ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Resistance Test

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Resistance Test

1. PURPOSE OF PROCEDURE

The purpose of the procedure is to ensure consistency of methodology for towing tank tests and the acquisition of correct results for deep-water resistance, sinkage and trim.

The procedure addresses conventional displacement vessels only. Vessels with design speeds which correspond to Froude numbers greater than to 0.45, and/or vessels with speeds which are above 3.7 $\nabla^{1/6}$ (m/s), as well as dynamically supported vessels and vessels for which high trim angles are expected, are addressed by procedure 7.5-02-05-01, High Speed Marine Vehicle Resistance Test.

2. PARAMETERS

2.1 Data Reduction Equations

Total resistance coefficient $C_\mathrm{T} = \frac{R_\mathrm{T}}{\frac{1}{2}\rho S \ V^2}$

Viscous resistance coefficient $C_\mathrm{V} = C_\mathrm{F}(1 + \mathrm{k})$

Wave making resistance coefficient

$$C_W = C_T - C_V = C_T - C_F(1 + k)$$

Frictional resistance coefficient - ITTC 57 model-ship correlation line,

$$C_\mathrm{F} = \frac{0.075}{(\log_{10}Re - 2)^2}$$
$$= (1 + 0.1194)\frac{0.067}{(\log_{10}Re - 2)^2}$$

Length Froude number $Fr = \frac{V}{\sqrt{gL}}$

Depth Froude number $Fr = \frac{V}{\sqrt{gL}}$

Reynolds number $\mathrm{Re} = \frac{VL}{\nu}$

Speed correction due to blockage $\frac{\Delta V}{V}$

Blockage parameter $m = \frac{A_\mathrm{X}}{A}$

2.2 Definition of Variables

A	Sectional area of the tank (m^2)
A_V	Transversal projected area of the ship above the waterline (m^2)
A_X	Area of maximum transverse section of the model (for blockage correction) (m^2)
b	Tank breadth (m)
B	Breadth (m)
C_A	Correlation allowance
C_AA	Air resistance coefficient
C_APP	Appendage resistance coefficient
C_B	Block coefficient
C_D	Drag coefficient
C_F	Frictional resistance coefficient
C_R	Residuary resistance coefficient
C_T	Total resistance coefficient
C_V	Viscous resistance coefficient
C_W	Wave making resistance coefficient
f	Frequency (Hz)
g	Acceleration of gravity ($\mathrm{m/s}^2$)
h	Water depth (m)
k	Form factor
L	Representative length [normally L_WL for Fr and L_OS for Re] (m)
L_OS	Length, overall submerged (m)
L_PP	Length between perpendiculars (m)
L_WL	Length of waterline (m)
m	Blockage parameter
P_E	Effective power (W)
R_T	Total resistance (N)
R_V	Total viscous resistance (N)
R_W	Wave making resistance (N)
S	Wetted surface area (m^2)
V	Speed (m/s)
X_CB	Longitudinal centre of buoyancy (m)
Z_CB	Vertical centre of buoyancy (m)
ΔC_F	Roughness allowance

∇ Displacement volume of the model (m^3)
ρ Mass density of water (kg/m^3)
ν Kinematic viscosity (m^2/s)

Subscripts $_M$ and $_S$ signify model scale and full scale (ship) values, respectively.

3. DESCRIPTION OF PROCEDURE

Resistance tests are conducted to provide data from which the resistance of the model hull at any desired speed may be determined. For this purpose, the model resistance and its speed through the water are simultaneously measured. The running attitude of the model - i.e. the sinkage fore and aft, or the running trim and sinkage - is usually also measured.

The resistance (or drag) is the horizontal component of the force opposing the steady forward motion of the model hull. The resistance is determined by measuring a towing force.

3.1 Model and Installation

3.1.1 Model

The model should be manufactured according to the ITTC Recommended Procedure 7.5-01-01-01, Ship Models with particular attention being paid to model manufacturing tolerances, surface finish, appendage manufacture, and the size and positioning of turbulence stimulation.

The model should generally be as large as possible for the size of the towing tank taking into consideration wall, blockage and finite depth effects (as discussed in Section 3.6.3), as well as model mass and the maximum speed of the towing carriage.

3.1.2 Test condition

Models should be tested in one or both of the following conditions:

1. Model hull without any appendages (naked model). This test is intended to determine the resistance coefficients of the basic form. If any appendage is included as a part of the hull it should be clearly stated. Rudders should be present in the resistance test if they form a streamlined extension of a skeg, and might also be included in other cases.
2. Model hull with appendages. This test is intended to determine the increase in resistance coefficients due to the appendages. All fixed appendages, except those, which are considered as propulsors, should be fitted to the model. Movable appendages or control surfaces should not be included in the standard inclusive resistance test. Bilge keels should not be fitted in the inclusive test if their resistance is expected to be small; their resistance will be estimated as an increase in the viscous resistance defined in Recommended Procedure 7.5-02-03-01.4. A clear description of the installed appendages for each and all specific tests should be documented.

3.1.3 Installation

The model should be run at the correct calculated displacement. For model installation, ballasting and trimming see ITTC Recommended Procedure 7.5-01-01-01, Ship Models.

The tow force should, where possible, be applied in the line of the propeller shaft and the horizontal component of the force measured. Careful consideration of the longitudinal location of the tow force is necessary since the product of the tow force and the running elevation change of the tow point induce a pitch moment. For models that experience heavy running trim, the tow force should, where possible, be applied at X_{CB} where the running elevation change is minimal in order to minimize artificial trim effects. Alternative approaches may be necessary for vessels with steeply-raked shafts and for those which have no defined shaft line. The tow force should also be applied at Z_{CB} in order to avoid artificial trim effects. It can be beneficial to tow the model at a forward longitudinal position to maintain a more directionally stable model. This reduces the amount of yaw moment the tow point must restrain and leads to a steadier measurement of the external tow force. This should only be performed for models that have minimal running trim.

The model should be attached to the measuring head of the resistance dynamometer by a connection, which can transmit and measure only a horizontal tow force, even though raked propeller shafts or heavy running trim would result in the line of action of the propeller thrust not being horizontal.

Guides may be fitted to prevent the model from yawing or swaying. These should not restrain the model in any other direction of movement, nor be able to impose any force or moment on the model, which would cause it to roll or heel. The arrangement of any such guides that include sliding or rolling contacts should be implemented in a way that imposes the least possible friction forces. In cases where transverse stability is low, guides may be used to restrain the model in heel.

The model should be positioned such that it is on the centreline of the tank and parallel to the carriage rails. Transverse alignment errors at *FP* and *AP* should both be less than 0.05% L_{PP}.

If any instruments carried in the model are linked to the carriage by flexible cables, great care should be taken to ensure that the cables do not impose any force on the model. In practice the cables should therefore hang vertically from the carriage and have enough slack not to impose forces during running sinkage and trim conditions. Care should also be taken to balance any instruments that must have attachments to both the model and the carriage (e.g. mechanical trim recorders).

3.2 Measurement Systems

Figure 1 shows a typical measurement system for a resistance test.

The following quantities are measured:

- Model speed
- Total resistance
- Sinkage fore and aft (or running trim and sinkage)
- Water temperature (for calculation of viscosity and density)

3.3 Instrumentation

The quoted bias accuracies are for indicative purposes only. Uncertainty analysis should be used to derive the actual requirements.

3.3.1 Resistance

The resistance dynamometer should measure the horizontal tow force to within 0.2% of the maximum capacity of the dynamometer or 0.05 N, whichever is the larger. This does not necessarily imply that the resistance itself is measured to within the same tolerance of its true value.

The range of the resistance dynamometer should be selected to be appropriate to the expected maximum resistance of the model.

3.3.2 Speed

Ideally the speed of the model through the water should be measured directly throughout the measuring run. Since this is in general impractical, one of the following two methods may be employed:

1. the speed of the towing carriage relative to the ground should be measured. This may be measured using a trailing wheel with encoder or similar, direct from the carriage drive, using optical/proximity sensors with a counter/timer, or by another appropriate method.
2. the speed of the towing carriage relative to the water should be measured by a current meter far in front of the model. In this case the current meter wake and waves should be minimised.

The speed of the model should be measured to within 0.1% of the maximum speed or to within 3 mm/sec, whichever is the larger.

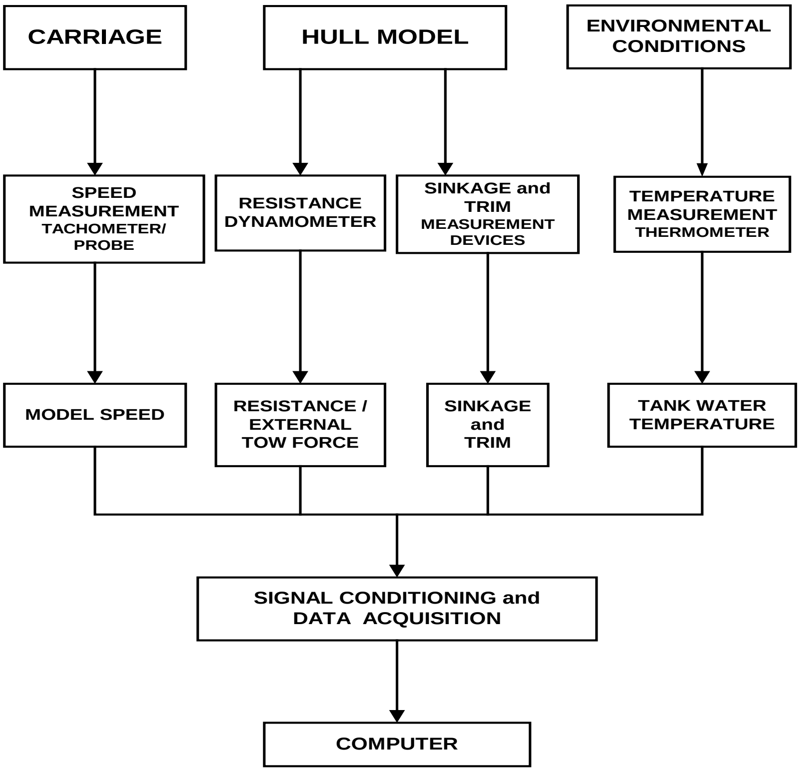

Figure 1 Typical measurement system

3.3.3 Sinkage and Trim

The model should be ballasted and trimmed according to Section 3.3 of the ITTC Recommended Procedure 7.5-01-01-01, Ship Models. The static immersion (draught) that forms the datum for the measurement of sinkage and trim should be confirmed using an appropriate method, such as accurately marked draught marks or using draught gauges.

Sinkage fore and aft may be measured with mechanical guides, potentiometers, encoders, LDVTs, optical tracking systems or with remote (laser or ultrasonic) distance meters. Typically, the running trim is calculated from the measured running sinkage fore and aft. Alternatively, the running trim may be measured directly using an angular measuring device in conjunction with the measurement of the sinkage at one point.

The sinkage fore and aft should be measured to within 1.0 mm. If the trim is measured directly, rather than deduced from a measurement of sinkage fore and aft, it should be measured to an accuracy of 0.1 deg.

3.3.4 Temperature

The water temperature should be measured at a depth near half of the model draught using a thermometer. It is recommended to continuously measure the temperature with the resistance data to account for tank gradients or fluctuations over the course of the test. If manual readings are conducted, they should be well documented and adequately reflect the overall condition of the tank throughout the test.

3.4 Calibration

3.4.1 General remarks

All devices used for data acquisition should be calibrated regularly. For calibration, the measured quantities should be either substituted by calibrated weights and pulses or checked by other measuring devices, which have already been calibrated. Calibration diagrams, where the measured quantities (output values) are plotted versus the calibration units (input units), may be useful to check the calibration itself as well as the linearity of the instruments. Calibration should generally be in accordance with ITTC Recommended Procedure 7.6-01-01, Control of Inspection, Measuring, and Test Equipment.

The calibration of the resistance dynamometer and the sinkage and/or trim sensors should be checked immediately prior to the testing. The calibrations should preferably include as much of the measurement chain as possible (amplifier, filter, A/D converter). If the check indicates that the required accuracies cannot be met, the calibration should be renewed or the instrument replaced and the check repeated. Daily checking of a pulse counter for speed measurements is usually not required. Instead, the check on this device is covered by calibrations carried out at regular intervals.

Where the gravitational constant g is used in calculations, the value chosen should be appropriate to the location of the tank.

3.4.2 Resistance dynamometer

The calibration of the resistance dynamometer should be carried out by the use of calibrated weights as an input to the instrument.

3.4.3 Sinkage and trim transducers

The calibration of linear measuring devices should be performed with a calibrated ruler or other appropriately calibrated device such as a length bar or Vernier height gauge.

3.4.4 Speed

The calibration of the carriage speed will depend mainly on how the carriage speed is measured. The carriage speed should be calibrated regularly and respective records should be stored.

Where possible the carriage speed measured with the primary speed measurement system should be checked with an alternative measurement system.

3.4.5 Thermometer

Thermometers should be calibrated according to common standards and/or following the advice of the manufacturer and should be accurate to within 0.1° C.

3.4.6 Signal conditioning and data acquisition system

The various components of the signal conditioning and data acquisition system (e.g. amplifies, filters, A/D converters) should be checked and calibrated according to the manufacturers recommended schedule. Key features of the system, such as cut-off frequencies of filters employed, and resolution and sampling rate of A/D converters should be recorded.

3.5 Test Procedure & Data Acquisition

3.5.1 Method

Before each run begins zero readings of all instruments must be taken, over a period long enough to give a representative mean value.

The model is towed at speeds corresponding to the same Froude numbers as for the full-scale ship.

The model speed is selected and the model accelerated to that speed.

It is important to minimise “overshoot” of speed, since this will result in waves overtaking the model. The measured resistance will therefore not be representative of the ship moving at that speed in calm water.

If the model has been held during initial acceleration, it is released as soon as the selected speed has been reached.

It is recommended that the data acquisition may either begin after a steady speed has been reached; or, alternatively, data acquisition may take place continuously from the time at which the zero readings are logged (in order to allow the entire speed profile to be determined).

The mean values are derived from a section of the time series during which the speed was steady. In some cases unsteady oscillations (related to unsteady wave resistance effects) may be observed in the measurements even when the model speed is constant. Where these oscillations have a significant magnitude, it is important to calculate the mean values of parameters of interest over an integer number of oscillation cycles. Where possible, it is desirable to use at least five oscillations to find the mean. Note that the frequency of these oscillations in an unbounded fluid may be estimated as:

$$f = 8\pi V/g \quad (Hz)$$

Maximum and minimum values together with mean and standard deviations should be stored for each run.

This process is repeated at other selected speeds covering the required range, avoiding continuous progression from one limit to the other. For example, runs at alternate speeds from the lowest speed to the highest followed by highest speed to the lowest filling in the gaps. A significant change in speed is desirable so that the change in pressure distribution on the hull is sufficient to change the running sinkage and trim of the model therefore achieving the proper resistance.

There should be sufficient waiting time between consecutive runs to achieve similar conditions for each of the runs and to obtain consistency in results. This waiting time will depend on the geometry of the test facility, the type and size of model and model speed. The waiting times should be recorded.

3.5.2 Range and interval

The speed range should extend from at least 5% below the lowest speed at which reliable data is required to at least 5% above the highest speed required. This range should be covered by a suitable number of speeds. Low speeds may also be used for the derivation of form factors (see Section 3.6.2). Care should be taken to ensure that there are sufficient number of speeds to define humps or hollows and other rapidly changing features of the curve.

3.5.3 Speed

The following aspects should be noted when measuring speed:

Attention should be paid to residual currents in the towing tank near the surface, which are caused by previous tests. It is not unusual to exclude the first run of the day if no active artificial circulating device is available. This has however not always shown to be necessary and can be confirmed through uncertainty analysis. For more information see General Guidelines for Uncertainty Analysis in Resistance Tests, provided in QM 7.5-02-02-02.

- It is essential that the speed of the model through the water should be constant throughout, and for a significant distance before, that part of the time series used for the calculation of the mean values of the parameters of interest.
- Steadiness of carriage speed is an essential element in achieving steady model speed, but is not necessarily sufficient since the rate of change of the initial acceleration and the moment and manner of release of the model may interact with the model-dynamometer system and cause it to oscillate.
- During the measuring run, the carriage speed should normally not vary by more than 0.1% of the mean speed or 3 mm/s, whichever is the larger. The cyclic characteristics of the carriage speed control system should be such as not to synchronise with the natural frequency of the model dynamometer system.

3.5.4 Measured quantities

During each run the measured values of model speed and resistance (and when necessary sinkage and trim) should be recorded continuously.

The sampling rate shall be selected following Nyquist requirements and taking into account low pass filtering to minimize the effects of aliasing.

Water temperature should be measured at a depth near half of the model draught. If there is a non-homogeneous temperature in the tank it should be recorded. Temperature measurements should be recorded at the beginning and end of each test sequence or at least on a daily basis.

3.6 Data Reduction and Analysis

The speed, resistance, sinkage and trim and any other continuously recorded quantities of the test should be presented as mean values derived from an integration of the instantaneous measured values over the same measuring interval (chosen according to the guidelines in Sections 3.5.1 and 3.5.2), with the appropriately averaged zero measurements subtracted from the average values.

Total resistance and wave making (residuary) resistance coefficients, together with Froude number, are calculated for each speed using the data reduction equations given in Section 2.1.

3.6.1 Analysis of model scale results

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

$$C_{TM} = \frac{R_{TM}}{\frac{1}{2}\rho_M S_M V_M^2}$$

Model wetted surface area, to be used in the analysis, is calculated from the model body plan to the still waterline. The transom area is not included in the wetted surface area. The surface areas of the appendages are calculated separately and added to model surface area (excluding their contact areas) for appended resistance tests. The speed should, if necessary, be corrected for blockage according to the equations given in Section 3.6.3. Values of water density and viscosity should be determined according to ITTC Recommended Procedure 7.5-02-01-03.

The wave making resistance of the ship is calculated from the model resistance tests assuming that the form factor is independent of scale and speed. The wave making resistance can therefore be calculated as:

$$C_{\mathrm{W}} = C_{\mathrm{TM}} - C_{\mathrm{V}} = C_{\mathrm{TM}} - (1 + \mathrm{k})C_{\mathrm{FM}}$$

where C_{FM} is derived from the ITTC – 1957 correlation line. It needs to be noted that the ITTC-1957 correlation line already contains a form factor correction. The value of this depends on the actual turbulent flat plate friction values, which today are still not known exactly. All turbulent flat plate friction values are based on experimental results which contain uncertainty.

The ITTC-1957 correlation line was based on the Hughes version of a flat plate friction line. The Hughes flat plate line is given by

$$C_{\mathrm{F}} = \frac{0.067}{(\log_{10} Re - 2)^2}$$

and the ITTC-1957 line is given by:

$$C_{\mathrm{F}} = \frac{0.075}{(\log_{10} Re - 2)^2} = (1 + 0.1194)\frac{0.067}{(\log_{10} Re - 2)^2}$$

If appendages are present during the resistance test but their resistance scaled separately the wave making resistance can be calculated as:

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

C_{APPM} is the model appendage resistance coefficient and can be derived by calculation or from the difference in resistance by testing with and without appendages. For calculation of appendage resistance see Recommended Procedure 7.5-02-03-01.4, 1978 ITTC Performance Prediction Method.

The form factor can be determined from low speed tests as described in Section 3.6.2.

The C_{W} or C_{T} curve is the best basis for judging if a sufficient number of test points have been obtained in order to define humps and hollows. The resistance curve should be faired in order to facilitate reliable interpolation to obtain the resistance at the required speeds. The smoothing should be carried out with care in order not to remove humps and hollows. An acceptance criterion for the test might be derived based on the scatter in the C_{W} or C_{T} curve.

3.6.2 Form factor

The recommended method for experimental evaluation of the form-factor is that proposed by Prohaska. If no separation is present, the total resistance can be written, to a first approximation, as

$$C_{TM}(Re, Fr) = (1 + \mathrm{k})C_{\mathrm{FM}}(Re) + C_{\mathrm{W}}(Fr)$$

If the wave-resistance component in a low speed region (say $0.1 < Fr < 0.2$) is assumed to be a function of Fr^4, the straight line plot of $C_{\mathrm{TM}}/C_{\mathrm{FM}}$ versus Fr^4 / C_{FM} will intersect the ordinate (Fr=0) at (1+k), enabling the form factor to be determined. In the case of a bulbous bow near the water surface (either being immersed or emerged) or in case of a partly submerged bulbous bow in partial loaded conditions these assumptions may not be valid and care should be taken in the interpretation of the results. In the above C_{FM} should be a true turbulent flat plate friction value.

Further it should be noted that Prohaska's method should not be used for any vessel with substantial transom sterns for which the transom runs wet at the speed range for the Prohaska test.

When using form factor methods for scaling the drag of appendages, the form factor increase due to fitting appendages should be determined from test results at higher speeds to avoid laminar flow.

$$\Delta k = d\big(C_{TM}(appended) - C_{TM}(barehull)\big)/dC_{FM}$$

This procedure avoids the need for low speed testing to determine the form factor.

3.6.3 Extrapolation to full scale

The total resistance coefficient of a ship without bilge keels is:

$$C_{\mathrm{TS}} = (1+k)\, C_{\mathrm{FS}} + \Delta C_{\mathrm{F}} + C_{\mathrm{A}} + C_{\mathrm{W}} + C_{\mathrm{AAS}}$$

where

k	is the form factor determined from the resistance test, see Section 3.6.2.
C_{FS}	is the frictional resistance coefficient of the ship according to the ITTC-1957 model-ship correlation line
ΔC_{F}	is the roughness allowance.
$\mathrm{C_A}$	is the correlation allowance.
C_{W}	is the wave making resistance coefficient.
C_{AAS}	is the full scale air resistance coefficient.

The total resistance for the ship can then be calculated using:

$$R_{TS} = 0.5\, \rho_S\, V_S^2\, S_S\, C_{TS}$$

Further details on the 3D (ITTC'78) extrapolation process from model to full scale can be found in Recommended Procedure 7.5-02-03-01.4 1978 ITTC Performance Prediction Method.

3.6.4 Blockage and finite depth corrections

The dimensions of the towing tank should be reported with the test result documentation (see Section 3.7).

The dimensions should be large enough to avoid significant wall, blockage, and finite depth effects.

The importance of these effects depends upon a range of factors; key parameters include the blockage parameter, m, defined as the ratio of model cross section area, A_X, to tank cross section area, A, the Froude number, Fr, and the depth Froude number Fr_{h} .

The following formulae are recommended for carrying out blockage corrections if they are necessary. For easy use and comparison the correctors are listed in their simplest form as given by the respective author, after neglecting second order terms or being simplified otherwise. Detailed information may be found in the original papers. The formulae are based on mean-flow theory:

3.6.4.1 Schuster

$$\frac{\Delta V}{V} = \frac{m}{1 - m - Fr_h^2} + \left(1 - \frac{R_V}{R_T}\right)\frac{2}{3} Fr_h^{10}$$

where $m = A_X/A$, and R_V/R_T is the ratio of viscous to total resistance.

The second term is the finite depth influence on wave making resistance, converted to a speed correction where Fr_h^{10} is a good approximation of the hyperbolic function of the finite depth wave velocity within the range $0 < Fr_h < 0.7$.

3.6.4.2 Scott

$$\frac{\Delta V}{V} = K_1 \nabla A^{\frac{-3}{2}} + BL^2 K_2 A^{\frac{-3}{2}}$$

The first term is the empirically improved version of Scott's original formula with K_1 as a function of *Re* and the form-parameter

$$\frac{C_B \nabla^{\frac{1}{3}}}{L}$$

as shown in Fig. 2. The second term is a function of *Fr* and form from experiments deduced to extend the range of applicability up to $Fr = 0.38$. K_2 is given in analytical form

$$K_2 = 2.4(Fr - 0.22)^2 \quad \text{for } 0.22 < Fr < 0.38$$

$$K_2 = 0 \qquad \text{for } Fr < 0.22$$

The validity of the formula is confirmed for the range of model size 3.5 m < L < 9 m, tanks of approximately 2:1 breadth to water depth ratio and speed range between $0.08 < Fr < 0.4$.

3.6.4.3 Tamura

$$\frac{\Delta V}{V} = 0.67m\left[\frac{L}{b}\right]^{\frac{3}{4}} \frac{1}{(1 - Fr_h^2)}$$

where $m = \frac{A_X}{A}$

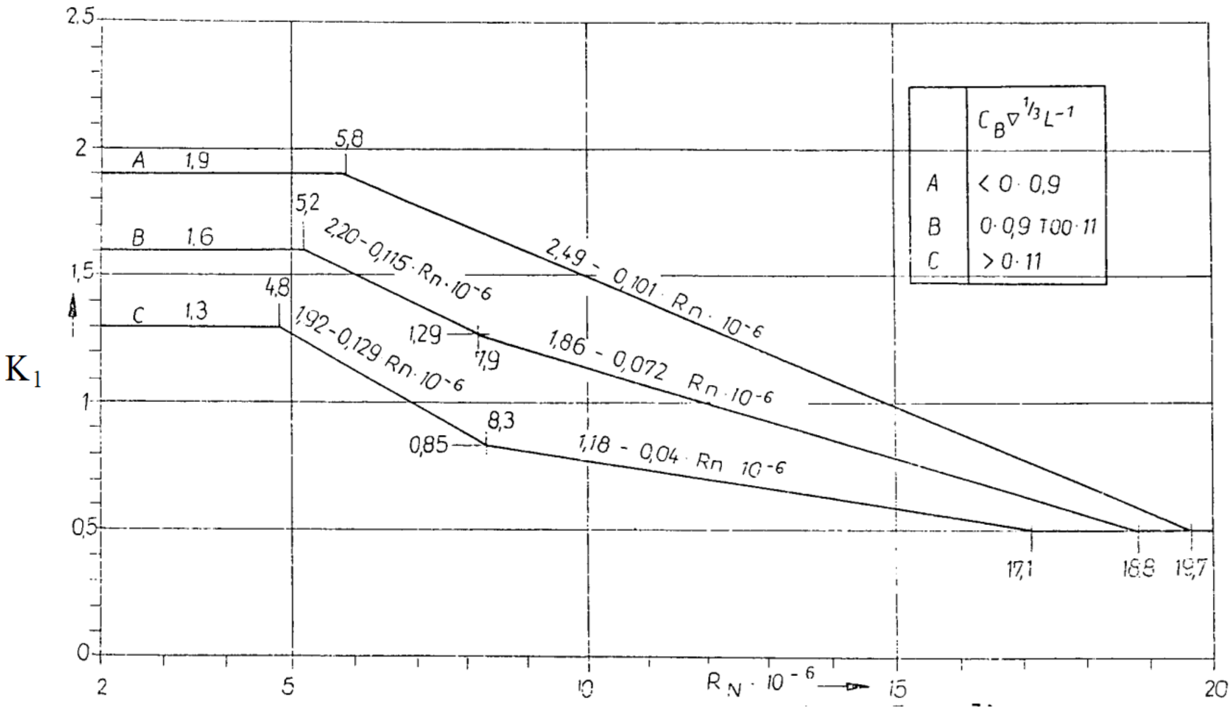

Figure 2 Correction factor K_1 (Scott, 1970)

3.6.4.4 Discussion

It is generally preferable for a blockage correction to be expressed as a correction factor for speed, as this form of correction is well suited to resistance and propulsion tests.

The influences on wake blockage or pressure defect at the propeller are however unknown and are not separately considered.

Of the different correctors the Scott corrector tends to fit most of the data best but its theoretical base may not be universally accepted. It does however seem to be the best method available and may be recommended for general use with the following limitations: Tanks of approximately 2:1 breadth to water depth ratio, model lengths between 3.5 m and 9.0 m and Froude number 0.08 to 0.4.

Based on the successful application of mean-flow theory in connection with finite depth wave theory, with no need for empirical adjustment and its easy employment, the Schuster corrector is also recommendable as a blockage correction formula with good overall qualities, up to say $Fr = 0.3$.

Another method commonly used is that due to Tamura which also includes finite depth effects.

All the previous comments are related to normal routine tank work. For blockage corrections in shallow water tanks essentially diverging from 2:1 breadth to water depth ratio, blockage ratios much larger than 0.03 and model tests at depth Froude numbers higher than 0.7, the proposal by Graff (1969) may be suggested as a useful guide.

3.7 Documentation

The results from the test should be collated in a report, which should contain at least the following information:

- Model specification:
  - Identification (model number or similar)
  - Loading condition
  - Turbulence stimulation method
  - Model scale
  - Main dimensions and hydrostatics, included static wetted surface area (see recommendations of ITTC Standard Procedure 7.5-01-01-01, Ship Models)
  - Towing point location
  - Model condition
- Particulars of the towing tank, including length, breadth and water depth
- Test date
- Parametric data for the test:
  - Water temperature of tank water
  - Water temperature of seawater
  - Density of tank water
  - Density of seawater
  - Kinematic viscosity of the water
  - Form factor (even if (1+k)=1.0 is applied, this should be stated)
  - C_{Air}
  - Correlation allowance, C_A
- For each speed, the following data should be given as a minimum:
  - Resistance of the model and ship
  - Dynamic sinkage fore and aft, or sinkage and trim
  - C_{TS}, R_{TS}, P_{ES}, C_{FM}, C_{FS}

4. VALIDATION

4.1 Uncertainty Analysis

Uncertainty analysis should be performed in accordance with the ‘Guide to the Expression of Uncertainty Analysis in Experimental Hydrodynamics’ 7.5-02-01-01 and ‘General Guidelines for Uncertainty Analysis in Resistance Tests’ 7.5-02-02-02.

4.2 Benchmark Tests

Benchmark data are described and collected in ‘Benchmark Database for CFD, Validation for Resistance and Propulsion’, ITTC 7.5-03-02-02.

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