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# Forensic Engineering Use of Graphics To Analyze and Reconstruct a Ladder Accident

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Plaintiff fell from a ladder in June, 1994. In 1997 he filed suit against the manufacturers of the ladder and ladder levelers which had been attached to the ladder. Upon visiting the accident site in April 1998, it was found that site conditions had changed. Careful inspection, an interview of the homeowner and graphical analysis of the site and ladder set-up enabled the author to determine what had actually happened and to prepare the case for litigation.

## The Problem

In June, 1994, plaintiff was using a portable aluminum ladder while preparing the side of a house for painting. The ladder was fitted with “automatic” self-leveling devices allowing easy set-up on cross slopes which would require one leg longer than the other in order for the ladder to be vertical and therefore stable. The ladder fell after the plaintiff had been working for a while, causing injury. A suit was filed against the manufacturers of the ladder and the ladder leveler in the County Circuit Court in June, 1997, which alleged negligence, breaches of the Implied Warranty of Merchantability and Fitness for Particular Use, and sale and/or transfer of a defective and/or unreasonably dangerous product.

The author was contacted by the ladder leveler manufacturer’s attorney in January, 1998 and retained as an expert in March. The first task was to review Plaintiff’s Complaint, other documents which had been filed, and depositions which had been conducted as of that time. This review revealed:

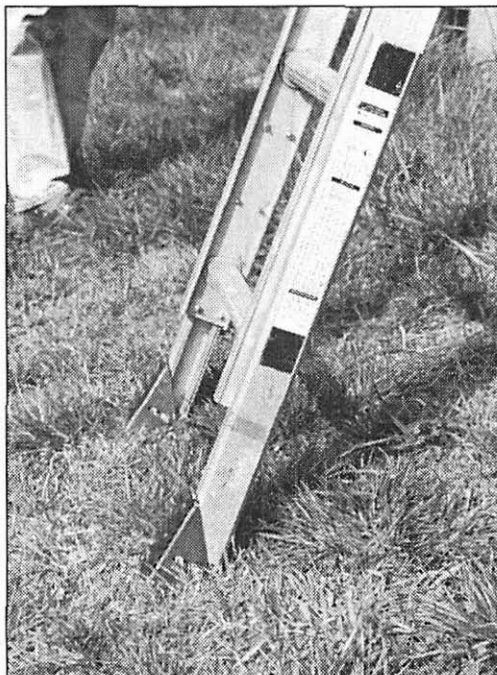
- Plaintiff was washing the siding of a house he was preparing to paint when the 32 foot long extension ladder (with levelers attached) slipped and fell ten to twelve feet. Plaintiff claimed that he landed on his right side and foot between the bushes over which he was working and the house.
- Plaintiff claimed that he sustained an injury to the tendon in his right foot and ankle.

- Plaintiff alleged that the ladder leveler malfunctioned, causing the fall.
- There were no witnesses to the accident.
- Plaintiff failed to report the accident the day it happened and continued to work for about ten days after the accident before seeing a doctor.
- Plaintiff stated in deposition that he had no difficulty adjusting the ladder leveler on the day of the accident, the ground was dry, and he supported the two rails of the top of the ladder with the apex of the roof overhang to keep the ladder from tipping sideways. He claimed the ladder was centered on the peak of the roof.
- Plaintiff was working on the ladder with his head at roof level and had sprayed water from a hose onto the house siding to wet the surface for cleaning. He was spraying cleaning chemicals onto the siding from a hand pump sprayer when he felt the ladder slip.
- At the time the ladder slipped, plaintiff stated he was facing it squarely and had both hands and feet on the ladder. The ladder feet slipped “straight out” (away from the house), and the ladder landed flat on the bushes. Plaintiff fell between the house and the bushes, hitting his head on the ground and landing on his right side.
- The ladder and its leveler were not examined immediately after the accident, however plaintiff stated that he had not noticed that any parts were damaged or broken.
- The ladder was used by plaintiff to finish the job; he stated that it had not been used again after the job was completed.
- Plaintiff could not recall the address or the location of the accident.
- Plaintiff stated that the bushes were at least six feet high at the time of the accident, and the ladder was positioned so it rested against the top of the bushes. Plaintiff could not recall how far the ladder was extended, however a 24 foot extension ladder he had previously tried was too short.
- The leveler had been purchased and installed on the ladder by the plaintiff’s supervisor.

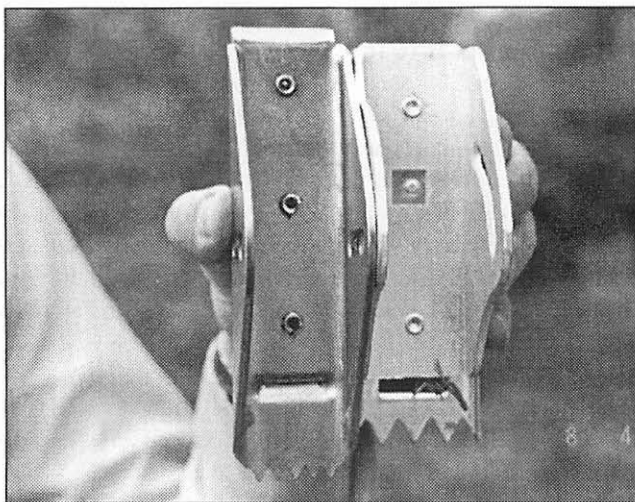
### Conditions at the Time of Investigation

The ladder was owned by plaintiff's previous supervisor and was stored in the back yard of the supervisor's home. Examination of the ladder was conducted with the ladder manufacturer's engineer at the home of the supervisor in early April, 1998. It was observed that the leveler had been removed from the ladder and the ladder had been in use without fixed or swivel feet. Burrs in the aluminum on the ends of the ladder rails indicated that the naked side rails had been set directly on the supporting surface(s). The author was informed that the supervisor had removed the leveler from the ladder and had stored the leveler pieces in his basement.

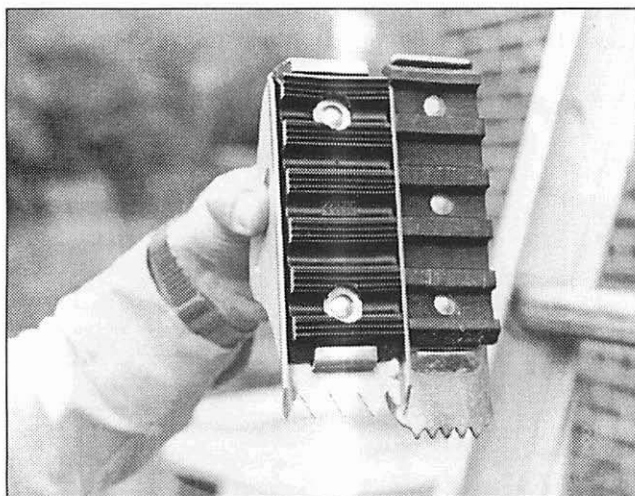
The ladder leveler is a device with a sliding leg fitted to each rail of the ladder. The motion of the legs is controlled by rack and pinion mechanisms, interconnected by a metal rod and locked by spring loaded "cams" when the ladder is loaded. See photograph 1. The ends of the legs are tipped with a fixed semi-circular rubber cap (a fixed foot) to which swivel feet are attached. The swivel feet are faced with a polymeric (rubber) anti-slip material for use on hard surfaces such as concrete, wood floors, etc. and there is a "spade" at one end with a serrated edge. The feet can be rotated so the spade can be pushed into softer



**Photo 1**  
Ladder Leveler with Swivel Feet



**Photo 2**  
Top of Swivel Feet



**Photo 3**  
Bottom of Swivel Feet

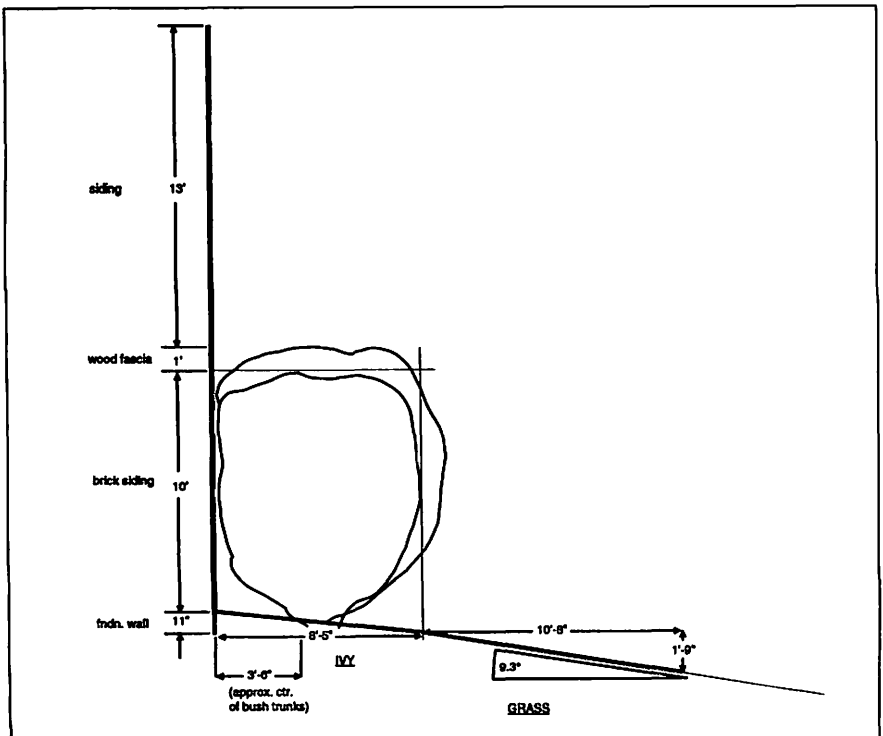
surfaces such as lawn, soil, etc. to provide stability for the ladder. Photographs 2 and 3 show the tops and bottoms of two different versions of swivel feet.

During the investigation the leveler mechanism was reinstalled on the ladder and examined and tested for condition, installation, and proper function. In spite of being off the ladder and stored under questionable conditions for sev-

eral years in the basement, the leveler was in good condition. A few parts were missing (one swivel foot and the connecting rod between the two legs) and they were replaced to make the installation complete. It was determined that although original installation and re-assembly were not entirely in accordance with manufacturer's instructions, installation was satisfactory and the leveler worked properly and easily.

After re-assembly, the ladder with the leveler was tested under loaded conditions for proper function against the side of the supervisor's house. Again, they worked easily and as designed by the manufacturers. Investigative work by the author's client (defense attorney) revealed the location of the incident site. The investigation was moved to the scene of the accident.

At the accident site, it was observed that the bushes had been severely cut back within recent months, based on the freshness and cleanliness of the cuts on their trunks. Measurements of site conditions were made and are shown on figure 1. The homeowner was interviewed and it was determined that although the



**Figure 1**  
Conditions at the Time of the Accident

bushes had been cut, the ground surface and the structure had not been altered. The homeowner stated that at the time of the incident the bushes were thick, up to the top of the brick veneer, and out to the edge of the ivy. The outline of the bushes as they were in 1994 are approximated on figure 1.

On figure 1 it will be noted that the ground was gently sloped away from the house for approximately 8-1/2 feet, to the edge of the ivy. The slope got steeper at that point with the slope in the grassy area calculated from field measurements to be 9.3°. The height of the house was indirectly measured to be 24 feet at the peak of the roof. The ladder was not available at the incident site for set-up and measurements at that time, as it was several miles away at the supervisor's home.

### **Analysis**

The plaintiff stated that the 24 foot extension ladder was too short, so he used the 32 foot extension ladder. Because of overlapping of the top and bottom sections where they slide together, the maximum working length of a 32 foot extension ladder is approximately 29 feet. The ladder leveler was attached so that it added another foot of effective length. Accordingly, for purposes of the analysis a 30 foot ladder was used.

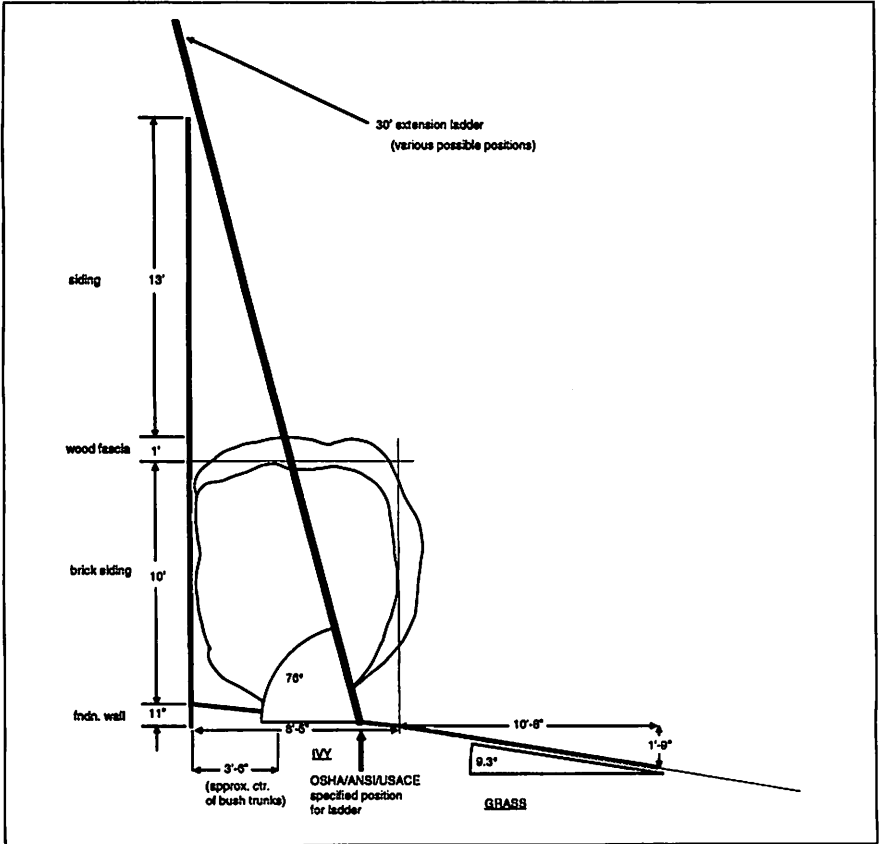
Occupational Safety and Health Administration (OSHA) Regulations state, "Non-self-supporting ladders shall be used at an angle such that the horizontal distance from the top support to the foot of the ladder is approximately one-quarter of the working length of the ladder..."<sup>1</sup> This equates to an angle of 75° 31'.

American National Standards Institute (ANSI) standard A14.2-1990 states, "Portable non-self-supporting ladders should be erected at a pitch of 75-1/2° from the horizontal for optimum resistance to sliding, strength of the ladder, and balance of the climber. A simple rule for setting up a ladder at the proper angle is to place the base a distance from the wall or upper support equal to one-quarter the effective working length of the ladder (the "quarter length rule")."<sup>2</sup>

The U.S. Army Corps of Engineers (USACE) requires that, "Portable ladders shall be used at such a pitch that the horizontal distance from the top support to the foot of the ladder will not be greater than one-fourth the vertical distance between these points."<sup>3</sup> This equates to an angle of 75° 58'.

### **Use of Graphics**

Because of the many variables in this situation and the infinite possibilities for the set-up of the ladder, it was decided to use graphics as the method of analysis. Since the author's computer drafting program is accurate to only one degree, 76° was chosen as the desirable angle of the ladder in the analysis. The

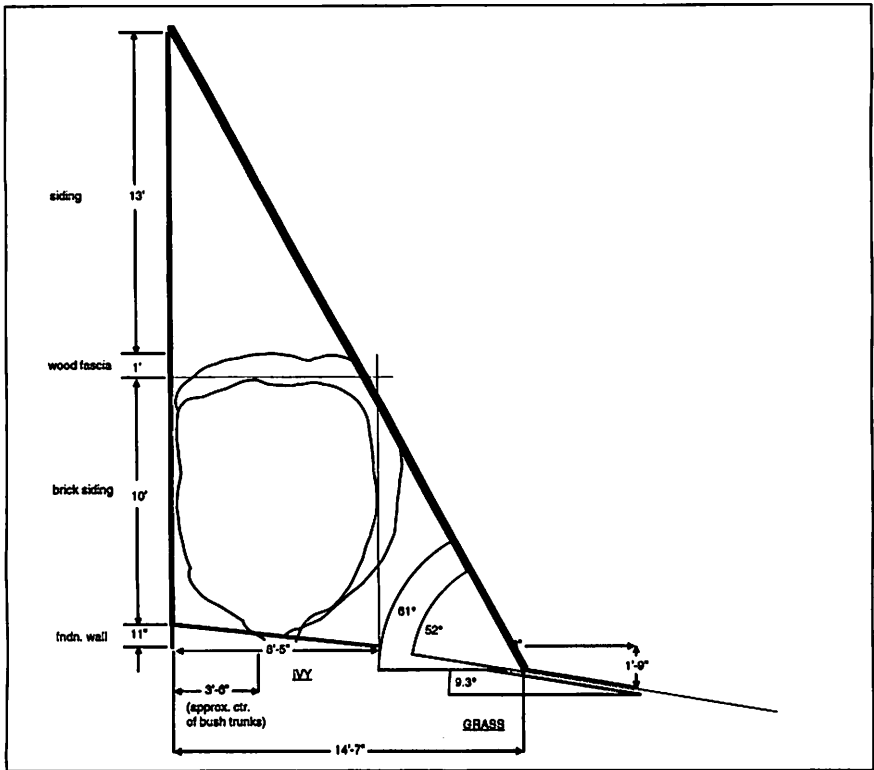


**Figure 2**  
Recommended Ladder Set-Up

first step was to show the OSHA/ANSI/USACE mandated position of the ladder superimposed on the drawing of the 1994 site conditions, producing figure 2. As can be seen, this would have placed the ladder in the middle of the bushes and was physically impossible.

The next step was to determine how the ladder would have had to have been placed in order to reach the peak of the roof, just touching the bushes. This position was considered to be the position most likely used by the plaintiff to set up the ladder at the time of the accident. Figure 3 shows the 30 foot ladder in this position. The angle it makes with horizontal is 61°. Since the ground sloped away from the house at an angle of 9.3°, the effective angle of the ladder with the ground surface is actually 52°, which is also shown on figure 3.

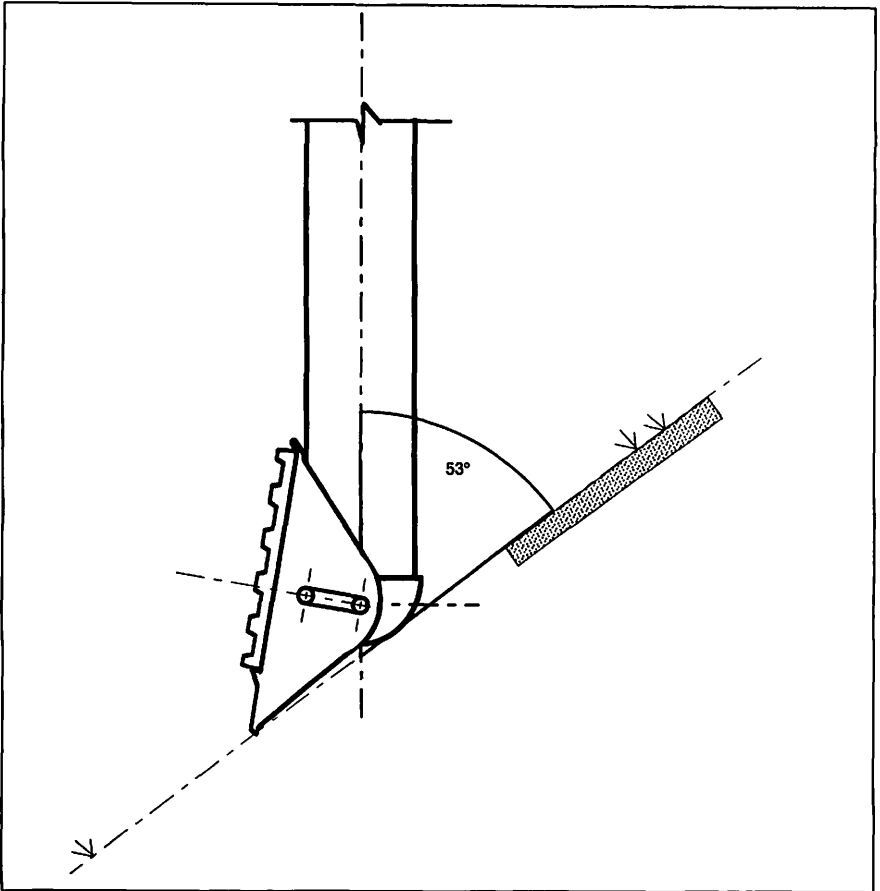




**Figure 3**  
Most Likely Position of Ladder at Time of Accident

Manufacturer's instructions direct the user to place the ladder against the wall, and on soft surfaces rotate the swivel feet so they are away from the wall with the spade pointed down, penetrating the soft surface upon which the ladder is set. In this case the soft surface was the lawn pitched  $9.3^\circ$  to drain away from the house. A leg of the ladder leveler and an exemplar swivel foot were measured and a half scale drawing of each was produced. These two sketches were then combined to show how the leveler leg looked with the mounted swivel foot rotated into position for use on soft ground. See figure 4.

A line was then drawn to represent the surface of the ground at the angle where the tip of the spade just contacted the ground and began to take a bite into the surface. This angle was measured with a protractor to be  $53^\circ$ . Please refer to figure 4. At this angle the spade becomes ineffective, and all that supports the ladder is the fixed rubber caps on the ends of the leveler legs so the ladder is dependent solely on friction with the bearing surface for stability against slipping.

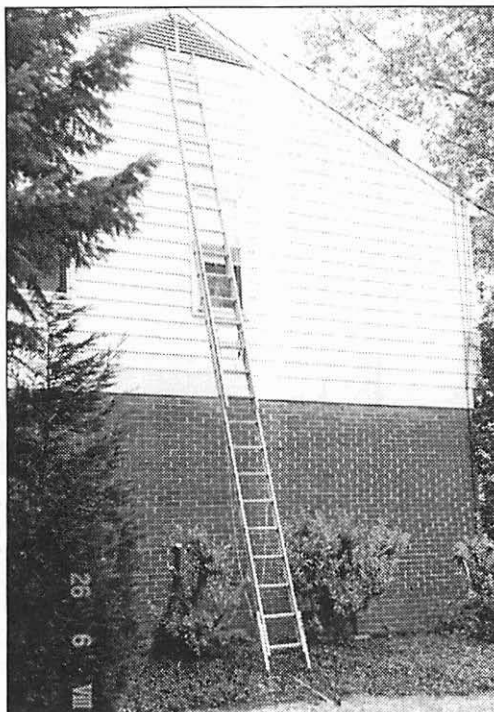


**Figure 4**  
Swivel Foot on Leg at Minimum Contact

When this result was compared to the angles shown on figure 3 it was noted that in the position in which the ladder was most likely used ( $61^\circ$  from horizontal), the effective angle with the ground surface was only  $52^\circ$ . This angle is in the range where only friction between the ground surface (grass) and the rubber leg cap prevents the ladder from slipping away from the wall.

#### **Field Testing and Confirmation**

On June 26, 1998 in preparation for court, the ladder was taken to the incident site and set up for video taping. At this time the author and client attorney had the opportunity to test the reassembled ladder and leveler "in situ" to confirm analysis results. Photographs 4 and 5 show the ladder set up at the recommended  $76^\circ$  angle, in compliance with safety regulations. It is clearly in the



**Photo 4**  
Ladder at 76°

thick of what used to be heavy bushes. Even if it could have been set up there, it would have been unusable. (In the re-construction the ladder was not fully extended and set to the peak of the roof because of safety concerns caused by the electrical power service to the house at that point and the desire to avoid damage to the attic vent louvers.)

The ladder was then extended to 29 feet, almost full usable length, and moved to a position at an angle of 63° with horizontal (again avoiding the louvers and power service.) See photographs 6 and 7. It was confirmed under these conditions the spades of the swivel feet did not penetrate the lawn (the soil was moist and soft enough to penetrate, had the angle of the spade been appropriate.) See photograph 8.

### **Opinion**

Site conditions at the time of the accident did not allow the plaintiff to set-up the ladder at the OSHA, et al specified angle of 76° with horizontal (4v:1h). Choosing to avoid the bushes, he set it up at an angle in the range of 60-65°. In



**Photo 5**  
Ladder at 76°

this position the spades on the swivel feet had minimal, if any, effect on stability; slipping away from the house was resisted entirely by friction between the rubber end caps of the ladder leveler legs and the grass in the lawn.

As the plaintiff washed the siding of the house in preparation for painting, water and detergent ran onto the ground and flowed around the base of the ladder, wetting the contact surface. The coefficient of friction between the grass and the feet of the ladder was reduced, and the base of the ladder slipped causing the fall.

### **Conclusion**

Is the opinion of the author, as rendered in his oral report, that the accident was not caused by negligence by the manufacturers of the ladder or the ladder leveler or by defective products. Rather, as demonstrated through the use of graphic analysis and confirmed by partial re-construction at the accident site, it was caused by the plaintiff through the improper use of the ladder. The installed leveler was not a causative factor in this accident. Graphics provided a good

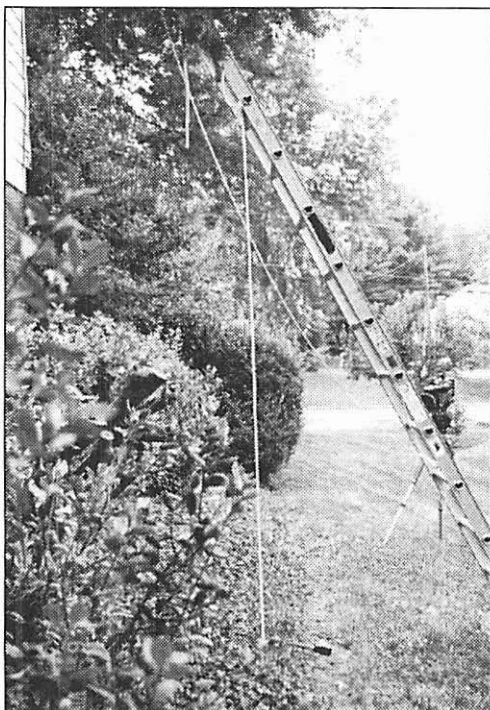


**Photo 6**  
Ladder at 63°

method of analysis which has the additional benefit of clearly showing what happened. The graphics and photographs were used when the author was deposed. The litigation was then settled without trial.

### References

1. U.S. Department of Labor Occupational Safety and Health Administration, Safety and Health Standards for the Construction Industry, OSHA Regulation 1926.1053(b)(5)(i).
2. American National Standard for Ladders - Portable Metal - Safety Requirements, ANSI A14.2-1990, article 8.3.3, (1990)
3. U. S. Army Corps of Engineers Safety and Health Requirements Manual, EM 985-1-1, article 30.B.03, (1987).



**Photo 7**  
Ladder at 63°



**Photo 8**  
Swivel Foot with Ladder at 63°