Computer simulation shows pools can be made safer by eliminating drains

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The death of a granddaughter of former Secretary of State James Baker brought to public attention the problem of suction entrapment in which a swimmer can become stuck to a pool drain. The common wisdom is that drains are necessary to achieve proper circulation in a pool, and many building codes even require pools to have drains. Yet some industry experts, such as Ray Cronise, co-founder of Trilogy Pools, are convinced that drains provide no circulation benefit and that proper circulation can be achieved solely by properly positioning and orienting inlets and skimmers.

Recently, consultants from computational fluid dynamics (CFD) industry leader Fluent Incorporated set out to test this hypothesis by simulating water circulation in computer models of pools that were identical except for the presence and absence of drains. The results showed that not only do inlets and skimmers provide adequate circulation but that, counterintuitively, the addition of drains does not improve circulation.

Dangers of pool drains

The police report filed in the death of 7-year-old Graeme Baker on June 15, 2002 told the story in horrific detail: “The mother … tried to pull her daughter out of the pool. The mother could not lift her daughter from the pool and struggled greatly. Two persons then came to her assistance and pulled the girl out by her ankles … Upon arrival, units … were on the scene performing CPR on Graeme Baker … [and we were] advised that they had no pulse or heartbeat on the young girl. There were approximately 75 [persons] on the scene when this unit arrived. A graduation party was being held at the residence … It was later determined that the girl’s hip or butt was suctioned to the drain.”

Although no lawsuits have been filed in this case, Robert T. Hall, an attorney for Nancy and James Baker IV, Graeme’s parents, said: “The swimming pool and spa industry has been well aware of these risks since the late 1970s. Their products are especially hazardous to children. Since the 1980s, there have been at least 147 entrapment incidents documented, resulting in 36 deaths.”

“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 rather quickly pass through the filter where it can be removed,” Cronise says. “But although accidents are rare, the risk associated with a drain is very real. Five different types of suction entrapment have been documented including body entrapment, limb entrapment, hair entrapment, mechanical entrapment, and evisceration.

“Children are most often the victims of suction entrapment because they are fascinated with the current created by the drain and often intentionally stick their hands and feet in it in order to feel the force generated by suction. New drain covers have been developed with improved safety

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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 (especially hair, limb, and evisceration), and presents the risk of mechanical failure."

Approaching the subject from a different perspective

Cronise retired from the National Aeronautics and Space Administration in 1999 and bought a composites manufacturing company that makes fiberglass pools and spas. Because he has a technical background, including both undergraduate and graduate degrees in chemistry and a publication history, he became involved in the suction entrapment issue. His technical background gave him a different perspective in an industry where designs have traditionally been based on style and experience rather than engineering. Cronise points out that none of the improvements that have been made or proposed completely removes the risk of injury or death as long as the drain continues to generate powerful suction forces. He approaches the problem from a different direction, asking whether the drain is necessary and even questioning whether there is any advantage to having a drain in the first place.

"Based on my observations and knowledge of fluid flow, I developed the idea that circulation occurs in a pool because of the flow generated by the inlets, or pool returns, while the drain has little or no impact," Cronise says. "My thesis is that 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. It's important to note that dense debris does not just get sucked into the drain but usually needs to be removed with a vacuum anyway. 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. I tried to use the example that you can easily blow a candle out at arm's length, but it's impossible to suck one out at the same distance. But I still had little success in convincing others in the industry to lobby for the updating of building codes to remove the requirement for drains."

Computer simulation used to address drain issue

With his technical background, Cronise knew of advancements in the last several decades that have made it possible to simulate the flow of fluids with a great deal of accuracy. He approached Fluent asking for help in testing his hypothesis. CFD software enables engineers to model the flow of either liquid or gas (or both) within a defined area and determine the impact of inflows, outflows, obstructions, boundaries, and a wide range of other factors. CFD software is used by engineers to design automobiles, airplanes, power plants, heating and cooling systems for buildings, chemical plants, and many other products and processes that depend on fluid flow. The key benefit of CFD software is that it enables engineers to understand through computer simulation exactly how fluid flows under a defined set of conditions without the time and expense and measurement difficulties involved in actually building and testing the design. Fluent Incorporated has better than a 50% market share in this rapidly growing field.

Cronise and consulting engineers at Fluent worked together to simulate the flow of water through computer models of swimming pools with and without drains. The pool modeled is 15 ft wide, 35 ft long, 6 ft deep at one end, and 3 ft deep at the other end. The pool has four inlets arranged around its circumference to provide circulation and a skimmer on the waterline where water leaves the pool. One of the pools has two main drains, while the other has none. The pool was circulated at the rate of approximately 60 gallons per minute. The simulation started with a sphere of contamination located near each inlet jet. Two monitors were positioned at each end of the pool, 2 ft below the surface of the shallow end and 3 ft below the surface of the deep end. The simulation proceeded over time, and each monitor tracked the concentration of contaminant.

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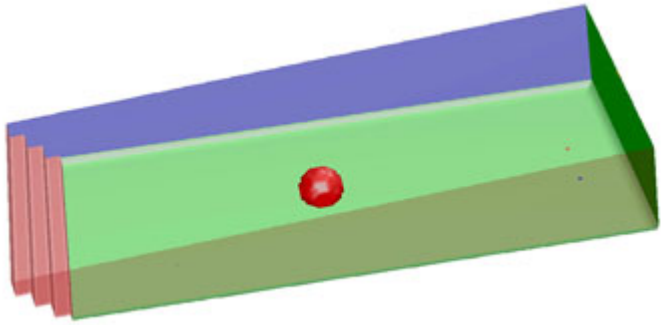
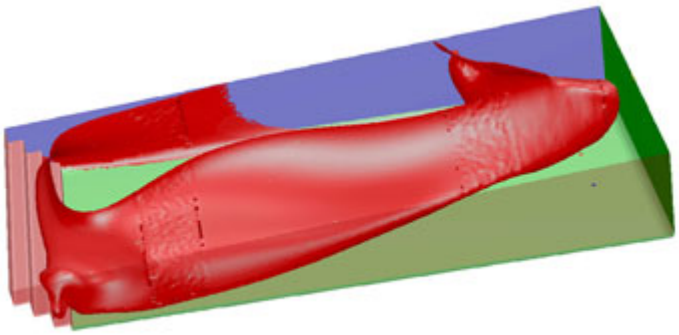
Simulation results show no benefits from drains

The simulation results showed that the pools with and without drains were essentially equal in their ability to remove the contamination.

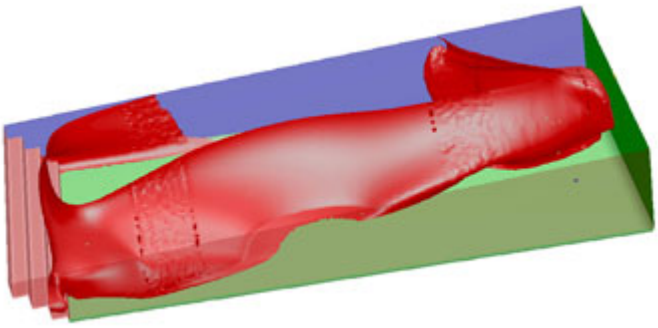
Iso-surfaces of contaminant concentration at various times in pools with and without main drains. The red surface indicates where the contaminant has a mass fraction of 0.0016. The circulation causes similar diffusion in each case.



For both scenarios at initialization, with a sphere of contaminant in the center of the pool



With main drains after 500 seconds.



Without main drains after 500 seconds.

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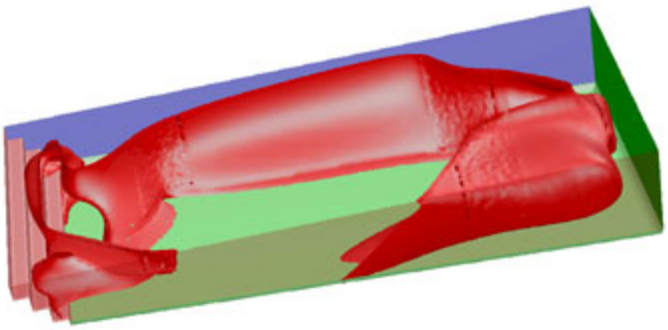
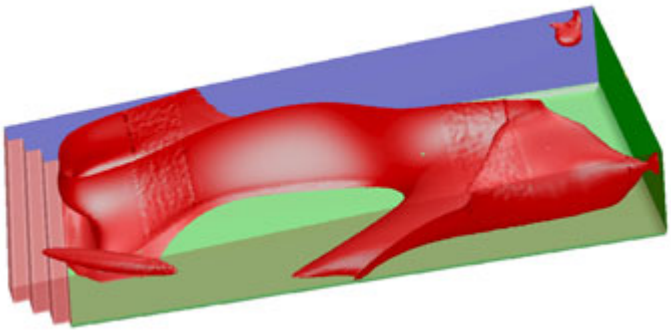


With main drains after 1,000 seconds.



Without main drains after 1,000 seconds.

The contaminant concentration at each monitoring point started at zero because the contaminants are initially released away from the monitoring points. The contaminant concentration was actually higher at most of the monitoring points in the pool with a drain during the first 1,000 seconds of the simulation. But at about the 1,000-second point, the contamination in the pool with a drain dropped to the level of the pool without a drain and the two pools showed essentially identical results from that point on. In short, the simulations showed that having a drain neither improves nor harms the circulation in the pool. The inlets and skimmers alone are sufficient to clear the contamination mass fraction to levels of about 0.0015 within about 1,000 seconds. After that point, the circulation system continues to reduce the level of contamination mass fraction to about 0.0010 after 6,000 seconds.

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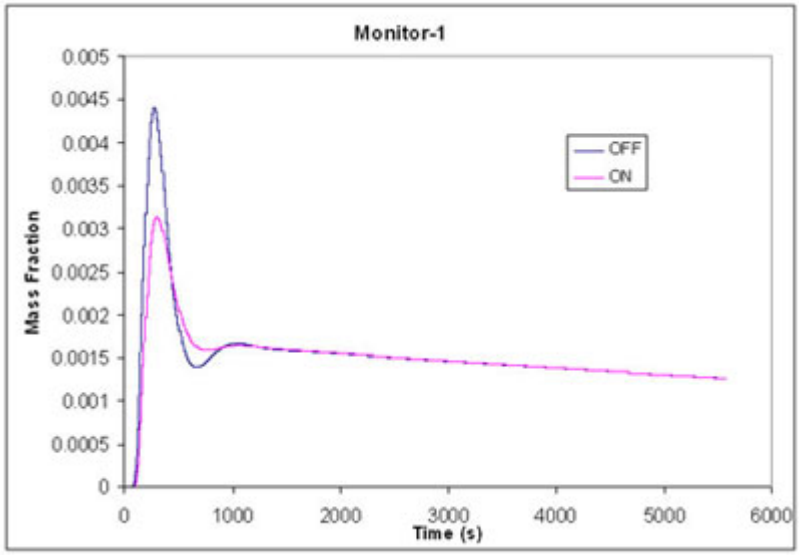

Simulation contamination monitors were positioned at each end of the pool, 2 ft below the surface of the shallow end and 3 ft below the surface of the deep end. Shown here is a comparison of contamination mass fraction over time both with and without drains in the shallow end of the pool, where the difference was greatest. While the contamination level is higher for the case without main drains for a short period, it becomes lower after about 600 seconds, with no visible difference after 1,000 seconds. The behavior at the other locations was found to be similar.

"Because the pool industry is not as technically advanced as some others, it has adopted building practices based largely on empirical information," Cronise concludes. "The circulation of water is something that is nearly impossible to see and very difficult to measure so in many cases designers have been using drains simply because pools that were built in the past have used them.

"By the same token, many building codes and Health Departments have required drains primarily because most pools have them. CFD simulation clearly shows that drains not only are not necessary but do not even improve the circulation in a pool and its ability to clear contamination. The number of injuries and deaths caused by drains in pools is not large compared with other hazards, yet future deaths and injuries could be prevented at no additional cost simply by building future pools without drains and sealing the drains in existing pools. Now that these results are out in the open, I think it's important for our industry, building officials, and health departments to proactively take action to allow pools without drains in their standards and codes.

"Further, the industry needs to focus efforts on high-flow-rate overflow devices, like skimmers, so that today's pool full of water features can be easily built without a drain. Certainly the only time I can really recommend any drain is in the case of in-floor cleaning systems. Based on these conclusive research results, it is clear that the customer or pool builder should be allowed to build a pool without a drain."

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