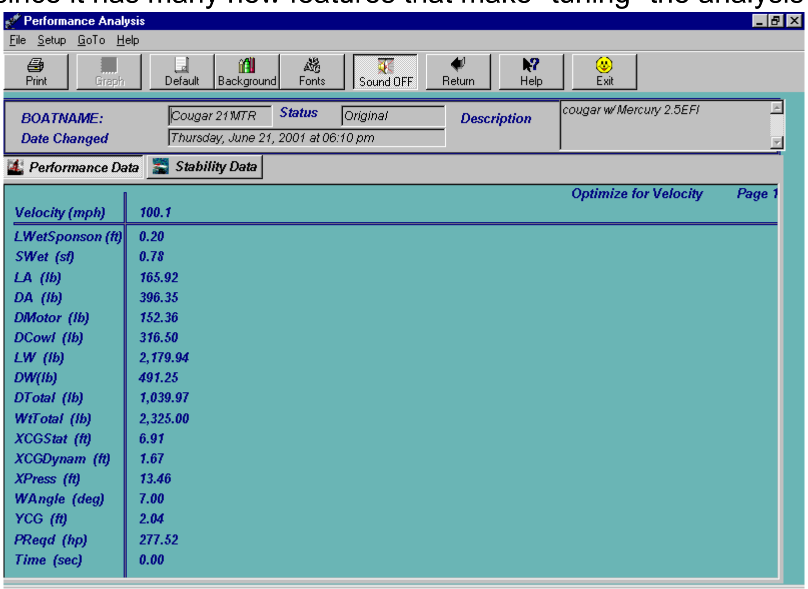
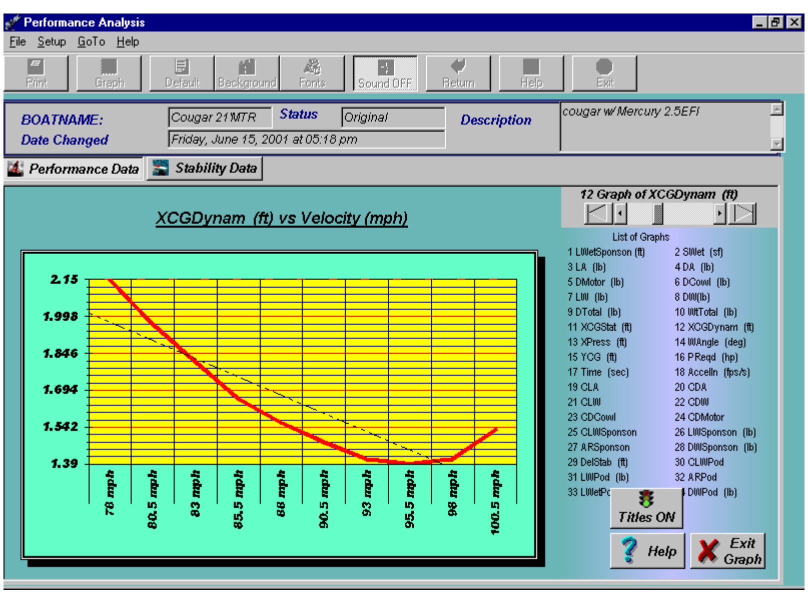
AeroMarine Research
TBDP Performance Boat Report

Cougar 21 MTR Performance Analysis

I wanted to do a "quick" analysis of top speed, and acceleration simulation. I used the (few) setup details from the boat test in F&PB's July 2001 issue. I admittedly, had to make some assumptions for many of the design and setup details that I was not aware of. The results should be, nevertheless, representative of the hull's capabilities. I used the new AeroMarine Research "Tunnel Boat Design Program", Version 6.3.3 for Windows 98 to do the analysis, since it has many new features that make "tuning" the analysis easy for top speed, acceleration and stability simulation. Here are the results and a few of my conclusions from the analysis done. You'll note that the TBDP© results are very similar to those that the F&PB boat test recorded.

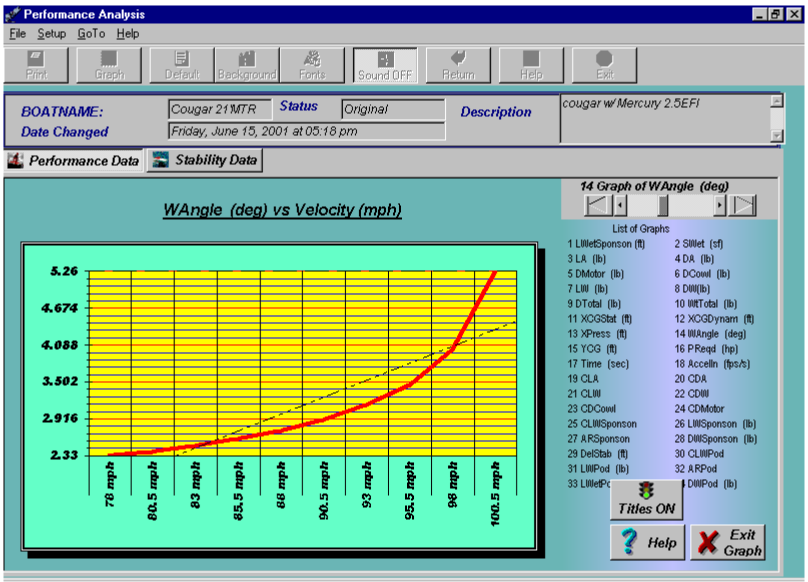




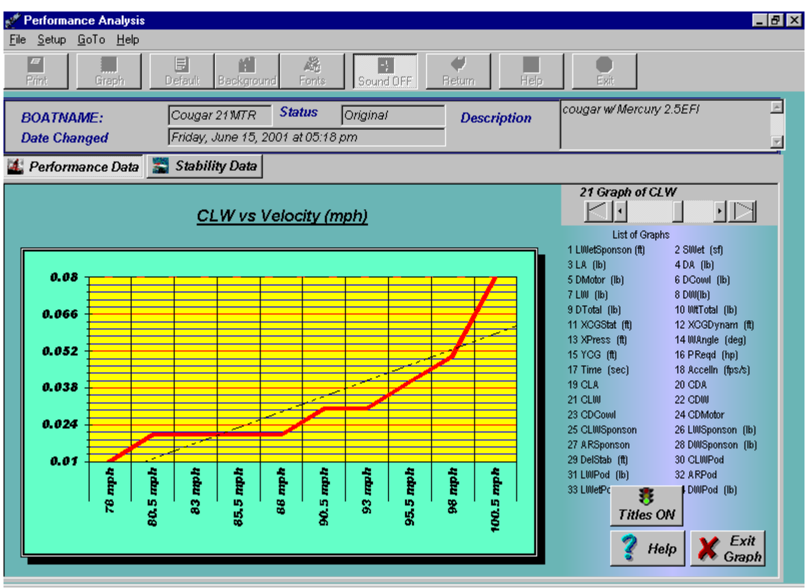
1. Top Speed is usually indicated by one or many of several performance parameters. I start by using the TBDP©'s "Velocity Optimizer" feature to predict maximum attainable velocity. By setting a purposely "too high" angle of attack (Wangle), the bounding maximum speed can be quickly approximated. ***For the Cougar 21MTR, this comes out as <u>100.1 mph</u>***. Sounds FAST, but for this hot boat, is reasonable. Further analysis can subsequently tell us more of the practical top speed.

2. Often one of the determining factors is stability. Since no tunnel hull can be inherently aerodynamically stable, I use a measure of stability that references the dynamic CG of the hull. This is the center of balanced

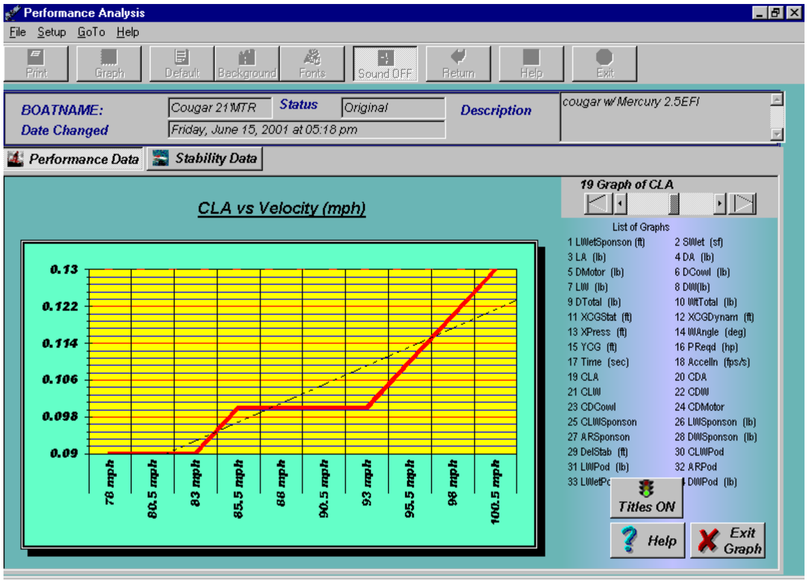
moments of all aerodynamic and hydrodynamic forces while the hull is under the specified running conditions, referenced fore (+) of the transom. The dynamic CG will change throughout the range of operating velocities. (To maximize stability at operating velocity, XCGDYNAM should be as close to the Static CG (deadweight balance) and ahead of the aerodynamic center, XPRESS). Well, this hull (like most tunnels) becomes inherently "unstable" at about 45mph, when the aerodynamic forces start becoming important. I define the stability measure as the *change* in the location of the dynamic CG with respect to the aerodynamic center. ***We can see from the graph of XCGDYNAM (ft) vs. Velocity that the whole stability of the hull changes at around 95.5 mph and REALLY changes at 98 mph. This indicates the onset of this hull's instability***. (This is normal for all tunnel's…just at different speeds). There's more top speed indicator's…



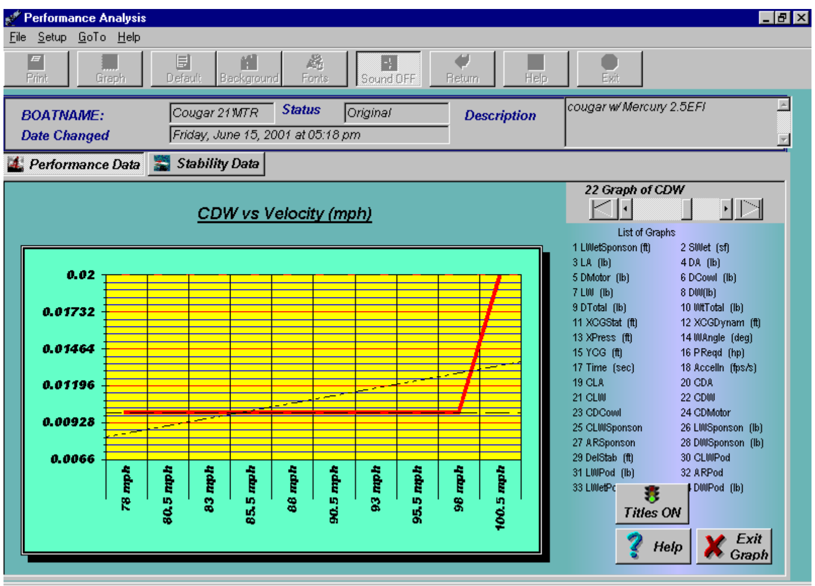
3. Of course tunnel boat drivers know that if you could keep giving it "up" trim forever without blowing over, the speed would be fantastic. The angle of attack that is required to attain higher velocities is shown in the graph Wangle (deg) vs Velocity. The graph shows that the *required* angle of attack of the Cougar 21MTR increases more and more as speed approaches 95 mph. At 98 mph the *required* angle of attack is 150% more than it was at 80 mph and the *rate of* change of the angle is now double what is was at 90 mph. ***We can conclude that 98 mph is about the velocity where the driver will have to react very quickly, and should have driving skill and experience before driving at these speeds in this or any other boat.*** There's still more indicators…



4. The coefficient of (total) Lift increases as the angle of attack increases. When the lift coefficient gets higher and higher, the boat finds it easier and easier to go faster. When the coefficient starts to increase quickly, it's time to be really careful. . The boat is going to see a lot more lift, and the driver will have to react much more quickly to compensate. This point of faster and faster increasing of (total) lift starts occuring with this design at about 93 mph, and becomes more pronounced at about 98 mph.



5. The coefficient of <u>aerodynamic</u> lift is somewhat stable up to about 90 mph, and then begins to increase a lot at about 93 mph. This means that the hull is going to find it ever easier to "fly".

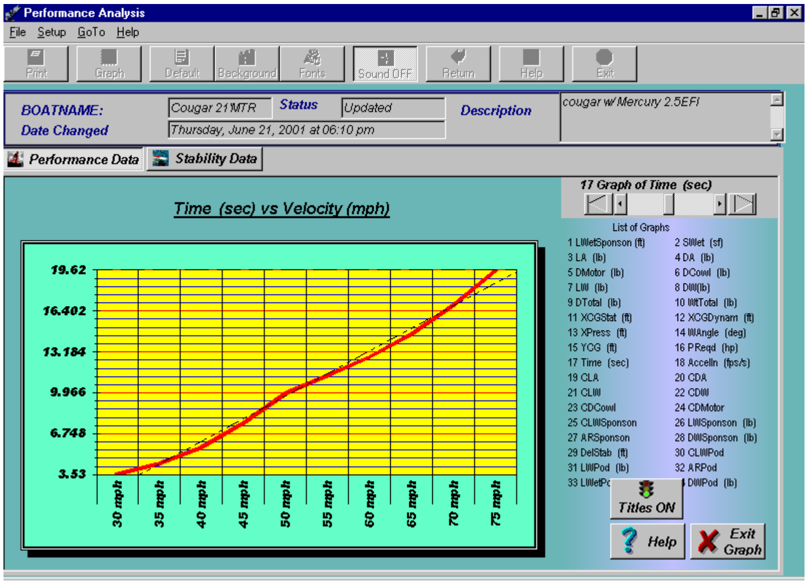


6. There's another easy clue in the drag coefficient. If we look at the graph of the hydrodynamic drag coefficient (CDW vs Velocity), we see that the CDW really JUMPS up at 98 mph. The sponson lifting efficiency improves, which means that the boat will start to exhibit more instability than at lower speeds, as the sponsons "skip" across the wave surfaces, with this higher efficiency occurring intermittently - ON…OFF…ON…OFF. Tunnel drivers know that this feeling at high speeds as a signal to pay very close attention.

<u>So, conclusion:</u> ***maximum velocity for this hull should be about 98 mph, with very good stability. It should have the capability of over 100 mph in good water conditions. What a great boat!***

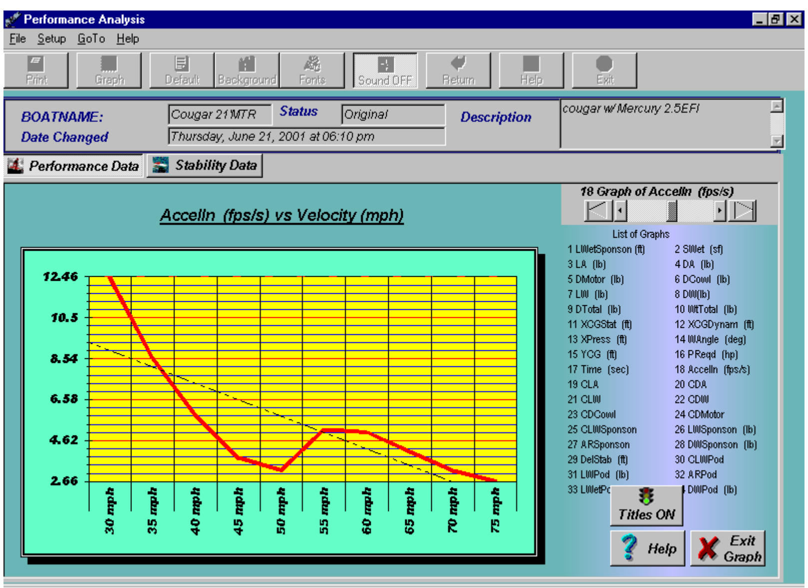
Let's look now at acceleration simulation…

The TBDP© does a simulation of elapsed time and acceleration. Lot's of factors influence these performance characteristics. The TBDP assumes ideal hull/motor setup (maximum efficiency) and ideal driving skills.



7. I analysed the same velocity range that the F&PB did during their boat test. Based on some assumptions of a controlled increase in angle of attack (Wangle), we predict the elapsed times for acceleration through the 30 mph to 75 mph range to be as shown in the Graph "Time (sec) vs Velocity. The predicted elapsed times are very similar to those that were recorded in the boat test:

	TBDP© prediction	F&PB boat test
0-30 mph	3.53 sec	4.4 sec
to 40mph	5.64 sec	6.3 sec
to 50 mph	9.88 sec	8.4 sec
to 60 mph	12.77 sec	12.3 sec
to 70 mph	16.86 sec	17.2 sec



8. The acceleration graph is merely a result of the elapsed time analysis. It is interesting to see that the acceleration or rate of increasing velocity (ft per second per second) decreases up to about 50 mph, and then increases again. This intermediate velocity range (50 mph to 75 mph) of is called the *transition zone*, and exists on all tunnel boats, but is different for each hull and setup. I'll bet that John Cougar saw this transition happen at about 50 mph and lasti until 65-75 mph, with this rig.

Here's the design input and performance output that I got in my review of the Cougar 21MTR.

TUNNEL BOAT DESIGN PROGRAM©
Version 6.3.3 - Copyright 1999-2001 by AeroMarine Research/Jim Russell
BoatName: Cougar 21'MTR
Description: cougar w/ Mercury 2.5EFI
Counter: 426 DateChanged: Thursday, June 21,2001 06:10 pm
Status: Updated Page 2 (Printed Thursday, June 21,2001 06:11 pm)

Output Data: for Power optimization:

Velocity (Mph)	30	35	40	45	50	55	60	65	70	75
LWetSponson (ft)	21.00	21.00	21.00	21.00	15.51	8.40	6.27	4.86	3.74	2.72
SWet (sf)	249.15	169.13	120.19	88.50	59.98	32.50	24.25	18.78	14.47	10.52
LA (lb)	7.87	11.04	14.83	19.30	24.46	30.35	37.00	44.44	52.71	61.81
DA (lb)	35.72	48.61	63.47	80.32	99.15	119.95	142.73	167.48	194.22	222.92
DMotor (lb)	14.51	19.60	25.42	31.99	39.28	47.31	56.07	65.56	75.77	86.70
DCowl (lb)	28.45	38.72	50.57	64.00	79.01	95.61	113.78	133.54	154.87	177.78
LW (lb)	2,317.13	2,313.96	2,310.17	2,305.70	2,321.81	2,312.45	2,302.17	2,293.26	2,290.46	2,281.87
DW(lb)	2,450.39	2,242.71	2,067.56	1,917.76	1,705.68	1,328.80	1,148.37	1,054.21	974.74	877.26
DTotal (lb)	2,500.62	2,310.91	2,156.46	2,030.06	1,844.11	1,496.07	1,347.17	1,287.25	1,244.73	1,186.89
WtTotal (lb)	2,325.00	2,325.00	2,325.00	2,325.00	2,325.00	2,325.00	2,325.00	2,325.00	2,325.00	2,325.00
XCGStat (ft)	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91
XCGDynam (ft)	10.79	10.78	10.78	10.78	8.06	4.54	3.51	2.86	2.37	1.93
XPress (ft)	10.37	10.49	10.61	10.73	10.84	10.95	11.06	11.17	11.28	11.38
WAngle (deg)	1.60	1.72	1.84	1.97	2.09	2.21	2.33	2.46	2.58	2.70
YCG (ft)	1.38	1.39	1.41	1.42	1.44	1.45	1.47	1.48	1.50	1.51
PReqd (hp)	200.05	215.69	230.02	243.61	245.88	219.42	215.55	223.12	232.35	237.38
Time (sec)	3.53	4.39	5.64	7.58	9.88	11.31	12.77	14.56	16.86	19.62
Accelln (fps/s)	12.46	8.59	5.84	3.78	3.19	5.15	5.02	4.09	3.18	2.66
CLA	0.0775	0.0798	0.0822	0.0844	0.0867	0.0889	0.0911	0.0932	0.0953	0.0974
CDA	0.0304	0.0303	0.0303	0.0303	0.0303	0.0302	0.0302	0.0302	0.0302	0.0302
CLW	0.0050	0.0054	0.0058	0.0062	0.0074	0.0113	0.0126	0.0139	0.0155	0.0185
CDW	0.0052	0.0052	0.0052	0.0051	0.0055	0.0065	0.0063	0.0064	0.0066	0.0071
CDCowl	0.0993	0.0993	0.0993	0.0993	0.0993	0.0993	0.0993	0.0993	0.0993	0.0993
CDMotor	0.0103	0.0102	0.0102	0.0101	0.0101	0.0100	0.0100	0.0099	0.0099	0.0099
CLWSponson	0.0048	0.0052	0.0056	0.0060	0.0076	0.0121	0.0134	0.0142	0.0154	0.0186
LWSponson (lb)	1,552.9	1,552.4	1,551.3	1,549.6	1,508.2	1,562.8	1,486.2	1,408.8	1,349.9	1,322.9
ARSponson	0.0745	0.0745	0.0745	0.0745	0.1101	0.2876	0.3167	0.3167	0.3387	0.4657
DWSponson (lb)	1,688.7	1,545.6	1,424.9	1,321.7	1,082.6	837.1	700.3	632.0	576.3	506.5
DelStab (ft)	0.4	0.3	0.2	0.0	-2.8	-6.4	-7.6	-8.3	-8.9	-9.5
CLWPod	0.0053	0.0057	0.0061	0.0065	0.0071	0.0099	0.0115	0.0133	0.0156	0.0184
LWPod (lb)	764.3	761.6	758.9	756.1	813.6	749.7	815.9	884.5	940.5	959.0
ARPod	0.0741	0.0741	0.0741	0.0741	0.0786	0.1421	0.1749	0.2163	0.2713	0.3523
LWetPod (lb)	18.0	18.0	18.0	18.0	17.0	9.4	7.6	6.2	4.9	3.8

TUNNEL BOAT DESIGN PROGRAM©
Version 6.3.3 - Copyright 1999-2001 by AeroMarine Research/Jim Russell
BoatName: Cougar 21'MTR
Description: cougar w/ Mercury 2.5EFI
Counter: 426 **DateChanged: Thursday, June 21,2001 06:10 pm**
Status: Updated **Page 1 (Printed Thursday, June 21,2001 06:11 pm)**

Hull Design					
1 TunnelHeight:	9	(inches)	2 TunnelWidth	41	(inches)
3 WingChord	19	(feet)	4 WingThickness	10	(inches)
5 PadWidth	12	(inches)	6 PadDeadrise	16	(degrees)
7 DeckWidth	89	(inches)			
Steps					
8 Step Selection	One Step	(selected)	9 StepLength1	4	(feet)
10 StepLength2		(feet)	11 StepHeight	0.25	(inches)
CentrePod					
12 CtrPodSelect	Yes	(selected)	13 CtrPodLength	18	(feet)
14 PodWidth	16	(inches)	15 PodDeadrise	12	(degrees)
16 PodHeight	-1	(inches)			
Spray Rails					
17 SprayHeight	5	(inches)	18 SprayWidth	3.25	(inches)
19 SprayFac	0.5	(factor)			
AeroFoil					
20 AngleInc	1	(degrees)	21 AeroType	Low Camber	(selected)
Lengths					
22 BoatLength	21	(feet)	23 DriverLength	9.5	(feet)
24 MotorLength	-1	(feet)	25 FuelLength	2	(feet)
26 MiscLength	2	(feet)	27 MotorHeight	36	(inches)
Weights					
28 BoatWeight	1300	(pounds)	29 DriverWeight	200	(pounds)
30 FuelWeight	300	(pounds)	31 MiscWeight	150	(pounds)
32 MotorWeight	375	(pounds)			
Cowlings/Cockpit					
33 CowlType	None	(selected)	34 CowlHeightRear	12	(inches)
35 CowlHeightFront	12	(inches)	36 CowlWidth	55	(inches)
Design Analysis					
37 Optimize	Power	(selected)	38 Accuracy	1	(percent)
39 StartVelocity	30	(mph)	40 VelocityInc	5	(mph)
41 StartAngle	2.7	(degrees)	42 Accel Model	Straight-Line From	(selected)
Conditions					
43 PowerMax	280	(hp)	44 PowerEffyFac	0.9	(percent)
45 Altitude	100	(feet ASL)	46 WaterType	Fresh	(selected)
Drive Unit(s)					
47 Number of Drives	One Drive	(selected)	48 SkegWidth	9	(inches)
49 SkegLength	10	(inches)	50 SkegThickness	0.2	(inches)
51 TorpedoDiam	4.75	(inches)	52 TorpedoLength	12	(inches)
53 Drive Type	Merc V6	(selected)	54		

MERCURY 2.5 EFI SPORT

Engine Tested: Mercury 280 EFI Sport

Type: Two-stroke spark EFI

Displacement: 153 cubic inches (2.5 liters)

Weight: 375 lbs. (advertised)

Optimum RPM range: 7,200-7,500

Gear Ratio: 1.87:1

Propeller: 14-1/2x30-inch Mercury Lightning ET

Jackplate: Bob's Machine hydroelectric

Setback: 6 inches

Weather Conditions

Air Temperature: 56 degrees F

Water Temperature: 49 degrees F

Wind: 5-10 mph

Humidity: 59 percent

Water conditions: 2- to 6-inch chop

Performance Test

RPM	MPH (Radar/ GPS avg.)
1,000	5.1
1,500	5.7
2,000	6.6
2,500	18.0
3,000	28.9
3,500	38.0
4,000	42.5
4,500	48.7
5,000	55.6
5,500	60.1
6,000	72.2
6,500	82.9
7,000	88.7
7,500	97.6
7,600	102.0 (driver only)

Top Speed: 97.6 mph @ 7,500 RPM (solo: 102 mph @ 7,600 rpm)

0-30 mph: 4.4 seconds
0-40 mph: 6.3 seconds
0-50 mph: 8.4 seconds
0-60 mph: 12.3 seconds
40-60 mph: 5.9 seconds
50-70 mph: 8.8 seconds

Base price: N/A (each boat custom-equipped)

Price as tested: $44,360

Construction: Fiberglass/ coremat/foam coring

Interior: Two buckets and rear bench; 111x55-inch cockpit

Length: 21 feet

Beam: 89 inches

Hull Weight: 920 lbs. bare (as advertised)

Fuel Capacity: 30 gallons

From: Family & Performance Boating

July 2001 Performance Test Cougar 21 MTR

www.aeromarineresearch.com
jimboat@aeromarineresearch.com

About AeroMarine Research:

Jim Russell is a professional engineer with a mechanical and aeronautics background. Currently living in Canada, he has done extensive aerodynamic research at University of Michigan, OH and University of Toronto, Canada and marine research at the NRC water channel laboratory in Ottawa, Canada. His published works and papers are highly acclaimed, and are specifically related to the aerodynamics and hydrodynamics of high performance catamarans and tunnel boats, vee and vee-pad hulls. Russell has designed and built many tunnel and performance boats. As a professional race driver, he piloted tunnel boats to Canadian and North American championships. He has written power boating articles for many worldwide performance magazines and has covered UIM and APBA powerboat races. He has appeared on SpeedVision's '*Powerboat Television'* as a guest expert on 'Tunnel Hulls', was performance/design technical consultant on National Geographic's '*Thrill Zone*' TV show, and editorial consultant on Discovery Channel's '*What Happened Next*' TV show. Russell is the author of the "Secrets of Tunnel Boat Design©" book, "The Wing in Ground Effect - Their relation to Powerboats©", book, and the "Secrets of Propeller Design©" book. His company has designed and published the well-known powerboat design software, "Tunnel Boat Design Program©" and "Vee Boat Design Program©" specifically for the design and performance analysis of tunnel boats, powered catamarans, performance Vee and Vee-Pad hulls.

Notes about this Report: The considerations addressed in this report are for a high performance powerboat design and application and thus results are highly dependent on detailed specifics of the hull design, modifications, construction, hull setup and operation, and other factors that are not within the scope of this report. The TBDP©/VBDP© software uses proven engineering algorithms to predict performance of planing hull designs of different configurations and lends itself well to comparative performance analysis. The software provides typical predictive performance data to aid in making design comparisons which may be helpful toward making design decisions.

Since the existing design of the hull, any subsequent modifications, and ultimate performance is complex, this performance review, this report and included recommendations are for your information only and cannot guarantee the results.