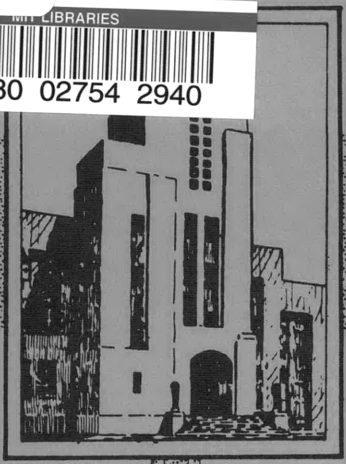

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# DAVID TAYLOR MODEL BASIN

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# APPLICATION OF THE LAP-TROOST EXTRAPOLATION METHOD TO SUBMERGED BODIES OF REVOLUTION

by

Morton Gertler

HYDROMECHANICS LABORATORY

**RESEARCH AND DEVELOPMENT REPORT**

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## ABSTRACT

Comparisons with experimental drag data for a number of submerged bodies of revolution tested at the David Taylor Model Basin indicate that these data cannot be satisfactorily fitted with the Lap-Troost formula. Since such a fit cannot be obtained within the model range of Reynolds numbers, it is concluded that the model viscous drags for submerged bodies cannot be validly extrapolated to full-scale values using the Lap-Troost method. This reasoning can be extended to surface-ship models whose viscous drags below wave-making speeds should be similar in nature to those of submerged bodies. A satisfactory fit to the submerged-body data can be obtained, however, with equations of the form of the Schoenherr formula plus a constant.

## INTRODUCTION

In a paper entitled "Frictional Drag of Ship Forms" presented at the February meeting of the North California Section of the Society of Naval Architects and Marine Engineers, the authors A.J.W. Lap and L. Troost presented a new method for extrapolating the measured viscous drags of models to corresponding full-scale values. The purpose of the present paper is to determine the applicability of this method to the treatment of resistance data for submerged bodies whose drags are entirely viscous. In retrospect, since the drags of submerged bodies are viscous in origin, such available data could have been initially used to empirically devise a viscous drag extrapolator, and consequently can now be used to evaluate existing extrapolators. It is believed that these evaluations will also have a significant bearing on the validity of the application of the Lap-Troost method to the viscous drags of surface-ship models.

## THE LAP-TROOST METHOD

The Lap-Troost method was evolved as the result of observations of trends of the drag-coefficient' versus Reynolds-number curves for three families of geosims; the Wageningen Simon Bolivar Series, the Hamburg Fast Passenger Liner Series, and the Hamburg Cruiser Series. For each of these families, the total-drag coefficient versus Reynolds-number curves, below Froude numbers at which wave-making resistance becomes evident, were considered to be made up entirely of viscous components. It was determined that a single line on a Reynolds-number plot could be validly used to join these viscous-drag coefficients for all of the different sized models comprising a given family of geosims. It was further observed that the resulting curves for these families were displaced from each other by a constant amount on the logarithmic scale of Reynolds number, and also that curves fitting the Nikuradse pipe data and the Schultz-Grunow flat-plate data were each similarly displaced from the remaining curves. These observations led to the establishment of the following general equations which have been offered as a method for extrapolating the viscous drags obtained from surface-ship model tests to the full-scale values at corresponding speeds:

$$C_{fd} = 0.133\ (\log R_n + 0.724 - \log A)^{-2.2} \qquad [1]$$

$$C_{fd} = 0.133\ (\log R_n - 1.356 - \log n)^{-2.2} \qquad [2]$$

where $C_{fd}$ is the viscous-drag coefficient,

$R_n$ is the Reynolds number,

$\log A$ is the logarithmic displacement on Reynolds number between the viscous-drag coefficient curve for the subject vessel and that for the Nikuradse pipe data, and

$\log n$ is the logarithmic displacement on Reynolds number between the viscous-drag coefficient curve for the subject vessel and that for the Schultz-Grunow data. $\log n = \log A - 2.08$.

The choice of either Equation [1] or [2] depends on whether it is desired to use the pipe data or flat-plate data as a reference. Equation [1] is shown graphically in Figure 1 for various selected even values of $\log A$.

## COMPARISON WITH EXPERIMENTAL DATA FOR SUBMERGED BODIES OF REVOLUTION

The results of submerged resistance tests of about 40 streamlined bodies of revolution are available at the David Taylor Model Basin, and these data provide an excellent opportunity to make comparisons with the Lap-Troost extrapolators. The data cover a wide variety of forms whose drags are entirely viscous, with little or no actual separation, as evidenced from flow tests. The experiments covered a range of Reynolds numbers from $2.0 \times 10^6$ to $2.6 \times 10^7$ as compared with the range of Reynolds numbers covered by the vicious drags of the Simon Bolivar experiments of from $1.3 \times 10^6$ to $1.9 \times 10^6$. Approximately 30 to 40 data points were taken for each model, which traversed this range of Reynolds numbers in small increments. Turbulence stimulation was provided by means of a half-inch strip of 20- to 30-mesh sand placed circumferentially around the nose of each model at a distance of 1/20 of the length from the nose. The effects of stimulation were consistent among all models, and the parasitic drag was accurately determinable. Typical experimental data are shown for two of the models in Figure 2. It may be noted that the maximum deviation of individual spots from the faired curve is, except for a few isolated spots, ± 0.3 percent. This accuracy was prevalent throughout the tests of the remaining models so that little interpretation was required to obtain the best faired curve in all cases.

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4. Bodies of revolution – Resistance
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