	<b>ITTC – Recommended Procedures</b>	<b>7.5 – 02 02 – 03</b> Page 1 of 4	
	<b>Resistance, Uncertainty Analysis Spreadsheet for Resistance Measurements</b>	Effective Date 2002	Revision 00

## CONTENTS

### 1 PURPOSE OF PROCEDURE

### 2 PARAMETERS

#### 2.1 Inputs

#### 2.2 Outputs

### 3 PROCEDURE


#### 3.1 Instructions

#### 3.2 Spreadsheet

### 4 VALIDATION

### 5 REFERENCES

Prepared by	Approved
Resistance Committee of 23 <sup>rd</sup> ITTC	23 <sup>rd</sup> ITTC 2002
Date	Date

	<b>ITTC – Recommended Procedures</b>	<b>7.5 – 02 02 – 03</b> Page 2 of 4	
	<b>Resistance, Uncertainty Analysis Spreadsheet for Resistance Measurements</b>	Effective Date 2002	Revision 00

## Uncertainty Analysis Spreadsheet For Resistance Measurements

### 1 PURPOSE OF PROCEDURE

Provide a spreadsheet for calculating the bias and precision limits and total uncertainty using single or multiple test methods for model scale towing tank resistance test following the Quality Manual Procedures 7.5-02-01-01 “Uncertainty Analysis in EFD, Uncertainty Assessment Methodology,” 7.5-02-01-02 “Uncertainty Analysis in EFD, Guidelines for Resistance Towing Tank Tests,” and 7.5-02-02-02 “Uncertainty Analysis in EFD, Example for Resistance Test.”

### 2 PARAMETERS

The data reduction, bias and precision limit, and total uncertainty equations are given in 7.5-02-02-02 “Uncertainty Analysis in EFD, Example for Resistance Test.” The uncertainty analysis spreadsheet for resistance test implements this procedure. Spreadsheet inputs and outputs are given in Sections 2.1 and 2.2, respectively, using same symbols, units, and definitions as 7.5-02-02-02 “Uncertainty Analysis in EFD, Example for Resistance Test.” Spreadsheet table of contents is as follows:

#### Table of Contents

1. General information
2. Data reduction equations
3. Single or multiple test uncertainty
4. Input variables
5. Uncertainty analysis equations
6. Bias Limits

### 6.1 Wetted surface

### 6.2 Speed

### 6.3 Resistance

### 6.4 Model basin water properties

### 6.5 Sensitivity coefficients

### 6.6 Total bias of resistance coefficient $C_T$

### 7. Precision limit

### 8. Total uncertainty

#### 2.1 Inputs


Symbol	Units	Definition
		Facility
		Type of ship
		Period of tests performed
		References
$M$		Number of Tests
$C_T$		Total Resistance
		Coefficient $C_T$ value (single test)
$\sigma_{C_T}$		Standard deviation of $C_T$ (single test)
$C_T$		Total Resistance
		Coefficient $C_T$ values (multiple test)
$L_{WL}$	m	Length along waterline
$B$	m	Beam
$T$	m	Draft, even keel
$S$	m <sup>2</sup>	Wetted surface, including rudder
$g$	m/s <sup>2</sup>	Model basin gravity
$\rho$	kg/m <sup>3</sup>	Model basin water density
$\nu$	m <sup>2</sup> /s	Model basin water kinematic viscosity
$k$		Form factor
$K$		Coverage factor for

$V$	m/s	standard deviation		$C_F^{tw}$	Frictional resistance coefficient at measured temperature, $t_w$
$t_w$	°C	Model speed			
$B_{S1}$	m <sup>2</sup>	Water temperature			% of $B_S^2$ due to $B_{S1}^2$
		Assumed error in hull form bias			% of $B_S^2$ due to $B_{S2}^2$
$B_{S2}$	m <sup>2</sup>	Error in displacement bias			
$B_V$	m/s	Speed bias	$B_S$	m <sup>2</sup>	Wetted surface bias
$B_{Mx1}$	kg	Resistance calibration bias			% of wetted surface range, $S$
$B_{Mx2}$	kg	Resistance curve fit bias			% of speed range, $V$
$B_{Mx3}$	kg	Resistance load cell misalignment bias			% of $B_{M_x}^2$ due to $B_{Mx1}^2$
$B_{Mx4}$	kg	Resistance towing force inclination bias			% of $B_{M_x}^2$ due to $B_{Mx2}^2$
$B_{tw}$	°C	Water temperature bias			% of $B_{M_x}^2$ due to $B_{Mx3}^2$
$B_\rho$	kg/m <sup>3</sup>	Water density bias			% of $B_{M_x}^2$ due to $B_{Mx4}^2$
			$B_{Mx}$	kg	Total resistance mass bias
					% of total resistance mass range, $Mx$
					% of water temperature range, $t_w$
					% of water density range, $\rho$
			$\theta_S$	1/m <sup>2</sup>	Sensitivity coefficient for wetted surface, $S$
			$\theta_V$	1/(m/s)	Sensitivity coefficient for speed, $V$
			$\theta_{Mx}$	m/N*s <sup>2</sup>	Sensitivity coefficient for total resistance mass, $Mx$
			$\theta_\rho$	m <sup>3</sup> /kg	Sensitivity coefficient for water density, $\rho$
			$\theta_{ptwp}$	1/°C	Sensitivity coefficient for water temperature, $t_w$
			$B_{CT}$		Resistance Coefficient bias limit
					% of Resistance Coefficient range, $C_T^{15\text{ deg } C}$
			$\sigma_{CT}$		Standard deviation of $C_T$
			$M$		Number of tests
			$P_{CT}$		Resistance Coefficient precision limit

## 2.2 Outputs

### Symbol Units Definition

$C_T(15^\circ\text{C})$		Statement of purpose			
		Total Resistance			
		Coefficient $C_T$ average (single test) at 15 °C	$\theta_S$	1/m <sup>2</sup>	Sensitivity coefficient for wetted surface, $S$
$C_T$		Total Resistance	$\theta_V$	1/(m/s)	Sensitivity coefficient for speed, $V$
		Coefficient $C_T$ average (multiple test)	$\theta_{Mx}$	m/N*s <sup>2</sup>	Sensitivity coefficient for total resistance mass, $Mx$
$C_T(15^\circ\text{C})$		Total Resistance	$\theta_\rho$	m <sup>3</sup> /kg	Sensitivity coefficient for water density, $\rho$
		Coefficient $C_T$ average (multiple test) at 15 °C	$\theta_{ptwp}$	1/°C	Sensitivity coefficient for water temperature, $t_w$
$\sigma_{CT}$		Standard deviation of $C_T$ (multiple test)	$B_{CT}$		Resistance Coefficient bias limit
$C_F(15^\circ\text{C})$		Frictional resistance coefficient at 15°C			% of Resistance Coefficient range, $C_T^{15\text{ deg } C}$
$Fr$		Froude Number	$\sigma_{CT}$		Standard deviation of $C_T$
$M_x$	kg	Total resistance mass in x-direction	$M$		Number of tests
$R_x$	N	Resistance average	$P_{CT}$		Resistance Coefficient precision limit
$C_T(\text{avg } 15^\circ\text{C})$		Total Resistance			
		Coefficient $C_T$ average at (15°C)			

 INTERNATIONAL TOWING TANK CONFERENCE	<b>ITTC – Recommended Procedures</b>	<b>7.5 – 02 02 – 03</b> Page 4 of 4	
	<b>Resistance, Uncertainty Analysis Spreadsheet for Resistance Measurements</b>	Effective Date 2002	Revision 00

$U_{CT}^{15 \text{ deg } C}$ 
  
% of Resistance  
Coefficient range,  $C_T^{15 \text{ deg } C}$   
% of Resistance  
Coefficient total  
Uncertainty,  $U_{CT}^{15 \text{ deg } C}$   
due to bias  
% of Resistance  
Coefficient total  
Uncertainty,  $U_{CT}^{15 \text{ deg } C}$   
due to precision  
Resistance Coefficient  
total uncertainty  
% of Resistance  
Coefficient range,  $C_T^{15 \text{ deg } C}$

### 3 PROCEDURE

#### 3.1 Instructions

The inputs appear as empty white boxes. The outputs appear as grey boxes and are calculated for the user. The user can select single or multiple test method by entering the corresponding number of tests, 1 for single test method, >1 for multiple test method. For single test method, enter average  $C_T$  and standard deviation of  $C_T$  from best available data. For multiple test method, enter measured  $C_T$  values from each test. There are 15  $C_T$  inputs for multiple test method. If the user does not have 15  $C_T$  inputs, use as many as necessary and leave the remaining  $C_T$  inputs blank, not zero. Water density and viscosity input values should be determined from the ITTC standard in 7.5-02-01-03 “Density and Viscosity of Water.” Upon entering of all inputs, the uncertainty will be calculated for the user at the end of the spreadsheet.

#### 3.2 Spreadsheet

The uncertainty analysis spreadsheet for resistance test is provided by attached Resistance-blank.xls excel document.



Resistance-blank.xls

### 4 VALIDATION

Example use of the uncertainty analysis spreadsheet for resistance test for single and multiple test methods are provided by attached Resistance-single test example.xls and Resistance-multiple test example.xls excel documents. The examples are based on Longo and Stern (1998), which was one of the 22<sup>nd</sup> ITTC Resistance Committee member contributions to 7.5-02-02-02 “Uncertainty Analysis in EFD, Example for Resistance Test.”



"Resistance-single test example.xls"



"Resistance-multiple test example.xls"

### 5 REFERENCES

Longo, J. and Stern, F., (1998) “Resistance, Sinkage and Trim, Wave Profile, and Nominal Wake and Uncertainty Assessment for DTMB Model 5512,” Proc. 25<sup>th</sup> ATTC, Iowa City, IA.