The 3rd ASEF

Dec. 2009

The Development of Ship Speed Verification Program Based on ISO 15016 Methodology for EEDI

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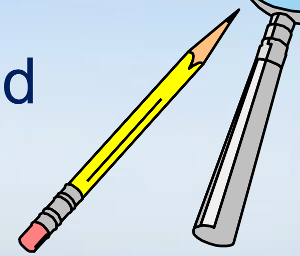
Verification of the Attained EEDI

- To verify reference speed of EEDI

$$\text{Attained EEDI} = \frac{P \cdot C_F \cdot SFC}{f_i \cdot \text{Capacity} \cdot V_{ref} \cdot f_w}$$



"Attained EEDI must be verified in a transparent, consistent and fair manner"

V_{ref} should be measured at sea trial condition and be analyzed to the standard condition.
If sea trial cannot be conducted in max. load condition, the ship speed should be adjusted by an appropriate correction method.

Speed Trial Analysis Conditions

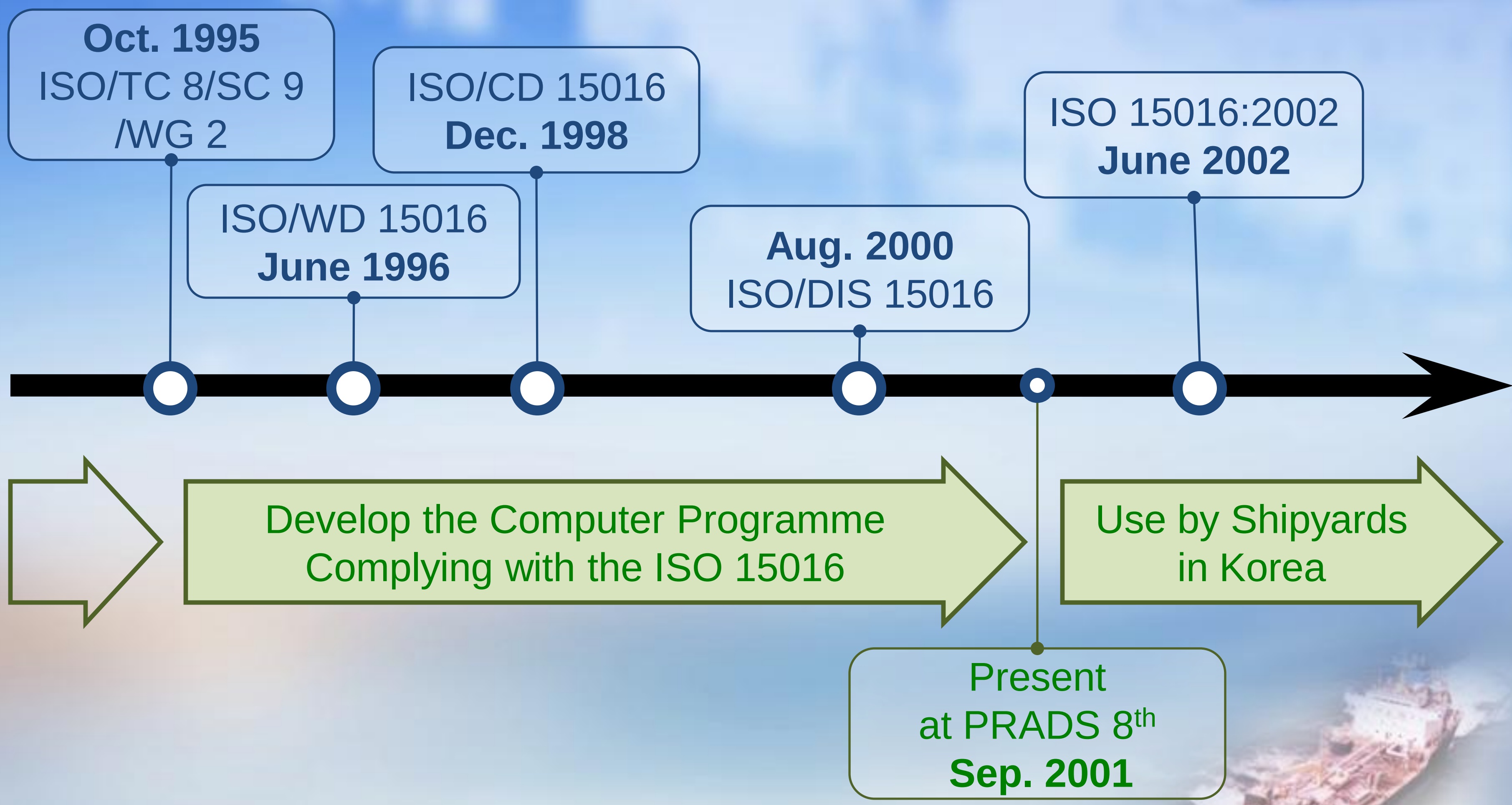
For the calm water and standard condition

ISO 15016:2002 Standard

"ISO international standard exists
that may be a starting point
for the development of
an EEDI verification procedure"

ISO 15016:2002
Guidelines for the assessment
of speed and power performance
by analysis of speed trial data

ISO 15016 & it's Computer Programme



Kim, Eun-Chan et al., Evaluation and Computer Program on the Speed Trial Analysis Method of the Ongoing Work in ISO/TC8, Proceedings of the Eighth International Symposium on Practical Design of Ships and Other Floating Structures, Shanghai, 2001

Objectives of Speed Trial & Analysis

- To obtain powering performance data
- To obtain ship-model correlation allowance
- To determine the relationship between ship speeds and propeller revolutions

☞ Ship Model Basin

- To fulfill contractual obligation at shipbuilding

☞ Shipyard & Shipowner

- To verify reference speed of EEDI

☞ IMO & Verifier

ISO 15016:2002
Guidelines for the assessment of speed and power performance by analysis of speed trial data

Contents of ISO 15016 Standard

1. Scope
2. Terms and definitions
3. Symbols and abbreviations
4. Trial conditions
5. Speed and power measurement
6. Analysis procedures

    Step 1: evaluation of acquired trial data.

    Step 2: correction of ship's performance for resistance increase.

    Step 3: correction of ship's performance for current.

    Step 4: correction of ship's performance for air resistance.

    Step 5: correction of ship's performance for shallow water.

    Step 6: final ship's performance.

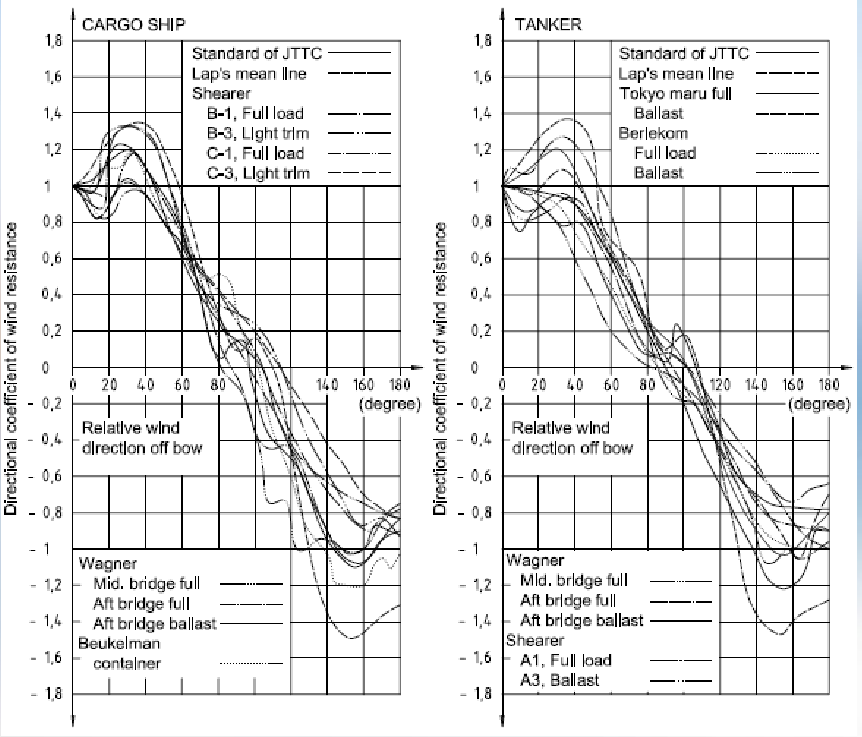
Analysis Methods of ISO 15016

Speed Trial Analysis	ISO 15016 Method
Speed loss from added resistance	Taniguchi-Tamura
Added resistance due to wind	Wind Test Results
	JTTC Chart
Resistance Increase due to waves	Maruo
Diffraction of incident waves in short waves	Faltinsen
	Kwon
	Fujii-Takahashi
Effect of steering for course keeping	SR208
Effect of drifting	SR208
Effect of water temperature and salt content	Simple Formula
Effect of displacement	Simple Formula
Effect of shallow water	Lackenby
Effect of hull roughness	-
Effect of propeller roughness	-

Resistance Increase due to Wind

- Model Test Results in Wind Tunnel, JTTC

$$R_{AA} = \frac{1}{2} \rho_A C_{AA} (\psi_{WR}) A_{XV} V_{WR}^{2}$$



(ISO 15016 Annex A Resistance increase due to wind)
In cases where data are available covering ships of similar type, such data may be used instead of carrying out model tests.

Resistance Increase due to Ship Motion

- Maruo's Method

$$\Delta r = \frac{\rho}{4\pi}\left[-\int_{-\infty}^{m_1} + \int_{m_2}^{m_3} + \int_{m_4}^{\infty}\right]\frac{k_u(m)(m - k\cos\chi)}{\sqrt{k_u^2(m) - m^2}}\left(\left|C(m)\right|^2 + \left|S(m)\right|^2\right)dm \ (N/m^2)$$

$$\left.\begin{matrix} m_1 \\ m_2 \end{matrix}\right\} = -\frac{k_0}{2}\left(1 + 2\tau \pm \sqrt{1 + 4\tau}\right)$$

$$\left.\begin{matrix} m_3 \\ m_4 \end{matrix}\right\} = \frac{k_0}{2}\left(1 - 2\tau \mp \sqrt{1 - 4\tau}\right)$$

$$k_u(m) = \frac{(m + k_0\tau)^2}{k_0}$$

$$\tau = \frac{V_S\omega_e}{g}$$

It can be ignore
in case of moderate sea conditions
because ship motion appears
at rough sea conditions.

Resistance Increase due to Wave Diffraction

- Fujii-Takahashi's Method or

$$\Delta r = \frac{1}{2}\rho g a_1 \varsigma_A^{\,2} (1+a_2)\left[\int_I \sin^2(\chi-\theta)\sin\theta\, dl + \int_{II} \sin^2(\chi+\theta)\sin\theta\, dl\right]$$

- Faltinsen's Method or

$$\Delta r = \frac{1}{2}\rho g a_1 \varsigma_A^{\,2}\left[\int_I \left[\sin^2(\chi-\theta) - \frac{2\omega V_S}{g}\{\cos\chi - \cos\theta\cos(\chi-\theta)\}\right]\sin\theta\, dl \right.$$

$$\left. + \int_{II}\left[\sin^2(\chi+\theta) - \frac{2\omega V_S}{g}\{\cos\chi - \cos\theta\cos(\chi+\theta)\}\right]\sin\theta\, dl\right]$$

- Kwon's Method

$$\Delta r = a^1 \cdot a^2 \cdot a^3 \cdot \frac{1}{2}\rho g \varsigma_A^{\,2} \int_{S_r}\left(\frac{\partial_y}{\partial_s}\right)^3 ds$$

Resistance Increase due to Irregular Waves

$$R_{AW}(\chi) = 2\int_{-\pi}^{\pi} G(\alpha - \chi)\left[\int_0^{\infty} S(f)\frac{\Delta r(f,\alpha)}{\zeta_A^2}df\right]d\alpha$$

for the frequency distribution of incident waves

- ITTC Standard Spectrum for Sea Wave

$$S(f) = \frac{0.11 H_{1/3}^2 T_{01}}{(T_{01} f)^5}\exp\left\{-\frac{0.44}{(T_{01} f)^4}\right\} \quad (m^2 \cdot s)$$

- JONSWAP Spectrum for Swell

$$S(f) = \frac{0.072 H_{1/3}^2 T_{01}}{(T_{01} f)^5}\exp\left\{-\frac{0.44}{(T_{01} f)^4}\right\} \times 3.3^{\exp\left\{-0.5(1.3T_{01}f-1)^2/\sigma^2\right\}} \quad (m^2 \cdot s)$$

Effect of Steering and Drifting

Effect of Steering for Course Keeping

- SR208 Report

$$R_{\delta\delta} = \frac{1}{2} \rho_A \, (1 - t_R) \; f_a(\lambda_R) \; A_R \, V_{eff}^{\;2} \, \delta_R^{\;2}$$

Effect of Drifting

- SR208 Report

$$R_{\beta\beta} = \frac{1}{4} \pi \, \rho \, d^2 \; V_S^{\;2} \, \beta^2$$

Effect of Water Temperature & Density

- Fundamental Method

$$R_{AS} = R_{TS}\left(1 - \frac{\rho_0}{\rho}\right) + \frac{1}{2}\rho\, S\, V^2 (C_F - C_{F0})$$

Effect of Displacement Deviation

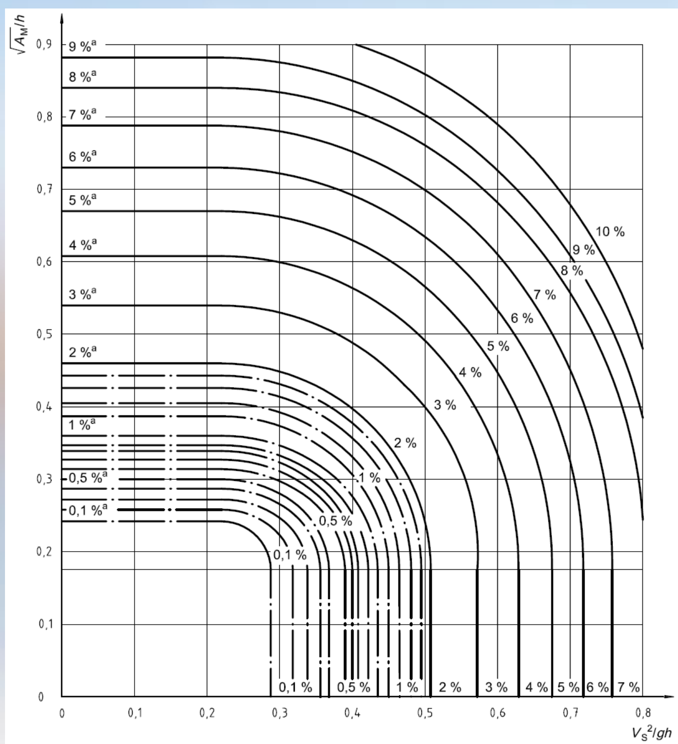
- Fundamental Method

$$R_{ADIS} = 0.65\ R_T \left(1 - \frac{\Delta_O}{\Delta} \right)$$

Effect of Shallow Water

- Lackenby's Method

$$\frac{\Delta V_S}{V_S} = 0.1242\left(\frac{A_M}{h^2} - 0.05\right) + 1.0 - \left(\tanh\left(\frac{1}{F_n^{\,2}}\right)\right)^{0.5}$$



Speed Loss from Resistance Increase

- Taniguchi & Tamura's Method

$$\Delta R = R_{AA} + R_{AW} + R_{\delta\delta} + R_{\beta\beta} + R_{AS} + R_{ADIS}$$

$$\tau = \frac{K_T}{J^2}$$

$$\Delta\tau = \frac{\Delta R}{R} \cdot \tau$$

$$\tau_1 = \tau - \Delta\tau$$

$$\tau_1(\tau : J) \Rightarrow J$$

$$\tau_1(\tau : K_Q) \Rightarrow K_{Q1}$$

$$n_1 = n \cdot \frac{J}{J_1}$$

$$n(n_1 : K_{Q1}) \Rightarrow K_Q^{'}$$

$$\Delta V_G = \frac{a \cdot D \cdot n \cdot (K_Q^{'} - K_Q)}{(1-w)_m}$$

Comprehensive Computer Programme ST10 Complying with the ISO 15016 Speed Trial Analysis Guidelines

Computer Programme ST10

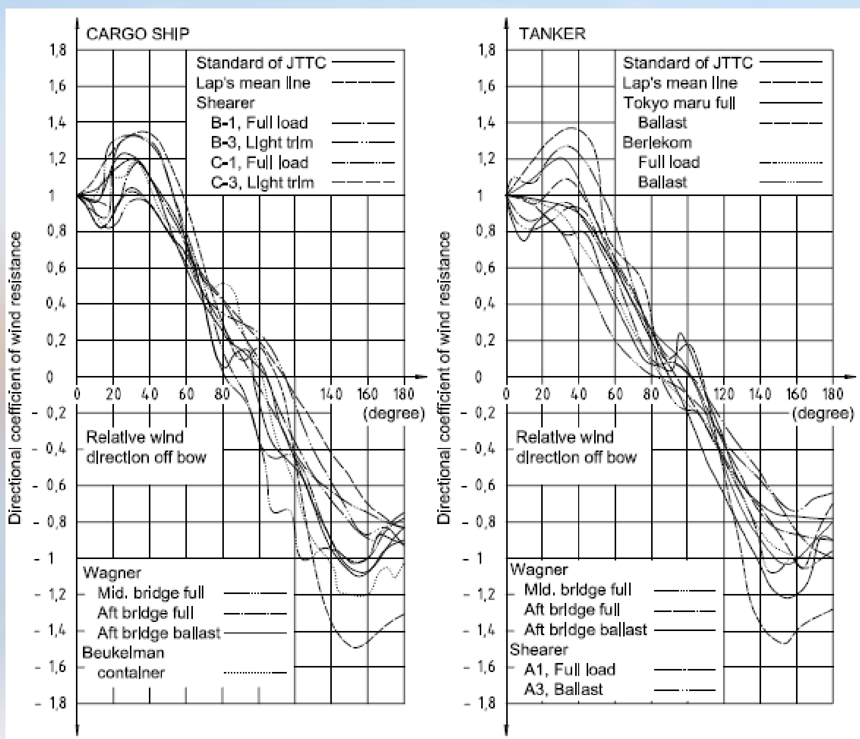
Speed Trial Analysis	Speed Trial Analysis Programme ST10	
	ISO 15016 Method	Supplemented Method
Speed loss from added resistance	Taniguchi-Tamura	
Added resistance due to wind	Wind Test Results	
	JTTC Chart	Blendermann Chart Isherwood Chart
Resistance Increase due to waves	Maruo	
Diffraction of incident waves in short waves	Faltinsen	
	Kwon	
	Fujii-Takahashi	
Effect of steering for course keeping	SR208	
Effect of drifting	SR208	
Effect of water temperature and salt content	Simple Formula	
Effect of displacement	Simple Formula	
Effect of shallow water	Lackenby	
Effect of hull roughness	-	ITTC '78
Effect of propeller roughness	-	ITTC '78

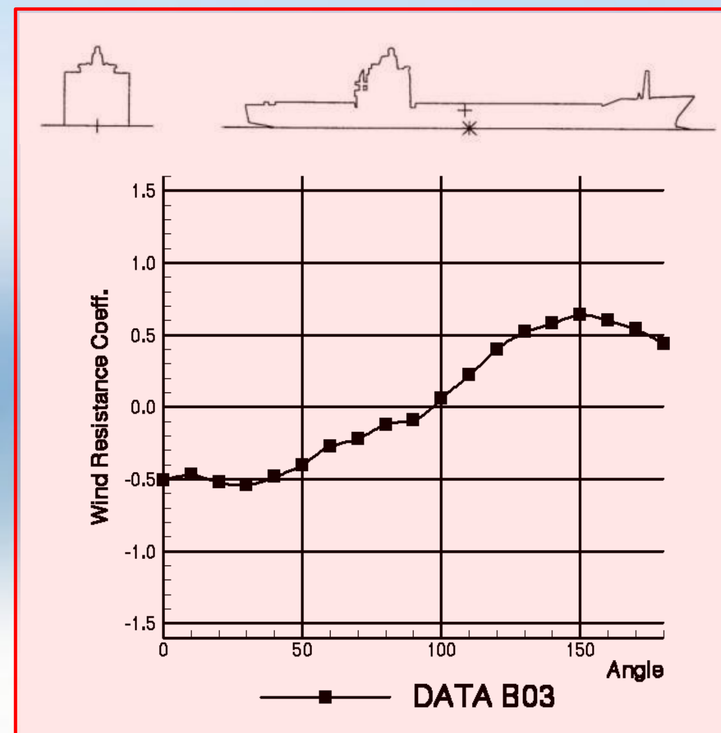
Resistance Increase due to Wind

- Model Test, JTTC, Blenderman or Isherwood

(Supplemented methods)

$$R_{AA} = \frac{1}{2}\rho_A C_{AA}(\psi_{WR}) A_{XV} V_{WR}^{2}$$





Effect of Hull Surface Roughness

(ISO 15016 E.2 Hull and propeller surface roughness)

The effect of surface roughness can no longer be neglected, some methods may be available for correcting such effects.

- ITTC-78 = Bowden's Formula
  (Supplemented methods)

$$R_{hull} = \frac{1}{2} \rho S V^2 \frac{105}{L^3} \left(k_{Sreal}^{1/3} - k_{Sstandard}^{1/3} \right) \cdot 10^{-3}$$

Effect of Propeller Surface Roughness

(ISO 15016 E.2 Hull and propeller surface roughness)

The effect of surface roughness can no longer be neglected, some methods may be available for correcting such effects.

- ITTC-78 = Schlichting's Formula
  (Supplemented methods)

$$K_{TSR} = K_{OTS} + \Delta C_D \, 0.3 \, \frac{P}{D} \frac{c}{D} Z$$

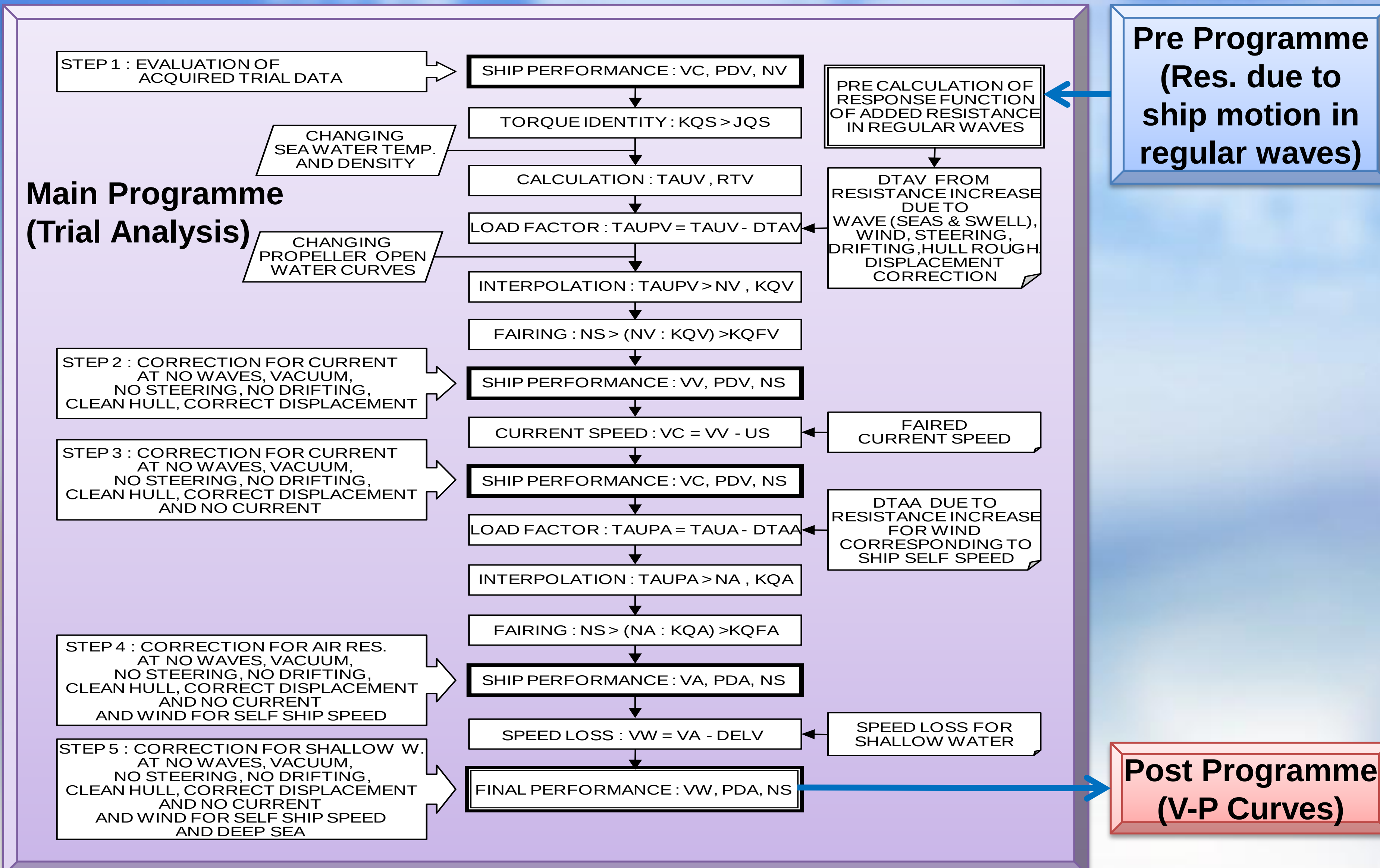
$$K_{QSR} = K_{OQS} - \Delta C_D \, 0.25 \, \frac{c}{D} Z$$

$$where \quad \Delta C_D = 2\left(1 + 2\frac{t}{c}\right)\left[\left(1.89 + 1.62 \log \frac{c}{k_{P0}}\right)^{-2.5} - \left(1.89 + 1.62 \log \frac{c}{k_P}\right)^{-2.5}\right]$$

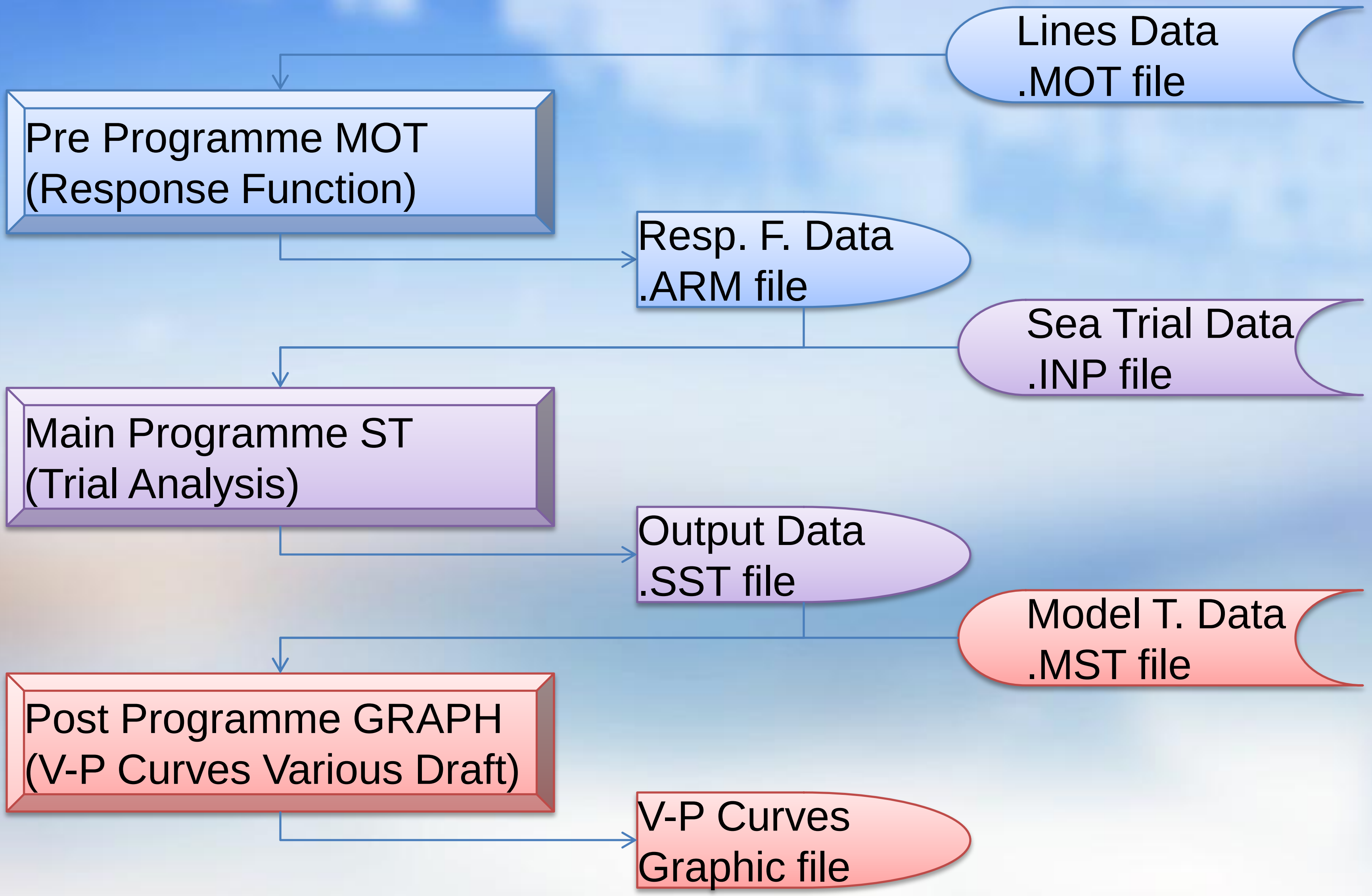
Interpolation Methods

Calculation	Interpolation Mathod
V : t, w, η_R	2nd Degree Polynomial
J : K_Q	2nd Degree Polynomial
J : TAU(=K_T/J^2)	2nd Rational Function
N : K_Q	Least Square
Time : Current	Cubic Spline
V : P_D, N	Least square or Cubic Spline

Flowchart of the Programme ST10



Construction of Programme ST10



Input of Main Programme

Input Data - [C:₩Program Files₩Speed Trial Analysis ST10 (EEDI)₩Input₩3600b1.inp]

INPUT DATA

Step 1 | Step 2 | Step 3 | Step 4 | Step 5

SPEED TRIAL RESULT

No. of Trial : 08 Apply

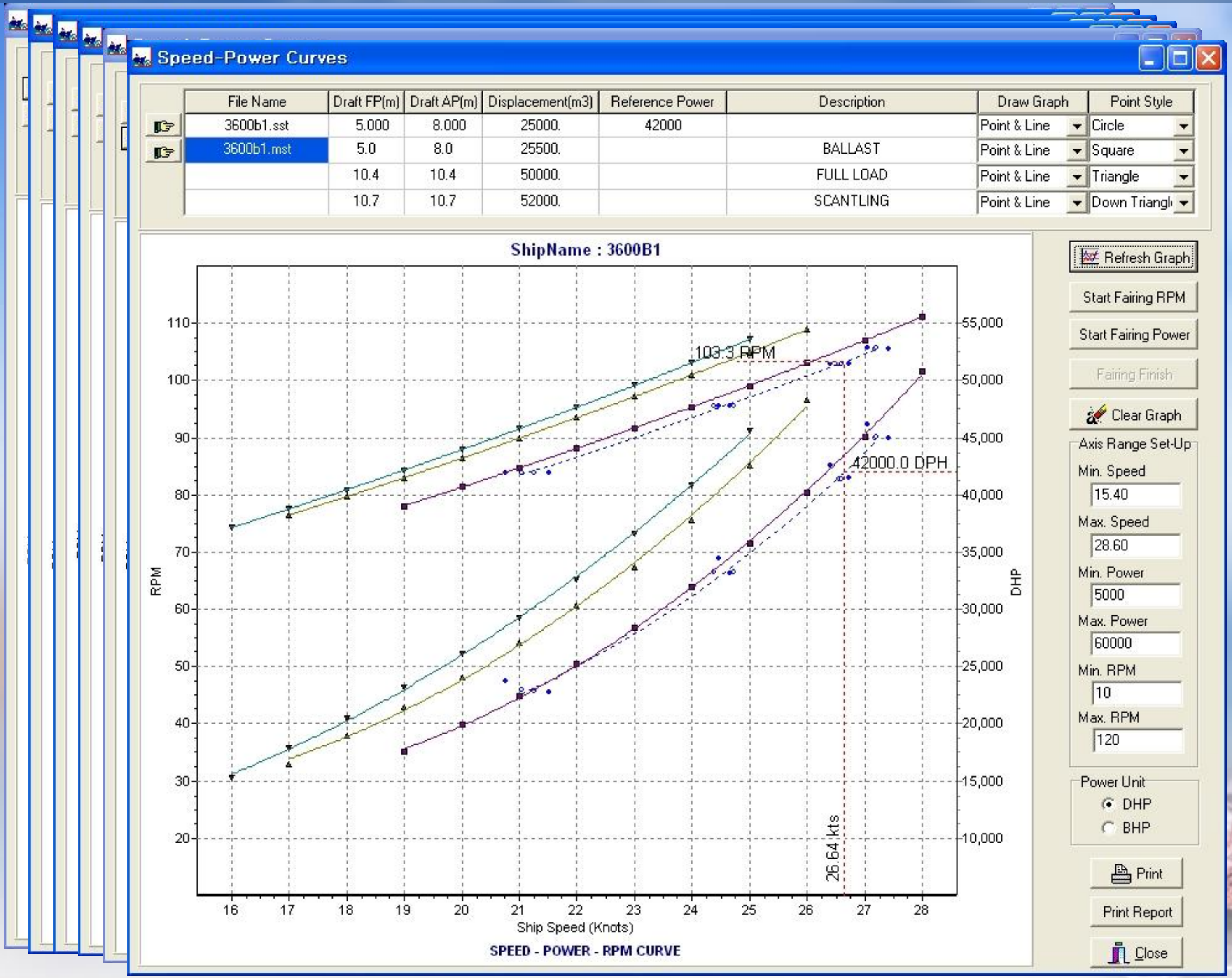
DISCRIPTION	VALUE							
RUN NUMBER	1	2	3	4	5	6	7	8
BEAUTFORT NUMBER	0.	0.	0.	0.	0.	0.	0.	0.
INNING TIME (HOUR)	9.	10.	11.	12.	13.	14.	16.	17.
LOAD CONDITION	0.25	0.25	0.50	0.50	0.75	0.75	0.90	0.90
WIND DIRECTION(P/S)	S	P	S	P	P	P	P	P
WIND ANGLE(DEG)	10.	145.	10.	135.	5.	150.	135.	5.
WIND VELOCITY(M/S)	13.50	4.00	15.00	2.80	16.00	0.70	0.40	16.50
RUNNING DIRECTION	20.0	200.0	20.0	200.0	20.0	200.0	200.0	20.0
SHIP SPEED	20.77	21.51	24.46	24.66	26.41	26.73	27.41	27.06
PROPELLER REV.(RPM)	83.90	83.80	95.60	95.60	102.80	102.80	105.60	105.70
SAFT POWER(PS)	23767.0	22725.0	34435.0	33150.0	42532.0	41518.0	44928.0	46160.0
CURRENT SPEED(KNOT)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Save As | Reset | Calculation

Run of Main Programme : .ARM+.INP→.SST

DESCRIPTION	VALUE							
RUN NUMBER	1	2	3	4	5	6	7	8
S. SPEED, FINAL (KNOT)	21.039	21.247	24.724	24.376	26.608	26.551	27.175	27.210
DHP, FINAL (PS)	22926.	22849.	33311.	33311.	41368.	41368.	44911.	45043.
PROP. REV. FINAL (RPM)	83.90	83.80	95.60	95.60	102.80	102.80	105.60	105.70

Run of Post Programme : .SST+.MST→Graph



Trial Performance of the ST10

Pre Programme MOT
(Response Function)

Main Programme ST
(Trial Analysis)

Post Programme GRAPH
(V-P Curves Various Draft)

Output of Main Programme .SST

Lines Data .MOT file → Pre Programme MOT (Response Function) → Resp. F. Data .ARM file

Sea Trial Data .INP file → Main Programme ST (Trial Analysis) → Output Data .SST file

Model T. Data .MST file → Post Programme GRAPH (V-P Curves Various Draft) → V-P Curves Graphic file

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==================================================
SPEED TRIAL ANALYSIS PROGRAM ST10E62 : INPUT DATA
==================================================
                         PROGRAMED BY KRISO ACCORDING TO ISO15016

FILE NAME : 3600b1.inp    3600b1.arm          TRIAL DATE    : 25-JUL-01
SHIP NAME : K3600       PROP.NAME : K3600     WEATHER       : CLOUDY
* LPP     = 230.000 M   * NO.PROP.=      1    COURSE        : DUMMY
* BREADTH =  32.200 M   * NO.BLADE=      6    * SEA DEPTH   :   100.0    M
* DEPTH   =  19.000 M   * DIAMETER=   7.850 M * ROUGH.HULL = 0.000180    M
DRAFT                   * PRO70    =  1.0000              STD.= 0.000150    M
*      MEAN=   6.500 M  * EAR      =  0.8000  * ROUGH.PROP.= 0.000036    M
*        FP=   5.000 M  * CHR      =  0.2500              STD.= 0.000030    M
*        AP=   8.000 M                        * CLEAN.HULL =      2.5 MONTH
*       MID=   6.400 M  RUDDER                * CLEAN.PROP.=      0.2 MONTH
* LWL     = 235.000 M   * AREA     =  100.00 M2 * AIR TEMP.  =   20.00    DEG
* S       =  7000.0 M2  * HEIGHT   =   9.000 M  *    DENSIYT=    1.225 KG/M3
* SBK     =   100.0 M2  * AREA R.  =  0.0200    * WATER TEMP.=   21.00 DEG:S
* AT      =  1100.0 M2                          *       DENS.= 1024.00 KG/M3
* AL      =  4000.0 M2  ENGINE      : K3600     *     K.VIS.= 1.0172 E6M2/S
* CM      =  0.9800 M3  * MCR BHP  =  50000. PS * W.STD.TEMP.=   15.00 DEG:S
* DISV    =  25000. M3  * MCR REV.=  100.00RPM  *       DENS.= 1024.00 KG/M3
      STD.=  25500. M3  * ETAT     =  0.9850    *     K.VIS.= 1.1873 E6M2/S

MODEL TEST RESULTS
-----------------------------------------------------------------------------
PREDICT METHOD: 2-D, KRISO-2D  SCALE= 30.0000              DELCF = -0.000100
-----------------------------------------------------------------------------
* VS(KNOT): 16.00 18.00 20.00 22.00 24.00 26.00 28.00 30.00
-----------------------------------------------------------------------------
* CRM*1000: 0.800 0.900 1.000 1.100 1.200 1.300 1.400 1.500
* TM      : 0.150 0.150 0.150 0.150 0.150 0.150 0.150 0.150
* WM      : 0.300 0.300 0.300 0.300 0.300 0.300 0.300 0.300
* WS      : 0.250 0.250 0.250 0.250 0.250 0.250 0.250 0.250
* ETARM   : 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000

PROPELLER OPEN-WATER CHARACTERISTICS AT FULL SCALE
-----------------------------------------------------------------------------
 *
J        :0.40000.45000.50000.55000.60000.65000.70000.75000.80000.85000.90000.9500
-----------------------------------------------------------------------------
 *
KTS      :0.34500.32500.29900.27700.24300.22100.19000.16800.14600.12400.09900.0720
 *
KQS*10   :0.54900.51500.48100.44000.40800.37100.33400.29600.25600.21700.18200.1460
 *
KTR      :0.34490.32490.29890.27690.24290.22090.18990.16790.14590.12390.09890.0719
 *
KQR*10   :0.54990.51590.48190.44090.40890.37190.33490.29690.25690.21790.18290.1469

WATERLINE OFFSETS : X(METER:FP=0)/Y(METER:B/2)
-----------------------------------------------------------------------------
  -5.00  -2.50   0.00   5.80  11.50  17.30  23.00  34.50  46.00  57.50  69.00
  80.50  92.00 103.50 120.80 138.00 149.50 161.00 172.50 184.00 195.50 207.00
 212.80 218.50 224.30 230.00
   0.00   2.27   2.30   2.40   2.61   3.06   3.81   6.30   9.22  11.90  14.02
  15.34  16.02  16.10  16.10  16.10  16.10  16.08  15.72  14.63  11.52   6.21
   3.18   0.75   0.52   0.00

WIND RESISTANCE C.: WIND DIRECTION(DEG.:BOW=0)/COEFFICIENT(CAA0*K)
-----------------------------------------------------------------------------
   0.00  10.00  20.00  30.00  40.00  50.00  60.00  70.00  80.00  90.00 100.00
 110.00 120.00 130.00 140.00 150.00 160.00 170.00 180.00
   0.69   0.71   0.77   0.83   0.76   0.59   0.42   0.28   0.17   0.10   0.04
  -0.08  -0.30  -0.49  -0.63  -0.71  -0.72  -0.66  -0.57
-----------------------------------------------------------------------------

SPEED TRIAL RESULTS
-----------------------------------------------------------------------------
RUN NUMBER             :     1       2       3       4       5       6       7       8
-----------------------------------------------------------------------------
BEAUTFORT NUMBER       :    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
INNING TIME      (HOUR):    9.0    10.0    11.0    12.0    13.0    14.0    16.0    17.0
LOAD CONDITION         :   0.25    0.25    0.50    0.50    0.75    0.75    0.90    0.90
WIND DIRECTION    (DEG): S 10.0 P145.0 S 10.0 P135.0 P   5.0 P150.0 P135.0 P   5.0
WIND VELOCITY     (M/S): 13.500  4.000 15.000  2.800 16.000  0.700  0.400 16.500
RUNNING DIRECTION      : 20.0   200.0    20.0   200.0    20.0   200.0   200.0    20.0
SHIP SPEED       (KNOT): 20.770 21.510 24.460 24.660 26.410 26.730 27.410 27.060
PROPELLER REV.    (RPM):  83.90  83.80  95.60  95.60 102.80 102.80 105.60 105.70
SHAFT POWER        (PS): 23767. 22725. 34435. 33150. 42532. 41518. 44928. 46160.
CURRENT SPEED    (KNOT):  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
WAVE  PERIOD      (SEC):   3.90   3.90   3.90   3.90   3.90   3.90   2.80   2.80
WAVE  HEIGHT        (M):   1.00   1.00   1.00   1.00   1.00   1.00   0.50   0.50
WAVE  INCD.ANG.   (DEG):  170.0  350.0  170.0  350.0  170.0  350.0  350.0  170.0
SWELL PERIOD      (SEC):  10.59  10.59  10.59  10.59  11.32  11.32  11.32  11.32
SWELL HEIGHT        (M):   2.00   2.00   2.00   2.00   2.50   2.50   2.50   2.50
SWELL INCD.ANG.   (DEG):   40.0  220.0   40.0  220.0   40.0  220.0  220.0   40.0
RUDDER ANGLE      (DEG):    1.0    1.0    1.0    1.0    1.0    1.0    1.0    1.0
DRIFT  ANGLE      (DEG):    0.2    0.2    0.2    0.2    0.2    0.2    0.2    0.2
CORRECTION METHOD OF ADDED RESISTANCE :
-----------------------------------------------------------------------------
* SEA WAVE AND SWELL       2 : SEA WAVE AND SWELL
* EFFECT OF SHIP MOTION    1 : MARUO METHOD
* EFFECT OF WAVE DIFFRACT. 1 : FALTINSEN METHOD
* EFFECT OF STEERING       1 : SR208 METHOD
* EFFECT OF DRIFTING       1 : SR208 METHOD
* EFFECT OF HULL ROUGHNESS 1 : ITTC METHOD
* EFFECT OF PROP.ROUGHNESS 1 : ITTC METHOD
* EFFECT OF SHALLOW WATER  1 : LACKENBY METHOD
* EFFECT OF DISPLACEMENT   1 : FACTOR 0.65 METHOD
* EFFECT OF TEMP.& DENSITY 1 : ITTC METHOD
* EFFECT OF CURRENT        1 : INPUT SPEED
* WIND RESISTANCE COEFF. J01 : STANDARD OF JTTC
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-----------------------------------------------------------------------------
 ADDED RESISTANCE CORRECTION BY SPEED TRIAL ANALYSIS PROGRAM ST10E62
-----------------------------------------------------------------------------
                         PROGRAMED BY KRISO ACCORDING TO ISO/DIS15016

FILE NAME : 3600b1.inp      3600b1.arm         TRIAL DATE    : 25-JUL-01
SHIP NAME : K3600       PROP.NAME : K3600      WEATHER       : CLOUDY
-----------------------------------------------------------------------------
RUN NUMBER           :     1      2      3      4      5      6      7      8
-----------------------------------------------------------------------------

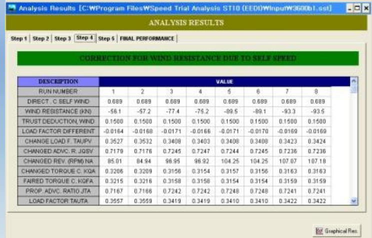
STEP I : EVALUATION OF ACQUIRED DATA
-----------------------------------------------------------------------------
SHIP SPEED      (KNOT): 20.770 21.510 24.460 24.660 26.410 26.730 27.410 27.060
DELIVERED POWER  (PS) : 23410. 22384. 33918. 32653. 41894. 40895. 44254. 45468.
PROPELLER REV.   (RPM):  83.90  83.80  95.60  95.60 102.80 102.80 105.60 105.70
TORQUE COEFFICIENT    : 0.3283 0.3151 0.3216 0.3096 0.3194 0.3118 0.3113 0.3189
PROP.ADVANCE RATIO    : 0.7088 0.7264 0.7178 0.7336 0.7207 0.7307 0.7314 0.7213
WAKE FRACTION         : 0.2717 0.2802 0.2864 0.2766 0.2865 0.2853 0.2833 0.2833
THRUST DEDUCTION      : 0.1500 0.1500 0.1500 0.1500 0.1500 0.1500 0.1500 0.1500
LOAD FACTOR           : 0.3702 0.3378 0.3533 0.3253 0.3481 0.3304 0.3292 0.3469
SHIP RESISTANCE  (KN) : 1202.1 1149.4 1527.5 1469.2 1754.1 1711.4 1802.8 1851.5

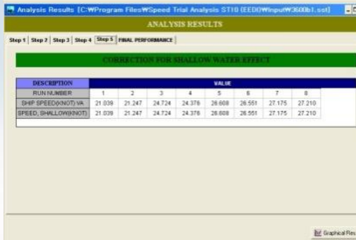
STEP II : CORRECTION FOR VARIOUS RESISTANCE INCREASE
-----------------------------------------------------------------------------
MOTION,SEA WAVE   (KN):    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
MOTION,SWELL      (KN):    0.5   22.7    0.2   24.7    0.2   32.4   32.9    0.1
DIFFRACT.SEA WAVE(KN) :   12.6    0.0   14.2    0.0   15.1    0.0    0.0    5.1
DIFFRACTION,SWELL(KN) :    0.0    4.2    0.0    4.5    0.0    5.3    5.4    0.0
DIRECT.C. FOR WIND    :  0.710 -0.676  0.710 -0.565  0.693 -0.710 -0.565  0.693
WIND EFFECT       (KN):   87.2   -7.3  107.7   -3.0  119.6   -0.2   -0.1  127.2
STEERING EFFECT   (KN):    3.2    3.3    4.3    4.3    5.0    5.1    5.3    5.3
DRIFTING EFFECT   (KN):    0.0    0.1    0.1    0.1    0.1    0.1    0.1    0.1
HULL ROUGHNESS    (KN):   23.3   24.9   32.3   32.8   37.6   38.5   40.5   39.5
DISPLACEMENT      (KN):  -15.6  -14.9  -19.9  -19.1  -22.8  -22.2  -23.4  -24.1
TEMP.DENS.K-VISC.(KN) :  -10.3  -11.0  -13.9  -14.1  -16.0  -16.4  -17.2  -16.8
TOTAL RES.INCR.   (KN):  100.8   22.0  125.0   30.1  138.7   42.6   43.6  136.4
LOAD FACTOR DIFFERENT : 0.0311 0.0065 0.0289 0.0067 0.0275 0.0082 0.0080 0.0256
CHANGED LOAD F. TAUPV : 0.3392 0.3314 0.3244 0.3186 0.3206 0.3221 0.3212 0.3213
CHANGED ADVC.R.  JQSV : 0.7253 0.7297 0.7339 0.7373 0.7361 0.7352 0.7358 0.7357
CHANGED REV.(RPM)  NV :  82.00  83.42  93.51  95.12 100.64 102.17 104.97 103.64
CHANGED TORQUE C. KQV : 0.3160 0.3126 0.3094 0.3067 0.3076 0.3084 0.3080 0.3080
FAIRED TORQUE C. KQFV : 0.3134 0.3135 0.3078 0.3078 0.3078 0.3078 0.3086 0.3086
PROP.ADVC.RATIO   JTV : 0.7274 0.7273 0.7347 0.7347 0.7347 0.7347 0.7337 0.7337
LOAD FACTOR     TAUTV : 0.3363 0.3365 0.3237 0.3237 0.3237 0.3237 0.3254 0.3254
SHIP SPEED (KNOT)  VV : 21.362 21.574 25.093 24.740 26.984 26.926 27.548 27.583
DELIV.POWER  (PS) PDV : 22345. 22271. 32468. 32468. 40374. 40374. 43867. 43997.
PROPELLER REV.(RPM)NS :  83.90  83.80  95.60  95.60 102.80 102.80 105.60 105.70

STEP III : CORRECTION FOR CURRENT
-----------------------------------------------------------------------------
CURRENT S.SPEED(KNOT) : 21.362 21.574 25.093 24.740 26.984 26.926 27.548 27.583
CURRENT ADVC.RATIO    : 0.7274 0.7273 0.7347 0.7347 0.7347 0.7347 0.7337 0.7337
CURRENT WAKE FRACTION : 0.2734 0.2815 0.2881 0.2779 0.2881 0.2866 0.2846 0.2849

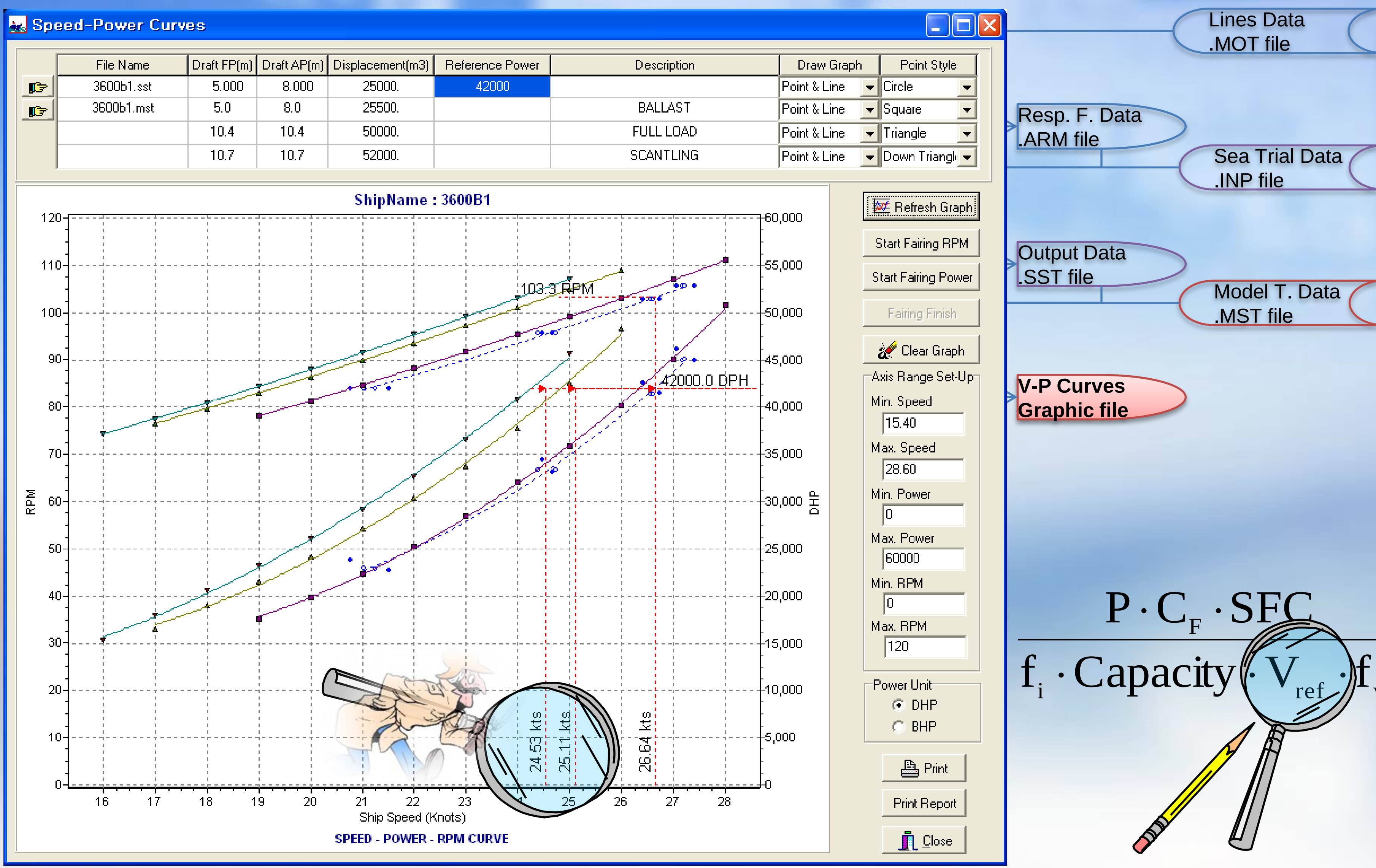
STEP IV : CORRECTION FOR WIND RESISTANCE DUE TO SELF SPEED
-----------------------------------------------------------------------------
DIRECT.C. SELF WIND   :  0.689  0.689  0.689  0.689  0.689  0.689  0.689  0.689
WIND RESISTANCE  (KN) :  -56.1  -57.2  -77.4  -75.2  -89.5  -89.1  -93.3  -93.5
THRUST DEDUCTION,WIND : 0.1500 0.1500 0.1500 0.1500 0.1500 0.1500 0.1500 0.1500
LOAD FACTOR DIFFERENT :-0.0164-0.0168-0.0171-0.0166-0.0171-0.0170-0.0169-0.0169
CHANGED LOAD F. TAUPA : 0.3527 0.3532 0.3408 0.3403 0.3408 0.3408 0.3423 0.3424
CHANGED ADVC.R.  JQSA : 0.7179 0.7176 0.7245 0.7247 0.7244 0.7245 0.7236 0.7236
CHANGED REV.(RPM)  NA :  85.01  84.94  96.95  96.92 104.25 104.25 107.07 107.18
CHANGED TORQUE C. KQA : 0.3206 0.3209 0.3156 0.3154 0.3157 0.3156 0.3163 0.3163
FAIRED TORQUE C. KQFA : 0.3215 0.3216 0.3158 0.3158 0.3154 0.3154 0.3159 0.3159
PROP.ADVC.RATIO   JTA : 0.7167 0.7166 0.7242 0.7242 0.7248 0.7248 0.7241 0.7241
LOAD FACTOR     TAUTA : 0.3557 0.3559 0.3419 0.3419 0.3410 0.3410 0.3422 0.3422
SHIP RES.    (KN) RTA : 1179.7 1177.2 1503.4 1503.4 1736.3 1736.3 1835.2 1838.8
SHIP SPEED (KNOT)  VA : 21.039 21.247 24.724 24.376 26.608 26.551 27.175 27.210
DELIV.POWER  (PS) PDA : 22926. 22849. 33311. 33311. 41368. 41368. 44911. 45043.
PROPELLER REV.(RPM)NS :  83.90  83.80  95.60  95.60 102.80 102.80 105.60 105.70

STEP  V : CORRECTION FOR SHALLOW WATER EFFECT
-----------------------------------------------------------------------------
SHIP S.,SHALLOW(KNOT) : 21.039 21.247 24.724 24.376 26.608 26.551 27.175 27.210
```





Output of Post Programme V-P Curves



$$\frac{P \cdot C_F \cdot SFC}{f_i \cdot Capacity \cdot V_{ref} \cdot f_w}$$

Evaluation of the Computer Programme

- to comply with the ISO 15016 procedure
- to contain all of the ISO 15016 methods
- to supplement few reliable methods
- to emphasize the graphic user interface and automatic calculation from input data
- to implement the evident reporting form
- to confirm the good agreement with the example of ISO 15016 standard values

Verification of the EEDI

- Verification process of reference speed (Vref) is a technical issue and one of the targets of the EEDI.

$$\text{Attained EEDI} = \frac{P \cdot C_F \cdot SFC}{f_i \cdot \text{Capacity} \cdot V_{ref} \cdot f_w}$$

- The ISO 15016 speed trial analysis guidelines which has already been developed by ISO is known to be a very sophisticated method that can consider various effects, such as wave, wind, steering, drifting, water temperature, salt content, shallow water and various vessel conditions.
- The computer programme complying with the ISO 15016 standard could be a solution for the consistent verification process of the reference speed from the sea trial condition of any draft condition to the standard condition of maximum design load condition.

December 2009 , The 3rd ASEF

The Development of Ship Speed Verification Program Based on ISO 15016 Methodology for EEDI

If you have any questions, please contact;
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Thank you very much