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LADDER CAGES

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ABSTRACT

It is inexplicable that the literature on fixed ladders is silent on the topic of ladder cage function in spite of ubiquitous codes and standards that have specified their use for eight decades. Cages enable a climber to rest at any level by leaning backward against the cage structure. Fall protection is provided whenever a climber loses both hand grips while retaining a foothold.

INTRODUCTION

There are two modes of falling from a vertical fixed ladder. One of these proceeds by the loss of foothold followed by the inability to regain equilibrium by hanging onto the ladder rungs or side rails. Barnett and Poczynok (Ref. 1) have shown that it is very unlikely that the friction grip on side rails will be sufficient to restrain a falling climber. The associated falling mode is a straight free-fall without rotation which lands the climber on his feet at the base of the ladder. A ladder safety cage will not prevent or mitigate the resulting injuries.

A second falling mode occurs when a climber releases both hands from the rungs or side rails while maintaining a foothold and a reasonably stiff torso. Under this condition, gravity always provides a moment about the lowest supporting rung. The climber's body rotates around this member and quickly intersects the close fitting ladder cage. It will be demonstrated that this interaction with the ladder cage terminates the fall.

REST CAPABILITY

Most common building code and access requirements for *stairways* specify landings where climbers can rest when ascending or descending. "Landings at least as wide as the stair itself are required at the top and bottom of the stair, and at intermediate points if necessary to ensure that no single flight has a rise greater than 12 ft. (3.658 m)" (Ref. 2). In contrast to this conservative standard, the safety standard for vertical fixed ladders allows a 24-foot climb without any provision for resting (Ref. 3, Fig. 2).

The cage is one of the safety devices approved by the ladder standard for climb heights over 24 feet (7.315 m). It is not widely known that the cage provides a rest station at every level along its length. This property was demonstrated using a ladder cage manufactured by Cotterman of Croswell, Michigan. Their cage precisely reflects the construction features and dimensions illustrated in Fig. 17 of the American National Standard for Ladders-Fixed-Safety Requirement, ANSI A14.3-2002 (Ref. 3). Our test setup used two intermediate cage sections as shown in Fig. 1. The corresponding dimensions are given

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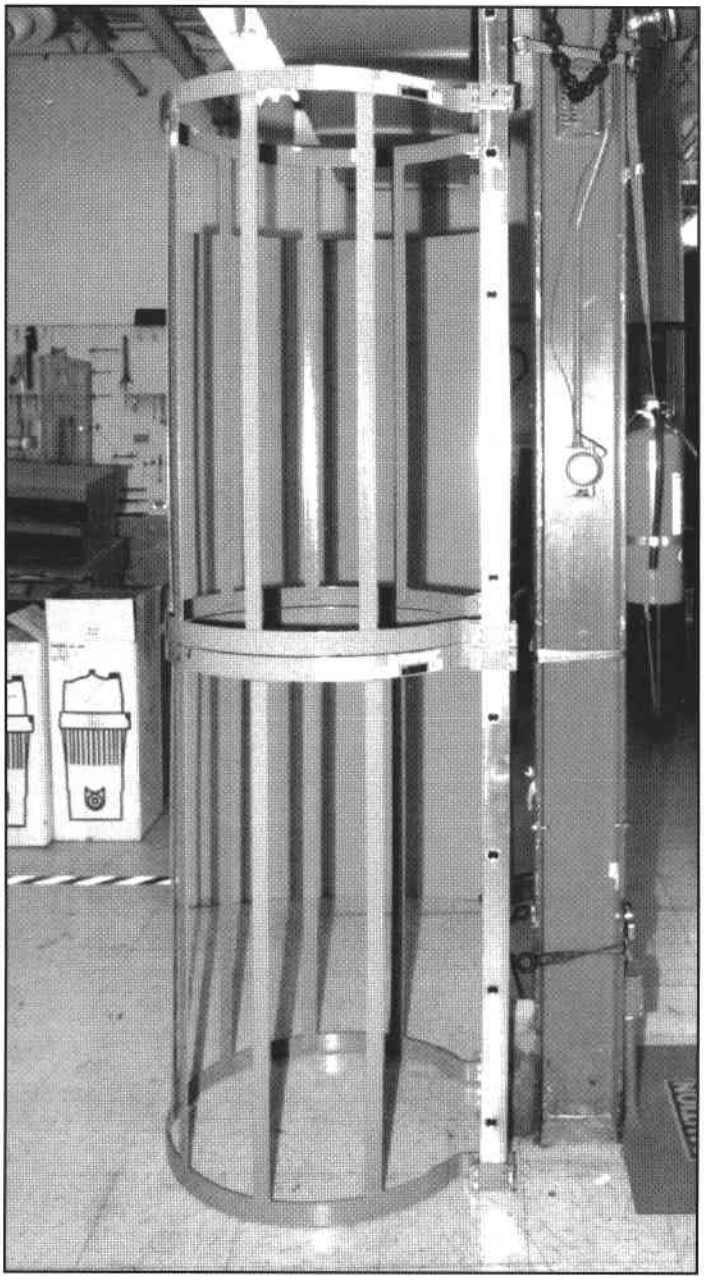


Figure 1 - Test Setup - Intermediate Ladder Sections

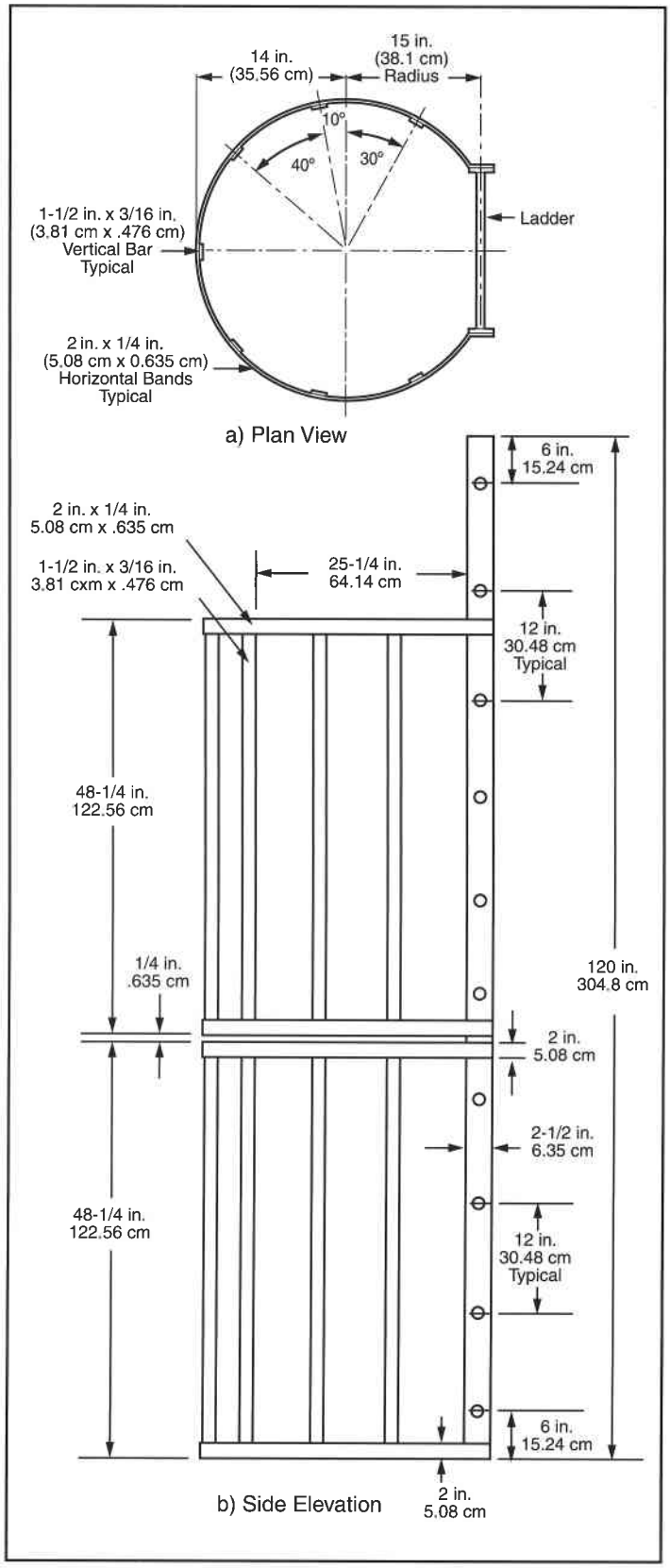


Figure 2 - Ladder Cage Test Fixture

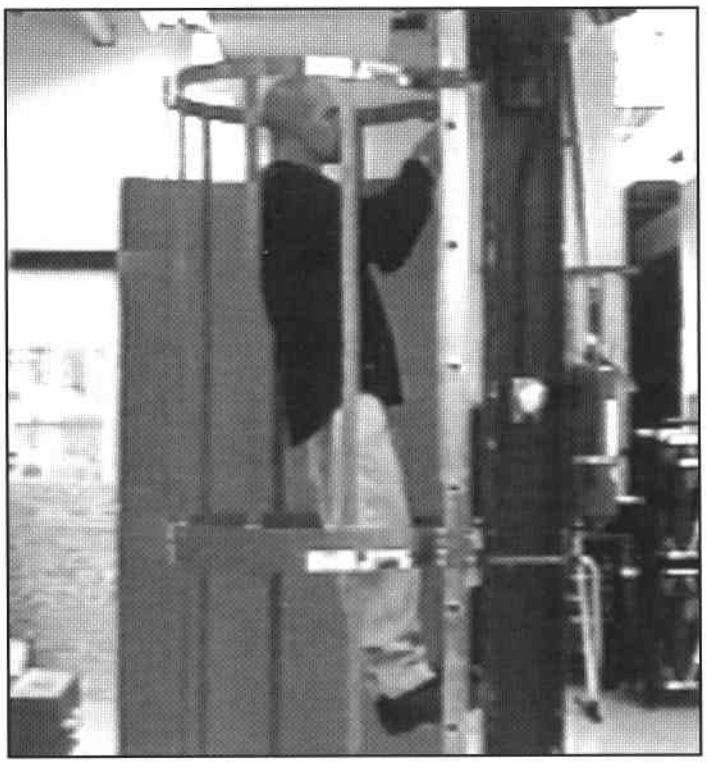
in Fig. 2. Four sequential images taken from a videotape are depicted in Fig. 3 which illustrate a climber lowering himself into a rest position. The first rest profile is shown in Fig. 3c and is characterized by the climber resting his back against the cage structure while simultaneously holding onto a ladder rung. The second rest profile is represented by Fig. 3d which portrays a climber with his back against the cage and his two feet on a rung; the hands are not used.

FALL RESTRAINT

Reaction forces provided by a climber's hands are required to equilibrate his body against the ever present overturning gravity moment. Release of both hands causes an erect body

a) Initial Position

c) Rest: Hands and Back



b) Lowering Maneuver

d) Rest: Back Only

Figure 3 - Rest Profiles Using A Ladder Cage

to execute a back dive. The presence of a ladder cage terminates this maneuver as illustrated in the sequential video frames shown in Fig. 4 for a dual hand release. The falling climber is seen to rotate rearward into the cage structure which arrests his movement.

The restraining action of the cage is also demonstrated in the series of video frames presented in Fig. 5 for a one-hand climb scenario where the climber carries a 35.75 lb (16.22 kg) Freon tank in his free hand. This one-hand scenario is prohibited by ladder safety standards which require both hands and arms remain free for climbing.

CRITICAL LADDER HEIGHT

As early as 1923, the American Standards Association recommended the use of cages on vertical fixed ladders (Ref. 4). Subsequent standards have all called for cages, wells, or ladder safety devices whenever the climb height exceeds some critical height H as depicted in Fig. 6 which illustrates the key elements of a ladder/cage system. All ladder standards have required at least a 4 inch (10.16 cm) flare at the bottom of the cage and a clear height above the ladder base of 7 feet (2.134 m) or more. Later standards have specified that the cage extend a minimum of 42 inches (106.68 cm) above the point of access/egress at the top of the ladder.

A review of typical fixed ladder codes and standards reveals the following values of critical height H:

Standard/Code	Critical Height, H
ASA A14-1935 (Ref. 5)	20 feet (6.096 m)
ASA A14.3-1956 (Ref. 6)	20 feet (6.096 m)
ANSI A14.3-1974 (Ref. 7)	20 feet (6.096 m)
ANSI A14.3-1984 (Ref. 8)	24 feet (7.315 m)
ANSI A14.3-1992 (Ref. 9)	24 feet (7.315 m)
ANSI A14.3-2002 (Ref. 3)	24 feet (7.315 m)
OSHA 29 CFR Ch.XVII §1910.27 (7-1-99) (Ref. 10)	20 feet (6.096 m)
California Code of Regulations General Industry Safety Orders Title 8,§3277, Register 81 No. 4, 1-24-81 (Ref. 11)	20 feet (6.096 m)
California Code of Regulations General Industry Safety Orders Title 8,§3277, Register 99 No. 12; 3-19-99 (Ref.12)	20 feet (6.096 m)

Other than cost, there is no downside associated with the ladder cage. It provides both a rest station and fall protection at all levels above the 3rd or 4th step above the base. It may even protect a climber in violent winds by limiting his side to side excursions. Furthermore, it provides penetration resistance to foreign objects which might impinge on climbers from outside of the ladder.

CONCLUSIONS AND DISCUSSION

1. A cage offers no protection to a climber who falls straight down to the base of a vertical fixed ladder.

2. Slippery or broken rungs can cause concurrent loss of support to both of a climber's feet. If he is grasping the ladder side rails, regaining equilibrium is almost impossible. The resulting straight free-fall may be controlled by ladder fall safety systems that satisfy section 7 of standard ANSI A14.3-2002 (Ref. 3). Such systems may consist of a carrier, safety sleeve, and full body harness.

3. If a climber has adequate rest during a climbing exercise, grasping a rung results in a power grip that can support a climber at the onset of a free-fall for sufficient time to reestablish his climbing maneuvers.

4. Proper climbing technique always involves appendages on three or four separate rungs. A minimum of three independent rung failures are required to achieve free-fall which is very unlikely. Proper climbing technique is explained in the paper entitled "How to Climb An Unsafe Ladder", (Ref 13). It is demonstrated by Woody Allen in his movie, "The Curse of The Jade Scorpion" (Ref. 14).

5. Even with proper climbing technique, a single slip of one hand when the other is reaching for the next rung can result in a back dive from the ladder. In this case the cage will arrest the fall and prevent an injury.

6. Ladder fall safety devices prevent all falling accidents. They are active devices that provide no resting capability. By contrast, cages are passive safety devices that protect against back dive scenarios only; they also provide an efficient rest capability.

7. A climber may choose a hands-free resting profile. He may also elect to continuously hold onto rungs, side rails, and safety cage elements while he rests.

8. From a safety point of view, all vertical fixed ladders should be protected by cages regardless of their height. The cage never compromises safety. It is a passive device that provides rest stations throughout its length and it protects climbers against back dive scenarios whenever they are standing above the third or fourth rung from the ladder base.

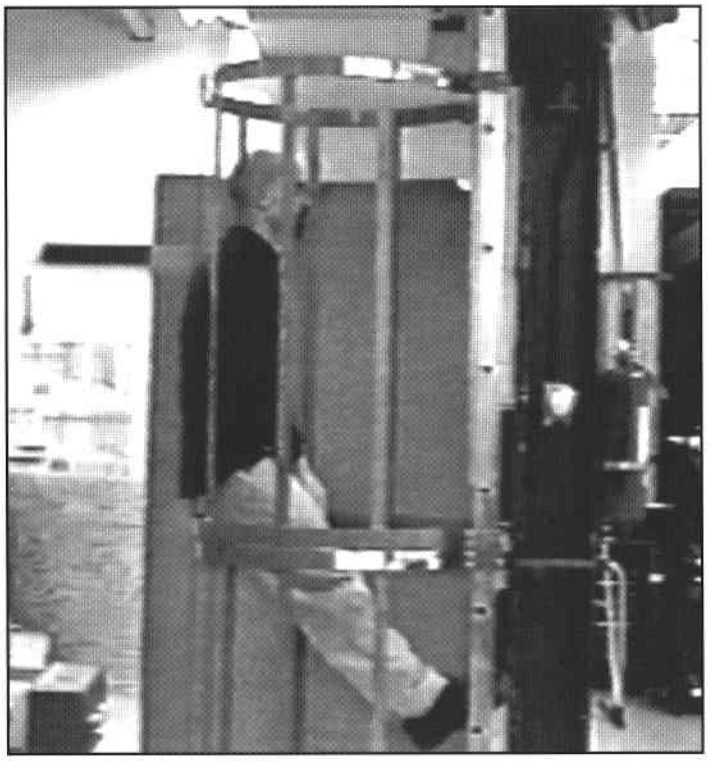
9. Ladder fall safety systems should not be used without cages; they should be used together on long climbs to provide both fall protection and rest opportunities.

10. Anecdotal evidence suggests that users of fixed ladders vaguely understand that the cage provides fall protection; they, on the other hand, are unaware of the rest capability of the cage.

a) Initial Position

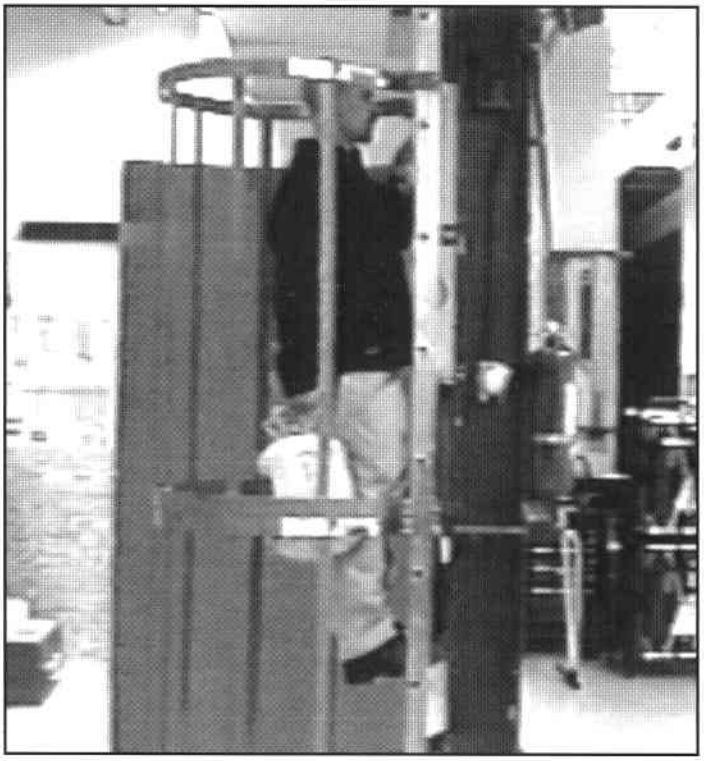
c) Intermediate Position

b) Dual Hand Release



d) Restrained Position

Figure 4 - Dual Hand Release Scenario



a) Initial Position

c) Intermediate Position

b) One Hand Release

d) Restrained Position

Figure 5 - One Hand Release Scenario

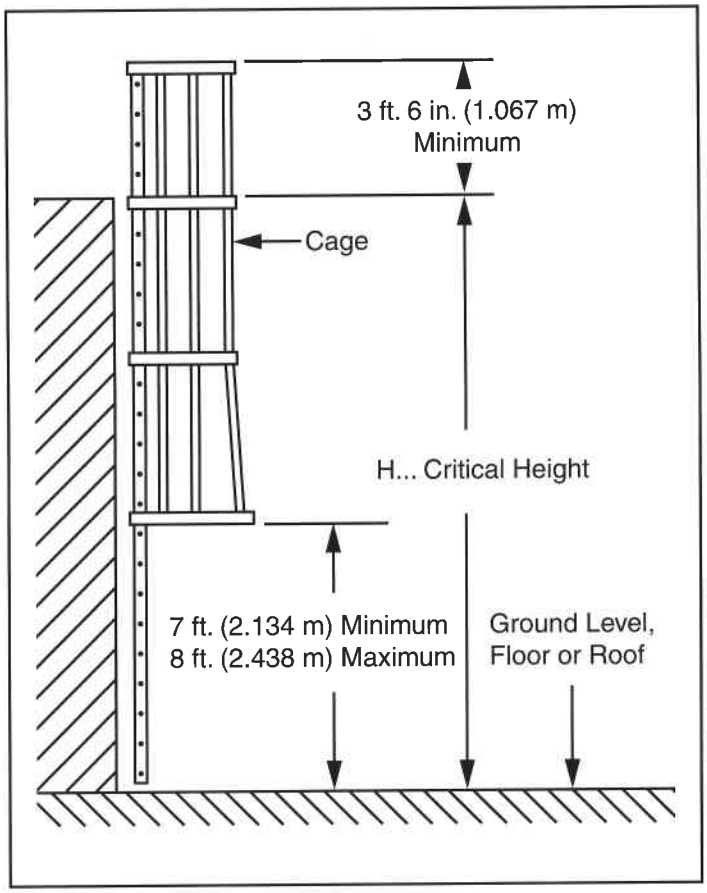


Figure 6 - Typical Ladder Cage System

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CONGRATULATIONS !

Triodyne's own Dr. Crispin Hales received the *2003 Meritorious Service to the Profession* award from the American Society of Mechanical Engineers Chicago Section on December 2, 2003.

Diane L. Peters, P.E. and Chair, ASME Chicago Section with Dr. Crispin Hales

Everyone at Triodyne knows that ASME made the obvious choice!

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