National Research Council Canada
Institute for Ocean Technology

Conseil national de recherches Canada
Institut des technologies océaniques

Institute Report

IR-1993-01

# Resistance standards for Canadian fishing vessels

W. D. Molyneux

January 1993

Molyneux, W. D., 1993. Resistance standards for Canadian fishing vessels. 45th Canadian Maritime Industries Association. Technical Conference, 16  February 1993, Ottawa, ON Session  A5 : 13 p.

Canada

National Research Council Canada
Conseil national de recherches Canada

Institute for Marine Dynamics
Institut de dynamique marine



# RESISTANCE STANDARDS FOR CANADIAN FISHING VESSELS

IR-1993-01

W.D. Molyneux

January 1993

# DOCUMENTATION PAGE

| REPORT NUMBER<br>IR-1993-01 | NRC REPORT NUMBER<br>33934 | DATE<br>January 1993 |
|---|---|---|
| REPORT SECURITY CLASSIFICATION<br>Unclassified | | DISTRIBUTION<br>Unlimited |

**TITLE**

**RESISTANCE STANDARDS FOR CANADIAN FISHING VESSELS**


**AUTHOR(S)**

W.D. Molyneux

**CORPORATE AUTHOR(S)/PERFORMING AGENCY(S)**

Institute for Marine Dynamics
National Research Council Canada



**PUBLICATION**

Proceedings of the 45th annual technical conference of the Canadian Maritime Industries Association, February, 1993, Ottawa, Canada

**SPONSORING AGENCY(S)**

Institute for Marine Dynamics
National Research Council Canada


| IMD PROJECT NUMBER<br>275 | NRC FILE NUMBER<br>- | | |
|---|---|---|---|
| **KEY WORDS:**<br>fishing boats, resistance, regression analysis | PAGES<br>iii, 13 | FIGS.<br>7 | TABLES<br>4 |


**SUMMARY:**

Canadian inshore fishing vessels have been constrained by length restrictions. In order to meet increased operational demands on these hulls, Naval Architects have reduced length to beam and beam to draft ratios beyond those of other small ships. This has placed them outside the range of many established industry standards of performance, and so designers have had no reliable method of evaluating their basic hydrodynamic performance. This paper describes the development of simple resistance standards for wide, deep fishing boat hull forms, based on the analysis of the resistance data obtained at the Institute for Marine Dynamics. It then uses these standards to evaluate some typical modern fishing boat hull forms.



**ADDRESS:** National Research Council
Institute for Marine Dynamics
P. O. Box 12093, Station 'A'
St. John's, NF
A1B 3T5

# Table of Contents

# Resistance Standards for Canadian Fishing Vessels

## 1. Introduction

The current Canadian fisheries regulations limit a fishing licence to a specific length of boat and so the only opportunity to increase vessel size is to extend beam and draught outside the ranges previously thought to be practical. Fishing boats also require a large deck area aft in order to facilitate handling the fishing gear. These factors combine to produce boats which are very wide in relation to their beam and have very large transom areas. The large transom provides good static stability for the hull, but comes with the associated penalty of a high resistance to forward motion, relative to a boat with a small transom.

Although the East Coast fishery is currently in a state of recession, with proper management it should soon return to its former economic significance. The lack of business activity presents an excellent time to review vessel designs in support of the longer term objective of providing an economically sustainable industry. One element of this process is the development of performance standards based on the existing boats. These standards can then be used to provide an objective evaluation of the efficiency of a new design against its predecessors. For this paper, a performance standard is defined as the average performance of a vessel, after allowing for the effects of the most significant variables.

The calm water resistance has an effect on the economics of fishing, since hulls with high resistance require larger and more expensive power plants, which are also more expensive to operate. Canadian fishing vessels are outside the range of many published empirical prediction methods, due to their shape. For this reason it was identified as a priority to develop standards of performance specifically for this type of boat. This work was carried out as part of the Institute for Marine Dynamics' research program and the detailed description of the analysis and methods used is given in Reference 1.

## 2. IMD Resistance Data for Canadian Fishing Vessels

Over the last forty years, IMD has collected resistance data on 21 hulls which were described as fishing vessels or had hull forms similar to those used by fishermen. All of these were tested for Canadian clients and the majority were classed as small inshore

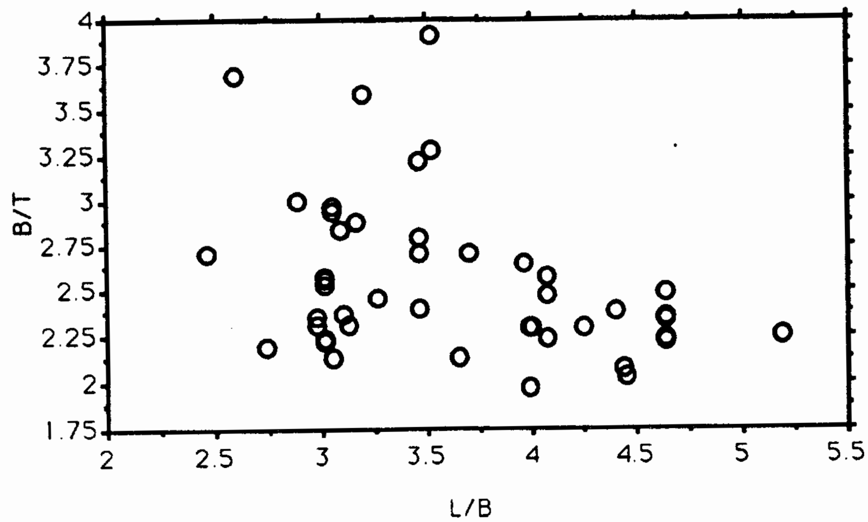


Figure 1, B/T against L/B

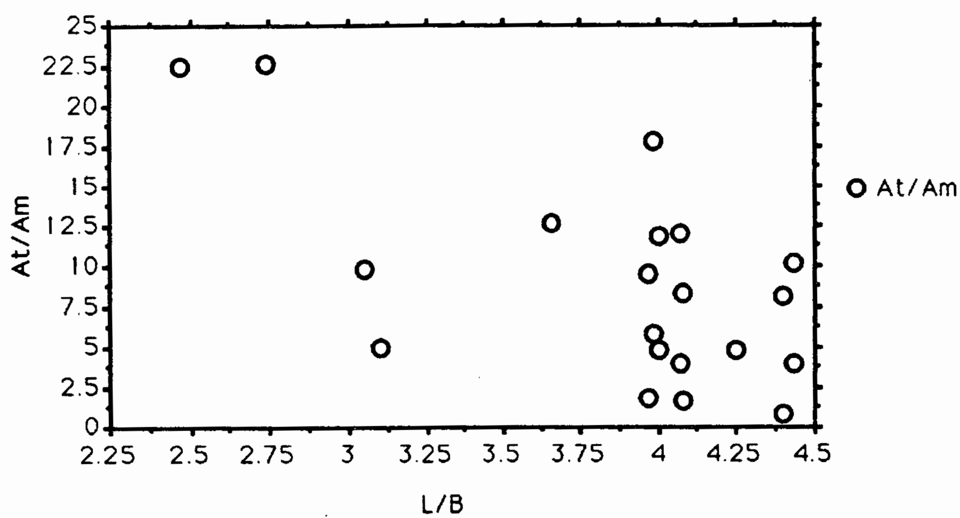


Figure 2, At/Am against L/B

Observations on the operating practice of fishing vessels and discussions with skippers showed that the vessels actually have a narrow range of operating speeds, when travelling to and from the fishing grounds. For lightly loaded vessels, such as salmon seine boats, the speed of the boat is close to the hull speed, whether the vessel is loaded or light. For a heavily loaded boat, such as a trawler, the speed is close to the hull speed when sailing out to the grounds but is reduced to approximately 80 percent of this value when it is fully loaded. The hull speed is the phase speed of a wave, equal to the length of the ship. This corresponds to a Froude number of 0.399 ($1/\sqrt{2\pi}$).

Given the limited range of operating speeds, the most practical analysis procedure was to consider distinct speeds, rather than a continuous function of residuary resistance against speed coefficient. This procedure avoided the requirement to fit high order polynomials to the data and the associated co-linearity problems. The values of Froude number chosen were 0.28, 0.32, 0.36 and 0.40, corresponding to 70, 80, 90 and 100 percent of the hull speed.

The data for some of the models did not extend to the minimum Froude number considered for this analysis and were excluded. These were all larger boats, which were not representative of the majority of the Canadian fleet. This reduced the number of data sets which could be used from 61 to 44.

It was decided that the best method of establishing an average performance, which would allow for the variation in resistance with principal hull form parameters, was multiple linear regression. The analysis was carried out with Statview SE+graphics for the Apple Macintosh (Reference 2).

The correlation matrix for the possible predictors for residuary resistance coefficient is given in Table 2. This gives values of correlation coefficient, r, (References 2 & 3) between the variables in the rows and columns. A value of 1 indicates a perfect correlation and a value of zero indicates no correlation. A high correlation between predictors is to be avoided, since adding the second variable adds little information to the prediction equation. It can be seen that there is some correlation between predictors such as LCF and LCB, LCF and Cm, LCB and Cm, Cb and Cm but otherwise there is very little correlation.

| | L/B | B/T | H_ANGLE | LCB | LCF | Cm | Cw | Cb | At/Am |
|---|---|---|---|---|---|---|---|---|---|
| L/B | 1 | | | | | | | | |
| B/T | -0.152 | 1 | | | | | | | |
| H_ANGLE | -0.579 | -0.286 | 1 | | | | | | |
| LCB | -0.307 | -0.214 | 0.323 | 1 | | | | | |
| LCF | -0.633 | -0.205 | 0.418 | 0.85 | 1 | | | | |
| Cm | 0.224 | 0.316 | -0.135 | -0.748 | -0.765 | 1 | | | |
| Cw | 0.229 | -0.683 | 0.464 | 0.343 | 0.093 | -0.154 | 1 | | |
| Cb | 0.057 | -0.153 | 0.309 | -0.524 | -0.513 | 0.819 | 0.304 | 1 | |
| At/Am | -0.601 | -0.221 | 0.433 | -0.027 | 0.369 | -0.306 | 0.008 | -0.049 | 1 |

Table 2
Correlation Matrix Between Predictors

For one speed (Froude number of 0.36) a preliminary analysis was carried out using step-wise multiple linear regression, to investigate the significance of the predictors which were available for all models (L/B, B/T, Half angle, Cm, Cw, and Cb). It was found that L/B and Cb were the only significant parameters.

The resulting predictor equation was

$$Cr*1000=3.779 - 2.848*L/B + 28.59*Cb \qquad [1]$$

$R^2=0.826$

and was derived from a total of 42 data points.

Although the correlation coefficient was relatively high, it was felt that it might be possible to obtain a better fit to the data, with a different set of predictors. For example, Cb is not consistently defined for small boats with significant rake of keel. Experience had also shown that transom area could also have a significant effect on the resistance of a hull.

A sub-set of 17 seperate conditions had complete information available for all the parameters given in Table 1. Step-wise regression on this data set, incorporating the three new predictors, gave the following predictor equation;

$$Cr*1000 = 15.979 - 1.784*L/B - 1.496*B/T + 0.142*At/Am \qquad [2]$$

$R^2=0.953$

This represents a good improvement in the fit of the regression equation to the data. However, to test if this was simply due to a reduction in the number of data points, the 17 models were regressed using the old predictors, which gave the following equation;

$$Cr*1000 = 5.892 - 2.844*L/B + 24.099*Cb \qquad [3]$$

$R^2=0.859$

Using statistical tests [Reference 3] it was found that equation [2] was more accurate than equation [3], at 95 percent confidence.

The next phase was to apply the same step-wise procedures to all speeds, using hull forms which had transom area data. At Froude numbers of 0.28 and 0.36 it was found that the same three predictors were the most significant. At a Froude number of 0.32, two additional predictors were included (LCF and Cm). It had to be decided if these extra predictors were due to some physical phenomena, which occurred at this speed, or simply due to the statistical nature of the fitting techniques.

It was found that if the regression at a Froude number of 0.32 was reduced to the same three predictors as the other speeds, the resulting equation was significantly less accurate at 95 percent confidence, but it was within the same level of accuracy as the two other speeds. A comparison of the results from the three parameter equation (for Froude number 0.32) against the measured data showed that this model gave a good prediction and although the extra parameters were statistically significant, in absolute terms their effect was relatively small. We may conclude that the three parameter model is sufficient to predict the average performance of an inshore fishing vessel, over the range of Froude numbers selected.

Special techniques were required for fitting data for the Froude number of 0.4 since only four models had values of At/Am recorded. The standard multiple regression analysis would not handle this small number and so an alternative method had to be used. There was sufficient data to build a two parameter model based on L/B and B/T, using 14 models. This regression was carried out. Residuals were calculated and regressed against the predictor At/Am, for the four values which data was available. The two equations were then combined and the resulting predictor equation was

$$Cr*1000 = 22.104 - 2.446 \; L/B - 1.507 \; B/T + 0.040 \; At/Am \qquad [4]$$

This should not be considered a true regression analysis, but a check of the predictor equation against the observations for a Froude number of 0.4 showed that it was a good fit.

The final set of coefficients for the predictor equations is given in Table 3.

| Fn | Const. | L/B | B/T | At/Am | $R^2$ |
|---|---|---|---|---|---|
| 0.28 | 9.965 | -1.106 | -1.262 | 0.083 | 0.956 |
| 0.32 | 14.216 | -1.663 | -1.807 | 0.121 | 0.963 |
| 0.36 | 15.979 | -1.784 | -1.496 | 0.142 | 0.953 |
| 0.40 | 22.104 | -2.446 | -1.507 | 0.040 | n/a |

Table 3
Coefficients for Predictor Equations

Other useful information obtainable from the regression analysis is the distribution of the residuals. This is given in Table 4, below. The standard assumption is that these are normally distributed about zero. The variance of the residuals for each of the three parameter models is given below. This can be used to compare with the observed values, for a model outside of the original data set.

| Fn | variance ($\sigma^2$) of residuals |
|---|---|
| 0.28 | 0.058 |
| 0.32 | 0.107 |
| 0.36 | 0.165 |
| 0.40 | not available |

Table 4
Variance of Residuals from Regression Analysis

The predictions from the regression equations were compared with the actual model data. Figure 3 shows the residuals for all speeds and

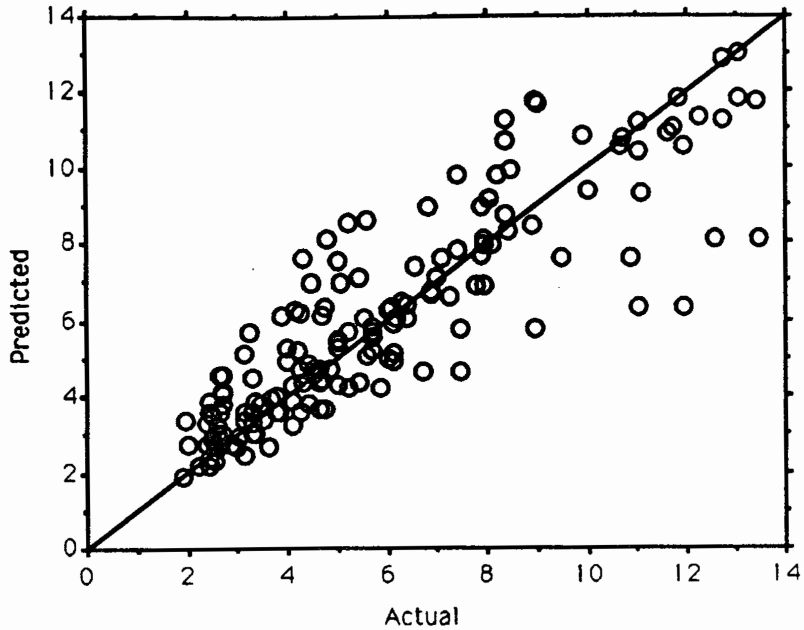


Figure 3, Comparison of Actual and Predicted Values of 1000*Cr, all speeds

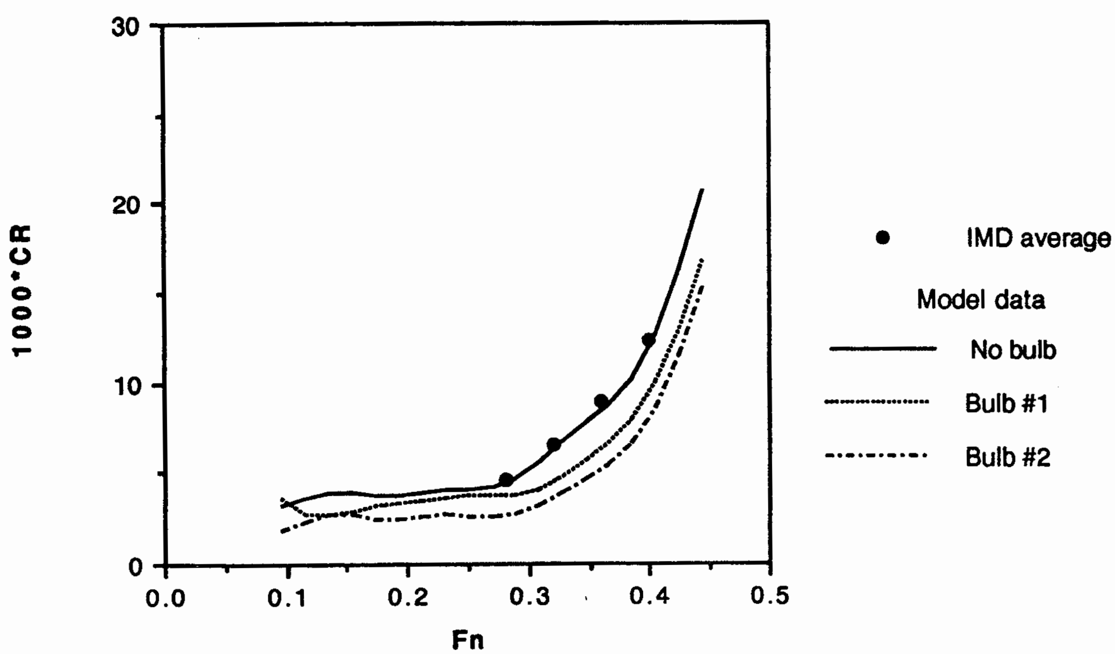


Figure 4, Hard Chine No. 1, Comparison with IMD Average all models. It can be seen that the data is evenly distributed about the 'best possible' fit. When no information was available for transom area, then the average value was used. This may bias hulls where the transom was unusually large or unusually small. The distribution of the residuals was plotted and was found to be sufficiently close to a normal distribution to assume that the equation for the average residuary resistance coefficient was unbiased. The variance of the residual, based on the complete data set was 2.161, based on 158 model-speed combinations.

## 4. Comparison with Project Data

As an example of the application of the standard, project data not used in the development of the standards was compared with the equivalent predictions from the regression equation. Three models were found, two of which had hard chines and one had round bilges. One of the hard chine models was fitted with two alternative bulbous bows, in addition to a normal bow. IMD had full access to the data, since it sponsored the tests jointly with the Department of Fisheries and Oceans and the Department of Fisheries of Newfoundland and Labrador.

The hard chine model, with its two alternative bulbous bows, is shown against the IMD standard in Figure 4. It can be seen that this model has a performance very close to average. The effect of the bulbs was to reduce the residuary resistance coefficient, by quite a large margin.

The round bilge design and the second hard chine design are compared with the IMD standard in Figures 5 and 6. Both these designs have resistance coefficients higher than average, even after allowances have been made for the hull form parameters identified above. These figures serve to illustrate how poor the resistance characteristics of some fishing vessel designs are and the current design trends do not have optimum hydrodynamics, even for the wide hull forms typically used for fishing boats.

## 5. Comparison with UBC Series

Another set of resistance data for modern Canadian fishing boats, which can be compared to the IMD standard, is a parametric series of salmon seiners tested by the University of British Columbia. This series is described in detail in Reference 4. This reference gives predictor equations for two families of hull form, with different block coefficients. These equations were programmed in a spreadsheet and

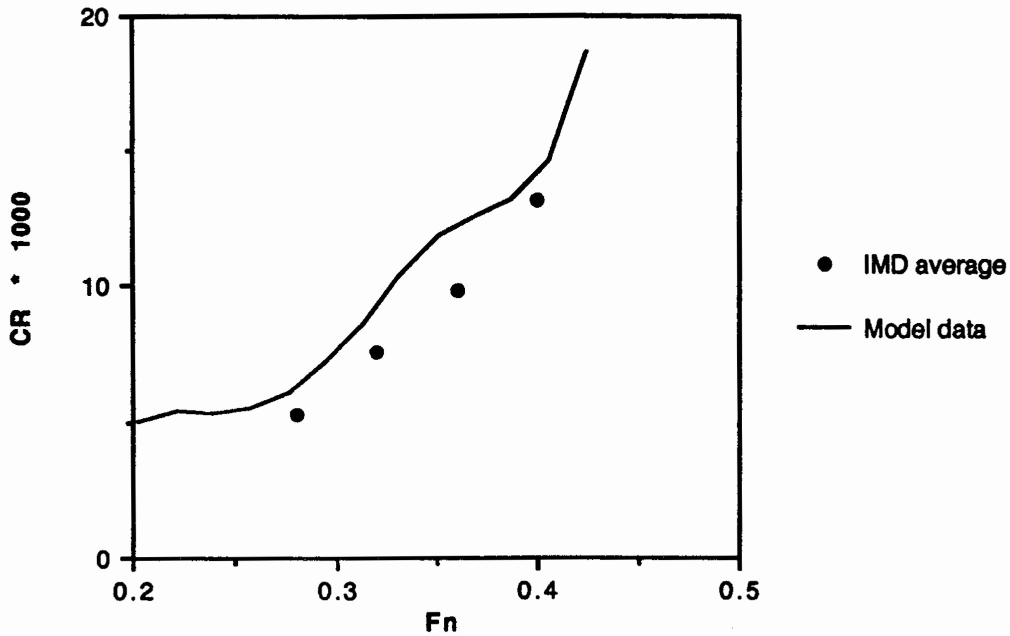


Figure 5, Round bilge No. 1, Comparison with IMD Average

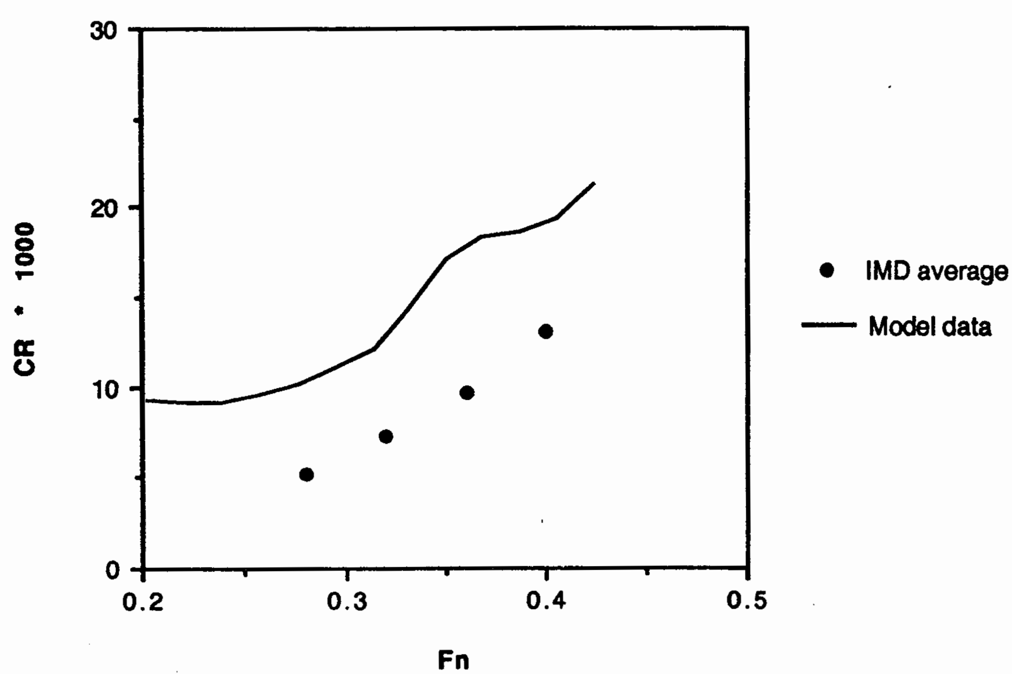


Figure 6, Hard Chine No. 2, Comparison with IMD Average predictions made for two UBC hull forms (high and low block coefficients) with proportions equal to the mean of the IMD data base. The predictions are compared with the IMD standard in Figure 7.

From this figure it can be seen that the low block coefficient form has a residuary resistance coefficient which is better than average, but the high block coefficient form has a resistance which is worse than average. It is worth noting that the high block coefficient was outside the range of the IMD data base.

## 6. Calculation of Wetted Surface Area

One objective in preparing the standard was to provide the basis for making informed comments on the relative performance of a new hull. Following these comments, suggestions can be made for possible methods of improving the resistance, which would result in a more hydrodynamically efficient design. However, the standard can also be used to predict the residuary resistance coefficient of an average fishing vessel. This can be expanded to the total resistance (and effective power), if the wetted surface area for the hull is known.

In order to provide a quick method of estimating the wetted area for a fishing boat, the wetted area data for the UBC series was regressed against hull form coefficient. The resulting predictor equation was found to be;

$$WSA/L^2 = 1.012 - 0.125*L/B - 0.073*B/T \quad [5]$$

$R^2$=0.908

## 7. Conclusions

This paper demonstrates that a simple predictor equation can be developed to calculate the average residuary resistance of Canadian fishing vessels. The analysis used takes into account the most significant hull shape parameters effecting resistance and can also be used to give some measure of the expected variation about that average. It is hoped that the equations will be used to provide information on the expected resistance coefficients for Canadian fishing boats, which are constrained by factors other than hydrodynamics.

It must be recognized that the cost of operating the fishing vessel is only part of the economic equation and a design with poor

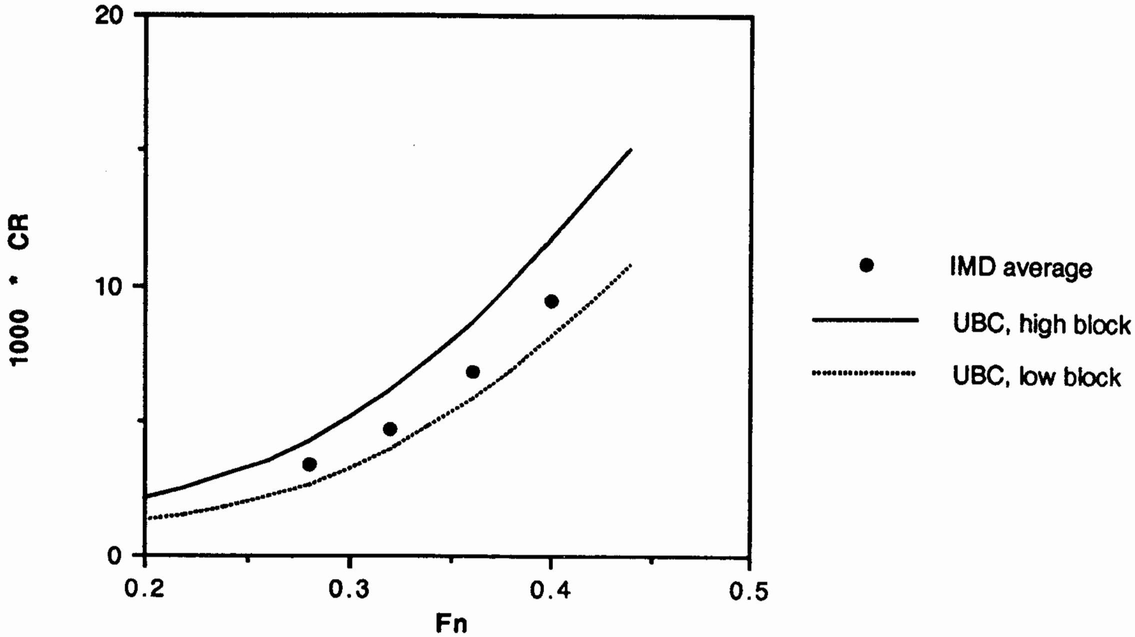


Figure 7, UBC Seiner Series, Comparison with IMD Average hydrodynamics but increased transportation capacity, deck area or other similar factors may be more profitable than one which is optimized for resistance. These standards however, should allow the effect of any non-optimum hydrodynamic performance to be quantified.

The standards presented in this report should only be considered interim standards and will be updated as more data becomes available.

## 8. References

1. Molyneux, W. D., 'IMD Standards for Resistance Coefficients of Canadian Fishing Vessels', NRC/IMD LM-1992-04, May 1992.

2. Feldman, D. S. et al, 'Statview SE+Graphics, User Manual', Abacus Concepts Inc. 1988.

3. Weisberg, S. 'Applied Linear Regression', Second Edition, John Wiley and Sons, 1985, page 96.

4. Calisal, S. M. and McGreer, D. 'Model Resistance Tests of a Systematic Series of Low L/B Vessels', Spring Meeting, S. N. A. M. E., Pacific Northwest Section, May 11/12, 1990.

## List of Symbols

| | |
|---|---|
| At/Am | 100*Immersed transom area/maximum section area |
| B | Maximum beam at waterline, m |
| Cb | Block coefficient |
| Cm | Area of maximum section/ (B*T) |
| Cr | Residuary resistance coefficient |
| Cw | Area of waterplane/ (L*B) |
| Half angle | Angle between waterline and centreline at bow |
| L | Length, at waterline, m |
| LCB | Centre of bouyancy, from midships, %L, positive forwards |
| LCF | Centre of floatation, from midships, %L, positive forwards |
| r, R | Statistical correlation coefficients |
| WSA | Wetted surface area, $m^2$ |
| $\sigma$ | Variance of residuals |