INTERNATIONAL TOWING TANK CONFERENCE

CONTENTS

COMMENTS OF PROPULSION COMMITTE OF 22nd ITTC

In its original form the ITTC 1978 Performance Prediction Method offers a valuable and reasonably accurate prediction tool for reference purposes and conventional ships.

Edited by 22nd ITTC QS Group 1999	Approved
15th ITTC 1978 pp388 – 402 17th ITTC 1984 pp326 - 333 18th ITTC 1987 pp266 - 273	15th ITTC 1978, 17th ITTC 1984 and 18th ITTC 1987
Date	Date

1978 ITTC Performance Prediction Method

1. PURPOSE OF PROCEDURE

The method predicts rate of revolution and delivered power of a ship from model results.

2. DESCRIPTION OF PROCEDURE

2.1.1 Introduction for the Original 1978 ITTC Performance Prediction Method for Single Screw Ships

The method predicts rate of revolution and delivered power of a ship from model results. The procedure used can be described as follows:

The viscous and the residuary resistance of the ship are calculated from the model resistance tests assuming the form factor to be independent of scale and speed.

The ITTC standard predictions of rate of revolutions and delivered power are obtained fromthe full scale propeller characteristics. These characteristics have been determined by correcting the model values for drag scale effects according to a simple formula. Individual corrections then give the final predictions.

2.1.2 Introduction for the 1978 ITTC Performance Prediction Method as Modified in 1984 and 1987

The 1978 ITTC Method developed to predict the rate of propeller revolutions and delivered power of a single screw ship from the model test results has been extended during the last two terms of the ITTC for a better and more convenient use of the program. These extensions are summarized as follows.

(1) Inclusion of prediction of propeller revolutions on the basis of power identity.

(2) Temporary measure for $w_{TS} > w_{TM}$

(3) Extension to twin screw ships

(4) Addition of speed trial data

(5) Extension for the case of a stock propeller in the self-propulsion test

(6) Adaptation to the input of the non-dimensional resistance coefficient and self-propulsion factors.

In recent years, many member organizations have been asked by their customers for a general description of the method, viz., model test and analysis of their results, calculation of full-scale power and rate of propeller revolutions, and the model-ship correlation factors used. Considering the above, it was decided to prepare a user's manual of the 1978 ITTC method which includes all of the extensions and modifications made.

2.2 Model Tests

Model tests required for a full scale comprise the resistance test, the self-propulsion test and the propeller open-water test.

In the resistance test the model is towed at speeds giving the same Froude numbers as for the full scale ship, and the total resistance of the model R_{TM} is measured. The computer program accepts either R_{TM} in Newton, or in a non-dimensional form of residuary resistance coefficient C_R assuming the form factor $1 + k$. In the latter case, the friction formula used can then be either of the ITTC 1957, Hughes, Prandtl-Schlichting or Schönherr's formulae.

The form factor $1 + k$ is usually determined from the resistance tests at low speed range or by Prohaska's plot of C_{FM} against Fn^4

The ship model is not in general fitted with bilge keels. In this case the total wetted surface area of them is recorded and their frictional resistance is added in calculating the full-scale resistance of the ship.

In the self-propulsion test the model is towed at speeds giving the same Froude numbers as for the full-scale ship. Generally a towing force F_D is applied to compensate for the difference between the model and the full-scale resistance coefficient.

During the test, propeller thrust (T_M), torque (O_M) and rate of propeller rotation (n_M) are measured.

In many cases, stock propellers are used which are selected in view of the similarity in diameter pitch and blade area to the full-scale propeller. Then the diameter and the open-water characteristics of the stock propeller have to be given as input data in the program. In the open-water test, thrust, torque and rate of revolutions are measured, keeping the rate of revolutions constant whilst the speed of advance is varied so that a loading range of the propeller is examined.

In the case when a stock propeller is used in the self-propulsion test, both the stock propeller and the model similar to the full-scale propeller should be tested in open water.

2.3 Analysis of the Model Test Results

Resistance R_{TM} measured in the resistance tests is expressed in the non-dimensional form

$$C_{TM} = \frac{R_{TM}}{\frac{1}{2}\rho S V^2}$$

This is reduced to residual resistance coefficient C_R by use of form factor k,

viz.,

$$C_R = C_{TM} - C_{FM}\,(1 + k)$$

Thrust, T, and torque Q, measured in the self-propulsion tests are expressed in the non-dimensional forms

$$K_{TM} = \frac{T}{\rho D^4 n^2} \quad \text{and} \quad K_{QM} = \frac{Q}{\rho D^5 n^2}$$

With K_{TM} as input data, J_{TM} and K_{QTM} are read off from the model propeller characteristics, and the wake fraction

$$w_{TM} = 1 - \frac{J_{TM} D_M}{V}$$

and the relative rotative efficiency

$$\eta_R = \frac{K_{QTM}}{K_{QM}}$$

are calculated. V is model speed.
The thrust deduction is obtained from

$$t = \frac{T + F_D - R_C}{T}$$

with

$$F_D = \frac{1}{2}\rho_M S_M V_M^2 \left[C_{FM} - \left(C_{FS} + \Delta C_F\right)\right]$$

where R_C is the resistance corrected for differences in temperature between resistance and self-propulsion tests:

$$R_C = \frac{(1+k).C_{FMC} + C_R}{(1+k).C_{FM} + C_R} R_{TM}$$

where C_{FMC} is the frictional resistance coefficient at the temperature of the self-propulsion test.

2.4 Full Scale Predictions

2.4.1 Total Resistance of Ship

The total resistance coefficient of a ship without bilge keels is

$$C_{TS} = (1+k)C_{FS} + C_R + \Delta C_F + C_{AA}$$

Where

- k is the form factor determined from the resistance test

- C_{FS} is the frictional coefficient of the ship according to the ITTC-1957 ship-model correlation line

- C_R is the residual resistance calculated from the total and frictional coefficients of the model in the resistance tests:

$$C_R = C_{TM} - (1+k)C_{FM}$$

-. ΔC_F is the roughness allowance

$$\Delta C_F = \left[105\left(\frac{k_S}{L_{WL}}\right)^{\frac{1}{3}} - 0.64\right]10^{-3}$$

where the roughness k_S=150.10^{-6} m and

- C_{AA}, is the air resistance

$$C_{AA} = 0.001.\frac{A_T}{S}$$

If the ship is fitted with bilge keels the total resistance is as follows:

$$C_{TS} = \frac{S + S_{BK}}{S}\left[(1+k)C_{FS} + \Delta C_F\right] + C_R + C_{AA}$$

2.4.2 Scale Effect Corrections for Propeller Characteristics.

The characteristics of the full scale propeller are calculated from the model characteristics as follows

$$K_{TS} = K_{TM} - \Delta K_T$$

$$K_{QS} = K_{QM} - \Delta K_Q$$

where

$$\Delta K_T = -\Delta C_D.0.3.\frac{P}{D}\frac{c.Z}{D}$$

$$\Delta K_Q = -\Delta C_D\ .0.25.\frac{c.Z}{D}$$

The difference in drag coefficient ΔC_D is

$$\Delta C_D = C_{DM} - C_{DS}$$

where

$$C_{DM} = 2\left(1+2\frac{t}{c}\right)\left[\frac{0.04}{(R_{nco})^{\frac{1}{6}}} - \frac{5}{(R_{nco})^{\frac{2}{3}}}\right]$$

and

$$C_{DS} = 2\left(1+2\frac{t}{c}\right)\left(1.89+1.62.\log\frac{c}{k_p}\right)^{-2.5}$$

In the formulae listed above c is the chord length, t is the maximum thickness, P/D is the pitch ratio and R_{nco} is the local Reynolds number at x=0.75. The blade roughness k_p is put k_p=30.10^{-6} m. R_{nco} must not be lower than 2.10^5 at the open-water test.

2.4.3 Full Scale Wake and Operating Condition of Propeller

The full scale wake is calculated from the model wake, w_{TM}, and the thrust deduction, t:

$$w_{TS} = (t+0.04) + (w_{TM} - t - 0.04)\frac{(1+k)C_{FS} + \Delta C_F}{(1+k)C_{FM}}$$

where 0.04 is to take account of rudder effect. The load of the full scale propeller is obtained from

$$\frac{K_T}{J^2} = \frac{S}{2D^2} \cdot \frac{C_{TS}}{(1-t)(1-w_{TS})^2}$$

With this K_T/J^2 as input value the full scale advance coefficient J_{TS} and the torque coefficient K_{QTS} are read off from the full scale propeller characteristics and the following quantities are calculated

- the rate of revolutions:

$$n_S = \frac{(1-w_{TS})V_S}{J_{TS}D} \qquad \text{(r/s)}$$

- the delivered power:

$$P_{DS} = 2\pi\rho D^5 n_S^3 \frac{K_{QTS}}{\eta_R} 10^{-3} \qquad \text{(kW)}$$

- the thrust of the propeller:

$$T_S = \frac{K_T}{J^2}.J_{TS}{}^2\rho.D^4.n_S^2 \qquad \text{(N)}$$

- the torque of the propeller:

$$Q_S = \frac{K_{QTS}}{\eta_R}\rho D^5 n_S^2: \qquad \text{(Nm)}$$

- the effective power:

$$P_E = C_{TS} 1/2\rho.V_S^3.S.10^{-3} \qquad \text{(kW)}$$

- the total efficiency:

$$\eta_D = \frac{P_{DS}}{P_E}$$

- the hull efficiency:

$$\eta_H = \frac{1-t}{1-w_{TS}}$$

2.4.4 Model-Ship Correlation Factors

Trial prediction of rate of revolutions and delivered power with C_P - C_N corrections

if CHOICE=0 the final trial predictions will be calculated from

$$n_T = C_N.n_S \qquad \text{(r/s)}$$

for the rate of revolutions and

$$P_{DT} = C_P.P_{DS} \qquad \text{(kW)}$$

for the delivered power.

Trial prediction with ΔC_{FC} - Δw_C corrections

If CHOICE=1 the final trial predictions are calculated as follows:

$$\frac{K_T}{J^2}=\frac{S}{2D^2}\cdot\frac{C_{TS}+\Delta C_{FC}}{(1-t)(1-w_{TS}+\Delta w_C)^2}$$

With this K_T/J^2 as input value, J_{TS} and K_{QTS} are read off from the full scale propeller characteristics and

$$n_T=\frac{(1-w_{TS}+\Delta w_C)V_S}{J_{TS}.D} \qquad \text{(r/s)}$$

$$P_{DT}=2\pi.\rho.D^5.n_T^3.\frac{K_{QTS}}{\eta_{RM}}.10^{-3} \qquad \text{(kW)}$$

Trial prediction with C_{NP} correction

If CHOICE = 2 the shaft rate of rotation is predicted on the basis of power identity as follows.

$$\left(\frac{K_Q}{J^3}\right)_T=\frac{1000.C_P.P_{DS}}{2\pi.\rho.D^2V_S^3(1-w_{TS})^3}$$

$$\frac{K_{Q_0}}{J^3}=\left(\frac{K_Q}{J}\right)_T.\eta_{RM}$$

$$n_S=V_S(1-w_{TS})/J_{TS}.D$$

$$n_T=C_{NP}n_S$$

2.5 Analysis of Speed Trial Results

The analysis of trials data is performed in a way consistent with performance prediction but starting P_D and n backwards, i.e. from

$$K_Q=\frac{P_D}{2\pi.\rho.D^5.n^3}.\eta_{RM}.10^3$$

J_S is obtained from the full-scale open-water characteristics $K_Q \approx J_S$ then

$$w_T=1-J_S.n.D/V$$

Further from $K_T \approx J_S$ characteristics

$$T=K_T.\rho.n^2D^4$$

$$C_T=\frac{T.(1-t)}{\frac{1}{2}.\rho.V^2.S}$$

Then we obtain

$$\Delta C_{FC}=C_T-C_{TS}$$

$$\Delta w_C=w_{TS}-w_T$$

2.6 Input Data

Input data sheets are given in ENCL.1

2.7 Output Data

- Output data I gives ITTC Standard Prediction with $C_P = C_N = 1.0$, together with model and full scale propulsive coefficients (ENCL. 4).
- Output data II gives the final ship prediction (ENCL. 5).

- Output data III gives the analysis of the speed trial results (ENCL. 6).

2.8 Test Example

To illustrate the program a prediction was made for a hypothetical ship with the following particulars:

length between perpendiculars	Lpp = 251.5m
breadth	B = 41.5m
draft	T = 16.5m
propeller diameter	D = 8.2m

Calculations were carried out with the ITTC Trial Prediction Test Program with:

$C_P = 1.01$
$C_N = 1.02$

The input data were taken as shown in ENCL. 1 and the printout of the input data and results are given in ENCL. 4 - 6.

INPUT DATA:

1978 ITTC Performance Prediction Method for Single Screw Ships (Modified in 1984 and 1987)

ENCL 1

PROJECT	SHIP MODEL	PROP. MODEL	SCALE FACTOR						
123	M-4567	P-89	37.0						
LENGTH PP (M)	LENGTH WL (M)	DRAFT FWD (M)	DRAFT AFT (M)	BREADTH (M)	WET. SURFACE (M^2)	DISPLACEMENT (M^3)	BILGE KEEL AREA (M^2)	PROJ. AREA ABOVE WL (M^2)	FORM FACTOR
251.5	260.0	16.5	16.5	41.5	16400.0	142000.0	144.0	600.0	0.25

NUMBER OF PROP.	NUMBER OF BLADER	PROPELLER DIAMETER (M)	PROPELLER CHAR. AT X = 0.75: PITCH RATIO	CHORD LENGTH (M)	BLADE THICK (M)	RNCM.10^5 OPEN WATER	RUDDER BEHIND PROP.	DIA. OF STOCK PUMP	H I P S FRICTION LINE	FORM FACTOR FOR H.(I).PS
[redacted] 1	5	8.2	0.76	2.52	0.078	5.60				

NUMBER OF J-KT KQ	NUMBER OF SPEED	DENSITY OF WATER: TANK (KG/M^3)	SEA (KG/M^3)	TEMP. OF WATER (CENTICR.): RESIST.	SELF. PR.	SEA	CHOICE OF TRIAL CORR.	CP	CN OR CNP	DCFC.10^3	DWC
[redacted] 10	[redacted] 7	1000.0	1025.0	16.3	18.5	15.0	[redacted] 0	1.01	1.02		

SPEED VS (KNOTS)	MOD. RESIST. RTM (N)	MOD. THRUST TM (N)	MOD. TORQUE QM x 100 (KM)	RATE OF REV. NM (RPS)	FRICT CORR. (N)	ADV. RATIO J	THRUST COEFF. KT x 10	TORQUE COEFF. KQ X 100	K_Tx10	KQx100
14.0	33.7	27.5	83.4	7.88	10.88	0.20	2.830	3.350		
15.0	38.3	32.4	96.9	8.53	12.38	0.25	2.630	3.160		
16.0	43.4	37.8	111.4	9.20	13.92	0.30	2.425	2.970		
17.0	49.7	44.0	127.8	9.87	15.38	0.35	2.215	2.780		
18.0	57.9	51.4	148.2	10.57	16.78	0.40	2.000	2.580		
19.0	67.7	61.9	178.3	11.45	18.18	0.45	1.780	2.380		
20.0	79.1	76.2	214.9	12.47	20.43	0.50	1.555	2.170		
	↑	↑	↑	↑	↑	0.55	1.325	1.940		
	C_R x 10^3	t	W_{TM}	n_R	ΔC_F x 10^3	0.60	1.090	1.690		
						0.65	0.850	1.410		

STOCK PROPELLER CHARACTERISTICS (applies to the last two columns, K_Tx10 and KQx100)

TRIAL			
15.	17.	19.	SHIP SPEED (KNOTS)
82.62	95.26	111.55	NO. OF REVS. (RPM)
17444.	26766.	44613.	DELV. POWER (HP)

ENCL.3

1978 ITTC PERFORMANCE PREDICTION
METHOD FOR SINGLE SCREW SHIPS (REVISED IN 1983)
TRIAL ANALYSIS

IDENTIFICATION :

PROJECT : 123
SHIP MODEL : M-4567
PROPELLER MODEL : P-89
SCALE FACTOR : 37.00

PROPELLER:

NUMBER OF PROPELLERS: 1
NUMBER OF BLADES : 5
DIAMETER : 8.200 (M)
PITCH RATIO 0.75R : 0.7600

SHIP:

LENGTH PP : 251.50 (M)
LENGTH WL : 260.00 (M)
DRAFT FWD : 16.50 (M)
DRAFT AFT : 16.50 (M)
BREADTH : 41.50 (M)
WETTED SURFACE : 16400. (M**2)
DISPLACEMENT : 142000. (M**3)

FRICTION COEFFICIENT CF
CALCULATED ACCORDING TO ITTC-57
FORM FACTOR : 0.250 (BASED ON ITTC-57)

TRIAL ANALYSIS ACCORDING TO ITTC 1978 METHOD

SHIP SPEED-TRIAL	15.00	17.00	19.00
PROP. RPM -TRIAL	82.62	95.26	111.55
DELIV.POWER-TRIAL	17444.	26766.	44613.
PROP. RPM -CN=1	81.00	93.39	109.37
DELIV.POWER-CP =1	17271.	26502.	44174.
PROP. RPM -CNP=1	81.30	93.78	109.71
CP	1.010	1.010	1.010
CN	1.020	1.020	1.020
CNP	1.016	1.016	1.017
DCFC*1000 CP=CN=1	-0.052	-0.054	-0.071
DWC CP=CN=1	0.048	0.050	0.054
DCF *1000 ITTC-57	0.200	0.200	0.186
DW = WM-WTRIAL	0.096	0.087	0.103
CR*1000	0.092	0.207	0.644
THDM	0.211	0.230	0.209
WTM	0.352	0.347	0.353
WTS CP=CN=1	0.304	0.311	0.304
WTS TRIAL	0.256	0.260	0.250
ETARM	0.980	1.004	0.999

1978 ITTC PERFORMANCE PREDICTION METHOD FOR SINGLE SCREW SHIPS
OUTPUT DATA 1

ENCL: 4
REPORT:

IDENTIFICATION :

PROJECT : 123
SHIP MODEL : M-4567
PROPELLER MODEL : P-89
SCALE FACTOR : 37.00

SHIP:

LENGTH PP : 251.50 (M)
LENGTH WL : 260.00 (M)
DRAFT FWD : 16.50 (M)
DRAFT AFT : 16.50 (M)
BREADTH : 41.50 (M)
WETTED SURFACE : 16400. (M**2)
DISPLACEMENT : 142000. (M**3)

PROPELLER:

NUMBER OF PROPELLERS: 1
NUMBER OF BLADES : 5
DIAMETER : 8.200 (M)
PITCH RATIO 0.75R : 0.7600

FRICTION COEFFICIENT CF CALCULATED ACCORDING TO ITTC-57
FORM FACTOR : 0.250 (BASED ON ITTC-57)

SHIP MODEL:

SPEED VS KNOTS	SPEED VM M/S	RES.COEFF. TOTAL CTM*1000	FRICT.COEFF. CFM*1000	THRUST DED. TM	MEAN WAKE WTM	REL.ROT. EFFIC. ETARM
14.0	1.184	4.013	3.152	0.182	0.355	0.968
15.0	1.269	3.973	3.113	0.211	0.352	0.980
16.0	1.353	3.957	3.078	0.231	0.346	0.993
17.0	1.438	4.014	3.045	0.230	0.347	1.004
18.0	1.522	4.171	3.015	0.210	0.352	1.006
19.0	1.607	4.377	2.987	0.209	0.353	0.999
20.0	1.691	4.616	2.961	0.238	0.358	1.009

ITTC STANDARD PREDICTION CP=CN=1.0 :

SPEED VS KNOTS	EFF.POWER PE KW	DELIV.POWER PD KW	RATE OF REVS N RPS	THRUST T KN	TORQUE Q KNM
14.0	6820.	10139.	1.256	1158.	1285.
15.0	8360.	12699.	1.350	1374.	1497.
16.0	10211.	15708.	1.449	1613.	1726.
17.0	12725.	19486.	1.557	1891.	1992.
18.0	16325.	24707.	1.681	2231.	2339.
19.0	21005.	32479.	1.823	2717.	2836.
20.0	26887.	43536.	1.986	3430.	3489.

SPEED KNOTS	TOT.EFF. ETAD	PROP.EFF. ETAO	HULL EFF. ETAH	SHIP WAKE WTS
14.0	0.673	0.602	1.154	0.291
15.0	0.658	0.593	1.132	0.304
16.0	0.650	0.587	1.115	0.310
17.0	0.653	0.582	1.117	0.311
18.0	0.661	0.579	1.135	0.304
19.0	0.647	0.570	1.137	0.304
20.0	0.618	0.546	1.122	0.321

OPEN WATER CHAR. FULL SCALE:

J	10*KT	100*KQ
0.200	2.841	3.235
0.250	2.641	3.045
0.300	2.436	2.855
0.350	2.226	2.665
0.400	2.011	2.465
0.450	1.791	2.265
0.500	1.566	2.055
0.550	1.336	1.825
0.600	1.101	1.575
0.650	0.861	1.295

```
1978 ITTC PERFORMANCE PREDICTION            ENCL:  5
METHOD FOR SINGLE SCREW SHIPS              REPORT:
OUTPUT DATA 2

IDENTIFICATION      :                  SHIP:

PROJECT             :      123         LENGTH PP        :  251.50 (M)
SHIP MODEL          :   M-4567         LENGTH WL        :  260.00 (M)
PROPELLER MODEL     :     P-89         DRAFT FWD        :   16.50 (M)
SCALE FACTOR        :    37.00         DRAFT AFT        :   16.50 (M)
                                       BREADTH          :   41.50 (M)
PROPELLER:                             WETTED SURFACE   :  16400. (M**2)
                                       DISPLACEMENT     : 142000. (M**3)
NUMBER OF PROPELLERS:         1
NUMBER OF BLADES     :        5     FRICTION COEFFICIENT OF
DIAMETER             :    8.200 (M) CALCULATED ACCORDING TO ITTC-57
PITCH RATIO 0.75R    :   0.7600     FORM FACTOR : 0.250 (BASED ON ITTC-57)


SHIP TRIALS PREDICTION CP=  1.010   CN=  1.020

SHIP     DELIVERED POWER      RATE OF REVS.
SPEED    ---------------      -------------
KNOTS      KW        HP        RPS     RPM

14.0     10241.    13927.     1.281    76.88
15.0     12826.    17444.     1.377    82.62
16.0     15865.    21576.     1.477    88.65
17.0     19681.    26766.     1.588    95.26
18.0     24954.    33937.     1.714   102.87
19.0     32804.    44613.     1.859   111.55
20.0     43972.    59801.     2.026   121.54
```

3. PARAMETERS

3.1 Parameters to be Taken into Account

Froude scaling law
ship-model correlation line ,friction line
kinematic viscosity
mass density
blockage
form factor
propeller loading
hull roughness

see also 3.3 Input Data

3.2 Recommendations of ITTC for Parameters

see 4.9-03-03-01.1 Propulsion Test

1987 p.263 In using the 1978 ITTC Method it is recommended that the rudder(s) be fitted in hull resistance experiments for barge type forms where inflow velocity is relatively large.

3.3 Input Data

All data are either non-dimensional or given in SI-units.

Every data card defines several parameters which are required by the program; each of these parameters must be input according to a specific format.

"I" format means that the value is to be input without a decimal point and packed to the right of the specified field.

"F" format requires the data to be input with a decimal point; the number can appear anywhere in the field indicated.

"A" format indicates that alphanumeric characters must be entered in the appropriate card columns.

The card order of the data deck must follow the order in which they are described below.

Card No. 1 Identifications

Card column	Form at	CC Symbol	Definition
1- 8	A	-	Project No.
9-16	A	-	Ship model No
17-24	A	-	Propeller model No.
25-32	F	SCALE	Scale ratio

Card No. 2 Ship particulars

Card column	For-mat	CC Symbol	Definition
9-16	F	LWL	Length of waterline
17-24	F	TF	Draft, forward
25-32	F	TA	Draft, aft
33-40	F	B	Breadth
41-48	F	S	Wetted surface, without bilge keels
49-56	F	DISW	Displacement
157-64	F	SBK	Wetted surface of bilge keels
65-72	F	AT	Transverse projected area of ship above waterline
72-80	F	C3	Form factor determined at resistance tests

Card No. 3 Particulars of full scale

Card column	For-mat	CC Symbol	Definition
8- 8	I	NOPROP	Number of propellers should be 1 since method is valid only for single screw ships
15-16	I	NPB	Number of propeller blades
17-24	F	DP	Diameter of propeller
25-32	F	PD075	Pitch ratio at x=0.75
33-40	F	CH075	Chord length of Propeller blade at x=0.75
41-48	F	TMO75	Maximum blade thick-ness of propeller at x=0.75
49-56	F	RNCHM	Reynolds number at open-water test based on chord length and local velocity $V = V_A\sqrt{1+\left(\frac{\pi.0.75}{J}\right)^2}$ at x-0.75.

Card No. 4 General

Card column	For-mat	CC Sym-bol	Definition
2.- 4	I	NOJ	Number of J-values in the open-water characteristics ($J \leq NOJ \leq 10$)
7- 8	I	NOSP	Number of speeds in the self- propulsion tests ($NOSP_{max}$=10)
9-16	F	RHOM	Density of tank water
17-24	F	RHOS	Density of sea water
25-30	F	TEMM	Temperature of resistance test
31-36	F	TEMP	Temperature at self-propulsion test -
36-41	F	TEMS	Temperature of sea water
48-48	I	CHOICE	CHOICE=0 $C_P - C_N$ trial corr. CHOICE==1: $\Delta C_{FC} - \Delta w_C$ trial corr.
49-56	F	CP	Trial correction for shaft power.
57-64	F	CN	Trial correction for rpm
65-72	F	DELT CFC	Trial correction for ΔC_F
72-80	F	DELTWC	Trial correction for Δw

Mean values of the trial correction figures, C_p and C_N can be obtained from the trial test material of the individual institutions by running the ITTC Trial Prediction Test Program. If an institution wishes to give predictions with a certain margin the input C_P-C_N-values must be somewhat higher than these mean values.

Cards Nos. 5-14 Result of resistance and self-propulsion tests and model propeller characteristics.

Card column	Format	CC Symbol	Definition
1- 8	F	VS	Ship speed in knots
9-16	F	RTM	Resistance of ship model
17-24	F	THM	Thrust of propeller
25-32	F	QM	Torque of propel-ler:Q_M:100
33-40	F	NM	Rate of revolution
41-48	F	FD	Skin friction correc-tion force
49-56	F	ADVC	Advance coefficient,. open water
57-64	F	KT	Thrust coefficient, open water
65-72	F	KQ	Torque coefficient, open water

The J-margin in the open-water characteristics must be large enough to cover the model and full scale J-values with some margin.

Input data sheets are given in ENCL. 1.

4. VALIDATION

4.1 Uncertainty Analysis

not yet available

4.2 Comparison With Full Scale Results

The data that led to t ITTC-78 method can be found in the following ITTC proceedings:

1) Proposed Performance Prediction Factors for Single Screw Ocean Going Ships (13th 1972 pp.155-180) Empirical Power Prediction Factor (1+X)

2) Propeller Dynamics Comparative Tests (13th 1972 pp.445-446)

3) Comparative Calculations with the ITTC Trial Prediction Test Programme (14th 1975 Vol.3 pp.548-553)

4) Factors Affecting Model Ship Correlation (17th 1984 Vol. 1, pp274-291)

5. ITTC- 1978 PERFORMANCE PREDICTION METHOD (COMPUTER CODE)

```
C
C     ***************************************************************************************
C     *                                                                                     *
C     *      1978  ITTC PERFORMANCE  PREDICTION  METHOD FOR SINGLE SCREW *
C     *      SHIPS                                                                          *
C     *      (REVISED 1983 TO INCLUDE TRIAL ANALYSIS AND TWIN SCREW SHIPS*  *
C     *                                                                                     *
C     ***************************************************************************************
C
C     DECLARATIONS
C
      COMMON /A/ FILE(2),MODELS(2), MODELP(2), LPP,LWL,TF,TA,B,S,
     *           SCALE,RNCHM,DISW,NOPROP,NPB,DP,PD075,CH075.
     *           TM075,C3,SBK,AT,CP,CN,DELCF,DELWC,KSI,KPI,
     *           RHOM,RHOS,TEMM,TEMP,TEMS,VS(10),RTM(10),THM(10),
     *           QM(10),NM(10),ADVC(10),KT(10),KQ(10),THD(10),
     *           FD(10),IC,NOJ,NOSP,PI
C
      COMMON /B/ ETARM(10),ETAO(10),ETAH(10),ETAD(10),AWTM(10),
     *           AWTS(10),ACFM(10),ACTM(10),AVS(10),AVM(10),
     *           ATS(10),AQS(10),APDS(10),APE(10),APDT(10),
     *           ANS(10),ANT(10),BPDT(10),BNT(10),KTSJ2(10),
     *           KQS(10),KTS(10),ACTS(10)
      DIMENSION  FILE1(2),MODLS1(2),MODLP1(2)
C
      REAL       LPP, LWL, KS1, KS, KP1, KP, NM1, NM, KT, KQ, KTM, KQ0, JTM,
     *           KTSJ2, JTS, NS, KQTS, KTS, KQS, KQM
      DATA       TRIAL /'TRIA'/
500   FORMAT(6A4,F8.0)
501   FORMAT(10F8.0)
502   FORMAT(2I4,9F8.0)
503   FORMAT(2I4,2F8.0,3F6.0,I6,4F8.0)
504   FORMAT(9F8.0)
600   FORMAT(/5X,'NUMBER OF ADV,KT AND KQ POINTS =',15/
     *        5X,'NUMBER OF SPEEDS                =',15/
     *        5X,'NUMBER OF SPEEDS OR ADVC POINTS  >10'/)
```

```
C
C       CONSTANTS
C
        G=9.81
        PI=3.14159
        KP1=30.0
        KS1=150.0
        KS=1.5E-4
        KP=0.3E-4
C
C       READ INPUT DATA
C
1000    CONTINUE
        READ(5,500,END=999) FILE,MODELS,MODELP,SCALE
        READ(5,501) LPP,LWL,TF,TA,B,S,DISW,SBK,AT,C3
        READ(5,502) NOPROP,NPB,DP,PD075,CH075,TM075,RNCHM
        READ(5,503) NOJ,NOSP,RHOM,RHOS,TEMM,TEMP,TEMS
        *               IC,CP,CN,DELCF,DELWC
        NMAX=MAX0(NOJ,NOSP)

        IF(FILE(1).EQ.TRIAL) GOTO 100

        READ(5,504)(VS(I),RTM(I),THM(I),QM(I),NM(I),FD(I),
        *                ADVC(I),KT(I),KQ(I);I=1,NMAX)


C
C       WRITE INPUT DATA
C
        CALL OUTPUT(1)
C
C       CHECK
C
        IF(NOJ.LE.10.AND.NOSP.LE.10)  GOTO 2
        WRITE(6,600) NOJ.NOSP
        GOTO 1000
    2   CONTINUE
```

```
C
C       RECALCULATION OF INPUT DATA
C
        DO  3  I=1,NOJ
        KT(I)=KT(I)*0.1
        KQ(I)=KQ(I)*0.01
....3   CONTINUE
        DELCF=DELCF*0.001
        RNCHM=RNCHM*100000.
        VISCP=((0.585E-3*(TEMP-12.0)-0.03361)*(TEMP-12.0)+
        *         1.2350)*1.0E-6
        VISCM=((0.585E-3*(TEMM-12.0)-0.0361)*(TEMM-12.0)+
        *         1.2350)*1.0E-6
        VISCS=((0.659E-3*(TEMS-1.0)-0.05076)*(TEMS-1.0)+
        *         1.7688)*1.0E-6
C
C       CORRECTION OF PROPELLER CHARACTERISTICS
C
        CDM=2.0*(1.0+2.0*TM075/CH075)*(0.044/RNCHM**0.16667-
        *         5.0/RNCHM**0.66667)
        CDS=2.0*(1.0+2.0*TM075/CH075)/(1.89+1.62*ALOG10(CH075
        *         /KP))**2.5
        DCD=CDM-CDS
        DKT=-0.3*DCD*PD075*CH075*NPB/DP
        DKQ=0.25*DCD*CH075*NPB/DP
        DO 4  I=1,NOJ
        KTS(I)=KT(I)-DKT
        KQS(I)=KQ(I)-DKQ
        KTSJ2(I)=KTS(I)/ADVC(I)**2
    4   CONTINUE
        DO 5  I=1,NOSP
        VS1=VS(I)*0.15444
        VM1=VS1/SQRT(SCALE)
        NM1=NM(I)
C
C
```

```
C       CALCULATE ROUGHNESS ALLOWANCE AND SHIP TOTAL RESISTANCE
C
        RNLP=LWL*VM1/(VISCP*SCALE)
        RNLM=LWL*VM1/(VISCM*SCALE)
        RNLS=LWL*VS1/VISCS
        CFMC=0.075/(ALOG10(RNLP)-2)**2
        CFM=0.075/(ALOG10(RNLM)-2)**2
        CFS=0.075/(ALOG10(RNLS)-2)**2
        CTM=RTM(I)*SCALE**3/(0.5*RHOM*VS1**2*S)
        CR=CTM-(1.0+C3)*CFM
        RTMC=RTM(I)*(1.0+C3)*CFMC+CR)/((1.0+C3)*CFM+CR)
        THD(I)=(THM(I)+FD(I)-RTMC)/THM(I)
        DELCF=(105.0*(KS/LWL)**0.33333-0.64)*0.001
        CAA=0.001*AT/S
        CTS=((1.0+C3)*CFS*DELCF)*(S+SBK)/S+CR+CAA
C
C       MODEL PROPULSIVE COEFFICIENTS
C
        FNOP=NPROP
        KTM=(THM(I)/FNOP)/(RHOM*(DP/SCALE)**4*NM1*NM1)
        KQM=(QM(I)*0.01/FNOP)/(RHOM*(DP/SCALE)**5*NM1*NM1)
        JTM=APOL(0,KT,ADVC,NOJ,KTM,IX)
        KQ0=APOL(0,ADVC,KQ,NOJ,JTM,IX)
        WTM=1.0-JTM*DP*NM1/(VM1*SCALE)
C
C       FULL SCALE WAKE
C
        IF(JRUDER) 6,5,6
   5    WTS=(THD(I)+0.04)+(WTM-THD(I)-0.04)*((1.0+C3)*CFS+DELCF)/
        *        ((1.0+C3)*CFM)
        GOTO 7
   6    WTS=(THD(I) )+(WTM-THD(I) )*((1.0+C3)*CFS+DELCF)/
        *        ((1.0+C3)*CFM)
        GOTO 7
   7    IF(WTS.GT.WTM)   WTS=WTM
        ETARM(I)=KQ0/KQM
C
C       SAVE AREAS
C
        ACTM(I)=CTM
        ACFM(I)=CFM
        AWTM(I)=WTM
        AWTS(I)=WTS
        ACTS(I)=CTS
        AVS(I)=VS1
        AVM(I)=VM1
   8    CONTINUE
C
C       ITTC  STANDARD  PREDICTION
```

```
C
      CALL IP
C
C     RETURN  FOR  NEW  INPUT
C
                   DO 20  I=1,2
                   FILE1(I)=FILE(I)
                   MODLS1(I)=MODELS(I)

   20              MODELP1(I)=MODELP(I)
                   SCALE1=SCALE
      GOTO 1000
C
  100 CONTINUE
                   DO 110  I=1,2
                   FILE(I)=FILE1(I)
                   MODELS(I)=MODLS1(I)
110                MODELP(I)=MODLP1(I)
                   SCALE=SCALE1
C
      CALL ANLSYS
C
C     RETURN FOR NEW INPUT
C
C
      GOTO 1000
  999 STOP
      END
C
```

```
C
C
      ************************************************************************************************
***
C
C     OUTPUT IS USED FOR PRINTING INPUT DATA AND RESULTS
C
C     IOUT= 1     INPUT DATA IS PRINTED
C           2     RESULT PAGE 1
C           3     RESULT PAGE 2
C
C
      ************************************************************************************************
***
C
      SUBROUTINE OUTPUT(IOUT)


      COMMON /A/ FILE(2),MODELS(2),MODELP(2),LPP,LWL,TF,TA,B,S
     *           SCALE,RNCHM,DISW,NOPROP,NPB,DP,PD075,CH075,
     *           TM075,C3,SBK,AT,CP,CN,DELCFC,DELWC,KSI,KPI,
     *           RHOM,RHOS,TEMM,TEMP,TEMS,VS(10),RTM(10);THM(10),
     *           QM(10),NM(10),ADVC(10),KT(10),KQ(10),THD(10),
     *           FD(10),IC,NOJ,NOSP,PI
C
      COMMON /B/ ETARM(10),ETA0(10),ETAH(10),ETAD(10),AWTM(10),
     *           AWTS(10),ACFM(10),ACTM(10),AVS(10),AVM(10),
     *           ATS(10),AQS(10),APDS(10),APE(10),APDT(10),
     *           ANS(10),ANT(10),BPDT(10),BNT(10),KTSJ2(10),
     *           KQS(10),KTS(10),ACTS(10)
C
      REAL       LPP,LWL,KS1,KS,KP1,KP,NM1,NM,KT,KQ,KTM,KQ0,JTM,
                 KTSJ2,JTS,NS,KQTS,KTS,KQS
      DIMENSION TEXT (16)
      DATA TEXT  /'INPU','T DA','TA  ','    ',
     *           'OUTP','UT D','ATA ','1   ',
     *           'OUTP','UT D','ATA..','2   ';
     *           `TRIA`,`L AN`,ÀLYS`,ÌS   `/
  600 FORMAT('1',19X,'1978 ITTC PERFORMANCE PREDICTION',10X,
     *     'ENCL:'/
C??  *     20X,'METHOD               ',8X,
     *     'REPORT:'/20X,4A4/)
```

```
   601 FORMAT(5X,'IDENTIFICATION         :',18X,'SHIP:'//
     *       5X,'PROJECT                 :',2A4,
     *      10X,'LENGTH PP          :',F8.2,'  (M)'/
     *       5X,'SHIP MODEL'        :',2A4,
     *      10X,'LENGTH  WL         :',F8.2,'  (M)'/
     *       5X,'PROPELLER MODEL    :',2A4,
     *      10X,'DRAFT FWD          :',F8.2,'  (M)'/
     *       5X,'SCALE FACTOR       :',F8.2,
     *      10X,'DRAFT AFT          :',F8.2,'  (M)'/
     *      43X,'BREADTH            :',F8.2,'  (M)'/
     *       5X,'PROPELLER:',
     *      28X,'WETTED SURFACE :',F8.0,'  (M**2)'/
     *      43X,'DISPLACEMENT       :',F8.0,'  (M**3)')
602 FORMAT(5X,'NUMBER OF PROPELLERS:',I8/
     *       5X,'NUMBER OF BLADES        :',I8,
     *       6X,'FRICTION COEFFICIENT CF'/
     *       5X,'DIAMETER                      :',F8.3,'  (M)',
     *       2X,'CALCULATED ACCORDING TO ITTC-57'/
     *       5X,'PITCH RATIO 0.75R            :',F8.4,
     *       6X,'FORM FACTOR   :',F6.3,'   (BASED ON ITTC-57)'/)
603 FORMAT(5X,'HULL ROUGHN.*10**6              :',F6.1,'  (M)',
     *       2x,'BILGE KEEL AREA               :',F6.1,'  (M**2)',
     *       5X,'PROPELLER BLADE ROUGHN.*10**6:',F6.1,'  (M)',
     *       2X,'PROJ.AREA ABOVE WL.     :',F6.1,'  (M**2)'/)
604 FORMAT(5X,'CHORD LENGTH OF PROP.BLADE AT X=0.75:',
     *       F7.4,'  (M)'/
     *       5X,'THICKNESS OF PROP.BLADE         AT X=0.75:',
     *       F7.4'  (M)'/)
605 FORMAT(5X,'DENSITY OF WATER (TANK                    ) :'F7.1,
     *            '   (KG/M**3)'/
     *            'DENSITY OF WATER (SEA                     ) :'F7.1,
     *            '   (KG/M**3)'/
     *       5X,'TEMP. OF WATER  (RESISTANCE TEST)  :'F7.2,
     *            '   (CENTIGRADES)'/
     *       5X,'TEMP. OF WATER  (SELF PROP.    TEST)  :'F7.2,
     *            '   (CENTIGRADES)'/
     *       5X,'TEMP. OF WATER  (SEA                    )  :'F7.2,
     *            '   (CENTIGRADES)'//
     *       5X,'MODEL  TEST RESULTS:',
     *      30X,'OPEN WATER CHARACT.;'/
     *      54X,'RNC  :''F5.2,'*10**5'/)
```

```
606 FORMAT(5X,'SHIP    RESIS-    FRICT.    THRUST    TORQUE    RATE OF ',
     *          2X,'ADVANCE   THRUST    TORQUE'/
     *         20X,'REVS.    RATIO    COEFF.    COEFF.'/
     *          5X,'KNOTS       N           N           N          NM         RPS     ',
     *          7X,'J        10*KT        100*KQ'/)
607 FORMAT(1X)
608 FORMAT('+',3X,F5.1,1X,F7.1,1X,F7.2,2X,2F7.1,F9.2)
609 FORMAT('+',49X,F10.3,F7.3,F8.3)
610 FORMAT(5X,'SHIP MODEL:'//
     *          8X,'SPEED   RES. COEFF.    FRICT. COEFF.    THRUST DED.',
     *          2X,'MEAN REL.ROT.'/
     *          6X,'VS             VM            TOTAL',32X, 'WAKE      EFFIC.'/
     *          5X,'KNOTS     M/S          CTM*1000         CFM*1000',8X,'TM',
     *           7X,'WTM        ETARM'/)
611  FORMAT(4X,F5.1,F7.3,F8.3,6X,F7.3,7X,F7.3,3X,F7.3,F8.3)
612 FORMAT(/5x,'ITTC STANDARD PREDICTION  CP=CN=1.0 :'//
     *          5X,'SPEED EFF. POWER   DELIV. POWER    RSATE OF REVS',
     *          2X,' THRUST     TORQUE'/
     *          6X,'VS',7X,'PE',10X,'PD',12X,'N',10X,'T',8X,'Q'/
     *          5X,'KNOTS',5X,'KW',10X,'KW',11X,'RPS',9X,'KN',
     *          6X,'KNM'/)
613 FORMAT(4X,F5.1,F10.0,3X,F9.0,4X,F9.3,3X,F9.0,F8.0)
614 (FORMAT(/5X,'SPEED   TOT. EFF.   PROP.EFF.    HULL EFF.    SHIP WAKE',
     *          3X,'OPEN WATER CHAR. FULL SCALE:'/
     *          5X,'KNOTS    ETAD      ETA0    ETAH',/X,'WTS',
     *          9X,'J        10*KT        100*KQ'/)
615 FORMAT('+',3X,F5.1,F8.3,3(3X,F7.3))
616 FORMAT('+',50X,3F7.3)
617 FORMAT(/5X,'SHIP     DELIVERED POWER      RATE OF REVS.'/
     *          5X, 'SPEED  --------------------------        ---------------------'/
     *          5X,'KNOTS     KW              HP               RPS         RPM'/)
618 FORMAT(4X,F5.1,2X,2F8.0,3X,F7.3,F8.2)
619 FORMAT(/5X,'SHIP   TRIALS  PREDICTION  CP=',F7.3,'   CN=,F7.3)
620 FORMAT(/5X,'SHIP   TRIALS PREDICTION   DELCFC*1000=',
     *          F6.3,'     DELCW=',F6.3)
      ITEX=ICUT*4-4
      WRITE(6,600)  (TEXT(ITEX+1),I=1,4)
      WRITE(6,601)   FILE,LPP,MODELS,LWL,MODELP,TF,SCALE,TA,B,S,DISW
      WRITE(6,602)    NOPROP,NPB,DP,PD075,C3
C
      GOTO(10,20,30,40)  , IOUT
```

```
C
C       INPUT DATA IS LISTED
C
   10   CONTINUE
        WRITE(6,603)  KS1,SBK,KP1,AT
        WRITE(6,604)  CH075,TM075
        WRITE(6,605)  RHOM,RHOS,TEMM,TEMP,TEMS,RNCHM
        WRITE(6,606)
        NMAX=MAX0(NOJ,NOSP)
        DO  1  I=1,NMAX
        WRITE(6,607)
        IF(I. LE. NOSP) WRITE(6,608)    VS(I);RTM(I);FD(I),THM(I),
                                     QM(I),NM(I)
        IF(I. LE.NOJ)     WRITE(6,609)       ADVC(I),KT(I),KQ(I)
    1   CONTINUE
        RETURN

C
C       RESULTS PAGE 1
C
   20   CONTINUE
        WRITE(6,610)
        DO  21  I=1,NOSP
        CFM=ACFM(I)*1000.0
        CTM=ACTM(I)*1000.0
        WRITE(6,611)  VS(I),AVM(I),CTM,CFM,THD(I),AWTM(I),ETARM(I)
   21   CONTINUE
        WRITE(6,612)
        DO  22  i=1,NOSP
        WRITE(6,613)  VS(I),APE(I),APDS(I),ANS(I),ATS(I),AQS(I)
   22   CONTINUE
        WRITE(6,614)
        DO 23 i=1,NMAX
        WRITE(6,607)
        IF(I.LE.NOSP) WRITE(6,615)          VS(I),ETAD(I),ETA0(I),ETAH(I);
                                     AWTS(I)
        XKTS=KTS(I)*10.0
        XKQS=KQS(I)*100.0
        IF(I.LE.NOSP) WRITE(6,616)          ADVC(I),XKTS,XKQS
   23   CONTINUE
        RETURN
```

```
C
C       RESULTS  PAGE  3
C
   30   CONTINUE
        DCFC=DELCFC*1000.0
        IF(IC.EQ.1)    WRITE(6,620)DCFC,DELWC
        IF(IC.NE.1)    WRITE         (6,619)CP,CN
        WRITE(6,617)
        DO 31 I=1,NOSP
        WRITE(6,618)VS(I),APDT(I),BPDT(I),ANT(I),BNT(I)
   31   CONTINUE
....40  RETURN
        END

C
C
        ****************************************************************************************************
***
C
C       IRAT= 0        INTERPOLATION WITH A  2:ND DEGREE POLYNOMIAL
C            =1        INTERPOLATION WITH A RATIONAL FUNCTION OF 2:ND DEGREE
C       X      =             ARGUMENT ARRAY
C       Y      =             VALUE ARRAY
C       N      =             NUMBER OF ARGUMENTS
C       EX     =             ARGUMENT
C       IFEL  =              ERROR RETURN CODE
C
C
        ****************************************************************************************************
***
C
        REAL  FUNCTION  APOL(IRAT,X,Y,N,EX,IFEL)
        DIMENSION X(1),Y(1)
C
C       CHECK NUMBER OF POINTS > 2
C
        IFEL=0
        IF(X(1).GT.X(N))  GOTO 2
        IF(X(1).GT.EX.OR.X(N).LT.EX)  GOTO 7
        DO 1  I=1,N
        L=1
        IF(EX-X(I)) 4,4,1
    1   CONTINUE
        GOTO 4
    2   CONTINUE
        IF(X(1).LT.EX.OR.X(N).GT.EX)  GOTO 7
        DO  3  I=1,N
        L=I
        IF(EX-X(I))  3,4,4
```

```
    3   CONTINUE
    4   CONTINUE
        M=2
        IF(L.EQ.1)  M=1
        IF(L.EQ.3)  M=3
        LM=L-M
        X1=X(LM+1)
        X2=X(LM+2)
        X3=X(LM+3)
        Y1=Y(LM+1)
        Y2=Y(LM+2)
        Y3=Y(LM+3)
C
C       INTERPOL. 2:ND DEGREE POLYNOMIAL
C
        X21=X2-X1
        X31=X3-X1
        X32=X3-X2
        IF(IRAT.EQ.1)  GOTO 6
        C1=Y1
        C2=(Y2-C1)/X21
        C3=(Y3-C1-C2*X31)/(X31*X32)
        APOL=C1+(EX-X1)*(C2+C3*(EX-X2))
        RETURN
  6     CONTINUE
C
C       INTERPOL.  RAT.  FUNCTION
C
        Y21=Y2*X2*X2-Y1*X1*X1
        Y32=Y3*X3*X3-Y2*X2*X2
        A0=(Y32-X32*Y21/X21)/(X32*X31)
        B0=(Y21/X21-A0*(X1+X2)
        C0=((Y1-A0)*X1-B0)*X1
        APOL=(C0/EX+B0)/EX+A0
        RETURN
  7     CONTINUE
        WRITE(6,8)
  8     FORMAT(/5X,'INCREASE THE J-RANGE')
        STOP
        END
```

```
C
C       ********************************************************************
C
C       ITTC PREDICTIONS
C
C       ********************************************************************
C
        SUBROUTINE IP

        COMMON /A/ FILE(2),MODELS(2),MODELP(2),LPP,LWL,TF,TA,B,S,
        *          SCALE,RNCHM,DISW,NOPROP,NPB,DP,PD075,CH075,
        *          TM075,C3,SBK,AT,CP,CN,DELCFC,DELWC,KSI,KPI,
        *          RHOM,RHOS,TEMM,TEMP,TEMS,VS(10),RTM(10),THM(10),
        *          QM(10),NM(10),ADVC(10),KT(10),KQ(10),THD(10),
        *          FD(10),IC,NOJ,NOSP,PI
C
        COMMON /B/ ETARM(10),ETA0(10),ETAR(10),ETAD(10),AWTM(10),
        *          AWTS(10),ACFM(10),ACTM(10),AVS(10),AVM(10),
        *          ATS(10),AQS(10),APDS(10),APE(10),APDT(10),
        *          ANS(10),ANT(10),BPDT(10),BNT(10),KTSJ2(10),
        *          KQS(10),KTS(10),ACTS(10)
C
        REAL  LPP,LWL,KS1,KS,KPI,KP,NM1,NM,KT,KQ,KTM,KQD,JTM,
        *     KTSJ2,JTS,NS,KQTS,KTJT2,KQOS,KQS,KTS
        DO 3 I=1,NOSP
        VS1=AVS(I)
        CTS=ACTS(I)
        WTS=AWTS(I)
C
C       CALCULATE THE FULL SCALE LOAD ADVANCE COEFF: AND
C       TORQUE COEFF.
C
        FNOP=NOPROP
        KTJT2=S*CTS*0.5/((DP*(1.0-WTS))**2*(1.0-THD(I))) /FNOP
        JTS=APOL(1,KTSJ2,ADVC,NOJ,KT,KTJT2,IX)
        KQOS=APOL(0,ADVC,KQS,NOJ,JTS,IX)
C
C       THE RATE OF REV. AND THE DELIVERED POWER
C
        NS=(1.0-WTS)*VS1/(JTS*DP)
        APDS(I)=2.0*PI*RHOS*DP**5*NS**3*KQOS/ETARM(I)*0.001
        ANS(I)=NS
```

```
C
C       THE THRUST AND TORQUE OF THE PROPELLER
C
        ATS(I)=KTJT2*JTS**2*RHOS*DP**4*NS*NS*0.001
        AQS(I)=KQOS*RHOS*DP**5*NS*NS/ETARM(I)*0.001
C
C       THE EFFECTIVE POWER, TOTAL AND HULL EFFICIENCY
C
        APE(I)=CTS*0.5*RHOS*VS1**3*S*0.001
        ETAD(I)=APE(I)/APDS(I)
        ETAH(I)=(1.0-THD(I))/(1.0-WTS)
        IF(IC.EQ.1) GOTO 1
C
                IC1=IC-1
        IF(IC1)10,11,12
C
C       TRIAL PREDICTION WITH CP-CN CORRECTIONS (ITTC1978 ORIGINAL)
C
   10   ANT(I)=CN*NS
        BNT(I)=ANT(I)*60.0
        APDT(I)=CP*APDS(I)
        BPDT(I)=1.36*APDT(I)
        GOTO 100
C
C       TRIAL PREDICTION WITH CP-CN CORRECTIONS
C                                               CN BASED ON POWER IDENTITY
C
   12   APDT(I)=CP*APDS(I)
        BPDT(I)=1.36*APDT(I)
                KQJ3T=1000.0*APDT(I)/(2.0*PI*RHOS*DP**2)  /FNOP
                KQJ3T=KQJ3T/(VS1**3*(1.0-WTS)**3)
                KQ0J3=KQJ3T*ETARM(I)
                JTS=APOL(1,KQSJ3,ADVC,NOJ,KQ0J3,IX)
                NS=(1.0-WTS)*VS1/(JTS*DP)
                ANT(I)=CN*NS
                BNT(I)=ANT(I)*60.0
        GOTO 100
  11    CONTINUE
```

```
C
C       TRIAL PREDICTION WITH DELCF-DELWC CORRECTIONS
C
        KTJT2=S*(CTS+DELCFC)/(2.0*(1.0-THD(I))*(DP*
*       (1.0-(WTS-DELWC)))**2)
        JTS=APOL(1,KTSJ2,ADVC,NOJ,KTJT2,IX)
        KQOS=APOL(0,ADVC,KQS,NOJ,JTS,IX)
        ANT(I)=(1.0-WTS+DELWC)*VS1/(JTS*DP)
        BNT(I)=ANT(I)*60.0
        APDT(I)=2.0*PI*RHOS*DP**5*ANT(I)**3*KQOS/ETARM(I)*0.001
        BPDT(I)=1.36*APDT(I)
    2   CONTINUE
        ETAD(I)=KTJT2*JTS**3/(2.0*PI*KQOS)
    3   CONTINUE
C
C       WRITE OUTPUT
C
        CALL OUTPUT(2)
        CALL OUTPUT(3)
        RETURN


              SUBROUTINE ANLSYS
C
C*********************************************************************************************************
****
C     *                                                                                          *
C     *          ANALYSIS  ACCORD1NG TO  1978  ITTC PREDICTION  METHOD                            *
C     *                                                                                          *
C*********************************************************************************************************
****
C
C
        DIMENSION   VST(10),XNT(10),XPD(10),
        *           THDT(10),WTMT(10),WTST(10),ETART(10),CRWT(10),
        *           YNT(10),YPD(10),CPT(10),CNT(10),CNPT(10),ZNT(10)
        *           DCFT(10),WTSS(10),DWT(10),DCFM(10),DWM(I0),
        *           KQJ3(10)
C
        COMMON /A/ FILE(2),MODELS(2),MODELP(2),LPP,LWL,TF,TA,B,S,
        *           SCALE,RNCHM,DISW,NOPROP,NPB,DP,PD075,CH075,
        *           TM075,C3,SBK,AT,CP,CN,DELCFC,DELWC,KS1,KP1,
        *           RHOM, RHOS,TEMM,TEMP,TEMS,VS(10),RTM(10),THM(10),
        *           QM(10),NM(10),ADVC(10),KT(10),KQ(10),THD(10),
        *           RA(10),IC,NOJ,NOSP,PI
```

```
C
      COMMON /B/ ETARM(10), ETA0(10),ETAH(10),ETAD(10),AWTM(10),
      *          AWTS(10),ACFM(10),ACTM(10),AVS(10),AVM(10),
      *          ATS(10),AQS(10),APDS(10),APE(10),APDT(10),
      *          ANS(10),ANT(10),BPDT(10),BNT(10),KTSJ2(10),
      *          KQS(10),KTS(10),ACTS(10)

C
      REAL  LPP,LWL,KS1,KS,KP1,KP,NM1,NM,KT,KQ,KTM,KQ0,JTM,
      *     KTSJ2,JTS,NS,KQTS,KTJT2,KQOS,KTS,KQS,KQM,
      *     KQJ3,KQJ3T
C
C
       DO   5    I = 1,NOJ
   5  KQJ3(I) = KQS(I) /ADVC(I)**3
C
      NOST=10

      READ(5,510)  (VST(I),  I=1,NOST)
      READ(5,510)  (XNT(I),  I=1,NOST)
      READ(5,510)  (XPD(I), .I=1,NOST)

 510  FORMAT (10F8.0)
C
C           COUNT NO. OF TRIAL RUNS
            NOST = 0
            DO 8   I = 1, 10
            IF (VST(I).GT.0. )  NOST=NOST+1
  8         CONTINUE
      IF(XNT(1).GT.20.)  GOTO 20
      DO 10   I=1, NOST
      XNT(I) = XNT(I)*60.0
  10  XPD(I) = XPD(I)*1.36
  20  CONTINUE
      DO 50  I=1, NOST
                                  VST1=VST(I)*1852.0/3600.0
      CTST =     APOL(0,AVS, ACTS,  NOSP,VST1, IX)
      THDT(I)=   APOL(0,AVS, THD,    NOSP,VST1, IX)
      WTMT(I)=  APOL(0,AVS, AWTM, NOSP,VST1, IX)
      WTST(I)=  APOL(0,AVS, AWTS,  NOSP,VST1, IX)
      ETART(I)= APOL(0,AVS, ETARM,NOSP,VST1, IX)
      CF        =APOL(0,AVS, ACFM,   NOSP,VST1, IX)
      CT        =APOL(0,AVS, ACTM,   NOSP,VST1, X)
```

```
      CRWT(I)=  CT - (1.0+C3)*CF
      FNOP   =NOPROP
      KTJT2  =S*(CTST/FNOP )*0.5 / ((DP*(1.0-WTST(I)))**2*(1.0-THDT(I)))
      JTS     =APOL(1, KTSJ2, ADVC, NOJ, KTJT2, IX)
      KQOS=APOL (0, ADVC, KQS, NOJ, JTS, IX)
      NS=(1.0-WTST(I))*VST1/(JTS*DP)
      PDS = 2.0*PI*RHOS*DP**5*NS**3*KQ0S/ETART(I)*0.001*FNOP
      YNT(I)= NS*60.0
      YPD(I) = PDS*1.36
      CPT(I)= XPD(I)/YPD(I)
      CNT(I)=XNT(I)/YNT(I)
            PDT1 = XPD(I) /1.36
            XNT1 = XNT(I) / 60.0
      FKQ = PDT1*START(I)*1000.0 / (2.0*PI*RHOS*DP**5*XNT1**3) / FNOP
      FJT = APOL(0,KQS,ADVC,NOJ,FKQ,IX)
      FKT = APOL(0,ADVC, KTS,NOJ,FJT,IX)
      KQJ3T=FKQ * (DP*XNT1)**3 / ((1-WTST(I))*VST1)**3
      FJQ= APOL( 1,KQJ3,ADVC,NOJ,KQJ3T,IX)
      ZNT(I)=(1.0 -WTST(I)) * VST1 / (FJQ*DP) * 60.0
      CNPT(I)=XNT(I) / ZNT(I)
      THS= FKT * RHOS * DP**4*XNT1**2
      CTS=THS*(1.0 - THDT(I)) / (0.5*RHOS*VST1**2*S) * FNOP
      DCFT(I)=(CTS - CTST)*1000.0
      WTSS(I)= 1.0 - FJT*DP*XNT1/VST1
      DWT(I) = WTST(I) - WTSS(I)
      DWM(I) = WTMT(I) - WTSS(I)

C
C           CALCULATION OF FRICTIONAL RESISTANCE ~COEFF. OF SHIP
C
            T = TEMS
            FNU = ((0.659E-3*(T-I.0)-0.05076)*(T-1)+1.7688)*1.0E-6
            RNLS= ALOG10(LWL*VST1/FNU)
            CFS = 0.075 / (RNLS-2.0)**2
C
            DCFM(I) = CTS - (I.0+C3)*CFS - ( CRWT(I)+0.001*AT / S )*S / (S+SBK)
            DCFM(I) = DCFM(I) * 1000.0
            CRWT(I) = CRWT(I) * 1000.0
   50 CONTINUE
C
      CALL OUTPUT(4)
            WRITE(6,600)
```

```
600         FORMAT(' ',19X,'TRIAL ANALYSIS ACCORDING TO ITTC 1978 METHOD',///)
      WRITE(6,610) ( VST(I), I=1, NOST)
610         FORMAT(5X..         ' SHIP SPEED - TRTAL',7(F10.2, 2X)  /)
      WRITE(6,620) ( XNT(I), I=1, NOST)
620         FORMAT(5X,          ‘ PROP, RPM –TRTAL  ',7(F10.2, 2X)  /)
      WRITE(6,630) ( XPD(I), I=1, NOST)
630         FORMAT(4X,           'DELIV.POWER-TRIAL ',7(F11.0,1X) //)
      WRITE(6,640) ( YNT(I), I=1, NOST)
640         FORMAT(/5X,          ‘ PROP. RPM -CN=1       ',7(F10.2,2X)  /)
      WRITE~(6,650) ( ~YPD(I), I=1,NOST)
650         FORMAT(4X,           ' DELIV. POWER -CP =1',7(F11.0,1X)  /)
      WRITE(6,660) ( ZNT(I),   I=1, NOST)
660         FORMAT(5X,          ‘ PROP. RPM  -CNP=1     ',7(F10.2,2X), //)
      WRITE(6,670) ( CPT(I),  I=1, NOST)
670         FORMAT(/5X,          ‘ CP                    ‘,7(F10.3,2X)  /)
      WRITE(6,680) (CNT(I),  I=1, NOST)
 680        FORMAT(5X,           ‘CN                     ‘,7(F10.3,2X)  /)
      WRITE(6,690) (CNPT(I), I=1,NOST)
690         FORMAT(5X,            ‘CNP                   ',7(F10.3,2X)  //)
      WRITE(6,700) (DCFT(I), I=1,NOST)
700         FORMAT(/5X,           ‘DCFC*1000   -CP=CN=1’,7(F10.3,2x)  /)
      WRITE(6,710) ( DWT(I), I=1, NOST)
710         FORMAT(5X,            ' DWC          CP=CN=1’,7(F10.3,2X)  //)
      WRITE(6,715) ( DCFM(I), I=1, NOST)
715         FORMAT(/5X,           'DCF *1000      ITTC-57’,7(F10.3,2x)   /)
      WRITE(6,717) (  DWM(I),  I=1,NOST)
717         FORMAT(5X,            ‘DW = WM-WTRIAL       ',7(F10.3,2X)  //)
      WRITE(6,720) (   CRWT(I)  ,I=1, NOST)
720         FORMAT(/5X,          ‘             CR*1000        ‘,7(F10.3,2X)   /)
      WRITE (6,730) ( THDT(I), I=1, NOST)
730         FORMAT(5X,          ‘         THDM                ',7(F10.3,2X)   /)
      WRITE(6,740) ( WTMT(I), I=1, NOST)
740         FORMAT(5X,          ’         WTM                  ',7(F10.3,2X)   /)
      WRITE(6,750) ( WTST(I),  I=1, NOST)
750         FORMAT(5X,          ‘         WTS     CP=CN=1  ',7(F10.3,2x)   /)
      WRITE(6,760) (  WTSS(I),  I=1, NOST)
760         FORMAT(5X,          ’         WTS       TRIAL       ',7(F10.3,2X)  /)
      WRITE(6,770) ( ETART(I),  I=1, NOST)
770         FORMAT(5X,          ‘              ETARM     ‘     ,7(F10.3,2X)   /)
      RETURN
      END
```