FD/HD

Fire Department High Directionals

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The urban fire department is presented with a unique set of problems when it comes to using high directionals (HD) for rope rescue. The problem comes from the fact that options to solve those problems are a little more complex than they appear at first glance. This paper will look at using (or not using) fire department aerial ladders as HD’s for rope rescue. Additionally, the development and usage of HDs for use in elevator rescue and urban anchoring will discussed.

The fire service has been staring at HDs in the form of the aerial ladder since Daniel Hayes invented it way back in 1868 for the San Francisco FD. The aerial is large ladder, usually 100 feet long nowadays, used to reach the upper floors of buildings on fire. In recent years, there has been an increased use of these ladders as HDs for rope rescue and confined space incidents. On at least one occasion, there has been a ladder failure when an aerial was used an HD in rope rescue system.

There are several different types of aerial ladders and tower ladders (those with a personnel bucket on the end). Depending on the construction of the ladder and the type and strength of the outrigger, the aerial devices are rated for different tip loads. In general, these tip loads range from 250 pounds to 1000 pounds. In addition to the tip load rating, there are many other variables of ladder suitability such as the soil the outriggers are placed as well as the angle of the ladder and the length of extension.

Basics of Aerial Ladder Construction
Aerial ladders are series of overlapping, telescoping, cantilevered trusses. The top chord of the truss is smaller than the bottom and designed to be loaded in tension. The bottom chord is designed to be loaded in compression. The fact that that aerials are a truss and not a column is important as they are not designed to be loaded in “compression” as one traditionally thinks of with a gin pole, tripod, Arizona Vortex, etc…

Aerial ladders, and particularly those made before 1991 when a new ladder construction standard was enacted, are susceptible to failure when torsionally loaded. Loading only one of the two beams, as could be accomplished by rigging a two point fixed anchor for a change of direction at the tip, is an example of a way of imparting a tremendous torsional load to the ladder. Below is a picture of a two point, non-fixed anchor at the tip. A second anchor, tied the same as this one would be used for belay. The thought is that a, should a leg of a two point fixed anchor fail, it would rest the entire load on one beam and cause a severe torsional load.

Aerial ladders can be thought of as a third class lever. They are hoisted to their desired angle by means of a hydraulic cylinder near the base (fulcrum) of the ladder. The pressure in these cylinders is monitored at the control pedestal by a cylinder pressure gauge. There are also double rod end cylinders with pulleys on each end that are used to extend the ladder. These are class three pulleys and are how you can extend a ladder 100 feet with a 15 foot cylinder.
What Does It Mean

There are several options on how to rig an aerial ladder for rope rescue. Popular conjecture is that it is a good idea to place the ladder into compression by attempting to get the resultant as close in line with the ladder as possible.

An aerial can be rigged so the haul system is on the ground and the ropes run either on top of below the ladder with a COD at the tip. This does place the resultant closest to the ladder; however, it also puts the greatest load on the tip. A one person load with a COD at the tip can easily exceed the tip load. Even though the ladder is being compressed by the resultant, the tip load still exceeds the recommendation of the manufacturers. Additionally, the load is being applied to the force multiplying end of the class three pulleys. This can create enough force to cause the extension cylinders to fail to extend because of overly high system pressure.

An aerial ladder can also be rigged with a block and tackle (4:1 w/COD) hanging from the tip of the ladder. This loads the aerial as it was designed to be loaded and only places an extra 25% of the load on the tip because of the COD on the block and tackle. This is less than the force applied by a simple pulley COD at the tip with the system rigged on the ground.

Lastly, a rope can be hung straight from the tip and all raising, lowering, and extending comes solely from the movement of the ladder. While the use of a mechanical device to move the load is often frowned upon, it places the least amount of load on the ladder as there are no force multipliers involved. Consider this like a short haul that is usually performed by helicopter.
Here is the crux of the problem: While an aerial ladder may well be strong enough to hold the load placed upon it, no manufacturer or person in a position of authority within the fire department chain of command will sign off on knowingly exceeding the tip load of an aerial ladder. Because the force multipliers involved, many departments will only allow for using a ladder with a 1000# tip load.

Attendant or No?

Right, wrong, or indifferent the fire service likes to put an attendant on a stokes basket operation. Informal polling amongst East Coast fire department shows that most people are, in general, opposed to placing an attendant on a stokes evolution when using an aerial as an HD. The decreased safety factor is the most often cited example as to the reason why.

The argument of this author against the use of aerial ladders as HDs at all is that we are simply not smart enough “field engineers” to determine that a single person load is totally okay for an aerial ladder, but a two person load is right of the question. Our margin for error or failure of a single persons weight added to the system is cutting too thin of a margin to make using an aerial a viable option.

Where Does the Belay Go?

Very rarely will an urban fire department forgo the use of a belay line. Aerial ladder based rope operations are no different. The belay line will usually follow the same path as the main line, regardless of whether it is a mirrored system or not.

A belay activation, even on a mirrored system, can put up to 2.5 times the force of the load on the line left holding the load. This is based on the spring constant theory and can be referenced in K. Mauthner’s 2015 ITRS presentation. When putting 2.5 times the force of the load on a line and then running it through the change of direction at the tip of the ladder, you can see how quickly forces add up. A 250# load that is suddenly placed on the belay line can easily put a force of 500# on that line. That force is now applied to the COD at the tip, with whatever force multiplier is there based on the interior angle. It’s easy to see how quickly you can get to a force which can overwhelm the ladders ability to hold it.

Some departments forgo a belay entirely to minimize damage to the aerial ladder in the event of a mainline failure. This completely ignores what happens to the load should a line fail!
Another belay option is to run the belay from the roof of a structure while using the ladder for the mainline. This option works well provided there is no chance for a swing fall in the event of mainline failure. If using an aerial over an excavation or subterranean space, the belay can be run from ground level.

There are, however, very few if any places where an aerial ladder is the only thing that can be used as an HD.

Why Do Aerial Ladders Come With Rope Attachments on Them?

If it is so easy to exceed the tip load of an aerial ladder, why do they come equipped with rope rollers at the tip and rated side anchor points? Manufacturers need to meet the entire spec of an agency requesting a quote or they stand the possibility of not getting the contract due to failure of meeting the spec. Therefore, if a department says they want rollers on the tip of a ladder and side anchor points, then a manufacturer will build it. It doesn’t mean that have to work together though.

The new ladder trucks in Washington DC came equipped with rollers at the tip and side rated anchor points, just as they were spec’d out. The manufacturer states that the rope system must be run on top of the ladder bed and that the side rated points are the only thing to be anchored to and that no part of the ladder is to be used for anchoring. This does not allow for a rope system to be operated at all. The rope would have to come up around the turn table to be operated in the ladder bed. Sure, they gave the department exactly what was specified. But, they worded the owner’s manual in such a way as to make it impossible to use it.

Where Does This Leave Us?

If you have a 1000# tip load aerial device and…

If you do not use an attendant and…

If you attach straight to the aerial as in a short haul and…

If you do not attach your belay to the aerial…

Then maybe you will be okay to use an aerial for rope rescue.
Other Fire Department High Directionals

In Washington DC, roughly 50% of the rope rescue calls there are for an injured construction worker in a below grade excavation. These usually range from 30-100 feet deep. In almost all cases, there is a tower crane on scene. A stokes basket attached directly to the crane hook with a two rope system. The crane hook is considered a bombproof anchor. And attendance is usually flown out with the basket to provide psychological support for the patient. The attendant is there to also provide medical care in the very rare instance that the power goes down to the crane.

Elevator Rescue

While Washington DC is a geographically small city, there are calls to the fire department for elevator emergencies at the rate of approximately 10 per day. The majority of these calls do not require any sort of rope rescue. Okay usually there are calls for a car stuck in a blind shaft. This is where there isn't entrance and exit at the top and bottom of the shaft, But the shaft itself is entirely encased in concrete with no other way to the car other than from the top.

On August 11, 2006 a call was received for the report of an elevator stuck at the Woodley Park Metro stop. This shaft is a blind shaft with an approximately 150 foot depth. There was a car stuck approximately halfway down the shaft.

With no obvious high points to run our rope through, the decision was made to anchor remotely and run the ropes over rope rollers and lower rescuers down into the shaft. In an effort to gain a couple more inches of height, A hose roller was substituted in place of a rope roller. While a little bit of extra height was gained, the construction of the hose roller caused it to tip over on to the fingers of the edge attendant and he suffered a crushing, degloving amputation of his finger.
This incident set in motion research into finding out how to create an elevated anchor in a doorway. It is ultimately what led to the several variations of the Appalachian Doortex; an obvious nod to the Arizona Vortex, but with an effort to bring some east coast influence into the rope world.

While there’re several variations of the Doortex, they all revolve around keeping the majority of the load directed towards the ground. Some of the load is pushing laterally against the wall. The key distinction when setting up any of these variations is that it is an elevated anchor point and not a high directional in the traditional sense. Because you’re anchoring your lowering and belay systems from the head, there is no resultant; just a downward force pulling into the hoistway. The hall system is constructed from the head of the high directional down into the hoistway.

Whether or not this is a bombproof system or not is up to the rescuer to decide. The biggest factor for consideration is the material the upper foot of the high directional is leaning against. If there is a possibility that the upper foot can penetrate the wall, precautions should be taken to spread the load out so that this does not occur.

**The End**

While an aerial ladder may be big chunk of metal seem like a bombproof piece of gear, it is a huge, heavy lever (what did Archimedes say?) with a COD out at the tip. It is the opinion of this author that they not be used for rope rescue high directionals until more is known about what safety factor we are actually dealing with.

The Arizona Vortex can really shine when applied with some ingenuity to the problems presented in the urban world. The most important consideration is that its use as a high directional not be confused with its use as an elevated anchor point.