New standard for Speed Trial Analysis - ISO 15016:2015

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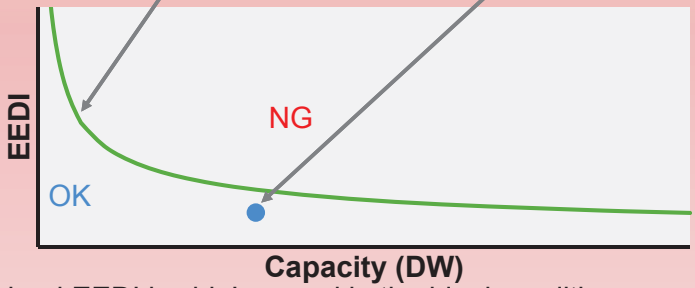
22 July 2015, International Workshop on Ship Technologies
Related to Energy Efficiency Design Index (EEDI), Tokyo

Brief review of EEDI regulation (EEDI value)

For all ships of 400 gross tonnage and above that engage in international voyages and whose building contract is placed on or after 1 January 2013, the attained EEDI shall be calculated and shall be as follows(**MARPOL ANNEX VI, Regulation 20 & 21**):

$(1-X/100)\times a\times \text{capacity}^{-c}$ (*) ≥ $\frac{CO_2 \text{ emission}}{\text{Speed} \times \text{Capacity}}$

Required EEDI ≥ **Attained EEDI**



Speed in the attained EEDI is ship's speed in the ideal condition assuming the weather is calm with no wind, no current and no waves and the site is at the deep water of standard temperature/density.

(*) : *X* is reduction factor depending on phase relative to the EEDI reference line, and *a* and *c* are parameters for determination of reference line.

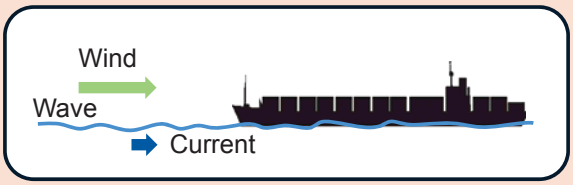
Brief review of EEDI regulation (Verification)

Design Stage

Pre-Verification ← Ship's speed predicted from model test results

Sea Trial Stage

Final Verification ← Ship's speed confirmed by speed trial at sea



In general, it can't be expected to conduct speed trial under no wind, no wave, no current condition at the site of standard water temperature/density.

⇩

"Speed trial analysis procedure" for evaluation and correction of speed trial data is required in order to eliminate the effect of environmental condition during sea trial.

Concept of ISO 15016:2015


INTERNATIONAL STANDARD

ISO 15016

Second edition
2015-04-01

Ships and marine technology — Guidelines for the assessment of speed and power performance by analysis of speed trial data

Navires et technologie maritime — Lignes directrices pour l'évaluation des performances de vitesse et de puissance par analyse des données d'essais de vitesse

Reference number
ISO 15016:2015(E)

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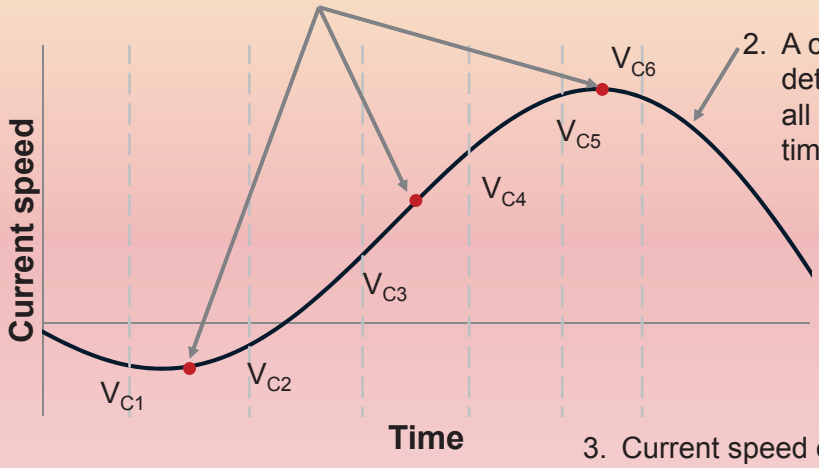
- "ISO 15016:2015" is the 2nd edition (revised edition of ISO 15016: 2002) of international standard for Speed Trial Analysis published on April 2015.
- This standard covers trial preparation, conduct and the analysis of speed trial data.
- This standard is more advanced, fair and transparent method than any other analysis method of speed trial.
- This standard has been developed with the full cooperation of ITTC and STA-group.
- This standard is expected to be revised three years later.

History from MEPC62 to 1st voting

- Norway requested to revise the ISO15016:2002 analysis method. (April 2011, IMO MEPC62).
- Japan and ITTC (International Towing Tank Conference) proposed to review the analysis method and specialist committee of ITTC started their study (December 2011).
- IMO MEPC65 (May 2013) assigned two international methods for Guidelines on survey and certificate of the EEDI,
  - *ITTC Recommended Procedure 7.5-04-01-01.2 (which is considered as preferable.)*
  - *ISO 15016:2002*
- It has been pointed out that there are some problems of both ITTC Recommended Procedure (e.g. containing black box, and inaccurate results) and ISO15016:2002 (e.g. too complicated, and ambiguous results).

Current correction in ISO15016:2002

1. Current speeds at mean times are calculated using ship's speed.



2. A current curve is determined manually using all current speeds at mean times

3. Current speed on the current curve at each time (V_{Ci}) which is to be used for current correction are calculated.

The process in which current curve is fitted manually involves arbitrariness and ambiguity.

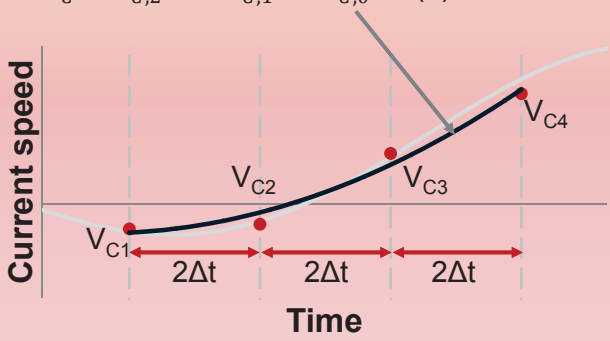
Mean of means method by STA

Current effect is automatically eliminated with the following formula for each power setting as mentioned below:

$$\frac{V_{G1} + 3V_{G2} + 3V_{G3} + V_{G4}}{8} = V_S \qquad (1)$$

1. In this method, current speed is assumed to vary parabolically over time within comparatively short time , e.g. time taken for measurement during one power setting.

$$V_C = V_{C,2}t^2 - V_{C,1}t + V_{C,0} \qquad (2)$$



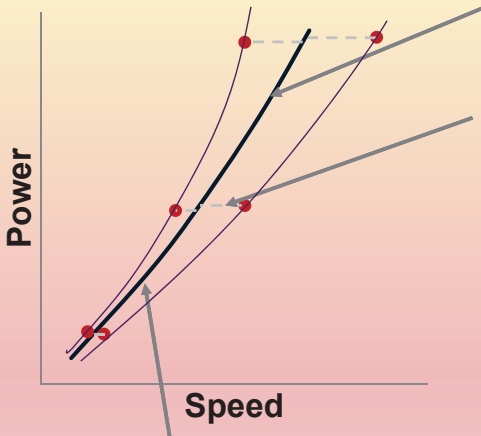
2. ship's speeds over ground at one power setting are expressed as follows using formula (2):

$$V_{G1} = V_S + \{V_{C,2}(t + 3\Delta t)^2 - V_{C,1}(t + 3\Delta t) + V_{C,0}\}$$
$$V_{G2} = V_S - \{V_{C,2}(t + \Delta t)^2 - V_{C,1}(t + \Delta t) + V_{C,0}\}$$
$$V_{G3} = V_S + \{V_{C,2}(t - \Delta t)^2 - V_{C,1}(t - \Delta t) + V_{C,0}\}$$
$$V_{G4} = V_S - \{V_{C,2}(t - 3\Delta t)^2 - V_{C,1}(t - 3\Delta t) + V_{C,0}\}$$

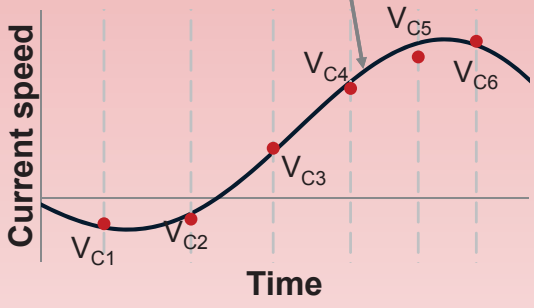
3. By substituting the above 4 formulae for formula (1), all terms of current are eliminated and only V_S remains.

There is a possibility that the accuracy is reduced when the trial needs long time interval, since the current curve can't be approximated by a parabolic function if the period of trial is long.

Current correction in BSRA method



1. A speed-power curve is considered to be approximately a mean line of 2 separate curves formed by the values in the current condition.
2. Current speed at each run which is assumed to be equal to the horizontal separation of the values from the mean line is obtained.
3. The obtained current speeds are plotted against time and a fair curve is fitted manually.
4. Current speed on the current curve at each run (V_{Ci}) is read.

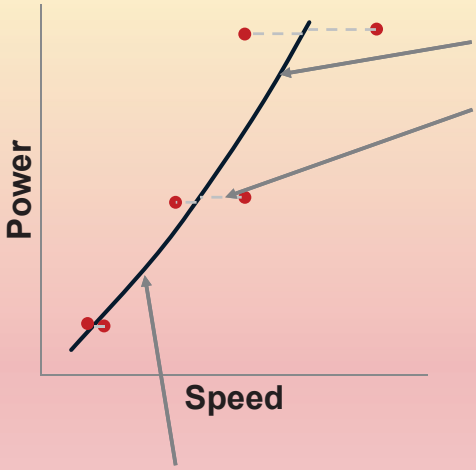


5. S-P curve is revised so that horizontal separation of values from revised curve are equal to the obtained current speeds as much as possible.
6. The above processes 2 - 5 are repeated until converged.

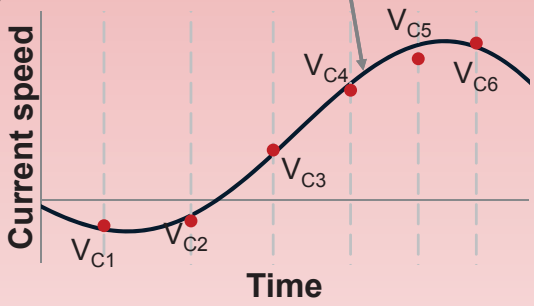
The process in which current curve is fitted manually involves arbitrariness and ambiguity.

Iterative method in ISO/DIS15016.2

Iterative method is based on the current correction method in BSRA standard method.



1. A speed-power curve is determined temporally considering the values in the current condition.
2. Current speed at each run which is assumed to be equal to the horizontal separation of the values from the mean line is obtained.
3. The obtained current speeds are plotted against time and a fair curve is fitted automatically using function.
4. Current speeds on the current curve at each run (V_{Ci}) are calculated.



5. S-P curve is revised so that horizontal separation of values from revised curve are equal to the obtained current speeds as much as possible.
6. The above processes 2 - 5 are repeated until S-P curve converged (fixed).

Validation study of this newly developed method was requested.

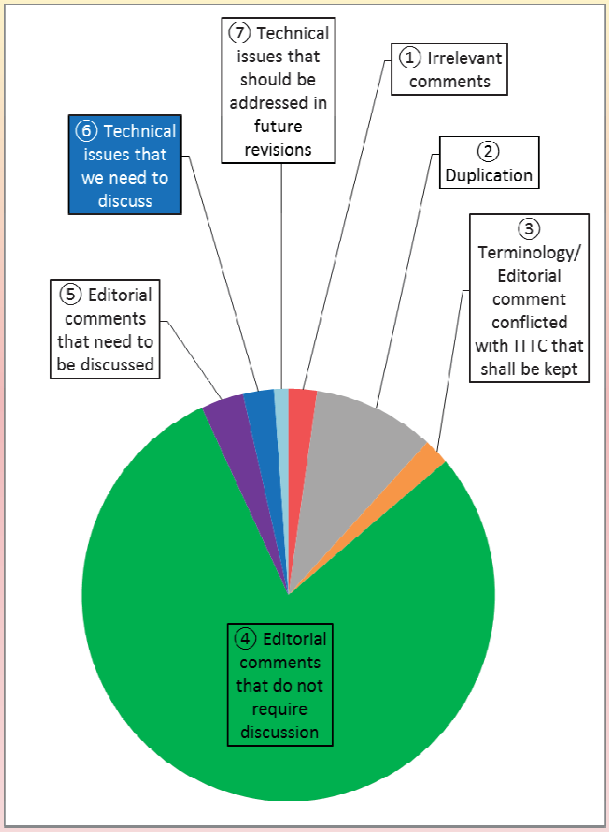
History from MEPC62 to 1st voting

- Since July 2012, ISO has started the revision of ISO15016:2002 by the experts, including ITTC members and STA-Group (*).

  (*) An international group of owners, shipyards, research institutes, classification societies and universities studying and improving sea trial procedures and Sea Trial Analyses (STA)

- IMO welcomed the collaborative efforts made by ISO and ITTC to harmonize their standards and urged ISO to submit the revised ISO15016 by early 2014, but the result of the 1st voting was "disapproved" (April 2014).

1st voting result



537 comments were gathered from the member countries.

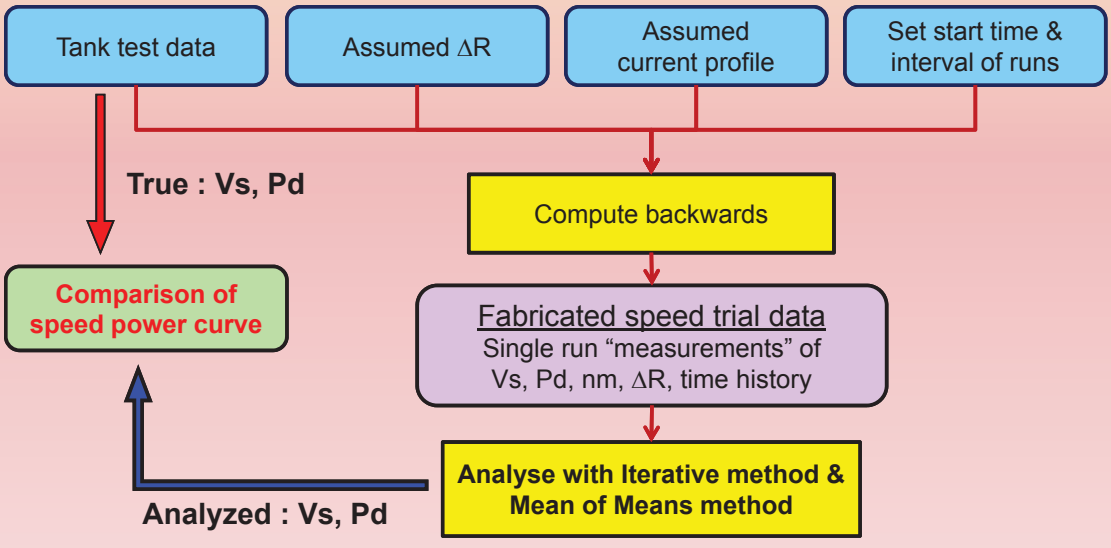
Technical comments (13 comments) should be solved for next 2nd voting.

These technical comments were narrowed down to only six items.

- Validation of “Iterative” method
- Run number of sister ships
- Standard G modules for shaft torque meter
- Power setting range
- Preparation and conducting the speed trial
- Using the CFD for wind and wave correction

Validation study of current correction by ITTC (1)

- Fabricated speed trial data based on tank test with some assumed current profiles and added resistance are used.
- Starting time and time intervals are varied to calculate.
- If the correction method is accurate, the results should be on the estimated speed power curve based on the tank test results



Direct Power Method

- Direct Power Method (DPM) is adopted for power correction.
- Power increase due to environmental conditions is eliminated directly with the following formula.

$$P_{\mathrm{Did}} = P_{\mathrm{Dms}} - \Delta P$$

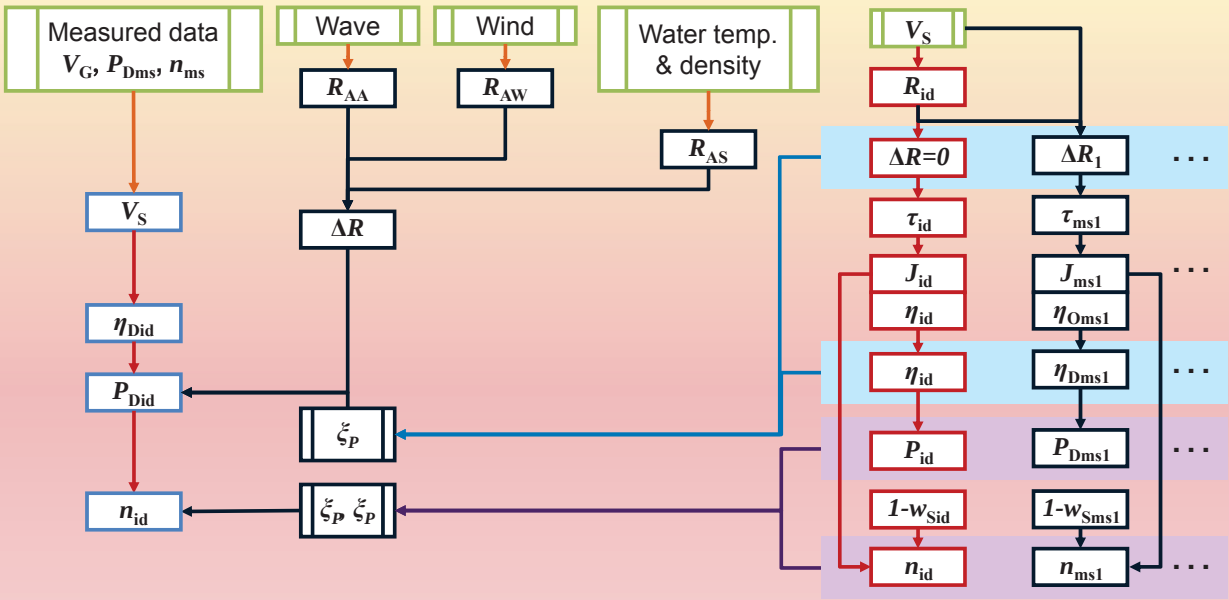
$$\Delta P = \frac{\Delta R V_{\mathrm{S}}}{\eta_{\mathrm{Did}}} + P_{\mathrm{Dms}}\left(1 - \frac{\eta_{\mathrm{Dms}}}{\eta_{\mathrm{Did}}}\right)$$

- As a result of transformation of the above formulae, the corrected power shall be calculated with the following formula, provided that $\boldsymbol{\xi_P}$ which represent the relation between change of propulsive efficiency and resistance increase are derived prior to the speed trial

$$P_{\mathrm{Did}} = \frac{1}{2}\left(P_{\mathrm{Dms}} - \frac{\Delta R V_{\mathrm{S}}}{\eta_{\mathrm{Did}}} + \sqrt{\left(P_{\mathrm{Dms}} - \frac{\Delta R V_{\mathrm{S}}}{\eta_{\mathrm{Did}}}\right)^2 + 4 P_{\mathrm{Dms}} \frac{\Delta R V_{\mathrm{S}}}{\eta_{\mathrm{Did}}} \xi_P}\right)$$

- Another method for power correction is also specified in the Annex K as a informative Annex.
- The above-mentioned two original formulae for DPM are used in this method.
- The procedures to derive propulsive efficiencies in this method are similar to the powering procedure.

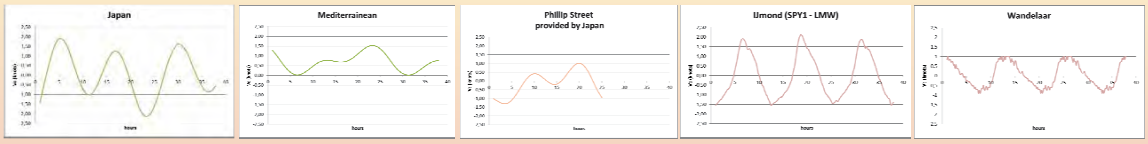
Flow of Direct Power Method



- This method is very simple when using it during sea trial.
- However, powering considering load variation effects at various speeds shall be carried out prior to the sea trial.

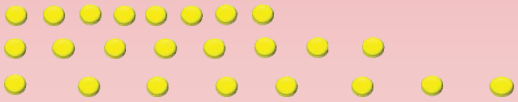
Validation study of current correction by ITTC (2)

- 5 current profiles : at various locations in Asia or Europe.



- 6 Ship types : small/large container ships, small/large tankers, cruise liner, LNGC
- Starting time : 0h - 18h

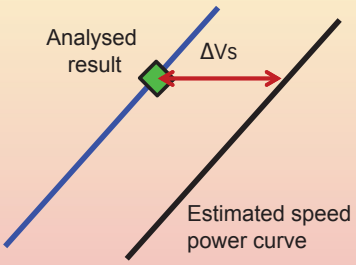
- Time intervals between consecutive runs: short and long uneven intervals, randomly

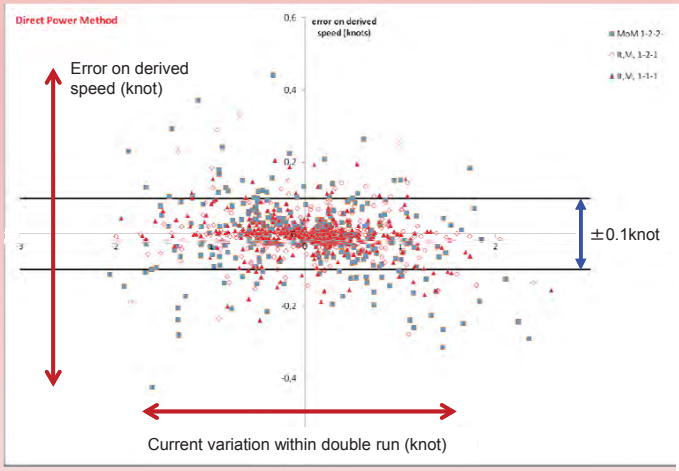


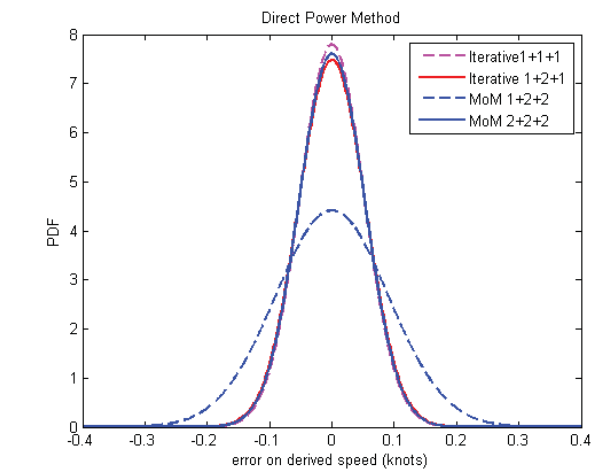
- Added resistance : 0% - 10%
- Run number :
  - Iterative method : 1+2+1(1+1+1) double runs
  - Mean of Means method : 1+2+2 double runs

Example of the validation result by ITTC

- The threshold for an acceptable variation:
  Difference between “true value” and analysed value of speed Vs <= 0.1knot







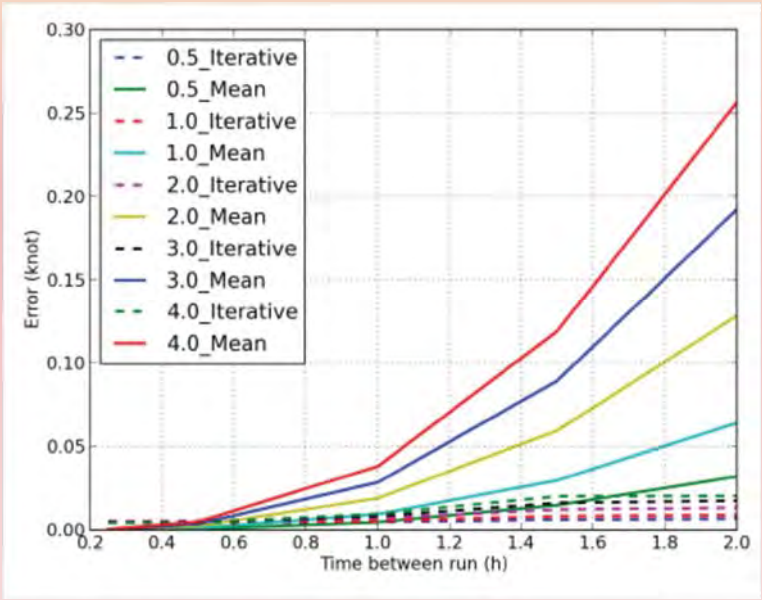
Outcome: Validation of Iterative Method (1)

ITTC concluded as follows based on their study:

- In general, the “Iterative” method of “1+1+1 double runs” leads to less errors in average of the tested cases when “1+2+2 double runs” are used in the “Mean of Means” method.
- Using the “Mean of Means” method, two double runs for each power setting (2+2+2 double runs) should be made to keep the enough accuracy.
- In the case of shorter time periods between the runs (up to 60 minutes), the both methods are equally adequate.
- In specific cases the “Mean of Means” method has advantages over the “Iterative” method.

Outcome: Validation of Iterative Method (2)

BV conducted the validation study by their own procedure and showed the results that the “Iterative” method (1+2+1 double runs) leads to less errors around EEDI power range based on the comparative study of their 16,320 simulations by both “Iterative” method and “mean of means” method.



Outcome: Validation of Iterative Method (3)

The other members reported the results of their validation study:

- According to the comparative study by ClassNK using actual trial data, both methods showed the same level accuracy.
- MOL expressed their views from the standpoint of the Ship Owner that the “Iterative” method is practical and allowed to be applied in the new ISO15016

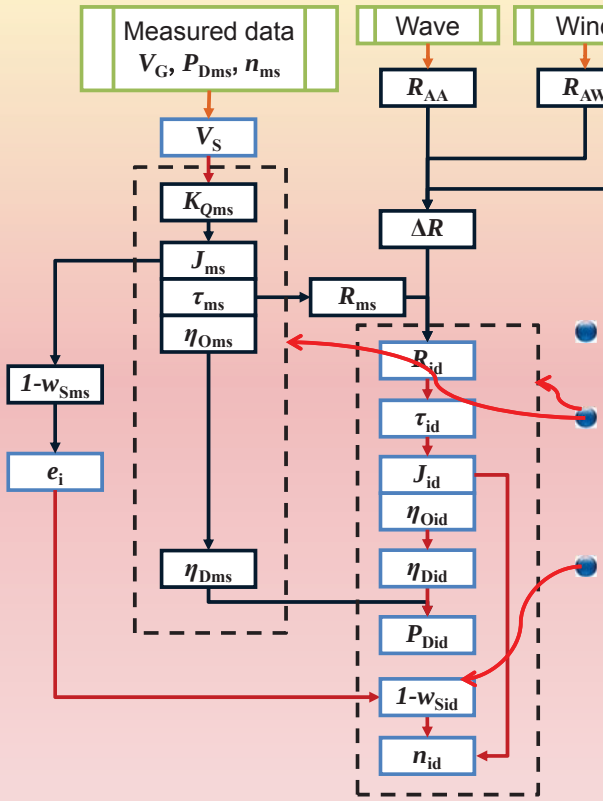
Taking into consideration of the Validation work by ITTC and others, the group agreed that the Iterative method was fully validated and confirmed to be accurate enough to be used as a current correction method in the ISO draft.

Outcome: Validation of Iterative Method (4)

The group agreed to follow the ITTC’s recommendation of the run numbers of the Iterative method and the Mean of Means method in order to achieve equivalent accuracy as follows:

- Iterative method
  - 1+2+1 Double Runs for the first ship
  - 1+1+1 Double Runs for sister ships
- Mean of Means method
  - 2+2+2 Double Runs for the first ship
  - 1+1+1 Double Runs for sister ships
  - For sister ships, when a current variation of above 0.2 knots within one Double Run is observed, one additional Double Run is needed for that power setting.

Flow of Extended Power Method



- The method described in Annex K looks complicated.
- However, the procedure in this method is similar to the powering procedure in that the propeller efficiencies are estimated using POC.
- Since the propeller advance coefficients are also estimated using POC, The full-scale wake fraction which is essential to know the physics of full scale ship propulsion can be calculated with this method.

G-Modulus

Research name		The number of G-modules
MOT, ITTC		$8.31*10^5$kg/cm^2
SNAME BS		$11.90*10^6$ lb/in^2 ($8.37*10^5$kg/cm^2)
Explanation added in the JIS (1968)		$8.35\sim8.37*10^5$kg/cm^2
B.S.R.A. (average of 68 intermediate shafts)		$11.89*10^6$ lb/in^2 ($8.36*10^5$kg/cm^2)
SR117	Measured by ultrasonic equipment (average of 43 actual intermediate shafts)	$8.365*10^5$kg/cm^2
	Measured by the conventional method (average of 76 actual intermediate shafts)	$8.383*10^5$kg/cm^2

- ISO proposal: 82,000 N/mm^2 equivalent to 8.367 x 10^5 kg/cm^2
- ITTC proposal: 82,649 N/mm^2 equivalent to 8.434 x 10^5 kg/cm^2
- Italy proposal: 82,400 N/mm^2

The group finally decided to adopt the default value of 82,400N/mm^2 proposed by Italy for G-Modulus, unless the Shipbuilder can prove another value based on an actual shaft torsional test.

History from 1st voting to current status

- ITTC and some other organizations conducted the validation studies of iterative method individually after 1st voting.
- 4th expert meeting was held in 25-27 June, 2014, in London and they reported the results of their validation work.
- Taking into consideration of the results of the validation work by ITTC and the others, the group agreed that the “Iterative” method was fully validated and confirmed to be accurate enough to be used as a current correction method in the draft revised ISO 15016 for the 2nd voting (ISO/DIS15016.2).
- All the participants of this group agreed on the substance of the ISO working draft as it is a practical and preferable standard for speed trial analysis.
- The members agreed to request ISO/TC8/SC6 for the 2nd DIS voting of the ISO/DIS15016.2.
- 2nd voting was started on 6 October and will be terminated on 6 December, 2014.

Main improvements from the conventional methods

	ISO15016:2002	BSRA	ISO/DIS15016.2
Current correction	● Current speed for each trial is obtained from a current curve determined manually using all current speed which is obtained from the speed difference between double runs.	● Current curve and speed-power curve are obtained by iterative process. ● In each step of iterative process, a current curve is determined manually using all trial data.	● <u>Mean of Means method</u> ➢ Current effect is eliminated automatically with four ship’s speeds of two double runs. ➢ In fact, current curve is approximated by quadratic function at each power setting. ● <u>Iterative Method</u> ➢ Current curve and speed-power curve are obtained by iterative process. ➢ In each step, a current curve is determined automatically using all trial data.
Preparation and conduct			● The procedures to be applied in the preparation, execution and reporting of speed trials are also specified.

Main improvements from the conventional methods

	ISO15016:2002	BSRA	ISO/DIS15016.2
Power correction	● Powers are corrected via propeller loads. ● Load variation is also corrected when estimating propeller load.	● Powers are corrected directly. ● It may be assumed that load variation effect due to propeller is small.	● Powers are corrected directly. (Direct Power Method) ● Load variation effect is considered.
Wind resistance	● Wind resistance coefficients shall be based on wind tunnel test. ● The data obtained from model tests are also provided in the document for guidance.	● Wind resistance coefficients for various ship types are provided in the document.	● Followings are accepted. ➢ Wind tunnel test ➢ Data set provided by STA-group ➢ Regression formula by Fujiwara et al.
Wave resistance	● Followings are accepted. ➢ Theoretical methods ➢ Tank test		● Followings are accepted. ➢ Simplified method (STAWAVE-1) ➢ Empirical method (STAWAVE-2) ➢ Theoretical method (NMRI) ➢ Tank test

Main improvements from the ITTC Guideline (2014)

"ISO/DIS 15016.2", which has been developed based on ITTC Recommended Procedure & Guideline (2014), achieves substantial improvements as follows:

- In addition to the "Mean of means" method for current correction, the newly developed "Iterative" method is introduced and applied.
- The required run number is re-established based on the validation results in order to achieve the same level of accuracy.
- The practical standard value of G-modulus for torsion meter is established.
- The appropriate restrictions are defined for the theoretical method with simplified tank test of added resistance due to waves based on their validation results.
- The following items of sea trial preparations, conditions, procedures and analysis are defined for clarity and to avoid arbitrary applications;
  - Sea trial area
  - Draft measurement method
  - Sister ships
  - Measured parameters
  - Application of shallow water correction
  - Power settings
  - Ship's profiles for Dataset of wind correction
  - Standard water temperature
  - ···

Current Situation

- 2nd DIS voting of the ISO/DIS15016.2 was conducted from October to December 2014.
- As a result of the voting, ISO/DIS15016.2 was approved without any objection.
- Through the proof reading done by ISO Central Secretariat, the second edition of ISO 15016 ("ISO 15016:2015") was published on April 2015.
- In MEPC 68 (May 2015), the Committee adopted the amendment of "the 2014 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI)" which refers ISO 15016:2015 as a tool for procedure of speed trial and for analysis of its results.
- ISO 15016:2015 is applicable for ships for which the sea trial is conducted on or after 1 September 2015.
- ISO 15016:2015 is expected to be revised three years later.

Thank you