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SAFETY BRIEF

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Above Ground Swimming Pools - Safety Concepts

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Figure 1 - Above Ground Pool with Perimeter Safety Barrier

ABSTRACT

The above-ground pool shown in Fig. 1 has been retrofitted with a perimeter safety barrier which consists of a fence, gate, ladder cage, water-side pool ladder, and an anti-grip/anti-foothold system. These safety concepts are combined to address the inadvertent and advertent foibles of bathers and bystanders who range from infants to adults, from uncoordinated to skillful, and from casual to mischievously determined.

There are no proprietary devices used in the safety system; all of the concepts are well known and can therefore be applied by anyone skilled in the art. The prototype safety system eliminates every classic danger including diving, jumping, deck-side horseplay and unauthorized access. The system itself introduces new hazards that may be controlled using safeguards that are described in the paper.

FAILURE MODES AND EFFECTS

When compared to in-ground pools, there are several safety advantages of the above-ground pool: a constant shallow depth, a high perimeter to area ratio, the absence of a

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main drain sump, and softer sidewalls and bottom. Nevertheless, there are many dangers to be addressed.

Diving/Jumping

Diving or jumping into an above-ground pool leads to an unacceptable risk of spinal cord injury including partial and complete quadriplegia. In 1989, the U.S Consumer Product Safety Commission (CPSC) summarized the diving problem in the United States as follows:

> *Approximately 700 spinal cord diving injuries are estimated to occur in the U.S. annually as a result of recreational diving into residential pools, public pools and other bodies of water. It has been further estimated that there are 150,000 -175,000 people presently living in the U.S. who have suffered traumatic spinal cord injury and that diving may account for 9-10% of them. The mean life expectancy for spinal cord injury victims is estimated at 30.2 years. Diving injuries are characterized by a high percentage of complete quadriplegics. Although there has been no large scale study of diving deaths, one study reports 2,700 diving related deaths during 1980-1981, another study reports that 38% of diving injuries admitted to a group of California hospitals were dead on arrival, and two additional studies showed that 10-11% of the victims died during hospitalization following a diving accident.*

Additional perspective is gained from a comparison of diving with other sports related accidents. In 1985 the University of Alabama Center published a book, Spinal Injuries - The Facts and Figures (Ref. A). Table 1, taken from that source, indicates that diving accounts for 66% of sports related injuries with football in second place with only 6.1%.

Table I - Distribution of Sports Related Accidents

Diving	66.0 %
Football	6.1
Snow Skiing	3.8
Surfing	3.1
Trampoline	2.6
Other Winter Sports	2.3
Wrestling	2.3
Gymnastics	2.2
Horseback Riding	2.0
Other	9.6

With respect to above-ground pools Gabrielsen has summarized the position of the entire aquatic's industry (Ref. B):

> *Where the water depth is less than 5 feet, there is not enough water to safely accommodate a diver attempting anything but a shallow racing type dive.*

Gabrielsen and Johnson (Ref. C) recommend the following:

> *In pools with constant depth shallow water, such as is usually found in above-ground pools, diving of any kind should be prohibited.*

This point of view has been universally adopted by both the safety and legal professions. Today all above-ground pools have on-product warning signs that admonish users not to dive or jump. In some states in the U.S., statutory laws preclude any legal remedy for diving mishaps when such warning signs are posted on or about the pools. Unfortunately, the effect of such laws is to remove any incentive for anti-diving research by pool manufacturers.

Patterns of diving and jumping associated with above-ground pools occur at the following stations:

1. The pool-side edge of a deck structure
2. The top edge of the pool sidewall
3. The ladder
4. The pool deck handrail

In addition to these patterns, random diving and jumping scenarios have involved trampolines, nearby garage roofs, generalized athletic swings and leaps from the shoulders of fellow bathers. When supervision is available it is very effective for controlling patterned behavior. Unfortunately, any individual act of diving may be executed in a fraction of a second without arousing a timely supervisory response.

Slip, Trip and Fall

Ambulation on deck structures that are often wet and oily will inevitably give rise to uncontrolled scenarios that will find actors in the water. Three types of hazard are encountered:

1. Persons on the deck may fall onto swimmers inside the pool.
2. A person falling onto the deck may be rendered unconscious and then tumble into the pool. Unaided, these people may drown.
3. Non-swimmers that are too short to keep their heads above the waterline may fall into the pool and drown if not rescued.

Horseplay

Rough and boisterous play often leads to pulling, pushing, or throwing children from the deck into the pool. Showing off, running, and rearward locomotion may cause the actors to fall into the water. Further, flinging objects such as pool furniture imperils swimmers. Unsupervised children can quickly develop a pattern of aberrant behavior.

Toddler Behavior

Young children who do not know how to swim and do not recognize or understand the dangers of water may from time to time breach perimeter fencing to gain access to an above-ground pool. Ladders are usually left in a deployed state. The resourcefulness and dexterity of very young children allow them to climb into pools without using the standard ingress/egress systems. Unfortunately, these scenarios and others frequently result in drowning.

Miscreant Behavior

Unfortunately, there are people who engage in aggressive, villainous, and vicious behavior. This community of users must be precluded from using the pool as must guests and strangers under the influence of drugs or alcohol.

Unauthorized Access

Pools must occasionally be closed to all swimmers for reasons such as water purity problems or maintenance. Sometimes restrictions must be imposed because of a lack of supervision. Sometimes small children cannot safely be mixed with older, more aggressive ones. No water, or inadequate water levels also demand that access to a pool be denied.

ANTI-DIVING / ANTI-JUMPING SAFETY SYSTEM

To encourage the aquatic industry to proactively tackle some of the failure modes associated with above-ground swimming pools, a straightforward, non-proprietary fencing concept is proposed to stimulate research in this nascent safety arena. The characteristics of the new concept will be measured against the previously identified safety problems.

Fencing

Figure 1 shows a prototype of the proposed above-ground pool safety system. The fencing circumnavigates the pool and is located at the interior edge of the sidewall coping to preclude the formation of a lip upon which swimmers might perch. Obviously, such a fence provides the smallest practical perimeter. The vertical portion of the fence is tall enough to accommodate a normal doorway for an adult male. Figure 2 depicts a cross-section of the prototype fence together with a radially disposed handrail. The use of partial decking that does not fully surround the pool gives rise to two short cross-railing sections that are perpendicular to the pool sidewalls. These railings protect against falls to the ground from the partial deck terminuses. Unfortunately, they also present an elevated platform from which swimmers can dive or jump. Figure 2 also shows a 64 in. (162.6 cm) female poised on top of the prototype cross-railing. It is clear how the cantilevered fence members at the crown of the fence will frustrate any attempt to jump or dive into the pool. It is

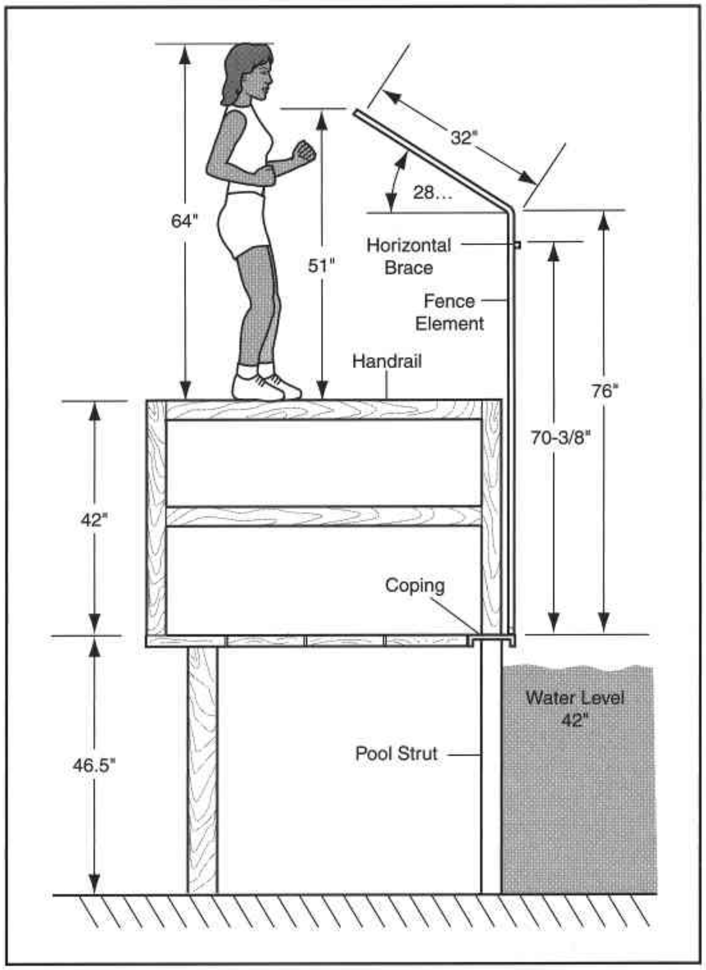


Figure 2 - Fence Cross Section

indicated in Fig. 2 that the fence top is 51 in. (129.5 cm) higher than the conventional 42 in. (106.7 cm) tall handrailing.

With respect to diving or jumping from the deck or sidewall coping, the 93 in. (236.2 cm) high fence characterized in Fig. 2 completely eliminates these activities. Furthermore, the fence precludes pool entry by means of slipping, tripping, bumping, running, or shoving. Horseplay scenarios that involve throwing swimmers or large objects into the pool are eliminated or minimized by the high fence with the umbrella-like cantilevered arms.

A front elevation of the fence is shown in Fig. 3 where the vertical members are fabricated using 3/4 in. (1.9 cm) square tubes with 4 in. (10.2 cm) spaces between members. The U.S. Consumer Product Safety Commission (CPSC) recommends that spacing between vertical members not exceed 4 inches (Ref. D). Anthropometric data compiled by the Society of Automotive Engineers, Inc. (SAE) in 1975 indicates that the fifth percentile head breadth of a 9 month old female is 10.8 cm (4.25 in.) (Ref. E).

Observe in Fig. 3 that the bottom of the fence is flush with the deck and sidewall coping. According to the CPSC, "If an above-ground has a barrier on the top of the pool, the maximum vertical clearance between the top of the pool and

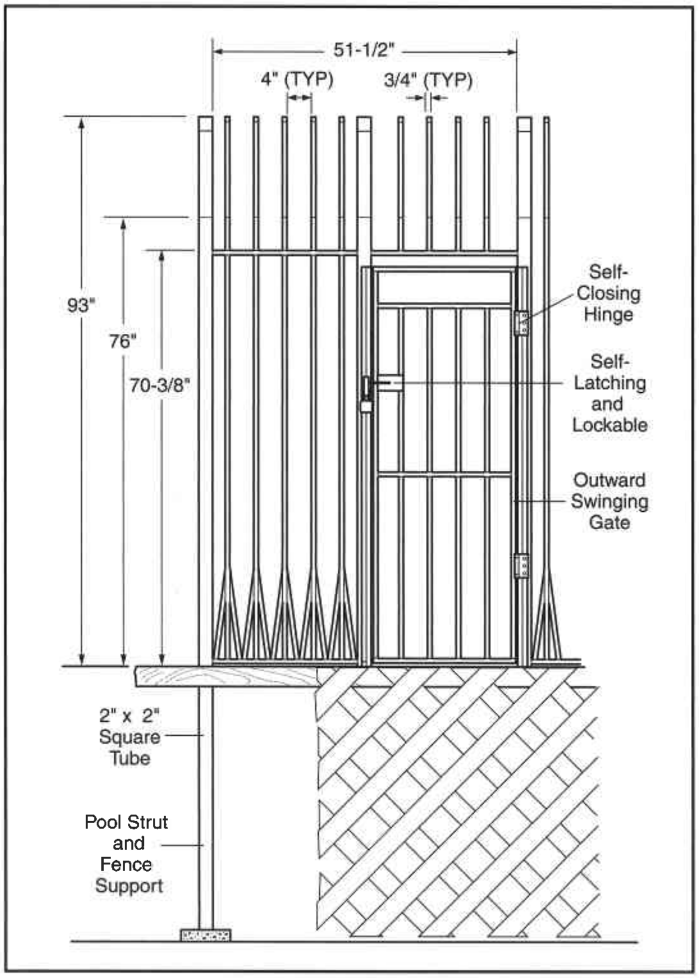


Figure 3 - Front Elevation - Fence and Gate

the bottom of the barrier should not exceed 4 inches." (Ref. D) These guidelines espouse the following CPSC philosophy:

> *A successful pool barrier prevents a child from getting OVER, UNDER, or THROUGH and keeps the child from gaining access to the pool except when supervising adults are present.*

To prevent children from climbing over a fence, the CPSC recommended guidelines advocate that the top of a pool barrier, measured on the side of the barrier which faces away from the pool, be at least 48 in. (122 cm) above grade. Furthermore, handholds and footholds must not be present. When the spacing between the vertical fence members is greater than 1.75 in. (4.45 cm), the foot width of young children, the CPSC guidelines require that the distance between the tops of horizontal members be 45 in. (114 cm) or more to discourage climbing.

Reference to Fig. 3 indicates that the fence height is 93 in. (236.2 cm) and that the distance to the top of the horizontal member is 70-3/8 in. (178.8 cm). It must be emphasized that the proposed fence system is designed with the capability to lock out all unauthorized personnel including young children, teenagers, and adults.

Anti-Foothold System

With respect to deck side activities, the proposed fence system has been shown to eliminate or mitigate all of the failure modes previously identified. Unfortunately, on the pool side of the fence new hazards are introduced by the fence itself. Swimmers can climb up the fence from the water side and, while gripping the vertical tubes, turn their bodies around with the back of their feet in the 4 in. spaces between the tubes. From this position a near perfect dive can be executed with its attendant dangers. Recall that the sidewall coping provides no diving or jumping ledge. To thwart diving or jumping from the bottom of the fence, protrusions can be added to the bottom horizontal member of the fence between the upright tubes. For example, that bare feet and hands are repelled when they contact surfaces such as aggressive non-slip floor plates. Such systems introduce increasing levels of pain as the normal surface force becomes greater. The idea is to inflict controllable pain without damage.

Tactile feedback designs based on surface asperities fail decisively in the face of water shoes and aqua socks. To deal with this reality, a bracing system has been fabricated at the base of each fence tube as illustrated in Figs. 1 and 3. One manifestation of this concept is depicted in Fig. 4 where the sole of a foot or shoe is symmetrically located in the "V" brace. Under a vertical load W, horizontal forces H develop which squeeze the foot because of the wedge angle α. From statics,

$$H = \frac{W}{2}\left(\frac{\tan\alpha - \mu}{1 + \mu\tan\alpha}\right)$$

where μ is the coefficient of friction between the sole and the tubular brace. The squeeze force can be seen to increase with greater angles α and smaller friction coefficients μ. If $\mu = 0.3$, stepping into the "V" with $W = 100$ lbs produces a squeeze $H = 111$ lbs. If the sole does not remain horizontal, the "V" brace will simultaneously squeeze the foot while rotating it almost 90 degrees.

Figure 4 indicates that the space at the bottom side of the "V" brace is 1.25 in. (31.75 mm). This dimension may be reduced if desired. The 1.25 in. dimension will prevent four year old children from inserting their heels on the sides of a "V" brace. Data presented by Norris and Wilson (Ref. F). indicates that the heel breadth of a fifth percentile four year old is 32 mm.

In summary, no swimmer can dive or jump from a perched position on the inside edge of a protected pool. There are scenarios where a swimmer can climb the inside of the fence without perching. A non-critical climbing protocol is illustrated in Fig. 5 where hand release will cause the climber to plop down into the pool. Such inefficient water entries will not lead to spinal cord injuries caused by impact with the bottom of the pool. Dropping on bathers, however, is a possibility.

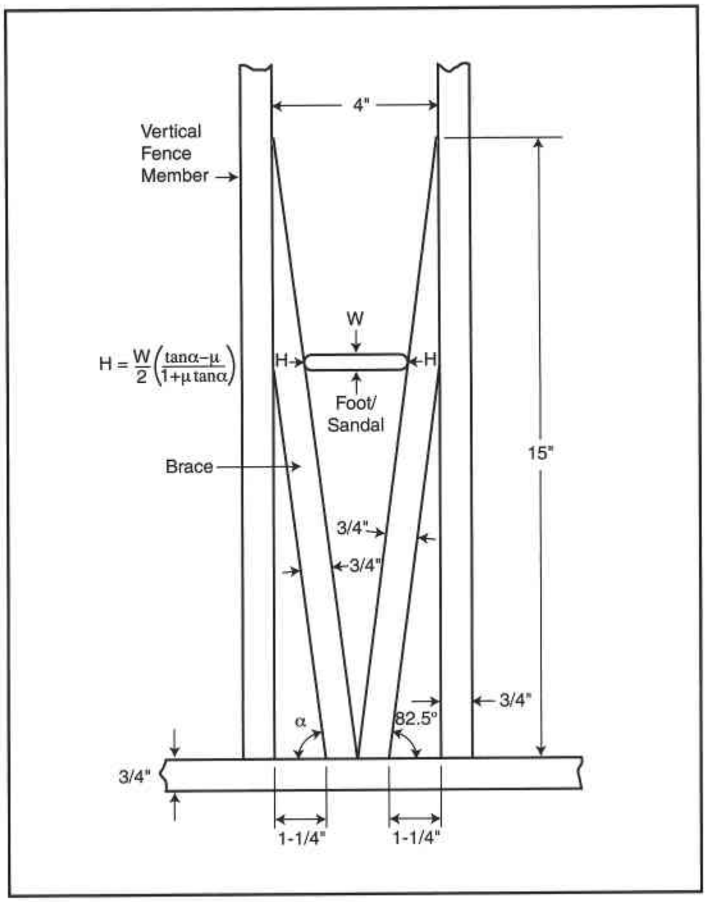


Figure 4 - Anti-Foot Hold System

Gate

The gate used on the prototype fencing is characterized in Fig. 3; it meets the CPSC guidelines which are reproduced herewith (Ref. D):

Pedestrian Gates

These are the gates people walk through. Swimming pool barriers should be equipped with a gate or gates which restrict access to the pool. A locking device should be included in the gate design. Gates should open out from the pool and should be self-closing and self-latching. If a gate is properly designed, even if the gate is not completely latched, a young child pushing on the gate in order to enter the pool area will at least close the gate and may actually engage the latch.

When the release mechanism of the self-latching device is less than 54 inches from the bottom of the gate, the release mechanism for the gate should be at least 3 inches below the top of the gate on the side facing the pool. Placing the release mechanism at this height prevents a young child from reaching over the top of a gate and releasing the latch.

Also, the gate and barrier should have no opening greater than 1/2 inch within 18 inches of the latch release mechanism. This prevents a young child from reaching through the gate and releasing the latch.

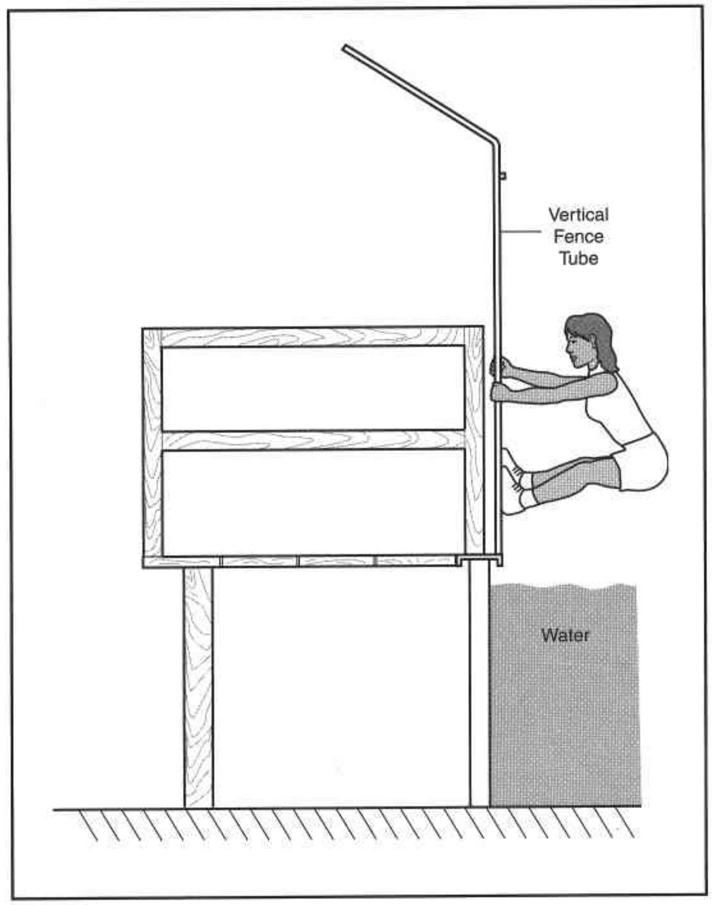


Figure 5 - Non-Critical Climbing Mode

Pool Ladder

A conventional plastic pool ladder has been incorporated into the proposed safety system. The most important characteristic of the ladder is that it protrudes into the pool about 16 in. (41 cm); this precludes jumping into the water from the top of the ladder for fear of hitting the ladder itself. A ladder cage confines the vertical drop zone.

A second feature of the prototype ladder is the ladder top platform which provides a safe haven for anyone accidentally locked within the pool. The ladder is sufficiently flexible to prevent underwater swimmers from becoming trapped between the ladder and the flexible sidewall. Finally, the lightweight flexible plastic construction will minimize untoward results stemming from underwater impacts by swimmers.

Ladder Cage

Among other things, tall fixed ladders usually require cages to help minimize accidental falls (Ref. G). The same geometric property of the cage that addresses accidental falls prevents diving. The cage surrounds and confines a climber's head until the submerged bottom steps are reached. Dangerous diving is impossible from the bottom steps. The bottom of the prototype cage is positioned 78 in. (200 cm) above the bottom of the pool; an adult can easily walk beneath the cage. As previously mentioned, the cage defines a potential drop zone which is invaded by the bottom of the angled ladder. Jumping is eliminated by this cage/ladder combination.

Whereas the ladder cage solves the problems of diving and jumping from the ladder, it is incumbent upon designers to investigate potential hazards introduced by this subsystem. Clearly, swimmers will have fun hanging from this structure which is cantilevered over the water. Hanging straight down from the bottom of the cage finds a swimmer's legs dangling in the water with a potential drop of less than two feet; this is not a critical drop height. Swimmers who hang with their bodies curled up will experience non-critical flops and plops which are hydrodynamically inefficient; they could, however, land on other swimmers. On the other hand, perching on any part of the cage is ominous.

Diving or jumping from the elevated cage structure must be prevented. This may be accomplished by removing footholds. Figure 6 suggests some control concepts that could be explored. A solid covered ladder cage is portrayed in Fig. 6a which provides no footholds or handholds. The 45° sloped cover will cause users to slide off because static equilibrium requires a friction coefficient of one or greater between the cover and the swimmer; $\mu \geq 1$ cannot be achieved.

The 45° slope has been proffered in the concepts shown in Figs. 6b and 6c. Users will slide off of the top edges of both open-cover designs. The front of the cage described in Fig. 6b is comprised of closely spaced vertical bars or tubes (e.g. one inch gaps, 2.54 cm) that are uneven in height and somewhat pointed. The idea is to prevent even sandaled swimmers from stepping on these uprights while maintaining their balance. The sides of this cage are constructed with the same anti-foothold braces used in the fence structure. The cage used in the prototype system is illustrated in Fig. 6c where closely spaced vertical bars protect both front and sides of the cage by precluding children's feet. Unlike the solid cage, the concepts presented in Figs. 6b and 6c allow swimmers to grip and swing from the component bars. The flexible hoop design depicted in Fig. 6d will collapse under a user's weight only to reconstitute its original shape when released (e.g. heavy rubber hoops). When unloaded the flexible hoops act as sentinels against diving and jumping.

CONCLUSIONS AND REMARKS

1. The proposed fence system provides a safety alternative and supplement to supervision, training, and on-product warnings for eliminating and mitigating the dangers concomitant to above-ground swimming pools.

2. The proposed fence system provides a demonstration of the potential of safety design as well as the challenges to this approach.

3. The proposed safety system prevents diving and jumping from pool decks, sidewall copings, pool ladders, deck railings, diving stands, and diving boards.

4. Deck-side pool entry is precluded from all sources of mischief and accident.

5. Without special equipment the locked fence is sufficiently robust that access will be denied even in the face of miscreant behavior.

6. Large objects cannot be thrown into or out of the pool. Life preservers that are less than 4 in. thick are compatible with the proposed fence system. A shepherd's staff can easily be inserted into the fence.

7. The prototype fence system was fabricated using conventional materials, accessories, and concepts.

8. The interior pool environment is fundamentally altered by the presence of the monkey bar-like grillage that characterizes the fence system. It introduces new play and usage patterns that are not fully understood because of the limited experience with the prototype pool.

9. Potential new dangers are associated with the new fence system which may or may not be under control. The fence system gives rise to non-critical scenarios involving limited height jumps, flops, plops, and swinging. It is believed that all diving and jumping protocols from perched positions on the fence system have been eliminated.

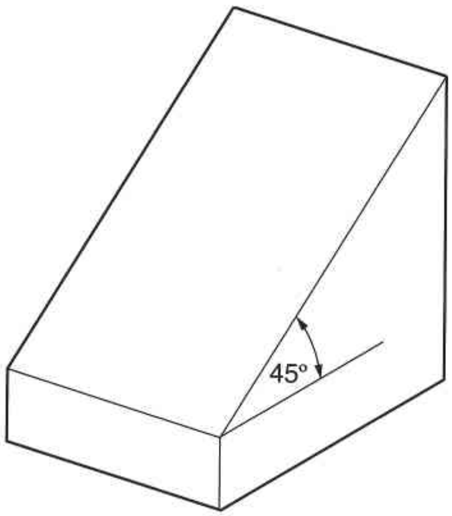
10. Many questions are inspired by the proposed safety system. For example:

    - Are the proposed anti-foothold concepts too aggressive?

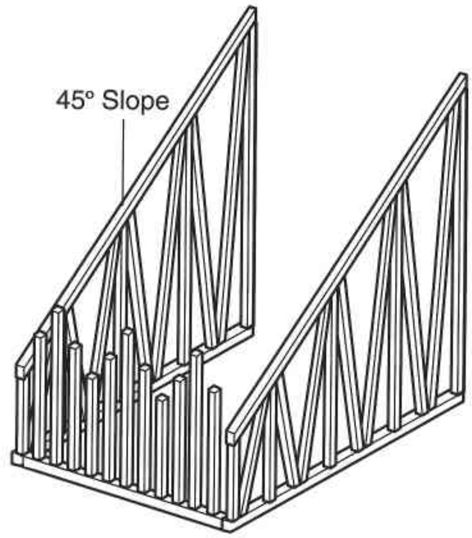
    - If the proposed anti-foothold concepts are unsafe or ineffective, is it feasible and desirable to line the entire lower section of interior fencing with, say a polycarbonate sheet with a thickness of 1/16 in. (1.6 mm)?

    - Are supervision and rescue capabilities compromised by the proposed fence system and can this be overcome by creating swing-away fence sections to be used during supervision?

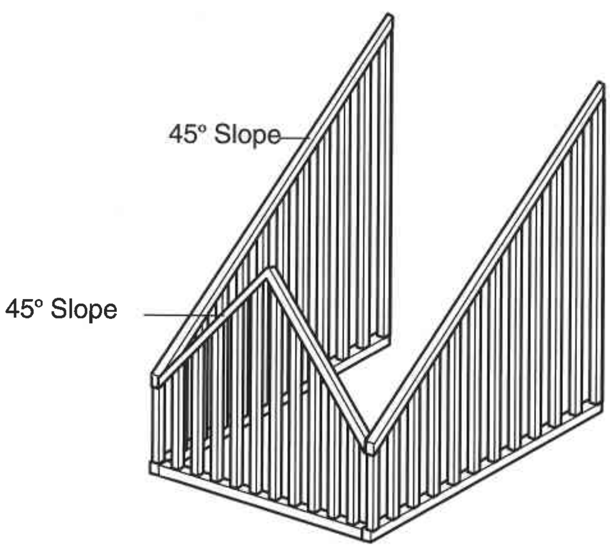
    - Should U.S. manufacturers of pools be held to a non-delegable duty to incorporate feasible safety devices into their products?



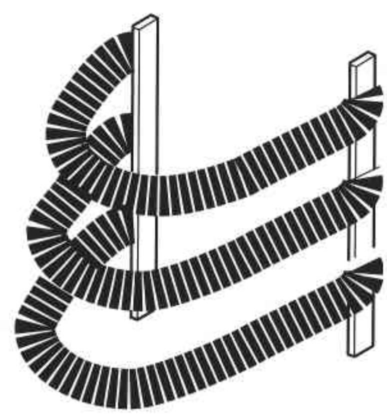
a) - Solid, Perforated, or
Grillage Cage - Covered Slope



b) - Front Stakes -
Anti-Foothold Sides - Open Top



c) - Gabled Front -
Closely Spaced Verticals - Open Top



d) - Flexible Hoops

Figure 6 - Anti-Foothold Concepts - Ladder Cage

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