to correct the situation.

4. The control person will then give the command “ready haul”. The haul team will bring the main lifeline up at a safe rate of speed for the rescuer(s), while the belay lifeline is kept slightly slack as it is pulled up through the tandem prusiks.

5. When the load has cleared the edge and is a safe distance from the edge, both lifelines can be removed from the load.

6. Upon completion, all equipment shall be inspected for damage or wear. Any damaged or worn equipment shall be removed from service immediately and sent to the Department's Rope Equipment Coordinator with a completed Form 47.

C. Mechanical advantage systems

1. The raising system described above was a manpower raising system that used a pulley only for a directional change in the raising system. There is no mechanical advantage in a raising system with a directional pulley. This is 1:1 pulley system. In order to move a 100-pound load 10 feet it will take 100 pounds of force and 10 feet of rope to move the load 10 feet.

1:1 Pulley system w/self-minding ratchet

2. A 2:1 mechanical advantage means it will take 50 pounds of force to move the 100 pound load, but it will take 20 feet of rope to move the load 10 feet. A ladder rig is a common 2:1 pulley system.

2:1 Ladder Rig

The *actual mechanical advantage* is less than 2:1 because of friction in the pulleys, rope abrasion, etc. The mechanical advantage referred to in any system is the *theoretical mechanical advantage*, and it should always be assumed that the actual mechanical advantage attained is going to be less in field situations.

3. The majority of Department raising systems can be accomplished with a simple manpower system. Occasionally, situations arise where a mechanical advantage pulley system would be the best choice for the rescue system. To do this requires a knowledge of pulley systems so the rescue can be completed easily and safely.

4. There are three classes of pulley systems:

    a. Simple

    b. Compound

    c. Complex

5. A simple pulley system is characterized by having one continuous rope flowing back and forth alternately between the pulleys on the load and the anchor (or the anchor and the load), and all pulleys at the load side (traveling pulleys) travel towards the anchor at the same speed. All pulleys at the anchor side of the system remain stationary. The tension in the rope remains the same throughout the pulley system.

6. Summary of simple pulley systems

    a. If the tied end of the rope is at the anchor, the mechanical advantage will be even, such as a 2:1, 4:1, 6:1, etc.

    b. The mechanical advantage of a simple system is determined by counting the number of ropes under tension at the load side of the pulley system.

    c. The number of pulleys required for a simple system (without a change of direction) is always the mechanical advantage minus one.

        Example: A 4:1 system needs three pulleys, a 3:1 system needs two pulleys, etc.

    d. To incorporate a self-minding ratchet located at the anchor, the mechanical advantage of the simple pulley system must be an odd number, such as a 3:1 system.

e. Examples of simple pulley systems:

Simple 2:1

Simple 2:1
w/ direction change

Simple 3:1
w/self-minding ratchet

7. Compound pulley systems are characterized as one simple pulley system pulling on another simple pulley system; the traveling pulleys travel towards the anchor at different speeds. Compound pulley systems are useful because they can provide greater mechanical advantage than simple systems for the same number of pulleys, thereby reducing overall friction loss for the same mechanical advantage.

8. Summary of compound pulley systems

   a. The mechanical advantage of a compound pulley system is determined by multiplying the mechanical advantage of each simple pulley system together. For example, a simple 3:1 pulling on a simple 2:1 becomes a compound 6:1 (as 3 x 2 = 6). Also, note that a simple 2:1 pulling on a simple 3:1 is also a compound 6:1 (as 2 x 3 = 6).

b. If you need to get the load up with the least number of resets and you are using a compound pulley system comprised of two dissimilar simple pulley systems, have the higher system pull on the lower system (3:1 pulling on the 2:1 in a compound 6:1).

c. The highest mechanical advantage with the least number of pulleys is achieved by repeatedly compounding a simple 2:1 on a simple 2:1.

d. Examples of compound pulley systems:

Compound 4:1
(2:1 on a 2:1)

Compound 6:1
(2:1 on a 3:1)

Compound 6:1
(3:1 on a 2:1)

Compound 9:1
(3:1 on a 3:1)

9. Complex pulley systems

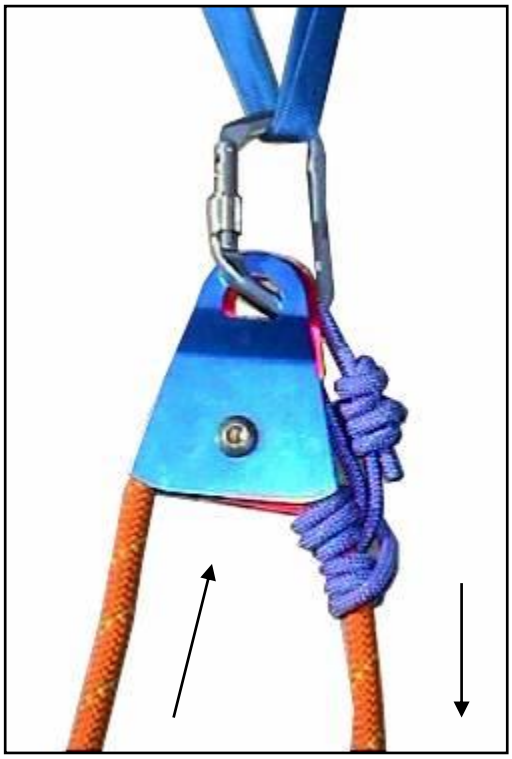
These are characterized by being either simple or compound pulley systems. Complex pulley systems will not be covered in this manual.

10. Self-minding ratchet

There are some components that can be added to a pulley system to make its operation practical during a rescue. A “Self-Minding Ratchet” enables the haul team to maintain lift distance gained without having to hold onto the rope at all times.

This requires a prusik (the shorter prusik, if available) and a prusik minding pulley. These together can act as a ratchet, allowing one way movement that also enables resets of the pulley system as they maintain the tension in the mainline while the pulley system is slackened and reset.

In order for this to work properly, the lifeline must make a 180° bend through the pulley. If a prusik minding pulley is not available a rescuer will be needed to tend the prusik which will hold the main lifeline while the pulley system is reset.



Self-minding ratchet