Engineering a Tree Removal

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Advanced Rigging

Illustrations by Bryan Kotwica

In years past, rigging a tree for removal seemed to be less complex. Choosing the necessary gear usually meant no more than the right size rope and chain saw. In retrospect, it now appears as if those days were actually more difficult and a whole lot longer. Arborists were limited by such things as the size and strength of limbs and crotches, as well as where they extended from the trunk. The highest suitable rigging point was often less than desirable in terms of leverage and the drop zone it created. In many ways the tree determined how it would be rigged—as well as how difficult the task would turn out to be.

The arborist of today, though he or she has a wide range of hardware and equipment to sift through, also reaps the rewards of technology. The tree may still have a lot to do with the rigging plan, but the freedom given by such things as false crotches and lowering devices helps to alleviate some of the climber's stress. Climbers can now create a false crotch in almost any part of the tree and utilize the strength of the trunk without having to rely on the strength of branches and natural crotches. Winch-style lowering devices can hoist large limbs and add more control to the operation.

Despite all of this technology and technique, however, the ability to perform a tree removal with no more than a rope and climbing gear should be the foundation of all training in removal techniques. Sometimes the fastest and easiest way is the traditional method of natural crotch rigging. Besides, what would happen if you forgot your pulleys (blocks) or damaged one of the components during a removal? Would you still be able to complete the job safely and on time?

Since the advent of the arborist-rigging block, complex pulley systems have come to be a daily routine. How these systems affect the distribution of a load throughout a tree is a topic that warrants further research. To analyze these forces would require significant knowledge of physics and its application to arboriculture. We can, however, begin to set up guidelines on what might prove to be a better rigging solution for a given situation by looking at a few engineering concepts. You may recall the work of Dr. Peter Donzelli, who recently began conveying some of these concepts to the arboricultural community. These are the very same concepts needed to establish our guidelines.

The most basic of the ideas we must fully grasp is the fact that there is a definite difference between simply hanging an object from a line in a tree and hanging an object from a pulley that is anchored in a tree and supporting the weight from the

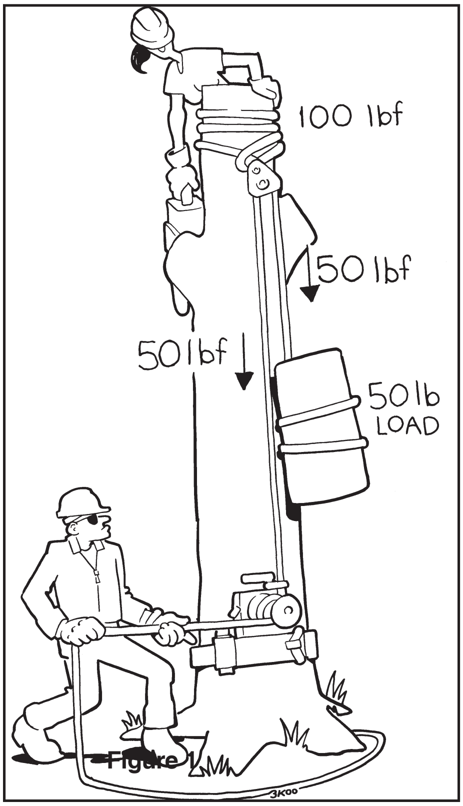

Figure 1

ground. In the first scenario, the tree will only see a force equal to that of the load, whereas the tree with the load hanging from a pulley may see twice the force of that load.

The easiest way to explain this is to say that in order to support a load of 50 pounds, we need 50 pounds of opposing force on the other end of the rope to keep the load from falling. Force always travels in a straight line and remains unchanged (unless additional force is applied from another source). Consequently, there is 50 pounds of force (lbf.) at the load end of the rope, which travels all the way to the anchored end where the same 50 lbf. is applied. If the rope is deflected through a block in a tree, we would have 50 lbf. pulling downward from the load side, and 50 lbf. pulling downward on our block from the anchor side. The resulting force on the block and its anchor would be 100 lbf., or twice the load (Fig. 1).

It is important to note that this is only the case in an ideal situation, that is if the pulley is 100 percent efficient (no friction), the ropes are hanging completely parallel (180 degrees) and the load is static. The load is said to be static when all of the forces balance and the load is still.

This is not to imply that the block will never see more than twice the force of the load on the line, especially during a dynamic situation. The forces applied at various points in the system will change when these variables change. In this article for purposes of simplicity, we will assume that ideal circumstances exist. So what does this mean to the arborist? Well, it means that if we drop a 1000-pound oak log into a block while working down trunk wood, when the forces balance, we could have 2000 pounds of force exerted on our block. The direction and influence of forces on objects are referred to as "vectors." Can we manipulate these vectors in our favor to lessen the possibility of excessive force in the tree? Absolutely!

Multiple-block rigging

Sometimes the one who creates a mess the fastest isn't the first one done. In many situations, it may be worthwhile to spend a few extra moments creating a multiple-block rigging system. By using more than one pulley, you can gain a great deal of efficiency and safety. The system will be able to support more of a load, enabling you to perform work faster and easier with more tolerance for error. The force will, in turn, be distributed between multiple points in the tree while also doubling as a safety net in the event of equipment or tree failure at any single point. Add one more block on a whoopie sling that you can carry on your harness and you are able to relocate a drop zone or reduce a dangerous swing at any given moment. The direction of the forces may also be coerced into traveling along the vertical axis of the tree by deflecting greater or lesser rope angles at each place. This concept alone can dramatically expand your working load limit. And since branches are more strongly attached on the underside than the top, groups of pulleys can be arranged in a manner that will exploit this anatomical strength as well. All of these factors combine to equal a safer, easier and more efficient operation, which should be the primary objective on every job. The ground crew will also appreciate this courtesy.

Columnar strength

Forces are vectors, since they have a definite size and direction. The direction of a vector determines which way a force is acting. Since a rope can only support a load along its length, the rope indicates which way the force is acting. If we turn a rope through a pulley, the force is now acting in two directions—the direction of each leg of the rope. The resulting force on the pulley now depends on these two component forces and the angle the rope enters the pulley. These two component forces create a single force that would cause the pulley to move toward the middle of this angle if it were free to move, much in the way a bow and arrow works (Fig. 2).

Why is this important in tree rigging? Well, if we can manage to direct the force exerted on the block to act along the length of a tree leader, as opposed to across the grain horizontally, we utilize the natural columnar strength of the tree, which can give us a greater working load limit. Everyone should understand how a 2-inch diameter limb is much easier to break if we step on its middle instead of standing it upright and stepping on it end to end. It would be nearly impossible to break. We can mimic this in the tree by incorporating more than one block into our rigging.

Block loading versus angle of deflection

In order to calculate the load on a block, we need to determine two things: the load on the rigging line and a block-loading factor. This loading factor is determined by the angle by which the rope is deflected by the block. The angle that we are referring to is not the angle between the two legs of rope, but the angle between an imaginary line drawn straight through the block from the load, and the leg of rope entering the block from the friction device (Fig. 3).

The greater the angle created by the block, the greater the resultant force placed on that block. For example, a block that turns a rope 180 degrees will see a load equal to twice that of the load on the rope itself. Conversely, a line that enters the block at 0 degrees or runs straight through the block would create a resultant force of zero on that block. In the middle of the road, we have a 90-degree angle. The block-loading factor of a right angle would be 1.41 times the weight of the load (Fig.4).

How can this be useful in our day-to-day operations? We can create lesser pulley angles on smaller rigging points or structurally compromised parts of the tree and use a second pulley to create a larger angle at a more beneficial spot to support more of the load. This can be very useful when dealing with co-dominant stems and other structural flaws. The rigging line itself can act as a temporary cabling system to lace the stems together (Fig.5).

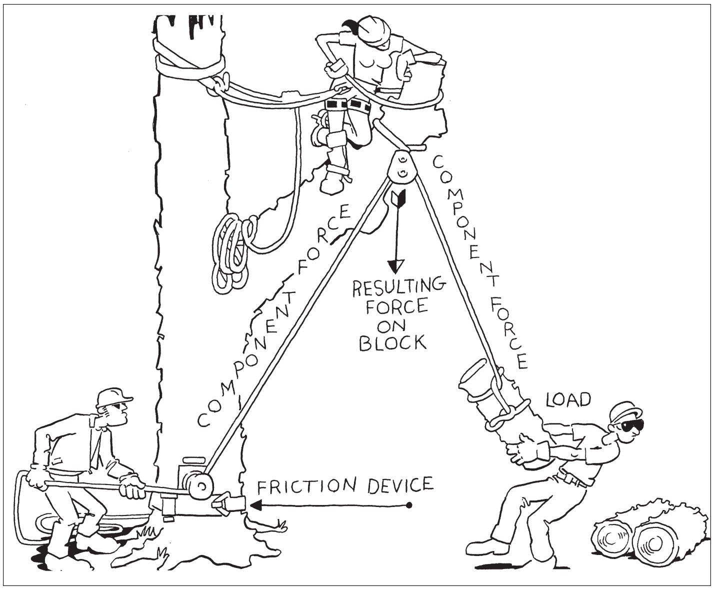

Figure 2

The resultant force will actually close the space between the two stems when loaded, instead of pulling them away from one another. This would be a much more efficient rigging plan because it may enable you to remove larger sections without the risk of failure from this defect. This can also be of use when the most ideal drop zone is created by a smaller lead than preferred for lowering. We could support the majority of the load at a stronger point in the tree and redirect it to a better area for lowering with a secondary block.

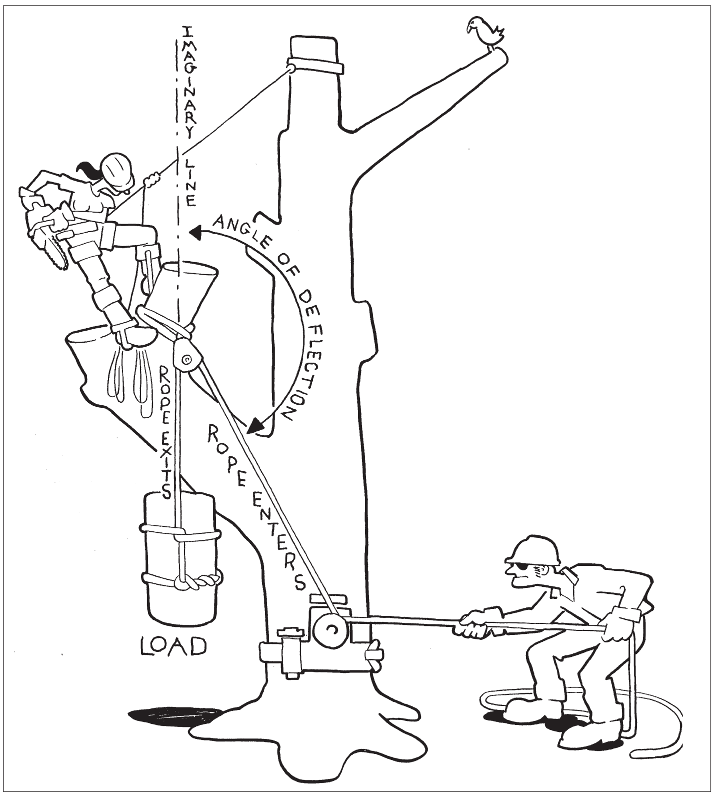

Figure 3

Negative impacts

If we are not careful with our design, the forces may be multiplied to the point of disaster. In terms of generating the least amount of force with our rigging, removing the false crotch altogether would be optimal. Instead, replace it with a friction device stationed in the canopy and lower directly from it. This way you are only subjecting the tree to a force equal to that of the load itself when examined statically. Since this is usually impractical, we need to look at other options.

The double-false crotch is one of the most unstable situations. By this I mean the practice of draping a pulley that is anchored to the end of a line over a natural crotch and running a lowering line through that pulley. To do this, we need to tie-off the end of the rope supporting the lowering block. We now have four legs of rope being supported by one limb or crotch. This scenario is dangerous because we have subjected that supporting crotch to a force equal to about four times that of the load. A weight of 500 pounds is now equivalent to a 2,000-pound load (Fig. 6).

A better possibility here would be to use the removable false crotch technique advocated by Robert Phillips, which uses a girth hitch in the tree to suspend the block and lowering line. There is no need to anchor the down leg, and, therefore, the load is not multiplied four times. It will see approximately half of the force of that in the other case.

The facts described in this article all point in one direction. To borrow a quote from Donald F. Blair in his book *Arborist Equipment*, "... the weakest link in our rigging system should be the lowering line." I also feel that, with the exception of the tree itself, the strongest link should be the block and the sling used for its attachment.

All of the descriptions leading to this indicate that the block will see more of a load than any other piece of equipment in the system, and, therefore, must be compensated for accordingly. Most blocks are also tested by a tensile pull and given a working load limit (WLL). This limit may need to be translated as half of that which is inscribed if you equate it to the size of the weighted object instead of the overall force on the block. In other words, a block labeled with a WLL of 2,000 pounds is interpreted as being able to withstand consistent loads of 2,000 pounds without failure. This does not mean that we should drop 2,000-pound pieces into that pulley on a daily basis and expect it to prevail. We must first consider the fact that the pulley will see a load equal to twice that of the rope, not to mention the possibility of a shock load. This 2,000 pound WLL really should be viewed as a 1,000 pound WLL, unless otherwise indicated by the manufacturer.

The design of the system is the key to its success. If the pulleys are in poor alignment with one another, the rope is not allowed to run cleanly through the block. Not only will there be added friction, the rope may also run across the side plates of the block. This can actually cut directly through your rigging line, leaving you subjected to the merciless laws of gravity. Many blocks are not meant to allow the rope to be used in this fashion and demand a certain amount of respect by the user.

RESULTANT FORCE ON BLOCK	
Angle of Deflection	Load Multiplier
30 °	.52 x Load (L)
45 °	.76 x (L)
60 °	1.00 x (L)
75 °	1.22 x (L)
* 90 °	1.41 x (L)
105 °	1.59 x (L)
120 °	1.73 x (L)
135 °	1.85 x (L)
150 °	1.93 x (L)
160 °	1.97 x (L)
180 °	2.00 x (L)
* Example: 90 ° Rope angle with 500 lb. load	= 705 lbf. on Block

Figure 4.

Just as there is more than one way to skin a cat, there always seems to be more than one solution for the same end result when dealing with tree removals. That is why the best climbers look at each job individually and create a unique plan for the specific job. I believe the safest route is the one the operators feel the most comfortable with, otherwise they will be unable to perform with the necessary confidence. They are the ones committed once the cut is made and should have the final say—assuming, of course, a level of experience sufficient for the task. As is so often the case with any rigging system, there are some limitations to using a multiple-block rigging system. This article is meant to provide only broad guidelines and to relay some basic concepts concerning the uses of rigging blocks. Nothing can replace the need for competent training when personal safety is at risk.

In summary, it should be noted that, while most arborists are not engineering graduates or experts in the field of physics, the techniques we employ should be both practically oriented and scientifically sound so that we may complete our daily tasks safely and efficiently. I hope that you can find use for this information and benefit from it as I have.

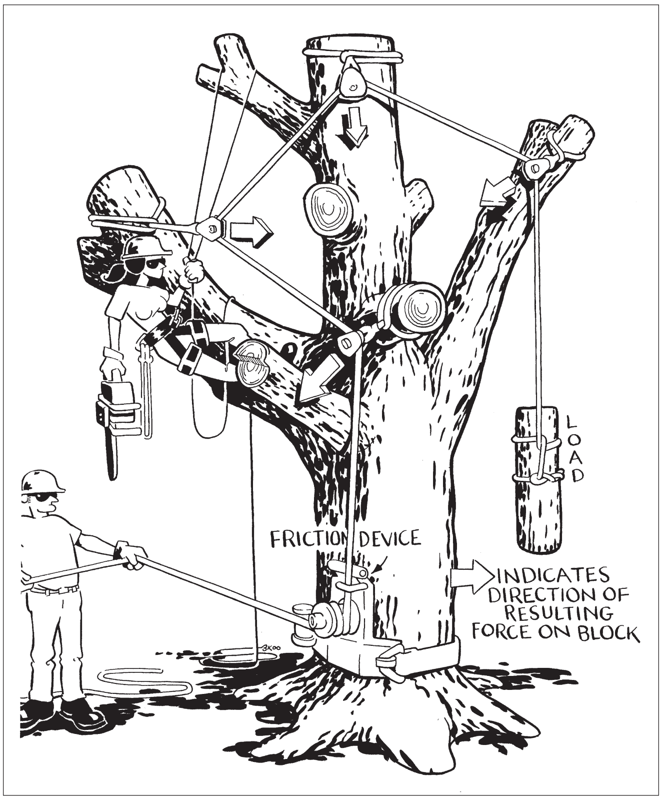

Figure 5

Mark J. Chisholm an owner of Aspen Tree Expert Company in Jackson, N.J., and 1997 International Tree Climbing Champion. Special thanks to Richard (Richey) Wright, executive director of Rescue Services for ESE Training Associates Inc., for all of his work and expertise to help maintain the accuracy and clarity of this article.