The fifth hullform tested was a λ=9 model of NSWC's 42' jet pump powered boat, given the designation PCC. This boat exhibited prismatic qualities in the after section, but had reverse chines. The hull's deadrise angle was 17.8 degrees, and its pump intakes and outlets had been plugged and faired over for this experiment. The model was run with the trim tabs mounted in the same fashion. The same trim tabs were used, despite the difference in scale factors. This was acceptable because the purpose of these tests was to establish methods for analyzing the properties of the low-aspect ratio trim tabs, and not to make full-scale predictions for a real boat. Towing tank experiments serve as a controlled environment in which analysis can be carried out, and the results define the geometry of the water flow across the model's hull and the movement of the center of pressure with respect to trim angle which ultimately determines porpoising inception.

Testing with the PCC model proceeded in the same manner as for the previous hull. The trim tab turnbuckles were remounted on the tab flanges, and the adjustment procedure was recalibrated to accommodate the new hull. Again, the tabs were mounted with a $^1/_8$" vertical offset. A summary of test results for the PCC appears in Figure 15, with trim tab deflections and effective deadrise angles tabulated in Table 5. After one day of testing with the PCC model, it was determined that the new setup was operating almost exactly as expected. Rather than expand the matrix laterally by running more load configurations, the opportunity was seized to analyze the effects of altering the trim tabs. The method set forth by Savitsky (1976) predicted trim tab force for high aspect ratio and full beam transom flaps and wedges, but did not appear to represent the lifting qualities of the low aspect ratio, tapered trim tabs in question.

The first modification consisted of simply cutting a pair of plates from $^1/_8$" thick PVC (polyvinyl chloride, a form of plastic) to the same planform as the trim tabs, and affixing them to the bottom surface of the trim tab with silicone adhesive. This resulted in a zero vertical offset condition, which could be confirmed by placing a ruler along the buttock line and tab combination. The expectation was that at the same deflection angles, the trim tab would produce more lift with the plates attached as the region of lift-robbing low pressure would not exist behind the vertical step up to the trim tab. As anticipated, when the model was run, it required approximately one degree less trim tab deflection at slow speeds, and up to three degrees less deflection at high speeds were required to bring the boat to the same stability condition. Eliminating the vertical mounting offset did in fact increase the pressure under the trim tabs. These tests were performed at the same loading configuration as the original test. The second modification again utilized $^1/_8$" PVC, except the plates were cut to be rectangles with a 2" width, equivalent to the width of the tapered trim tab at the root. Adding the rectangular plate not only increased the tab area, but the effective aspect ratio as well.

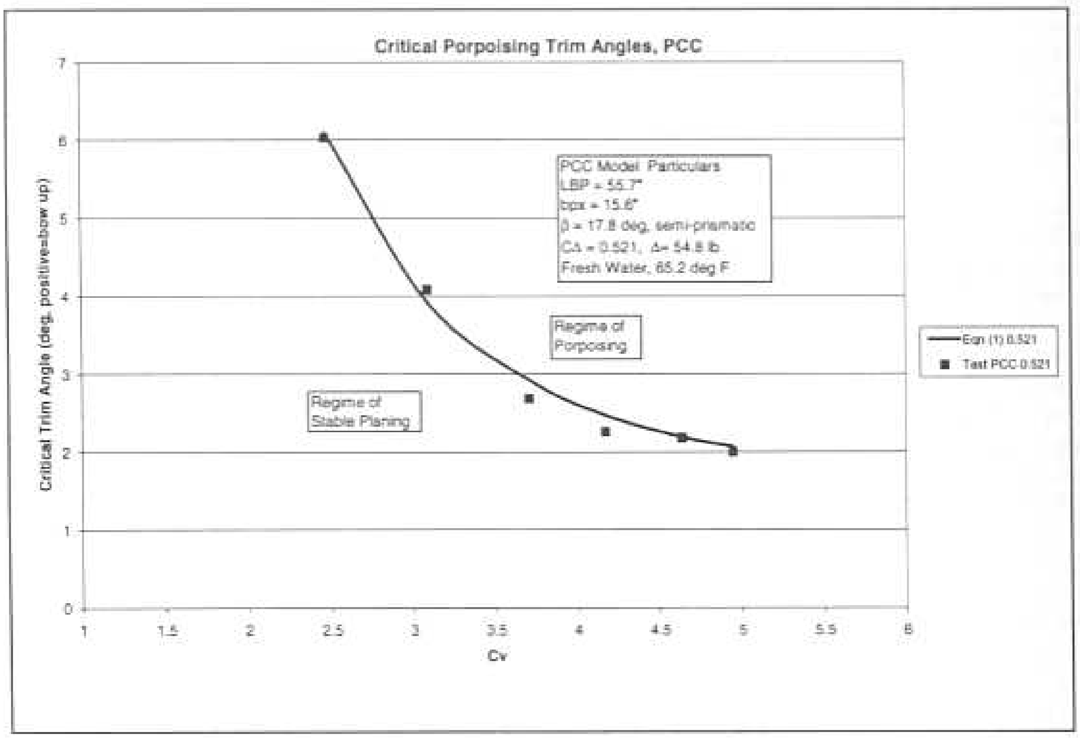

Figure 15 – Results of Testing, PCC

V, condition ft/sec	TabDef deg	Cδ	Effective Deadrise
16, A	14	0.377	12
20, A	15	0.362	12
24, A	15	0.345	12
27, A	15	0.331	12
30, A	13	0.326	12
32, A	11	0.329	12

Table 5 –Model Test Data, PCC

Because of the tapered design of the Kiekhaefer trim tabs, there existed a degree of uncertainty as to how to determine their effective aspect ratio as a lifting surface. Up to this point, the experimenter could only draw inference about how much lift was actually being produced from their effects on the stability of the craft. This method depended on the accuracy of several empirically derived equations, most notably the Savitsky Equation 28 (1964) used to predict the center of pressure of the planing surface. This equation clearly did not predict the effects of the lifting strakes. Also, the influence of the hull features forward of the trim tabs could have an effect upon the boundary layer in the region of the trim tabs and/or the flow patterns to the trim tabs themselves. The equations for the center of pressure and trim tab lift could both be adjusted such that they worked in harmony, but without actually determining the characteristics of one of the forces, both would remain questionable guesses. With such complex influences present, it was clear that in order to develop a reliable method from a scientific approach, a model or full scale test would have to be carried out to determine the trim tab lifting characteristics.

The major requirement for the dynamometry intended for lift measurement was that it would not interfere with the water flow to the trim tabs or produce any extra lift itself. The resulting design is pictured in Figure 16. A 2" force block with a 10 lb. capacity was selected to serve as the force transducer, and an aluminum plate was fabricated to serve as a mounting surface for the port trim tab. The force block was bolted to the top of this plate so that it straddled the transom as shown. A second plate was bolted to the opposite side of the block, and the entire mechanism was bolted through a PVC block to the inside of the transom. The apparatus was shimmed so as to provide approximately 0.02" clearance between the plate and the transom. Therefore, the lift force developed by the trim tab would be transferred completely through the force block for measurement. The apparatus was assembled on the port side, and a $^1/_4$" PVC plate was fabricated and fitted as a spacer on the starboard side to make both sides hydrodynamically similar. The same $^1/_8$" vertical mounting offset was preserved.

Runs were conducted in the standard manner at a variety of speeds. After several runs, it was determined that the lift generated by the measured trim tab was independent of the running trim angle of the model hull, once the rig had accelerated to the fully planing condition. As the model accelerated, the trim tab lift increased exponentially, as expected. As can be seen in Figure 17, the lift time history for this sample run was constant at steady state speed, and then decreased exponentially upon deceleration. The resulting time history of the lift signal appears as a plateau with parabolic sides. It was found that the lift coefficient for all speeds above 17 ft/sec remained essentially constant for each trim tab deflection. Even though the model oscillated several times before settling out, the lift being generated by the trim tab remained essentially constant. The forces due to pitching accelerations were likely the cause of the small variation that did exist.

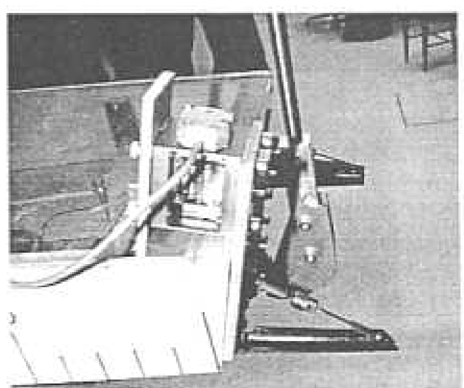

Figure 16 – Trim Tab Lift Dynamometer

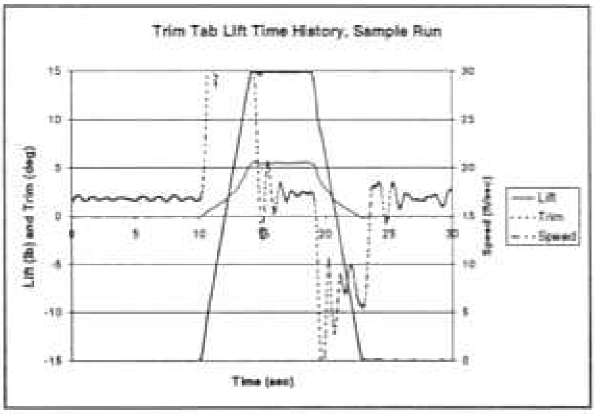

Figure 17 –
Sample Time History of Trim Tab Lift Test

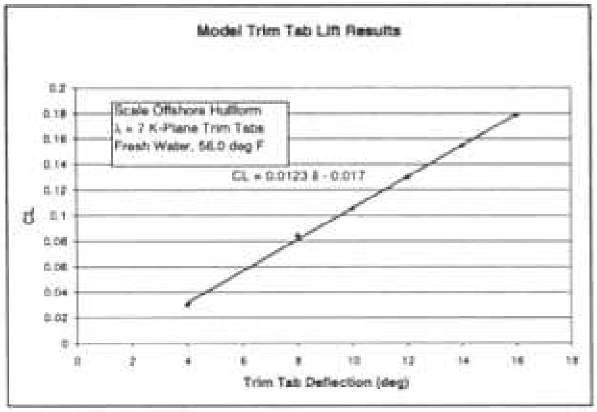

Figure 18 –
Lift Coefficient vs. Trim Tab Angle of Attack

Upon compilation of the data, the lift coefficient increment, measured per degree of deflection was also very linear for all deflections above four degrees. Figure 18 shows the near-linear character of the lift coefficient data with increasing angle of attack. A linear regression line has been plotted with the points as well, with the equation displayed on the plot. The C_L value appears to occur well above zero degrees tab deflection, and this is believed to be due to the aforementioned vertical mounting offset.

Once the lifting properties of the trim tabs were determined, the next step was to evaluate the existing theoretical methods for calculating lift and select one which would be accurate and suitable for use. Jones' formula predicts the linear lift curve slope for airfoils solely based on the aspect ratio, AR, of the surface. The trim tabs during testing produced a lift curve slope of 0.0123 per degree when measured normal to the trim tab surface, perpendicular to the deadrise surface. When the trim tab span at the one-quarter chord point was used to calculate the aspect ratio, Jones' Formula predicts a lift curve slope of 0.0120 per degree, a difference of 2.5%. This method was adopted for determining the lift produced by low aspect ratio, tapered trim tabs and, since the center of pressure of a lifting surface is generally assumed to be at or very near the one-quarter chord point, it is logical. Equations (8) and (9) are applicable to transom mounted trim tabs for high speed planing hulls.

$$\frac{dC_L}{d\alpha} = \frac{\pi * AR}{2 * 57.3} \quad \text{per degree} \tag{8}$$

$$L_{TAB} = \frac{1}{2}\alpha\frac{dC_L}{d\alpha}\rho V^2 A \tag{9}$$

SUMMARY

A total of 247 runs were made in the NAHL 380' towing tank at or near porpoising inception boundaries, with 5 separate model hulls. The load and LCG were varied for the prismatic models, and for the scale models, the trim tab deflection was varied for each displacement setup. All told, the efforts applied to the testing aspect of this program yielded 67 inception points from which to conduct analysis. Equation (1) has been shown to predict the critical porpoising trim angle with a good degree of accuracy for prismatic and semi-prismatic hulls, if the effect of lifting strakes can be accounted for.

The following trends can be observed from the data:

1. Porpoising inception for a given hull at a given speed depends on running trim angle no matter how that trim angle is attained.
2. The critical trim angle increases with increasing deadrise.
3. The critical trim angle increases with increasing loading.
4. The critical trim angle decreases with increasing boat speed.

These observations, while pertinent, do not actually address the significance of the critical trim angle with respect to the natural trim angle the hull would assume for a given speed and loading. Therefore, as a predictive method, knowledge of the critical trim angle is merely a starting point for the ensuing analysis.

In order to determine the running characteristics with respect to the critical running trim angle, every significant force and moment would have to be accounted for, and the system should be in equilibrium. It was clear that such a tool had the potential to become a predictive method itself, but was required to conduct the present