BIG SURF WATERPARK

DESIGNATED A HISTORIC MECHANICAL ENGINEERING LANDMARK

BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

August 17 2013,

1500 N. McClintock Dr., Tempe, AZ 85281

"What was there about the waves? I do not know, except that they were beautiful. To me they were very beautiful when people were riding them"

-Phil Dexter

Figure 1: Phil Dexter at Big Surf Waterpark (Sports Illustrated, 1969)

THE ENTREPRENEUR

In 1965, while driving from one job in San Diego to another in Los Angeles, construction engineer Phil Dexter would often pull over to watch the surfers. "What was there about the waves?" I do not know, except that they were beautiful. To me, they were very beautiful when people were riding them," says Dexter, now 86 and living in Connecticut.

Dexter's fascination with waves fueled him to create his own, and once his California projects were complete, he sought to make his dream a reality in Phoenix. Long before the notion of the Waterpark, Dexter stayed busy trying to develop what he then referred to as a "surf center." In his backyard, he developed a hydraulic-propelled model that he later expanded inside an abandoned billiards hall. This design, which accounted for the height of the head of water, the size and speed of a submerged gate, the shape and height of the baffle, and the configuration of a lagoon over which the waves would roll, created 60 thousand rolling waves in one summer. Soon, Dexter enlisted an engineering firm, began the patent process for his wave maker, and sought investors.

HISTORIC MECHANICAL ENGINEERING LANDMARK

BIG SURF WATERPARK

1969

BIG SURF WATERPARK WAS THE FIRST WAVE POOL IN NORTH AMERICA TO CONSISTENTLY GENERATE 3–5 FOOT SPILLING WAVES SUITABLE FOR SURFING. DESIGNED BY PHIL DEXTER, THE FACILITY USES 15 GATES THAT EMPTY WATER FROM A RESERVOIR INTO A 2.5 MILLION GALLON LAGOON WITH CONTOURS THAT REPLICATE A NATURAL BEACH. WATER RELEASED BY THE GATES FLOWS OVER A BAFFLE, SIMILAR TO A NATURAL REEF, THAT FORMS ONE WAVE PER CYCLE. PUMPS RECIRCULATE WATER FROM THE LAGOON BACK TO THE RESERVOIR.

A FAST-ACTING DIRECTIONAL VALVE CONTROLS OIL FLOW TO HYDRAULIC PISTONS THAT ACTUATE THE GATES. THIS SYSTEM CAN ALTER THE HEIGHT AND FREQUENCY OF THE WAVES. IT USES WATER-SOLUBLE OIL AND INCLUDES AN ACCUMULATOR AND PIPE SNUBBERS TO CONTROL WATER HAMMER AND SHOCK. ALL HYDRAULIC SYSTEM COMPONENTS ARE ORIGINAL.

ASME THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS 2013

AT A GLANCE

ASME has designated Big Surf Waterpark as an ASME historic mechanical engineering landmark recipient as the first inland surfing facility in North America.

Big Surf Waterpark opened in 1969 as a 20 acre complex in Tempe, 10 miles east of downtown Phoenix. The Waterpark's Waikiki Beach uses a mechanical wave machine that creates a single transverse wave of sufficient height and duration to permit surfing.

Dexter showed off the wave machine at Big Surf's first press conference in September 1969. At the grand opening of Big Surf, the machine generated waves five feet tall every minute. The waves generated by the wave maker are considered perfect spilling waves that are ideal for surfing, in particular for beginner to intermediate surfers. The facility is still in operation, using all the original components for surfing, body surfing, boogie boarding and rafting.

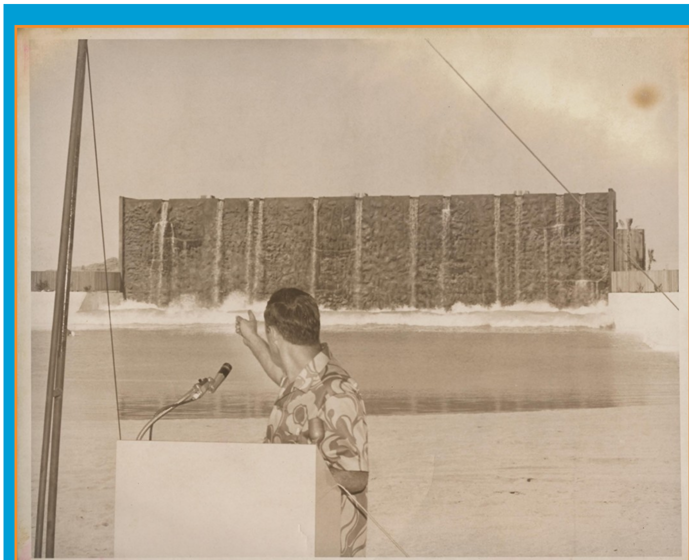


Figure 2: Picture from first press conference with Phil

HISTORY AND SIGNIFICANCE

Unfortunately, surfing is dependent on the natural wave action of the ocean. Normally, surfers must go to the ocean to enjoy this sport and learners must face the unpredictable waves the ocean throws at them. Big Surf is capable of generating a single translatory wave, perfect for surfing. Prior to the opening of Big Surf, wave pools used surface agitation to generate waves, unsuitable for the sport of surfing.

Wave Pool technology can be traced back to the 19th century when Ludwig II of Bavaria, known as the "mad King," built a swimming pool with a "wave board" to imitate the swell of the ocean in Castle Linderhof, Germany (Membery, 2000). 1912 marked the construction of a saltwater wave pool, 400 feet by 600 feet (240 thousand sq. ft.), with waves generated by a waterfall at the famed Palisades Amusement Park in New Jersey (Myers, 1981). An artificial wave pool, 5,382 square feet, was built in 1927 at the Gellért Baths, Budapest, Hungary that to this day creates a series of broken waves (Gellért Bath and Spa). Other wave pools include the 1934 Wembley Swimming Pool which used a submerged paddle wheel to create a series of "ankle slapping waves" (Warshaw, 2010). The only wave pool contemporary to Big Surf is Point Mallard Wave Park, opened on August 8th, 1970 with a 75 foot by 140 foot (16 thousand square feet), 400 thousand gallon pool generating three-and-a-half feet tall waves.

Big Surf was the first wave pool in the US to create a single traveling wave – perfect for surfing with waves originally up to five feet in size every 45-80 seconds. Waves are produced by storing a predetermined head that is released beneath the surface of a body of water against a baffle. Simple in design, it uses minimal components, and reduces a water pollution by utilizing a filtration system. The Big Surf Waterpark mechanisms are over 40 years old and continue to work flawlessly.

WAVEPOOL DESCRIPTION

In order to generate single surfable waves, two things are required: a surfing area, known as the lagoon, and a reservoir area for wave production. A pump takes water from the recirculation basin and stores the water until reaching a predetermined head. Then, 15 gates at the bottom of the reservoir are opened and water is released, converting potential energy into kinetic energy. Upon release, the water hits a baffle, designed specifically to deflect the water upwards to create a translatory (straight moving) surface wave. To summarize, the wave is created by virtue of the potential energy of the hydraulic head due to the raised water, the speed at which the gates open, the duration of time the gates are open and the shape of the baffle.

Main components that make up a wave pool , as seen in Figure 3.

1. A water-distribution system
2. A wave generation mechanism comprising the water-collection reservoir
3. A water release mechanism, a series of gates at the bottom of the reservoir
4. A giant, slanted swimming pool – known as the lagoon
5. A return canal, leading from the beach area to the pumping system
6. Control circuit for opening and closing the gates

Each component will be discussed in turn in the following sections.

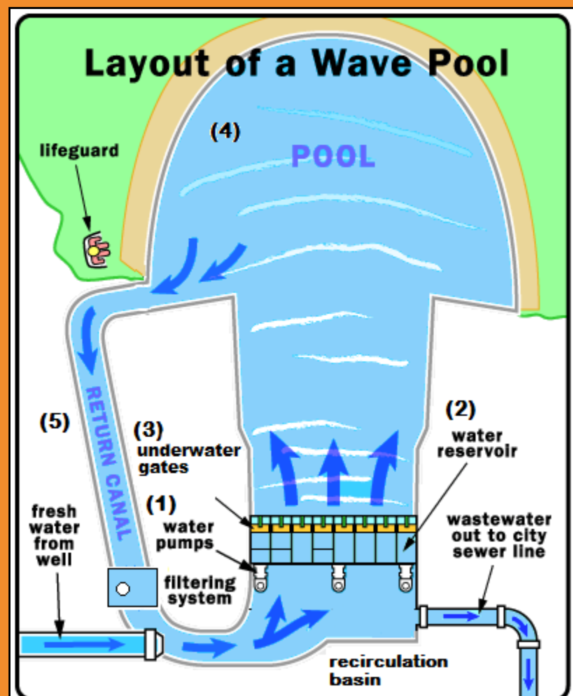


Figure 3: Schematic of wavepool layout

THE LAGOON

In its entirety, the lagoon dimensions is 400 feet long and 300 feet wide, including the artificial beach and external walk ways for lifeguards. It contains four million gallons of re-circulating treated water. The floor of the lagoon becomes shallower further away from the reservoir and the width increases to prevent waves from reflecting and spoiling the purity of the oncoming waves. Prior to opening in 1969 the original surface floor of the lagoon was changed from vinyl to concrete as this material was more durable. **Figure 4,** in the background**,** shows the engineering drawing of the built lagoon.

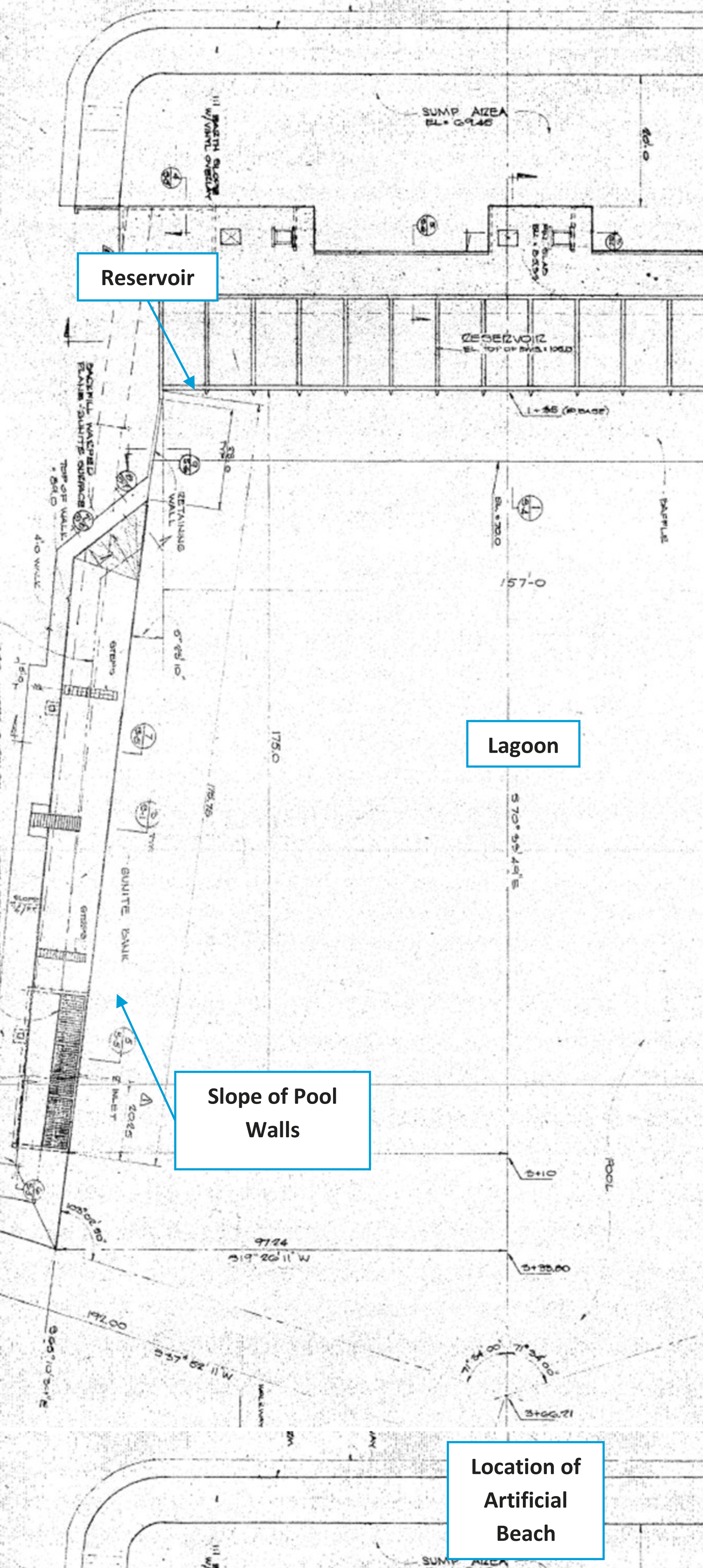


Figure 4 (Background): Engineering drawing of built lagoon.

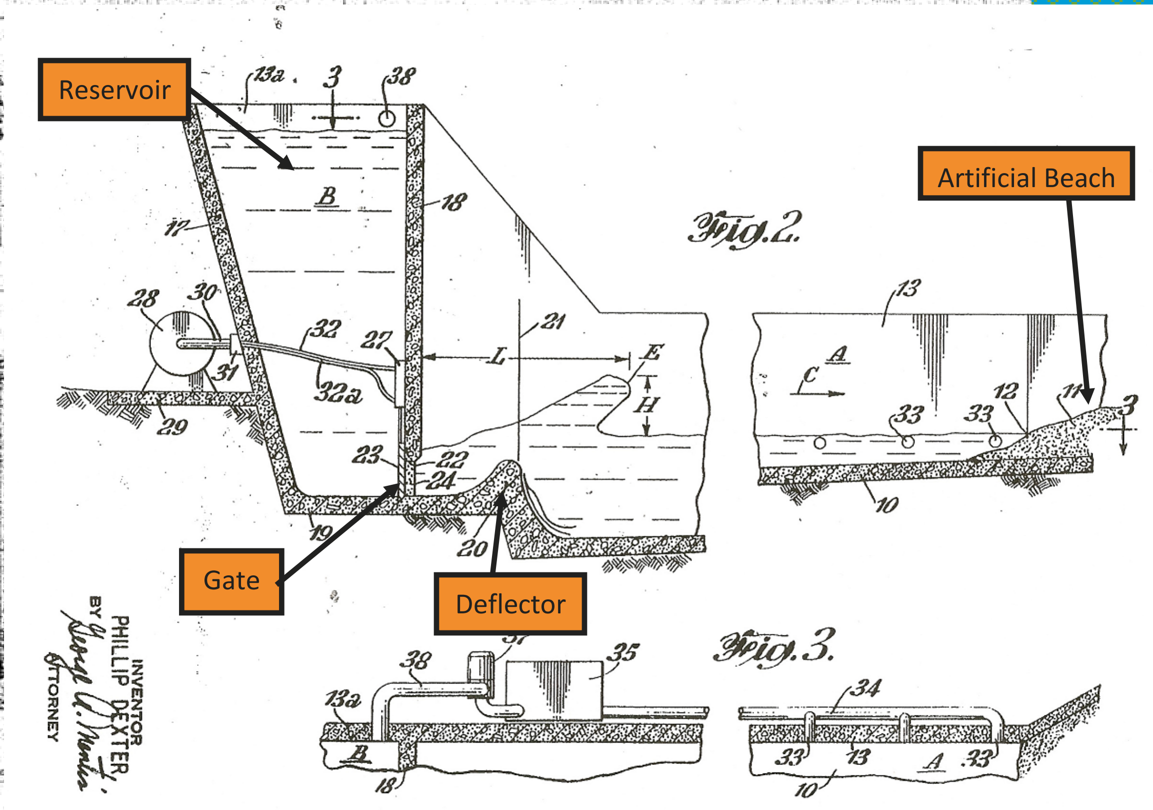


Figure 6: From Phil Dexter's patent, a schematic of the reservoir and baffle area. Symbols and numbers denote patent application bullets and are not herein described.

WAVE GENERATION MECHANISM

The construct is simple in design – it employs an underwater gate that works in a similar way to the flapper on a toilet: filtered water is pumped into a reservoir that is separated from the "surfable" lagoon by a wall with an underwater gate. The design distinguishes itself from a toilet by the presence of an underwater baffle and variable depth lagoon (Dexter, 1969).

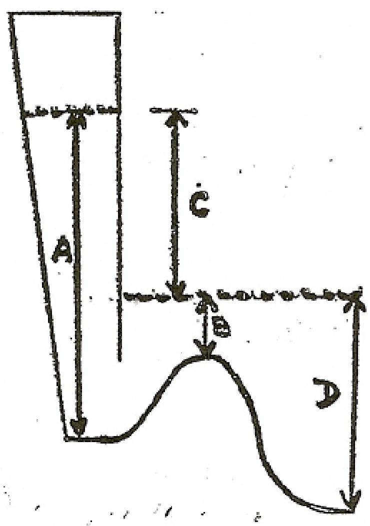
The gate opens rapidly and the released water then pushes through the underwater opening hitting the underwater baffle, as shown by the engineering drawing located in the background in **Figure 5**. As water hits the baffle, it deflects and rotates the oncoming water mass toward the surface. As the water moves forward, the lagoon shallows in depth, allowing the waves to effectively break as they would at a shoreline in nature. **Figure 6** shows a schematic of the baffle and shoreline from Dexter's original patent. The artificial shoreline also eliminates the reflection of waves, which therefore preserves the wave's shape. These waves are known as spilling waves. The height of the spilling waves is controlled by the horizontal water velocity and water mass, which is in turn controlled by the height of water within the reservoir as well as the speed at which the gate opens. Upon releasing the water from the reservoir, potential energy is converted to kinetic energy, and the mass flow rate of water is controlled by two interre-

Figure 5 (Background): Original engineering drawing showing the reservoir and the baffle.

Table 1 is reproduced from Dexter's original patent (Dexter, 1969) where the relationship between reservoir depth, depth over the apex of the baffle, the hydraulic head and lagoon depth, and wave formation quality is explained. In the final build, the reservoir depth (A) was 20 feet, the depth of the lagoon (B) is eight feet and water depth over apex is two feet, which creates optimal conditions for developing translatory waves for surfing. The reservoir is 24 feet high, 20 feet deep and 157 feet wide and made out of steel/rebar reinforced concrete.

Table 1: Relationships between key parameters of the wavemaker and type of wave formation .

TABLE I.—BAFFLE A-1
Approx. Gate Opening Speed=150′ min.
Dist. from Gate to Apex=9′
Apex Height=3′



Legend	Reservoir Depth (A)	Water Depth Over Apex (B)	Hydraulic Head (C)	Lagoon Depth (D)	Wave Formation Quality Description
	15′	2′	10′	8′	SWELL
	17′	2′	12′	8′	↑
	19′	2′	14′	8′	IDEAL RANGE
	21′	2′	16′	8′	
	23′	2′	18′	8′	↓
	25′	2′	20′	8′	EXPLOSION
	19′	3′	13′	9′	SWELL
	21′	3′	15′	9′	↑
	23′	3′	17′	9′	IDEAL RANGE
	25′	3′	19′	9′	
	27′	3′	21′	9′	↓
	29′	3′	23′	9′	EXPLOSION
	22′	4′	15′	10′	SWELL
	24′	4′	17′	10′	|
	26′	4′	19′	10′	|
	28′	4′	21′	10′	↓
	30′	4′	23′	10′	IDEAL RANGE

Factors of Wave Formation:

1. The pressure difference between the height of the water in retained head of the reservoir and the height of the surfing area (lagoon area). This is a direct function of the hydraulic head in the reservoir, which varies proportionally with height of the column of retained water in the reservoir.

2. The interval of time through which the pressure difference operates to discharge water from the reservoir and the amount of water released during that interval of time. The size of the gate, the speed at which the gates open and the amount of time the gate remains open dictate the speed and the mass flow rate of water released.

3. The amount of vertical rise of the front upward sloping face of the baffle.

4. The slope of the bottom of the body of water with respect to the frictional value of the material comprising the bottom. This is a fundamental part of the invention as without this slope the wave would revert to a swell and not break to form a translatory wave suitable for surfing.

WATER DISTRIBUTION SYSTEM

The settling basin (recirculation basin) holds 500 thousand gallons of water, the reservoir holds 500 thousand gallons of water, and the lagoon holds 2.5 million gallons of water. Water is pumped from the recirculation basin to the reservoir using two of the three pumps 250 HP natural gas engines (Model G342). Each Caterpillar pumps 110 thousand gallons per minute from the recirculation basin into the reservoir. At maximum capacity each pump can pump 35 thousand gallons of water per minute. Fifteen gates open simultaneously to release 70-90 thousand gallons of water into the lagoon area. Water returns from the lagoon and passes through a filtration system. This is achieved using a 250 HP Caterpillar engine which pumps 8,000 gallons per minute from the settling basin through a high rate sand filter system. Once the water is filtered, it passes through an automatic gas chlorination system for water treatment.

WATER RELEASE MECHANISM

There are 15 gates in total, each 10 feet, weighing approximately 1,000 pounds per foot. Each gate is made of foam-filled steel and is fixed to a shaft at one end. Once the reservoir is full, each gate is opened simultaneously by a hydraulic piston. The activation of the hydraulic piston is controlled by a high-speed directional control valve, and is powered by a hydraulic pump. The pump keeps a steady stream of pressurized oil flowing into the system to move the piston inside the cylinder, therefore, moving the gate. Since the hydraulic pistons are underwater, water-soluble oil is used to prevent contamination of the swimming water in the event of an oil leak.

At the time of the grand opening, it was reported that the gate opened in 1.7 seconds (Sports Illustrated, 1969). This requires an extremely fast directional valve, as well as a hydraulic circuit that permits fast switching and minimizes any fluid hammers and dynamic pressure spikes. The system designed was custom-made specifically for this purpose by John Hauskins. To this day, Big Surf still has all the original blueprints from construction, as well as the original equipment still running the wave generator, including the Vickers Eaton hydraulics.

CONTROL CIRCUIT

As previously discussed, the speed at which the gates open and the amount of time the gate remains open dictate the speed and the mass flow rate of water released, thus a key variable in the generation of surfable waves.

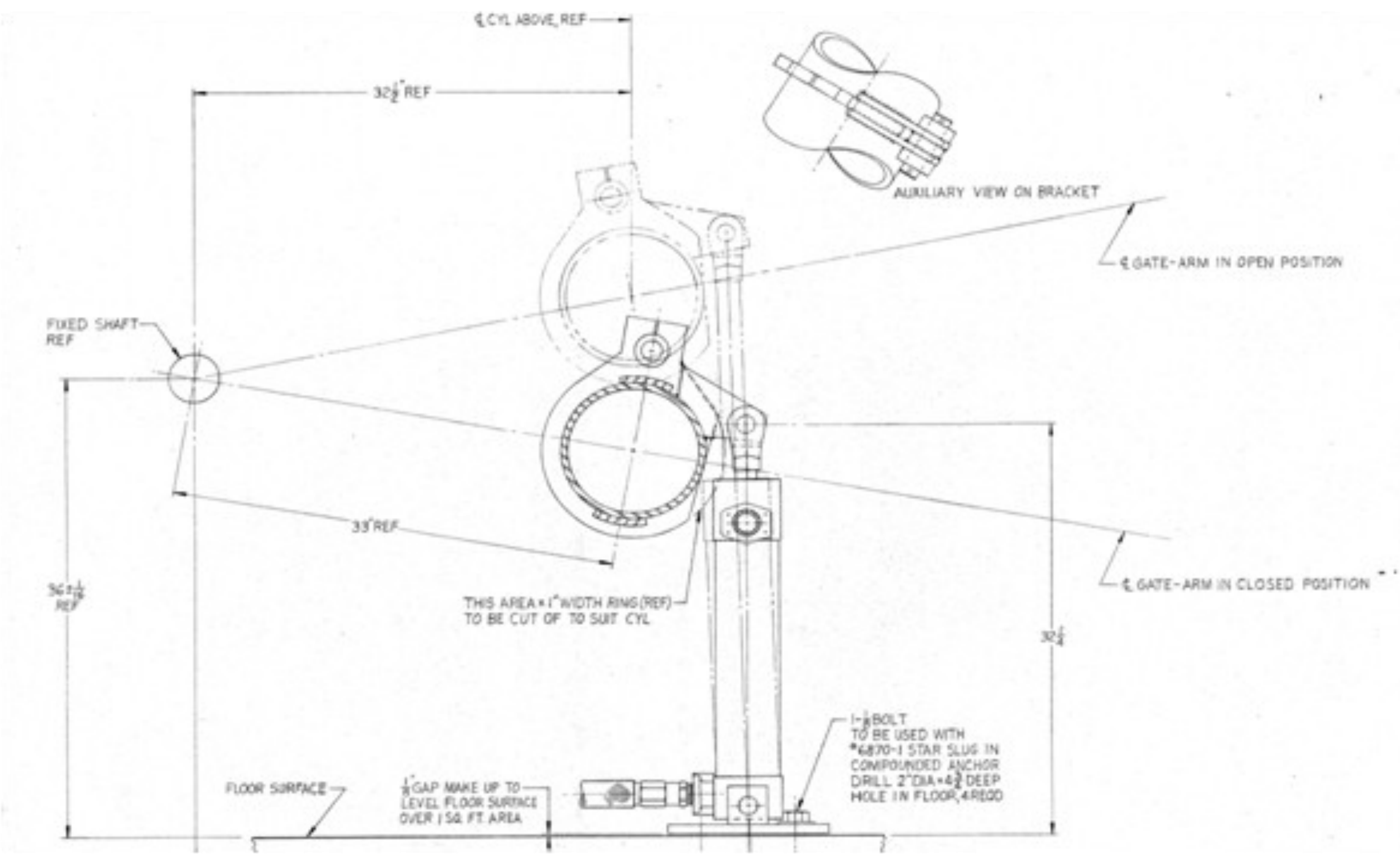


Figure 7: Engineering drawing showing the hydraulic system interaction with the gate.

The speed of opening and closing of the gates is controlled by a control circuit, a schematic is shown in Figure 8. Components of the control circuit include:

- Hydraulic Pump (50 HP). Provides hydraulic power to the 15 lifting cylinders.
- Lifting Cylinder, or hydraulic actuator, raises and lowers a single gate. Each cylinder is filled with vegetable oil to prevent lagoon contamination.
- Hydraulic Tank. Acts as a return flow, oil reservoir and ensures adequate oil availability.
- Accumulator. A compressed gas, closed accumulator is located close to the pump to dampen pressure spikes. Unwanted pressure spikes are caused by sudden stops in fluid motion or changes in momentum (e.g. gate reaching open/close position) and damage system components.
- Snubbers. Prevent sudden hydraulic tube movement due to dynamic pressure spikes.
- High Speed Valve and Gas Actuators. Two mechanically connected, solenoid-driven, gas actuators provide power to the high speed (spool) valve. The spool valve alternately ports working and return pressure to the lifting cylinder. In the position shown, the spool valve ports working pressure and return flow to raise the gate [cylinder activating]. When the valve is spooled to its opposite end, working pressure and return flow are reversed, commanding the gate to lower.
- Timing Circuit. System timing is provided by the electrical timing circuit [not detailed here]. Proper settings of 15 independent timing circuits permit all gates to open simultaneously. Alternatively, staggering each solenoid trigger time permits creation of a diagonal wave.

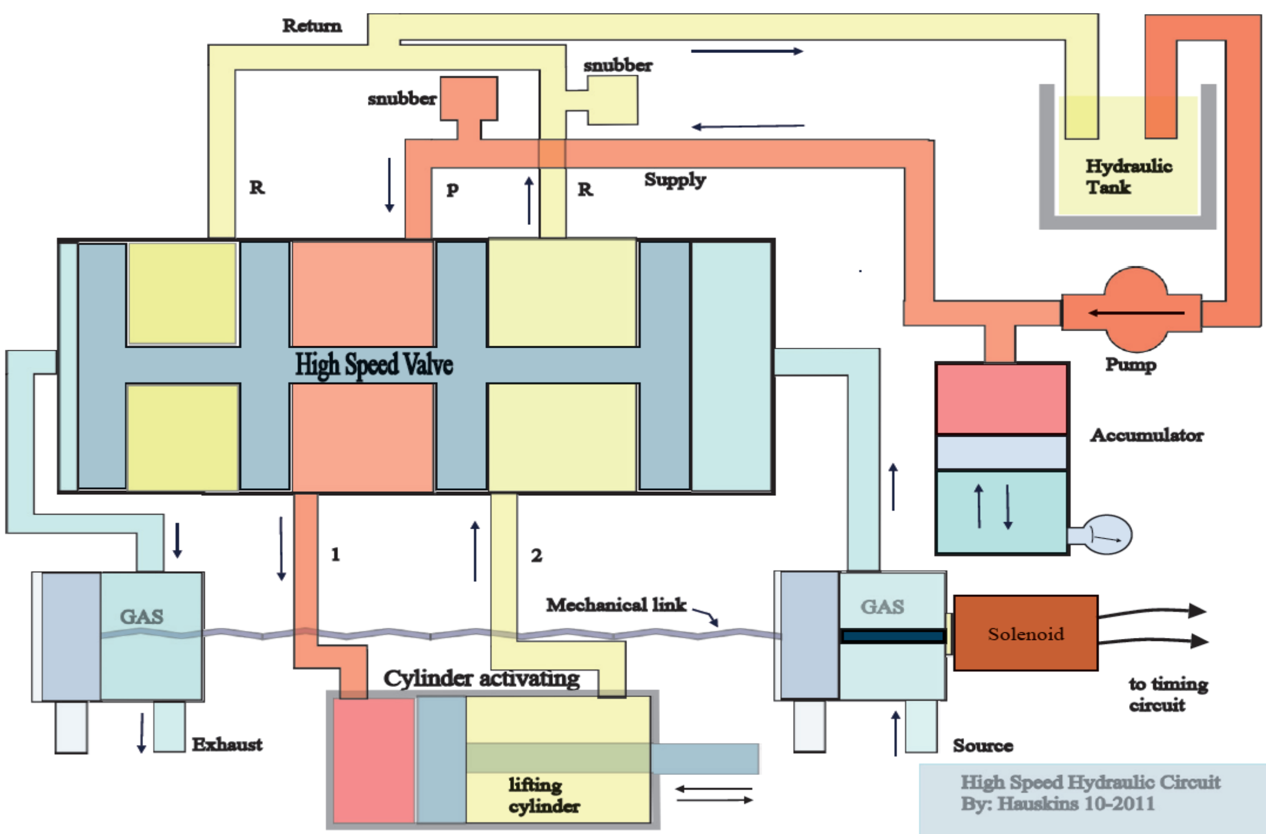


Figure 8: Schematic of Hydraulic Circuit (Personal communication with John Hauskins, October, 2011)

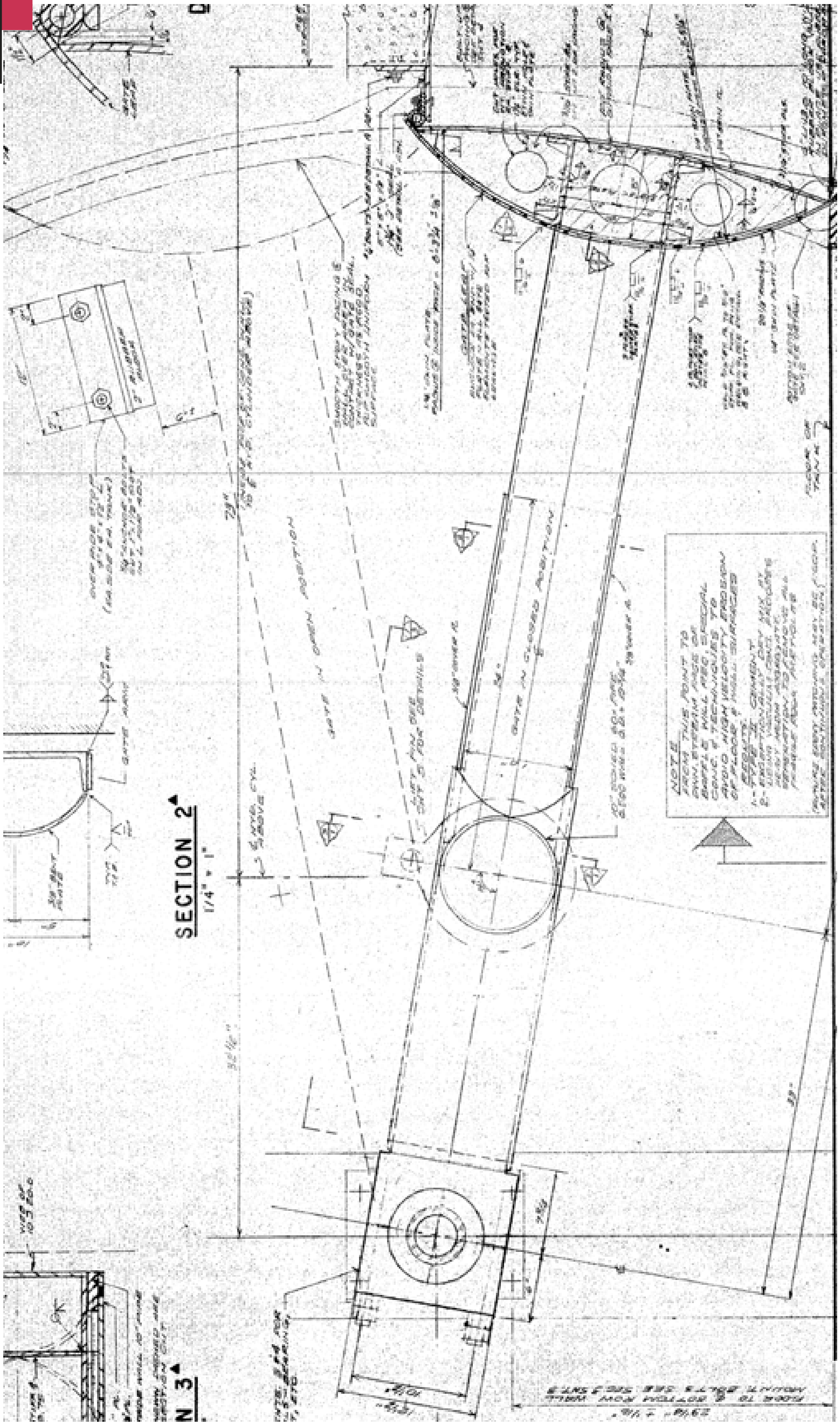


Figure 9: Original Engineering Drawing of a Single Gate

DEVELOPMENT AND CONSTRUCTION

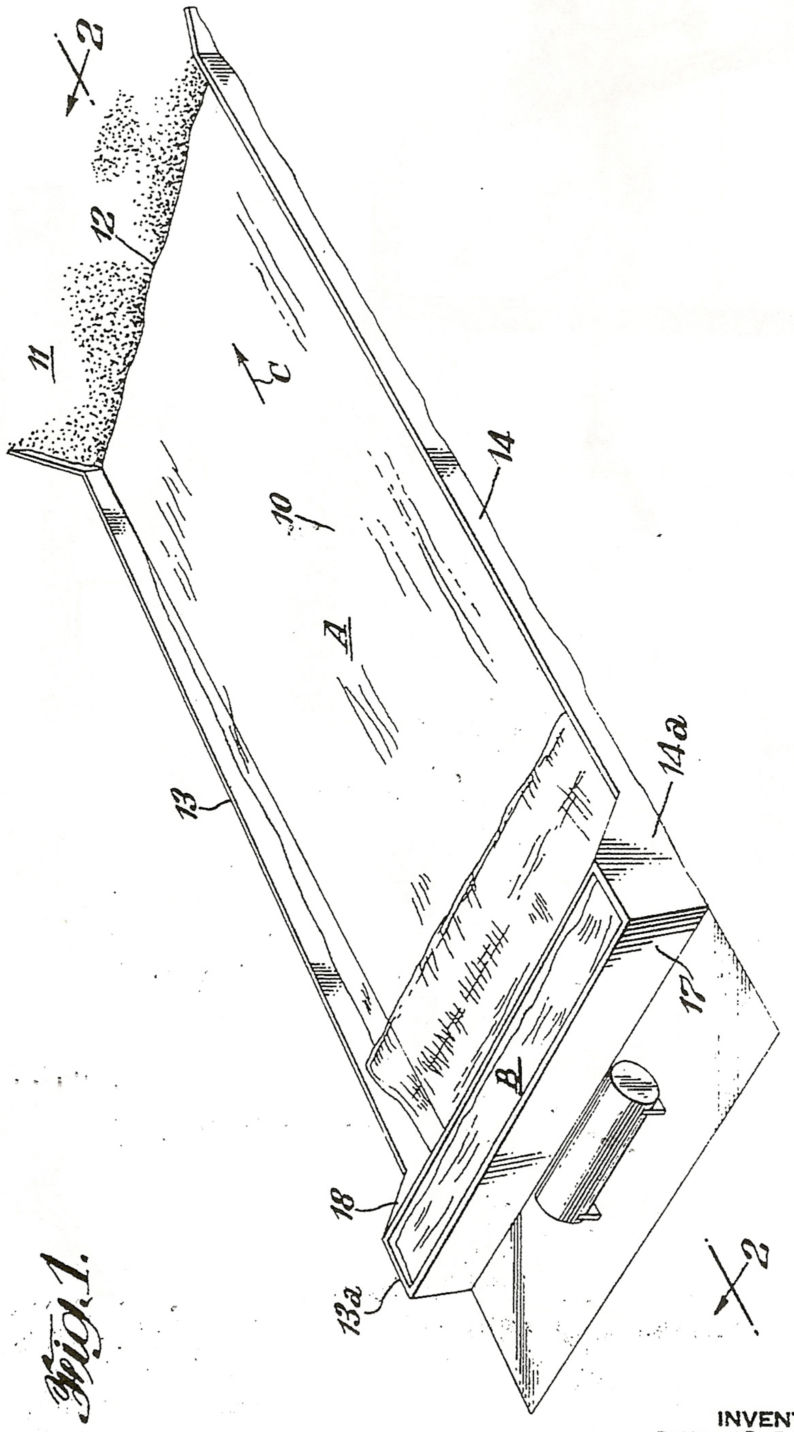
Dexter filed a patent on "Apparatus and Method for Producing Waves" on December 7th, 1966 (Ser. No. 599,758) (Dexter, 1969).

By the end of the summer of 1967, in a bankrupt billiards hall in Phoenix, he had made another prototype that automatically created waves every 20 seconds in a miniature lagoon, 40 feet by 30 feet, and held 1,000 gallons of water. This prototype was a miniature replica of the final wave pool at Big Surf Waterpark. Nineteen-year old John Hauskins, a young student, was studying at the University of Arizona and working on the project during his summer breaks. The consulting firm, Sergent, Hauskins & Beckwith, aided the construction and the design of this replica. Norwegian architect, Dr. Brunt, was called in to consult on this project.

Oct. 21, 1969 P. DEXTER 3,473,334

APPARATUS AND METHOD FOR PRODUCING WAVES

Filed June 24, 1968 4 Sheets-Sheet 1

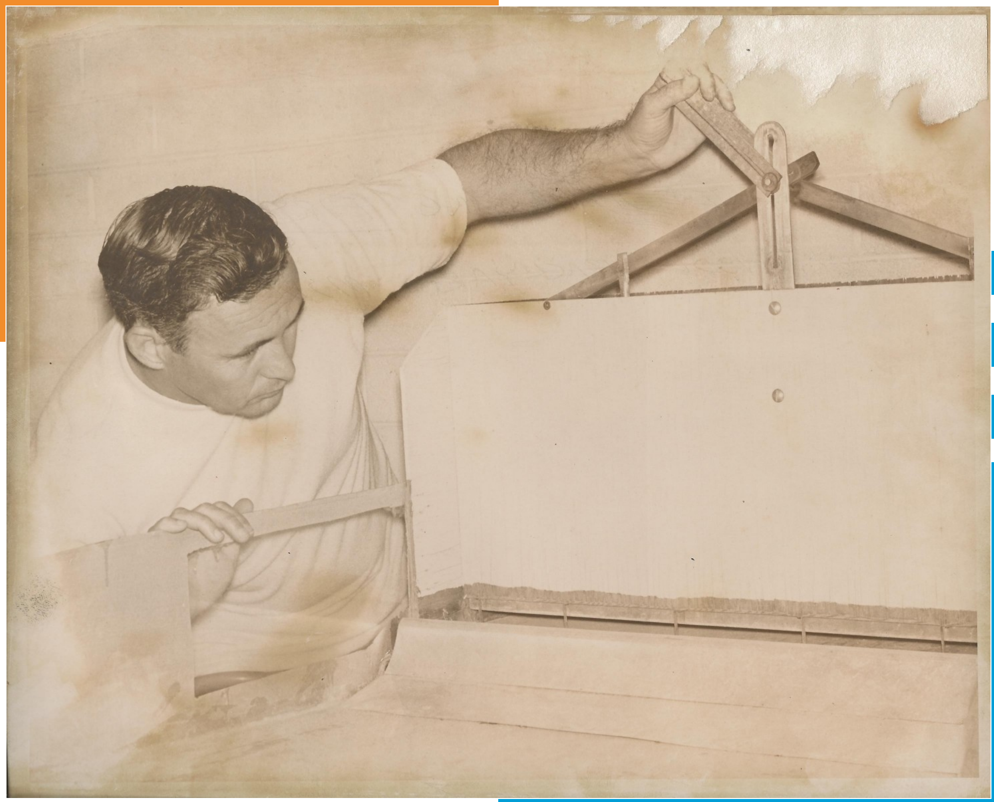


INVENTOR
PHILLIP DEXTER
BY George A. Mentis
ATTORNEY

THE PROTOTYPE WAVEMAKER

Figure 10, left, shows the original drawing of the prototype wavemaker. The drawing shows a **reservoir** of water held in a container. A gate, not pictured, releases this water which is then forced over the **deflector**. This produces a translating wave which travels along the length of the **lagoon**, and finally ends at the **artificial beach** where the

Figure 10: Original Prototype Wavemaker Schematic as described in Patent 3473334



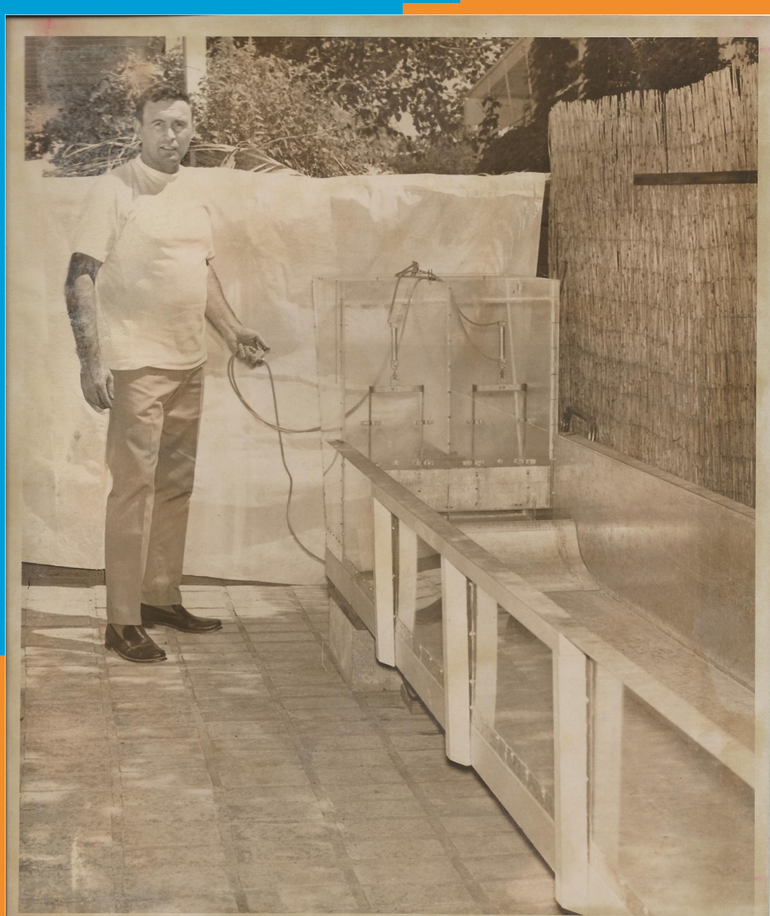


Figure 11: Clockwise from top: (1) Phil With Proof of Concept Tabletop Model, (2) Phil With Large-Scale Wavemaker Model; (3) Scale Model of Waikiki Beach

PROGRESSION OF BIG SURF

Although all of the original equipment is still used at Big Surf, many operational functions have been modified to better accommodate maintenance and the preferences of guests.

Originally, Big Surf employed three pumps, powered by 250 HP Caterpillar natural gas engines. At maximum capacity, each pump can pump 35 thousand gallons of water per minute. Currently, two pumps, 250 HP Caterpillar natural gas engines (Model G342), pump 73 thousand gallons per minute from the settling basin into the reservoir. The third pump is kept in reserve to be used during the maintenance of the other pumps. Originally, three to five feet waves were generated every 45 to 80 seconds. Currently, waves are kept to three feet and are generated every three minutes. Dexter was found that if waves were generated any faster than this, the surfers could not get back on the surf board fast enough.

Figure 12: Surfers at Big Surf Waterpark, 1970. (Life Magazine)

Table 2: Details of Big Surf's Design Characteristics Over Time

	Original	Current
Water Stored in Settling Basin	500 thousand Gallons of Water	500 thousand Gallons of Water
Water Stored in Storage of Reservoir	500 thousand Gallons of Water	500 thousand Gallons of Water
Water Stored in Storage of Lagoon	Four million Gallons of Water	2.5 million Gallons of Water
Engines Utilized	Three 250 HP Caterpillar natural gas engines (Model G342)	Two 250 HP Caterpillar natural gas engines (Model G342)
Size of Waves Generated	Three to Five feet	Three feet
Time Between Wave Generation	45 to 80 Seconds	Three Minutes

PRESENT DAY BIG SURF WATERPARK

The waterpark continues to evolve: The park features water slides, a toddler's area, and inner tubes. In its current configuration, the wave pool contains 2.5 million gallons of water, covers two-and-a-half acres, and creates lasting memories, wave after wave. Churning out waves for over 40 years, the water park delivers refreshment and relief to droves of guests, under a hot Arizona sun; while paying homage to one Phil Dexter. As Dexter put it, while recanting an arduous 1969, "Building Big Surf was a wonderful experience." And a wonderful experience awaits everyone who visits Big Surf Waterpark.

Figure 13: Present day view of the wavepool at Big Surf Waterpark.

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SETTING THE STANDARD

PHIL DEXTER

Phil Dexter was born in St. Clair, MI., in 1927. He grew up and attended school in Michigan and served with the United States Navy during World War II. While on a construction assignment in San Diego in 1965, Dexter first tried surfing and began developing his idea. He built his first model of the wave-making machine in his backyard in August, 1966, and tested it extensively that fall and winter. The following spring, he built a second, larger, full engineering model in an abandoned Phoenix pool hall. In October of 1969 in Tempe, AZ., North America's first wave pool, Big Surf, Inc., was open for business. Dexter walked away from Big Surf a few years after the surf center opened and moved between Arizona and Southern California. He always kept busy: investing in a company called Mural Masters, taking time out to sail in San Diego, and working for the Forest Service and the paper mill in Snowflake, AZ. In the late 80's Dexter and his wife, Valerie moved to Pinetop. After the passing of his wife, Dexter moved to New Bern, NC. He currently resides in Connecticut.

JOHN HAUSKINS, P.E. Transportation Director/County Engineer

John Hauskins is a native Arizonan, born in Phoenix. At 19 John worked on Big Surf WaterPark as part of his father's company, XXX. He has been a Registered Engineer in the State of Arizona for over 40 years. He has experience in the development community and private sector as a consultant. John worked for the Arizona Department of Transportation for 30 years prior to assuming his current position as Director of the Maricopa County Department of Transportation in 2007. During his diverse career, John has held increasingly responsible positions ranging from Project Design Engineer, to Research Engineer, to ADOT District Engineer, to his current leadership role as County Engineer for one of the largest counties in the United States. comprehensive perspective and knowledge of regional transportation-related issues.

BOB PENA General Manager, Big Surf, Tempe, AZ

A Prescott native, Bob began his career with Big Surf Waterpark as a maintenance mechanic in 1985. Shortly thereafter, Bob was elevated to maintenance director overseeing all of the waterpark's features with a keen understanding of the Waikiki Beach Wave Pool's original mechanics. In 2010, when ownership reclaimed management of the park from a third-party, Bob was elevated to General Manager overseeing, admissions, food and beverage service, marketing and of course maintenance.

THE HISTORY AND HERITAGE PROGRAM OF ASME Since the invention of the wheel, mechanical innovation has critically influenced the development of civilization and industry as well as public welfare, safety and comfort. Through its History and Heritage program, the American Society of Mechanical Engineers (ASME) encourages public understanding of mechanical engineering, fosters the preservation of this heritage and helps engineers become more involved in all aspects of history.

In 1971 ASME formed a History and Heritage Committee composed of mechanical engineers and historians of technology. This Committee is charged with examining, recording and acknowledging mechanical engineering achievements of particular significance. For further information, please visit http://www.asme.org

LANDMARK DESIGNATIONS There are many aspects of ASME's History and Heritage activities, one of which is the landmarks program. Since the History and Heritage Program began, 251 artifacts have been designated throughout the world as historic mechanical engineering landmarks, heritage collections or heritage sites. Each represents a progressive step in the evolution of mechanical engineering and its significance to society in general.

The Landmarks Program illuminates our technological heritage and encourages the preservation of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers. It also provides reminders of where we have been and where we are going along the divergent paths of discovery.

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