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SAFETY BULLETIN

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Extension Ladders – Going Out on a Limb

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ABSTRACT

Sawing off a limb in back of you – this image has become cartoon cliche. On the other hand, sawing off a limb in front of you does not conjure up the slightest portent of danger. Nevertheless, when this activity is combined with an extension ladder, it can and has led to the telescoping collapse of the ladder.

TALKING TO AN EXTENSION LADDER

A tree trimming operation is depicted in Fig. 1 where the cross-hatched portion of the limb is cut free and the trimmer maintains his hold on the ladder and the uncut limb. Under these circumstances the uncut limb springs upward as it is unloaded and this action raises the operator and the fly section of the extension ladder.

It should be noted that an operator of an extension ladder communicates his intention to lower the fly section by lifting the fly section approximately two inches. Once lifted, the locking hardware, which normally maintains the overlap between the base and fly sections, unlocks and remains unlocked as the telescoping members retract. Hence, the accident scenario under consideration leads to the complete collapse of the ladder.

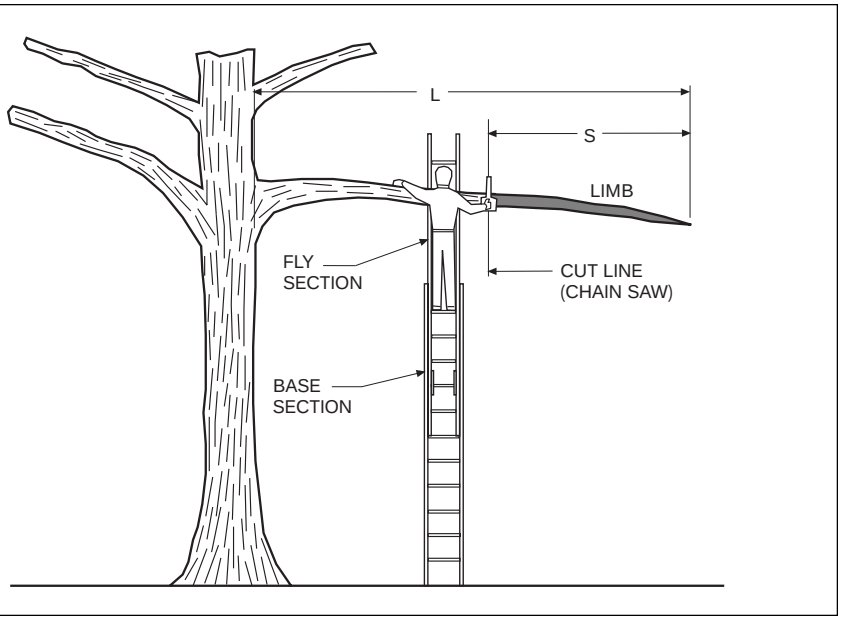

Fig. 1 Tree Trimming Set Up

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LOTS OF BOUNCE TO THE OUNCE

Is the springback of a limb sufficient to unlock an extension ladder? To answer this question, a conical limb is constructed which develops a deflection Δ at the cut end when subjected to the weight of the trimmed off section and its associated branches and foilage. For the cone shaped limb of length L shown in Fig. 2, the dynamic springback 2Δ caused by a cut at section S is given by:

$$2\Delta = \frac{(\sigma_{ult}/\gamma)^2}{(E/\gamma)\,f^2\alpha}(S/L)^2\left[-6(S/L)^3 + 21(S/L)^2 - 24(S/L) + 9\right]$$

where

- σ_{ult} - ultimate breaking stress of wood
- E - modulus of elasticity of wood
- γ - weight density of wood
- f - nature's safety factor; ratio of σ_{ult} to the maximum static working stress at the limb support
- α - multiplier of the limb's self weight to account for branches and foliage[3].

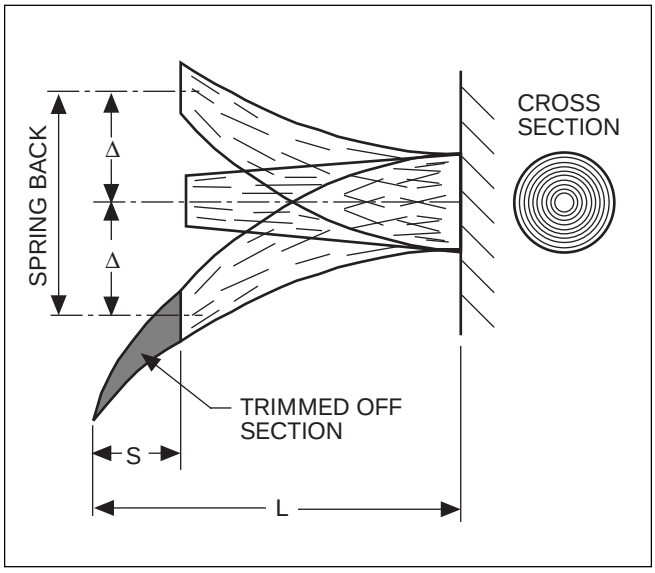

Fig. 2 Tree Limb Deflection

Taking Douglas Fir [2] as an example, we find:

- E/γ = 100 X 10^6 inches (specific stiffness)
- σ_{ult}/γ = 500 X 10^3 inches (specific tenacity)
- f = 7 (nature's safety factor)
- α = 2 (limb weight = foliage weight)

25% Cut Off: S/L = 0.25, 2Δ = 6.73 inches

50% Cut Off: S/L = 0.50, 2Δ = 9.57 inches

75% Cut Off: S/L = 0.75, 2Δ = 4.04 inches.

In each case, the springback is sufficient to unlock the ladder hardware.

SAFETY IMPLICATIONS

Using an extension ladder in a tree is a critical application. Ladder safety philosophy will usually preclude this usage since the top and bottom ends of the ladder are not "firmly supported" as recommended in Marking No. 10, Safety Requirements for Portable Metal Ladders, ANSI A14.2 – 1990 [1]. The footing support is often uneven and unstable; the top support is always flexible and may undergo large deflections in every direction as the wind loads and unloads the limbs.

The failure mode and effect analysis found in this bulletin indicates that trimming limbs may produce substantial springback which can lift the fly section of an extension ladder, unlock its restraining hardware and allow the ladder to retract catastrophically. No accident prevention strategy is described in the ANSI standard that will eliminate or mitigate the accident scenario.

On the other hand, some ladder manufacturers use an on-product instruction/warning label that "recommends tying bottom fly rung to adjacent base rung." This procedure will prevent the telescoping type of accident. It should be noted that securing the fly section to a tree limb by procedures offering vertical restraint will guarantee unlocking whenever the limb rises over two inches. In this circumstance, collapse will not occur immediately upon unlocking; however, when the fly section is unsecured at the end of the task, the operator is at peril. It is unfortunate that the admonition to secure the top end of the ladder does not invariably improve safety because it is usually very effective.

[3] The derivation of this formula is available from Triodyne.

REFERENCES

1 "American National Standard for ladders – portable metal – safety requirements," *ANSI A 14.2 – 1990*, approved November 12, 1990. Washington: American National Standards Institute, p. 65.

2. Barnett, R.L. and A. Humphreys, "Design for Minimum Weight," *Materials in Design Engineering 55*, no. 1 (January 1962): 83–85.