Design and Construction of Nat Herreshoff's X.P.D.N.C

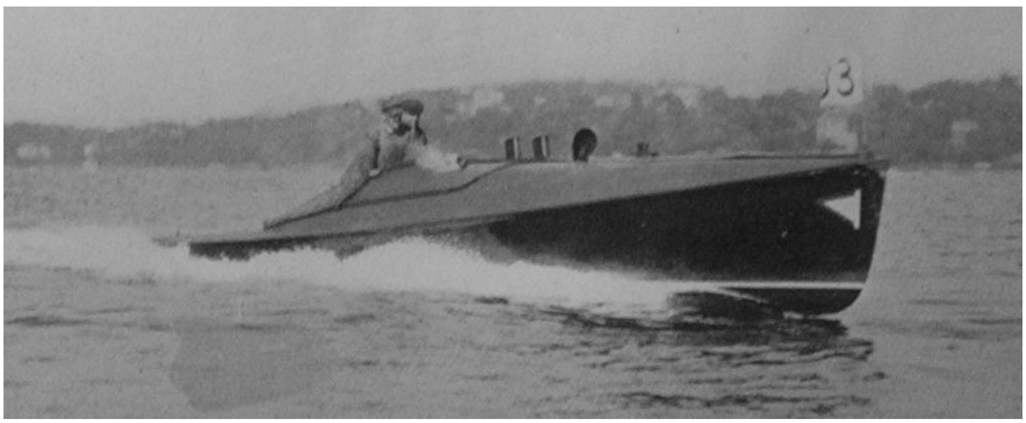


Figure 1: X.P.D.N.C (The Rudder, 1910)

by Michael G. Morabito

Introduction

X.P.D.N.C. (EXPEDIENCY) was built during the tumultuous racing season of 1904, the year that the first major power boating events in America were held. This was a time when long, slender motorboats, built as light as strength would permit, roared across racecourses in New York, Narragansett Bay, France and England at speeds sometimes in excess of 25 miles per hour. In the midst of this motorboat fever, Nat Herreshoff built SWIFTSURE a 100-hp steam launch to show that it was possible to build a lightweight steam plant that would drive a launch just as fast as a gasoline engine would, while being more reliable (Crane 1952). Although SWIFTSURE was an excellent design, and a very fast boat, she was defeated by the gasoline launches STANDARD, winner of the first Gold Cup, and VINGT-ET-UN II, a fast boat designed by Clinton Crane, and the winner of the second Gold Cup.

A few months later, Herreshoff built X.P.D.N.C., a racing launch powered by a 90-horsepower Mercedes gasoline engine. The boat raced against Crane's VINGT-ET-UN II and CHALLENGER, rumored to be fastest motor boat in the world, in the last, and longest, race of the season, a 136.6-mile round trip from Eighty-Sixth Street, in New York City, to Poughkeepsie and back. Herreshoff's boat ran nonstop, traveling at "railroad speed," and dashed across the finish line 59 minutes ahead of VINGT-ET-UN II. This made X.P.D.N.C. the fastest boat in America and put Nat Herreshoff on top of powerboating in the United States.

The success of X.P.D.N.C. was largely due to the light construction of her hull and the reliable 90-horsepower Mercedes engine that drove her. This was one of the best engines available coupled with a well-built hull from a great designer. The boat participated in races until 1910, a long and distinguished career.

Over one hundred years after her first race, Mr. Halsey Herreshoff showed an interest in having a replica of X.P.D.N.C. built. The purpose of this paper is to discuss the history, design, and construction of this boat and spark the interest of museums and boatbuilders in these early racing boats.

Historical Significance of X.P.D.N.C.

To Herreshoff enthusiasts, X.P.D.N.C. is representative of early Herreshoff torpedo boat design. She is also the most significant of the few gasoline racing boats that Herreshoff built. The success of this motorboat shows a side of the company that is usually eclipsed by Herreshoff sailboats.

For racing boat historians, X.P.D.N.C. is important because she has a well-documented racing history. The boat competed in major events from 1904 to 1910. She posted the best times during 1904, the very first year of significant motorboat racing in America. She was known worldwide as a benchmark of excellence in boat design.

For those interested in the construction and performance of classic boats, a replica of X.P.D.N.C. would occupy a special niche. There are very few large (35+ foot) displacement racers still in existence, and none in a condition to be run at speed. A replica of X.P.D.N.C. driven at race speeds, would demon-

Figure 2: Dixie and X.P.D.N.C. preparing for a race (The Rudder, 1905)

strate to everyone the amazing performance of these boats.

Basis for the Design of X.P.D.N.C.

"Model Made 1888" is written on the back of the half-hull model from which X.P.D.N.C. was built[1]. In L. F. Herreshoff's book, Captain Nat Herreshoff, he indicates that this was the model for a torpedo boat that was not built.

The torpedo boat was first developed during the American Civil War. These early torpedo boats carried spar torpedoes, explosives that were held at the end of twenty or twenty-five foot poles and detonated through an electrical connection. The job of the torpedo boat crew was to maneuver up to a large ship, bringing the explosives near to hull at the waterline, and then detonate them. Before the development of spotlights and rapid-fire weapons, this job was not as impossible as it may seem; however, fast, maneuverable and quiet boats were a requirement. After the Civil War, Herreshoff began building many torpedo boats for foreign nations. These boats were light, slender, and double-ended, and they could go ahead or astern at almost the same speed.

In 1876, Herreshoff built LIGHTNING, which eventually became the first torpedo boat the U.S. Navy bought after the Civil War. "She was 58 ft long, fitted with spar torpedoes, and made about 17.5 knots on trial" (Gillmor, 1897). A photo of LIGHTNING can be seen in Figure 3.

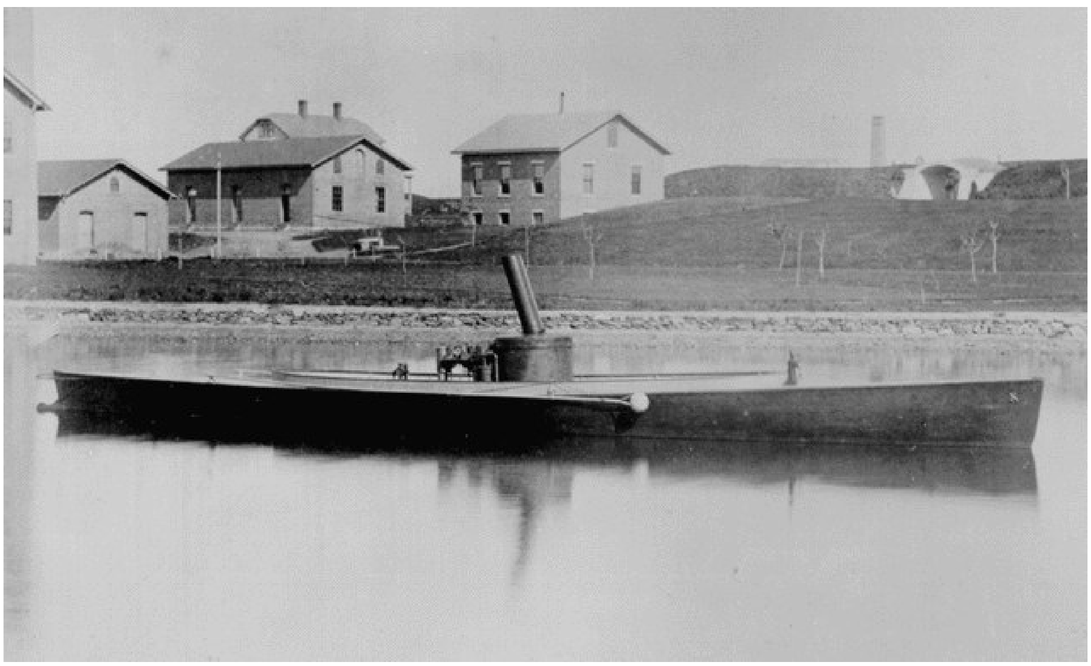


Figure 3: LIGHTNING (© Herreshoff Marine Museum)

In 1885, during a time of great prosperity from sales of steam vessels in the U.S. and torpedo boat sales to foreign nations, J. B. and Nat Herreshoff had the speed yacht, STILLETTO, built. The 94-foot boat became famous when the Herreshoffs challenged the 300-foot

1. Model text provided by Herreshoff Marine Museum

MARY POWELL to a Hudson River race. The MARY POWELL was capable of speeds up to 25 miles per hour and had been the fastest boat in American waters since 1861. STILLETTO defeated MARY POWELL and set a world record of 26.2 miles per hour. The Navy purchased STILLETTO in 1888 and converted her to a torpedo boat. A lithograph of STILETTO defeating MARY POWELL can be seen in Figure 4. Two years later, Herreshoff took the order for CUSHING, the first purpose-built U.S. seagoing torpedo boat.

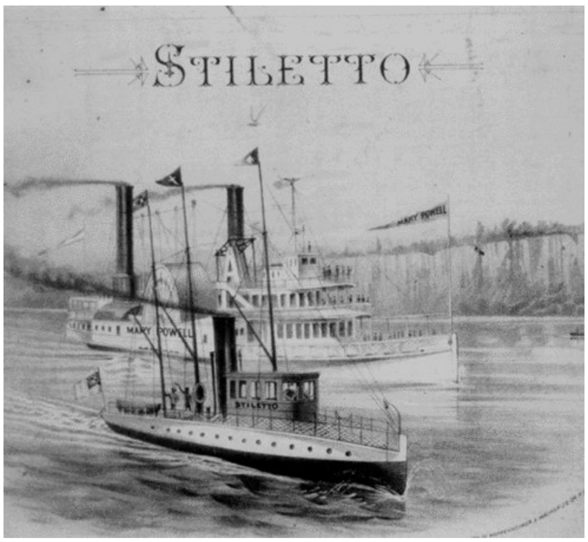


Figure 4: STILETTO defeating MARY POWELL (Courtesy Herreshoff Marine Museum)

When the first gasoline engines became available for marine use, speed was not a primary concern. However, by 1900, the French were building slender racing launches, powered by lightweight automotive engines. Initially, the rest of the world looked down on these boats because of their limited functionality and their fragility, but the boats soon became very popular, captivating the imaginations and pocket books of many. The best hull form for these "speed launches," or "autoboats," was that of the torpedo boat. Speed launches from this time period were operating at the same Froude numbers and displacement-length ratios as the larger, faster torpedo boats. This made the well-refined torpedo boat design the most efficient solution to the problem of high-speed autoboats.

Description of the Design of X.P.D.N.C.

General Description

X.P.D.N.C. was forty-five feet long. Her hull was patterned after an early torpedo boat. She was long, slender and designed for the sole purpose of racing, with good freeboard and flare forward, a long and well-crowned turtleback, and a generally staunch and seaworthy look (Stephens, 1904). Her lines approached perfection for the ideal displacement racer operating in her speed range. Her Mercedes 90 horsepower

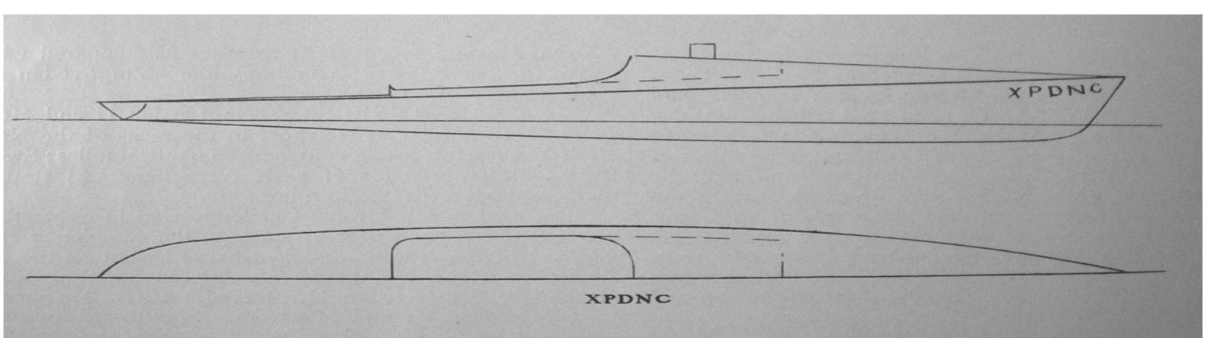


Figure 5: Drawing of X.P.D.N.C. (Stephens, 1904)

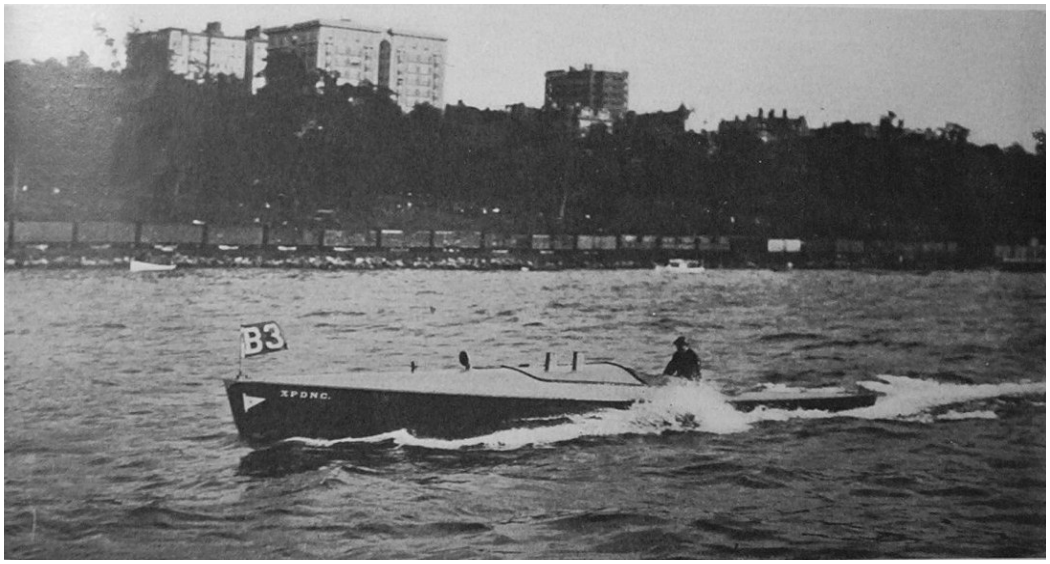


Figure 6: Hudson River Water Carnival (The Rudder, 1906)

engine drove a single screw. Both a mechanic and a driver were needed to operate the boat. Her extremely light construction employed the best materials available. A sketch of X.P.D.N.C. can be seen in Figure 5.

Hull Lines

The bow of X.P.D.N.C. lacked the deep forefoot that many other racing boats had at the time. The hull had rounded sections throughout. The sections had fairly constant deadrise from amidships aft. The waterline beam at the stern was roughly half that of amidships.

A displacement racer with a wide stern has a resistance penalty at lower speeds, but a reduced resistance at higher speeds. The stern of X.P.D.N.C. was optimized for her operating speed. The transom design, which can be seen clearly in Figure 5, also served to

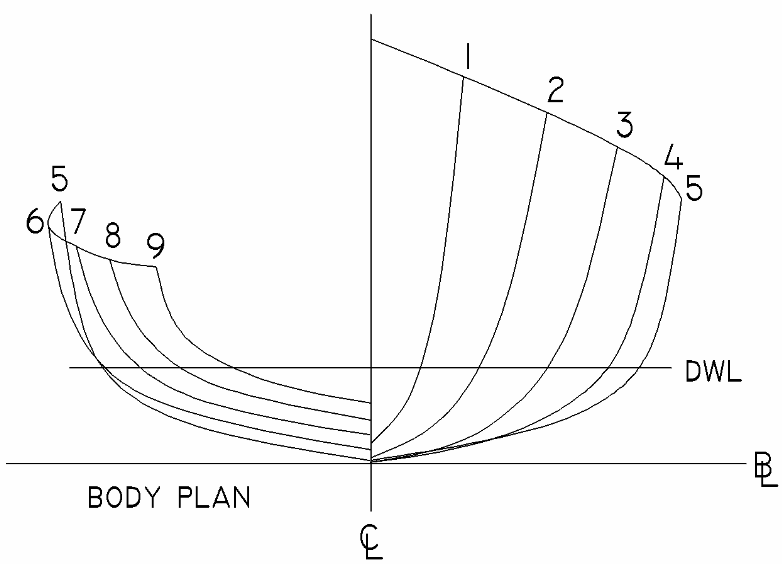


Figure 7: Body Plan of X.P.D.N.C. (Drawn by the author)

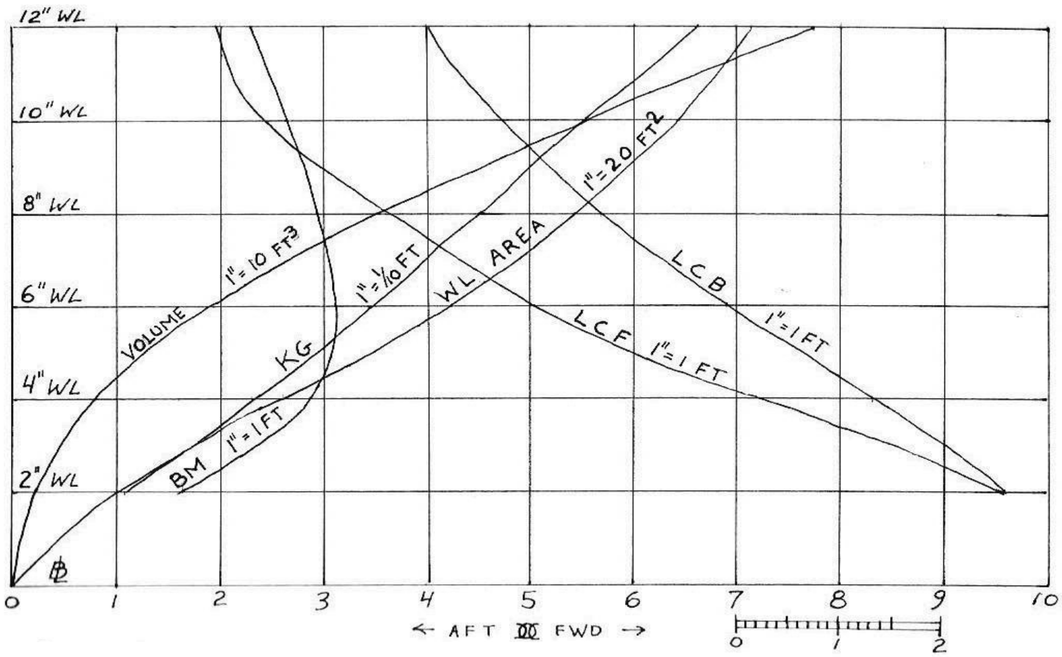


Figure 8: Curves of Form of X.P.D.N.C. (Drawn by the author)

protect against a following sea and assist in backing. The body plan of X.P.D.N.C. can be seen in Figure 7, and the construction drawing (HMCo 001-039) in the foldout.

Hydrostatic calculations were done using the offsets from the original construction booklet (MIT Catalog # HH.4.36). The curves of form can be seen in Figure 8.

The sectional area curve, seen in Figure 9, shows that the maximum area is located near amidships. During the time period that these lines were developed, designers put great emphasis on using the sectional area curve of "least resistance", swearing by specific forms, such as the versed sine. Herreshoff's sectional area curve is very simple. At the design waterline, the curve increases linearly until amidships, where it turns and then decreases linearly.

A table of principal characteristics, seen

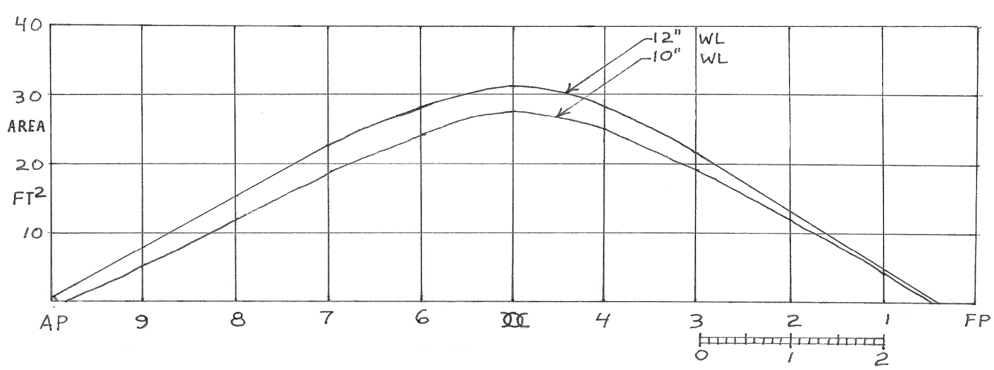


Figure 9: Section Area Curve of X.P.D.N.C. (Drawn by the author)

Table 1: Principal Characteristics of X.P.D.N.C

Name:	X.P.D.N.C.
Length Over All:	45 feet
Beam:	5'4"
Waterline Beam:	4' 9"
Draft:	10"
Speed:	26.2 mph / 22.75 knots
Displacement:	3400 lb
Length/Beam:	9.5
Beam/Draft:	5.7
Block Coefficient:	0.31
L/V^1/3:	11.9
Longitudinal Center of Floatation:	5.8% Loa aft Amidships
Longitudinal Center of Buoyancy:	0.6% Loa aft amidships
KB:	0.56 ft
KM:	3.05 ft
BM:	2.63 ft
Tons Per Inch Immersion:	665 lb/in
Waterplane Coefficient:	0.60
Moment to change trim 1":	0.74 ft-lb/inch
Beam at stern/Beam at amid-ships:	0.5
Horsepower:	90 HP
Range:	135+ miles
Pounds per Horsepower:	38 lb/HP

in Table 1, was compiled from the construction drawing, historical records, and the hydrostatics calculated from the offsets.

Arrangement and Decking

X.P.D.N.C. had a cockpit located amidships. Behind the cockpit was a very flat section of deck, whose deck beam moulds were the same as hull No. 243, SWIFTSURE, Herreshoff's steam-powered racing launch. The similarity can be seen in Figures 10 and 11.

The deck at the bow, or hood, had high camber to it. There was a removable

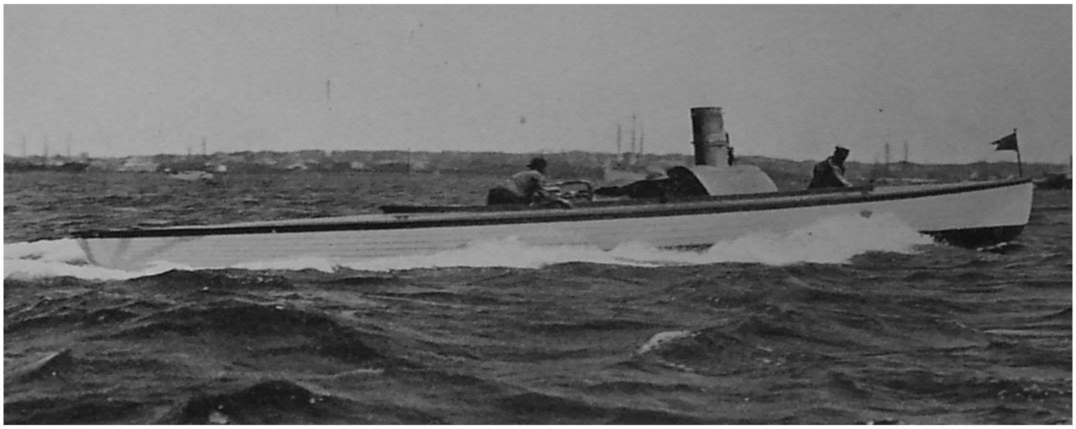


Figure 10: Stern of SWIFTSURE (Crane, 1905)

Figure 11: Stern of X.P.D.N.C (The Rudder, 1905)

portion of decking above the engine. There were three bench seats in the cockpit. The forward bench was for the mechanic. From here, he could crank start the engine and tend to its performance. The middle bench was for the driver, who controlled the rudder through an aluminum steering wheel connected to a rack-and-pinion arrangement that acted on the rudder via steering cables. The aft bench was for additional passengers. Figure 11 shows the mechanic and the driver at work. The aft bench is covered with a removable cover.

Mechanical Arrangement

The engine of X.P.D.N.C. was situated atop two 2 ¼-inch wide by roughly 6-inch deep oak engine beds, spaced 22-inches apart. The engine beds were tapered depth-wise at the ends and ran 54% of LBP. The engine was located 10% of LBP forward of amidships. This allowed for a shallow shaft angle of 3.5 degrees and followed the convention of the day, putting the engine far forward to keep the bow down. The arrangement of the engine compartment can be seen in Figure 12.

A hand crank, located in the front of the

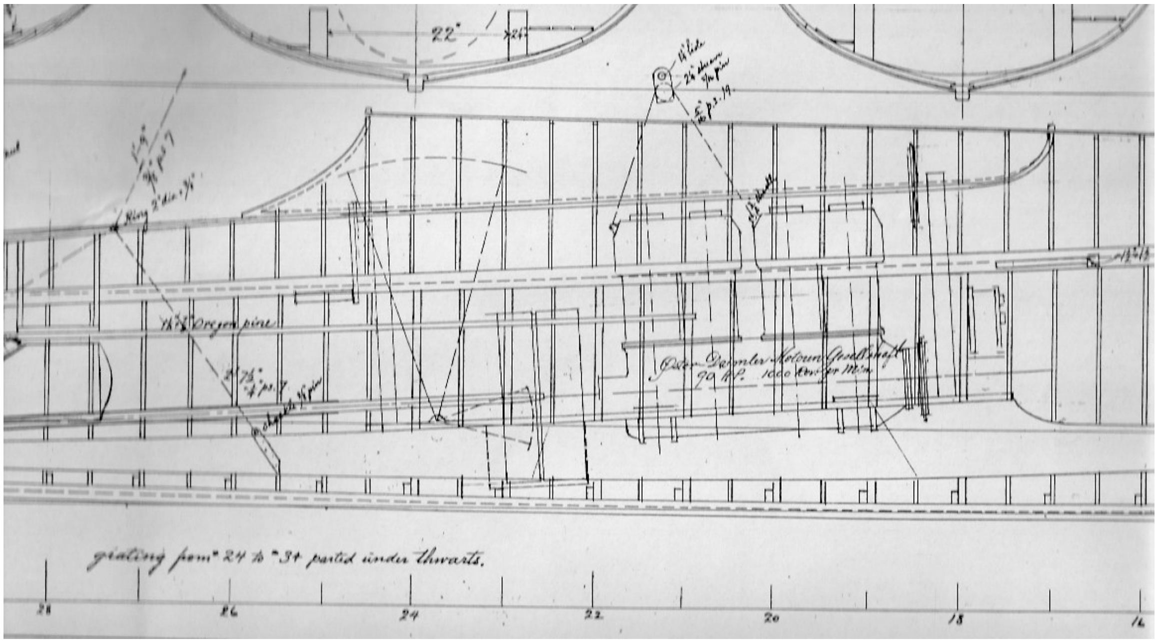


Figure 12: Mechanical Arrangement—HMCo Construction Drawing 001-039 (Courtesy Hart Nautical Collections; MIT Museum)

cockpit, was used to start the engine. This crank was connected via shaft and chains to the forward end of the engine's crankshaft.

The propeller shaft was supported inside the boat by a bearing near the clutch, a journal bearing and the stuffing box. Outside the hull there were two struts, one just aft of where the shaft pierced the hull and one just forward of the propeller. The hardware and configuration are very similar to those used on modern inboards.

The fuel tanks had a capacity of 15 ¼ gallons each. These copper tanks were cylindrical, with slightly crowned ends.

Engine

Daimler Motor Company built the engine of X.P.D.N.C. in 1904. The engine was originally designed for a Mercedes racing car. At the time, it was one of the best racing engines in the world. In January of 1904, W. K. Vanderbilt set seven U.S. automotive records in a 90 hp Mercedes car at Ormond Beach, now known as Daytona Beach. In May of the same year, a Mercedes 90 broke the world land speed record. In September, a Mercedes 90 won the Semmering Hill Climb. And, in the Ormond Beach races of 1905, E. R. Thomas (future owner of DIXIE) drove a Mercedes 90 to a speed of 153.3 km/h. A photograph of a Mercedes 90 racing

Figure 13: Mercedes 90 Race Car (DaimlerChrysler)

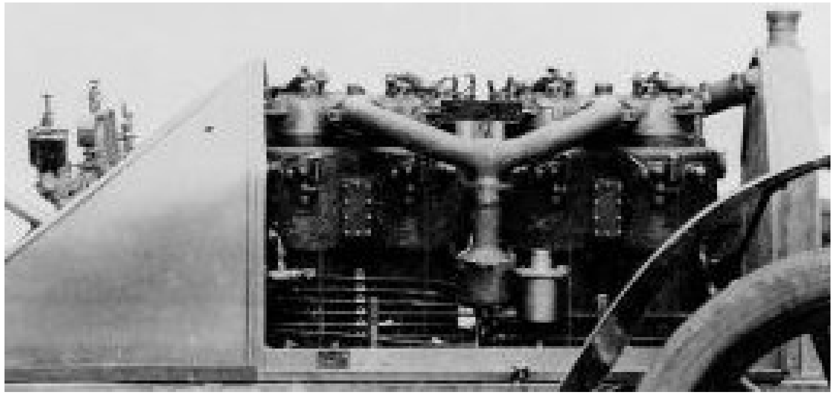


Figure 14: Inlet manifold side of Mercedes 90 (DaimlerChrysler)

Figure 15: Exhaust manifold side of Mercedes 90 (DaimlerChrysler)

car and two close-up photographs of the engine are shown in Figures 13-15. The Mercedes 90 engine ran at 1000 RPM and had four cylinders, each nearly the size of a one-gallon paint can. Early cylinder castings could not withstand the high internal pressures from compression ratios much over four (modern automotive engines are usually over eight). Additionally, these early engines could not rotate at much over 1000 RPM, whereas modern (post 1930) auto engines commonly run at 3000-4000 RPM. Since horsepower is dictated by compression ratio, RPM and cylinder volume, the only way to get 90 horsepower in 1904 was to use enormous cylinders.

Early high-performance engines required roughly eight times more volume than modern engines to generate the same horsepower, making early engines significantly heavier than people are used to today. Fifteen-pounds-per-horsepower was common for high-performance engines of 1904, but these heavy gas engines were still lighter than similar steam plants. One excited boat-builder stated in 1903, "We now have gasoline engines that give us sixteen horsepower with the weight of only one horse" (Davis, 1903). The Mercedes engine was indeed an engineering accomplishment when put into this context. The specifications of the Mercedes 90 are shown in Table 2.

Table 2: Mercedes 90 Specifications (DaimlerChrysler)

Engine type:	M 16544
No. of cylinders / arrangement:	4 / in line
Configuration:	Front, longitudinal; vertical
Combustion principle:	Four-stroke Otto
Bore x Stroke:	165 x 140 mm (6 ½ x 5 ½ inches)
Total displacement:	12700 cc (775 cubic inches)
Compression ratio:	4.0
Max output / rated output:	98 hp at 1150 /min; 90 hp at 1050 /min
Rated torque:	at 825 /min
Maximum revolutions:	1150 /min
Cylinders:	Gray cast iron, cylinders cast in pairs
Cylinder head:	Gray cast iron, cast in one piece together with cylinders
Inlet valves:	1 overhead valve per cylinder, actuated via push rod and rocker arm
Outlet valves:	1 side valve per cylinder
Valve operation:	2 lateral camshafts (1 of them actuating only the ignition system), gear drive
Crankshaft:	3-bearing (friction bearings of Magnalium)
Fuel system:	1 Throttle-valve spraying-nozzle carburetor
Fuel supply:	Air pressure, via hand pump operated by co-driver
Lubrication:	Central exhaust-pressure lubrication via lubricating pump
Starter:	Starting crank
Generator:	Not fitted
Battery:	Not fitted
Ignition:	Low-voltage magneto make-and-break ignition, combined with battery ignition
Ignition system:	Bosch
Ignition sequence:	1-3-4-2
Ignition adjustment:	Manually with lever on steering wheel
Spark plugs:	1 Ignition pin and 1 spark plug per cylinder

There is a great deal of uncertainty about the horsepower of the Mercedes 90. Herreshoff and Mercedes referred to it as a 90-horsepower. The American Power Boat Association reported it to be 57 horsepower. Clinton Crane stated in his 1905 SNAME paper that the boat had 75 horsepower as did L. Francis Herreshoff in his 1953 book. In a description of the engine from DaimlerChrysler, translated from German, the author stated, "The 90 HP engine (?!! this is the announced achievement) is to have delivered 130 HP on the test stan with 1000 rpm." (DiamlerChrysler Classic)

Two very rough horsepower prediction formulas were presented in the Webb Institute thesis, *Early Racing Power Boats* (Morabito, 2005). The first, a 1904 APBA horsepower equation based on engine displacement and RPM, predicts between 60 and 65 horsepower. Another formula, which is based on compression ratio, engine displacement and RPM, predicted 57 horsepower. If the Mercedes 90 actually produced 90 horsepower, or the 130 claimed, with the reported compression ratio and displacement, it was indeed a very special engine.

Propeller

The shaft power was transmitted to the water through a single screw. X.P.D.N.C. had three different propellers designed for it. The characteristics of these three-bladed and left-handed propellers can be seen in Table 3. According to the construction drawing, propeller #8906 was substituted for the original #8879 on October 18, 1904, eleven days before the Poughkeepsie race. The last propeller in the list is presumably the propeller Frank Croker wanted to run in the 1905 Palm Beach regatta. This propeller has a higher pitch, which indicates the boat may have been capable of higher speeds than it made during the Poughkeepsie race.

Propellers designed during the time of X.P.D.N.C. were very comparable in form and efficiency to modern submerged propellers. They generally had elliptical blade outlines and were often based on the Froude series, which was later expanded upon by D.W. Taylor (Taylor, 1910). Early propellers generally lacked skew and rake, which have very little impact on propeller efficiency. A propeller designed by a qualified naval architect in 1904 is most-likely a good propeller, even by today's standards.

The propellers for X.P.D.N.C. were made of a material called Tobin Bronze. Tobin Bronze was a product of The Ansonia Brass and Copper Company. It was produced as hot rolled, or cast, and could be forged or drawn into wire. This material had excellent prop-

Table 3: Propeller Characteristics

Casting #	Diameter	Mean Pitch	Initial Pitch	Final Pitch	Date
8879	20"	40"	32"	48"	Oct 15, 1904
8906	21"	44"	35"	52 3/4"	Sept 7, 1904
N/A	21"	48"	38 1/2"	57 1/2"	Jan 15, 1905

erties. It was lighter than copper, and corrosive tests showed it to be unchanged after five months in saturated salt.

Steering System

The steering system had to be robust and reliable so that it could safely control the fast forty-five foot boat. Rotating the steering wheel would move the rack of a rack and pinion gear back and forth. Cable was attached to each side of the rack and ran through a series of pulleys to communicate the motion over the deck to a steering yoke located on the deck at the stern. The rudderpost ran through the deck and down through the bottom of the boat, preserving the aesthetics of the transom and cutting down on rudder ventilation by having the rudder totally under the hull. Many other powerboats had rudders mounted on the stern to make construction easier. The rudder of X.P.D.N.C. had an area of approximately 250 square inches. It was made of Tobin Bronze, 7/32 of an inch thick, and measured roughly 17-inches square. The leading edge of the rudder was swept back on a curve from top to bottom. The three remaining corners were rounded.

Construction Details

Hull Construction

The builders of X.P.D.N.C. were given a construction drawing and an offsets booklet to guide them. Moulds were built from the offsets, and the oak frames were steam bent over each mould. These moulds were saved and re-used in later projects, such as the construction of CALOOLA. The frames measured ½" x 5/8" at the forward and aft ends of the boat, and 7/8" x 5/8" in way of the engine. Ribbands were used to help hold the frames. The curved stempiece was made of oak. Good practice at the time called for it to be made from a natural bend in the tree, instead of out of multiple pieces, so that it would be stronger.

The inner planking, consisting of 5/32" mahogany, was laid in after the frames, keel and stempiece were in place. A coat of shellac was put between layers of planking. The outer planking, 5/32" cedar, was screwed through the inner planking to the frames. The hull was then lifted off the moulds and inverted. The floors were installed after the boat was inverted, and were riveted or screwed to the frames.

The deck beams were ½" x ½" oak. The deck was ¼" cedar covered in canvas. There were two (presumably watertight) bulkheads, made of double-layer 5/32" cedar, one forward of the engine and one aft of the cockpit. There was elm grating in the cockpit, set between the 2 ¼" oak engine beds. These solid engine beds, spaced 22 inches apart, ran over half the length of the boat.

The scantlings show that the boat was of extremely light construction. The total bottom planking thickness was less than a third of an inch. Much like today, light construction was needed to win races. This is one of the reasons why so few of these fragile racing boats survived.

Marine Hardware

Herreshoff could produce an extensive variety of metal parts. Items like deck cleats, steering parts, propellers and shafting were made of non-corrosive materials such as Tobin Bronze. Certain items, such as the steering wheel and some clutch parts, were made of aluminum. This was a very modern and expensive material at the time.

A boat of the size and complexity of X.P.D.N.C. has a multitude of small parts, each one requiring considerable attention to build. This paper cannot cover the design of each part; however, the drawing numbers for each of the parts are denoted on the construction drawing, so it would be possible to have them built from the original plans. Since these parts were originally low-volume production, it stands to reason that they would not be extremely difficult to replicate.

Performance of X.P.D.N.C.

Basics of Displacement Racer Performance

There were a few fundamental performance limitations that the designers of displacement racers had to deal with. First is that the shorter the boat (with speed held constant), the higher the Froude number and hence the higher the resistance per horsepower. This means that a one-hundred-foot boat has a considerable advantage over a thirty-foot boat with the same weight-per-horsepower. Length was the basis for many early handicapping rules and race entry limitations.

As the speed of a displacement racer (or any displacement vessel) increases beyond a certain point, stern squatting occurs. If a boat went above a certain speed, it trimmed more and more, causing the resistance to increase at an incredible rate. Eventually no amount of horsepower would propel the boat any faster. Early race boat designers held the trimming off to higher speeds by placing the center of gravity far forward to keep the bow down, but the problem was unavoidable beyond certain speeds. Charles Parsons used a special stern design to keep the bow of TURBINIA down. This pointed the way toward the future. Race boat designers eventually learned (1906-1908) that widening the stern and placing the engine aft would permit higher speeds because the wide stern would lift, holding the boat at the optimum trim angle and allowing the bow to be carried out of the water, reducing frictional resistance. Boats that worked under this principle were almost fully planing at higher speeds.

Displacement racers were built excessively narrow to reduce resistance. They also had very large, top-heavy engines. This made stability a major issue. During acceleration, the propeller torque could sometimes capsize these boats. In addition, many racers rolled over once they began to rise dynamically because the decreased water-plane area reduced the stability. Turning was sometimes dangerous because many displacement racers would roll outward on turns, unlike planing boats (Hickman 1910). The narrow beam, top-heavy engines, limited dynamic stability, round bottoms, and the difficulty on turns made these early racers very dangerous if not handled properly. Danger has always been present in powerboat racing.

The fundamental principles of naval architecture become major issues when designing any type of boat to the limits of speed and technology. Many respectable designers were caught with designs that capsized, handled poorly, or broke apart at speed.

Seakeeping and Stability of X.P.D.N.C.

The fact that X.P.D.N.C. did not roll over once she was put underway would have been considered a major design accomplishment for the average designer. Herreshoff, a designer with exceptional expertise, was able to design a safe and reliable hull. By all accounts, X.P.D.N.C. was a perfect balance of safety and speed. There are no published instances of the boat capsizing. In a few cases, however, the boat was withdrawn due to bad weather. This can be attributed to prudence on the part of her owners.

Strength of X.P.D.N.C.

The hull of X.P.D.N.C. was very lightly built, like the hulls of many other early racers. Before the time of planing boats, the hulls of racers did not have to withstand the heavy pounding and dynamic forces of planing, allowing extremely thin construction. There is nothing published about a fault in the strength of the hull of X.P.D.N.C. Her six-year career indicates an above-average longevity, mostly due to the quality of her construction and the care her owners took in handling her.

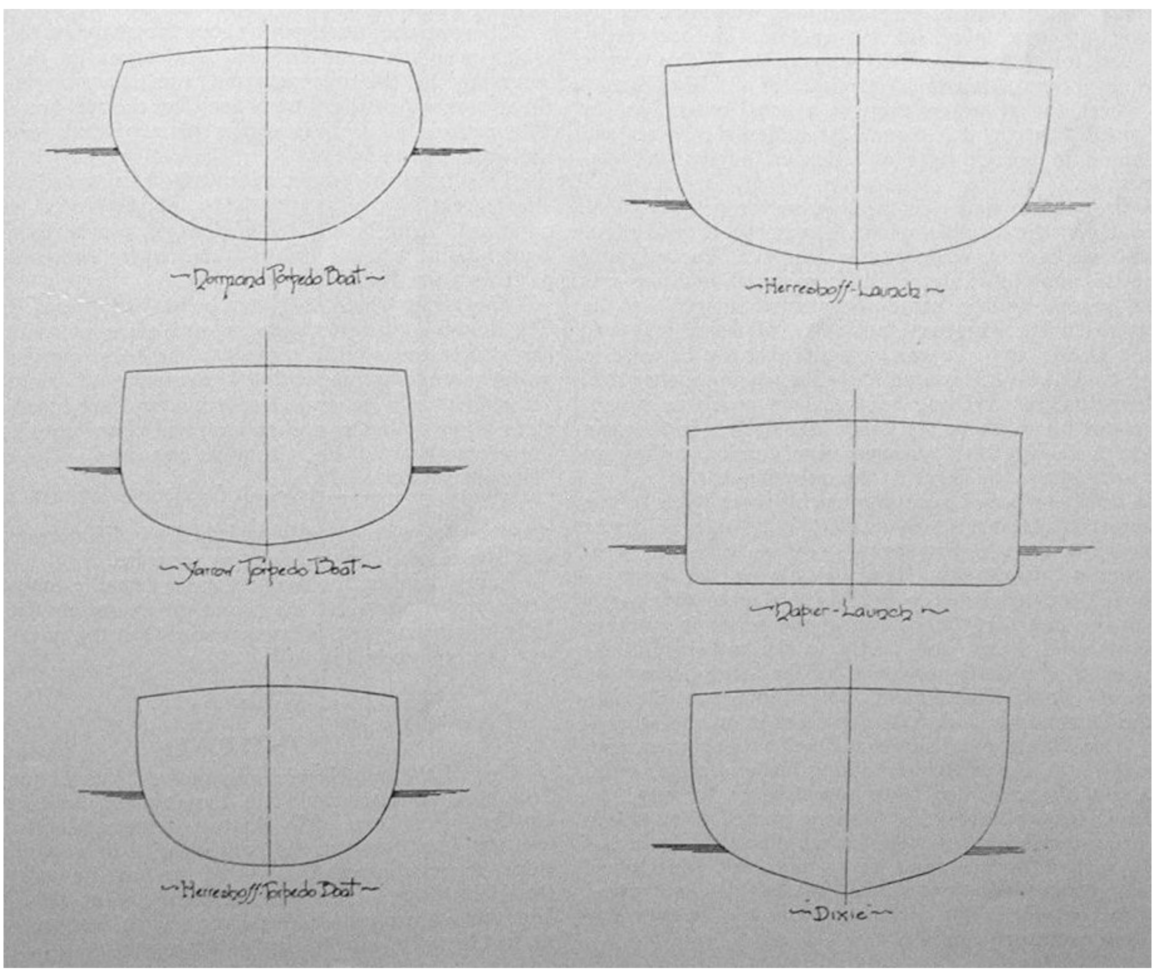


Figure 16: Popular Midship Sections (Crane, 1905)

Hull Form Comparison

In 1905 Clinton Crane did a comparison of the different hull forms for displacement racers. Most of the forms were very similar. Crane concluded that in most instances the small differences in section shape and sectional area distribution had little to do with the resistance of a displacement racer, but had a great influence on seakeeping and safety. Figure 16 shows midship drawings of many of the prominent designs of the time. Most of the boats are very similar, with the exception of the Napier Launch, an experimental early form of planing boat.

Figure 16 shows that the Herreshoff launch and torpedo boat are very similar to DIXIE, a popular early racing boat by Clinton Crane. The difference-maker for displacement racers was the weight, stability, seakeeping, and the reliability of the engines, not so much which midship section was the section of least resistance.

Mechanical Reliability

X.P.D.N.C. is reported to have had only one mechanical breakdown during her six-year career. This was due to a bearing failure. During the early part of a race, the crew shouted to the dock for oil. None available, they continued for another lap, and when they stopped to oil the bearing, the bearing locked and they could not restart. This is a very minor breakdown when compared to those of many other boats. Sometimes boats would have their shafting knocked off by driftwood, or their engine cylinders would crack, or they would catch fire from fuel leaks and backfires. The Mercedes 90 engine showed itself to be a robust and reliable piece of machinery. Its installation in X.P.D.N.C. was nothing short of excellent. The handling of the boat was also done with the utmost care.

Race Results

The best way to evaluate a boat is to see if it meets its design objectives. The design objective of X.P.D.N.C. was to bring owner Frank Croker fame by defeating the fastest boat in the country, CHALLENGER, in a long-distance, high-stakes match race. This was a 135-mile run from Eighty-Sixth Street in New York to the Poughkeepsie Bridge and back, for a prize of $1,000 (roughly $20,000 in 2005 dollars). The boat successfully met the design objective, as Croker is being written about over one hundred years later for his amazing victory.

The construction drawing for X.P.D.N.C. was dated less than a month before the match with CHALLENGER, indicating that the boat was built in an extremely short time. At the last minute, the race was opened up to other contestants, but the only other boat that was available so late in the season was VINGT-ET-UN II, winner of the second Gold Cup race of 1904. During the race, X.P.D.N.C. was ahead of both CHALLENGER and VINGT-ET-UN II when CHALLENGER hit driftwood and withdrew. X.P.D.N.C. continued nonstop and won the race in record time, setting the American autoboat speed record, the Hudson River autoboat speed record, and the long-distance autoboat speed record. The boat was scheduled to compete again in January 1905, but the accidental death of Frank Croker while preparing for the 1905 Ormond Beach automobile race prevented this.

Late in 1905, J. Siegel and G. Gillig of Red Bank purchased X.P.D.N.C. from the Croker estate. She won her first race, the 1905 National Trophy, a significant racing event against the biggest and fastest autoboats in the country. Siegel and Gillig continued to campaign X.P.D.N.C. until 1910. She was a strong competitor in some of the most important races in the United States during this time; however, she never attained the fame, or the speed, that she had under Croker. Since the boat was not designed to be raced for six years, the later races are of less significance than the earlier in determining the success of the boat. It is probable that after a year or two, Croker would have re-powered the boat, or had an entirely new X.P.D.N.C. built.

Table 4 shows when and by whom the records that X.P.D.N.C. set during her Poughkeepsie run were broken. There is some doubt about when her long distance Hudson River record was broken, because of two conflicting accounts of her original speed. Table 5 shows the results of all the Poughkeepsie races that were published. It can be seen that over seven Poughkeepsie races, her speed was only approached once, by DEN, a boat that was designed by Charles Herreshoff, Nat Herreshoff's brother. Table 6 shows the results of the races that X.P.D.N.C. was involved in. All three of these tables were compiled from contemporary race reports in major publications.

To give the reader a better idea of the state of the art in boat design at the time, some photographs and information of the contemporaries of X.P.D.N.C. are presented in Table 7. These are some of the many boats that competed against X.P.D.N.C. between 1904 and 1910. X.P.D.N.C. was relatively underpowered when compared to these boats, especially those in the Na-

Table 4: Records of X.P.D.N.C That Were Broken

Record	Broken By	MPH	Date
America Autoboat	CHALLENGER	29	Feb 1-3, 1905
Hudson River Autoboat	DIXIE	26.45	Sept 13-16, 1905
Long-Distance Autoboat*	DEN	26.22	Sept 23, 1907

* X.P.D.N.C. ran 26.208 – 26.29 mph depending on the source.

Table 5: Results of NYC—Poughkeepsie Runs

Date	1st	Average MPH	2^{nd}	3^{rd}
1904: Oct 29	X.P.D.N.C.	26.208	VINGT-ET-UN II	CHALLENGER
1905: Sept 15	SIMPLEX III	18.085	WIZARD	-
1906: Sept 10-15	ARTFUL	21.93	SPARROW	SIMPLEX VI
1907: Sept 23	DEN	26.22	SKEDADDLE	-
1908: Sept	VIM	23.2	ELEO	SPEEDWAY
1909: Sept	GUNFIRE II	22.88	DEN	-
1910: Sept	PETER PAN III	25.13	VANISH	EDITH II

Table 6: Results of Published Races

Date	Race Site	What happened	1st	2^{nd}	3^{rd}
'04 Oct	Hudson River NYC-Poughkeepsie	Finished	X.P.D.N.C.	VINGT-ET-UN II	CHALLENGER
'05 Feb	Palm Beach Regatta	Did not participate due to death of F. Croker	CHALLENGER	-	-
'05 Sept	National Trophy Race NYC	Finished	X.P.D.N.C.	SKEETER	VERITAS
'05 Sept	Vanderbilt Cup Long Island	DNF bad thrust bearing	DIXIE	SIMPLEX III	4 boats DNF
'06 Sept	National Trophy Race NYC	-	SKEDADDLE	ELCO	X.P.D.N.C.
'06 Sept	Mile Trials NYC	Finished	STANDARD	DIXIE	X.P.D.N.C.
'06 Oct	Larchmont Gold Cup, NY	Did not participate due to argument	-	-	-
'07 Sept	National Trophy Race NYC	Won by 4 seconds, but lost due to handicap	SKEDADDLE	X.P.D.N.C.	-
'07 Sept	Mile Trials Hudson River	Professional timers confused times	-	-	-
'08 Aug	Huntington Bay Regatta	Withdrew due to weather	DEN	X.P.D.N.C.	-
'10 Sept	National Trophy Race NYC	Withdrew	TARTAR	X.P.D.N.C.	-

tional Trophy races. Since X.P.D.N.C. was over forty feet in length, she was put in a category of extremely large boats with mammoth engines. In her last National Trophy Race, she competed against a sixty-foot boat with four times the horsepower. Surprisingly, she could have defeated that boat, if she had not withdrawn.

Design Information Available to Guide the Replication

<u>Plans Available from MIT</u>

Fortunately, Herreshoff kept excellent records, which were later donated to MIT and reside in the Haffenreffer-Herreshoff Collection of the Hart Nautical Collections, MIT Museum. The drawings are organized in a few different ways. The first, seen in Table 8, is by hull number (X.P.D.N.C. is No. 245).

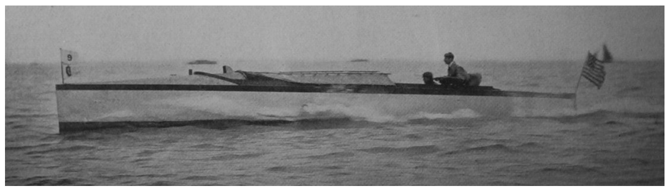
Although Table 8 shows the drawings that come up when you search for hull No. 245 in the MIT museum's database, there are many parts that are not on that list. On the construction drawing, there are arrows to many of the metal parts specifying either the casting number or the drawing number. These do not come up when you search for 245 because they were parts that were used on many different boats. Table 9 can be used to locate the drawings for these parts at MIT.

There was never a lines plan for X.P.D.N.C. Instead, there is an offsets booklet. This is MIT Catalog # HH.4.36. The same offsets booklet is applicable

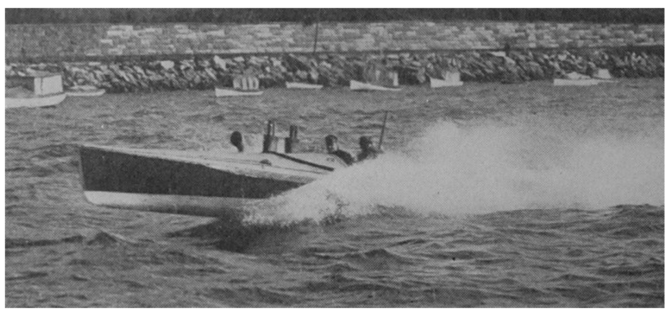
Table 7: Contemporaries

X.P.D.N.C.
57-90HP
45 feet
26 mph
38 lb/hp

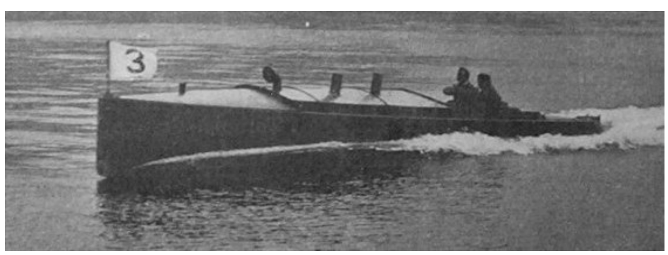
CHALLENGER
150 HP
40 feet
29 mph



DEN
72 HP
33 feet
26.22 mph

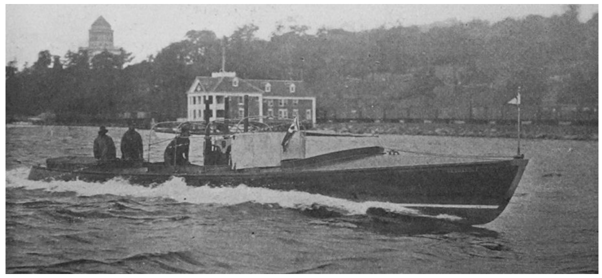


DIXIE
150 HP
40 feet
30 mph
34.4 lb/hp

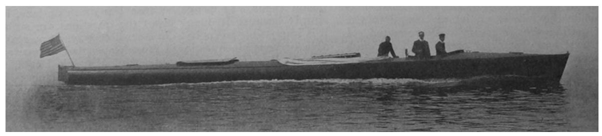


SPARROW
31.8 HP (APBA)
30 feet
22 mph

SKEDADDLE
190 HP
60 feet

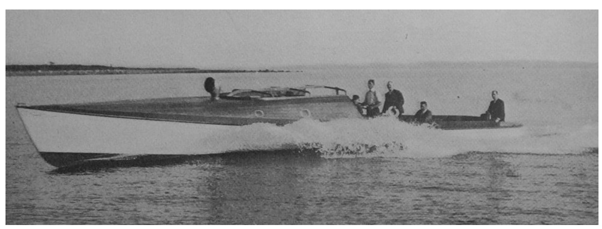


STANDARD
100-500 HP
(depending on year)
58 feet



TARTAR
300 HP
60 feet

VERITAS
200 HP
56 feet
26.7 mph
42.4 lb/hp



VINGT-ET-UN II
75 HP
40 feet
25.3 mph
51.4 lb/hp

for hulls #245 (X.P.D.N.C.), #254 (CALOOLA), #256 (¾ scale, 26-feet long, Aug. 06) and #269 (¾ scale, 33-feet long, Dec. 08). The offsets booklet and the construction drawing are enough to build the hull.

Engine Information

It is unlikely that a Mercedes 90 can be found or built for the new X.P.D.N.C. DaimlerChrysler is unwilling to release the plans for the Mercedes 90 engine due to concern that replicas will be built. There is also very little chance that a 1904 Mercedes 90 racecar could be purchased at a reasonable price so that the engine could be used for the new X.P.D.N.C. If the museum prefers a 1904 engine, the best alternative is to reconstruct an engine that was designed by Nat Herreshoff's older brother, Charles Herreshoff, founder of the Herreshoff automobile. This engine is the same size as that of X.P.D.N.C. and was used to power DEN, which in 1907 broke X.P.D.N.C.'s Hudson River record. There were only a handful of these engines built. It is probable that it could be built in a short time with very simple machining and casting tools. The specifications of this engine are given in Table 10. A photograph of the engine can be seen in Figure 17.

If the engine of DEN proves unfeasible, the next best alternative would be a pre-WWII marine engine. The ideal engine would be heavy, reliable, common enough to be repaired easily, and around 90-horsepower at 1,000 RPM.

Information needed

A good replica of X.P.D.N.C. can be built from the drawings and information that are currently available; however, this material was originally intended for

Table 8: Drawings Available from Hart Nautical Collections, MIT Museum for Hull #245

Plan #	Year	Plan Title
001-039	1904	Racing Launch 45' (Construction Drawing)
008-037	1904	Shafts
011-042	1904	Sterntube and stuffing box
011-043	1904	Shaft bearing (outside) for 1 7/8" dia
011-044	1904	Shaft bearing for 1 3/8" dia shaft.
058-035	1904	Strut for propeller shaft
062-061	1904	Rudder tiller & sheave holder
145-001		Friction Pulley Gas. Eng. For 245
145-002		Forgings for reversing Gear 245
145-003		Bed Plate Reversing Gear 245
145-004	1906	For 245 (reverse gears)
145-009	1906	Cast Iron Pullies for Gas. Eng. 245
167	1904	Detail Construction #245

Table 9: Drawings Denoted on Construction Drawing 001-039

Casting #	Drawing #	Description	Frame #
#8886		Stempiece	1
#8892		Bow Fairlead	1
		7 ¼" deck cleat	11
#3324	68-59	Steering Parts (rack and pinion box)	30
#3325	68-59	Steering Parts (rack and pinion box)	30
#3327	68-59	Steering Parts (rack and pinion box)	30
#8703		Steering Rack	30
#3422		Shaft Bearing	30
#8883	11-42	Sterntube/Bearing	34
#8884	11-42	Sterntube/Bearing	34
		7 ¼" deck cleat	38
#8882	11-43	Forward shaft strut	39
#8885	58-35	Aft shaft strut	46
#8879		Propeller (not used in race)	46
#8906		Propeller Oct 18 '04	46
#8893		Prop nut	46
	62-61	Aft steering deck pulley (2)	46
#1537		4" deck plate	46
#1537		4" deck plate	46
#8881		Steering tiller	47
#3381		Eye at top of rudderpost	48
#4725-½		Rudderpost collar	48
	62-61	Rudder	48

people who were already building boats at the Herreshoff Manufacturing Company. An accurate replica could only be built if the builders cooperated with the museum to identify exactly how HMCo built boats. This process will be fun and educational for everyone involved.

Previous Replications of Early Power Boats

Never before has there been a replication effort on the scale of X.P.D.N.C. for an early displacement racer; however, the skills and knowledge are available.

The Antique Boat Museum in Clayton, NY has significant experience building

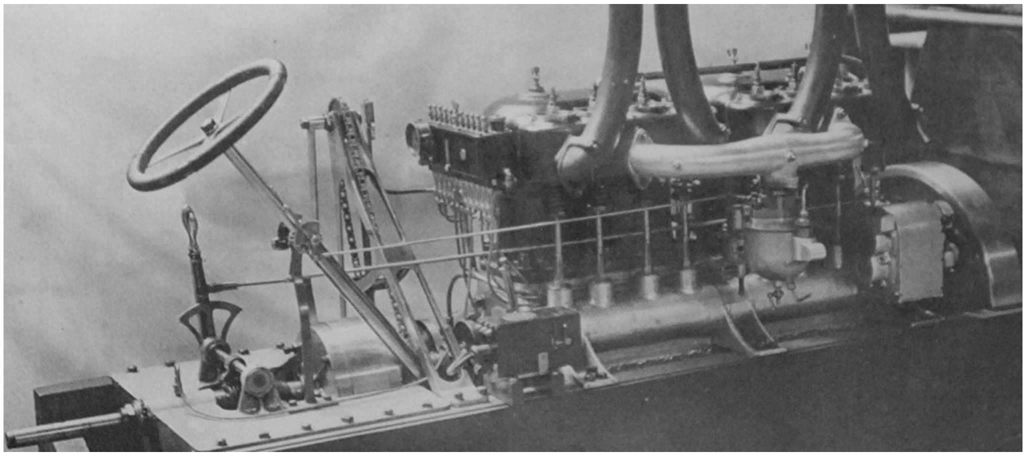


Figure 17: Engine of DEN (*The Rudder*, 1908)

Table 10: Specifications of the single engine of DEN

Engine type:	Herreshoff 1908 – design from 1904
No. of cylinders / arrangement:	4 / in line
Configuration:	Engine, gearbox and all controls mounted on one movable base
Combustion principle:	Four-stroke Otto
Bore x Stroke:	6-7/8 x 5 ¾ in (175 x 146 mm)
Total displacement:	853 cu in (13978 cc)
Compression ratio:	Roughly 4.6
Maximum / output / rated output:	72 hp at 1000 RPM
Cylinders:	Iron with 20% steel and silicon
Lubrication:	Oil tank in bottom of engine is cooled by a water jacket. This keeps the bearings and the center of the piston cool.
Starter:	Starting crank
Generator:	Not fitted
Battery:	Not fitted
Ignition adjustment:	Manual

small boats in their Living Exhibit, including a replica of the small, 1903 racing launch, KATZ. This is one of the earliest racing boats to be replicated. They have a thorough understanding of very early racing boats, but do not currently have the ability to build one the size of X.P.D.N.C.

Many builders have constructed replicas of racing boats by George Crouch, John Hacker, and Gar Wood. There have been too many of these boats built to list. The builders of these boats would certainly be qualified to build a wooden powerboat the size of X.P.D.N.C., but they would not be used to her type of construction. Most of the replicas being built are planing boats from the 1920s, not round-bottomed boats from 1900.

Currently, there are many groups repairing and replicating large sailboats from the early 20th century. These people have been restoring large Herreshoff sailboats with bent frames for years. They would have an excellent grasp of how to build the hull of X.P.D.N.C. so that it would last for a long time. Most boatbuilders could build X.P.D.N.C., but the sailboat experts would have the experience and skill to build it in the best way possible.

If a good sailboat builder partnered with an experienced wooden powerboat builder, like the ones who are building the Gar Wood and Hacker boats, the hull could be built with the utmost precision, and the engine could be fitted properly. Both are very important.

Potential Design Modifications

The new X.P.D.N.C. needs to meet three objectives. The first is to show off the original design and construction methods from a bygone era. The second is to demonstrate how these boats worked at speed. The third is to last a long time. The original X.P.D.N.C. was designed to last only a few years, putting our first and third objectives at odds with each other.

It is up to the museum to determine which objectives they weigh more heavily. If the boat is modified too much, it defeats the purpose of building a replica. One way of increasing longevity while leaving the design mostly unaffected is to replace the shellac in between the layers of planking with a modern material to add strength and bond the planks. Another solution is to build the boat as it was originally, use it, and maintain it well. A replica could be beat up and then properly repaired without the worries that accompany repairs on an original boat.

There is no evidence of any deficiency in the performance of the original X.P.D.N.C. It was safe and a stellar performer in races. The closer the boat is to original, the better it will be. For instance, if a heavy, inefficient, old engine cannot be located, weights should be placed near the engine to preserve the stability and seakeeping properties of the boat. Parts should be made of materials as close to the originals as feasible. If a propeller cannot be built from the original drawing, a stock propeller with the same characteristics and style should be selected.

Rough Cost Projection/Bill of Materials

A number of classic boatbuilders were contacted to provide a rough cost projection for the construction of X.P.D.N.C. Many of the boatbuilders were unable to produce an estimate in such a short period of time; however, one responded with a ballpark number. Hacker Craft, builders of replicas of EL LAGARTO, IMPSHI, DELPHINE IV, RAINBOW IV, and restorers of MISS DETROIT VII, MISS CANADA III, MISS LOS ANGLES, and MISS CALIFORNIA, said that a 45-foot race boat would cost between $175,000 and $200,000 for them to build.

One way to reduce this figure would be if the Herreshoff Museum purchased the materials and then partnered with a boatbuilding school to build the boat.

This would benefit the boatbuilding school because they would be given an exciting and well-publicized project to work on. They would also have all of their materials funded for a long-term project. And of course, they would be able to take the boat out any time. This plan would make the construction of the boat economically feasible.

A few rough estimates for material costs were made. These are broken down into the categories of wood for the hull, metal parts, engine, propeller, and miscellaneous. The author would like to ask forgiveness from the more experienced boatbuilders for the inaccuracy of this estimate.

Wood For the Hull

Table 11 shows a rough estimate for the cost of wood. The board feet were estimated from the construction drawing, with some margins added for waste. The cost per board foot came from discussions with a local lumberyard. This table shows a total cost of $9,200. $10,000-$15,000 may be a safe estimate.

Metal Parts

A company that offers custom castings said that the various cast pieces would cost roughly $10 to cast. However, the patterns for these castings cost $250-400. There are roughly 20-25 such parts on X.P.D.N.C. Therefore, these parts could cost somewhere between $5,000 and $10,000. The cost for all the cast and machined parts can safely be included in a rough total of $10,000.

Engine

Engines vary in price. A rebuilt pre-WWII marine engine and gearbox may cost around $5,000. A new marine engine and gearbox may be $10,000-15,000. A 1904 Mercedes 90 may cost $200,000-$500,000. If a volunteer machinist would be willing to build the engine of DEN, the materials would probably be less than $5,000. If the machinist charged for his time, it might be significantly more expensive.

Table 11: Approximate Wood Cost Estimate

Item	Material	Thickness	Board ft	Cost/Bf	Cost
Inner Planking	Mahogany	5/32-inch	400	$10	$4000
Outer Planking	Cedar	5/32-inch	400	$4	$1600
Frames	Oak	5/8-inch	20	$11	$220
Floors	Oak	3/4-inch	40	$11	$440
Intermediate Timbers	Oak	7/16-inch	20	$11	$220
Decking	Cedar	1/4-inch	170	$4	$680
Deck beams	Oak	1/2-inch	20	$11	$220
Bulkheads	Cedar	5/32-inch	100	$4	$400
Bulkhead Stiffeners	Oak	3/4-inch	10	$11	$110
Grating	Elm	3/4-inch	20	$10	$200
Misc Structure	Oak	-	100	$11	$1100
				Total:	$9190

Propeller
A 21-inch Michigan Wheel costs around $1,000 to $1,500; however, their stock pitch/diameter ratios do not approach the 2.1 required for X.P.D.N.C. This detail may double the price of the propeller.

Miscellaneous
There are many parts that have heretofore not been accounted for. These include deck canvas, screws, bolts, varnish, shellac, fuel lines, and anything else that will go into the boat. The total for miscellaneous parts could be estimated at around $5,000.

Table 12: Rough Material Cost Total

Item	Cost
Wood	$15,000
Metal Parts	$10,000
Engine	$10,000
Propeller	$3,000
Miscellaneous	$5,000
Total	$43,000

Rough Total
The total cost estimate can be seen in Table 12. Although the author does not have experience in financing a 45-foot 1904 racing boat, the total of $43,000 seems like a safe figure for material costs. With some luck, this figure could be much lower.

Conclusion

X.P.D.N.C. is an ideal boat to reconstruct. She is representative of Herreshoff torpedo boat design; she set a long-standing distance speed record; and she had a long and distinguished career, originating at the very beginning of powerboat racing and ending at the dawn of the hydroplane. Herreshoff kept extremely good records, so thorough that the boat could be built in a shop starting tomorrow. The boat, once completed, would be a shining example of marine technology from a time period of rapid development and excitement. With the cooperation of boatbuilders, lumberyards, machinists and museums, this boat could become a reality.

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About the Author:

Mike Morabito is a recent graduate of Webb Institute. He has long been interested in classic power boats and was able to pursue this interest in his undergraduate thesis, *Early Racing Power Boats.* He is slowly restoring a 1920s inboard hydroplane, a 1946 Plymouth automobile, and assisting with his parents' New Hampshire woodworking mill. He started graduate work in Ocean Engineering in January of 2006.