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SUMMARY

The Report describes Open Water Resistance Tests undertaken with a 1/20 scale model of the R-Class in fresh water and in EGADS solution to determine any experimental differences between the two solutions. Results show a small difference which may not be totally attributable to the different solutions.

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OPEN WATER RESISTANCE TESTS IN THE ICE TANK - A COMPARISON OF EGADS AND FRESH WATER

1.0 INTRODUCTION

While it has been the normal practice to conduct model ice resistance tests in IMD's Ice Tank and separately conduct open water resistance tests in the Towing Tank, it remained a question as to whether the Ice Tank could be used successfully for open water tests given the physical differences between the two tanks. The Ice Tank has a clear water run length of approximately 65 meters (m) with a water depth of 3 m compared to the 130 m run length of the Towing Tank which is 7.5 m deep. Both tanks are 12 m wide. The Ice Tank carriage has a maximum speed of 4 m/s. The maximum speed of the Towing Tank Carriage is 10 m/s. But the major difference between the tanks is that whereas the Towing Tank contains fresh water the Ice Tank usually contains a mixture of chemical dopants for the making of model ice and is known as EGADS from its chemical constituents Ethylene Glycol, Aliphatic Detergent and Sugar in respective concentrations of 0.39, 0.036 and 0.04 %. This solution has a density of 1002.5 kg/m3 at 0°C compared to 999.0 of fresh water at 15°C. Because of this and possible changes to the viscosity and surface tension it was unknown what the combined effects of these would have on clear water resistance, though it has been shown that the addition of detergent has little if any effect on the fluid friction factor (Ref. 1).

1993 was a particularly busy year in the Towing Tank and the Ice Tank undertook a number of fresh water projects to ease the load on the other tank. The Ice Tank facility has the capacity of storing the EGADS solution, some 4 million litres, in an holding tank located beneath the woodwork shop. This permits the Ice Tank to use another solution, fresh water for instance, for an indefinite period without going to the expense of discarding the original chemicals. As an example, in 1989 the EGADS solution was stored for several weeks while extensive tests were performed on fresh water ice sheets. The transfer between the two tanks can be accomplished in about half a day but to fill with fresh water or to discard altogether takes approximately 2 days. Thus to transfer from the Ice Tank to the holding tank, fill with fresh water, discard the fresh water, and transfer back from the holding tank takes 5 - 6 days, - a substantial amount of time. There is also concern for the alignment of the carriage rails. The rails are aligned within 0.1mm and changes in hydrostatic loading of the tank walls could encourage movement. If it could be demonstrated that the difference in open water resistance between the two solutions was negligible then this would allow more economical use of tank time, eliminate the cost and need for 4 million litres of city water and minimize movement of the tank walls.

A number of experiments were undertaken in the Ice Tank using the 1/20 scale model of the R-Class icebreaker. This model was chosen as being typical of the kind of vessel tested in both ice and fresh water and also for the substantial amount of test data available for both model and full scale (Refs. 2,3,4,5). The model was first tested in the Ice Tank when it was still full of fresh water required by other projects. The water was then disposed of and the EGADS solution brought back. This solution, normally held at 0°C in the Ice Tank had warmed to approximately 10°C during the 2 months it had been stored. The model was tested in the EGADS solution at this temperature and again when it had been chilled to 0°C for comparison.

2.0 EXPERIMENTAL PROCEDURES.

The 1/20 scale R-Class model, number 327, was ballasted at a level trim according to the Hydrostatic Particulars in Table 2.1 with fixed rudder, and fairing cones attached to the propeller bossings. Turbulence stimulators, comprised of brass studs 3.5mm diameter, 3.5mm high at a spacing of 25mm, were placed either side of the bow parallel to the stem according to Ref.2, 5 percent aft of the forward perpendicular. The model was towed from its centre of buoyancy at midships by a flexible line attached to a 50 lb Intertechnology cantilever type load cell at the tow post and counterweighted by an 8 kg mass. The model was restrained from yaw and sway by grasshoppers fore and aft. It was restrained from surging during acceleration and deceleration phases by a pneumatic clamp. The mode of towing is the only known difference in test set up between the Ice Tank and the Towing Tank experiment with which test data was eventually compared. The Towing Tank normally employs the just described "soft" tow method but, in this case, it utilised a rigid tow post and gimbal assembly (Ref. 3) since the test program also called for ice resistance and much higher expected loads. This system restrained the model from surge, yaw and sway. Ice Tank carriage speeds varied from 0.2 to 2.0 m/s corresponding to full scale values of 2 to 17.9 knots. The load cell was sampled at a rate of 50 hz. At low speeds 3 test runs were accommodated in the length of the tank, decreasing to 1 at the higher speeds. The resistance values were averaged from a steady state period. The experimental procedures were thus very similar to those in the Towing Tank.

The model was first tested in fresh water in the Ice Tank with a water temperature of 15.9°C. The model was then removed from the tank while the tank was drained of fresh water and refilled with the EGADS solution from the holding tank. The model was then tested as before in the EGADS at a temperature of 10.9°C, and with the same ballast without attempting to correct for the small density difference between the 2 solutions (less than 0.3% translating to less than 3 kg displacement for the same water line). However, it was found that the model was shipping water over the bows at higher speeds and the fastest speed had to be prematurely terminated due to the amount of water being shipped. It was later found that the model was 15 kg heavier than at the time of the fresh water tests. It is thought that water perhaps shipped from the first tests and also leaking in from the propeller tubes and consequently sitting in the model for a number of days may have soaked in and added to the mass. The freeboard at the bow was only a few inches and perhaps this extra mass, and the effect of reduced surface tension of the solution due to the presence of the detergent, was enough to cause the shipping of water at higher speeds.

The EGADS solution was then chilled to almost zero. A plastic sheet canopy was fixed over the bow of the model to prevent further shipping of water and the model was checked for proper displacement and trim. The test sequence was satisfactorily repeated in cold EGADS at a temperature of 0.4°C.

3.0 DATA ANALYSIS and RESULTS.

For the purpose of this study the model resistance results from the Towing Tank (Ref.4) were accepted as the norm, since the model was tested at an identical trim and draught, and all the Ice Tank values compared against this. These values, corrected for any zero offset, are listed in Table 2. The Towing Tank values were retrieved from IMD's data base and represent results from one series of tests. These values are compared with those obtained from the three Ice Tank tests in Figure 1. The Specific Total Resistance Coefficient (CTM) was plotted against the Froude Number (FN) for each of the Ice Tank solutions at their test temperatures and a line faired through the data points. These are plotted in Figure 2 with the Towing Tank curve which had already been determined. From the figures there does not appear to be a marked difference between the two tanks for fresh water. There was a slight increase in model resistance in warm EGADS at the higher speeds which could be in part due to the shipping of water and consequent down by the bow attitude of the model. Resistance in the cold EGADS was almost uniformly greater over the range of speed, probably due to the temperature effect on the viscosity and density of the solution.

The data was analysed according the standard ITTC 1957 method and Figure 3 shows the CTM curves when the data has been corrected to the same

EGADS curves diverge slightly. This divergence could be due to the line fairing of the raw data, or may demonstrate a real but small difference in the solutions. To try and resolve this, additional CTM(15) curves from the Towing Tank by Mesh and Simões Ré (Ref.5) and the old Ottawa tank by Murdey (Ref.2) were then drawn in Figure 4. The Mesh data overlies the previous curves obtained from the model in fresh water while the data from Murdey lies between the fresh water and the EGADS. Both of these other model tests were conducted with the model in a trimmed by the stern condition and the model in Ottawa had a different surface coating. These differences might have a slight influence on the test results.

Finally, Figure 5 and Table 3, show the results of the full scale prediction of Effective Power against ship's speed for all data sets with corrections for blockage. All the points appear to lie very closely to the same line. Comparing data points from the 5 curves with the Towing Tank data, accepted as a standard, those of Mesh and Simões Ré and those from the Ice Tank fresh Water are at an average of 2% from the Towing Tank data. The Cold EGADS is within 4%, and Warm EGADS at 4% with those from Ottawa also at 4.0%.

4.0 CONCLUSIONS.

The Ice Tank fresh water results compare favourably (within 2%) with the test results from the Towing Tank. There appears to be a some difference (4%) when tested in EGADS solution, but part of this difference could be due to the difference in model displacement of 15 kg (1.5%). Therefore, based on this series of tests, the effects of EGADS on open water resistance remain inconclusive. Analysis of other data may clarify this issue, but for the time being it is concluded that experiments to determine open water resistance in the ice tank should be carried out in fresh water.

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TABLE 1

HYDROSTATIC PARTICULARS FOR 1:20 R-CLASS MODEL 327

LENGTH BETWEEN PERPENDICULARS (LPP), m	4.397
LENGTH ON WATERLINE (LWL), m	4.691
WATERLINE BEAM AT MISDHIPS, m	0.970
WATERLINE BEAM AT MAXIMUM SECTION, m	0.970
MAXIMUM WATERLINE BEAM, m	0.970
DRAUGHT AT MIDSHIPS, m	0.358
DRAUGHT AT MAXIMUM SECTION, m	0.358
MAXIMUM DRAUGHT, m	0.358
DRAUGHT ABOVE DATUM, m	0.358
MAXIMUM SECTION FORWARD OF MIDSHIPS, m	-0.196
PARALLEL MIDDLE BODY, FROM, AFT OF MIDSHIPS, m	0.196
TO, FORWARD OF MIDSHIPS, m	-0.034
AREA OF MIDSHIP STATION, m^2	0.318
AREA OF MAXIMUM STATION, m^2	0.318
CENTRE OF BUOYANCY FORWARD OF MIDSHIPS (LCB), m	0.007
CENTRE OF AFT BODY BUOYANCY FORWARD OF MIDSHIPS (LCB), m	-0.825
CENTRE OF FORE BODY BUOYANCY FORWARD OF MIDSHIPS (LCB), m	0.832
CENTRE OF BUOYANCY ABOVE DATUM, m	0.201
WETTED SURFACE AREA, m^2	5.476
VOLUME OF DISPLACEMENT, m^3	0.994
DISPLACEMENT OF FRESH WATER, kg	992.6
CENTRE OF FLOATATION FORWARD OF MIDSHIPS (LCF), m	-0.014
C. OF FLOATATION (AFT BODY), FORWARD OF MIDSHIPS (LCF), m	-0.981
C. OF FLOATATION (FORE BODY), FORWARD OF MIDSHIPS (LCF), m	0.966
AREA OF WATERLINE PLANE, m^2	3.641
TRANSVERSE METACENTRIC RADIUS (BM), m	0.238
LONGITUDINAL METANCENTRIC RADIUS (BML), m	4.753
C. OF AREA OF PROFILE PLANE FORWARD OF MIDSHIPS (CLR), m	-0.005
C. OF AREA OF PROFILE PLANE ABOVE DATUM, m	0.185
AREA OF PROFILE PLANE, m^2	1.459

TABLE 2

Summary of Open Water Resistance Values

Model: 327
Draft (fore & aft): 0.358 m
Wetted Surface: 5.476 m²
Waterline Length: 4.691 m

Vm = Model Speed (m/s)
N = Model Resistance (Newtons)

Towing Tank		Ice Tank f/w		IT Warm EGADS		IT Cold EGADS	
Vm	N	Vm	N	Vm	N	Vm	N
0.23	0.7	0.23	1.0	0.23	1.0	0.23	1.0
0.34	1.8	0.34	1.8	0.34	1.9	0.34	1.9
0.46	3.0	0.46	3.0	0.46	3.2	0.46	3.2
0.57	4.9	0.57	missing	0.57	4.9	0.57	5.0
0.69	6.9	0.69	6.6	0.69	6.9	0.69	7.2
0.80	9.4	0.80	9.4	0.80	9.4	0.80	9.8
0.92	12.3	0.92	12.2	0.92	12.3	0.92	13.0
1.03	15.2	1.03	15.2	1.03	15.1	1.03	16.1
1.15	18.9	1.15	17.9	1.15	18.5	1.15	19.9
1.26	22.9	1.26	23.0	1.26	22.3	1.26	24.1
1.37	28.5	1.37	28.8	1.37	28.0	1.37	28.9
1.49	33.6	1.49	33.1	1.49	32.6	1.49	33.5
1.60	40.5	1.60	39.8	1.60	39.2	1.60	41.3
1.72	49.1	1.72	49.1	1.71	49.2	1.72	50.9
1.76	54.2	1.75	52.4	1.75	53.9	1.76	56.4
1.83	68.9	1.83	65.9	1.82	66.1	1.83	70.2
1.89	79.4	1.89	84.8	1.88	81.5	1.89	84.0
1.95	97.8	1.94	97.2	1.94	98.3	1.95	103.4
2.00	110.2	1.99	113.4	1.99	114.3	2.00	116.7
2.06	133.6	2.05	128.5	2.05	140.0	2.06	133.0

TABLE 3

Summary of Predicted Ship Resistance

Model: 327
Draft (fore & aft): 0.358 m
Correlation Allowance: 0.0004
Water Temperature: 15.0° C
Water Salinity: 35 ‰
Wetted Surface: 5.476 m²
Waterline Length: 4.691 m

Fn = Froude Number based on waterline length, $V/\sqrt{(g\ LWL)}$

Model Speed (m/s)	Ship Speed (knots)	Fn	Effective Power, PE (KW)			
			Tow/Tank	I.T. f/w	w.EGADS	c.EGADS
0.34	3.0	0.050		15	16	15
0.46	4.0	0.068		34	36	33
0.57	5.0	0.084		67	70	67
0.69	6.0	0.102	127	119	122	119
0.80	7.0	0.118	204	199	196	196
0.92	8.0	0.136	303	304	295	299
1.03	9.0	0.152	429	429	413	425
1.15	10.0	0.169	597	584	563	587
1.26	11.0	0.186	824	807	759	797
1.37	12.0	0.202	1118	1114	1033	1042
1.49	13.0	0.219	1473	1460	1354	1335
1.60	14.0	0.236	1871	1897	1810	1764
1.72	15.0	0.253	2515	2527	2495	2488
1.84	16.0	0.271	3928	3739	3807	3942
1.95	17.0	0.287	6124	6231	6137	6347

Figure 1

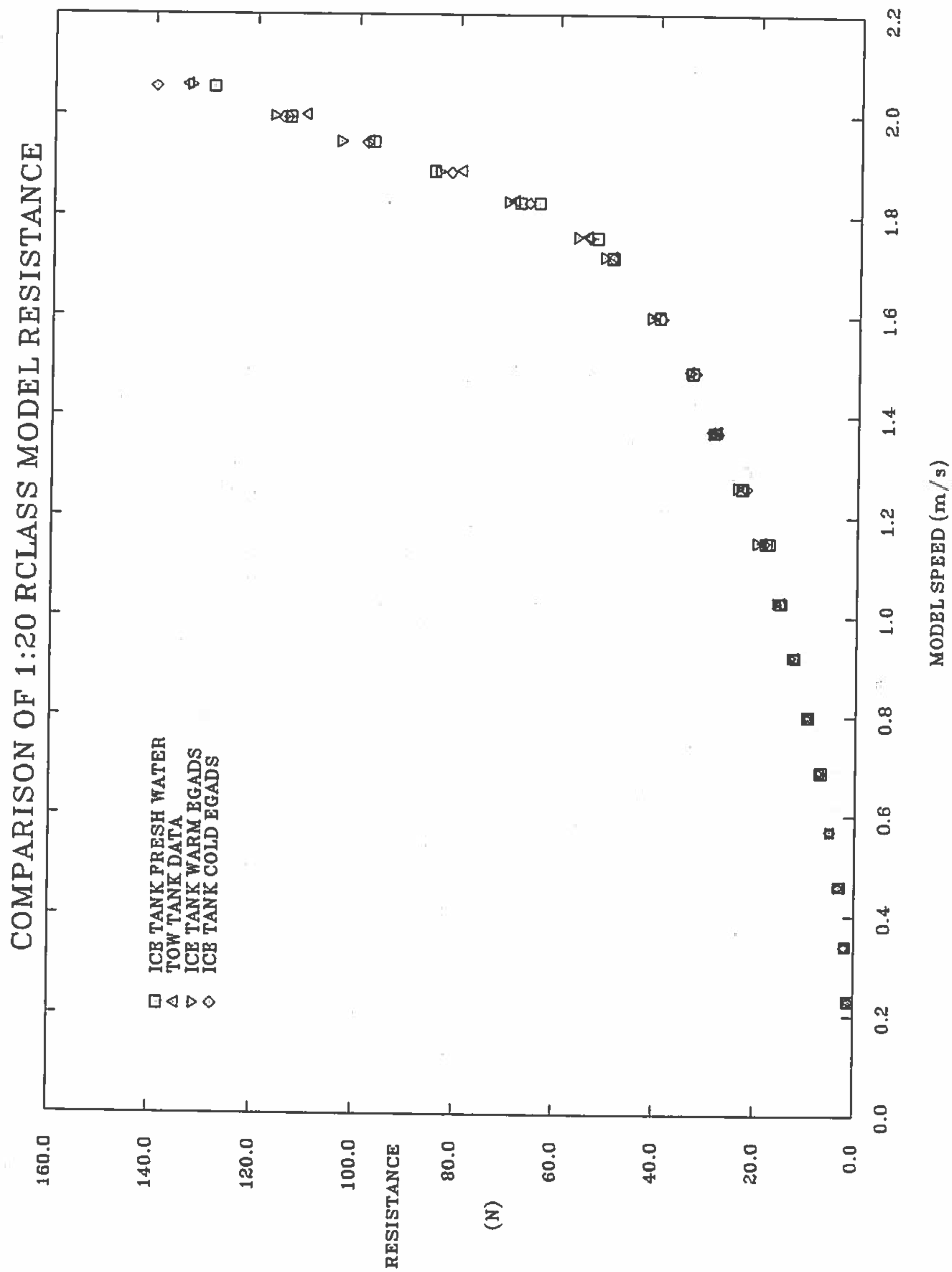

COMPARISON OF 1:20 RCLASS MODEL RESISTANCE
ICE TANK FRESH WATER
TOW TANK DATA
ICE TANK WARM EGADS
ICE TANK COLD EGADS
RESISTANCE
(N)
MODEL SPEED (m/s)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2

Figure 2

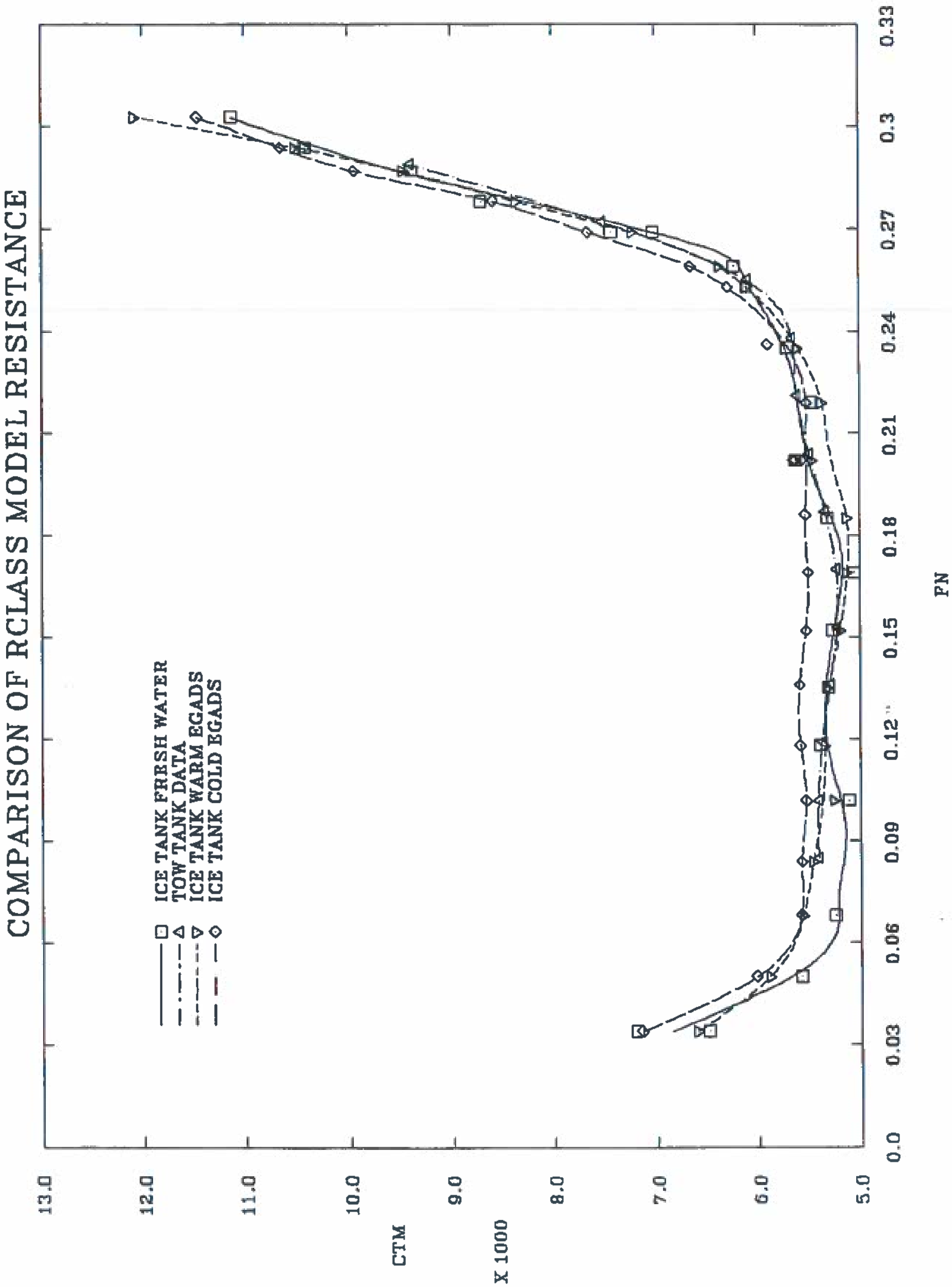

COMPARISON OF RCLASS MODEL RESISTANCE
ICE TANK FRESH WATER
TOW TANK DATA
ICE TANK WARM EGADS
ICE TANK COLD EGADS
CTM
X 1000
FN
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
0.0
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.3
0.33

Figure 3

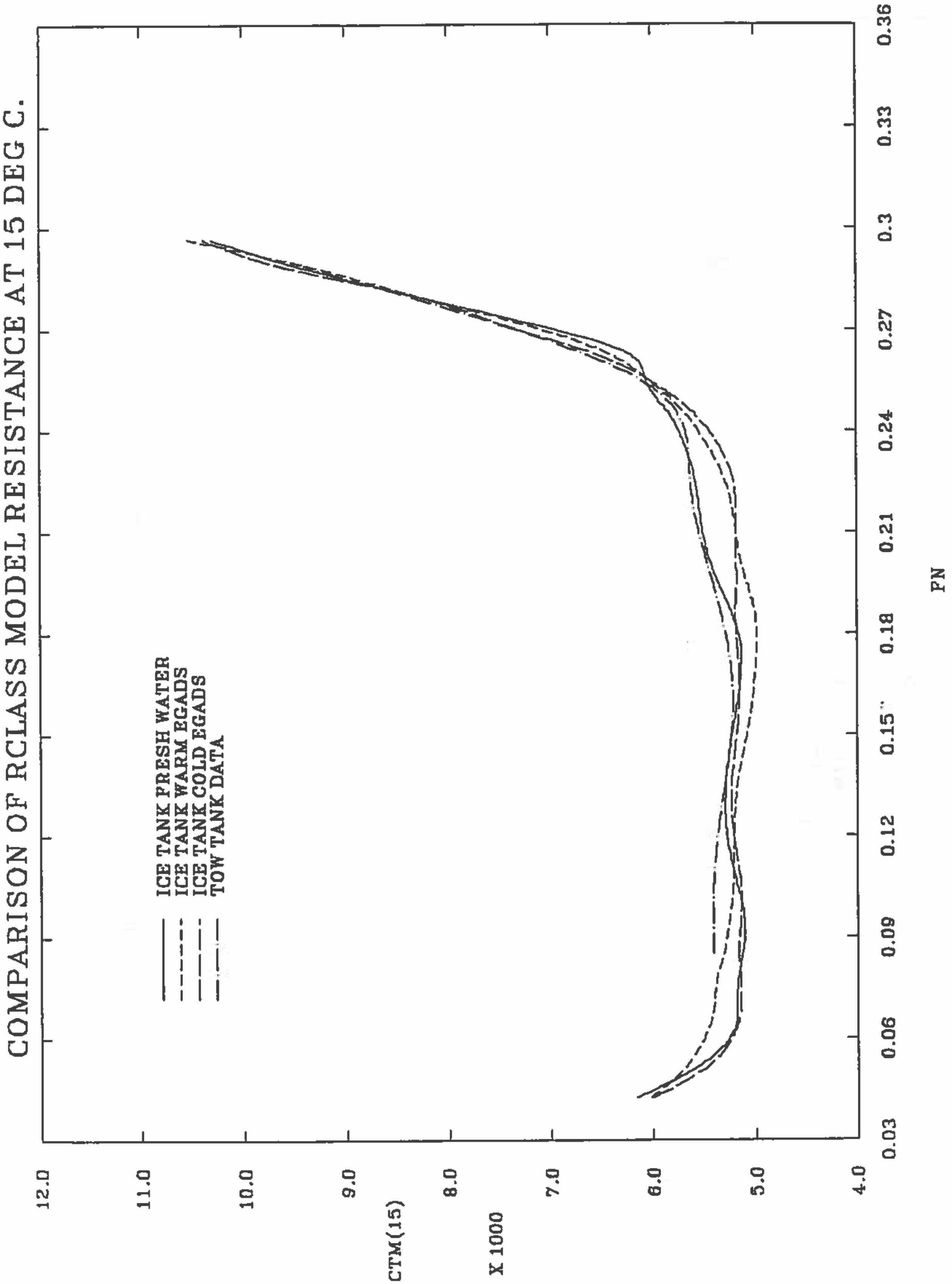

COMPARISON OF RCLASS MODEL RESISTANCE AT 15 DEG C.
ICE TANK FRESH WATER
ICE TANK WARM EGADS
ICE TANK COLD EGADS
TOW TANK DATA
CTM(15)
X 1000
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
FN
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.3
0.33
0.36

Figure 4

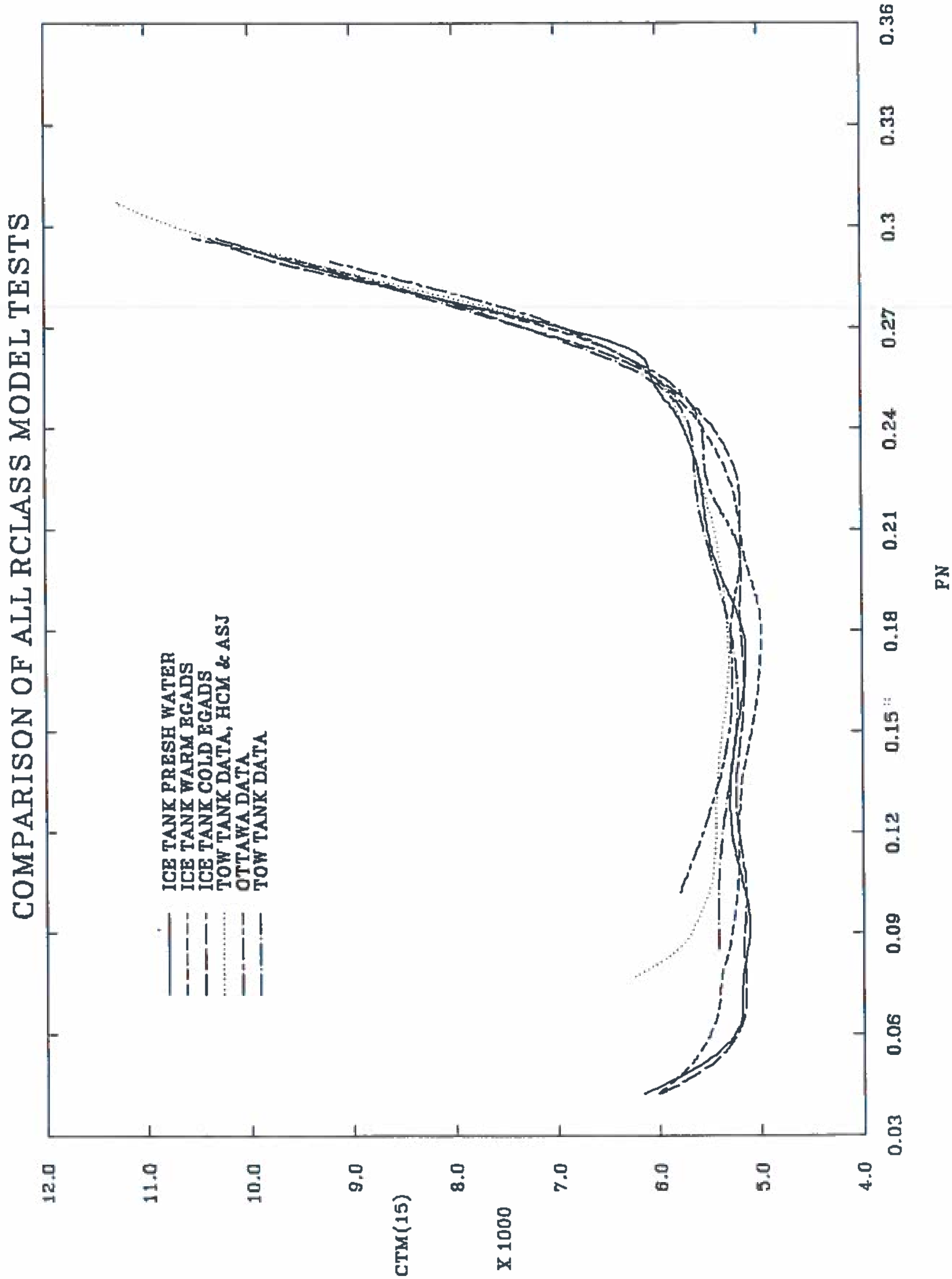
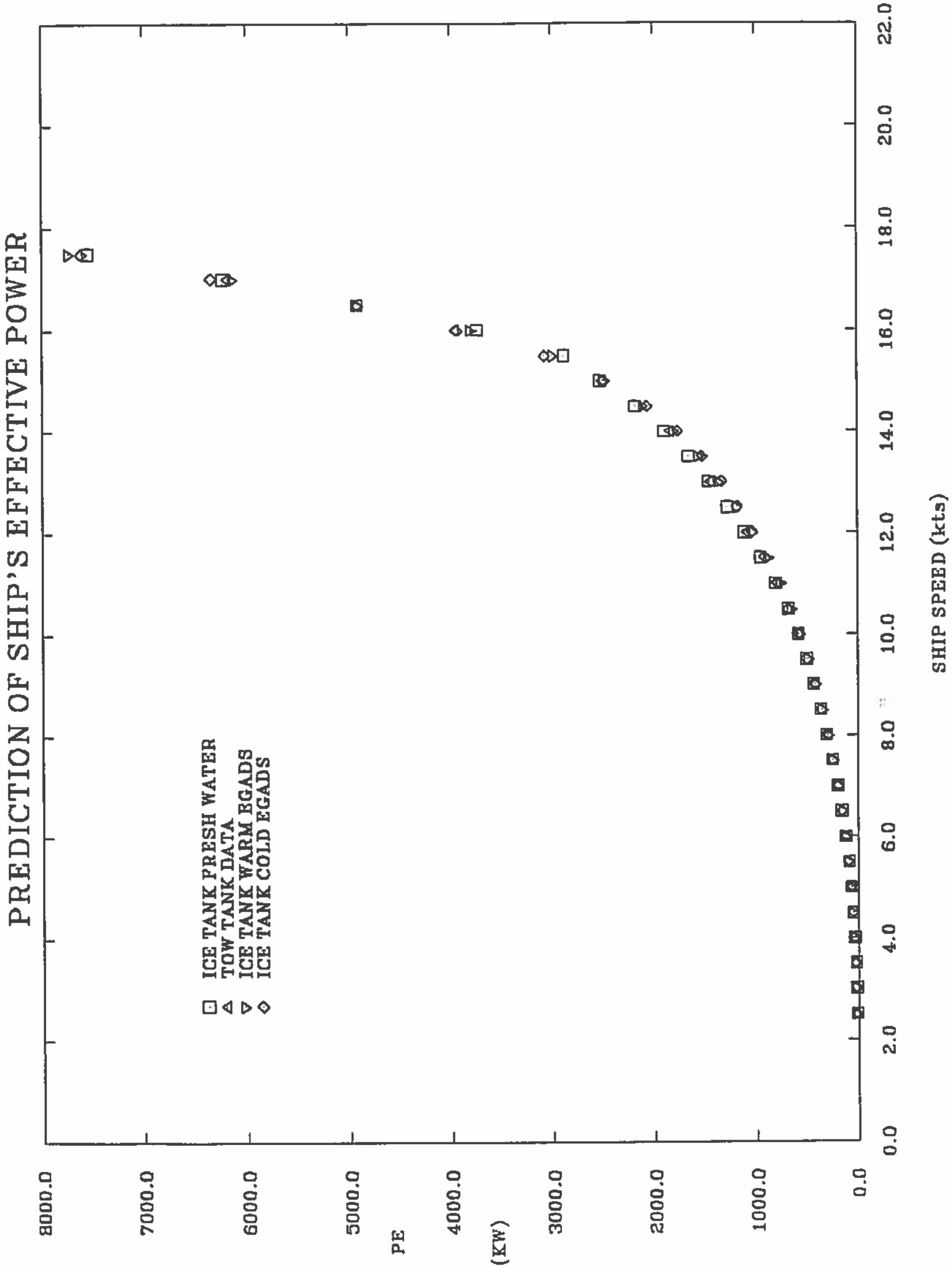

COMPARISON OF ALL RCLASS MODEL TESTS
ICE TANK FRESH WATER
ICE TANK WARM EGADS
ICE TANK COLD EGADS
TOW TANK DATA, HCM & ASJ
OTTAWA DATA
TOW TANK DATA
FN
CTM(15)
X 1000
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.3
0.33
0.36
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

Figure 5


PREDICTION OF SHIP'S EFFECTIVE POWER
ICE TANK FRESH WATER
TOW TANK DATA
ICE TANK WARM EGADS
ICE TANK COLD EGADS
PE
(KW)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
8000.0
SHIP SPEED (kts)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0