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ARTICLE #5 - GROUP 1:

DEFICIENCIES FOUND IN MANY MARINE STAIRWAYS AND LADDERS RESULTING IN ACCIDENTS

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- *Summary*:

After inspecting more than 100 marine stairways, in which accidents occurred, we found several deficiencies in the steps and handrails of stairs that are consistently repeated.

The following are extractions from reports of inspections of stairs from large passenger vessels to small tugboats.

- *Glossary*:

Tread Depth: The distance from the front edge to the riser wall exclusive of nosing or overhang.

Nosing:	The projection of the front edge of a stair Tread beyond the riser wall.
Open Riser:	A riser which lacks a riser wall.
Overhang:	Essentially the same as a "nosing" as measured from the riser wall to a vertical line drawn from the above tread edge or nosing to the tread surface below.
Railing:	A barrier to the sides of a stair system, i.e., a handrail, or a barrier at a landing area, i.e., a guardrail.

Rise:	The vertical distance from one tread surface to an adjacent tread surface.
Rise Angle:	The angle of a stair system as measured from adjacent tread edges or nosings to the horizontal plane.
Riser:	The vertical face or space between two adjacent treads.
Run:	The horizontal distance between risers or between treads.
Slope:	Same as rise angle.

- *Deficiencies Commonly Found on Passenger Vessels*:

1. Nosing:

The stairs of most passenger vessels are covered with luxurious plush carpets with thick padding, but some times there is excessive carpeting that is not properly attached to the solid portion of the step, primarily in the nosing area or step edge. The excess of carpet or padding around the nose makes the tread depth appear greater than what it really is, resulting, in some cases, a nose having 1 1/2" to 2 ½" radius, and consequently reducing by this amount the solid and flat portion of the tread depth. Furthermore, the thick carpet and/or thick padding creates a "bouncy" or spring like tread surface for the moving foot, which can produce excessive forward motion of the shoe in the downward direction when a person is descending the stairs.

In one case, the plaintiff's metatarsal arch most probably stepped on the large 2 ½" unsupported step edge or soft nosing resulting in false support or "undetected lack of support" and the plaintiff fell more than 20 steps downstairs.

Instead of a 2 ½" radius, the nosing should have had no more than a 1" to 1 ½" radius.

2. The Geometry of the Stairs:

There is a formula regarding step geometry, which is codified in various building codes and have been time-tested since it was developed around 1672 by the Royal Academy of Architecture of Paris, France.

The "Universal formula for total step geometry" requires the following relation between riser heights (r) and tread depths (t): $2r + t = 24$ to 25 inches.

In the stairs related to the accident mentioned in the previous section, the average riser was 6 ¾ inches (r) and the solid portion of the step was 9 inches (t), therefore, the relation between the riser heights (r) and the tread depths (t) resulted in: $2r + t = 22.5$ inches, while if the nosing would have a been 1 inch nose radius instead of 2 ½ inches, the Universal formula would have been satisfied: $2r + t = 24$ inches.

If instead of a 2-½ inch nose radius, a 1-inch nose radius was used, and the solid part of the step would have been measured 10 ½ inches, the Universal formula would have been satisfied and the accident prevented.

3. The variation of riser heights:

Most building codes allow some variation to the riser dimensions between 3/16 inches to 3/8 inches, but others require the risers to be uniform. We have found that very often, the first and last steps do not meet the limitation on variation of riser heights.

When descending or ascending a stairway, after a person takes one or two steps, the brain becomes "programmed" or automatically adjusted for the riser and tread depth dimensions and governs his gait.

If suddenly there is a change in the raiser height, the person's brain gets confused and the sole or the heel of his shoe will strike the step and he (or she) will loose equilibrium, probably resulting in a fall.

The Code of Federal Regulations, 46CFR72.05-20 (0) requires that the sum of the raiser height and the tread depth shall be at least 17 inches and no more than 18 inches.

When a pedestrian begins to descend on a stair system, the human gait is best suited to a seven-inch riser drop.

4. The angle of inclination of the stairs:

A common deficiency of incline stairs is the excessive angle of inclination or pitch.

Inclined stairs have angles with the horizontal varying from 20 degrees to 55 degrees. The preferred angles for inclined stairs, according to most architectural standards are in the range of 30 degrees to 35 degrees, because it requires less effort to climb. The U.S.C.G. requires a maximum angle of 40 degrees for passengers and 50 degrees for crew, for interior stairways, but the rules indicate that they may allow special consideration for relief in the case of small vessels if it is shown to be unreasonable or impracticable to meet the requirements. OSHA indicates in Subpart D, part 1910.24 (e) Fixed Industrial Stairs, that the angles shall be between 30 degrees and 50 degrees, and defines the range between 60 to 75 degrees as "CRITICAL and SUBSTANDARD" (OSHA Part 1910.27). Furthermore, the National Safety Council considers the angle of 50 degrees as "CRITICAL ANGLE", and indicates that the preferred angles for fixed ladders (vertical) are between 75 and 90 degrees.

If a stair has an apparent angle in excess of 60 degrees, the person attempting to go down on the stair must decide if the stair should be negotiated as a "vertical stair" or as an "inclined stair".

If the apparent angle of the stair is less than 60 degrees, most people arriving to the upper landing will descend the stair facing away from the stair.

Private industries studies in which the author of this article participated many years ago, indicated that to reduce the possibility of accidents, inclined stairs shall have handrails extending continuously beyond the upper end of the stairs (this is also recommended by the USCG), in order to allow the person attempting to go downstairs, to hold onto one of the handrails with one of his hands behind his advancing body, that is, leaving one arm in tension to support the weight of his body in case of a fall, rather than having both hands ahead of him placing the arms in compression and in a position that may result in a pitch pooling effect.

Stairs with an angle in excess of 75 degrees should be considered vertical ladders, and should be negotiated facing the steps, for which two hands to hold the eccentric weight of the body are needed.

The U.S.C.G. (46 CFR 108.160) uses as reference the American National Standard Institute (ANSI) Standard 14.3 for most aspects of "ladders". ANSI A 143-1984 covers a range of ladders from 60 to 90 degrees. U.S.C.G. refers to "inclined stairway" when the angle does not exceed 50 degrees. From ANSI A 14.3, page 15, the preferred range for fixed (vertical) "ladders" is from 90 to 75 degrees. Nevertheless, ANSI A 14.3 contains the following exception: "Substandard fixed ladders shall be permitted only where it is found necessary to meet installation conditions …".

5. Handrails:

Good simplified information about railing can be found in a publication entitled "Guide to Safe Stairways, Walkways and Railings", published by the Petroleum Extensions Service – University of Texas in Austin, TX in 1978.

Page #9 of "Guide to Safe Stairways and Railings", which is a guide from OSHA, indicates: "Mounts should be firmly secured to the wall and should provide a minimum 3 inch clearance between the rail and the wall".

Information from the U. S. Department of Housing and Urban Development indicating that the distance between the railing and the wall should be 2" minimum.

Page 103 of Chapter XVII of OSHA Safety and Health Standards (29 CFR 1926/1910), OSHA 2207, which indicates: " (iii) All handrails and railings shall be provided with a clearance of approximately 3 inches between the handrail or railing and any other object".

The safest handrail is one, which is between 1 ½ inches and 2 inches in diameter, as the human hand approximates a circle when it closes.

The handrails should start at least 18 inches before the upper and lower tread to guide the hands into the slope of the stairs, and preferably more than 20 inches to apply the "hand behind system" previously described.

6. Industrial Stairs:

The minimum requirements for industrial stairs can be found in 29 CFR 1910.24. The stairs should be designed to carry a load of five times the normal live load anticipated. Each step is required by ANSI A 14.3 to be designed for a single concentrated load of 250-pound minimum. Although 29 CFR 1910.27 (OSHA) requires a minimum load of 200 pounds. Nevertheless, it is not uncommon to observe permanently deformed steps, as well as total failure of steel rungs in vertical steel ladders, due to reduction of strength by corrosion.

7. <u>Hitting an overhead structure when climbing is a common occurrence</u>:

Many crew boats and offshore supply-utility boats have inclined ladders to reach the pilothouse deck from passenger compartment.

Hitting the overhead deck when climbing an inclined ladder has been a common incident resulting in serious injuries in several cases. These injuries could be avoided by increasing the clearance to more than 7 feet or could be minimized by installing some padding materials.

When climbing a stair the foot being lifted must clear the nose of the tread vertically by one or two inches, or the person will trip on the nose of the tread. Part of this lift is obtained by rising on the ball of the supporting foot and part by a vertical rise in the pelvis as the lifting leg starts it swing. The net result is that the dynamics of climbing requires a greater clearance than the static height of a person.

Therefore, to provide a safe clearance for all persons and various situations construction codes and other sources require a minimum of 7 feet (84 inches) from the nose of any stair tread to an overhead obstruction. Examples of these codes or sources are:

OSHA 29 CFR 1910.24(i)	7 feet
USA Standard A64.1-1968	7 feet
Rosen, Slip & Fall Handbook Page 33, Paragraph 3.7	7 feet
B.O.C.A.	6 2/3 feet
U.B.C.	6 ½ feet
S.B.C.	6 2/3 feet
L.S.C.	6 2/3 feet

Numerous standards are used as the basis of good marine practice specifies seven (7) feet. For instance, the American National Standards Institute, in their USA standard ANSI 64.1-1968 indicates:

> "VERTICAL CLEARANCE: Vertical clearance above any stair tread to an overhead obstruction shall be at least seven feet measure from the leading edge of the tread."

In one case, a crewmember was seriously injured by climbing an inclined stair when raising his body 5 ¼ inches, or approximately one half the stair riser. He struck his head, in the middle of the dynamic action of his muscles in an effort to gain elevation and upward velocity.

The natural human gait for climbing is to rise 7 to 8 inches. An additional lift in excess of the natural gait gives a signal to the brain, which causes the muscles to exert extra output, which, if resisted by an obstruction, such as the deck, would result in an unusually strong blow. The muscles of the ankle, knee, femur and hip act together in lifting and these muscles are the strongest in the body.

About the Author:

Hector V. Pazos is a Naval Architect, Marine Engineer and a Registered Mechanical Engineer and has been engaged in Accident Investigation/Reconstruction for more than 35 years. He has been retained as an Expert Witness in over 1,200 Maritime cases, related to both commercial vessels and pleasure crafts, for both defense and plaintiff.

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