The Association of Pool & Spa Professionals®

CASE STUDY: The Option of Pools without "Main Drains"

February 2009

Background

The Virginia Graeme Baker Pool and Spa Safety Act ("VGB Act") and the *ANSI/APSP-7 Standard for Suction Entrapment Avoidance in Swimming Pools, Wading Pools, Spas, Hot Tubs, and Catch Basins*[i] are dedicated to the common goal of saving lives by eliminating entrapment deaths and injuries in pools and spas.

The focus of this study is public and commercial pools. Most public pools are regulated by state health departments. These departments formulate and enforce, among other things, the requirements for circulation and sanitation of these pools. Review of all epidemiological reports collected by the U.S. Consumer Product Safety Commission (CPSC) has revealed five distinct entrapment hazards related to drains:

- **Body entrapment**
- **Limb entrapment**
- **Hair entrapment**
- **Evisceration (disembowelment)**
- **Mechanical entrapment**

The CPSC and the industry have acknowledged these 5 forms of entrapment as affirmed in national standards approved by the American National Standards Institute (ANSI), CPSC guidelines, and many building codes. Further research has revealed three underlying causes of entrapment hazards and some serious misconceptions on the part of many regulatory agencies. Sadly, these misconceptions have contributed to entrapment deaths and injuries.

A goal of this study is to dispel those misconceptions and reveal the simplicity, functionality, and efficacy of the most overlooked solution to all of the five known suction entrapment hazards. Hopefully, this will induce health departments across the United States to take immediate action to employ this simple solution and completely eliminate even the possibility of such entrapments in the future.

To accomplish this goal it is first necessary to understand the three underlying causes of the five entrapment hazards.

1. **Flow** (speed or velocity) of moving water through the submerged outlet

    Responsible for hair entrapment

2. **Suction** (atmospheric pressure) or the force pushing water through the submerged outlet

    Responsible for body entrapment and evisceration

3. **Mechanical causes** (shape and/or size of openings and edges of components)

    Responsible for limb entrapment and mechanical entrapment (finger, jewelry, belts, etc.)

The VGB Act and the ANSI/APSP-7 standard both require that, when submerged suction outlets are used, each outlet be protected by a cover that meets the ASME/ANSI A112.19.8 2007 suction fitting standard. When in place, with water flowing at or below the listed flow rate, these covers will prevent all five hazards.

However, as the ANSI/APSP-7 standard correctly states, there is no such thing as a backup for a broken or missing cover. Hence, should a cover become missing or broken, the only safe course is to immediately close the pool or spa to bathers until repairs can be made. It must also be noted, however, that in each of the reported entrapment tragedies in recent years, including the death of Abigail Taylor in Minnesota, the cover was not in place, and the facility was not closed as required by the ANSI/APSP-7 standard or applicable laws. This was the same issue involved in the June 24, 1993, evisceration of Valerie Lakey[ii] and also what killed Kiah Milsom on July 20, 2008. We can't be certain why screws become "missing," but we know that it continues to happen. Human error cannot be legislated away. There is no way to assure that such mistakes will not occur in the future. Every hazard protection method relies, to some extent, on human behavior and common sense. Elimination of the hazard though, when accomplished through design, is foolproof. It is for this reason that the U.S. Consumer Product Safety Commission wrote the following words in the latest "CPSC Staff's Guide to Complying with the Law":

> *CPSC staff recommends that to ELIMINATE and not just MITIGATE the drain entrapment hazard in pools and spas, pool owners should disable old drains or build new pools without any drains and use gutters, overflows and/or skimmers to provide water to the pump.*[iii]

The following historical and scientific review provides irrefutable evidence that submerged suction outlets are not required for proper sanitation or circulation of public pools and common sense dictates that elimination of the hazard is superior to mitigation every time. NO DRAINS = NO HAZARD.

Myth

A main drain is essential in a pool to maintain healthy water.

Science does not support this conclusion. In fact, science concludes just the opposite. In a 2006 issue of Fluent News, the leading manufacturer of computational fluid dynamics software, an article ran that compared pools with and without drains. The conclusion: there were no significant differences between the circulations of the two pools. In fact, the skimmer-only pool was slightly better.[iv] What is even more disturbing is that on page 50 of this same 2006 issue, the software was used to model a revolutionary new swim skin technology that was sure to dominate the upcoming 2008 Olympic Games. Pictured in that review: Michael Phelps, Olympic swimming gold medalist. The swim-speed technology was embraced, but the swim-safety technology was essentially overlooked by the mainstream media.

Circulating and sanitizing water in recreational bathing facilities (hereinafter referred to as pools), both residential and commercial, is neither complex nor difficult to achieve. There are only three reasons, historically, associated with requiring drain(s). First, cleaning the water. Second, sanitizing it. Both are achieved through the use of circulation and filtration systems. The third reason, historically cited, is the practical need to empty a pool.

One need only look at the wording in current state codes, for example the state code[v] in Kentucky where Kiah Milsom died on an uncovered drain in 2008, to validate that all state codes once reflected the science behind circulation:

> *Section 9. Facility Water Treatment Systems.*
>
> *(7)(c) Inlets shall be located and permanently directed to produce uniform circulation of water to facilitate the maintenance of a uniform disinfectant residual throughout the entire facility without the existence of dead spots. Inlets in facilities with skimmers shall be twelve (12) inches below the midpoint on the skimmer throat. Inlets in facilities with a prefabricated perimeter overflow system shall be eight (8) inches or more below the lip of the gutter.*
>
> *(7)(f) At least one (1) inlet shall be located in each recessed stairwell or other space where water circulation might be impaired.*

Water is cleaned mechanically by filtering out particulate matter, which is collected by vacuuming the pool, either manually or with an automatic cleaner. Water is sanitized through the use of chemicals, which can be distributed throughout the pool manually or through automatic chemical feeders. We could expand this discussion further by going into detail regarding the various methods and devices for distributing sanitizer, but for purposes of this discussion, this ancillary information will only complicate the obvious: submerged suction outlets are not necessary to accomplish either of these tasks.

The issue at hand is: where possible, "design out" the main drain. Its potential to create a hazard far outweighs its insignificant contribution to cleanliness or sanitation. This doesn't mean drains should be outlawed, but if main drains are used, they must be safeguarded. The purpose of this discussion is to examine whether submerged suction outlets (drains) are required to achieve adequate circulation and sanitation. All of the ANSI/APSP pool and spa construction and design standards, the VGB Act, and the latest *ANSI/APSP-7 Standard for Suction Entrapment Avoidance in Swimming Pools, Wading Pools, Spas, Hot Tubs, and Catch Basins* allow for pools to be built without submerged suction outlets (main drains).

The focus of this report is on the potential risk associated with uncovered suction outlets (main drains). Even properly installed suction outlets with approved safety covers have a potential to become a hazard if a cover becomes missing or broken. Incident reports (see data chart below) collected by the Consumer Product Safety Commission conclude that the main reason for body and limb entrapment is a missing or broken main drain cover. The data also revealed that limb entrapments have occurred in coverless open pipes when there was no water flowing through the system at all; the pumps weren't even running.[vi]

First, let's look at the history. Why do we have drains in the first place? To answer that question, one need look no further than the Biltmore Estate in North Carolina. Completed in 1895, it included a 70,000-gallon swimming pool. The Vanderbilt family would fill the pool, invite guests from all over the world to stay for a weekend, feed them southern fried chicken and collard greens, and encourage everyone to go for a swim. When the guests left for home on Monday, they would pull the plug from the bottom drain and empty the pool.

When technology advanced to the point where circulation systems were developed for recreational water facilities to clean the water, they simply hooked a pipe to the existing bottom drain and used it to feed water to the pump for filtration. That is where drains originated. They were the convenient way to transfer water from the pool to the pump. This building practice was carried over to the soon-to-be-born pool and spa industry after World War II. Research reveals no scientific basis linking the need for a main drain to properly maintained healthy pool water.

Interestingly, this advancement, from "drain and fill" to "circulate and sanitize," leads to another misconception which stubbornly persists to this day: the belief that drains are necessary to empty the pool. The reality is that pool circulation pumps drawing their water through the piping systems from the bottom drains are terribly inefficient at emptying pools. Pools today are typically emptied using high-volume centrifugal pumps designed for the task. The pump is placed on the deck near the deep end of the pool, a flexible suction hose, usually 3" or 4" in diameter is placed into the water at the deepest point, and the pump is started. A typical deck-mounted centrifugal pump will empty a 15,000-gallon pool in about 1½ hours. The typical pool circulation pump could take all day to do the same job. While one might think that because a public pool requires a 6-hour turnover, that means the pool can be completely drained in 6 hours, this is not the case. As the pool water level falls, the circulation pump typically begins to lose prime and the flow rate drops dramatically.

Again, the Kentucky state code example from above confirms this misconception in its section for pool outlets:

> *Section 9. Facility Water Treatment Systems.*
>
> *(8) Outlets.*
>
> *(a) All facilities shall be provided with a main outlet at the deepest point to permit the facility to be completely and easily drained.*

In fact, even the most often-used term – *main drain*, not outlet – is a clear sign of what these devices were used for before we had inexpensive and improved means to drain a pool. With the risk of suction entrapment reaching the point of requiring federal legislation, it is time to let go of tradition, and let science and engineering dictate how swimming pools are built in order to completely eliminate the possibility of entrapment.

Now, let's take a look at the empirical data and experience that challenges the "need" for drains. To begin, tens of thousands of residential in-ground concrete, fiberglass, and vinyl liner pools are constructed without bottom drains. Further, there are more than 4 million above-ground pools in use across the United States today. Typically, these pools have minimal circulation systems, many with one skimmer and one circulation return fitting. Yet, even without drains, these pools are able to circulate and sanitize pool water very effectively. There have been no health or disease epidemics reported in these pools. Consider these numbers and the evidence becomes compelling – main drains aren't necessary.

There is a tendency to attribute a different set of parameters to public pools because they are typically larger and hold more bathers. That may be true, but they also have larger and typically more sophisticated filtration and sanitation systems. Systems designed for a specific bather load are designed and equipped to maintain sanitary conditions for said load.

The pool shown below is located at a very well known South American resort and it has no submerged suction outlets (main drains). All of the water for the circulation system is delivered from skimmers placed around the perimeter of the pool spaced approximately every 15 feet. This is typical of new, leading edge, public pool construction technology. In fact, the pool in Omaha, Nebraska, where the Olympic Swimming Trials were held for the 2008 Olympics, was constructed without drains; this training pool was 25 meters wide, 50 meters long, and had a minimum depth of 2 meters.

What this shows is that a healthy bathing environment can be achieved and maintained without main drains despite huge bather loads – and is being achieved in public pools with hundreds of thousands of gallons of water.

As to the science behind cleaning and circulating sanitized water, there is one simple scientific fact at the core of this discussion: ***water, like air, cannot support a tensile force; water cannot be "pulled.***" This means that if water is to be moved, it must be "pushed" as it is through the return side of pool circulation systems. Water and air share this common characteristic. To illustrate, try sucking out a birthday candle a foot from your mouth – it is impossible. You can, however, blow it out from a couple of feet away by pushing or forcing a blast of air at the flame. The same scientific principle applies to water.

Accepting this scientific fact leaves only one significant question relating to the suction side of any circulation system: how can the water be most effectively moved or "pushed" from the pool back to the pump? Historically, installing suction outlets (main drains) was one of the methods used to simply deliver or "push," through force of atmospheric pressure, water towards the pump. The function of the pump was to then deliver or "push" the water through the filter and back into the pool by way of the circulation returns. Utilizing drains is one way to deliver the water; all they do is deliver the water. Utilizing only surface skimmers or overflow gutters are other accepted delivery systems that provide the additional benefit of not only delivering the water, but also cleaning the water by skimming floating debris from the surface.

The force exerted on a bottom drain, even in a gravity flow design, where the bottom drain delivers water to a collector tank with no direct connection to the pump, can be extraordinary. Atmospheric pressure is 14.7 pounds per square inch and increases as the water depth increases. This is the force that pushes the water through the piping to the pump. At a depth of 6 feet, the atmospheric pressure and the hydrostatic pressure (weight of the water) pushing on an 8-inch round drain sump could produce a force exceeding 700 lbs.

Public pools designed and constructed utilizing these same engineering concepts would actually be easier and less expensive to build – and clearly safer than pools utilizing submerged suction outlets (drains). There have been other articles on building pools without drains in *Pool & Spa News*[vii] dating back to 2003 – and others as recently as the November 2008 Issue of *WaterShapes* magazine.[viii]

The single most commonly held, yet mistaken, belief regarding drains is that they "vacuum or suck in dirt" and somehow "clean the floor." They do not. Remember the candle experiment? Pool drains are no different. If a leaf is placed two inches from the opening of a flowing two-inch pipe, it will never enter the pipe unless it is pushed in – either by a brush or by a stream of water specifically directing it to the pipe opening. In fact, a pool left un-vacuumed for several weeks is complete proof that the drain alone cannot clean the settled debris. Some debris does enter the drain, by chance, but the pool will still require routine vacuuming in order to remove settled debris. Since vacuuming, manually or via automatic cleaner, is a routine part of pool maintenance, why rely on a drain that might remove "some" of the settled debris, but also leaves bathers exposed to a proven lethal hazard?

When one vacuums a dirty pool, it clearly leaves a "clean spot" where the submerged vacuum head has moved across the bottom of the dirty pool floor. If one pushes too fast, the settled debris will be agitated and stirred up into the water – and not enter the vacuum. This happens with direct suction on the vacuum cleaner head. Vacuuming the pool requires slow, careful movement of the head so as not to disturb the settled dirt.

At home, one need look no further than the living room for proof of this same phenomenon. When vacuuming carpet next to the couch, does it suck dirt out from under the couch or must the couch be moved to clean under it? In fact, if we were to spread some dirt out on the living room carpet and vacuum it with direct suction, it would indeed leave a clean track, just like vacuuming a pool. Now imagine if we were to switch from a vacuum cleaner to a leaf blower and try to blow that dirt out the front door? You can easily see the picture. In moments, the entire house would be consumed with clouds of dust that would settle out on every bookshelf, windowsill, china cabinet, and counter top.

Not unlike the leaf blower, it is the strategically placed return inlets that are responsible for distributing sanitizer throughout the pool. Additionally, as pools scale in dimension and size, more return inlets are required, as are skimmers. Interestingly, no matter how large a pool is, not a single state residential or public pool code requires that more than one set of drains be installed. If drains are critical to circulation, how could all states have made such a universal mistake? Submerged suction outlets, unless part of a strategically designed in-floor cleaning system, do little to clean the pool floor. Professional engineers and designers understand this phenomenon and design public pools accordingly.

Licensed professional engineers who design the construction documents and specify the circulation system requirements for commercial and public pools call for the addition of circulation return inlets as pools grow in size and shape to effectively distribute sanitized water throughout the pool. For example, they call for return inlets to be placed in alcoves and step areas outside the pool perimeter. They may call for additional skimmers or conversion from skimmers to a perimeter overflow gutter to better clean the pool surface in large pools.

They never call for additional submerged suction outlets (drains). This is not an oversight or an error. The professional design engineers clearly understand that circulation and distribution of sanitizer is achieved by the "pushing water" phenomenon through the return side of the system – and not through suction outlets (drains). And they specify separate vacuum pump systems for debris removal, knowing that drains do not remove dirt or contaminants. Number, location, size, and direction of return inlets and fittings determine how well water is circulated, agitated, and distributed to all areas of the pool.

In summary, with regard to sanitation and distribution of sanitizer, main drains contribute virtually nothing to the distribution of sanitizer in a pool. They simply deliver "used" water back to the pump after the sanitizer has done its job. The main drain delivers the "used" water back to the pump where it is pushed through the filters and picks up fresh new sanitizer to be delivered back to the pool on its return trip.

Another myth regarding drains is that they are required to produce adequate water flow. Consider the circulation requirements. The *ANSI/APSP-5 2003 Standard for Residential In-ground Swimming Pools* requires that all the water in the pool must be filtered and circulated at least once in 12 hours. In a 15,000-gallon pool, that would equate to a flow rate of 21 gallons per minute (gpm). Most skimmer manufacturers recommend a minimum flow rate of 30 gpm for effective skimming. Many of these skimmers are NSF-rated to 55 gpm and some skimmers are rated up to 80 gpm by the National Sanitation Foundation. By arranging the return fittings in a pattern to direct the water into all areas of the pool, a single skimmer is all that is needed. And all the water in a 15,000-gallon pool could be filtered in 7 hours and 15 minutes, saving energy at the same time. If the equipment were run for a full 12-hour cycle, it could filter and sanitize 25,200 gallons effectively.

Commercial codes vary as to circulation requirements, but short of some theme parks, wave pools, and special effect pools, virtually all of them could operate without submerged suction outlets and most of their circulation systems are already capable of providing 100% of the flow from the skimmers or gutter system.

Finally, consider existing public pools. Old, single drain pools should be the highest priority when considering drain safety, since they represent the greatest potential hazard. Why? Because they are prone to having older covers and sumps on single-source piping connected directly to a pump. These covers and sumps have probably degraded and weakened over time, posing a greater risk of failure. The solution, in almost every case, is a relatively simple re-piping at the equipment to reverse the flow and transform the main drain suction outlet into a return inlet. Disconnect the drain(s) from the suction side of the pump and re-connect them to the return side of the system after the heater and sanitizer. By converting the drain(s) to a return, circulation and sanitation can be greatly improved and you have successfully "designed out" the primary cause of suction entrapment in a pool. If there is a concern for enough water to supply the pump in a residential application, a skimmer could be added or the flow rate could be reduced. As shown above, most residential pools currently flow at a rate exceeding the needs of the system.

Most commercial pools are already sized to have the capacity to deliver all of the required system flow from the skimmers or overflow gutter. If the piping is not accessible or for some reason cannot be reversed, permanent drain disablement is the next best option. Permanently “glue in” a plug or fill the drain outlet with concrete.

Even in the case of flow reversal or drain disablement, it is still critically important to keep listed safety covers in place to prevent a limb entrapment or mechanical entrapment.

The Consumer Product Safety Commission has reported 155 entrapment incidents over a 17-year period from February1985 through August 2002. Of the 155 data files, there were 141 that provided enough information to categorize. Of the reported incidents, 52% occurred in residential pools and 48% in public pools.

CPSC DATA

Entrapment Type	**# Entrapped**	**# Deaths**	**% Deaths**
Hair	50	14	28%
Limb	39	10	26%
Body	47	8	17%
Evisceration	5	0	0%

These incidents were investigated, analyzed, discussed, and categorized – all in the effort to find solutions and prevent such tragedies in the future.

The *ANSI/APSP-7 Standard for Suction Entrapment Avoidance in Swimming Pools, Wading Pools, Spas, Hot Tubs, and Catch Basins* offers this technology and other options that are completely consistent with the federal Virginia Graeme Baker Pool and Spa Safety Act which, too, allows for pools to be built without a main drain.

For further study and test data, go to this scientific Fluent Study[ix] and review this Dye Test Video[x] of water entering a drain flowing at 800 gpm under only 11 inches of water. Note that the dye casually disperses and is not immediately “sucked” into the drain.

The conclusion of all these investigations is that none of the reported entrapment incidents would have or could have occurred if there were no submerged suction outlets. The message is clear. Where possible, “design out” the main drain – but if drains are used, they need to be safeguarded with existing technology.

[i] *ANSI/APSP-7 Standard for Suction Entrapment Avoidance in Swimming Pools, Wading Pools, Spas, Hot Tubs, and Catch Basins,* The Association of Pool & Spa Professionals (the ANSI/APSP-7 standard was approved in 2006 by the American National Standards Institute).

[ii] During the 2004 U.S. Vice-Presidential Debate (October 5, 2004, in Cleveland, Ohio), Senator John Edwards stated: "It turns out the company knew of 12 other children who had either been killed or severely injured by the same problem. They hid it. They didn't tell anybody. They could have fixed it with a 2-cent screw. That's wrong."

[iii] U.S. Consumer Product Safety Commission, Virginia Graeme Baker Pool and Spa Safety Act, CPSC Staff's Guide to Complying With the Law (2008).

[iv] "Eliminating the Risk of Swimming Pool Drains," *Fluent News: Applied Computational Dynamics*, Volume XV, Issue 2 (2006).

[v] Kentucky State Code: 902 KAR 10:120. Kentucky public swimming and bathing facilities.

[vi] "Limb entrapment in a swimming pool suction outlet: A multidisciplinary approach to in-hospital extraction," Injury Extra, Toosy, N.A. *et al.*, Volume 37, pp. 225-337 (2006).

[vii] "A Draining Experience – a pool builder's fight to change Florida's dual main drain code and 50-year-old industry assumptions," *Pool and Spa News*, April 2003.

[viii] "Considering an Option," *WaterShapes* magazine, Volume 10, Number 11 (2008).

[ix] "Computer Simulation Shows Pools Can Be Made Safer by Eliminating Drains," 2006 (http://www.fluent.com/solutions/sports/CS103-trilogy-pools.pdf).

[x] "Drain Testing Using Dye for Effect on Pool Circulation," 2008 (http://www.youtube.com/watch?v=0IOUGhuKkSM).

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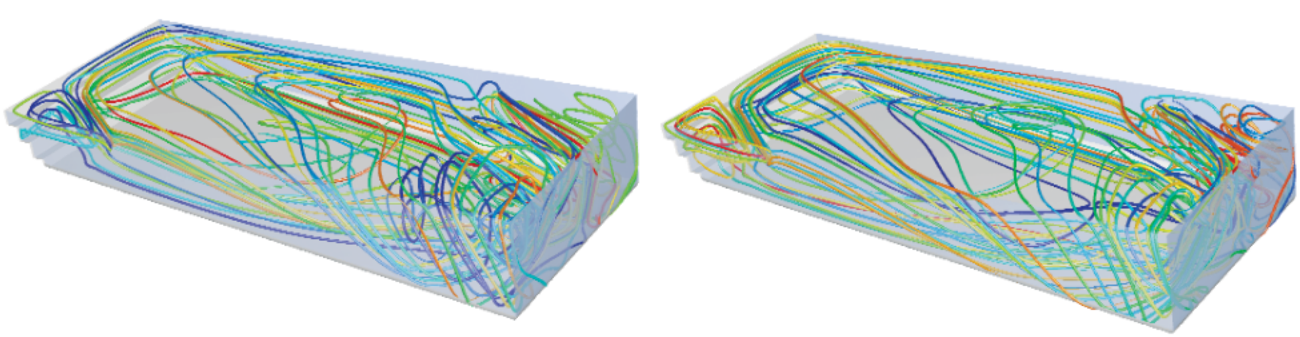
Eliminating the Risk of Swimming Pool Drains

By Ray Cronise, *Trilogy*, Fayetteville, Tennessee, USA, and David Schowalter, *Fluent Inc.*

Summertime brings with it a huge increase in the number of people enjoying the clean, clear water of swimming pools. Common wisdom is that drains at the bottom of pools are necessary to maintain water quality by promoting ongoing circulation. Indeed, many building codes require them. Unfortunately, a number of accidents have occurred over the years in which swimmers, usually children, have become entangled or suctioned onto the drains. Ironically, some industry experts are convinced that drains provide no circulation benefit and that proper circulation can be achieved by strategically positioned inlets and skimmers instead.

To test this hypothesis, CFD was recently used to simulate water circulation in computer models of generic pools that were identical except for the presence or absence of drains. The results confirmed that, for the pool geometry in question, inlets and skimmers do provide adequate circulation and that there is no additional benefit associated with the use of drains.

The pool industry has long used drains because of the belief that they are required in order to provide circulation throughout the pool so that contamination will not remain in stagnant areas but will quickly pass through the filter where it can be removed. Although accidents are rare, the risk associated with a drain is very real. Five different types of suction entrapment have been documented.



Pathlines in the pool without (left) and with (right) drains show that both designs promote large scale circulation as well as small scale circulation in the corners

Children are most often the victims because they are fascinated with the currents and forces created by the drain and often intentionally place their hands and feet over it. New drain covers have been developed with improved safety features, but the risk always exists that even these devices could break or be removed. Others have suggested using a safety vacuum release system that is designed to shut off the pump when it senses an excessive vacuum buildup, but this approach adds considerable expense, does not necessarily provide protection from all forms of entrapment, and does not preclude the risk of mechanical failure.

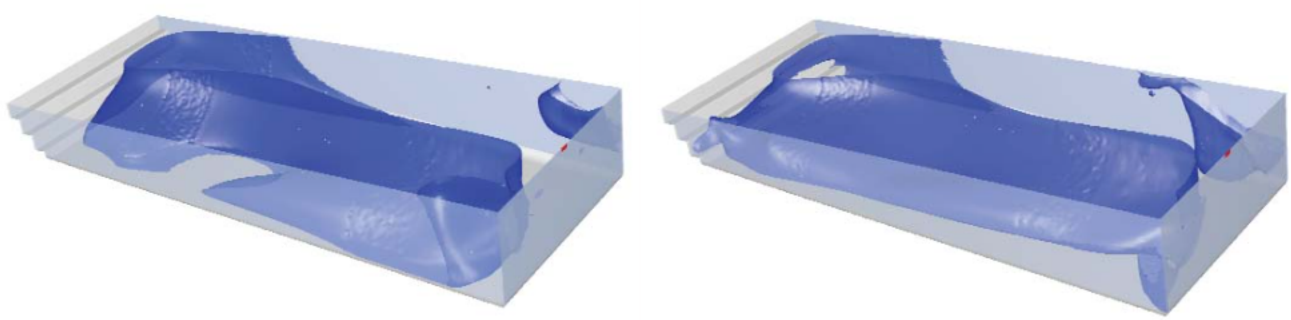
Based on observations of fluid flow, circulation occurs in a pool because of the flow generated by the inlets (or returns) while drains have little or no impact. Consider, for example, that a candle can be blown out at arm's length, but it cannot be extinguished by suction at the same distance. Thus, if one simply points the returns toward the bottom, the water in the lower section of the pool will circulate whether or not there is a drain. Suspended debris with a density less than water can be removed by the skimmer. Settled debris with a density greater than water can be removed with a vacuum, as is normally done. Unless someone has installed an in-floor cleaning system that is designed specifically to remove debris, there is really no compelling reason to install a drain.

The CFD simulations were performed on a swimming pool with and without drains. The pool modeled was 15x35 sq ft, with a depth that ranged from 3 to 6 ft. It had four inlets arranged around its periphery to provide circulation and a skimmer on the waterline where water was extracted. For one of the simulations, the pool had two main drains in the floor, while for the other simulation, the pool had no drains. The water in the pool circulated at the rate of about 60 gallons/min. The steady state flow fields in the two pools were computed first. Both cases showed large scale circulation driven by the returns. A two-foot diameter sphere of contaminant (tracer) was then positioned at the center of the pool, near the floor. Two monitors were placed at each end of the pool, two feet below the surface of the shallow end and three feet below the surface of the deep end. Transient simulations were performed and each monitor tracked the concentration of contaminant for 20 minutes.

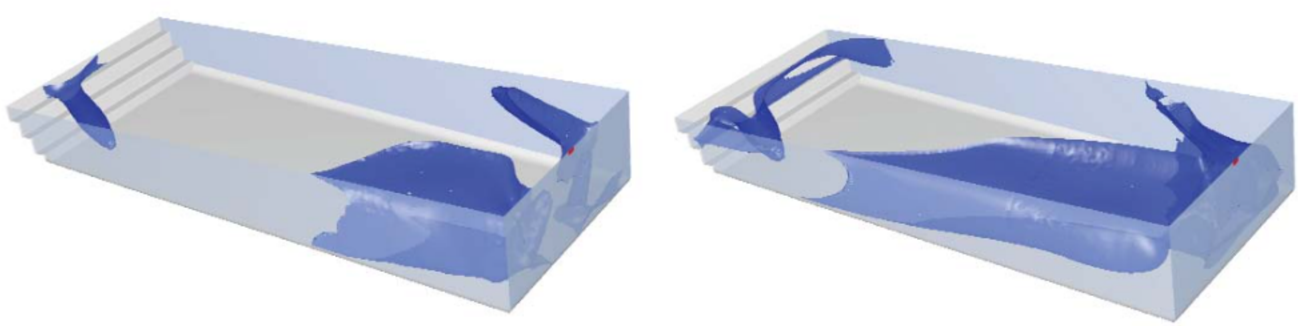
The results showed that the pools with and without drains were essentially equal in their ability to remove the contamination. While the two cases differed initially, after about 15 minutes the level of contaminant at each of the monitor points was the same. In short, the simulations showed that having drains neither improves nor harms the circulation in the pool.

The pool industry has adopted building practices based largely on empirical information. The circulation of water is something that is nearly impossible to see and difficult to measure without sophisticated flow visualization equipment, so in many cases designers have been using drains for historical reasons. By the same token, many building codes and health departments have required drains for the same reasons. The CFD simulations have clearly suggested that drains are not necessary, and that they do not improve the circulation in a pool for the purpose of clearing contamination. The number of injuries and deaths caused by drains in pools may seem small compared with other hazards, yet future episodes could be prevented at no additional cost simply by building pools without drains and sealing the drains in existing pools. Hopefully, these results will allow the pool industry, building officials, and health departments to proactively take steps to allow pools without drains in their standards and codes of the future.

In addition to the type of analysis presented here, CFD can be a useful tool for determining the optimum position and orientation of the returns for complex pool shapes to ensure proper circulation. ■



A surface of contaminant in the pool without (left) and with (right) drains after 10 minutes, suggesting that the drains do not reduce the amount or spread of contaminant



After 20 minutes, the pool without drains (left) has a surface of contaminant that is no worse than that in the pool with drains (right)

Inside: Bruce Zaretsky on Decking Options

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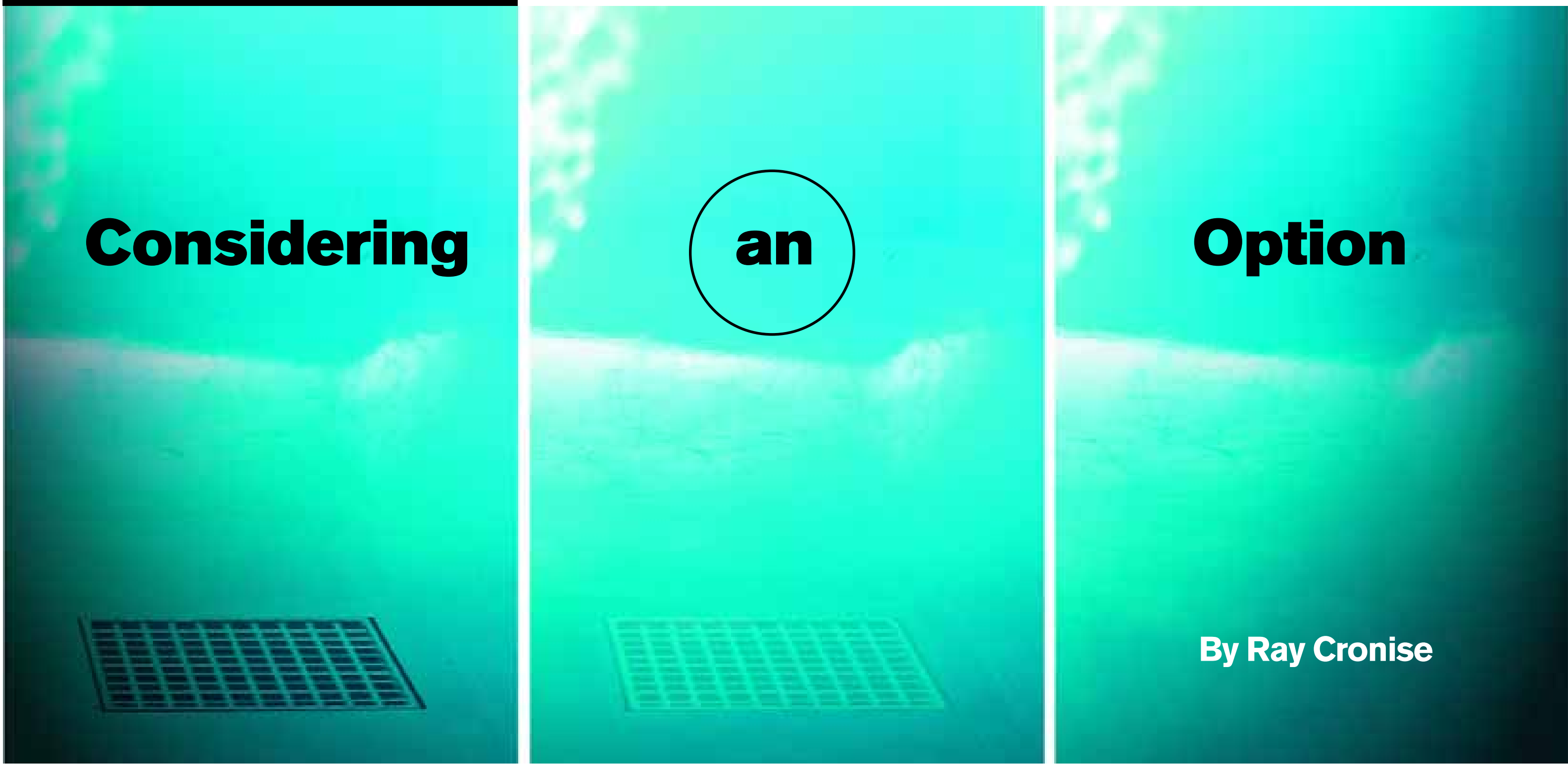
Considering an Option

By Ray Cronise



Most suction-entrapment accidents occur when someone gets caught on a swimming pool, spa or wading pool drain that has somehow been compromised. This fact prompted Ray Cronise, a former NASA scientist and current pool company executive, to take a scientific approach and use sophisticated computer software to see what was really going on. His conclusion: For proper circulation, watershapes don't need the drains that seem to be the focus of the problem.

The death in 2002 of the granddaughter of former U.S. Secretary of State James Baker brought the problem of suction entrapment to unprecedented public attention.

That incident – and others in which bathers have become stuck atop pool drains – have led to development of new legislation and pool-construction standards as well as increased awareness of the hazard. To me and some others, however, the new rules represent a reactive, regulatory solution to what might better be approached as a proactive matter of technology and engineering.

In stepping back and carefully examining the anatomy of these terrible accidents, it becomes clear that, although steps can be taken to *reduce* risks, there is no single approach, given current design and construction practices, that will *eliminate* risks altogether. So far, in fact, all of the industry education and media attention we've witnessed is focused on solutions that at best mitigate entrapment hazards. These are *not* approaches that lead us to complete solutions.

As an industry, we have not grappled with what I see as the true, addressable core of the issue – that is, whether the drains really need to be there in the first place.

Common wisdom and long-established building practice hold that these suction points are needed to achieve proper circulation in watershapes, and such thinking is so ingrained that many building codes and health departments mandate their use. What is surprising is that most state codes are very specific in acknowledging that the inlets (or returns) are what distribute sanitizer and circulate the water. Armed with that fact, it should be clear that adequate circulation can be achieved by proper positioning and orienting of inlets and by using skimmers as a sole source of suction.

In fact, I am now convinced that drains can be omitted from most watershape circulation systems – a step that would entirely eliminate the risk of suction entrapment. And this isn't just my belief: Recent research has taken this thought and given it real substance.

We can't, of course, simply outlaw drains. Right now, in fact, we need them as sources of water for spas, waterfeatures and other systems that call for flows that exceed what current skimmers can provide. But that in itself is simply a technological issue – one that definitely should be addressed by companies that manufacture these fittings.

pool-drain issues

The pool and spa industry has been broadly aware of suction-entrapment risks at least since the late 1970s and has long been aware that submerged outlets (that is, *drains*) can be especially hazardous to children.

Since the 1980s, at least 150 entrapment incidents have been documented, including nearly 50 in which death was the outcome. When weighed against the millions of people who safely use pools and spas each year, that number may be statistically insignificant, but the horrific and needless nature of these tragedies nonetheless requires us to pursue reliable solutions to the problem.

Complicating the issue somewhat is the fact that five different forms of suction entrapment have been identified: hair entrapment, body entrapment, limb entrapment, evisceration and mechanical entrapment (which is not technically a form of *suction* entrapment). Each type involves a different underlying physical phenomenon that makes developing firm, broad-scale, mandated solutions difficult. It's also less than helpful that system configurations vary widely and that there's also a complex interdependency among various entrapment-mitigation strategies.

We know, however, that children are most often at risk of suction entrapment because they can become fascinated by the currents created by drains and will often intentionally stick their hands and feet on them to experience the force generated by the suction. In the case of wading pools, that fascination might lead a hapless child to sit on the drain.

The grim realities that attend discussion of these issues make almost every aspect of them controversial. My own experience has shown that running in the face of industry practice by suggesting that drains are unnecessary is itself controversial, even though it removes suction entrapment on drains as a practical possibility. I can't fathom the resistance to this idea, but as mentioned above, I and others have long thought "drainless watershapes" to be a concept worth exploring.

Furthermore, I have for some time believed we all needed to step back and take the emotion out of our conversations by using a scientific approach, developing an understanding the underlying physics of suction entrapment and then applying what we might learn in the field.

This sort of investigation is familiar to me: Before forming Trilogy Pools, a fiberglass-pool manufacturer in Fayetteville, Tenn., I was employed by the National Aeronautics & Space Administration doing research in microgravity material science and saw the potential for using advanced computer modeling to test ideas and reach conclusions based on fact rather than supposition or habit.

With some help, I was able to simulate water circulation in computer models of pools that were identical to one another except for the presence of a drain in one version and the absence of a drain in the other. The results showed that not only can inlets and skimmers provide adequate circulation but, further and counterintuitively, that the addition of drains does *nothing at all* to improve circulation. This in fact supports what most state codes once specified – that it is the inlets rather than outlets that ensure proper circulation by virtue of the way they distribute water within pools.

In a realm in which the only acceptable number of suction-entrapment incidents is zero with zero deaths, I believe that the reliable solution we've all been looking for is at hand.

debunking drains

Part of the problem with the pool industry's approach to circulation systems has to do with its longstanding, uncritical acceptance of design and construction precedent – an approach based on tradition more than on engineering and science. Although there have certainly been voices (in the debate about suction entrapment in particular and hydraulic design in general) that do reflect a more disciplined engineering perspective, they have failed to gain significant traction or counter the weight of sanctioned, standard practice.

In point of fact, the pool industry has traditionally used drains in the belief that they are required to ensure circulation at the deepest point of the pool and avoid accumulation of contaminants in supposed "stagnant areas" near that low point. When considered in light of basic fluid dynamics, however, it becomes clear that this desired effect simply does not occur.

Indeed, the simple existence of in-floor cleaning systems is evidence that drains do almost nothing by themselves to remove material and contaminants from the bottom of a pool. These systems rely on strategically placed, moving floor returns that push debris to the drain, but while they provide an example of good use of a drain, these in-floor systems are themselves under attack as a result of generic dual-outlet piping mandates that disallow installation of drains in series. (What is needed here is another reasoned technological solution and more flexibility than traditional dual-drain T configurations allow: The fact is that drains in series are often used safely.)

Here's a simple analogy that illustrates the source of this misconception about the role of drains in circulation systems: We all know you can blow out a candle at arm's length. What most people don't know is that it is impossible to *suck* out that same can-

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dle: Air can effectively be *pushed*, but it can't readily be *pulled*. The same holds true for water flowing in or out of pipes: As with an in-floor cleaning system, you can push debris in a general direction, but it's impossible to reverse the physics and achieve the desired effect of cleaning up a pool's floor by sucking the debris. Even the most efficient drain's influence is measured in inches, not feet.

To accommodate the persistence of standard practice, the industry has developed a number of approaches that seek to increase the safety of the drains it installs:

◗ *Drain covers* have been modified to include improved safety features and seem to help, but there is no protection if the cover is broken or missing – a factor that continues to be a root cause of entrapment incidents and therefore make these covers less than serviceable as part of a complete solution. (Some 15 years ago Valerie Lakey was severely injured in an entrapment accident because the screws were missing from a cover – the same reason Kiah Milsom died in July 2008.)

An important element of the new ASME/ANSI A112.19.8-2007 has to do with testing of the cover and sump along with the fasteners as a *system*. Not all testing laboratories are following the standard, however, with the result that the very deficiencies that cause the problem – that is, missing screws or insufficient attachment – may *not* be addressed in hundreds of thousands of covers now being replaced in compliance with new federal legislation.

◗ *Safety vacuum-release systems* have been developed that will shut off a pump when the SVRS device senses an excessive vacuum buildup, but this approach adds considerable expense to a project, does not necessarily provide protection from all forms of entrapment (especially the transient or incomplete blockages associated with evisceration and hair or limb entrapment) and presents the risk of mechanical failure of the sensing system itself.

◗ *Multiple (dual) drains* have been identified as a possible preventive measure. Although there has never been a documented suction-entrapment accident on a dual drain that has been properly installed, covered and maintained, the risk is negligible. Yet in absolute terms, dual drains are also subject to improper maintenance in the same way as are single drains. Further, I would argue that because all suction-entrapment accidents are statistical anomalies, we cannot reasonably assume that simply because a multiple drain hasn't yet been implicated in such an accident doesn't mean it is entirely beyond the realm of possibility.

◗ *Proper flow rates* are extremely important for a variety of reasons, and it is true that drains operating within specified flow rates with proper covers or grates have the ability to minimize risk. In practice, however, it's unreasonable to assume that all designers and installers will adhere to sizing guidelines for pumps and plumbing. In fact, we have seen increasing evidence of underestimated flow rates in efforts to comply with new "green" legislation. As a result, while mandating proper flow rates is beneficial on a number of operational and safety levels, such requirements alone will not completely solve the problem.

It's my position that none of the improvements that have been offered or proposed to date *completely* removes the risk of injury or death: So long as drains continue to generate powerful suction forces; so long as grates may become damaged or malfunction as a result of improper installation; so long as screws continue to go missing; so long as pumps might be oversized; and so long as SVRS devices are tested with one set of piping and flow conditions and installed in completely different and unknown environments, bathers will be put at some level of risk.

As a result, I have chosen to tackle the problem from the direction of asking whether drains are even necessary – an approach that has led me to a further exploration of whether there is any circulatory advantage to drains being there in the first place.

computer simulation

While it seems obvious to those trained in fluid dynamics that the presence or absence of a drain would not significantly influence circulation dominated by high-velocity return inlets, I thought: *Why not just prove it?* Some of the best discoveries happen when you test a hypothesis and see where the results fall. And if the candle analogy holds, I thought it would be fairly easy to demonstrate that, in fact, the inlets (rather than the outlets) are what dominate pool circulation.

In this vein, my hypothesis was that simply pointing the returns toward the bottom would create adequate circulation in a pool with or without a drain. Debris with a density less than water would be suspended and eventually removed by the skimmer; debris with a density greater than water would sink to the bottom, where a vacuum-cleaning device of some kind would remove it.

I have chosen to tackle the problem from the direction of asking whether drains are even necessary – an approach that has led me to a further exploration of whether there is any circulatory advantage to drains being there in the first place.

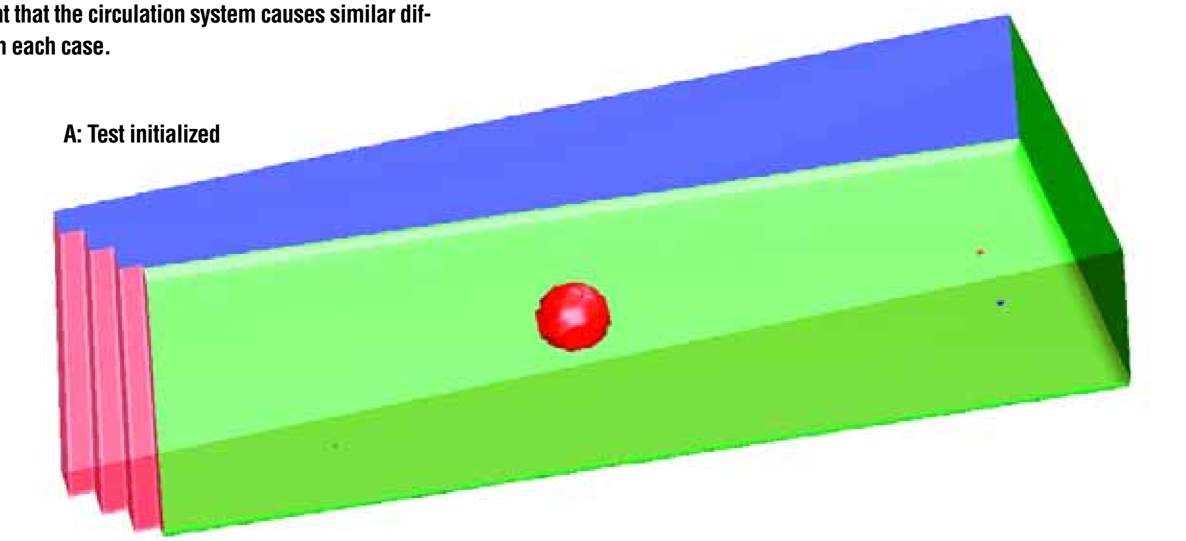
In-floor cleaning systems offer an exception, but in the absence of such an alternative approach, my hypothesis held that there is really no compelling reason to install a drain to achieve proper pool circulation.

Based on my experience at NASA, I knew of technical advancements that make it possible to simulate the flow of fluids with a great deal of accuracy. That in mind, I approached the New Hampshire office of ANSYS, a computer-modeling firm based in Canonsburg, Pa., and asked for help. ANSYS had developed Computational Fluid Dynamic (CFD) software that allows engineers to model the flow of either liquids or gases (or both) within defined areas while also systematically determining the effects of inflows, outflows, obstructions, boundaries and a wide range of other factors.

This is the sort of software that engineers use in designing

These computer-modeling readouts show what happens after a sphere of contaminant (A) is introduced to pools identical in every way – except that one has a drain (B & C) and the other doesn't (D &E). The red indicates where the contaminant has a mass fraction of 0.0016, and it's apparent that the circulation system causes similar diffusion in each case.

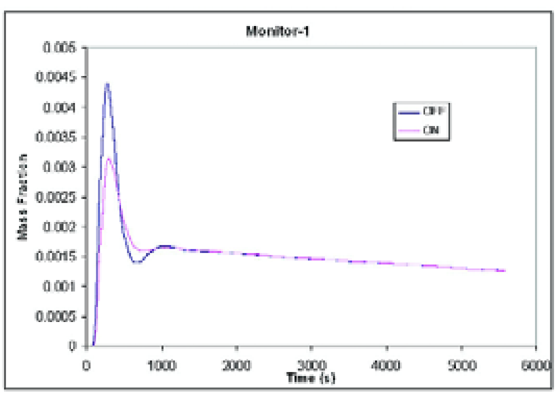
A: Test initialized



automobiles, airplanes and mass-scale heating and cooling systems for buildings, power plants and chemical plants – not to mention a range of products and processes that depend on fluid flow. (Moving closer to our aquatic endeavors, this same software was used to engineer the high-performance skins that helped Michael Phelps set all those records and win all those gold medals during the Beijing Olympics.) The key benefit of CFD software is that it enables engineers to simulate fluid flows while avoiding the time, expense and measurement difficulties involved in actually building and testing designs.

I worked closely with the consulting engineers at ANSYS to simulate the flows of water through computer models of swimming pools, both with and without drains. The concept pool was 15 feet wide by 35 feet long and had a depth of six feet at one end and three at the other. The pool had four inlets arranged around its perimeter to provide circulation and a skimmer at the waterline through which water exited the pool. Both pools had circulation rates of approximately 60 gallons per minute (slightly higher than the 50 gpm required for a six-hour turnover rate with a pool of this size); one had a split main drain, the other had none.

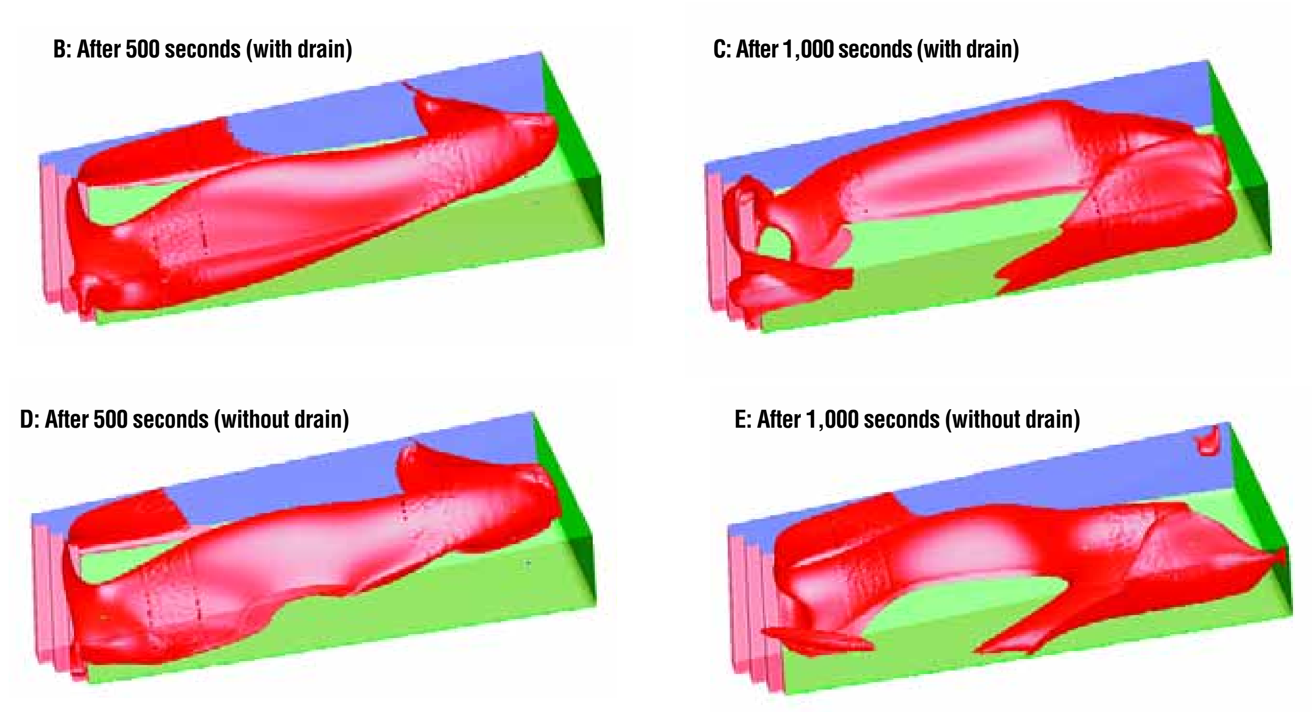
As a first exercise, we computed the steady-state flow fields in the two pools. In both cases, we observed that large-scale circulation was mostly driven by the returns. We then placed a two-foot-diameter contaminant sphere (that is, a tracer) in the center of the pool near the floor. Multiple mon-



Monitors were positioned at each end of the pool – two feet below the surface of the shallow end and three feet below the surface of the deep end. Shown here is a comparison of contaminant's mass fraction through time, both with and without drains in the shallow end of the pool (where the difference was greatest, although similar results were observed at the other monitoring points). The contamination level was higher without main drains for a short period, but the level dropped after about 600 seconds and there was no visible difference after 1,000 seconds.

Editor's note:

Ray Cronise's 'Commentary' is provocative and bound to be controversial, and we encourage you to respond to it by writing us a letter or sending us an e-mail to register your own thoughts. What do you think? Please let us know.



itors were placed at either end of each pool, two feet below the surface of the shallow end and three feet below the surface of the deep end.

a closer look

Simulations were initiated, and the monitors tracked the concentration of the contaminants for 20 minutes. The results were both interesting and provocative: With and without drains, the pools were essentially *equal* in their ability to clear away the contamination.

In observing the contaminant loads, we noted that the concentration at each monitoring point started at zero, basically because the contaminants were initially released away from the monitors.

Once the simulation started, we noted that the contaminant concentration was lower in the pool with a drain until about 1,000 seconds into the simulation. After that, the contamination levels in both pools evened out and essentially showed identical results from that point forward. In sum, the simulations showed that having a drain neither improved nor harmed circulation in the pool.

The process also showed that inlets and skimmers alone were sufficient to clear the contaminant's mass fraction to levels of about 0.0015 within about 1,000 seconds. After that point, the circulation system continued to reduce that level to about 0.0010 after 6,000 seconds – that is, 1.7 hours.

If there is no practical difference in circulation performance in pools with properly arrayed systems of inlets and skimmers and no drains, and if the presence of drains is a known agent in incidences of suction entrapment, why install drains at all? If our interest is in reducing risk to bathers, what possible reason can we have to include these suction devices in our watershapes?

Believe me, I don't fault the industry for its building practices, which have always been based on empirical information amassed in the absence of sound scientific data. The circulation of water is something that is nearly impossible to predict through observation and difficult to measure, so following precedent by using drains simply makes sense. And it makes even more sense given the fact that building codes and health departments have fallen into the same sort of empirical thought processes.

But now, CFD simulation clearly shows that drains not only are unnecessary but do not even improve the circulation in a pool or demonstrate a superior ability to clear away contamination. So let's set aside supposition and deal with fact: Now that these results are out in the open, it's time for the watershaping industry, building officials and health departments to take action and mandate that pools (with the exception of those with in-floor cleaning systems and waterfeatures that need more water than current skimmers provide) be built without drains when a sufficient water supply can be obtained from overflows. Further, industry suppliers need to focus on those exceptions and develop high-rate overflow devices (including skimmers) to make it easier to build drain-free pools, spas and associated waterfeatures.

It's my contention that future deaths and injuries can be prevented (at some cost savings, I might add) simply by designing and building future pools without drains and by sealing the drains in existing pools – or by reversing the flow through drains so that they become inlets. At the very least, this research shows that the rules need to change and that designers and builders should no longer be constrained by mandates requiring them to include unnecessary drains in their watershapes.