Understanding Anchor Systems

This paper, is the first in a series of documents, intended to serve as a knowledge base for our department. Each paper in the series, is intended to cover, in depth, a topic critical to rope rescue. While this document, will be examining anchor systems, it is not the purpose of this paper, to teach the reader how to tie a "wrap 3 pull 2 anchor system", or how to tie a "tensionless hitch". That is the job for the department ropes instructor. There are also, many sources available, containing that information. The goal of this paper, is to present the reader with basic ideas, concepts, and information, not readily available from other sources, that will help, more fully understand, the factors that go into the construction of safe, strong anchor systems. The diagrams in this paper, are for illustration purposes only, and are not meant to depict viable, rescue anchor systems.

Terminology

Anchor___ Any object a rope or rope system is attached to.

Anchor System___ The collection of gear, carabiners, cord, rope, webbing, rigging plates, e.t.c. used to connect a rope or rope system to one or more anchors.

Natural Anchor___ trees, large boulders, e.t.c. to which a rope or rope system is attached.

Man Made Anchor___ Guard rails, vehicles, structural beams, e.t.c. used to attach a rope or rope system.

Single Point Anchor System___ an Anchor System that relies on a single Anchor object.

Multi Point Anchor System___ an Anchor System that makes use of more then one anchor object.

Master Point/Collection Point___ Used to describe the single point at which all anchors come together, in a multi point Anchor System.

Anchor Leg___ Used to describe the portion of a multi point Anchor System, between an anchor, and the master point/collection point.

Load Sharing Anchor System___ a multi point Anchor System, that divides the load, between two or more anchors. The actual amount of load sent to each anchor, changes with the the line of force created by the load.

Load Distributing Anchor System___ A multi point Anchor System, that divides the load between two or more anchors, roughly equally, regardless of the line of force created by the load.

Extension___ if one leg of a multi point Anchor System should fail. "Extension" Is The distance the load will free fall, before being stopped by one of the remaining legs in the system.

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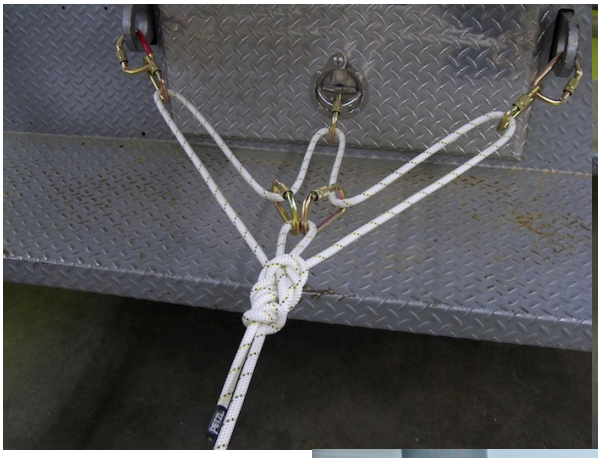

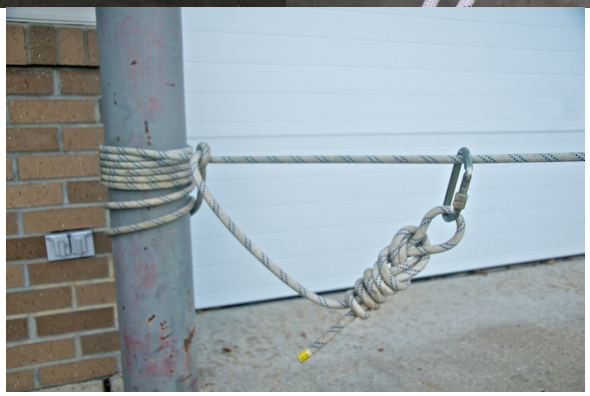

What makes a good safe anchor system?

Fist fights have started over easer questions to answer. But, one thing everyone agrees on, is that good, safe anchor systems, all share common traits. They are quick to construct, strong, have some safety backup included in them, were constructed with an understanding of the forces at work on them, and how they will react, if any part of the system should fail.

The truth is, there is no one correct answer, to this question. A good safe anchor system, for a victim access line, is not likely to make a great main haul line Anchor System . My goal is to present you with the information you will need, to answer the question for yourself. Since every situation is different, the answer you come up with, will be the system that best matches the situation you are facing.

In rope rescue, knowledge is truly power. The better our understanding of what is going on in rope systems, the more tools we have at our disposal, to solve problems.

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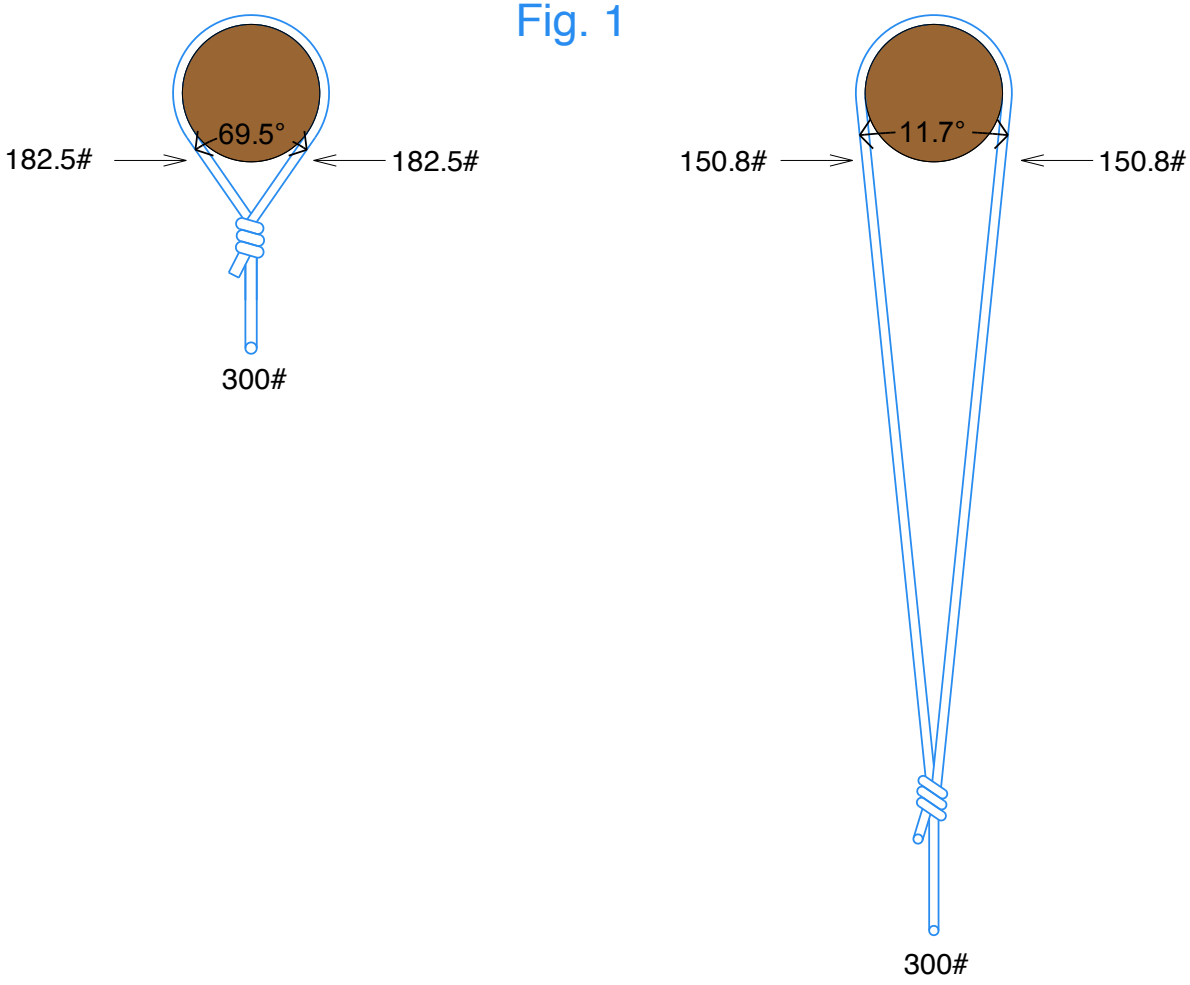
Angles and The forces at work

Whether we are simply tying rope around the base of a tree, or constructing a complex , multi point anchor system, we are affecting how the force is being distributed throughout the rope system. A quick look at figure 1, shows how the length of a loop of rope, tied around a tree, can affect the tension on the rope. The short loop creates a much greater angle, then the long loop. The angle in each case, acts as a force multiplier. The greater the angle, the greater the force multiplication. In rope rescue, we call this affect, “Vector Force”. It happens whenever rope forms an angle. If vector forces were not at work, the tension on each side of the anchors, in both examples, would be 150#. Half of the load being supported by each side of the anchor loop. Notice however, in both cases, that the true, tension on each side of the anchor rope, is greater then half the actual load. While the tension on the long loop only increased by a little less then 1 pound, over half the actual load, the tension on the short loop, increased by 32.5 pounds.

Fig. 1



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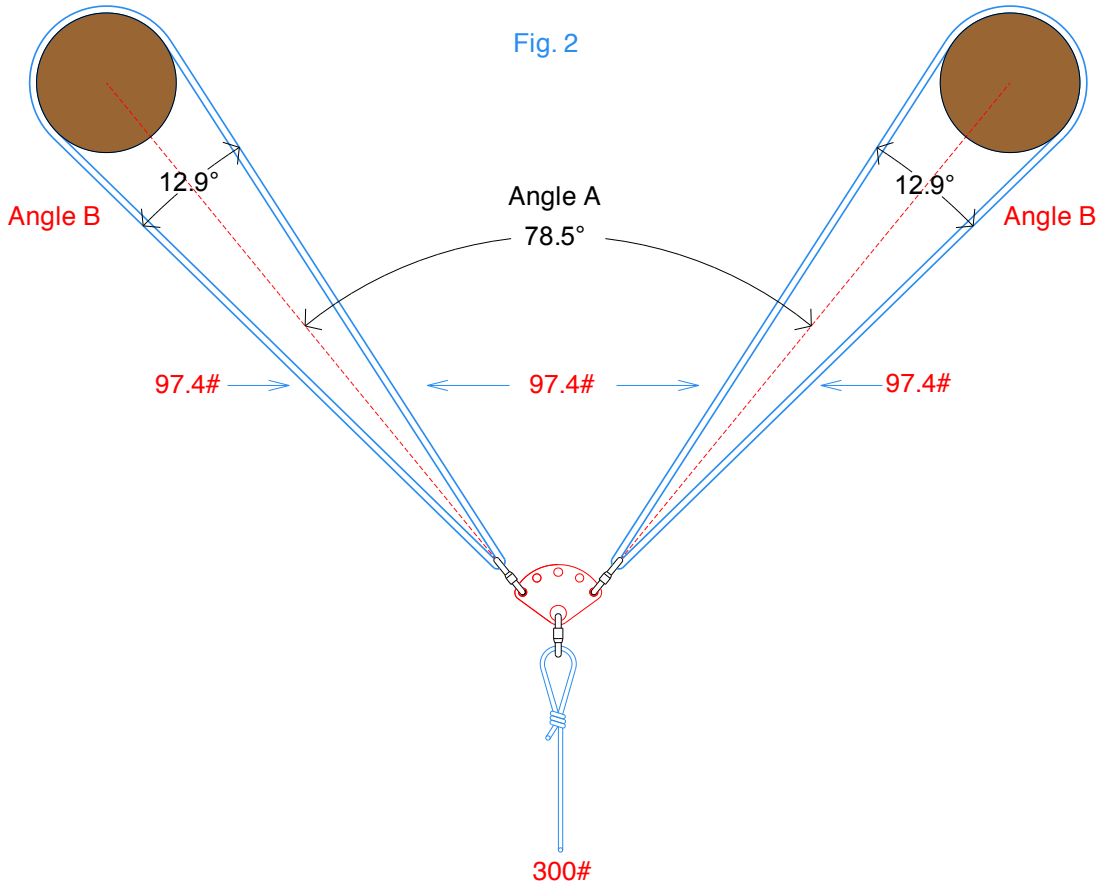
Now that we understand, that vector forces are at work, whenever rope systems form angles, we can begin to understand multi point anchor systems. When we construct more complex anchor systems, understanding vector forces, becomes more important. Consider a multi point anchor system, using two trees as anchors. A loop around each tree, brought together at a common collection point. The load attached at this point. Figure 2.

Fig. 2



In Figure 2, we are dividing the load between two trees, and each anchor loop, divides that load again. If vector forces were not at work, the tension on each side of our anchor loops, would be 75#. 300 /2 = 150, going to each tree. So, 150/2 = 75, going to each side, of each anchor loop. However, the vector forces, created by the angle between the trees, and the collection point, (Angle A) increase the force directed to each tree, from 150# to193.7#. Then, the angle formed by each anchor loop, (Angle B) contributes it's vector force. Increasing the tension, on each side of the anchor loop, from 96.8# (half of the true load 193.7#) to 97.4#. While the difference between 75# and 97.4#, may seem insignificant, the point is, whenever there is an angle, vector forces are at work.

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Equalization in multi point anchor systems

In an ideal world, an anchor system would take the load, and distribute it to all anchors equally, without regard for the angle of the force applied to the system. The term “Equalization”, is misleading, because no anchor system, truly distributes forces, like our “ideal world” system. There are two approaches to multi point systems, load sharing, and load distributing. In terms of constructing them, the difference lays only in how the equipment is arranged. The real difference, is in how each system, manages the forces running through them.

Load sharing Anchor systems

“Load sharing” systems, only distribute the force equally, when the force is applied along the bisector of the angle, formed by the anchor legs. Figure 3A. When the line of force changes, one anchor leg becomes dominant, taking the majority of the load. Figure 3B. This is because, the length of the anchor legs, is fixed. Any force pulling at an angle, means one leg would have to become longer, and the other shorter, for both to remain loaded.

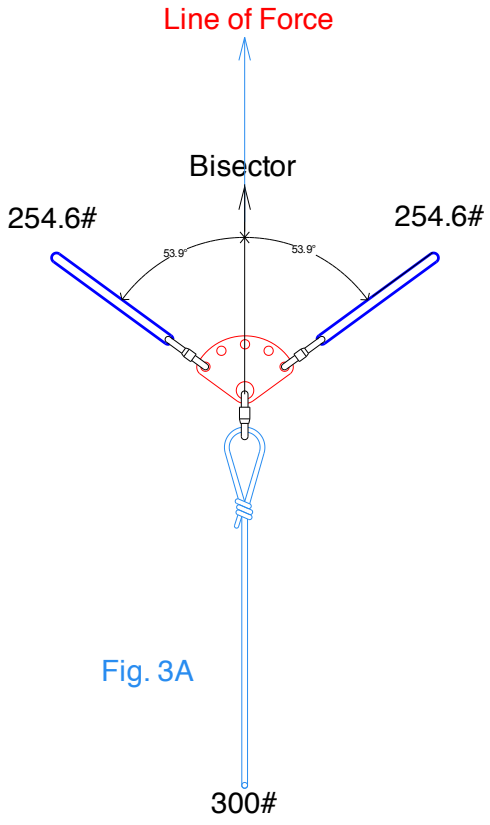

Fig. 3A

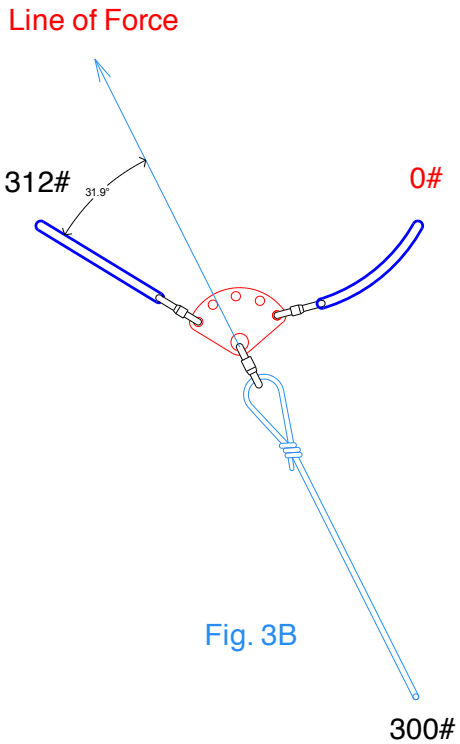

Fig. 3B

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Load Distributing Anchor Systems

"Load Distributing" systems, again, only distribute the load equally, when the force is applied along the bisector of the angle formed, by the anchor legs. Figure 4A. Under these conditions, the load is equally divided between the anchors, and the vector forces for each anchor, are also equal. In a load distributing system, when the line of force changes, the master point moves in response to the change in line of force, in an effort to balance the force between the anchors, thereby changing the lengths of the legs. This means however, that the angle of the line of force, relative to each anchor leg, also changes. Figure 4B. This in turn, changes the vector force that each leg is subjected to. Increasing the vector force on one anchor, and decreasing it on the other. Net result, no true equalization. While this system, does not truly equalize force for us, each anchor, will always have some load on it, regardless of the line of force. Unlike load sharing systems.

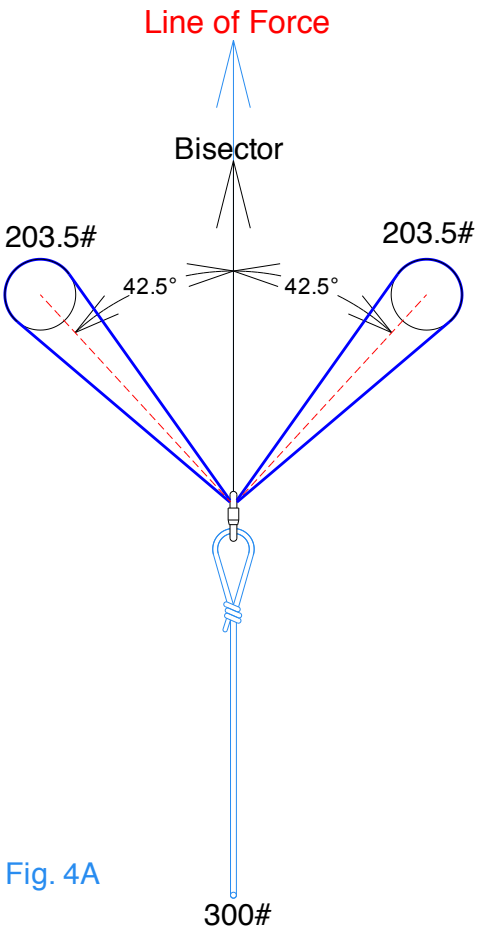

Fig. 4A

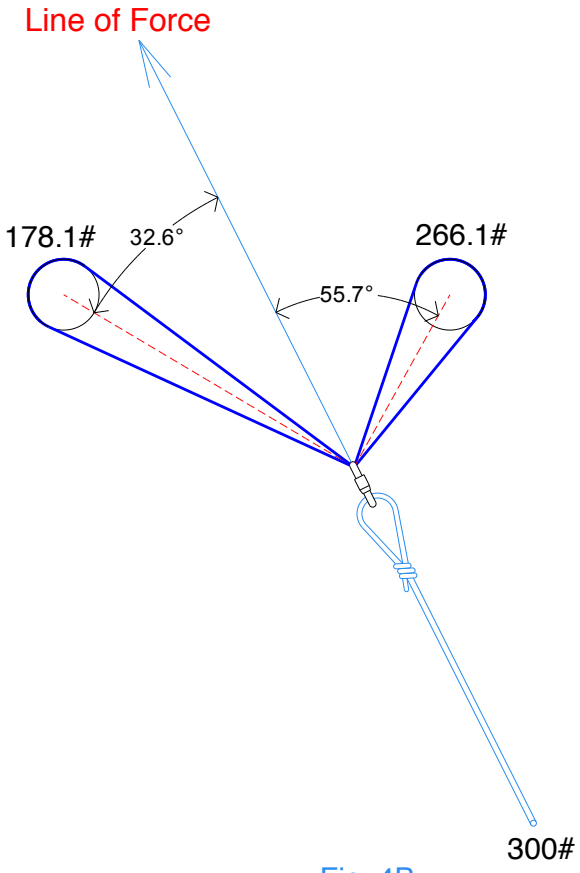

Fig. 4B

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Redundancy

The reason we go to the trouble to construct multi point anchor systems, is a simple one, Safety! The idea, that if one anchor is good, then two is even better. If one anchor fails, the other one may just save your life. In rope rescue we call this “redundancy”. Redundancy, comes in many different forms, and some form of it must be included in every anchor system. Even single point anchor systems, must be backed up in some way. For example, two webbing loops tied around a single tree, each with it’s own carabiner, clipped into the rope. If one loop, or carabiner should fail, the backup anchor system takes over.

Extension

Well designed Multi point anchor systems, while redundant by their nature, often pose other problems. We have to understand what the affect will be, if one of the legs of the system should fail. Figure 5 shows the result of a typical, multi point load sharing anchor system failure. The distance the load free falls is called “extension”. The distance the load shifts sideways, is called “translation”.

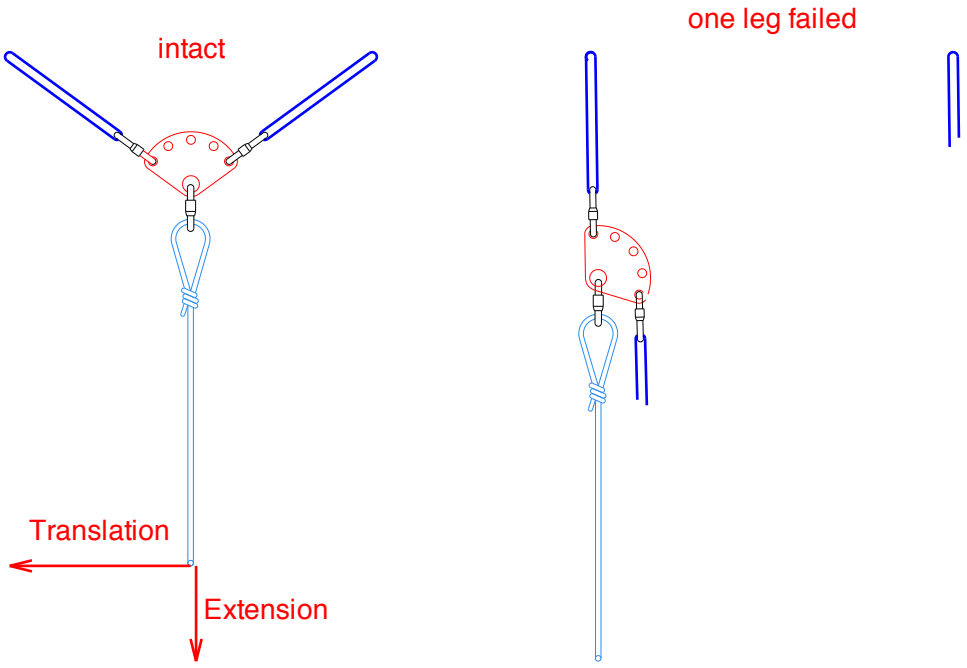

Fig 5

Extension and translation, are a problem because, the sudden shock that occurs, when the remaining leg stops the load from free fall, can, if great enough, cause the entire remaining anchor system to fail. Extension in any anchor system, is to be avoided at all cost. If it exists at all, it must be kept to an absolute minimum.

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Strength

While it's true, multi point systems, decrease the tension on each anchor loop, they also, decrease the load on each "anchor", by dividing the force between multiple anchors. When we are discussing multi point anchor systems, it is important to understand, that each leg of the system, must be strong enough to support the entire expected load, with a healthy 15/1 safety factor on top.

The best Anchor Systems follow these simple rules

E Equalized
The anchor system, should be designed so the force is equally divided between the anchors, for the expected line of force.

A Angle appropriate
The anchor system, should be designed to keep all angles as small as possible.

R Redundant
The anchor system, should be designed, to include some backup, incase any part of the system should fail.

N No
E Extension
The anchor system, should be designed, to eliminate extension.

S Strong
The anchor system, should be designed, so each leg, is strong enough to safely support the entire load.

T Timely
The anchor system, should be quick to construct in the field.