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

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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 from the 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 pro-

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gram 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 propel-

ler 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

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

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with

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

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

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

where the roughness $k_s = 150 \cdot 10^{-6}$ m and

- C_{AA} is the air resistance

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

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

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

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


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

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

The difference in drag coefficient ΔC_D is

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

where

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

and

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

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 $k_p=30 \cdot 10^{-6}$ m. R_{nco} must not be lower than $2 \cdot 10^5$ 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:

$$n_s = \frac{(1-w_{TS})V_s}{J_{TS}D} \quad (\text{r/s})$$

- the delivered power:

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

- the thrust of the propeller:

$$T_S = \frac{K_T}{J^2} \cdot J_{TS}^2 \rho \cdot D^4 \cdot n_s^2 \quad (\text{N})$$

- the torque of the propeller:

$$Q_S = \frac{K_{QTS}}{\eta_R} \rho D^5 n_s^2 \quad (\text{Nm})$$

- the effective power:

$$P_E = C_{TS} 1/2 \rho \cdot V_s^3 \cdot S \cdot 10^{-3} \quad (\text{kW})$$

- 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

$$n_r = C_N \cdot n_s \quad (\text{r/s})$$

for the rate of revolutions and

$$P_{Dr} = C_p \cdot P_{DS} \quad (\text{kW})$$

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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

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

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

Trial prediction with C_{NP} correction

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

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

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

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

$$n_T = C_{NP} n_S$$

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

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

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

$$w_T = 1 - J_S \cdot n \cdot D / V$$

Further from $K_T \approx J_S$ characteristics

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

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

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).

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

propeller diameter $D = 8.2\text{m}$

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

2.8 Test Example

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

length between perpendiculars	$L_{pp} = 251.5\text{m}$
breadth	$B = 41.5\text{m}$
draft	$T = 16.5\text{m}$

$C_p = 1.01$
 $C_N = 1.02$

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.



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ENCL.3

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

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)
PROPELLER:			BREADTH	: 41.50 (M)
			WETTED SURFACE	: 16400. (M**2)
			DISPLACEMENT	: 142000. (M**3)
NUMBER OF PROPELLERS:		1		
NUMBER OF BLADES	:	5	FRICITION COEFFICIENT CF	
DIAMETER	:	8.200 (M)	CALCULATED ACCORDING TO ITTC-57	
PITCH RATIO 0.75R	:	0.7600	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	0.990	1.004	0.999



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

ENCL: 4
REPORT:

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	FRICITION COEFFICIENT CF	
DIAMETER	:	8.200 (M)	CALCULATED ACCORDING TO ITTC-57	
PITCH RATIO 0.75R	:	0.7600	FORM FACTOR	: 0.250 (BASED ON ITTC-57)

SHIP MODEL:

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

ITTC STANDARD PREDICTION CP=CN=1.0 :

SPEED VS	EFF. POWER PE	DELIV. POWER PD	RATE OF REVS N	THRUST T	TORQUE Q
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 KNCTS	TOT. EFF. ETAD	PRGP. EFF. ETAD	HULL EFF. ETAH	SHIP WAKE WTS	OPEN WATER CHAR. J	FULL SCALE: 10*KT	100*KG
14.0	0.673	0.602	1.154	0.291	0.200	2.841	3.235
15.0	0.658	0.593	1.132	0.304	0.250	2.641	3.045
16.0	0.650	0.587	1.115	0.310	0.300	2.436	2.855
17.0	0.653	0.582	1.117	0.311	0.350	2.226	2.665
18.0	0.661	0.579	1.135	0.304	0.400	2.011	2.465
19.0	0.647	0.570	1.137	0.304	0.450	1.791	2.265
20.0	0.618	0.546	1.122	0.321	0.500	1.566	2.055
					0.550	1.336	1.825
					0.600	1.101	1.575
					0.650	0.861	1.295



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1978 ITTC PERFORMANCE PREDICTION
METHOD FOR SINGLE SCREW SHIPS
OUTPUT DATA 2

ENCL: 5
REPORT:

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 SPEED KNOTS	DELIVERED POWER		RATE OF REVS.	
	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

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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, with- out 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 deter- mined at resistance tests

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Card No. 3 Particulars of full scale

Card column	Format	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 thickness of propeller at x=0.75
49-56	F	RNCHM	Reynolds number at open-water test based on chord length and local velocity $V = V_s \sqrt{1 + \left(\frac{\pi \cdot 0.75}{J}\right)^2}$ at x=0.75.

Card No. 4 General

Card column	Format	CC Symbol	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 propeller: $Q_M:100$
33-40	F	NM	Rate of revolution
41-48	F	FD	Skin friction correction 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.

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4. VALIDATION

4.1 Uncertainty Analysis not yet available

4.2 Comparison With Full Scale Results

The data that led to the 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)


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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), MODEL(2), LPP,LWL,TF,TA,B,S,
* SCALE,RNCHM,DISW,NOPROP,NPB,DP,PD075,CH075.
* TM075,C3,SBK,AT,CP,CN,DELFCF,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'/)

```

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```

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,MODEL P,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,DELFCF,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


```

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```

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

```

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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


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```

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

20      MODEL P1(I)=MODEL P(I)
          SCALE1=SCALE
          GOTO 1000
C
100    CONTINUE
          DO 110 I=1,2
          FILE(I)=FILE1(I)
          MODELS(I)=MODLS1(I)
          MODEL P(I)=MODLP1(I)
          SCALE=SCALE1
C
          CALL ANLSYS
C
C   RETURN FOR NEW INPUT
C
C
          GOTO 1000
999   STOP
      END
C

```

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C
C

C
C
C
C
C
C
C
C
C

OUTPUT IS USED FOR PRINTING INPUT DATA AND RESULTS

IOUT= 1 INPUT DATA IS PRINTED
 2 RESULT PAGE 1
 3 RESULT PAGE 2

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`,`ALYS`,`IS ` /
```

600 FORMAT('1',19X,'1978 ITTC PERFORMANCE PREDICTION',10X,

* 'ENCL:')

C??

* 20X,'METHOD ' ,8X,

* 'REPORT:'/20X,4A4/)



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```

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')

```

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```

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,MODEL,TF,SCALE,TA,B,S,DISW
```

```
WRITE(6,602) NOPROP,NPB,DP,PD075,C3
```

C

```
GOTO(10,20,30,40) , IOUT
```

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C
C
C

INPUT DATA IS LISTED

```

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
C


RESULTS PAGE 1

```

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

```

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```

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

```

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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

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C
C
C
C
C
C
C

ITTC PREDICTIONS

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

C

C

CALCULATE THE FULL SCALE LOAD ADVANCE COEFF: AND
TORQUE COEFF.

```
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

C

THE RATE OF REV. AND THE DELIVERED POWER


```
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
```

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```

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

```

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```

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 ACCORDING 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(10),
*          KQJ3(10)
C
COMMON /A/ FILE(2),MODELS(2),MODEL(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

```

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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)

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


C
C CALCULATION OF FRICTIONAL RESISTANCE ~COEFF. OF SHIP
C

T = TEMS
 $FNU = ((0.659E-3 * (T - 1.0) - 0.05076) * (T - 1) + 1.7688) * 1.0E-6$
 $RNLS = ALOG10(LWL * VST1 / FNU)$
 $CFS = 0.075 / (RNLS - 2.0) ** 2$

C
 $DCFM(I) = CTS - (1.0 + C3) * CFS - (CRWT(I) + 0.001 * AT / S) * S / (S + SBK)$
 $DCFM(I) = DCFM(I) * 1000.0$
 $CRWT(I) = CRWT(I) * 1000.0$

50 CONTINUE

C
CALL OUTPUT(4)
WRITE(6,600)

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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

```