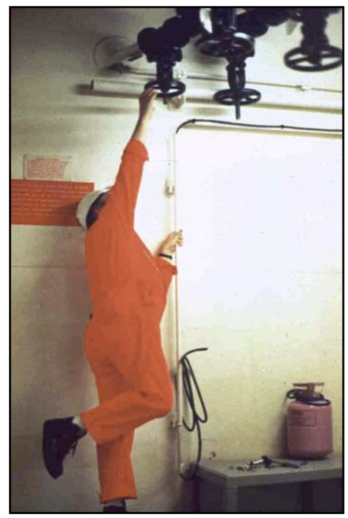
Discussion Paper
Designing Means of Access and Related Access Aids

INTRODUCTION

Falls are the leading cause of injury and death on commercial ships and offshore installations, and are common in other workplaces, including offices. Recorded fall accidents range from slips and trips while walking on even surfaces to falls from ladders and on stairs.

The most frequent types of falls are associated with stairs. In 1988, a major study was completed of approximately 602 significant accidents (i.e., those resulting in major physical injuries such as broken limbs, severe lacerations, concussions, burns or any injury requiring hospitalization). Falls down stairs were the most frequent and most costly accidents in terms of mariner lost time days and total accident costs (Templer, 1992; Templer 1985). Accident data obtained from vessels and offshore installations reveals that a cause for slips, trips and falls is a lack of adequate design for means of access.



Design or construction practices which were utilized in the past often presented situations wherein persons had to stand on pipes, cable trays, and/or wire-ways to gain eye or hand access, increasing the possibility of a fall.

Implementing suitable design of access aids will result in fewer near misses and injuries. A number of access aids and their safety concerns will be discussed in detail in the following sections. These include:

- Inclined stairs
- Vertical ladders
- Handrails
- Walkways and passageways

TERMS/DEFINITIONS

Access/Access Aids: Any item used to safely and efficiently assist movement of personnel, materials or supplies, for operation or maintenance purposes in normal and emergency conditions, or provide working surfaces (e.g., doors, stairs, vertical ladders, ramps, walkways, passageways, hatches, manholes, lightening holes, handrails, railings, and work platforms, and landings).

Accessibility: The ability for personnel to easily access equipment that requires maintenance, inspection, removal, or replacement while wearing the appropriate clothing, including personal protective equipment, and using all necessary tools and test equipment.

Anthropometry: Data relating to physical body dimensions. It includes body characteristics, such as size and breadth; the distances between anatomical landmarks, such as elbow to finger-tip; and height measured from the bottom of the feet to the top of the head.

International Maritime Organization (IMO): The arm of the United Nations (UN) that establishes policies, crew training requirements/skill levels, and ship design standards for maritime vessels to protect seafarers and the environment.

Means of Access: Any item used to safely and efficiently assist movement of personnel, materials or supplies. These can include doors, stairs, vertical ladders, ramps, walkways, passageways, hatches, manholes, lightening holes, handrails, railings, work platforms and landings.

Percentile: Given the range of variability of human bodily dimensions, anthropometric data are typically expressed as percentile statistics, such as 5th or 95th percentile. A percentile statistic defines the anthropometric point at which a percentage of a population falls above or below that value. For example, the seated eye height of a 95th percentile North American male is 853 mm (33.5 in), so by definition, 5% of North American males will have a seated eye height of greater that this figure, and 95% will have a lesser seated eye height.

Vessel: Any ship, boat, or offshore installation where people work, live and are subjected to the marine environment.

DISCUSSION

Bodily Injuries

Vessel motions can have a negative influence on a person's mobility. They can introduce instability and increase the energy expended to counter those motions. Using access aids can be awkward in a best case scenario, but with motion access aids present significant safety concerns. When motion-induced instabilities are introduced and the danger of personnel injury is increased, the use of some accesses can be rendered unsafe.

The body can be injured simply from the posture required to complete a single access task; for example, a strained muscle or tendon. The body can also suffer injuries such as muscular and skeletal disorders from repeated exposure to awkward postures required to gain access and to complete tasks. Inefficient access designs can also cause extensive damage to equipment, piping insulation, frayed wires, etc., either due to a fall or from using the damaged equipment as a foot hold. As a result, design guidance and standards for accesses are provided in the recent design standards (ABS, 2009; ASTM, 2007).

A final concern to consider is that crew members often do not use means of access safely, often carrying too much, carrying objects that are too heavy, taking several steps at a time, or not using safety devices such as harnesses.

Inclined Stairs

Stairs are noted as necessary access aids that are associated with more accidents on a vessel than any other access aid.

Traditional maritime design practices allowed for stairs of up to 60° inclination. However, as the angle of inclination of stairs increase, the stair tread gets narrower and the riser height increases. This in turn decreases the amount of tread available to step on, especially during descent, thereby increasing the likelihood of a crew member's foot slipping from, or missing, a step.

In 1990, a major oil and gas exploration and production (E&P) company initiated a program to assist in the design of their first deepwater drilling and production platform. One initiative selected by the company was to reduce accidents and incidences that repeatedly appeared in the company accident database. Over a five-year span the company had 21 serious fall accidents involving stairs. Six of these falls required hospital treatment or hospital stays for the crew members involved. More recent reviews of offshore accidents revealed that these accidents were not unique to this company, but rather reflected a general picture of fall injuries for the offshore industry.

Further research into the reasons or causes as to why these falls up and/or down stairs occur with such frequency influenced new stair design guidance. In a follow-up study of stair falls five years later, the company had only one fall associated with the new stair design (compared to 21 falls over a five-year period as discussed above) (Templer, 1992; Templer 1985). See ASTM F 1166 (2007), and ABS (2014) for the new stair design guidance.

Vertical Ladders

Falls from vertical ladders are less frequent than for stairs but can be extremely injurious or deadly. Fall data clearly shows that the risk of a fall being fatal increases after age 45. Also, the average height of a fatal fall decreases as the age of the fall victim increases, dropping from an average height of 55 feet (18.3 meters) for the 20-24 year old males to 21 feet (6.9 meter) for men between 55-59 years of age (Agnew , 1993). Translating these results into practical maritime design suggests that positive fall protection would be beneficial in the case of vertical ladder design in excess of 20 feet (6 meters) in height.

Vertical ladder landing location is another important concern. There is an increased risk of a crew member falling further when a landing is within about six feet (1830mm) from the edge of a deck. A crew member could fall over the handrail to the next deck level below, or fall overboard if falling from a ladder near the deck edge.

Design guidance for a variety of vertical ladder configurations is contained in the ASTM F1166 design standard (ASTM, 2007), the ABS Guide for Means of Access to Tanks and Holds for Inspection (ABS 2009), and the ABS Guidance Notes on the Application of Ergonomics to Marine Systems (ABS, 2014).

Handrails

Handrail heights for stairs have traditionally been 35 inches (890mm). Recently, it has been proposed that stair handrails should be closer to 36 to 37 inches (915mm to 940mm). The reasoning behind this shift in thinking is that crew members today are generally taller, and as a result their vertical center of mass is higher. The higher handrail heights help to compensate for this growth and render the increased vertical center of mass to the same level as safety rail height (ABS, 2014; ASTM, 2007).

Handrail heights for safety at deck edges can vary depending on what ship design standard is selected. Design dimensions have traditionally accommodated the lower limit required, 39 inches (1000mm); however, it has recently been recommended that 39 inches (1000mm) is insufficient. The general opinion of safety engineers is that the lower limit is no longer adequate to deter falls over a rail for the 95th% male, especially those from the Northern European and North American regions. At the lower limit, it is judged more likely for taller crew members to rotate over the rail, as the center of mass (for a 95% Northern European and North American male) is about three inches higher than the height of the rail.

When the center of mass of a human body acts above a guardrail, a person falling against that guard rail will have a greater tendency to rotate over the top of the railing. Further, when the center of mass of a human body acts below the top of a rail that person would have a tendency to rotate under the railing. This action (rotating under the top rail), along with the provision of intermediate rail(s), helps prevent a fall either over or under the top safety rail.

The provision of lower guardrail heights puts taller offshore workers or mariners at a safety disadvantage. When considering the taller potential worker population, a guardrail height of 42 inches (1070 mm) can help protect approximately 99% of all potential workers (men and women) from falls over the rail.

Based on the state of knowledge, and a large collection of anecdotal data, a number of significant changes in vertical ladder designs have occurred over the past decade. These now appear in related and recent design standards and guidance documents (ABS, 2014; ASTM, 2007). Changes include:

- Elimination of vertical flat bar stringers
- Changes in rung design
- Limitation in the height of a single ladder run
- Use of positive fall protection (i.e., not just climber cages) for ladders over a certain height
- Special protection for ladders located within six feet of the edge of a ship or offshore installation

Walkways and Passageways

A major concern related to the simple task of walking down a passageway is the presence of bulkhead mounted equipment. Items mounted on a bulkhead, such as an electrical junction box or a fire hose box and fittings, present safety hazards. Further, it is advisable that passageways be kept free of any bulkhead-mounted objects if a passageway has any of the following characteristics (Zohar, 1978):

- Passageway is used under emergency conditions (e.g., foot traffic may be moving at accelerated speeds, passageway is used to transport injured crew members or emergency equipment)
- Passageway width is narrow
- Marginal lighting is present (such as emergency lighting lanterns, bridge companionways).

Where minimum widths are offered in walkway and passageway design standards they define the minimum clear walking surface. This is different than the dimensions of the walkways or passageway bulkheads with a walking area impeded by items mounted on walkway or passageway bulkheads. There should be suitable upper clearance for items mounted on a walkway or passageway bulkhead to prevent a person from accidentally walking into these items (Zohar, 1978).

Other Accesses

Providing appropriate means of access designs are not limited to just the stairs, ladders, walk-ways, etc. As an example, vessels often have lighting holes provided in bilge tanks, fuel, oil, and potable water tanks, as well as void spaces. Not only are these holes cut to help lighten the weight of the vessel or structure, but they also serve as crew member access routes during tank inspection and/or maintenance are required. These holes can be cut and located to maximize access for crew members without compromising the vessel or offshore installation structural integrity.

Dimensions and orientation of hatches, man-ways, lightening holes, inspection ports, kick-out panels (or any opening used by a crew member to pass or reach through) should be determined by the user's anthropometry, body postures required to use the opening (i.e., does the person step through, reach through, crawl through, or look through), and the tasks required of the person once the opening is passed. In addition, access openings which are used for emergency ingress or egress of spaces are routinely made larger and easier for passing through than openings infrequently used (such as entry into bilge tanks for inspection). However, in keeping with a good safety philosophy that design should be directed at the *worst case scenario*, openings into tanks in which a person could be rendered unconscious should be suitably large to accommodate the removal of that person.

REFERENCES

Agnew, Jacqueline and Suruda, Anthony. *"Age and Fatal Work-Related Falls",* Human Factors, 35(4), pp 731-726, (1993).

ABS. "*Guidance Notes on the Application of Ergonomics to Marine Systems."* Houston, TX. February, 2014.

ABS. "*Guide for Means of Access to Tanks and Holds for Inspection."* Houston,*,* TX. February, 2009.

American Society of Testing and Materials. "*Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities".* ASTM Standard F1166. West Conshohocken, PA, 2007.

Templer, John. *"Staircase Studies of Hazards, Falls and Safer Designs*", MIT Press, 1992.

Templer, John, Archea, John, and Cohen, Harvey. *"Study of Factors Associated With Risk of Work-Related Stairway Falls", Journal of Safety Research, Vol 16, pp183-196, 1985*.

Zohar, Dov. *"Why do we Bump Into Things While Walking"*, Human Factors, December, 1978.