International Journal of Aquatic Research and Education

Volume 2 | Number 3 Article 2

8-1-2008

Dual-Main-Drain Suction-Entrapment Test Report

William N. Rowley
National Swimming Pool Foundation, info@rowleyinternational.com

Glen H. Egstrom
University of California - Los Angeles

Donald H. Witte
National Swimming Pool Foundation

Ester Rocha
Mac-Win Technical Support, Costa Mesa, CA

Francisco Rocha
Mac-Win Technical Support, Costa Mesa, CA

Recommended Citation

Rowley, William N.; Egstrom, Glen H.; Witte, Donald H.; Rocha, Ester; and Rocha, Francisco (2008) "Dual-Main-Drain Suction-Entrapment Test Report," *International Journal of Aquatic Research and Education*: Vol. 2: No. 3, Article 2.
DOI: https://doi.org/10.25035/ijare.02.03.02
Available at: https://scholarworks.bgsu.edu/ijare/vol2/iss3/2

RESEARCH

International Journal of Aquatic Research and Education, 2008, 2, 190-212

Dual-Main-Drain Suction-Entrapment Test Report

William N. Rowley, Glen H. Egstrom, Donald H. Witte, Ester Rocha, and Francisco Rocha

Life-threatening suction-entrapment events have been recorded in swimming pools and spas since before World War II, although formal documentation and investigation did not occur until the Consumer Product Safety Commission began maintaining National Electronic Incident Surveillance System data. Of 147 incidents documented between 1985 and 2002, 36 incidents, 1 in 4, were fatal. Suction entrapment occurs in wading pools, spas, or swimming pools when a person's body blocks the flow of water from a pool or spa to the circulation pump. When the source of suction to the pump is blocked, the pump continues to operate, creating a strong suction on whatever is blocking the water flow. The dual-main-drain suction-entrapment tests were developed to determine the effectiveness of dual main drains as a means of avoiding suction-entrapment accidents.

Keywords: water safety, drowning/near drowning, aquatic facility design, swimming pools, swimming facilities, aquatic risk management

Since the mid-1970s the National Swimming Pool Foundation (NSPF) has maintained a strong interest in and commitment to better understanding and preventing suction-entrapment accidents such as body entrapment, limb entrapment, evisceration, and hair entrapment or entanglement. After the Consumer Products Safety Commission (CPSC) chairman's roundtable meeting on swimming pool and spa entanglement in Bethesda, MD, on July 11, 1996, and after receiving letters requesting help and assistance from CPSC engineer Troy Whitfield (October 9, 1996) and assistant executive director of the CPSC Office of Hazard Identification and Reduction, Ron Medford (November 5, 1996), the NSPF proceeded to fund a suction-entrapment test (November 7, 1996). This test would be funded solely by the NSPF and technically coordinated with the CPSC. The preliminary test protocol on testing single and dual main drains for suction entrapment, evisceration, and hair entrapment was developed by Dr. William N. Rowley for the NSPF and later coordinated with the CPSC. The initial dual-main-drain suction-entrapment tests were conducted in California during April 1997 and May 1997 as a continuation of the initial basic test work on suction entrapment that was started under

Rowley and Witte are with the National Swimming Pool Foundation. Egstrom is with the Dept. of Physiological Science, University of California, Los Angeles, Los Angeles, CA. E. and F. Rocha are with Mac-Win Technical Support, Costa Mesa, CA.

Dr. Rowley's direction at the Swimquip hydraulic test laboratory in El Monte, CA, in June 1974 (Ehret & Rowley, 1974a, 1974b). These and other early test reports (Ehret & Rowley, 1974c, 1974d; Rowley, 1974; Rowley & Egstrom, 1997; Rowley & Ehret, 1976; Rowley, 2002) can be obtained from the National Swimming Pool Foundation, Colorado Springs, CO, 80906, (719) 540-9119.

During April 29 through May 1, 2006, and December 7 and 8, 2007, we completed the latest series of dual-main-drain suction-entrapment tests in a test facility located at Big Pine Key, FL. The purpose of the study was to validate the 1997 dual-main-drain suction-entrapment test results and further determine operational parameters and the effectiveness of dual main drains as a means of avoiding suction-entrapment accidents. These tests were funded by the NSPF.

The 2007 test results confirmed the 1997 dual-main-drain suction-entrapment test results that concluded that maintaining the pump suction velocity under six feet per second (6 ft/s) with one of the dual-main-drain grates or plates removed and covered with a human subject did not produce suction entrapment. Suction entrapment did not occur in any of the 24 dual-main-drain suction-entrapment tests in 2007 in which one drain was blocked with a human being. Tests with 1.5″ suction-pipe velocities to 17.8 ft/s and 2″ suction-pipe velocities reaching 11 ft/s did not produce entrapment. Debeugny, Bonnevalle, Besson, and Basset (1990) concluded that any vacuum pressure above 2.13 pounds per square inch (lb/in.^{2}), or 4.34 inches of mercury (in. Hg) might cause evisceration; this amount of vacuum pressure is called Debeugny's threshold of evisceration and was used as the baseline threshold for suction entrapment in this study. Evisceration, in the context of this study, occurs as a result of sitting on an open drain and creating a seal on the drain with the genitalia exposed to the suction. This condition is the worst-case scenario for our tests. Suction velocities of 6 ft/s in 36″-deep water with a 1.5″ pipe developed a maximum vacuum of 1.82 in. Hg, or 0.89 lb/in.^{2}, when one of the dual main drain's covers was removed and that drain was blocked with a human subject while the second drain was not blocked. Six-feet-per-second suction velocity with our test apparatus (see Figure 1) provides a safety factor of 2.4–1 (4.34 in. Hg/1.82 in. Hg) using Debeugny's threshold of evisceration of 4.34 in. Hg vacuum.

A single, blocked, coverless sump in a typical single-drain system can create vacuum pressure sufficient to cause evisceration (Centers for Disease Control, 1992).

Suction-Entrapment Test Platform

The test apparatus shown in Photograph 1 was configured in the bottom of an 11′-diameter 42″-deep test pool with a 48″ × 96″ flat, removable working surface under the vinyl liner (see Figure 1). The test-bench working surface could be located at different depths: The first test depth was 18″ beneath the water surface to simulate the depth of a wading pool, and the second test depth was 36″ beneath the water surface to simulate the depth of a spa.

The underwater working surface was fitted with two Hayward 7.75″-diameter SP-1052AV main-drain fittings and sumps and two Pentair 12″ × 12″ main-drain fittings and sumps. Each dual-main-drain assembly was configured with valves to permit operation as a single unit or as a dual-main-drain assembly.

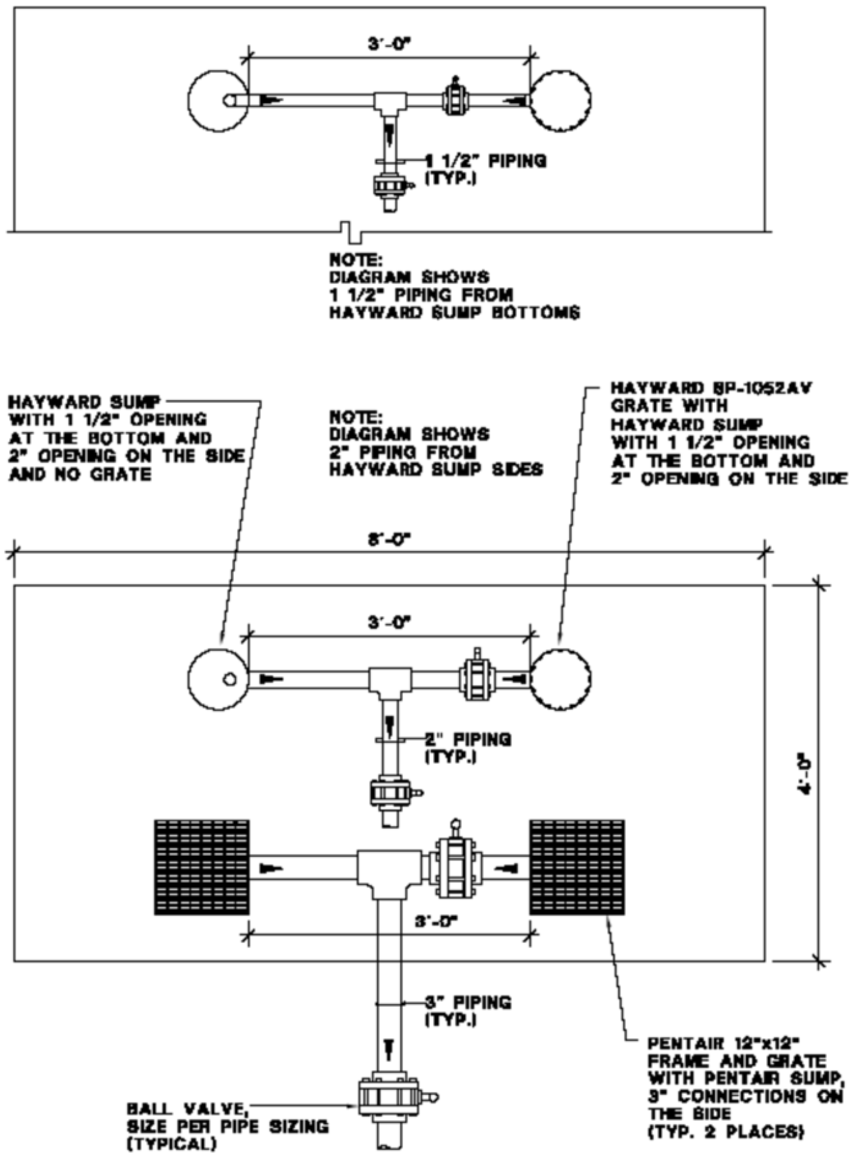
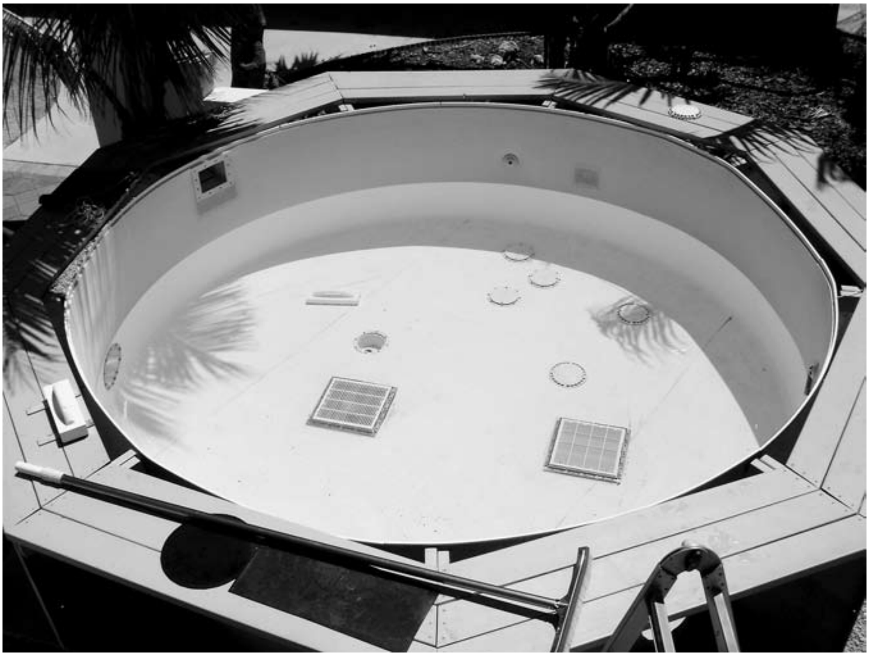


Figure 1 — Test-apparatus schematic.

During the dual-main-drain suction-entrapment testing, one drain was uncovered while the other drain was covered with an antivortex cover or grate.

For all 25 tests in 2006 and 2007, the test-bench plumbing (see Figure 1) was connected with 25′ of flexible suction plumbing to the suction end of either a



Photograph 1 — Test apparatus.

Pentair WisperFlo WFE-12, 3-horsepower (HP), 230-V, 3,450-rpm, 1ϕ pump with a 1.15 service factor or a Sta-Rite K56P2PM100A1, 3-HP, 230-V, 3,450-rpm, 1ϕ pump with a 1.15 service factor. The discharge/return plumbing from either pump to the test pool was also 25′ in length. An Ashcroft ATE-100 handheld digital LCD calibrator (last calibrated on November 1, 2007) and an Ashcroft AQS-1 pressure transducer (0–30″ Hg, last calibrated on November 5, 2007) were used for vacuum measurements and calibrations.

The flow in gallons per minute (gal/min) was measured with a 1.5″ Blue and White F 30150PR (20–100 gal/min), a 2″ Blue and White F30200PR (40–150 gal/min), and a 3″ Signet 5090 (0–200 gal/min) flowmeter.

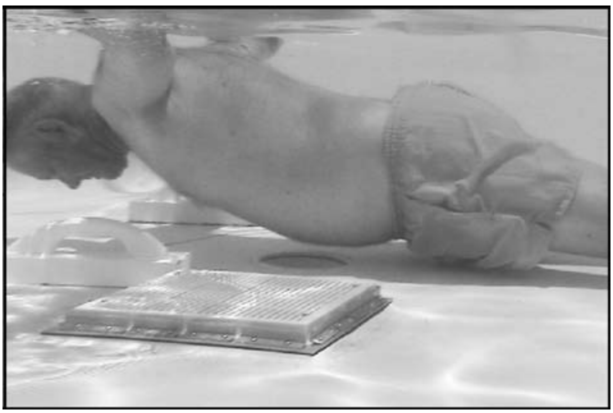
Suction-Entrapment Test Procedures

The following three parameters were monitored during all of the tests: suction flow (in gallons per minute), vacuum pressure (in inches of mercury) in the main drain sump with the missing grate, and time (in seconds). In all, 24 dual-main-drain suction-entrapment tests were performed using a live human subject (6′-2″ and 205 lb). He was able to cover one of the sumps with his abdomen while the other sump was covered with an antivortex cover/grate. These videotaped tests were conducted on the dual 7.75″-diameter Hayward SP-1052AV sumps, each using 2″ side outlets or 1.5″ bottom outlets.

The test director and his assistant monitored and maintained the suction flow rate during each test run. Vacuum pressure in the main drain sump with the missing antivortex cover/grate was also monitored and recorded before and during blockage and after release in each test run. During each test, the subject's abdomen was used to block the uncovered sump while the antivortex cover protected the other drain. Two weights with handles were used to assist in positioning the subject's body over the drain.

In Photograph 2, the subject can be observed positioning his body over the open 7.75″-diameter Hayward SP-1052AV sump, and he can be seen floating off of it in Photograph 3. The tests were visually recorded through an underwater window in the test apparatus as seen in Photograph 4 and Photograph 5; in Photograph 6 and Photograph 7, the subject's abdomen is shown starting to float off after sealing off the sump.

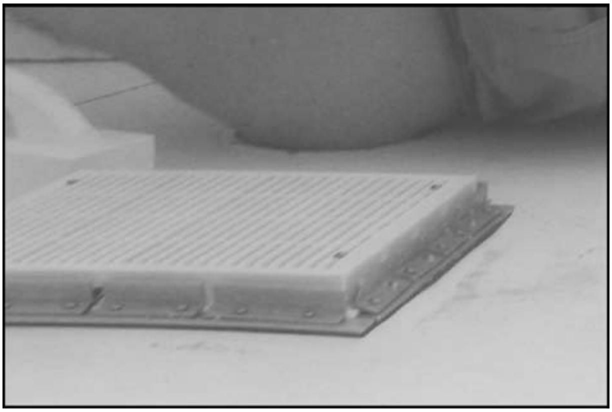
Photograph 2 — Subject uses weights with handles to position himself over open drain.



Photograph 3 — Subject releases weights with handles and floats off drain.

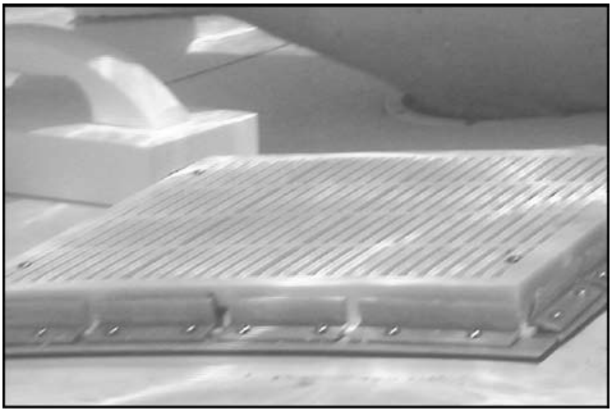
Photograph 4 — Subject releasing himself on open main drain.

Photograph 5 — Test director (standing) and test recorder in front of underwater window.



Photograph 6 — Subject starting to float off of open main drain.

DOI: https://doi.org/10.25035/ijare.02.03.02



Photograph 7 — 12″ × 12″ grate with subject in background floating off of open main drain.

One additional test, #25, was conducted in 18″-deep water using a 3″ suction pipe with dual 12″ × 12″ Pentair grates with a flow of 178 gal/min and a flow velocity of 7.7 ft/s. This test was conducted using a 1/8″-thick neoprene rubber sheet to block the grate because the subject was not able to shut off a 12″ × 12″ Pentair grate with his body.

Suction-Entrapment Test Results

The seven dual-drain tests in Table 1 were conducted in 18″-deep water using a 1.5″ suction pipe from the sump. The subject was able to block the water flow to a single drain with his abdomen in each test. In the first four tests of the series, he did not need to use pressure from his hands or feet to push off the bottom; he simply released the weight handles and floated off. In Test Runs #5–7 a slight bit of pressure from his arm or leg was all that was necessary to release. There was no suction entrapment. In Test Run #7, the 3-HP pump was unthrottled and was producing the maximum flow that could be obtained with this system. Figure 2 shows the recorded vacuum pressure over time for Test Runs #1–5; Figure 3, the recorded vacuum pressure over time for Test Runs #6 and #7. A video of Test Run #7 is available in the online version of the journal.

The five dual-drain tests in Table 2 were conducted using 2″ suction pipe from the sump in 18″-deep water. The subject was able to block the water flow to a single drain with his abdomen in each test. In the first four tests of the series, he did not need to use pressure from his hands or feet to push off the bottom; he simply released the weight handles and floated off. There was no suction entrapment. In Test Run #12, the 3-HP pump was unthrottled and was producing the maximum flow that could be obtained with this system, yet a slight bit of pressure from the subject's knee was all that was necessary to release. The recorded vacuum pressure over time for Test Runs #8–12 is shown in Figure 4. A video of Test Run #12 is available in the online version of the journal.

Table 1 Dual-Main-Drain Suction-Entrapment Tests 2007, Series 1, Test Runs #1–7

Test run#	Water depth (in.)	Pipe size (in.)	Flow rate (ft/s)	Flow rate (gallons/ min)	Suction (in. of mercury)	Suction (lb/in.^{2})	When the subject covered the open sump with his abdomen . . .
#1	18″	1.5″	6	38	1.61	0.79	He felt just a slight bit of vacuum. He simply released the weights with handles and floated off.
#2	18″	1.5″	8	51	2.98	1.46	He could feel the vacuum, but he simply released the weights with handles and floated off.
#3	18″	1.5″	10	63	3.18	1.56	The vacuum pulled him down, but he simply released the weights with handles and floated off.
#4	**18″**	**1.5″**	**12**	**76**	**4.73**	**2.32**	There was almost enough suction to hold him, but it was not quite enough. He released himself from the weights and just barely floated off.
#5	**18″**	**1.5″**	**14**	**89**	**5.15**	**2.52**	He could feel a slight suction. He could not float off and had to push off a little bit with his hands, whereupon he came right off. There was no suction entrapment.
#6	**18″**	**1.5″**	**16**	**103**	**6.47**	**3.18**	The open sump held him down enough that he could not float off. He had to push off with a little bit of pressure, although not much. It was not a struggle; it just took a slight bit of pressure to push off. There was no suction entrapment.
#7	**18″**	**1.5″**	**17.8**	**115**	**7.24**	**3.55**	The suction seemed slightly more than in Run #6, but it was not hard to push off at all. There was no suction entrapment.

Note. Bold rows indicate tests in which the suction exceeded the Debeugny threshold of evisceration of 4.34 in. of mercury, or 2.13 lb/in.^{2}.

The seven dual-drain tests in Table 3 were conducted using 1.5″ pipe in 36″-deep water. The subject was able to block the water flow to a single drain with his abdomen in each test. In the first four tests of the series, he did not need to use pressure from his hands or feet to push off the bottom; he simply released the weight handles and floated off. In Test Runs #17–19 a slight bit of pressure from his hand or arm was all that was necessary to release. There was no suction entrapment. In Test Run #19, the 3-HP pump was unthrottled and was producing

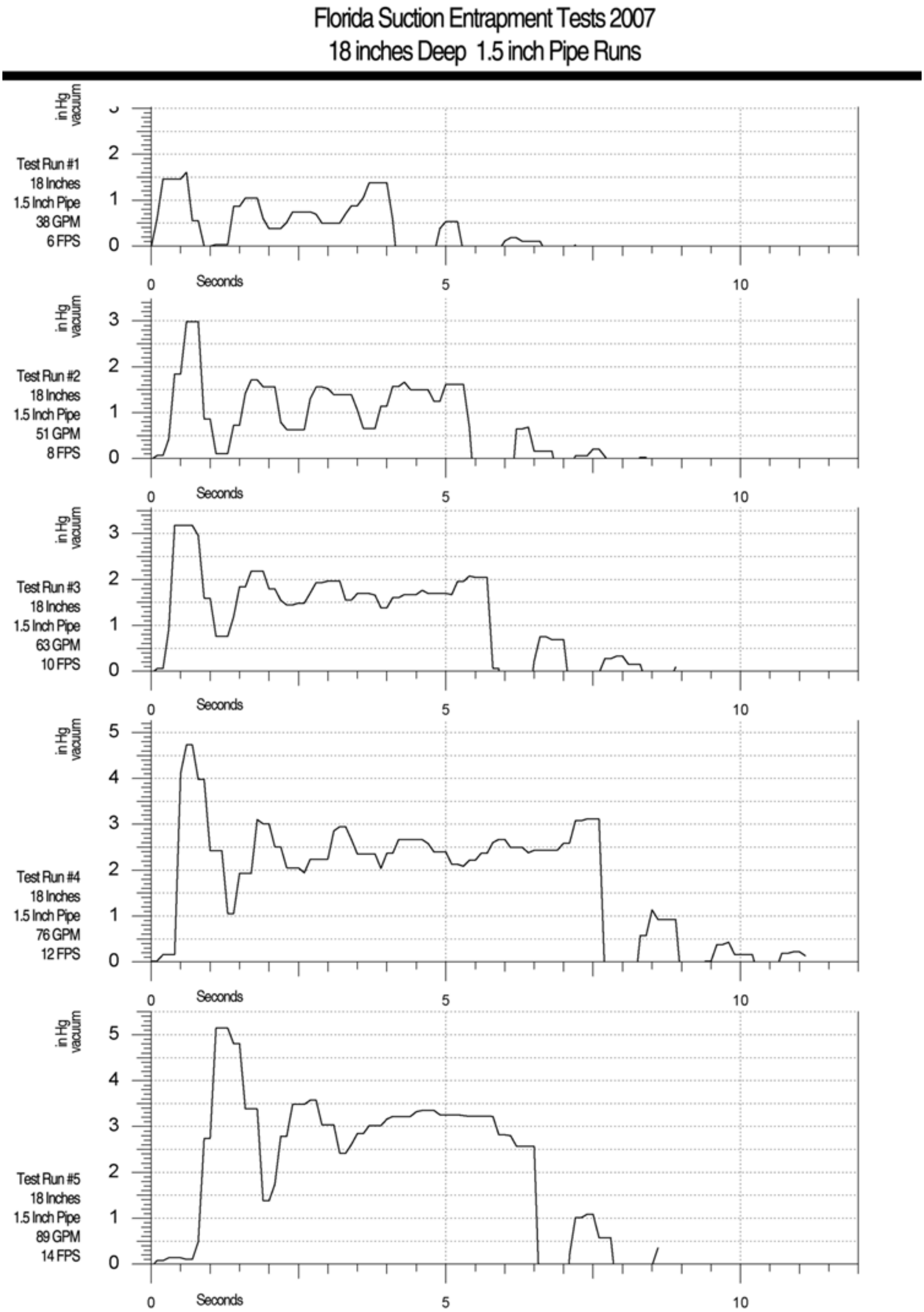


Figure 2 — Test Runs #1–5, vacuum pressure versus time.

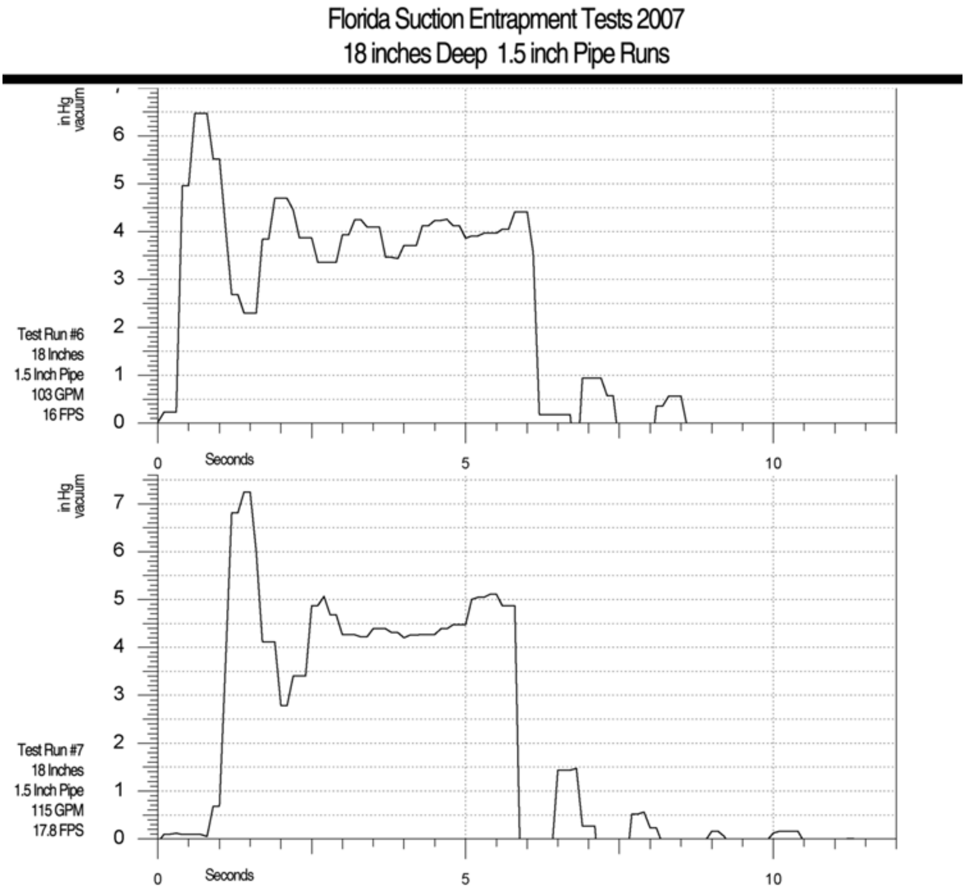


Figure 3 — Test Runs #6 and #7, vacuum pressure versus time.

the maximum flow that could be obtained with this system. Figure 5 shows the recorded vacuum pressure over time for Test Runs #13–17; Figure 6 shows the recorded vacuum pressure over time for Test Runs #18 and #19. A video of Test Run #19 is available in the online version of the journal.

Note that the initial surge or spike in Test Run #18 was higher than that in Test Run #19, although the water velocity was greater in Test Run #19. This hydraulic phenomenon is caused by the speed with which the human subject blocks the open main drain. The faster the blockage, the higher the spike. The surge/spike plateau in Test Run #18 was below the one in Test Run #19, which would be expected.

The five dual-drain tests in Table 4 were conducted using 2″ pipe in 36″-deep water. The subject was able to block the water flow to a single drain with his abdomen in all tests. Test #24 was conducted with the 3-HP Pentair WisperFlo WFE-12 pump running unrestricted, that is, maximum flow for the system. In the first four tests of the series, the subject did not need to use pressure from his hands or feet to push off the bottom; he simply released the weight handles and floated off. In Test

Table 2 Dual-Main-Drain Suction-Entrapment Tests 2007, Series 2, Test Runs #8–12

Test run#	Water depth (in.)	Pipe size (in.)	Flow rate (ft/s)	Flow rate (gallons/min)	Suction (in. of mercury)	Suction (lb/in.^{2})	When the subject covered the open sump with his abdomen . . .
#8	18″	2″	4	42	1.06	0.52	He could feel some suction, but it was not enough to hold him down. He released from the weights and simply floated off.
#9	18″	2″	6	63	1.15	0.56	He could feel a suction that was slightly stronger than Test #8 but far short of creating an entrapment problem. He released the weights and simply floated off.
#10	18″	2″	8	84	1.97	0.97	There was slightly more suction than Test #9 but enough to hold him down. He released the weights and slightly rolled his body and floated off with little effort.
#11	18″	2″	10	105	2.67	1.31	There was slightly more suction than in Test #10. It was enough to hold him down so that he could not float loose. He released himself from the weights, wiggled a bit, rolled his body, and then floated off with little effort.
#12	18″	2″	11	115	2.85	1.40	There was slightly more suction than in Test #11. He simply pushed off with his knee and floated off with little effort. The suction was not strong, and there was no suction entrapment.

Run #24 a slight bit of pressure from his knee was all that was necessary to release. There was no suction entrapment. In Test Run #24, the 3-HP pump was unthrottled and was producing the maximum flow that could be obtained with this system. Figure 7 shows the recorded vacuum pressure over time for Test Runs #20–24. A video of Test Run #24 is available in the online version of the journal.

The dual-drain test in Table 5 was conducted in 2006 using 3″ pipe in 18″-deep water. This test was conducted with the 3-HP Pentair WisperFlo WFE-12 pump running unrestricted, that is, maximum flow for the system. This test was conducted using a 1/8″-thick, 50-durometer neoprene rubber sheet because the subject was not able to shut off a 12″ × 12″ Pentair grate with his body. In Test Run #25, the

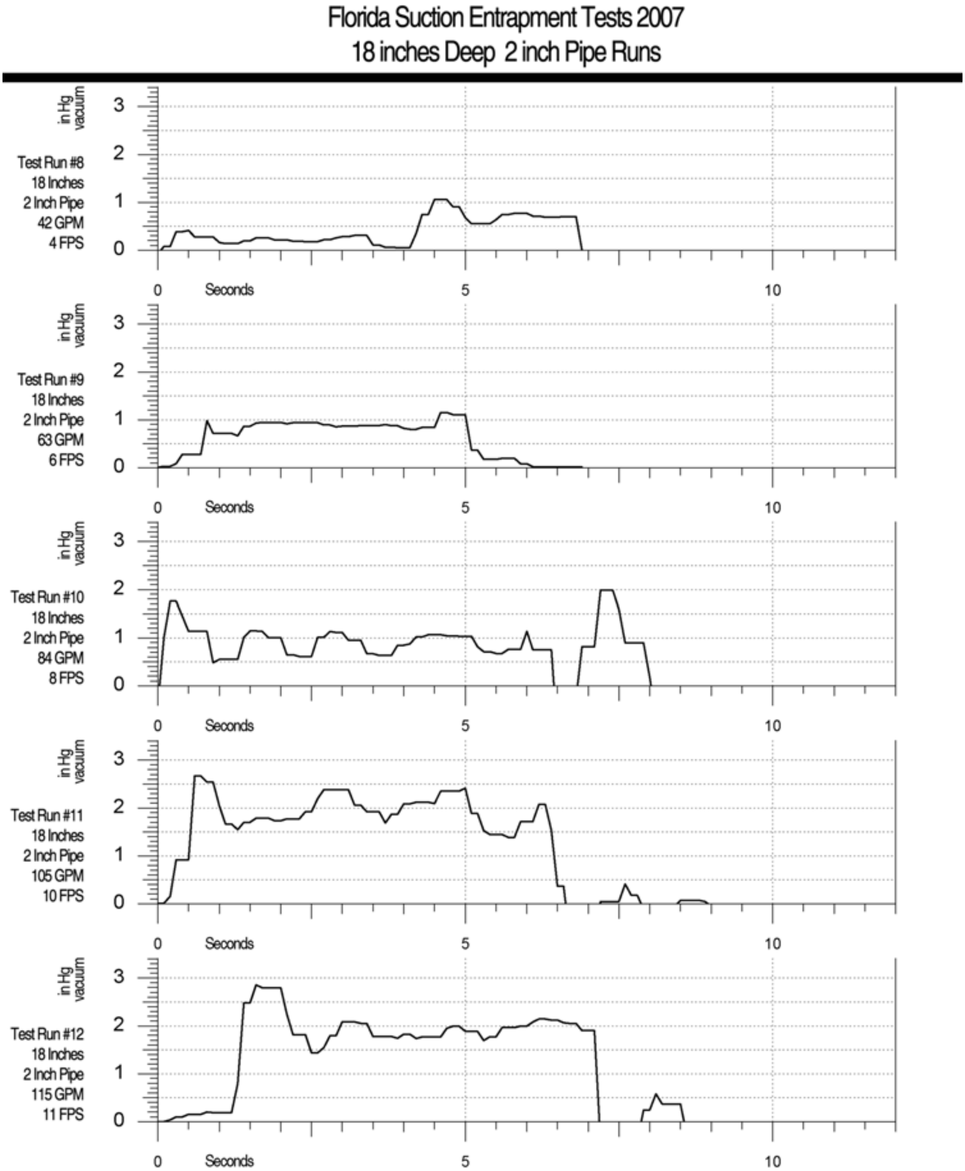


Figure 4 — Test Runs #8–12, vacuum pressure versus time.

3-HP pump was unthrottled and was producing the maximum flow that could be obtained with this system. Figure 8 shows the recorded vacuum pressure over time for Test Run #25. The neoprene rubber sheet is shown covering the main drain in Photograph 8 and being pulled off in Photograph 9.

Table 3 Dual-Main-Drain Suction-Entrapment Tests 2007, Series 3, Test Runs #13–19

Test run#	Water depth (in.)	Pipe size (in.)	Flow rate (ft/s)	Flow rate (gallons/ min)	Suction (in. of mercury)	Suction (lb/in.²)	When the subject covered the open sump with his abdomen . . .
#13	36″	1.5″	4	25	0.43	0.21	He could barely feel the suction. He was able to remove himself without using his arms or legs to push off. He simply released himself from the weights and floated off with no effort.
#14	36″	1.5″	6	38	1.82	0.89	He could barely feel the suction. He was able to remove himself without using his arms or legs to push off. He simply released himself from the weights and floated off with no effort.
#15	36″	1.5″	8	51	2.75	1.35	He could feel the suction. He simply released himself from the weights and floated off with no effort.
#16	36″	1.5″	10	63	3.70	1.82	He simply released himself from the weights, flexed his body, and floated off with no effort.
#17	36″	1.5″	12	76	3.97	1.95	He felt suction and was unable to float off. He released himself from the weights and used one hand to push off slightly and floated free. There was no suction entrapment.
#18	**36″**	**1.5″**	**14**	**89**	**5.91**	**2.90**	There was more suction than in Test #17, and he was unable to float off. He released himself from the weights and used one hand to slightly push off and floated free. There was no suction entrapment.
#19	**36″**	**1.5″**	**15.8**	**100**	**5.74**	**2.84**	He definitely felt suction. He released himself from the weights and used one arm to slightly push off and floated free. This level of suction did not approach a suction-entrapment problem.

Note. Bold rows below indicate tests in which the suction exceeded the Debeugny threshold of evisceration of 4.34 in. of mercury, or 2.13 lb/in.².

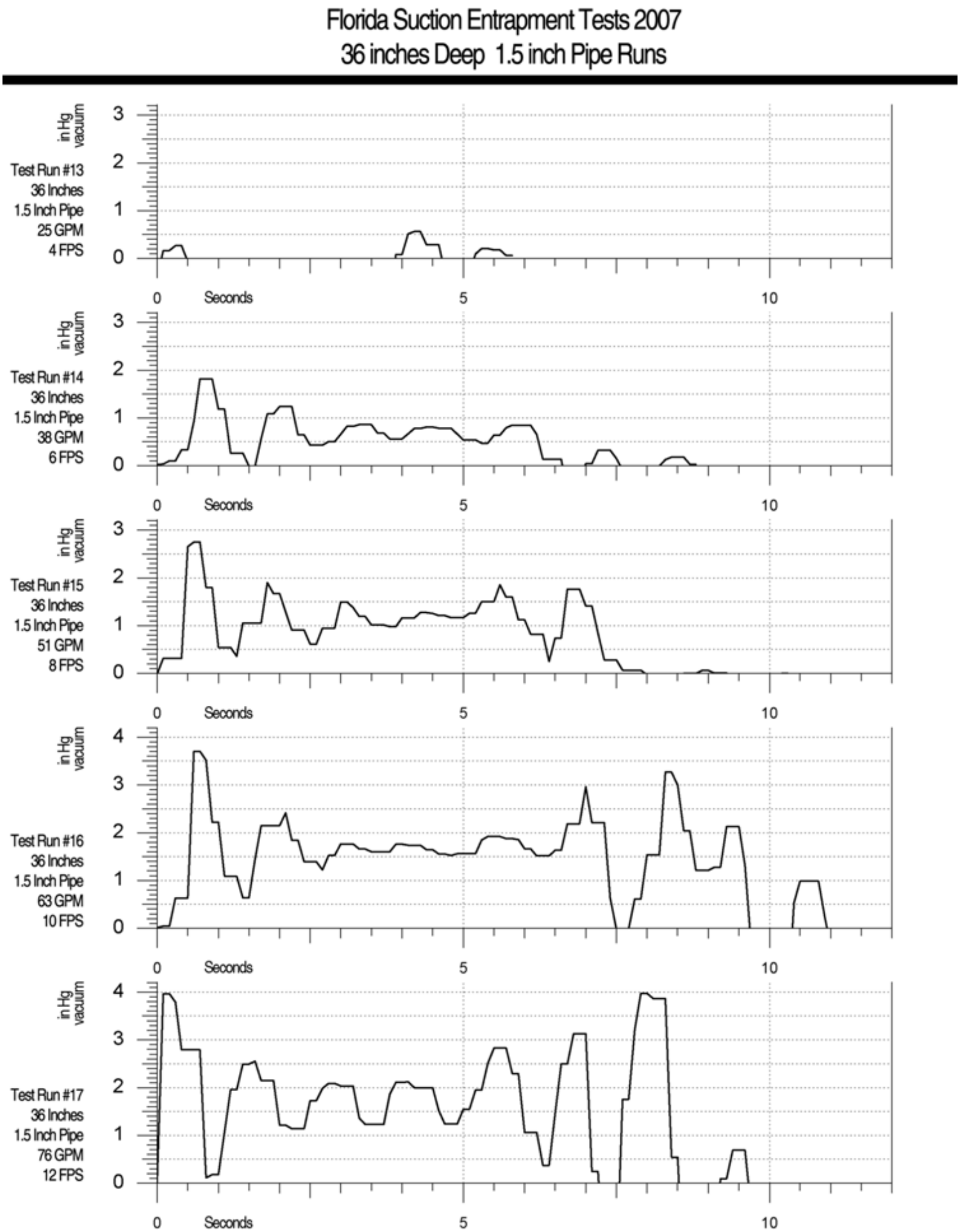


Figure 5 — Test Runs #13–17, vacuum pressure versus time.

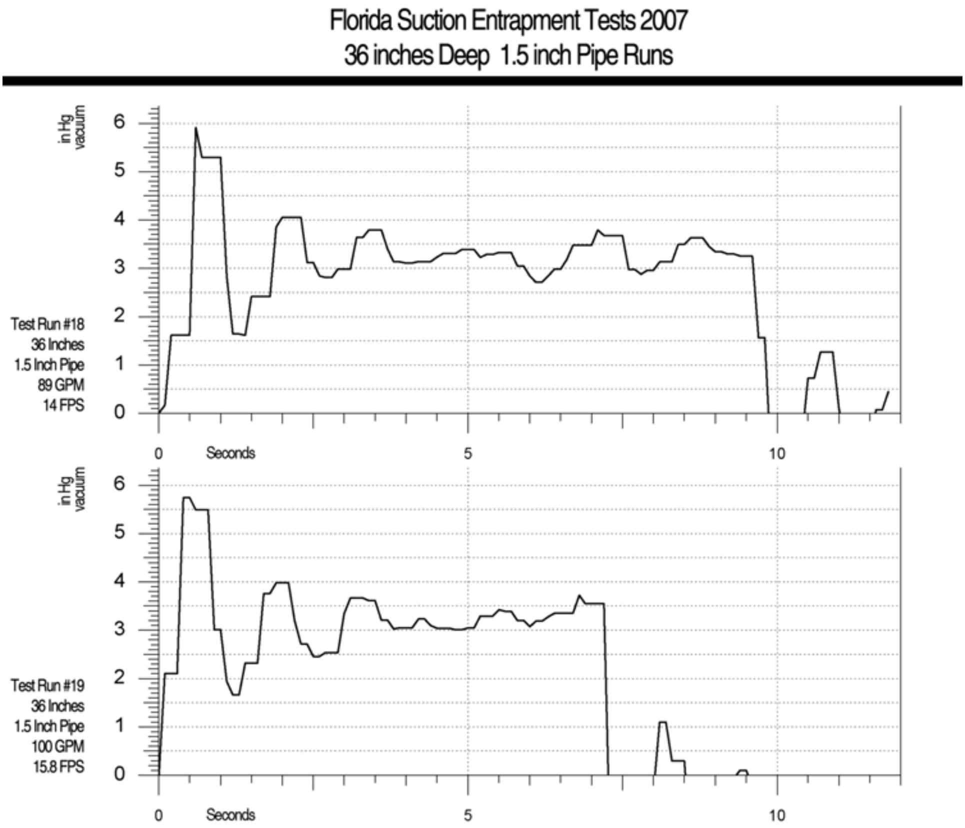


Figure 6 — Test Runs #18–19, vacuum pressure versus time.

Discussion

To our knowledge, this is the first time that dual-depth (i.e., 36″ and 18″) dual-main-drain suction entrapment has been investigated using a human as a subject. When all four hazards (body entrapment, limb entrapment, evisceration, and hair entrapment or entanglement) are reviewed simultaneously, the safety solution becomes vastly more complex; a safe condition for any one of the four entrapment conditions might not be a safe condition for the others. Because hair entrapment or entanglement was not in the testing protocol for this series of tests, there are no data on this issue. Nonetheless, very low-risk operating conditions can be achieved with the proper design and sizing of the grate/antivortex cover and the proper water velocity through the system. Only grossly reducing all four hazardous conditions can lead to an acceptable level of risk. A relatively safe condition in this complex problem area that provides reasonable protection against suction entrapment, evisceration, and hair entrapment or entanglement can be developed with dual

Table 4 Dual-Main-Drain Suction-Entrapment Tests 2007, Series 4, Test Runs #20–24

Test run#	Water depth (in.)	Pipe size (in.)	Flow rate (ft/s)	Flow rate (gallons/min)	Suction (in. of mercury)	Suction (lb/in.^{2})	When the subject covered the open sump with his abdomen . . .
#20	36″	2″	4	42	0.03	0.01	He could just feel the suction. He simply released himself from the weights and floated off.
#21	36″	2″	6	63	0.97	0.47	He could just feel the suction. He simply released himself from the weights and floated off.
#22	36″	2″	8	84	1.59	0.78	He felt a little bit more suction than in Test #21. He released himself from the weights, slightly rolled his body, and floated off.
#23	36″	2″	10	105	2.40	1.18	He felt a little bit more suction than in Test #22. He released himself from the weights, simply wiggled and flexed, and floated off.
#24	36″	2″	11	115	3.18	1.56	The suction felt the same as the previous test. He released himself from the weights, simply pushed off with one knee, and floated off. There was no suction entrapment.

main drains as described. Earlier tests by Ehret and Rowley (1974c) concluded that suction entrapment might also occur on an open single main drain that is also connected to a skimmer. The following discussion is the result of the examination of solutions that could significantly reduce the risks of body entrapment, evisceration, and limb entrapment.

The 24 dual-main-drain suction-entrapment tests in the 2007 series of tests were conducted on a flat test bench at water depths of 18″ and 36″ using 1.5″ and 2″ suction piping with a 25′ run to the pump. In our 1997 tests, in no case in a two-main-drain system did the vacuum in the blocked open main drain sump exceed 1.6 in. Hg, or 0.8 lb/in.^{2}, with the above parameters and a maximum of 6-ft/s suction velocity. We obtained almost identical results in our 2007 tests, and in no case, with the above parameters and a maximum of 6-ft/s suction velocity, did the vacuum in the blocked open main drain sump exceed 1.8 in. Hg, or 0.9 lb/in.^{2}. This is confirmation of our previous testing and leads us to the conclusion that, using Debeugny et al.'s (1990) criteria of 150 cm of water or 2.13 lb/in.^{2} or 4.34 in. Hg vacuum for evisceration, with this dual-main-drain hydraulic arrangement

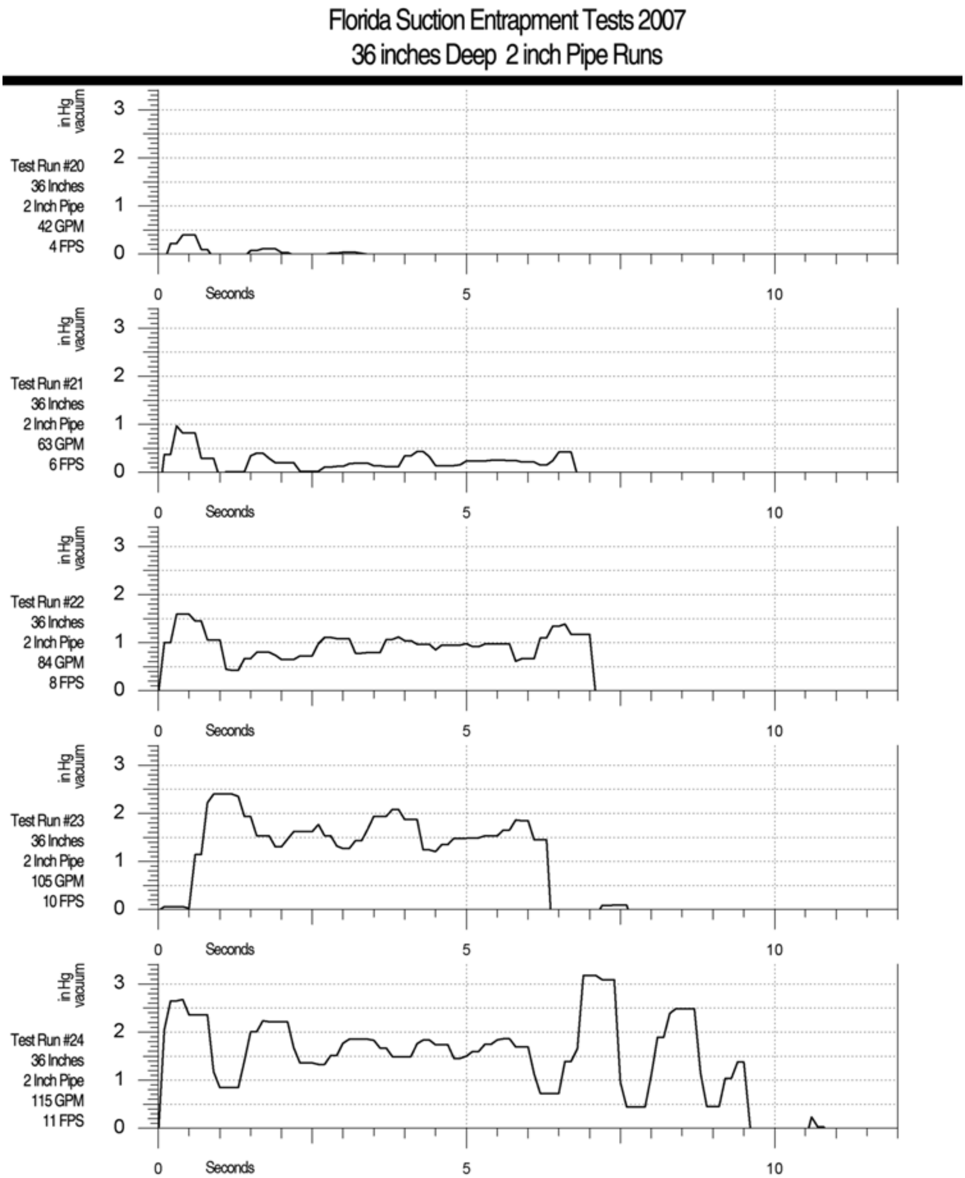


Figure 7 — Test Runs #20–24, vacuum pressure versus time

and a maximum of 6-ft/s suction velocity, there is a safety factor of about 2.4. Even with one drain cover removed, there was not a suction-entrapment problem during the tests. The subject was able to remove himself on 16 tests by simply releasing himself from the weights and floating off. On eight tests (#5, #6, #7, #12, #17, #18,

Table 5 Dual-Main-Drain Suction-Entrapment Tests 2006, Neoprene Rubber Sheet Test, Test Run #25

Test run#	Water depth (in.)	Pipe size (in.)	Flow rate (ft/s)	Flow rate (gallons/min)	Suction (in. of mercury)	Suction (lb/in.^{2})	When the subject covered the open sump with the neoprene rubber sheet . . .
#25	36″	3″	7.73	178	1.04	0.51	He was able to remove the sheet by simply pulling up on a cord attached to one corner (see Photograph 9). The pull on the cord was so slight that the spring scale attached to the cord did not register a reading.

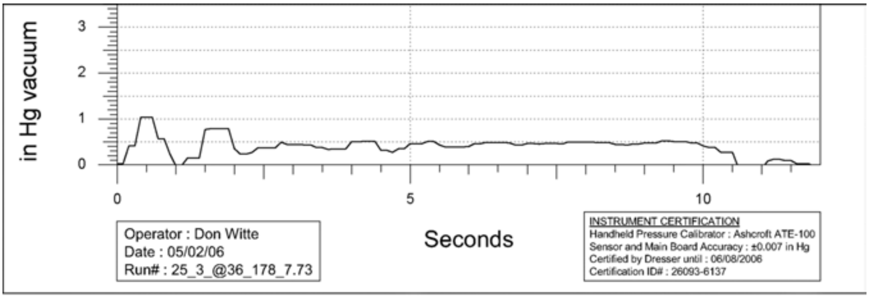
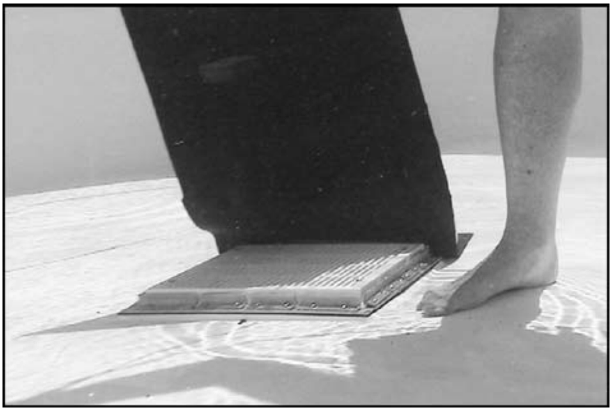


Figure 8 — Test Run #25, vacuum pressure versus time.

Photograph 8 — Neoprene rubber sheet covering 12″ × 12″ main drain.



Photograph 9 — Neoprene rubber sheet covering being pulled off of main drain.

#19, and #24) he used his arms or legs to nudge the floor and push off. In none of the 24 tests was the state of suction entrapment approached; the subject was able to remove himself from the main drain in each test run with almost no effort.

It is clear that all suction-entrapment test protocols should immediately be revisited to examine the maximum water velocity of 6 ft/s on the suction side of the pump as an upper limit with regard to evisceration and suction entrapment. The maximum acceptable water velocity providing at least a 2.4–1 safety factor, with two main drains, one sump open, and one covered with a grate or antivortex plate, is 6 ft/s. Six-feet-per-second velocity in a 1.5″ Schedule 40 PVC pipe represents a flow of 38.1 gal/min and in a 2″ pipe represents a flow of 62.8 gal/min. When maintaining a factor of safety in the hydraulic design of the suction side of the circulation system of over 2.4 using Debeugny's evisceration criteria, it is extremely important that the 6-ft/s velocity parameter in the suction piping not be exceeded in any wading pool, spa, or swimming pool. Some IAPMO- and ASME-listed 2″ suction fittings can develop suction velocities in excess of 14 ft/s when operating as listed. This high velocity, because of the inertia/kinetic energy it develops, has the potential to cause evisceration or suction entrapment considering Debeugny's criteria, 150 cm of water or 2.13 lb/in.^{2} or 4.34 in. Hg vacuum, even with dual main drains with one sump open and one covered with a grate or antivortex plate.

An average-sized 25′ diameter, 3,672-gallon wading pool, 6″ deep at its edge and 18″ deep at center, with a 61.2-gal/min circulation flow, turns over in under 1 hr, which is an adequate wading-pool turnover. A flow of 3,672 gallons per hour (61.2 gal/min) can be handled quite easily with a 2″ pipe operating at less than 6-ft/s velocity.

In analyzing the hydraulics of evisceration, there has been concern about the hydraulic inertia of the suction system and the separation distance of the two main drains. In most residential pools and spas, this appears to be a moot point. In most wading pools and spas the deep area is relatively small; therefore, the dual main drains will have to be located fairly close together. The separation distance of the main drains in the test fixture was 3′ (see Figure 1).

To be conservative, we are recommending that all main drains in any swimming pool, wading pool, or spa be (at least) dual main drains with a minimum separation distance of 3′ between drains in any dimension. Apparently, the distance of 3′ between the closest points on the drains has been used in many codes simply because it was always used. No substantiated research can be found to validate this dimension; however, in reviewing the separation distances in the suction-entrapment test and Dreyfuss 1993 anthropometric data (Tilley, 1993) on a 99th-percentile man (6′, 3.6″ tall, 244 lb), the distance between his hip and his shoulder is 20.5 in., indicating that a minimum 3′ separation distance between any dimension on a dual-main-drain system should be more than sufficient to prevent a single person from blocking two main drains simultaneously.

Next, the inertia of the suction side of the hydraulic system must be taken into account to prevent evisceration. It is recommended that the velocity in the suction side of the circulation system be limited to 6 ft/s. This hydraulic criterion has been used for years on the suction side of conservative aquatic circulation-system designs. The closer the main drains are to each other in a wading pool, spa, or a small swimming pool, the less the hydraulic inertia will be in a two-drain system when one of the drains is blocked. In this case, closer is better to a point, with a main-drain separation of a minimum of 3′ in any dimension. It is not necessary or even desirable in larger swimming pools with main drains that are 12″ × 12″ or larger to place them in such close proximity, because the grates are larger and separation gives better flow distribution in larger bodies of water.

In all 24 of the 2007 suction-entrapment test runs, the vacuum surged (spiked) in approximately the first second after the open main drain was blocked in the dual-main-drain tests. This dynamic phenomenon was caused by the changing hydraulic inertia in the system when the source of the water for the pump suction changed from two sources—two main drains—to one and by the speed with which the human subject blocked the open main drain. In Test Run #18 the initial spike was higher than in Test Run #19 even though the water flow was 11 gal/min more in Test Run #19. This spike was caused by the speed of the blockage, and it is observed that the spike plateau in Test Run #18 is below the one in Test Run #19, which would be expected.

The vacuum reading after the spike when one main drain was blocked is the increase in hydraulic friction because of increased water velocity in the system when the source of the water for the pump suction is changed from two main drains to one.

In the 2007 Florida tests with sufficient flow, when the subject blocked off the drain with his body he could feel the suction initially pull steadily at his abdomen. Shortly after blockage occurred, the strength of the suction began to undulate slightly during blockage until release.

Using a 3-HP pump, the largest swimming pool pump normally used on residential swimming pools in the United States, and 25′ of 1.5″ suction piping, it was easy to produce flows of 115 gal/min and a 17.8-ft/s velocity through the 1.5″ suction line piping in a dual-main-drain system. With this flow in Test Run #7, the vacuum in the blocked main drain was 7.24 in. Hg, or 3.55 lb/in.[2], and would not be expected to cause suction entrapment on the Hayward 7.75″-diameter SP-1052AV dual-main-drain system with one sump open and one covered with a grate or antivortex plate. *This level of suction would be expected to cause evisceration in that it is way beyond the Debeugny threshold of evisceration* of 4.34 in. Hg vacuum (2.13 lb/in.^{2}). Higher water velocities such as the 17.8 ft/s established in Test Run #7 in a 1.5″ suction pipe could increase the potential for suction entrapment. On Test Run #7, which did not cause suction entrapment on the Hayward 7.75″-diameter SP-1052AV sump, the subject had 3.55-lb/in.^{2} vacuum or 167.5 lb (Force [lb] = area [in.^{2}] × pressure [lb/in.^{2}] = [π × diameter^2/2^2 × pressure]; 3.14 × 7.75^2 × 3.55)/4 = 167.5 lb) on his abdomen holding him down, but it was not hard for him to break the seal and push off. When a person is able to release himself or herself from main-drain suction, he or she does not lift straight up but, rather, rolls off. The moment the seal is broken, the person is released from the suction.

Using a 3-HP pump and 25′ of 2″ suction piping, it was easy to produce flows of 115-gal/min and 11-ft/s velocity through the 2″ suction line piping in a two-main-drain system. With this flow the vacuum in the blocked main drain was 3.18 in. Hg, or 1.56 lb/in.^{2}, and would not be expected to cause evisceration or suction entrapment on the Hayward 7.75″-diameter SP-1052AV dual-main-drain system with one sump open and one covered with a grate or antivortex plate. This level of suction is *below* the Debeugny threshold of evisceration of 4.34 in. Hg vacuum (2.13 lb/in.^{2}) and would not be expected to be a risk for evisceration or suction entrapment.

Using a 3-HP pump and 25′ of 3″ suction piping, it was easy to produce flows of 178 gal/min and a 7.7-ft/s suction velocity through the 3″ suction line piping in a Pentair 12″ × 12″ dual-main-drain system. With this flow the vacuum in the blocked main drain was 1.2 in. Hg, or 0.6 lb/in.^{2}, and would not be expected to cause evisceration or suction entrapment.

In the 1.5″-suction-pipe test runs with 18″ water depth, the Debeugny threshold of evisceration was exceeded in four test runs: #4 (12 ft/s), #5 (14 ft/s), #6 (16 ft/s), and #7 (17.8 ft/s). In the 1.5″-suction-pipe test runs with 36″ water depth, the Debeugny threshold of evisceration was exceeded in two test runs: #18 (14 ft/s) and #19 (15.8 ft/s). The Debeugny threshold of evisceration was not exceeded in any of the test runs with 2″ suction pipe.

When maintaining a factor of safety in the hydraulic design of the suction side of the circulation system of over 2.4 using Debeugny's evisceration criteria, it is extremely important that the 6-ft/s velocity parameter in the suction piping not be exceeded in any wading pool, spa, or swimming pool.

In all of the test runs using 2″ pipe, dual main drains, and an unthrottled 3-HP pump, the largest pump normally used on a residential swimming pool, the Debeugny threshold of evisceration was not exceeded. The highest vacuum level reached was in Test Run #24, 3.18 in. Hg (2″ suction pipe, 18″ water depth, water velocity 11 ft/s and 115 gal/min).

Recommendations

Because of the large number of variables in the suction-entrapment process, there can be no absolute guarantee that entrapment in all of its forms will be universally avoided if the recommendations are followed. The recommendations significantly reduce risk but cannot guarantee the elimination of the potential for suction entrapment under all conditions.

To guard against and reduce the risk of suction entrapment and evisceration, we recommend the following:

- All wading pools, spas, and swimming pools should have at least two main drains that are connected to the circulation pump.
- All main drains and recirculation outlets in wading pools, spas, or swimming pools should be covered with approved/listed antivortex covers/grates/protective devices, which should be removable only with the use of tools. In the event that a main-drain cover is broken or missing the wading pool, spa, or swimming pool should immediately be closed until it is replaced.
- All the dual-main-drain suction-entrapment tests that operated at flows from 4 to 10 ft/s in water depths of 18″ and 36″ developed suction values below Debeugny's threshold of evisceration, whereas *some flows above 10 ft/s developed suction values in excess of Debeugny's threshold of evisceration*. Therefore, all present standards and suction-entrapment test protocols should be immediately revisited with regard to suction entrapment or evisceration.
- In any wading pool, spa, or swimming pool, a factor of safety of over 2 should be maintained. The maximum water velocity on the suction side of the pump should be limited to 6 ft/s or less to provide a safety factor of at least 2.4.
- There should be a minimum separation distance of 3′ between the main drains in any dimension, or, in the case of spas, the main drains should be located on different planes—floor and wall or wall and opposite wall—when the 3′ separation cannot be accomplished on the floor.
- In any wading pool, spa, or swimming pool, the suction side of the circulation system should be a "T" fitting and split, hydraulically balanced. Branches of the T shall have the same size plumbing as the main suction plumbing (see Figure 1). If the T is not equidistant between the two main drains, it is not hydraulically balanced and there is a potential problem because the friction losses are not uniform when one of the two main drains is blocked.

References

Centers for Disease Control. (1992). Suction-drain injury in a public wading pool—North Carolina, 1991. *Morbidity and Mortality Weekly Report, 41*(19), 333–335.

Debeugny, P., Bonnevalle, M., Besson, R., & Basset, T. (1990). Lesion recto-sigmoldiene par aspiration trans-anale [A recto-sigmoid lesion due to trans-anal aspiration. Apropos of a case]. *Chirurgie Pediatrique, 31*(3), 191–194, 31.

Ehret, G.F., & Rowley, W.N. (1974a). *Swimming pool main outlet tests*. El Monte, CA: Swimquip, Inc.

Ehret, G.F., & Rowley, W.N. (1974b). *Swimming pool main outlet tests*. El Monte, CA: Swimquip, Inc.

Ehret, G.F., & Rowley, W.N. (1974c). *Swimming pool main outlet tests (skimmer in line)*. El Monte, CA: Swimquip, Inc.

Ehret, G.F., & Rowley, W.N. (1974d). *Swimming pool main outlet tests*. El Monte, CA: Swimquip, Inc.

Rowley, W. N. (1974). *Swimming pool main outlet tests (adjunct report)*. El Monte, CA: Swimquip Inc.

Rowley, W.N., & Egstrom, G.H. (1997, June). *Dual main drain suction entrapment-hair entrapment/entanglement test report*. Colorado Springs, CO: National Swimming Pool Foundation.

Rowley, W.N., & Ehret, G.F. (1976). *Primer on suction entrapment in swimming pools or therapeutic pools*. El Monte, CA: Swimquip Inc.

Tilley, A. (1993). *R., the measure of man and woman*. New York: Henry Dreyfuss Associates/ The Whitney Library of Design.