CHAPTER 6

SUNNY II, a RHODES 19

The new sailboat

A full year after writing "Electric Propulsion for Boats" (2002), I decided to use all the knowledge I had gained and convert one more boat to electric power. It had to be a sailboat because the hulls of readily available motor boats are just not designed to operate at hull speed. The experiment with the Carolina skiff was ample proof of that.

I had looked for an O'Day Rhodes 19 on and off in the past but I could not find one at a reasonable price. Then one day, a boater advertised four of them for sale. He had raced the Rhodes 19 for years and had accumulated a barn full of boats and all sorts of parts and accessories. By the time I got to his house on Cape Cod, he had sold two of them and he was holding a third one for a friend. The 1970 Rhodes 19 that was left was truly in tough shape. It had been beached during a hurricane damaging the hull, the rudder was lost, some of the floor boards were broken and the centerboard was wedged in the trunk.

He did have it on a good trailer and he was selling it with an expensive tapered mast to replace the missing one. The price was commensurate with the damaged goods and I quickly snapped it up.

I spent the whole summer getting it back in presentable shape. The previous owner was very helpful: he had lots of spare parts for the Rhodes 19 such as floor boards and he had a milling machine to remove the damaged surface of the wood to bring the mahogany back to its original beauty. I built a mahogany rudder from a copy of the original and since I would be installing heavy batteries in the boat, I built a lightweight fiberglass centerboard to replace the cast iron one. Three suits of sails came with the boat. None were very good but I selected the best of the bunch and decided to make do with that. The rest of the repairs took a great deal of elbow grease but came out spectacularly well.

The only improvement that I made to the boat was to install a tabernacle which is a pivot at the bottom of the mast. Normally, the mast slips through a hole in the ceiling of the cabin and rests on the keel. Without the tabernacle, stepping the mast with the boat on a trailer is a difficult operation and it is almost impossible to do single handed.

To support the tabernacle, I used one of my slightly bent 1" propeller shaft from my drive shaft collection (see photo 6.2). It worked out very well. Since 5 of the 6 stays could remain attached and properly adjusted, stepping the mast with the tabernacle turned into a very simple operation.

I did add wheel steering (which would repulse Rhodes 19 purists) but I wanted to do my motoring in style and that worked out very well also. Before selling the boat I removed most of the modifications that I had made and found a very happy buyer: when I asked him if he liked the boat, his response was “What is there not to like?”

Sunny II Restored

Photo 6.1 on the next page, shows the restoration work performed on Sunny II. The new rudder is an exact copy of the original with many layers of mahogany glued together. The new console with the electric instruments and the steering was built up from the smallest Carolina Skiff console. With a cushion, the rear deck could be used as a seat. The picture shows the two openings for storage in the cuddy cabin. The space below was modified for the storage of the batteries. Three number 27, deep cycle batteries just fit in that space.

Photo 6.1 “Sunny II” Restored with New Rudder and Console

Battery Storage

Photo 6.2 on the next page is a close up of the storage area in the bow, where life jackets, anchor and other large items can be stowed. Below, I added a shelf and a large access hatch to reach the three 12 volt batteries housed there. Note the vents on each side of the hatch.

The bronze shaft is the support for the tabernacle which I installed on the cabin top for the new tapered mast.


Photo 6.2 “Sunny II” Battery Box and Tabernacle Support

Sunny II’s Inboard

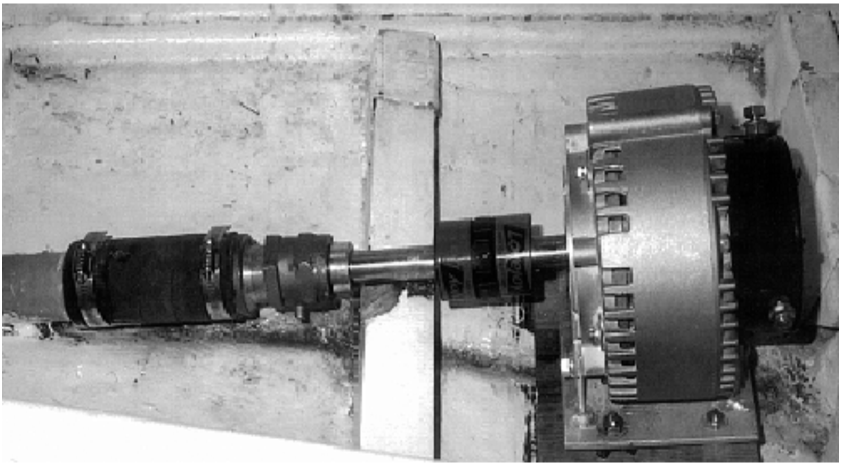
Photo 6.3 “Sunny II” Inboard Construction with Etek Motor

The construction of Sunny II's inboard was considerably simpler than Sunny's. By eliminating the reduction gear, the Etek motor which has a 7/8 inch drive shaft could be connected directly with a Lovejoy coupler (shown) or a solid coupler to the propeller shaft which was also 7/8 inch in diameter.

Looking at Photo 6.3, we see at the far left the 1 ¾ inch fiberglass stern tube (outside diameter) which was fiberglassed in the bottom of the boat at an angle of approximately 15 degrees to the water line.

The black hose which is 4 ½ inches long with an inside diameter of 1¾ was attached to the stern tube with the other end connected to the 1¾ inch body of the stuffing box. The collar on the shaft was installed to stop the shaft from pulling out of the coupler. With a solid coupler which I used for most of the in-the-water testing, this is unlikely to happen. But, remember that if the prop and shaft should slide out of the boat, they would be lost and the boat would be left with a one inch opening to the water.

The stainless steel shaft is 7/8 inch in diameter and 48 inches long. I bought it as replacement shaft from "Boat US" (now West Marine) for $250 with all the standard machine work already done. The shaft was attached to the coupler and then to the Etek drive motor.

Under the boat, photo 6.4 shows the strut holding up the other end of the shaft as well as the reworked propeller. The strut angle is not adjustable but its 20 degree angle and the 6 ½ inch dimension from the base of the strut to the center of the shaft provides the exact angle needed to keep the shaft angle at a minimum. The best possible drive efficiency is obtained with a low shaft angle.

A cutless bearing was inserted in the bottom part of the strut. It has the same inside diameter as the propeller shaft and of the same length as the strut. Cutless bearings are made of ribbed rubber allowing water to circulate in the grooves and lubricate the bearing surface. With proper alignment, they require no adjustment and last for many years.

The stuffing box mentioned above is designed to seal the rotating shaft so that sea water will not enter the boat. A packing nut with a locking nut squeezes the packing material (cotton rope impregnated with graphite) just enough to allow the shaft to turn freely but stop the water from flowing in. The rule is to have no leaking when the shaft is stopped and one drop per minute when the shaft turns. If you are lucky enough to achieve this goal lock the setting in place…post haste!

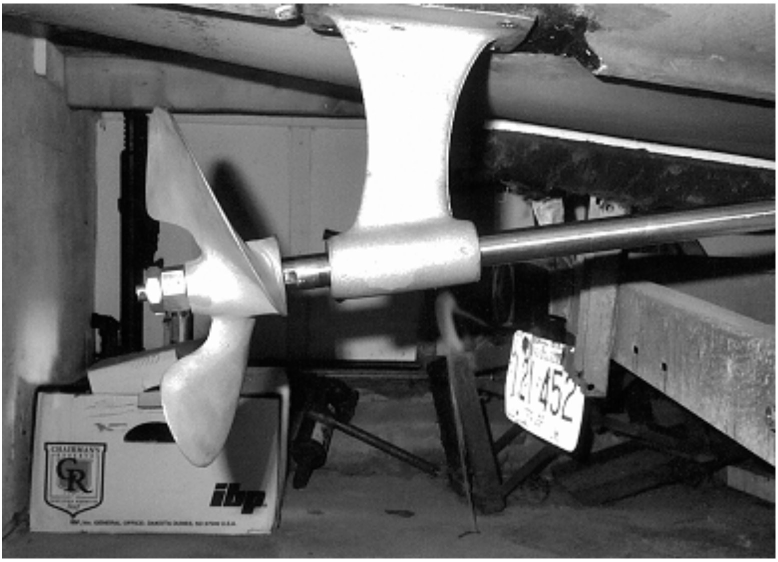

Photo 6.4 “Sunny II” Outside Construction

The alignment of the strut and the motor shaft are key to a quiet, vibration free and efficient operation. The stuffing box, being attached to a rubber hose will adjust slightly to the alignment of the shaft. However, with the walls of the hose fully 5/16 inch thick and the hose being quite short, there is very little give: it needs to be centered and aligned along with the other components.

While doing some alignment work on the shaft, I discovered a fool proof way to determine the best possible shaft alignment. When all the components are properly positioned, the motor should be adjusted in height and angle so that a solid coupler, 7/8 inch in diameter can slide from the driveshaft onto the motor shaft without undue strain. The final, fine adjustments can then be done electrically. The no load current to the motor with a 12 volt source is measured with the shaft disconnected. Say it measures 4 amps. The shaft is then connected and the current is measured a second time, (after lubricating the cutless bearing and the stuffing box with a shot of WD-40). If the current does not increase by more than 1 amp, the alignment is acceptable provided that the motor mounting bolts are tightened to their final torque setting.

More construction details are provided in Part 3 the "Build it Yourself Projects" section of this book. The alignment procedure described above was duplicated on the bench so that the shim sizes needed to obtain the correct alignment could be correlated with the electric measurements.

Why an O'Day Rhodes 19?

Besides saying that I always liked the looks of the Rhodes 19 and wanted to own one, it was just the right size for me. Not too big to trailer, yet roomy enough for 5 or 6 people. As a candidate for an electric drive, it had a fairly wide beam (7 feet) but it was fairly light: with the lighter center board, the 3 batteries and the console it weighed about 1200 pounds.

I had promised myself to measure the amount of pull needed to drag it in the water at hull speed before buying my next boat, but I never did. I reasoned that a boat with such a successful racing record must be well designed and slippery in the water. I was not disappointed.

Although I did more motoring than sailing, it was a nice change of pace to take it for a sail when the wind cooperated. Hingham Harbor which is within Boston Harbor is the home of a small fleet of Rhodes 19's.

The New Etek Motor

When I surveyed all the possible motors that were suitable for electric propulsion of boats, I was very impressed by the Lynch motor developed in the UK specifically for boat propulsion. The motor is light in weight, the speed is low at low battery voltages and, due to permanent magnet field, its efficiency is very high.

Except for the price which was three times as much as other DC motors of its size, it was the perfect boat motor.

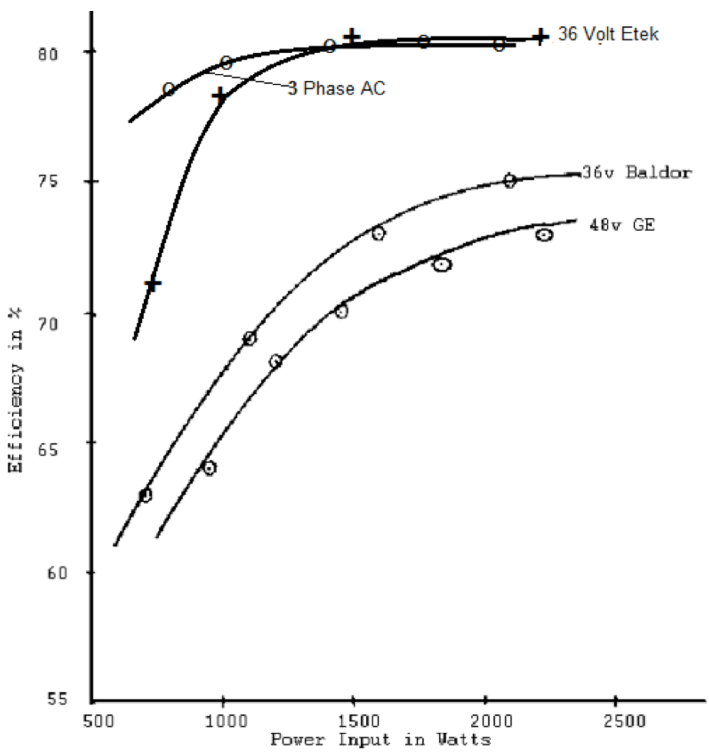

Figure 6.1 Efficiency of the Etek Motor

Mainly because of the high price of specialty motors like the Lynch motor, I carried on a research and development program hoping to find other efficient electric boat motors. I concentrated on the 3 phase AC motor which could run on DC batteries with an appropriate inverter/controller and would have equally good efficiency. It would also be safer for boating applications because it had no commutator and it had the potential of being even less expensive than the “golf cart” DC motors that were available at the time. The 3 phase AC motor will be discussed in Part 2.

Around that time (2002), Briggs and Stratton bought a license to build and sell the Lynch motor under the name Etek. The motor was built in China. It sold for a price competitive with other DC motors of that horsepower: about $400. Today, the Etek R is available for about $470.

Figure 6.1 (above) shows the dynamometer test results on 3 DC motors suitable for powering a boat like the Rhodes 19. The impressive Etek is nearly 10% more efficient than my original golf cart Baldor or the GE motor that was used in the Ray electric outboards at that time. Notice also that, unlike the other two DC motors, the efficiency remains high even though the motor operates at less than full power**.**

Figure 6.1 also compares the Etek motor with the 3 phase AC motor which was used in the “big test” at Mort Ray’s shop. The efficiencies are very comparable but notice that the 3 Phase AC motor’s efficiency remains even higher at very low power requirements. This AC motor was a prototype and every indication pointed to higher efficiencies as the motor continued to be refined with better Mosfet switches in the inverter/controller.

My dynamometer results on the Etek motor were about 5% less than the published results as they were for all the other motors that I tested. This is due mostly to the power lost in the bearings of the dynamometer as well as some wind losses that don’t show up in the pull of the spring scale readings.

In the Water Test Results

The in-the-water tests results (as seen in figure 6.2) compare the results of the other two sailboats tested with the Rhodes 19. Readings obtained from the curves show that it takes far less power to drive the Rhodes than the other boats. For example, at 5 mph the Rhodes requires 500 watts while the other 2 boats average about 1200 watts. At 6 mph, the Rhodes requires 1000 watts while the other two boats need 2000 watts.

At 19' 2" the Rhodes is the smallest of the 3 boats and the lightest. It weighs about 1200 lbs compared to the O'Day 20 at 2000 lbs and the 23 foot Sunny at 3000 lbs. Nevertheless, these very low power requirements are impressive and are due in large measure to the efficiency of the Etek motor.

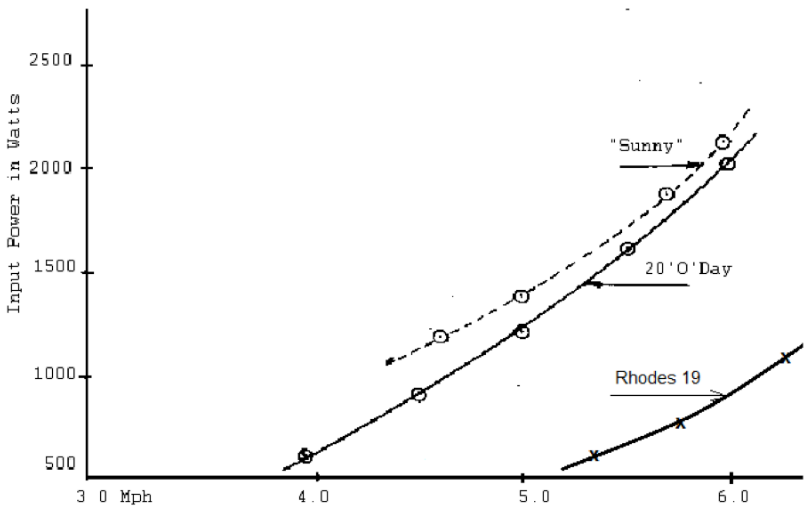

Figure 6.2 Input Power of Rhodes 19 vs. two Sailboats

In the box below, I added a column to a previously shown box to compare the Rhodes 19 results with those of the 20' O'Day and the 23 foot "Sunny".

Performance Comparison between "Sunny", 20' O'Day, and the Rhodes 19			
Speed in Knots	"Sunny" 1.75/1 Ratio (Watts)	20' O'Day 1.75/1 Ratio (Watts)	Rhodes 19 9X6 Prop (Watts)
4.0	1064 (Corrected from 1400)	1000	400
5.0	2050	1800	750

The results show that less than one half of the power is needed to move the Rhodes 19 compared to the other boats. These results are amazing but absolutely correct. We have been saying that for best results, the efficiency of the boat hull, the motor and the prop have to be optimized. This is the proof of the pudding!

With just three #27 deep cycle batteries discharging at less than 25 amps, the range for this boat is about 20 miles at 5.5 miles per hour.

Unfortunately, I do have in-the-water performance results for the 3 hp 3 phase AC motor in Sunny II. From the dynamometer tests we can tell that the efficiency of the two motors is almost equal and the low speed characteristics of 3 phase AC motors would make it even easier to match it to an efficient propeller for a direct drive. I would therefore expect exceptionally good results from a three phase AC motor also.

Propellers for the Rhodes 19

Another factor that contributed to the excellent results shown above is the choice of a proper propeller. Figure 6.3 below summarizes the results of in-the-water tests with various propellers. Four propellers were used for numerous in the water tests: A plastic 12x6, a brass 10x6, a brass 9x8 and finally the best prop, the 9x8 brass prop that was re-pitched into a 9x6 propeller.

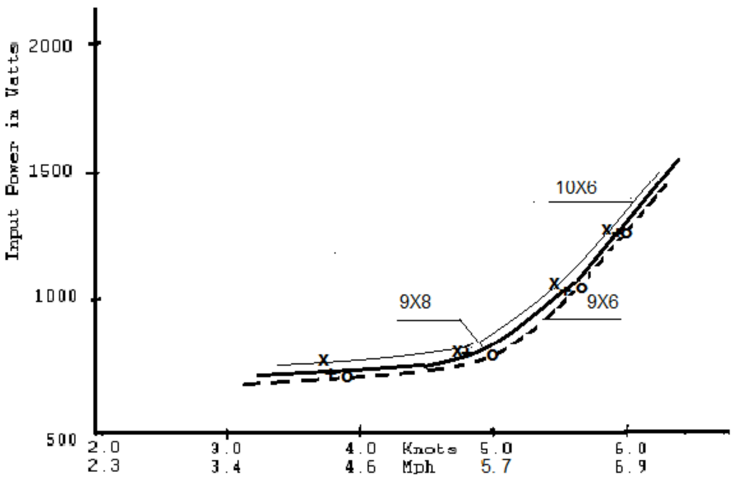

Figure 6.3 Three Propellers Tested in the Water

Early during the prop testing, I determined that the plastic 12x6 prop did not give better results than the brass 9x8 prop. It was therefore set aside while the testing of the other props proceeded.

Figure 6.3 above shows the average of many runs. The difference between props is not great, but it does show that the reworked brass 9x8 prop with the new pitch making it a 9x6 prop gives the best results.

The 9x6 propeller curve was used in figure 6.2 to compare the performance of the Rhodes 19 with the performance of the other two sailboats.

Drive shaft Alignment

An important consideration when attempting to obtain maximum efficiency is not to waste power in the shaft bearings. Misaligned bearings cause unwanted noise and vibrations.

As I mentioned before, with an electric drive, the fine adjustments for a perfect alignment can be made electrically. I set up a drive shaft mockup on a work bench complete with strut, stuffing box and Etek motor to simulate the full drive train that was used in Sunny II. My hope was to obtain a good correlation between out of line situations and the extra amount of current required. More about shaft alignment in Chapter 14.

Lessons Learned in Part 1- First 6 Chapters

In the first six chapters, we saw some very good examples of substantial improvements in performance in two of the three major areas of concern, namely:

The hull, where the sailboat hulls were so much more efficient at hull speed than the hull of the Carolina Skiff.

The correct propeller speed. We found that the electric outboard with a 2.42 reduction ratio provided a measurable improvement over the 1.75 ratio when used with a properly sized propeller.

We found that when the more efficient Baldor motor was replaced with the smaller Advance DC motor, the performance suffered badly. Part 2 of the book is dedicated to solving this third area of concern, namely what can be done to improve the efficiency of the electric motor.

We also found that an electric boat conversion based on a very efficient hull and a very efficient Etek motor installed as an inboard propulsion system provided unbeatable results. Equally good results would result from the use of a 3 Phase AC motor.

Part 2 of the book "Electric Boat Theory and Testing" includes two chapters on the specifications of a number of different DC motors. These are compared to a 3 phase AC motor which, with its custom designed controller, operates on DC batteries. Dynamometer tests are run to compare the performance of these motors.

Four more chapters are dedicated to the theory of electric motors, boat hulls, propellers, and batteries.