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ITTC Symbols and Terminology List

Version 2021

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Supersedes all previous versions

Updated by the 29th ITTC Quality Systems Group

ITTC Symbols and Terminology List, Version 2021

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NOTE: bold letters are used to denote vectors
Red colour identifies the additions/modifications of this ver4sion of the List

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1. GENERAL
1.1 Fundamental Concepts
1.1.1 Uncertainty

(The following table follows ISO/IEC Guide 98-3:2008 – Annex J)

a		Half-width of a rectangular distribution	Half-width of a rectangular distribution of possible values of input quantity X_i: $a = (a_+ - a\_) / 2$	
a_+		Upper bound	Upper bound, or upper limit, of input quantity X_i:	
$a\_$		Lower bound	Lower bound, or lower limit, of input quantity X_i:	
b_+		Upper bound of the deviation	Upper bound, or upper limit, of the deviation of input quantity X_i from its estimate x_i: $b_+ = a_+ - x_i$	
$b\_$		Lower bound of the deviation	Lower bound, or lower limit, of the deviation of input quantity X_i from its estimate x_i: $b\_ = x_i - a\_$	
c_i		Sensitivity coefficient	$c_i = \partial f/\partial x_i$.	1
f		Function	Functional relationship between measurand Y and input quantities X_i on which Y depends, and between output estimate y and input estimates x_i on which y depends.	1
$\partial f/\partial x_i$		Partial derivative	Partial derivative of f with respect to input quantity x_i	1
k		Coverage factor	For calculation of expanded uncertainty $U = ku_c(y)$	1
k_p		Coverage factor for probability p	For calculation of expanded uncertainty $U_p = k_p u_c(y)$	1
n		Number of repeated observations		1
N		Number of input quantities	Number of input quantities X_i on which the measurand Y depends	1
p		Probability	Level of confidence: $0 \le p \le 1.0$	1
q		Random quantity		1
$\overline{q}$		Arithmetic mean or average		1
q_k		kth observation of q	k^{th} independent repeated observation of randomly varying quantity q	1
$r(x_i,x_j)$		Estimated correlation coefficient	$r(x_i, x_j) = u(x_i, x_j)/(u(x_i)\, u(x_j))$	1
s_{p}^2		Pooled estimate of variance		1
s_{p}		Pooled experimental standard deviation	Positive square root of s_{p}^2	1
$s^2(\overline{q})$		Experimental variance of the mean	$s^2(\overline{q}) = s^2(q_k)/n$; estimated variance obtained from a Type A evaluation	1
$s(\overline{q})$		Experimental standard deviation of the mean	Positive square root of $s^2(\overline{q})$	1
$s^2(q_k)$		Experimental variance from repeated observations		1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$s(q_k)$		Experimental standard deviation of repeated observations	Positive square root of $s^2(q_k)$	1
$s^2(\overline{X}_i)$		Experimental variance of input mean	From mean $\overline{X}_i$, determined from n independent repeated observations $X_{i,k}$, estimated variance obtained from a Type A evaluation.	1
$s(\overline{X}_i)$		Standard deviation of input mean	Positive square root of $s^2(\overline{X}_1)$	1
$s(\overline{q},\overline{r})$		Estimate of covariance of means		1
$s(\overline{X}_i,\overline{X}_j)$		Estimate of covariance of input means		1
$t_p(v)$		Inverse Student t	Student t-distribution for v degrees of freedom corresponding to a given probability p	1
$t_p(v_{\text{eff}})$		Inverse Student t for effective degrees of freedom	Student t-distribution for v_{eff} degrees of freedom corresponding to a given probability p in calculation of expanded uncertainty U_p	1
$u^2(x_i)$		Estimated variance	Associated with input estimate x_i that estimates input quantity X_i	1
$u(x_i)$		Standard deviation	Positive square root of $u^2(x_i)$	1
$u(x_i,x_j)$		Estimated covariance		1
$u_c^2(y)$		Combined variance	Combined variance associated with output estimate y	1
$u_c(y)$		Combined standard uncertainty	Positive square root of $u_c^2(y)$	1
$u_{cA}(y)$		Combined standard uncertainty from Type A	From Type A evaluations alone	1
$u_{cB}(y)$		Combined standard uncertainty from Type B	From Type B evaluations alone	1
$u_c(y_i)$		Combined standard uncertainty	Combined standard uncertainty of output estimate y_i when two or more measurands or output quantities are determined in the same measurement	1
${}_I u_i^2(y)$		Component of combined variance	$u_i^2(y) \equiv [c_i u(x_i)]^2$	1
${}_I u_i(y)$		Component of combined standard uncertainty	$u_i(y) \equiv \lvert c_i \rvert u(x_i)$	1
$u(x_i)/\lvert x_i \rvert$		Relative standard uncertainty of output estimate x		1
$u_c(y)/\lvert y \rvert$		Relative combined standard uncertainty of output estimate y		
$[u(x_i)/\lvert x_i \rvert]^2$		Estimated relative variance	Estimated relative variance associated with input estimate x_i	
$[u_c(y)/\lvert y \rvert]^2$		Relative combined variance	Relative combined variance associated with output estimate y	
$u(x_i,x_j))/\lvert x_i\, x_j \rvert$		Estimated relative covariance	Estimated relative covariance associated with input estimates x_i and x_j	

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
U		Expanded uncertainty	Expanded uncertainty of output estimate y that defines an interval $Y = y \pm U$ having a high level of confidence, equal to coverage factor k times the combined standard uncertainty $u_c(y)$ of y: $U = k\, u_c(y)$	
U_p		Expanded uncertainty associated to confidence level p	Expanded uncertainty of output estimate y that defines an interval $Y = y \pm U_p$ having a high level of confidence p, equal to coverage factor k_p times the combined standard uncertainty $u_c(y)$ of y: $U_p = k_p\, u_c(y)$	
x_i		Estimate of input quantity X_i	Estimate of input quantity X_i NOTE when x_i is determined from the arithmetic mean or average of n independent repeated observation $x_i = \overline{X}_i$ $x_i = \overline{X}_i$	
X_i		i^{th} input quantity	i^{th} input quantity on which measurand Y depends NOTE X_i may be the physical quantity or the random variable	
$\overline{X}_i$		Estimate of the value of input quantity X_i	Estimate of the value of input quantity X_i equal to the arithmetic mean or average of n independent repeated observation $X_{i,k}$ of X_i	
$X_{i,k}$		k^{th} independent repeated observation of X_i		
y		Estimated of measurand Y or Result of a measurement or Output estimate		
y_i		Estimate of measurand Y_i	Estimate of measurand Y_i when two or more measurands are determined in the same measurement	
Y		A measurand. Estimated relative uncertainty of standard uncertainty $u(x_i)$ of inputs estimate x_i		
μ_p		Expectation or mean of the probability distribution	Expectation or mean of the probability distribution of random-varying quantity q	
ν		Degrees of freedom (general)		
ν_i		Degrees of freedom	Degrees of freedom, or effective degrees of freedom of standard	

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
			uncertainty $u(x_i)$ of input estimate x_i	
ν_{eff}		Effective degrees of freedom	Effective degrees of freedom of $u_c(y)$ used to obtain $t_p(\nu_{eff})$ for calculating expanded uncertainty U_p	
σ^2		Variance of a probability	Variance of a probability distribution of (for example) a randomly-variing quantity q, estimated by $s^2(q_k)$	
σ		Standard deviation of a probability distribution	Standard deviation of a probability distribution, equal to the positive square root of σ^2	
$\sigma^2\left(\bar{q}\right)$		Variance of $\bar{q}$ $\bar{q}$	Variance of $\bar{q}$, equal to σ^2 / n, estimated by $s^2\left(\bar{q}\right)=\frac{s^2\left(\overline{q_k}\right)}{n}$ $s^2(\bar{q})=\frac{s^2(q_k)}{n}$	
$\sigma\left(\bar{q}\right)$		Standard deviation of $\bar{q}$	Standard deviation of $\bar{q}$, equal to the positive root of $\sigma^2(\bar{q})$	
$\sigma^2\left[s\left(\bar{q}\right)\right]$		Variance of experimental standard deviation $s\left(\bar{q}\right)$ $s(\bar{q})$ of $\bar{q}$		
$\sigma\left[s\left(\bar{q}\right)\right]$		Standard deviation of experimental standard deviation $s(\bar{q})$ of $\bar{q}$, equal to the positive square root of $\sigma^2\left[s\left(\bar{q}\right)\right]$ $\sigma^2[s(\bar{q})]$		

1.1.2 Coordinates and Space Related Quantities

Orientation of coordinates

A problem of general interest, the orientation of the axes of coordinate systems, has been treated extensively in the Report of the 17th ITTC Information Committee. The present QS Group recommends that the orientations of the coordinate systems chosen for convenience should be stated explicitly in any case. The coordinate system orientation should not be inferred from the symbols and/or names of the concepts or from national or professional traditions. All sign conventions of related Quantities should be consistent with the orientation chosen.

For ready reference the recommendation of the 17th ITTC Information Committee is quoted in the following.

"In order to adapt ITTC nomenclature to common practice a proposal for a standard coordinate system was published in the newsletter No 7, March 1983, to generate discussion. The response was quite diverse. On the one hand it was suggested that instead of the two orthogonal right handed systems with the positive x-axis forward and the positive z-axis either up- or downward as proposed only one system should be selected, in particular the one with the positive z-axis upwards. On the other hand the attention of the Information Committee was drawn to the fact that in ship flow calculations neither of the two systems proposed is customary. Normally the x-axis is directed in the main flow direction, i.e. backwards, the y-axis is taken positive to starboard and the z-axis is positive upwards. The origin of the co-ordinates in this case is usually in the undisturbed free surface half way between fore and aft perpendicular.

In view of this state of affairs the Information Committee (now Quality System Group - QSG) may offer the following recommendation, if any:

Axes, coordinates

Preferably, orthogonal right handed systems of Cartesian co-ordinates should be used, orientation and origin in any particular case should be chosen for convenience.

Body axes (x,y,z)

ISO Standard 31-11 makes the following suggestions

Coordinate systems fixed in bodies, ocean platforms, or ships.

For the definition of hull forms and ocean wave properties and the analysis of structural deflections it is customary to take the x-axis positive forward and parallel to the reference or base line used to describe the body's shape, the y-axis positive to port, and the z-axis positive upwards.

For seakeeping and manoeuvrability problems the co-ordinate system is defined as follows: usually the x-axis as before the y-axis positive to starboard, and the z-axis positive downwards, the origin customarily at the centre of mass of the vehicle or at a geometrically defined position.

For ship flow calculations usually the x-axis positive in the main flow direction, i.e. backwards, the y-axis positive to starboard, and the z-axis positive upwards, the origin customarily at the intersection of the plane of the undisturbed free-surface, the centre plane, and the midship section.

Fixed or space axes (x_0,y_0,z_0)

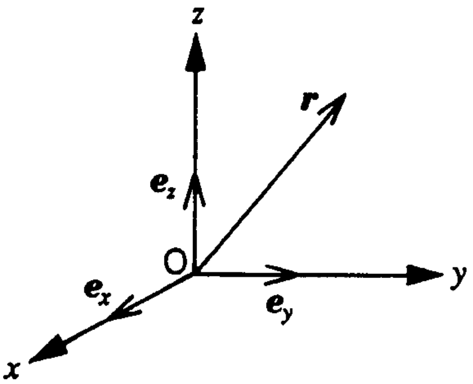
Coordinate systems fixed in relation to the earth or the water. For further references see ISO Standard 1151/1 ...6: Terms and symbols for flight dynamics.

There may be other coordinate systems in use and there is no possibility for the adoption of a single system for all purposes. Any problem requires an adequate coordinate system and transformations between systems are simple, provided that orientations and origins are completely and correctly documented for any particular case."

Origins of coordinates

In seakeeping and manoeuvrability problems customarily the centre of mass of the vehicle is chosen as the origin of the coordinates. This is in most cases not necessarily advantageous, as all the hydrodynamic properties entering the problems are related rather to the geometries of the bodies under investigation. So any geometrically defined point may be more adequate for the purposes at hand.

Item No.	Coordinates	Position vector and its differential	Name of coordinate system	Remarks
11-12.1 (-)	x, y, z	$\boldsymbol{r} = x\boldsymbol{e}_x + y\boldsymbol{e}_y + z\boldsymbol{e}_z$ $\mathrm{d}\boldsymbol{r} = \mathrm{d}x\, \boldsymbol{e}_x + \mathrm{d}y\, \boldsymbol{e}_y + \mathrm{d}z\, \boldsymbol{e}_z$	cartesian coordinates	$\boldsymbol{e}_x$, $\boldsymbol{e}_y$ and $\boldsymbol{e}_z$ form an orthonormal right-handed system. See Figure 1.
11-12.2 (-)	ρ, φ, z	$\boldsymbol{r} = \rho\boldsymbol{e}_\rho + z\boldsymbol{e}_z$ $\mathrm{d}\boldsymbol{r} = \mathrm{d}\rho\, \boldsymbol{e}_\rho + \mathrm{d}\varphi\, \boldsymbol{e}_\varphi + \mathrm{d}z\, \boldsymbol{e}_z$	cylindrical coordinates	$\boldsymbol{e}_\rho(\varphi)$, $\boldsymbol{e}_\varphi(\varphi)$ and $\boldsymbol{e}_z$ form an orthonormal right-handed system. See Figures 2 and 3. If $z = 0$, then ρ and φ are the polar coordinates
11-12.3 (-)	r, ϑ, φ	$r = r\boldsymbol{e}_r;$ $\mathrm{d}\boldsymbol{r} = \mathrm{d}r\, \boldsymbol{e}_r + r\, \mathrm{d}\vartheta\, \boldsymbol{e}_\vartheta +$ $r \sin\vartheta\, \mathrm{d}\varphi\, \boldsymbol{e}_\varphi$	spherical coordinates	$\boldsymbol{e}_r(9, gyp)$, $\boldsymbol{e}_\vartheta(\vartheta, \varphi)$ and $\boldsymbol{e}_\varphi(\varphi)$ form an orthonormal right-handed system. See Figures 2 and 4.
NOTE 1 If, exceptionally, a left-handed system is used for certain purposes, this shall be clearly stated to avoid the risk of sign errors.				



The x-axis is pointing towards the viewer.

Figure 1 – Right-handed Cartesian coordinate system

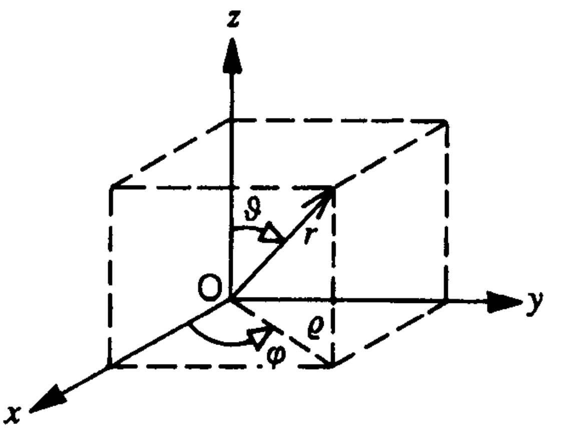


Figure 2 – Oxyz is a right-handed coordinate system

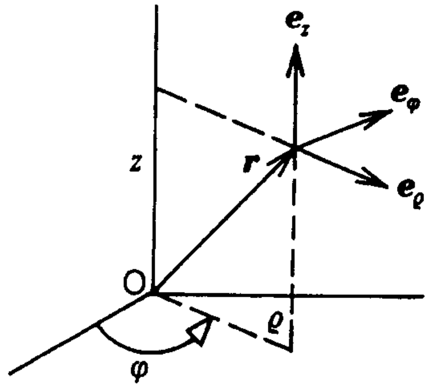


Figure 3 – Right-handed cylindrical coordinates

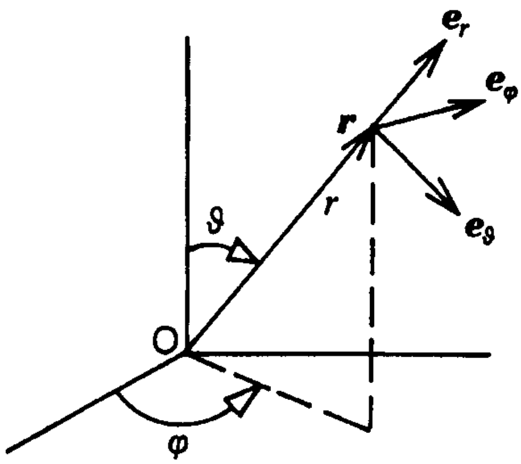


Figure 4 – Right-handed spherical coordinates

1.1.2.1 Basic Quantities

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
s	S	Any scalar quantity distributed, maybe singularly, in space	$\int ds$	
S^0_{ij}	SM0(I,J)	Zero[th] order moment of a scalar quantity	$\int \delta_{ij} ds = \delta_{ij} S$	
S^1_{ij}	SM1(I,J)	First order moment of a scalar quantity, formerly static moments of a scalar distribution	$\int \varepsilon_{ikj} x_k ds$	
S^2_{ij}	SM2(I,J)	Second moment of a scalar quantity, formerly moments of inertia of a scalar distribution	$\int \varepsilon_{kli} x_l \varepsilon_{jkm} x_m ds$	
S_{uv}	S(U,V)	Generalized moment of a scalar quantity distributed in space	$S_{ij} = S^0_{ij}$ $S_{i,\,3+j} = {S^1_{ij}}^T$ $S_{3+i,\,j} = S^1_{ij}$ $S_{3+i,\,3+j} = S^2_{ij}$	
T_{ij}	T(I,J)	Tensor in space referred to an orthogonal system of Cartesian coordinates fixed in the body	$T_{ij}^s + T_{ij}^a$	
T_{ij}^{A}	TAS(I,J)	Anti-symmetric part of a tensor	$(T_{ij} - T_{ji})/2$	
T_{ij}^{S}	TSY(I,J)	Symmetric part of a tensor	$(T_{ij} + T_{ji})/2$	
T_{ij}^{T}	TTR(I,J)	Transposed tensor	T_{ji}	
$T_{ij}\, v_j$		Tensor product	$\Sigma\, T_{ij}\, v_j$	
$u_i,\ v_i$	U(I), V(I)	Any vector quantities		
$u_i\ v_i$	UVPS	Scalar product	$u_i v_i$	
$u_i\ v_j$	UVPD(I,J)	Diadic product	$u_i v_j$	
$u \times v$	UVPV(I)	Vector product	$\varepsilon_{ijk} u_j v_k$	
V^0_i, V_i	V0(I),V(I)	Zeroth order moments of a vector quantity distributed in space, referred to an orthogonal system of Cartesian coordinates fixed in the body	$\int dv_i$	
V^1_i	V1(I)	First order moments of a vector distribution	$\int \varepsilon_{ijk} x_j dv_k$	
V_u	V(U)	Generalized vector	$V_i = V^0_i$ $V_{3+i} = V^1_i$	
$x,\ x_1$ $y,\ x_2$ $z,\ x_3$	X, X(1) Y, X(2) Z, X(3)	Body axes and corresponding Cartesian coordinates	Right-hand orthogonal system of coordinates fixed in the body	m
$x_0,\ x_{01}$ $y_0,\ x_{02}$ $z_0,\ x_{03}$	X0, X0(1) Y0, X0(2) Z0, X0(3)	Space axes and corresponding Cartesian coordinates	Right-hand orthogonal system of coordinates fixed in relation to the space	m
$x_{\mathrm{F}},\ x_{\mathrm{F1}}$ $y_{\mathrm{F}},\ x_{\mathrm{F2}}$ $z_{\mathrm{F}},\ x_{\mathrm{F3}}$	XF, XF(1) YF, XF(2) ZF, XF(3)	Flow axes and corresponding Cartesian coordinates	Right-hand orthogonal system of coordinates fixed in relation to the flow	m
ε_{ijk}	EPS(I,J,K)	Epsilon operator	+1 : ijk = 123, 231, 312 1 : ijk = 321, 213, 132 0 : if otherwise	
δ_{ij}	DEL(I,J)	Delta operator	+1 : ij = 11, 22, 33 0 : if otherwise	

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.1.3 Time and Frequency Domain Quantities

1.1.3.1 Basic Quantities

a	ADMP	Damping	s^r, in Laplace variable	1/s
f	FR	Frequency		Hz
f_C	FC	Basic frequency in repeating functions	$1 / T_C$	Hz
f_S	FS	Frequency of sampling	$1 / T_S$ period in repeating spectra	Hz
i	I	Imaginary unit	sqrt(-1)	1
I	IM	Imaginary variable		1
j	J	Integer values	$-\infty \ldots +\infty$	1
R	R	Complex variable	$\exp(s\ T_S)$ Laurent transform	
s	S	Complex variable	$a + 2\pi i f$ Laplace transform	1/s
t	TI	Time	$-\infty \ \ldots +\infty$	s
t_j	TI(J)	Sample time instances	$j\ T_S$	
T_C	TC	Period of cycle	$1 / f_C$ duration of cycles in periodic, repeating processes	s
T_S	TS	Period of sampling	Duration between samples	s
x	x	Values of real quantities	$x(t)$	
X		Real "valued" function		
x_j	X(J)	Variables for samples values of real quantities	$x(t_j) = \int x(t)\delta(t - t_j)dt$	
z	Z	Complex variable		

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.1.3.2 Complex Transforms

x^A	XA	Analytic function	$X^A(t) = X(t) + iX^H(t)$	
x^{DF}	XDF	Fourier transform of sampled function	$X^{DF}(f) = \Sigma x_j exp(-i2\pi fjT_S)$ i.e. periodically repeating $= X(0)/2 + f_S \Sigma X^F(f + jf_S)$ sample theorem: aliasing!	
x^{DL}	XDL	Laurent transform of sampled function	$X^{DL}(s) = \Sigma x_j \exp(-sjT_S)$	
x^F	XFT	Fourier transform	$X^F(f) = \int X(t)\exp(-i2\pi ft)dt$ inverse form: $= \int X^F(f)\exp(-i2\pi ft)dt$ if $X(t) = 0$ and a = 0 then $X^F(f)=X^L(f)$	
$x^F{}_j$	XFT(J)	Fourier transform of periodic function	$1/T_C \int X(t)\exp(-i2\pi jt/T_C)dt$ $t = 0 \,..\, T_C$ $X^F = \Sigma x^F{}_j \delta(f - j/T_C)$ inverse form: $X(t) = \Sigma x^F{}_j \exp(-i2\pi fjT_C)$	
x^H	XHT	Hilbert transform	$X^H(t) = 1/\pi \int X(\tau)/(t - \tau)d\tau$	
x^{HF}	XHF	Fourier transform of Hilbert transform	$X^{HF}(f) = X^F(f)(-i \operatorname{sgn} f)$ $(1/t)^F = -i \operatorname{sgn} f$	
x^L	XLT	Laplace transform	$X^L(s) = \int X(t)\exp(-st)dt$ if $X(t<0) = 0$ then $= (X(t)\exp(-at))^F$	
x^R	XRT	Laurent transform	$X^R(r) = \Sigma x_j r^{-j} = X^{DL}$	
x^S	XS	Single-sided complex spectra	$X^S(f) = X^F(f)(1 + \operatorname{sgn} f)$ $= X^{AF}$ i.e. $= 0$ for $f < 0$	
$x^S{}_j$	XS(J)	Single-sided complex Fourier series	$X^F{}_j(1 + \operatorname{sgn} j)$ line spectra	

1.1.3.3 Complex Quantities

z^a	ZAM	Amplitude	$\text{mod}(z) = \text{sqrt}(z^{r2}+z^{i2})$	
z^c	ZRE	Real or cosine component	$z^c = \text{real}(z) = z^a\cos(z^p)$	
z^i	ZIM	Imaginary or sine component	$\text{imag}(z) = z^a\sin(z^p) = z^s$	
z^j	ZCJ	Conjugate	$z^r - iz^i$	
z^l	ZLG	(Phase) Lag		
z^p	ZPH	Phase	$\text{arc}(z) = \text{arctg}(z^i / z^r)$	
z^r	ZRE	Real or cosine component	$\text{real}(z) = z^a\cos(z^p) = z^c$	
z^s	ZIM	Imaginary or sine component	$z^s = \text{imag}(z) = z^a\sin(z^p)$	

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.1.4 Random Quantities and Stochastic Processes

1.1.4.1 Random Quantities

g^{E}, g^{M}, g^{MR}	*G*MR	Expected value of a function of a random quantity	$E(g) = \int g(x) f_x(x) dx$ $x = -\infty \ldots \infty$	
x, y	*X, Y*	Random quantities	$x(\zeta)$, $y(\zeta)$	
x_i, y_i	*X*(I), *Y*(I)	Samples of random quantities	i = 1... n n : sample size	
$(x^m)^E$	*X*mMR	m-th moment of a random quantity	$(x^m)^{\mathrm{E}}$	
x^{D}, x^{DR}, σ_x	*X*DR	Standard deviation of a random quantity	$x^{\mathrm{VR}\ 1/2}$	
x^{DS}, s_x	*X*DS	Sample deviation of a random quantity	$x^{\mathrm{VS}\ 1/2}$, unbiased random estimate of the standard deviation	
xx^{R}, xx^{MR}, R_{xx}	*XX*MR	Auto-correlation of a random quantity	$x\, x^{\mathrm{E}}$	
xy^{R}, xy^{MR}, R_{xy}	*XY*MR	Cross-correlation of two random quantities	$x\, y^{\mathrm{E}}$	
x^{E}, x^{M}, x^{MR}, μ_x	*X*MR	Expectation or population mean of a random quantity	$E(x)$	
x^{A}, x^{MS}, m_x	*X*MS	Average or sample mean of a random quantity	$1/n\ \Sigma\ x_i$, $i = 1 \ldots n$ unbiased random estimate of the expectation with $x^{\mathrm{AE}} = x^{\mathrm{E}}$ $x^{\mathrm{VSE}} = x^{\mathrm{V}} / n$	
x^{PD}, f_x	*X*PD	Probability density of a random quantity	$d\, F_x / dx$	
xy^{PD}, f_{xy}	*XY*PD	Joint probability density of two random quantities	$\partial^2 F_{xy} / (\partial x\, \partial y)$	
x^{PF}, F_x	*X*PF	Probability function (distribution) of a random quantity		1
xy^{PF}, F_{xy}	*XY*PF	Joint probability function (distribution) function of two random quantities		1
x^{V}, x^{VR}, xx^{VR}	XVR, XXVR	Variance of a random quantity	$x^{2\ \mathrm{E}} - x^{\mathrm{E}\ 2}$	
x^{VS}, xx^{VS}	*X*VS, *XX*VS	Sample variance of a random quantity	$1/(n-1)\ \Sigma\ (x_i - x^{\mathrm{A}})^2$ $i = 1 \ldots n$ unbiased random estimate of the variance $x^{\mathrm{VSE}} = x^{\mathrm{V}}$	
xy^{V}, xy^{VR}	*XY*VR	Variance of two random quantities	$x\, y^E - x^E\, y^E$	
ζ		Outcome of a random "experiment"		

1.1.4.2 Stochastic Processes

g^{MR}	*G*MR	Mean of a function of a random quantity	$M(g(t)) = \lim(1/T \int g(t) dt)$ $t = -T/2 \ldots +T/2$ $T = -\infty \ldots +\infty$	
g^{MS}	*G*MS	Average or sample mean of a function of a random quantity	$A(g(t)) = 1/T \int g(t) dt$ $t = 0 \ldots +T$	
x, y	*X, Y*	Stationary stochastic process	$x(\zeta,t)$, $y(\zeta,t)$	
xx^{C}, xx^{CR}, C_{xx}	*XX*CR	Auto-covariance of a stationary stochastic process	$(x(t) - x^{\mathrm{E}})(x(t+\tau) - x^{\mathrm{E}})^{\mathrm{E}}$	

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
xy^{C}, xy^{CR}, C_{xy}	*XY*CR	Cross-covariance of two stationary stochastic processes	$(x(t) - x^{E})(y(t + \tau) - y^{E})^{E}$	
xx^{R}, xx^{RR}, R_{xx}	*XX*RR	Auto-correlation of a stationary stochastic process	$x(t)x(t + \tau)^{E} = R_{xx}(\tau)$ $R_{xx}(\tau) = R_{xx}(-\tau)$ if x is ergodic: $R_{xx}(\tau) = x(t)x(t + \tau)^{MR}$ $R_{xx}(\tau) = \int S_{xx}(\omega)\cos(\omega\tau)d\tau$ $\tau = 0 \dots \infty$	
xy^{R}, R_{xy}	*XY*RR	Cross-correlation of two stationary stochastic processes	$x(t)y(t + \tau)^{E} = R_{xy}(\tau)$ $R_{yx}(\tau) = R_{xy}(-\tau)$ if x, y are ergodic: $R_{xy}(\tau) = x(t)y(t + \tau)^{MR}$	
xx^{S}, S_{xx}	*XX*SR	Power spectrum or autospectral power density of a stochastic process	xx^{RRSR}	
xy^{S}, S_{xy}	*XY*SR	Cross-power spectrum of two stationary stochastic processes	xy^{RRSR}	
τ	TICV	Covariance or correlation time		s
ζ		Outcome of a random "experiment"		

1.1.4.3 Probability Operators (Superscripts)

A, MS	MS	Average, sample mean
C, CR	CR	Population covariance
CS	CS	Sample covariance
D, DR	DR	Population deviation
DS	DS	Sample deviation
E, M, MR	MR	Expectation, population mean
PD	PD	Probability density
PF	PF	Probability function
S	SR	(Power) Spectrum
SS	SS	Sample spectrum
R, RR	RR	Population correlation
RS	RS	Sample correlation
V, VR	VR	Population variance
VS	VS	Sample variance

1.1.5 Balances and System Related Concepts

q	QQ	Quantity of the quality under consideration stored in a control volume		Q^U
Q		Quality under consideration		Q^U/s
Q^C	QCF	Convective flux		Q^U/s
Q^D	QDF	Diffusive flux		Q^U/s
Q^F	QFL	Total flux across the surface of the control volume	Inward positive!	Q^U/s
Q^M		Molecular diffusion		Q^U/s
Q^P	QPN	Production of sources in the control volume		Q^U/s
Q^S	QRT	Storage in the control volume, rate of change of the quantity stored	dq / dt	Q^U/s
Q^T	QDT	Turbulent diffusion		Q^U/s

1.2 Solid Body Mechanics

1.2.1 Inertial and Hydrodynamic Properties

1.2.1.1 Basic Quantities

A_{ij}	AM(I,J)	Added mass coefficient in *i*th mode due to *j*th motion		
B_{ij}	DA(I,J)	Damping coefficient in *i*th mode due to *j*th motion		
C_{ij}	RF(I,J)	Restoring force coefficient in *i*th mode due to *j*th motion		
D^{h}_{uv}	DH(U,V)	Generalized hydrodynamic damping	$\partial F_u^h / \partial V_v$	
F^{h}_{u}	FH(U)	Generalized hydrodynamic force		
I^{h}_{uv}	IH(U,V)	Generalized hydrodynamic inertia	$\partial F_u^h / \partial \dot{V}_v$	
I_L	IL	Longitudinal second moment of water-plane area	About transverse axis through centre of floatation	m^4
I_T	IT	Transverse second moment of water-plane area	About longitudinal axis through centre of floatation	m^4
I_y , I_{yy} , $m^2{}_{22}$, m_{55}	IY, IYY, M2(2,2), MA(5,5)	Pitch moment of inertia around the principal axis *y*		kg m^2
I_z , I_{zz} , $m^2{}_{33}$, m_{66}	IZ, IZZ, M2(3,3), MA(6,6)	Yaw moment of inertia around the principal axis z		kg m^2
I_{xy} , I_{12} I_{yz} , I_{23} I_{zx} , I_{31}	IXY, I2(1,2) IYZ, I2(2,3) IZX, I2(3,1)	Real products of inertia in case of non-principal axes		kg m^2
k_x, k_{xx} k	RDGX	Roll radius of gyration around the principal axis *x*	$(I_{xx}/m)^{1/2}$	m
k_y, k_{yy}	RDGY	Pitch radius of gyration around the principal axis *y*	$(I_{yy}/m)^{1/2}$	m
k_z, k_{zz}	RDGZ	Yaw radius of gyration around the principal axis *z*	$(I_{zz}/m)^{1/2}$	m
m	MA	mass		kg
$m^0{}_{ij}$, m_{ij}	M0(I,J), MA(I,J)	Zero-th moments of mass, i.e. inertia distribution, mass tensor	$m_{ij} = m\ \delta_{ij}$	kg
$m^1{}_{ij}$	M1(I,J)	First moments of mass, i.e. inertia distribution	Alias static moments of mass	kg m
$m^2{}_{ij}$, I_{ij}	M2(I,J), IN(I,J)	Second moments of mass, i.e. inertia distribution	Alias mass moments of inertia	kg m^2
M_{uv}	MA(U,V)	Generalized mass, i. e. generalized inertia tensor of a (rigid) body referred to a body fixed coordinate system	$M_{ij} = M^0{}_{ij}$ $M_{i,\,3+j} = M^{1T}{}_{ij}$ $M_{3+i,\,j} = M^1{}_{ij}$ $M_{3+i\,,\,3+j} = M^2{}_{ij}$	

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.2.2 Loads

1.2.2.1 External Loads

F_u	F(U)	Force, generalized, load, in body coordinates	$M^F{}_u = M^M{}_u$ $F_i = F^0{}_i$ $F_{3+i} = F^1{}_i$	N
g_u	G(U)	Gravity field strength, generalized, in body coordinates	$g_i = g^1{}_i$ $g_{3+i} = 0$	m/s^2
g_i	G1(I)	Gravity field strength, in body coordinates!		m/s^2
K, M_x, $F^1{}_1, F_4$	K, M(1), F1(1), F(4)	Moment around body axis x		Nm
M, M_y, $F^1{}_2, F_5$	M, M(2), F1(2), F(5)	Moment around body axis y		Nm
N, M_z, $FN^1{}_3, F_6$	N, M(3), F1(3), F(6)	Moment around body axis z		Nm
X, F_x, $F^0{}_1, F_1$	X, FX, F0(1), F(1)	Force in direction of body axis x		Nm
Y, F_y, $F^0{}_2, F_2$	Y, FY, F0(2), F(2)	Force in direction of body axis y		Nm
Z, F_z, $F^0{}_3, F_3$	Z, FZ, F0(3), F(3)	Force in direction of body axis z		Nm
G_u	G(U)	Gravity or weight force, generalized, in body co-ordinates!	$G_u = m_{uv}\, g_v$	N
G^0i, G_i	G0(I)	Gravity or weight force in body coordinates!	$G_i = G^0{}_i = m^0{}_{ij}\, g_j$ $= mg_i$	N
$G^1{}_i$	G1(I)	Gravity or weight moment in body coordinates!	$G_{3+i} = G^1{}_i = \varepsilon_{ikj}\, x_k\, G^0{}_j$ $= m^1{}_{ij}\, g_j$	Nm
q	UNQ	Load per unit length		N/m
w	WPUL	Weight per unit length	dW / dx_1	N/m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.2.2.2 Sectional Loads

F^{S}_{u}	FS(U)	Force or load acting at a given planar cross-section of the body, generalized, in section coordinates!	$F^{S}_{i} = F^{S0}_{i}$ $F^{S}_{3+i} = F^{S1}_{i} = M^{B}_{i}$	N Nm
F^{S}_{i}	FS(I)	Shearing force	F^{S0}_{2} , F^{S0}_{3}	N
F^{T}	FT, FS(1)	Tensioning or normal force	F^{S0}_{1}	N
M^{B}_{i}	MB(I)	Bending moment	F^{S1}_{2} , F^{S1}_{3}	Nm
M^{T}	MT, MB(1)	Twisting or torsional moment	F^{S1}_{1}	Nm

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.2.3 Rigid Body Motions

1.2.3.1 Motions

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$\boldsymbol{L}$	L	Angular momentum	$\boldsymbol{L} = I\boldsymbol{\omega}\ (= r^2 mv)$	Kg m s^{-1}
$\boldsymbol{P}$	P	Linear momentum	$\boldsymbol{P} = m\,\boldsymbol{v}$	Kg m s^{-1}
p , ω_x , v^0_1 , v_4	P, OMX, V0(1), V(4)	Rotational velocity around body axis x		rad/s
q , ω_y , v^0_2 , v_5	Q, OMY, V0(2), V(5)	Rotational velocity around body axis y		rad/s
r , ω_z , v^0_3 , v_6	R, OMZ, V0(3), V(6)	Rotational velocity around body axis z		rad/s
u , v_x , v^1_1 , v_1	U, VX, V1(1), V(1)	Translatory velocity in the direction of body axis x		m/s
v , v_y , v^1_2 , v_2	V, VY, V1(2), V(2)	Translatory velocity in the direction of body axis y		m/s
w , v_z , v^1_3 , v_3	W, VZ, V1(3), V(3)	Translatory velocity in the direction of body axis z		m/s
v_u	V(U)	Components of generalized velocity or motion relative to body axes	$v_i = v^1_i$ $v_{3+i} = v^0_i$	m/s rad/s
$\dot{p}$ $\dot{q}$ $\dot{r}$	PR QR RR	Rates of change of components of rotational velocity relative to body axes		rad/s^2
$\dot{u}$ $\dot{v}$ $\dot{w}$	UR VR WR	Rates of change of components of linear velocity relative to body axes		m/s^2
α	AA	Angular acceleration	$d\omega/dt$	rad/s^2

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.2.3.2 Attitudes

α	AT ALFA	Angle of attack	The angle of the longitudinal body axis from the projection into the principal plane of symmetry of the velocity of the origin of the body axes relative to the fluid, positive in the positive sense of rotation about the y-axis	rad
β	DR BET	Angle of drift or side-slip	The angle to the principal plane of symmetry from the velocity vector of the origin of the body axes relative to the fluid, positive in the positive sense of rotation about the z-axis	rad
γ	RO GAMR	Projected angle of roll or heel	The angular displacement about the x_o axis of the principal plane of symmetry from the vertical, positive in the positive sense of rotation about the x_o axis	rad
φ	X(4) RO PHIR	Angle of roll, heel or list	Positive in the positive sense of rotation about the x-axis	rad
θ	X(5) TR TETP	Angle of pitch or trim	Positive in the positive sense of rotation about the y-axis	rad
ψ	X(6) YA PSIY	Angle of yaw, heading or course	Positive in the positive sense of rotation about the z-axis	rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.3 Fluid Mechanics

1.3.1 Flow Parameters

1.3.1.1 Fluid Properties

c	CS	Velocity of sound	$(E / \rho)^{1/2}$	m/s
E	EL	Modulus of elasticity		Pa
w	WD	Weight density	ρg (See 1.1.1)	
κ	CK	Kinematic capillarity	σ / ρ	m^3/s^2
μ	VI	Viscosity		kg/ms
ν	VK	Kinematic viscosity	μ / ρ	m^2/s
ρ	DN, RHO	Mass density		kg/m^3
σ	CA	Capillarity	Surface tension per unit length	kg/s^2

1.3.1.2 Flow parameters

Bo	BN	Boussinesq number	$V / (g R_H)^{1/2}$	1
Ca	CN	Cauchy number	$V / (E / \rho)^{1/2}$	1
Fr	FN	Froude number	$V / (g L)^{1/2}$	1
Fr_h	FH	Froude depth number	$V / (g h)^{1/2}$	1
Fr_∇	FV	Froude displacement number	$V / (g \nabla^{1/3})^{1/2}$	1
Ma	MN	Mach number	V / c	1
Re	RN	Reynolds number	$V L / \nu$	1
$Re_{0.7}$	RN07	Propeller Reynolds number at 0.7 R	$Re_{0.7} = \dfrac{c_{0.7}\sqrt{V_A^2 + (0.7\pi nD)^2}}{\nu}$	1
St	SN	Strouhal number	$f L / V$	1
Th	TN	Thoma number, Cavitation number	$(p_A - p_V)/q$	1
We	WN	Weber number	$V^2 L / \kappa$	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.3.1.3 Boundary conditions

k	HK	Roughness height or magnitude	Roughness height, usually in terms of some average	m
k_s	SK	Sand roughness	Mean diameter of the equivalent sand grains covering a surface	m
R_H	RH	Hydraulic radius	Area of section divided by wetted perimeter	m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.3.2 Flow Fields

1.3.2.1 Velocities etc.

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
e	ED	Density of total flow energy	$\rho V^2 / 2 + p + \rho g h$	Pa
f_i	FS(I)	Mass specific force	Strength of force fields, usually only gravity field g_i	m/s^2
h	HS	Static pressure head	Δz_0 , z_0-axis positive vertical up!	m
H	HT	Total head	$e / w = h + p/w + q/w$	m
p	PR, ES	Pressure, density of static flow energy		Pa
p_0	P0	Ambient pressure in undisturbed flow		Pa
q	PD, EK	Dynamic pressure, density of kinetic flow energy,	$\rho V^2 / 2$	Pa
Q	QF, QFLOW	Rate of flow	Volume passing across a control surface in time unit	m^3/s
S_{H}	THL	Total head loss		m
s^{R}_{ij}	SR(I,J)	Turbulent or Reynolds stress	$\rho\, v_i v_j^{\mathrm{CR}}$	Pa
s_{ij}	ST(I,J)	Total stress tensor	Density of total diffusive momentum flux due to molecular and turbulent exchange	Pa
s^{V}_{ij}	SV(I,J)	Viscous stress		Pa
$u,\ v_x ,v_1$ $v,\ v_y ,v_2$ $w,\ v_z ,v_3$	VX, V1 VY, V2 VZ, V3	Velocity component in direction of x, y, z axes		m/s
v_i	V(I)	Velocity		m/s
V	VA	Velocity	$V = v_i v_i^{1/2}$	m/s
V_0	V0	Velocity of undisturbed flow		m/s
τ_w	TAUW	Wall shear stress	$\mu\ (\partial U / \partial y)_{y=0}$	Pa

1.3.2.2 Circulation etc.

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
Γ^{n}	CN	Normalized circulation	$\Gamma / (\pi D V)$ π is frequently omitted	1
I	ID	Induction factor	Ratio between velocities induced by helicoidal and by straight line vortices	1
Γ	VD	Vortex density	Strength per length or per area of vortex distribution	m/s
Γ	CC	Circulation	$\int V\, ds$ along a closed line	m^2/s
Φ	PO	Potential function		m^2/s
Ψ	SF	Stream function	ψ = const is the equation of a stream surface	m^3/s

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.3.3 Lifting Surfaces

1.3.3.1 Geometry

A	AP	Projected area	$b\ c_M$	m^2
b	SP	Wing or foil span		m
b_F	BSPF	Flap span		m
c_M	CHME	Mean chord length	$A\ /\ b$	m
c_T	CHTP	Tip chord length		m
c_r	CHRT	Root chord length		m
f_L	FML	Camber of lower side (general)		m
f_U	FMU	Camber of upper side		m
γ	ANSW	Sweep angle		rad
δ_s	ANSL	Slat deflection angle		rad
δ	DELTT	Thickness ratio of foil section (general)	$t\ /\ c$	1
δ_B	DELTB	Thickness ratio of trailing edge of struts	$t_B\ /\ c_S$	1
δ_F	DELTF	Camber ratio of mean line (general)	$f\ /\ c$	1
δ_{FL}	DLTFL	Angle of flap deflection		rad
δ_L	DELTL	Camber ratio of lower side of foil	$f_L\ /\ c$	1
δ_S	DELTS	Thickness ratio of strut	$t_S\ /\ c_S$	1
δ_{STH}	DELTT	Theoretical thickness ratio of section	$t_S\ /\ c_{STH}$	1
δ_U	DELTU	Camber ratio of upper side	$f_U\ /\ c$	1
λ	TA	Taper ratio	$c_t\ /\ c_r$	1
Λ	AS	Aspect ratio	$b^2\ /\ A$	1

1.3.3.2 Flow angles etc

V_I	VI	Induced velocity		m/s
V_T	VT	Resultant velocity of flow approaching a hydrofoil	Taking vortex induced velocities into account	m/s
α	AA, ALFA	Angle of attack or incidence	Angle between the direction of undisturbed relative flow and the chord line	rad
α_{EFF}	AAEF, ALFE	Effective angle of attack or incidence	The angle of attack relative to the chord line including the effect of induced velocities	rad
α_G	AAGE, ALFG	Geometric angle of attack or incidence	The angle of attack relative to the chord line neglecting the effect of induced velocities	rad
α_H	AAHY, ALFI	Hydrodynamic angle of attack	In relation to the position at zero lift	rad
α_I	AAID, ALFS	Ideal angle of attack	For thin airfoil or hydrofoil, angle of attack for which the streamlines are tangent to the mean line at the leading edge. This condition is usually referred to as "shock-free" entry or "smooth"	rad
α_0	AAZL, ALF0	Angle of zero lift	Angle of attack or incidence at zero lift	rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.3.3.3 Forces

D_{F}	DRF	Foil drag	Force in the direction of motion of an immersed foil	N
D_{I}	DRIND	Induced drag	For finite span foil, the component of lift in the direction of motion	N
D_{INT}	DRINT	Interference drag	Due to mutual interaction of the boundary layers of intersecting foil	N
D_{P}	DRSE	Section or profile drag at zero lift	Streamline drag	N
L_{F}	LF	Lift force on foil	$C_L A_{\mathrm{FT}} q$	N
L_0	LF0	Lift force for angle of attack of zero	$C_{L0} A_{\mathrm{FT}} q$	N

1.3.3.4 Sectional coefficients

C_D	CDSE	Section drag coefficient		1
$C_{D\mathrm{I}}$	CDSI	Section induced drag coefficient		1
C_L	CLSE	Section lift coefficient		1
C_{L0}	CLSE0	Section lift coefficient for angle of attack of zero		1
C_M	CMSE	Section moment coefficient		1
ε	EPSLD	Lift-Drag ratio	L/D	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.3.4 Boundary Layers

1.3.4.1 Two-dimensional Boundary Layers

C_{f}	CFL	Skin friction coefficient	$\tau / (\rho\ U_e^2 / 2)$	1
F	CQF	Entrainment factor	$1 / (U_e\ dQ / dx)$	1
H	HBL	Boundary layer shape parameter	δ^* / Θ	1
H_{E}	HQF	Entrainment shape parameter	$(\delta - \delta^*) / \Theta$	1
p	PR	Static pressure		Pa
P	PT	Total pressure		Pa
Q	QF	Entrainment	$\int_a^b U dy$	$\mathrm{m^2/s}$
Re_{δ^*}	RDELS	Reynolds number based on displacement thickness	$U_\infty \delta^* / \nu$ or $U_e \delta^* / \nu$	1
Re_θ	RTHETA	Reynolds number based on momentum thickness	$U_\infty \Theta / \nu$ or $U_e \Theta / \nu$	1
u	UFL	Velocity fluctuations in boundary layer		m/s
u^s	UFLS	Root mean square value of velocity fluctuations		m/s
u^+	UPLUS	Non-dimensional distance from surface	U / u_τ	1
u_τ	UTAU	Shear (friction) velocity	$(\tau / \rho)^{1/2}$	m/s
U_{m}	UMR	Time mean of velocity in boundary layer		m/s
U_{i}	UIN	Instantaneous velocity		m/s
U_∞	UFS	Free-stream velocity far from the surface		m/s
U_{e}	UE	Velocity at the edge of the boundary layer at $y=\delta_{995}$		m/s
ΔU	UDEF	Velocity defect in boundary layer	$(U_{\mathrm{e}} - U) / u_\tau$	1
y^+	YPLUS	Non-dimensional distance from the wall	$y\ u_\tau / \nu$	1
β	BETE	Equilibrium parameter	$\delta^* / (\tau_w\ dp / dx)$	1
δ_{995}	DEL	Thickness of a boundary layer at $U=0.995U_{\mathrm{e}}$		m
δ^*, δ_1	DELS	Displacement thickness of boundary layer	$\int (U_{\mathrm{e}} - U) / U_{\mathrm{e}}\ dy$	m
K	K	von Karman constant	0.41	1
Λ	PRGR	Pressure gradient parameter	$\delta_{995} / (\nu\ dU_{\mathrm{e}} / dx)$	1
θ^*, δ^{**}	ENTH	Energy thickness	$\int (U / U_{\mathrm{e}}) (1 - U^2 / U_{\mathrm{e}}^2) dy$	m
Θ	THETA	Momentum thickness	$\int (U / U_{\mathrm{e}}) (1 - U / U_{\mathrm{e}}) dy$	m
τ_w	TAUW	Local skin friction	$\mu\ (\partial U / \partial y)_{y=0}$	Pa

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.3.5 Cavitation

1.3.5.1 Flow parameters

a_s	GR	Gas content ratio	α / α_S	1
α	GC	Gas content	Actual amount of solved and undissolved gas in a liquid	ppm
α_S	GS	Gas content of saturated liquid	Maximum amount of gas solved in a liquid at a given temperature	ppm
σ	CNPC	Cavitation number	$(p_A - p_C) / q$	1
σ_I	CNPI	Inception cavitation number		1
σ_V	CNPV	Vapour cavitation number	$(p_A - p_V) / q$	1

1.3.5.2 Flow fields

D_C	DC	Cavity drag		N
l_C	LC	Cavity length	Stream wise dimension of a fully-developed cavitating region	m
p_A	PA	Ambient pressure		Pa
p_{AC}	PACO	Collapse pressure	Absolute ambient pressure at which cavities collapse	Pa
p_{AI}	PAIC	Critical pressure	Absolute ambient pressure at which cavitation inception takes place	Pa
p_C	PC	Cavity pressure	Pressure within a steady or quasi-steady cavity	Pa
p_{CI}	PCIN	Initial cavity pressure	Pressure, may be negative, i.e. tensile strength, necessary to create a cavity	Pa
p_V	PV	Vapour pressure of water	At a given temperature!	Pa
U_I	UNIN	Critical velocity	Free stream velocity at which cavitation inception takes place	m/s
V_L	VOLS	Volume loss	W_L / w	m^3
W_L	WTLS	Weight loss	Weight of material eroded from a specimen during a specified time	N/s
δ_C	HC	Cavity height or thickness	Maximum height of a fully-developed cavity, normal to the surface and the stream-wise direction of the cavity	m

1.3.5.3 Pumps

H_N	HTNT	Net useful head of turbo-engines		m
H_U	HTUS	Total head upstream of turbo-engines		m
$Th,\ \sigma$	TN	Thoma number	$(H_U - p_V / w) / H_N$	1

1.4 Environmental Mechanics

1.4.1 Waves

This section is related to Sections 3.1.2 Time and Frequency Domain Quantities and 3.1.3 Random Quantities and Stochastic Processes.

1.4.1.1 Periodic waves

c_W	VP	Wave phase velocity or celerity	$L_W / T_W = \sqrt{g L_W / 2\pi}$ in deep water	m/s
c_{Wi}	VP(I)	Wave phase velocity of harmonic components of a periodic wave	const = c_W for periodic waves in deep water	m/s
c_G	VG	Wave group velocity or celerity	The average :rate of advance of the energy in a finite train of gravity waves	m/s
f_W	FW	Basic wave frequency	$1 / T_W$	Hz
f_{Wi}	FW(I)	Frequencies of harmonic components of a periodic wave	$i\, f_W$	Hz
H_W	HW	Wave height	The vertical distance from wave crest to wave trough, or twice the wave amplitude of a harmonic wave. η_C - η_T	m
k, κ	WN	Wave number	$2\,\pi / L_W = \omega^2/g$	1/m
L_W , λ_W	LW	Wave length	The horizontal distance between adjacent wave crests in the direction of advance	m
T_W	TW	Basic wave period	Time between the passage of two successive wave crests past a fixed point. $1 / f_W$	s
μ	WD	Wave direction	The angle between the direction of a component wave and the x_0 axis	rad
η	EW	Instantaneous wave elevation at a given location	z-axis positive vertical up, zero at mean water level;	m
$\eta^{\alpha}{}_i$	EWAM(I)	Amplitudes of harmonic components of a periodic wave	$\eta^{FS\alpha}$	m
$\eta^{p}{}_i$, ε_i	EWPH(I)	Phases of harmonic components of a periodic wave	η^{FSp}	rad
η_C	EC	Wave crest elevation		m
η_T	ET	Wave trough depression	Negative values!	m
ζ	DW	Instantaneous wave depression	z-axis positive vertical down, zero at mean water level	m
ζ_A	WAMP	Wave amplitude	Radius of orbital motion of a surface wave particle	m
ω_W, σ	FC	Circular wave frequency	$2\,\pi\, f_W = 2\,\pi / T_W$	rad/s

1.4.1.2 Irregular waves

H_d	HD	Wave height by zero down-crossing	The vertical distance between a successive crest and trough.	m
H_u	HU	Wave height by zero up-crossing	The vertical distance between a successive trough and crest	m
$H_{1/3}$	H13	Significant wave height	Average of the highest one third wave heights	m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$T_{1/3d}$	T13D	Significant wave period	By downcrossing analysis	s
$T_{1/3u}$	T13U	Significant wave period	By upcrossing analysis	s
T_{d}	TD	Wave periods by zero down-crossing	Time elapsing between two successive downward crossings of zero in a record	s
T_{u}	TU	Wave periods by zero up-crossing	Time elapsing between two successive upward crossings of zero in a record	s
η_C	EC	Maximum of elevations of wave crests in a record		m
η_T	ET	Elevations of wave troughs in a record	Negative values!	m
λ_{d}	LD	Wave length by zero down-crossing	The horizontal distance between adjacent down crossing in the direction of advance	m
λ_{u}	LU	Wave length by zero up-crossing	The horizontal distance between adjacent up crossing in the direction of advance	m

1.4.1.3 Time Domain Analysis

H_{WV}	HWV	Wave height estimated from visual observation		m
$H_{W1/3}$	H13	Significant wave height. Sum of significant wave height of swell and wind waves	Average of the highest one third wave heights	m
$H_{1/3\mathrm{S}}$	H13S	Significant wave height of swell	Average of the highest one third wave heights of the swell.	m
$H_{1/3\mathrm{W}}$	H13W	*(environmental mechanics, waves)* Significant wave height of wind waves.	Average of the highest one third wave heights of the wind waves.	m
$H_{1/3\mathrm{u}}$	H13U	Zero up-crossing significant wave height	Average of the highest one third zero up-crossing wave heights	m
H_σ	HWDS	Estimate of significant wave height from sample deviation of wave elevation record		m
L_{WV}	LWV	Wave length estimated by visual observation	Measured in the direction of wave propagation	m
T_{rt}	TRT	Return period	The average interval in years between times that a given design wave is exceeded	
T_{R}	TR	Duration of record	$1 / f_{\mathrm{R}}$	s
T_{S}	TS	Sample interval	$1 / f_{\mathrm{S}}$, time between two successive samples	s
T_{WV}	TWV	Wave period estimated from visual observation		s

1.4.1.4 Frequency Domain Analysis

b	B	Bandwidth of spectral resolution	Sampling frequency divided by the number of transform points	Hz
C_{r}	CRA	Average reflection coefficient		1
$C_{\mathrm{r}}(f)$	CRF	Reflection coefficient amplitude function		1
f_{P}	FRPK	Spectral peak in frequency	Frequency at which the spectrum has its maximum	Hz

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
f_R	FRRC	Frequency resolution	$1 / T_R$	Hz
f_S	FRSA	Sample frequency	$1 / T_S$	Hz
H_{mo}	HMO	Significant wave height based on zeroth moment for narrow banded spectrum	$4\ (m_0)^{1/2}$	m
H_σ	HWDS	Estimate of significant wave height from sample deviation of wave elevation record		m
m_n	MN	n-th moment of wave power spectral density	$\int f^n\ S(f) df$	m^2/ s^n
$S_i(f)$, $S_i(\omega)$	EISF, EISC	Incident wave power spectral density		m^2/Hz
$S_r(f)$, $S_r(\omega)$	ERSF, ERSC	Reflected wave power spectral density		m^2/Hz
$S_\eta(f)$, $S_\eta(\omega)$	EWSF, EWSC	Wave power spectral density		m^2/Hz
T_P	TP	Period with maximum energy	$2\pi f_P$	s
T_{01}	T1	Average period from zeroth and first moment	m_0/m_1	s
T_{02}	T2	Average period from zeroth and second moment	$(m_0/m_2)^{1/2}$	s

1.4.1.5 Directional Waves

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$D_X(f,\theta)$, $D_X(\omega,\mu)$, σ_θ	DIRSF SIGMAOX	Directional spreading function	$S(f,\theta)=S(f)D_X(f,\theta)$ where $\int_0^{2\pi} D_X(f,\theta) d\theta = 1$	rad
f	FR	Frequency	$2\pi\omega=1/T$	Hz
$S_\zeta\ (\omega,\mu)$ $S_\theta\ (\omega,\mu)$ etc.	S2ZET S2TET etc.	Two dimensional spectral density		1
$S_\rho(f,\theta)$ $S_\zeta(\omega,\mu)$	STHETA	Directional spectral density		$m^2/Hz/rad$
θ, μ	CWD	Component wave direction		rad
θ_m	MWD THETAMOX	Mean or dominant wave direction		rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.4.2 Wind

1.4.2.1 Basic Quantities

C_{10}	C10M	Surface drag coefficient	$(0.08 + 0.065U_{10})10^{-3}$	
F	FETCH	Fetch length	Distance over water the wind blows	m
t_{d}	DURATN	Wind duration		s
T_{rt}	TRT	Return period	The average interval in years between times that a given wind speed is exceeded	
u_z , u_{zi}	UFLUCT	Turbulent wind fluctuations		m/s
U_A, u_*	USHEAR	Wind shear velocity	$C_{10}^{1/2}\, U_{10}$ or $0.71U_{10}^{1.23}$	m/s
U_{10}	U10M	Reference mean wind speed at elevation 10 meters above sea surface	$U_{10} = (10/z)^{1/7}\, U_z^A$	m/s
U_z^{A}	UZA	Average wind speed at elevation z above the sea surface	$(U_z + u_{zi})^A$ $U_z^A = (z/10)^{1/7}\, U_{10}$ or $U_z^A = U_{10} + U_A \ln(z/10)$	m/s
V_{WR}	VWREL	Apparent wind velocity	see section 1.4.1	m/s
V_{WT}	VWABS	True wind velocity	see section 1.4.1	m/s
X_{F}	FDIM	Dimensionless Fetch	gF/U_{10}^2	
z	ZSURF	Height above the sea surface in meters		m
β_{WA}	BETWA	Apparent wind angle (relative to vessel course)	see section 2.6	rad
β_{WT}	BETWT	True wind angle (relative to vessel course)	see section 2.6	rad
θ_{W}	TETWI	Wind direction		rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.4.3 Ice Mechanics
1.4.3.1 Basic Quantities

E_I	MEI	Modulus of elasticity of ice		Pa
S_I	SAIC	Salinity of ice	Weight of salt per unit weight of ice	1
S_W	SAWA	Salinity of water	Weight of dissolved salt per unit weight of saline water	1
t_A	TEAI	Temperature of air		°C
t_I	TEIC	Local temperature of ice		°C
t_W	TEWA	Temperature of water		°C
δ_I	ELIC	Deflection of ice sheet	Vertical elevation of ice surface	m
ε_I	STIC	Ice strain	Elongation per unit length	1
$\dot{\varepsilon}_I$	STRTIC	Ice strain rate	$\partial\varepsilon / \partial t$	1/s
μ_I	POIIC	Poisson's ratio of ice		1
v_A	POAI	Relative volume of air	Volume of gas pores per unit volume of ice	1
v_B	POBR	Relative volume of brine	Volume of liquid phase per unit volume of ice	1
v_0	POIC	Total porosity of ice	$v_0 = v_A + v_B$	1
ρ_I	DNIC	Mass density of ice	Mass of ice per unit volume	kg/m^3
ρ_{SN}	DNSN	Mass density of snow	Mass of snow per unit volume	kg/m^3
ρ_W	DNWA	Mass density of water		kg/m^3
ρ_Δ	DNWI	Density difference	$\rho_\Delta = \rho_W - \rho_I$	kg/m^3
σ_{CI}	SCIC	Compressive strength of ice		Pa
σ_{FI}	SFIC	Flexural strength of ice		Pa
σ_{TI}	SNIC	Tensile strength of ice		Pa
τ_{SI}	STIC	Shear strength of ice		Pa

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

1.5 Noise

1.5.1 Underwater Noise

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
d	DIDR	Distance hydrophone to acoustic centre		m
L_p	SPL	Sound pressure level	$L_p = 10 \log_{10}\left(\frac{\bar{p}_{rms}^2}{p_{ref}^2}\right)$ dB, $p_{ref} = 1$ μPa	
L_{s}	SRNL	Underwater sound radiated noise level at a reference distance of 1m	$L_{\mathrm{s}} = L_{\mathrm{p}} + 20 \log_{10}\left[\frac{d}{d_{ref}}\right]$ dB, $d_{ref} = 1$ m	
p	SPRE	Sound pressure		Pa

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2. SHIPS IN GENERAL
2.1 Basic Quantities

a, a^1	AC, A1	Linear or translatory acceleration	dv / dt	m/s^2
A	A, AR, AREA	Area in general		m^2
B	B, BR	Breadth		m
C, F^F_2	FF(2)	Cross force	Force normal to lift and drag (forces)	N
Cc	CC	Cross force coefficient	$C_\mathrm{C} = \dfrac{C}{qA}$	1
D, F^F_1	FF(1)	Resistance, Drag (force)	Force opposing translatory velocity, generally for a completely immersed body	N
d, D	D, DI	Diameter		m
E	E, EN	Energy		J
f	FR	Frequency	$1 / T$	Hz
F, F^0	F, F0	Force		N
g	G, GR	Acceleration of gravity	Weight force / mass, strength of the earth gravity field	m/s^2
h	DE	Depth		m
H	H, HT	Height		m
I	I, IN	Moment of inertia	Second order moment of a mass distribution	kg m^2
L	L, LE	Length		m
L, F^F_3	FF(3)	Lift (force)	Force perpendicular to translatory velocity	N
m	M, MA, MASS	Mass		kg
M, F^1	M1, F1	Moment of forces	First order moment of a force distribution	Nm
M	MO	Momentum		Ns
n, N	FR, N	Frequency or rate of revolution	Alias RPS (RPM in some propulsor applications)	Hz
P	P, PO	Power		W
r, R	RD	Radius		m
R, F^F_1	R, RE, FF(1)	Resistance (force)	Force opposing translatory velocity	N
s	SP	Distance along path		m
t	TI	Time		s
t	TE	Temperature		K
T	TC	Period	Duration of a cycle of a repeating or periodic, not necessarily harmonic process	s
U	U, UN	Undisturbed velocity of a fluid		m/s
v, V^1	V, V1	Linear or translatory velocity of a body	ds / dt	m/s
V	VO	Volume		m^3
w	WD	Weight density, formerly specific weight	$dW / dV = \rho g$	N/m^3
W	WT	Weight (force), gravity force acting on a body		N
γ	MR	Relative mass or weight, in English speaking countries called specific gravity	Mass density of a substance divided by mass density of distilled water at 4°C	1
η	EF, ETA	Efficiency	Ratio of powers	

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
ρ	DN, RHO	Mass density	dm / dV	kg/m^3
ρ_0	RHO0	water density for reference water temperature and salt content		kg/m3
ρ_{A}	DNA, RHOA	Mass density of air	Mass of air per unit volume	kg/m^3
τ	ST, TAU	Tangential stress		Pa
λ	SC	Scale ratio	Ship dimension divided by corresponding model dimension	1
σ	SN, SIGS	Normal stress		Pa
ω	FC, OMF	Circular frequency	$2\ \pi f$	1/s
ω, V^0	V0, OMN	Rotational velocity	$2\ \pi\ n$	rad/s

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.2 Geometry and Hydrostatics

2.2.1 Hull Geometry

2.2.1.1 Basic Quantities

A_{BL}	ABL	Area of bulbous bow in longitudinal plane	The area of the ram projected on the middle line plane forward of the fore perpendicular	m^2
A_{BT}	ABT	Area of transverse cross-section of a bulbous bow (full area port and star-board)	The cross sectional area at the fore perpendicular. Where the water lines are rounded so as to terminate on the forward perpendicular A_{BT} is measured by continuing the area curve forward to the perpendicular, ignoring the final rounding.	m^2
A_M	AM	Area of midship section	Midway between fore and aft perpendiculars	m^2
A_T	ATR	Area of transom (full area port and starboard)	Cross-sectional area of transom stern below the load waterline	m^2
A_V	AV	Area exposed to wind	Area of portion of ship above waterline projected normally to the direction of relative wind	m^2
A_{XV}	AXV	Transverse projected area above the waterline including superstructures	Projected area of the ship above the waterline projected on a transversal plane	m^2
A_W	AW	Area of water-plane		m^2
A_{WA}	AWA	Area of water-plane aft of midship		m^2
A_{WF}	AWF	Area of water-plane forward of midship		m^2
A_X	AX	Area of maximum transverse section		m^2
B	B	Breadth, moulded, of ships hull		m
B_M	BM	Breadth, moulded of midship section at design water line		m
B_T	BTR	Breadth, moulded of transom at design water line		m
B_{WL}	BWL	Maximum moulded breadth at design water line		m
B_X	BX	Breadth, moulded of maximum section area at design water line		m
d, T	T	Draught, moulded, of ship hull		m
d_{KL}	KDROP	Design drop of the keel line	T_{AD} - T_{FD} alias "keel drag" or "slope of keel"	m
D	DEP	Depth, moulded, of a ship hull		m
f	FREB	Freeboard	From the freeboard markings to the freeboard deck, according to official rules	m
i_E	ANEN	Angle of entrance, half	Angle of waterline at the bow with reference to centre plane, neglecting local shape at stem	rad
i_R	ANRU	Angle of run, half	Angle of waterline at the stern with reference to the centre-plane, neglecting local shape of stern frame	rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
L	L	Length of ship	Reference length of ship (generally length between the perpendiculars)	m
L_E	LEN	Length of entrance	From the forward perpendicular to the forward end of parallel middle body, or maximum section	m
L_{OA}	LOA	Length, overall		m
L_{OS}	LOS	Length, overall submerged		m
L_P	LP	Length of parallel middle body	Length of constant transverse section	m
L_{PP}	LPP	Length between perpendiculars		m
L_R	LRU	Length of run	From section of maximum area or after end of parallel middle body to waterline termination or other designated point of the stern	m
L_{WL}	LWL	Length of waterline		m
L_{FS}	LFS	Frame spacing	used for structures	m
L_{SS}	LSS	Station spacing		m
S	S, AWS	Area of wetted surface		m^2
t	TT	Taylor tangent of the area curve	The intercept of the tangent to the sectional area curve at the bow on the midship ordinate	1
T, d	T	Draught, moulded, of ship hull		m
T_A, d_A	TA, TAP	Draught at aft perpendicular		m
T_{AD}	TAD, TAPD	Design draught at aft perpendicular		m
T_F, d_F	TF, TFP	Draught at forward perpendicular		m
T_{FD}	TFD, TFPD	Design draught at forward perpendicular		m
T_H	THUL	Draught of the hull	Maximum draught of the hull without keel or skeg	m
T_M, d_M	TM, TMS	Draught at midship	$(T_A + T_F) / 2$ for rigid bodies with straight keel	m
T_{MD}	TMD, TMSD	Design draught at midship	$(T_{AD} + T_{FD}) / 2$ for rigid bodies	m
T_T	TTR	Immersion of transom	Vertical depth of trailing edge of boat at keel below water surface level	m
∇, V	DISPVOL	Displacement volume	$\Delta / (\rho g) = \nabla_{BH} + \nabla_{AP}$	m^3
∇_{BH}	DISPVBH	Displacement volume of bare hull	$\Delta_{BH} / (\rho g)$	m^3
∇_{APP}	DISPVAP	Displacement volume of appendages	$\Delta_{AP} / (\rho g)$	m^3
Δ	DISPF	Displacement force (buoyancy)	$g \rho \nabla$	N
Δ_{BH}	DISPFBH	Displacement force (buoyancy) of bare hull	$g \rho \nabla_{BH}$	N
Δ_{APP}	DISPFAP	Displacement force (buoyancy) of appendages	$g \rho \nabla_{AP}$	N
Δ_m	DISPM	Displacement mass	$\rho \nabla$	kg
λ	SC	Linear scale of ship model	$\lambda = L_S / L_M = B_S / B_M = T_S / T_M$	1

2.2.1.2 Derived Quantities

B^C	CIRCB	R.E. Froude's breadth coefficient	$B / \nabla^{1/3}$	1
C_B	CB	Block coefficient	$\nabla / (L B T)$	1
C_{GM}	CGM	Dimensionless $\overline{GM}$ coefficient	$\overline{GM} / \nabla^{1/3}$	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
C_{GZ}	CGZ	Dimensionless $\overline{GZ}$ coefficient	$\overline{GZ}\ /\nabla^{1/3}$	1
C_{KG}	CKG	Dimensionless $\overline{KG}$ coefficient	$\overline{KG}\ /T$	1
C_{IL}	CWIL	Coefficient of inertia of water plane, longitudinal	$12\ I_L / (B L^3)$	1
C_{IT}	CWIT	Coefficient of inertia of water plane, transverse	$12\ I_T / (B^3 L)$	1
C_M	CMS	Midship section coefficient (midway between forward and aft perpendiculars)	$A_M / (B\ T)$	1
C_P	CPL	Longitudinal prismatic coefficient	$\nabla / (A_X L)$ or $\nabla / (A_M L)$	1
C_{PA}	CPA	Prismatic coefficient, after body	$\nabla_A / (A_X L / 2)$ or $\nabla_A / (A_M L / 2)$	1
C_{PE}	CPE	Prismatic coefficient, entrance	$\nabla_E / (A_X L_E)$ or $\nabla_E / (A_M L_E)$	1
C_{PF}	CPF	Prismatic coefficient fore body	$\nabla_F / (A_X L / 2)$ or $\nabla_F / (A_M L / 2)$	1
C_{PR}	CPR	Prismatic coefficient, run	$\nabla_R / (A_X L_R)$ or $\nabla_R / (A_M L_R)$	1
C_S	CS	Wetted surface coefficient	$S / (V L)^{1/2}$	1
C_{VP}	CVP	Prismatic coefficient vertical	$\nabla / (A_W T)$	1
C_{WA}	CWA	Water plane area coefficient, aft	$A_{WA} / (B L / 2)$	1
C_{WF}	CWF	Water plane area coefficient, forward	$A_{WF} /(B L / 2)$	1
C_{WP}	CW	Water plane area coefficient	$A_W /(L B)$	1
C_X	CX	Maximum transverse section coefficient	$A_X / (B\ T)$, where B and T are measured at the position of maximum area	1
C_∇	CVOL	Volumetric coefficient	∇ / L^3	1
f_{BL}	CABL	Area coefficient for bulbous bow	$A_{BL} / (L\ T)$	1
f_{BT}	CABL	Taylor sectional area coefficient for bulbous bow	A_{BT} / A_X	1
f_T	ATR	Sectional area coefficient for transom stern	A_T / A_X	1
M^C	CIRCM	R.E. Froude's length coefficient, or length-displacement ratio	$L / \nabla^{1/3}$	1
S^C	CIRCS	R.E. Froude's wetted surface area coefficient	$S/\nabla^{2/3}$	1
T^C	CIRCT	R.E. Froude's draught coefficient	$T / \nabla^{1/3}$	1

2.2.1.3 Symbols for Attributes and Subscripts

A	AB	After body
AP	AP	After perpendicular
APP	APP	Appendages
B	BH	Bare hull
	DW	Design waterline
E	EN	Entry
F	FB	Fore body
FP	FP	Fore perpendicular
FS	FS	Frame spacing
H	HE	Hull
	LR	Reference Line
LP	LP	Based on LPP
LW	LW	Based on LWL

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
M	MS	Midships		
	PB	Parallel body		
R	RU	Run		
SS	SS	Station spacing		
W	WP	Water plane		
S	WS	Wetted surface		

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.2.2 Propulsor Geometry
2.2.2.1 Screw Propellers

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
A_D	AD	Developed blade area	Developed blade area of a screw propeller outside the boss or hub	m^2
A_E	AE	Expanded blade area	Expanded blade area of a screw propeller outside the boss or hub	m^2
A_0	AO	Propeller Disc Area	$\pi D^2 / 4$	m^2
A_P	AP	Projected blade area	Projected blade area of a screw propeller outside the boss or hub	m^2
a_D	ADR	Developed blade area ratio	A_D / A_0	1
a_E	ADE	Expanded blade area ratio	A_E / A_0	1
a_P	ADP	Projected blade area ratio	A_P / A_0	1
c	LCH	Chord length		m
$c_{0.7}$	C07	Chord length	Chord length at r/R=0.7	m
c_LE	CHLE	Chord, leading part	The part of the Chord delimited by the Leading Edge and the intersection between the Generator Line and the pitch helix at the considered radius	m
c_M	CHME	Mean chord length	The expanded or developed area of a propeller blade divided by the span from the hub to the tip	m
c_S	CS	Skew displacement	The displacement between middle of chord and the blade reference line. Positive when middle chord is at the trailing side regarding the blade reference line	m
c_TE	CHTE	Chord, trailing part	The part of the Chord delimited by the Trailing Edge and the intersection between the Generator Line and the pitch helix at the considered radius	m
d_h	DH	Boss or hub diameter	$2\ r_\mathrm{h}$	m
d_ha	DHA	Hub diameter, aft	Aft diameter of the hub, not considering any shoulder	m
d_hf	DHF	Hub diameter, fore	Fore diameter of the hub, not considering any shoulder	m
D	DP	Propeller diameter		m
f	FBP	Camber of a foil section		m
G_Z	GAP	Gap between the propeller blades	$2\ \pi\ r \sin(\varphi) / z$	m
h_0	HO	Immersion	The depth of submergence of the propeller measured vertically from the propeller centre to the free surface	m
H_TC	HTC	Hull tip clearance	Distance between the propeller sweep circle and the hull	m
i_G, R_k(ISO)	RAKG	Rake	The displacement from the propeller plane to the generator line in the direction of the shaft axis. Aft displacement is positive rake.	m
i_S	RAKS	Rake, skew-induced	The axial displacement of a blade section which occurs when the propeller is skewed. Aft displacement is positive rake	m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
i_T	RAKT	Rake, total	The axial displacement of the blade reference line from the propeller plane $i_G + i_S = c_S \sin\varphi$ Positive direction is aft.	m
l_h	LH	Hub length	The length of the hub, including any fore and aft shoulder	m
l_{ha}	LHA	Hub length, aft	Length of the hub taken from the propeller plane to the aft end of the hub including aft shoulder	m
l_{hf}	LHF	Hub length, fore	Length of the hub taken from the propeller plane to the fore end of the hub including fore shoulder	m
N_P	NPR	Number of propellers		1
p	PDR	Pitch ratio	P / D	1
P	PITCH	Propeller pitch in general		m
r	LR	Blade section radius		m
r_h	RH	Hub radius		m
R	RDP	Propeller radius		m
t	TM	Blade section thickness		m
t_0	TO	Thickness on axis of propeller blade	Thickness of propeller blade as extended down to propeller axis	m
x_B	XBDR	Boss to diameter ratio	d_h / D	
x_P	XP	Longitudinal propeller position	Distance of propeller centre forward of the after perpendicular	m
y_P	YP	Lateral propeller position	Transverse distance of wing propeller centre from middle line	m
Z, z	NPB	Number of propeller blades		1
z_P	ZP	Vertical propeller position	Height of propeller centre above base line	m
α	AA	Angle of inclination of the propeller shaft	Angle between propeller shaft and horizontal	deg
ε, ψ^{bP}	PSIBP	Propeller axis angle measured to body fixed coordinates	Angle between reference line and propeller shaft axis	rad
θ_s	TETS	Skew angle	The angular displacement about the shaft axis of the reference point of any blade section relative to the generator line measured in the plane of rotation. It is positive when opposite to the direction of ahead rotation	rad
θ	RAKA	Angle of rake		rad
θ_{EXT}	TEMX	Skew angle extent	The difference between maximum and minimum local skew angle	rad
φ	PHIP	Pitch angle of screw propeller	arctg $(P / (2\,\pi\,R))$	1
φ_F	PHIF	Pitch angle of screw propeller measured to the face line		1
ψ^{aP}	PSIAP	Propeller axis angle measured to space fixed coordinates	Angle between horizontal plane and propeller shaft axis	rad
τ_B		Blade thickness ratio	t_0 / D	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.2.2.2 Ducts

A_{DEN}	ADEN	Duct entry area		m^2
A_{DEX}	ADEX	Duct exit area		m^2
d_D	CLEARD	Propeller tip clearance	Clearance between propeller tip and inner surface of duct	m
f_D	FD	Camber of duct profile		m
L_D	LD	Duct length		m
L_{DEN}	LDEN	Duct entry part length	Axial distance between leading edge of duct and propeller plane	m
L_{DEX}	LDEX	Duct exit length	Axial distance between propeller plane and trailing edge of duct	m
t_D	TD	Thickness of duct profile		m
α_D	AD	Duct profile-shaft axis angle	Angle between nose-tail line of duct profile and propeller shaft	rad
β_D	BD	Diffuser angle of duct	Angle between inner duct tail line and propeller shaft	rad

2.2.2.3 Waterjets (see also section 1.3.5)

A_n, A_6		Nozzle discharge area		m^2
A_s		Cross sectional area at station *s*		m^2
D		Impeller diameter (maximum)		m
D_n		Nozzle discharge diameter		m
H_{ij}		Head between station *i* and *j*		m
H_{JS}		Jet System Head	$\frac{P_{JSE}}{Q_J}$	m
h_{1A}		maximum height of cross sectional area of stream tube at station 1A		m
K_H		Head coefficient:	$\frac{gH}{n^2 D^5}$	1

2.2.2.4 Pods

A_{PB}	APB	Wetted Surface Area of Pod Main Body		m^2
A_{PBF}	APBF	Wetted Surface Area of Bottom Fin		m^2
A_{PS}	APS	Wetted Surface Area of Strut		m^2
C_{BFTC}	CBFTC	Thickness Cord Ratio of Bottom Fin		1
C_{STC}	CSTC	Thickness Cord Ratio of Strut		1
D_{PB}	DPB	Maximum Diameter of Pod Body		m
L_{PB}	LPB	Length of Pod Main Body		m
L_{PBF}	LPBF	Length of Bottom Fin	Code length of bottom fin under pod main body	m
L_{PS}	LPS	Length of Upper Strut	Code length of strut between forward edge and aft edge	m
T_{PBS}	TPBS	Bottom Thickness of Strut		m

2.2.2.5 Operators and identifiers

a	absolute (space) reference	(superscript)
b	body axis reference	(superscript)
P	propeller shaft axis	(subscript)
D	Duct	(subscript)

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.2.3 Appendage Geometry

Related information may be found in Section 3.3.3 on Lifting Surfaces.

2.2.3.1 Basic Quantities

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
A_{C}	AC	Area under cut-up		m^2
A_{FB}	AFB	Area of bow fins		m^2
A_{FR}	AFR	Frontal area	Projected frontal area of an appendage	m^2
A_{RF}	AF	Projected flap area		m^2
A_{R}	ARU	Lateral rudder area	Area of the rudder, including flap	m^2
A_{RX}	ARX	Lateral area of the fixed part of rudder		m^2
A_{RP}	ARP	Lateral area of rudder in the propeller race		m^2
A_{RT}	ART	Total lateral rudder area	$A_{RX} + A_{Rmov}$	m^2
A_{FS}	AFS	Projected area of stern fins		m^2
A_{SK}	ASK	Projected skeg area		m^2
S_{WBK}	SWBK	Wetted surface area of bilge keels		m^2
c	CH	Chord length of foil section		m
c_{M}	CHME	Mean chord length	A_{RT} / S	m
c_{R}	CHRT	Chord length at the root		m
c_{T}	CHTP	Chord length at the tip		m
f	FM	Camber of an aerofoil or a hydrofoil	Maximum separation of median and nose-tail line	m
L_{F}	LF	Length of flap or wedge	Measured in direction parallel to keel	m
t	TMX	Maximum thickness of an aerofoil or a hydrofoil	Measured normal to mean line	m
α_{FB}	ANFB	Bow fin angle		rad
α_{FS}	ANFS	Stern fin angle		rad
δ_{F}	DELFS	Flap angle (general)	Angle between the planing surface of a flap and the bottom before the leading edge	rad
δ_{W}	DELWG	Wedge angle	Angle between the planing surface of a wedge and the bottom before the leading edge	rad
δ_{FR}	ANFR	Flanking rudder angle		rad
δ_{FRin}	ANFRIN	Assembly angle of flanking rudders	Initial angle set up during the assembly as zero angle of flanking rudders	rad
δ_{R}	ANRU	Rudder angle		rad
δ_{RF}	ANRF	Rudder-flap angle		rad
λ_{R}	TARU	Rudder taper	c_{T} / c_{R}	1
λ_{FR}	TAFR	Flanking rudder taper		1
Λ_{R}	ASRU	Rudder aspect ratio	b_{R}^{2} / A_{RT}	1
Λ_{FR}	ASRF	Flanking rudder aspect ratio		

2.2.3.2 Identifiers for Appendages (Subscripts)

BK	Bilge keel
BS	Bossing
FB	Bow foil
FR	Flanking rudder
FS	Stern foil
KL	Keel
RU	Rudder
RF	Rudder flap

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
	SA	Stabilizer		
	SH	Shafting		
	SK	Skeg		
	ST	Strut		
	TH	Thruster		
	WG	Wedge		

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.2.4 Hydrostatics and Stability

2.2.4.1 Points and Centres (Still under construction)

A		Assumed centre of gravity above keel used for cross curves of stability		
b		Centre of flotation of added buoyant layer or centre of lost buoyancy of the flooded volume		
B		Centre of buoyancy	Centroid of the underwater volume	
F		Centre of flotation of the water plane		
g		Centre of gravity of an added or removed weight (mass)		
G		Centre of gravity of a vessel		
K		Keel reference		
M		Metacentre of a vessel	See subscripts for qualification	
X_{CB} , L_{CB}	XCB	Longitudinal centre of buoyancy (LCB)	Longitudinal distance from reference point to the centre of buoyancy, B such as X_{MCF} from Midships	m
X_{CF} , L_{CF}	XCF	Longitudinal centre of flotation (LCF)	Longitudinal distance from reference point to the centre of flotation, F such as X_{MCF} from Midships	m
x_{Cb}	XACB	Longitudinal centre of buoyancy of added buoyant layer	Longitudinal distance from reference point to the centre of buoyancy of the added buoyant layer, *b* such as x_{MCb} from Midships	m
x_{Cf}	XACF	Longitudinal centre of flotation of added buoyant layer	Longitudinal distance from reference point to the centre of flotation of the added buoyant layer, *f* such as x_{MCf} from Midships	m
x_{Cg}	XACG	Longitudinal centre of gravity of added weight (mass)	Longitudinal distance from reference to the centre of gravity, *g*, of an added or removed weight (mass) such as x_{MCg} from Midships	m
X_{CG} , L_{CG}	XCG	Longitudinal centre of gravity (LCG)	Longitudinal distance from a reference point to the centre of gravity, G such as X_{MCG} from Midships	m
Y_{CG}	YCG	Lateral displacement of centre of gravity (YCG)	Lateral distance from a reference point to the centre of gravity, G	m
Z	ZRA	Intersection of righting arm with line of action of the centre of buoyancy		
Z_{CB}	ZCB	Vertical centre of buoyancy	Vertical distance from reference point to the centre of buoyancy, B	m

2.2.4.2 Static Stability levers

$\overline{AB}$	XAB	Longitudinal centre of buoyancy from aft perpendicular	Distance of centre of buoyancy from aft perpendicular	m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$\overline{AF}$	XAF	Distance of centre of flotation from aft perpendicular		m
$\overline{AG}_{\mathrm{L}}$	XAG	Longitudinal centre of gravity from aft perpendicular	Distance of centre of gravity from aft perpendicular	m
$\overline{AG}_{\mathrm{T}}$	YAG	Transverse distance from assumed centre of gravity A, to actual centre of gravity G		m
$\overline{AG}_{\mathrm{V}}$	ZAG	Vertical distance from assumed centre of gravity A, to actual centre of gravity G		m
$\overline{AZ}$	YAZ	Righting arm based on horizontal distance from assumed centre of gravity A, to Z	Generally tabulated in cross curves of stability	m
$\overline{BM}$	ZBM	Transverse metacentre above centre of buoyancy	Distance from the centre of buoyancy B to the transverse metacentre M. $\overline{BM} = I_T / \nabla = \overline{KM} - \overline{KB}$	m
$\overline{BM}_L$	ZBML	Longitudinal metacentre above centre of buoyancy	$\overline{KM}_L - \overline{KB}$	
$\overline{FB}$	XFB	Longitudinal centre of buoyancy, L_{CB}, from forward perpendicular	Distance of centre of buoyancy from forward perpendicular	m
$\overline{FF}$	XFF	Longitudinal centre of floatation, L_{CF}, from forward perpendicular	Distance of centre of flotation from forward perpendicular	m
$\overline{FG}$	XFG	Longitudinal centre of gravity from forward perpendicular	Distance of centre of gravity from forward perpendicular	m
$\overline{GG}_{\mathrm{H}}$	GGH	Horizontal stability lever caused by a weight shift or weight addition		m
$\overline{GG}_{\mathrm{L}}$	GGL	Longitudinal stability lever caused by a weight shift or weight addition		m
$\overline{GG}_1$, $\overline{GG}_{\mathrm{V}}$	GG1, GGV	Vertical stability lever caused by a weight shift or weight addition	$\overline{KG}_1 = \overline{KG}_0 + \overline{GG}_1$	m
$\overline{GM}$	GM	Transverse metacentric height	Distance of centre of gravity to the metacentre $\overline{KM} - \overline{KG}$	m
$\overline{GM}_{\mathrm{EFF}}$	GMEFF	Effective transverse metacentric height	$\overline{GM}$ corrected for free surface and/or free communication effects	m
$\overline{GM}_{\mathrm{L}}$	GML	Longitudinal centre of metacentric height	Distance from the centre of gravity G to the longitudinal metacentre M_L $\overline{GM}_{\mathrm{L}} = \overline{KM}_{\mathrm{L}} - \overline{KG}$	m
$\overline{GZ}$	GZ	Righting arm or lever	$\overline{GZ} = \overline{AZ} - \overline{AG}_{\mathrm{V}} \sin\varphi - \overline{AG}_{\mathrm{T}} \cos\varphi$	m
$\overline{GZ}_{\mathrm{MAX}}$	GZMAX	Maximum righting arm or lever		m
$\overline{KA}$	ZKA	Assumed centre of gravity above moulded base or keel	Distance from the assumed centre of gravity A to the moulded base or keel K	m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$\overline{KB}$	ZKB	Centre of buoyancy above moulded base or keel	Distance from the centre of buoyancy B to the moulded base or keel K	m
$\overline{KG}$	ZKG	Centre of gravity above moulded base or keel	Distance from centre of gravity G to the moulded base or keel K	m
$\overline{Kg}$	ZKAG	Vertical centre of gravity of added or removed weight above moulded base or keel	Distance from centre of gravity, g, to the moulded base or keel K	m
$\overline{KM}$	ZKM	Transverse metacentre above moulded base or keel	Distance from the transverse metacentre M to the moulded base or keel K	m
$\overline{KM}_L$	ZKML	Longitudinal metacentre above moulded base or keel	Distance from the longitudinal metacentre M_L to the moulded base or keel K	m
l	XTA	Longitudinal trimming arm	x_{CG} - x_{CB}	m
t	YHA	Equivalent transverse heeling arm	Heeling moment /Δ	m

2.2.4.3 Derived Quantities

C_{GM}	CGM	Dimensionless $\overline{GM}$ coefficient	$\overline{GM}\,/\nabla^{1/3}$	1
C_{GZ}	CGZ	Dimensionless $\overline{GZ}$ coefficient	$\overline{GZ}\,/\nabla^{1/3}$	1
C_{KG}	CKG	Dimensionless $\overline{KG}$ coefficient	$\overline{KG}\,/T$	1
C_{MTL}	CMTL	Longitudinal trimming coefficient	Trimming moment divided by change in trim which approximately equals $\overline{BM}_L\,/\,L$	1

2.2.4.4 Intact and Damage (Flooded) Stability

C_{MTL}	CMTL	Longitudinal trimming coefficient	trimming moment divided by change in trim which approximately equals $\overline{BM}_L\,/\,L$	1
f	FREB	Freeboard	From the freeboard markings to the freeboard deck, according to official rules	m
A_{SI}, I_{AS}	ASI	Attained subdivision index	(to be clarified)	1
M_S	MS	Moment of ship stability in general	$\Delta\overline{GZ}$ Other moments such as those of capsizing, heeling, etc. will be represented by MS with additional subscripts as appropriate	Nm
m	SHIPMA	Ship mass	$W\,/\,g$	kg
M_{TC}	MTC	Moment to change trim by one centimetre		Nm/cm
M_{TM}	MTM	Moment to change trim by one meter	ΔC_{MTL}	Nm/m
R_{SI}	RSI	Required subdivision index		1
t_s, t_{KL}	TRIM	Static trim	T_A - T_F - d_{KL}	m
W	SHIPWT	Ship weight	$m\,g$	N
z_{SF}	ZSF	Static sinkage at FP	Caused by loading	m
z_{SA}	ZSA	Static sinkage at AP	Caused by loading	m
z_S	ZS	Mean static sinkage	$(z_{SF} + z_{SA})\,/\,2$	m
δ	D	Finite increment in...	Prefix to other symbol	1
δt_{KL}	DTR	Change in static trim		m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
Δ	DISPF	Displacement (buoyant) force	$g \rho \nabla$	N
Δ_m	DISPM	Displacement mass	$\rho \nabla$	kg
∇	DISPVOL	Displacement volume	$\Delta / (\rho g)$	m^3
∇_{fw}	DISVOLFW	Displacement volume of flooded water	$\Delta f_w / (\rho g)$	m^3
θ_{S}	TRIMS	Static trim angle	$\tan^{-1}((z_{\mathrm{SF}} - z_{\mathrm{SA}}) / L)$	rad
μ	PMVO	Volumetric permeability	The ratio of the volume of flooding water in a compartment to the total volume of the compartment	1
ϕ	HEELANG	Heel angle		rad
ϕ_{F}	HEELANGF	Heel angle at flooding		rad
ϕ_{VS}	HEELANGV	Heel angle for vanishing stability		rad

2.2.4.5 Symbols for Attributes and Subscripts (under construction)

a	apparent
A, att	attained
d, dyn	dynamic
e, EFF	effective
f	false
KL	keel line
L	longitudinal
MAX	maximum
MTL	longitudinal trimming moment
R, req	required (to be clarified)
s	Static
S, sqt	Sinkage, squat
*T*C	Trim in cm
*T*M	Trim in m
T	transverse
V	vertical
0	Initial
ϕ	at heel angle ϕ
θ	at trim angle θ

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.3 Resistance and Propulsion

2.3.1 Hull Resistance

(see also Section 1.4.1 on Waves)

2.3.1.1 Basic Quantities

m	BLCK	Blockage parameter	Maximum transverse area of model ship divided by tank cross section area	1
R_{A}	RA	Model-ship correlation allowance	Incremental resistance to be added to the smooth ship resistance to complete the model-ship prediction	N
R_{AA}	RAA	Air or wind resistance		N
R_{APP}	RAP	Appendage resistance		N
R_{AR}	RAR	Roughness resistance		N
R_{C}	RC	Resistance corrected for difference in temperature between resistance and self-propulsion tests	$R_{\mathrm{TM}}[(1 + k)\, C_{\mathrm{FMC}} + C_{\mathrm{R}}] / [(1 + k)\, C_{\mathrm{FM}} + C_{\mathrm{R}}]$ where C_{FMC} is the frictional coefficient at the temperature of the self-propulsion test	N
R_{F}	RF	Frictional resistance of a body	Due to fluid friction on the surface of the body	N
R_{F0}	RF0	Frictional resistance of a flat plate		N
R_{P}	RP	Pressure resistance	Due to the normal stresses over the surface of a body	N
$R_{P\mathrm{V}}$	RPV	Viscous pressure resistance	Due to normal stress related to viscosity and turbulence	N
R_{R}	RR	Residuary resistance	$R_{\mathrm{T}} - R_{\mathrm{F}}$ *or* $R_{\mathrm{T}} - R_{\mathrm{F0}}$	N
R_{RBH}	RRBH	Residuary resistance of the bare hull		N
R_{S}	RS	Spray resistance	Due to generation of spray	N
R_{T}	RT	Total resistance	Total towed resistance	N
R_{TBH}	RTBH	Total resistance of bare hull		N
R_{V}	RV	Total viscous resistance	$R_{\mathrm{F}} + R_{P\mathrm{V}}$	N
R_{W}	RW	Wave making resistance	Due to formation of surface waves	N
R_{WB}	RWB	Wave breaking resistance	Associated with the breakdown of the bow wave	N
R_{WP}	RWP	Wave pattern resistance		N
S	S	Wetted surface area, underway	$S_{\mathrm{BH}} + S_{\mathrm{APP}}$	m^2
S_0	S0	Wetted surface area, at rest	$S_{\mathrm{BH0}} + S_{\mathrm{APP0}}$	m^2
S_{APP}	SAP	Appendage wetted surface area, underway		m^2
S_{APP0}	SAP0	Appendage wetted surface area, at rest		m^2
S_{BH}	SBH	Bare Hull wetted surface area, underway		m^2
S_{BH0}	SBH0	Bare Hull wetted surface area, at rest		m^2
ΔC_{F}	DELCF	Roughness allowance		1
V	V	Speed of the model or the ship		m/s
V_{K}	VKN	Speed in knots		
V_{WR}	VWR	Wind velocity, relative		m/s
$z_{V\mathrm{F}}$	ZVF	Running sinkage at FP		m
$z_{V\mathrm{A}}$	ZVA	Running sinkage at AP		m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
z_{VM}	ZVM	Mean running sinkage	$(z_{VF} + z_{VA}) / 2$	m
η	EW	Wave Elevation	see 3.4.1	m
θ_V, θ_D	TRIMV	Running (dynamic) trim angle	$\tan^{-1}((z_{VF} - z_{VA}) / L)$	1
τ_W	LSF, TAUW	Local skin friction	see 3.3.4	N/ m^2

2.3.1.2 Derived Quantities

C_A	CA	Incremental resistance coefficient for model ship correlation		1
C_{AA}	CAA	Air or wind resistance coefficient	$R_{AA} / (S q)$ $= C_{DA} \dfrac{\rho_A}{\rho_S} \dfrac{A_V}{S_S} = -C_X \dfrac{\rho_A}{\rho_S} \dfrac{A_V}{S_S}$	1
C_{APP}	CAPP	Appendage resistance coefficient	$R_{APP} / (S q)$	1
C_D	CD	Drag coefficient	$D / (S q)$	1
C_{DA}	CDA	Air or wind resistance coefficient, from wind tunnel tests	$= \dfrac{R_{AA}}{A_V \frac{1}{2} \rho_A V^2}$	1
C_F	CF	Frictional resistance coefficient of a body	$R_F / (S q)$	1
C_{F0}	CF0	Frictional resistance coefficient of a corresponding plate	$R_{F0} / (S q)$	1
C_p	CP	Local pressure coefficient		1
C_{PR}	CPR	Pressure resistance coefficient, including wave effect	$R_P / (S q)$	1
C_{PV}	CPV	Viscous pressure resistance coefficient	$R_{PV} / (S q)$	1
C_R	CR	Residuary resistance coefficient	$R_R / (S q)$	1
C_S	CSR	Spray resistance coefficient	$R_S / (S q)$	1
C_T	CT	Total resistance coefficient	$R_T / (S q)$	1
C_{TL}	CTLT	Telfer's resistance coefficient	$g R L / (\Delta V^2)$	1
C_{TQ}	CTQ	Qualified resistance coefficient	$C_{T\nabla} / (\eta_H \eta_R)$	1
$C_{T\nabla}$	CTVOL	Resistance displacement	$R_T / (\nabla^{2/3} q)$	1
C_V	CV	Total viscous resistance coefficient	$R_V / (S q)$	1
C_W	CW	Wave making resistance coefficient	$R_W / (S q)$	1
C_{WP}	CWP	Wave pattern resistance coefficient, by wave analysis		1
C_X	CXA	Air or wind resistance coefficient, usually from wind tunnel tests	$-R_{AA} / (A_V q_R)$	1
C^C	CIRCC	R.E. Froude's resistance coefficient	$1000 R_T / (\Delta (K^C)^2)$	1
F^C	CIRCF	R.E. Froude's frictional resistance coefficient	$1000 R_F / (\Delta (K^C)^2)$	1
f	FC	Friction coefficient	Ratio of tangential force to normal force between two sliding bodies	1
k	K	Three dimensional form factor on flat plate friction	$(C_V - C_{F0}) / C_{F0}$	1
$k(\theta)$	WDC	Wind direction coefficient	C_{AA} / C_{AA0}	1
K^C	CIRCK	R.E. Froude's speed displacement coefficient	$(4 \pi)^{1/2} Fr_\nabla$ or $(4\pi/g)^{1/2} V_K / \nabla^{1/6}$	
K_R	KR	Resistance coefficient corresponding to K_Q, K_T	$R / (\rho D^4 n^2)$	1
q	PD, EK	Dynamic pressure, density of kinetic flow energy,	$\rho V^2 / 2$ see 3.3.2	Pa

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
q_R	PDWR, EKWR	Dynamic pressure based on apparent wind	$\rho\ V_{WR}^2 / 2$ see 3.4.2	Pa
S^C	CIRCS	R. E. Froude's wetted surface coefficient	$S/\nabla^{2/3}$	1
ε	EPSG	Resistance-displacement ratio in general	R / Δ	1
ε_R	EPSR	Residuary resistance-displacement ratio	R_R / Δ	1

2.3.1.3 Symbols for Attributes and Subscripts

FW	Fresh water
MF	Faired model data
MR	Raw model data
OW	Open water
SF	Faired full scale data
SR	Raw full scale data
SW	Salt water

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.3.2 Ship Performance
2.3.2.1 Basic Quantities

A_{XV}	AXV	Transverse projected area above the waterline including superstructures	Projected area of the ship above the waterline projected on a transversal plane	m^2
F_D	SFC	Friction deduction force in self propulsion test	Towing force applied to a model to correct the model resistance for different *Re* between model and full scale.	N
F_P	FP	Force pulling or towing a ship		N
F_{P0}	FPO	Pull during bollard test		N
k_S	KHS	Roughness height of Hull surface		m
n	N	Frequency, commonly rate of revolution		Hz
P_B	PB	Brake power	Power delivered by prime mover	W
P_{BW}	PBW	Brake power in representative sea condition		W
P_D , P_P	PD, PP	Delivered power, propeller power	$Q\ \omega$	W
P_{DT}	PDT	Delivered Power, corrected using correlation factor	$P_{DT} = C_P \cdot P_{DS}$	W
P_E , P_R	PE, PR	Effective power, resistance power	$R\ V$	W
P_I	PI	Indicated power	Determined from pressure measured by indicator	W
P_S	PS	Shaft power	Power measured on the shaft	W
P_T	PTH	Thrust power	$T\ V_A$	W
Q	Q	Torque	P_D / ω	Nm
R_0	R0	Full scale resistance without overload		N
R_{Tw}	RTW	Total resistance in wind and waves		N
t_V	TV	Running trim		m
V	V	Ship speed		m/s
V_A	VA	Propeller advance speed	Equivalent propeller open water speed based on thrust or torque identity	m/s
V_{ref}	VREF	Design ship speed when the ship is in operation in a calm sea condition (no wind and waves)		m/s
V_w	VW	Design ship speed when the ship is in operation under the representative sea condition		m/s
z_V	ZV	Running sinkage of model or ship		m
ω	V0,OMN	Rotational shaft velocity	$2\ \pi\ n$	1/s

2.3.2.2 Derived Quantities

a	RAUG	Resistance augment fraction	$(T - R_T) / R_T$	1
B_f	BF	Bluntness coefficient	7.5-04-01-01.1	1
C_{ADM}	CADM	Admiralty coefficient	$\Delta^{2/3}\ V^3 / P_S$	1
$C_{D\nabla}$	CDVOL	Power-displacement coefficient	$P_D / (\rho\ V^3\ \nabla^{2/3} / 2)$	1
C_N	CN	Trial correction for propeller rate of revolution at speed identity	n_T / n_S	1
C_{NP}	CNP	Trial correction for propeller rate of revolution at power identity	P_{DT} / P_{DS}	1
C_P	CDP	Trial correction for delivered power		1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
f_w	FWE	Weather factor, a non-dimensional coefficient indicating the decrease of speed in representative sea conditions	$f_w = \frac{\text{speed in wind and waves}}{\text{speed in calm water}} = \frac{V_w}{V_{ref}}$	1
K_1	C1	Ship model correlation factor for propulsive efficiency	η_{DS} / η_{DM}	1
K_2	C2	Ship model correlation factor for propeller rate revolution	n_S / n_M	1
K_{APP}	KAP	Appendage correction factor	Scale effect correction factor for model appendage drag applied at the towing force in a self-propulsion test	1
s_V	SINKV	Sinkage, dynamic	Change of draught, fore and aft, divided by length	1
t_V	TRIMV	Trim, dynamic	Change of the trim due to dynamic condition, divided by length	1
t	THDF	Thrust deduction fraction	$(T - R_T) / T$	1
w	WFT	Taylor wake fraction in general	$(V - V_A) / V$	1
w_F	WFF	Froude wake fraction	$(V - V_A) / V_A$	1
w_Q	WFTQ	Torque wake fraction	Propeller speed V_A determined from torque identity	1
w_R		Effect of the rudder(s) on the wake fraction		1
w_T	WFTT	Thrust wake fraction	Propeller speed, V_A, determined from thrust identity	1
ΔR_{waves}	DRWA	Added wave resistance		N
ΔR_{wind}	DRWI	Added wind resistance		N
Δw	DELW	Ship-model correlation factor for wake fraction	$w_{T,M} - w_{T,S}$	1
Δw_C	DELWC	Ship-model correlation factor with respect to $w_{T,S}$ method formula of ITTC 1978 method		1
x	XLO	Load fraction in power prediction	$\eta_D P_D / P_E - 1$	1
β	APSF	Appendage scale effect factor	Ship appendage resistance divided by model appendage resistance	1
ξ_n		Load variation coefficient of the shaft revolution speed		1
ξ_P		Load variation coefficient of the delivered power		1
ξ_V		Load variation coefficient of the ship speed		1

2.3.2.3 Efficiencies etc.

η_{APP}	ETAAP	Appendage efficiency	P_{Ew0APP} / P_{EwAPP}, R_{TBH} / R_T	1
η_B	ETAB, EFTP	Propeller efficiency behind ship	$P_T / P_D = T V_A / (Q \omega)$	1
η_D	ETAD, EFRP	Quasi-propulsive efficiency coefficient	$P_E / P_D = P_R / P_P$	1
η_{Did}	ETADID	Propulsive efficiency in ideal condition, from model test		1
η_G	ETAG, EFGP	Gearing efficiency		1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
η_H	ETAH, EFRT	Hull efficiency	$P_E / P_T = P_R / P_T$ $= (1 - t) / (1 - w)$	1
η_M	ETAM	Mechanical efficiency of transmission between engine and propeller	P_D / P_B	1
η_O	ETAO, EFTPO	Propeller efficiency in open water	$P_T / P_D = T\,V_A / (Q\,\omega)$ all quantities measured in open water tests	1
η_P	ETAP	Propulsive efficiency coefficient	P_E / P_B	1
η_R	ETAR, EFRO	Relative rotative efficiency	η_B / η_O	1
η_S	ETAS, EFPS	Shafting efficiency	$P_D / P_S = P_P / P_S$	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.3.3 Propulsor Performance

2.3.3.1 Basic Quantities

A_O	AO	Propeller disc area	$\pi D^2 / 4$	m^2
D	DP	Propeller diameter		m
n	FR	Propeller frequency of revolution		Hz
n_T		Propeller rate of revolution, corrected using correlation factor	$n_T = C_N \cdot n_S$	1
k_P	KS	Roughness height of propeller blade surface		m
q_A	QA	Dynamic pressure based on advance speed	$\rho V_A^2 / 2$	Pa
q_S	QS	Dynamic pressure based on section advance speed	$\rho V_S^2 / 2$	Pa
Q_S	QSP	Spindle torque	About spindle axis of controllable pitch propeller $Q_S = Q_{SC} + Q_{SH}$ positive if it increases pitch	Nm
Q_{SC}	QSPC	Centrifugal spindle torque		Nm
Q_{SH}	QSPH	Hydrodynamic spindle torque		Nm
R_U	RU	Pod unit resistance	Resistance of a podded drive unit	N
T	TH	Propeller thrust		N
T_U	TU	Pod unit thrust	Pod unit resistance subtracted from the propeller thrust	N
T_D	THDU	Duct thrust of a ducted propeller unit		N
T_P	THDP	Propeller thrust of a ducted propeller unit		N
T_T	THDT	Total thrust of a ducted propeller unit		N
T_{xP}	TXP	Propeller Thrust along shaft axis		N
T_{yP}	TYP	Propeller normal force in y direction in propeller axis		N
T_{zP}	TZP	Propeller normal force in z direction in propeller axis		N
V_A	VA	Advance speed of propeller		m/s
V_P	VP	Mean axial velocity at propeller plane of ducted propeller		m/s
V_S	VS	Section advance speed at 0.7 R	$(V_A^2 + (0.7\, R\, \omega)^2)^{1/2}$	m/s
Y_U	YU	Pod unit side force		N
γ_i		Resistance fraction for one propeller	The portion of the resistance (load fraction, γ_i) that the ith propeller is responsible for	1
ρ_P	DNP	Propeller mass density		kg/m^3
τ_i		Thrust deduction sensitivity for one propeller	$\tau_i = 1 + \left(\frac{\Delta F}{\Delta T}\right)_i$	1
ω	V0P	Propeller rotational velocity	$2\, \pi\, n$	1/s

2.3.3.2 Derived Quantities

B_P	BP	Taylor's propeller coefficient based on delivered horsepower	$n\, P_D^{½} / V_A^{2.5}$ with n in revs/min, P_D in horsepower, and V_A in kn (obsolete)	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
B_U	BU	Taylor's propeller coefficient based on thrust horsepower	$n\, P_T^{½} / V_A^{2.5}$ with n in revs/min, P_T in horsepower, and V_A in kn (obsolete)	1
C_P	CPD	Power loading coefficient	$P_D / (A_P\, q_A\, V_A)$	1
C_{Q*}	CQS	Torque index	$Q / (A_P\, q_S\, D)$	1
C_{Th}	CTH	Thrust loading coefficient, energy loading coefficient	$T / (A_P\, q_A) = (T_P / A_P) / q_A$	1
C_{T*}	CTHS	Thrust index	$T / (A_P\, q_S)$	1
J	JEI	Propeller advance ratio	$V_A / (D\, n)$	1
J_A , J_H	JA, JH	Apparent or hull advance ratio	$V / (D\, n) = V_H / (D\, n)$	1
J_P	JP	Propeller advance ratio for ducted propeller	$V_P / (D\, n)$	
J_T , J_{PT}	JT, JPT	Advance ratio of propeller determined from thrust identity		1
J_Q , J_{PQ}	JQ, JPQ	Advance ratio of propeller determined from torque identity		1
K_P	KP	Delivered power coefficient	$P_D / (\rho\, n^3\, D^5) = 2\, \pi\, K_Q$	1
K_Q	KQ	Torque coefficient	$Q / (\rho\, n^2\, D^5)$	1
K_{SC}	KSC	Centrifugal spindle torque coefficient	$Q_{SC} / (\rho\, n^2\, D^5)$	1
K_{SH}	KSH	Hydrodynamic spindle torque coefficient	$Q_{SH} / (\rho\, n^2\, D^5)$	1
K_T	KT	Thrust coefficient	$T / (\rho\, n^2\, D^4)$	1
K_{TD}	KTD	Duct thrust coefficient for a ducted propeller unit	$T_D / (\rho\, n^2\, D^4)$	1
K_{TP}	KTP	Propeller thrust coefficient for a ducted propeller unit	$T_P / (\rho\, n^2\, D^4)$	1
K_{TQ}	KTQ	Thrust coefficient achieved by torque identity		1
K_{TT}	KTT	Total thrust coefficient for a ducted propeller unit	$K_{TP} + K_{TD}$	1
K_{Q0}	KQ0	Torque coefficient of propeller converted from behind to open water condition	$K_Q\, \eta_R$	1
K_{QT}	KQT	Torque coefficient of propeller determined from thrust coefficient identity		1
P_J	PJ	Propeller jet power	$\eta_{TJ}\, T\, V_A$	
S_A	SRA	Apparent slip ratio	$1 - V / (n\, P)$	1
S_R	SRR	Real slip ratio	$1 - V_A / (n\, P)$	1
δ	ADCT	Taylor's advance coefficient	$n\, D / V_A$ with n in revs/min, D in feet, V_A in kn	1
η_{JP}	EFJP	Propeller pump or hydraulic efficiency	$P_J / P_D = P_J / P_P$	1
η_{JP0}	ZET0, EFJP0	Propeller pump efficiency at zero advance speed, alias static thrust coefficient	$T / (\rho\, \pi / 2)^{1/3} / (P_D\, D)^{2/3}$	1
η_I	EFID	Ideal propeller efficiency	Efficiency in non-viscous fluid	1
η_{TJ}	EFTJ	Propeller jet efficiency	$2 / (1 + (1 + C_{Th})^{1/2})$	1
η_0 , η_{TP0}	ETA0, EFTP0	Propeller efficiency in open water	$P_T / P_D = T\, V_A / (Q\, \omega)$ all quantities measured in open water tests	1
λ	ADR	Advance ratio of a propeller	$V_A / (n\, D) / \pi = J / \pi$	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
τ	TMR	Ratio between propeller thrust and total thrust of ducted propeller	T_P / T_T	1

2.3.3.3 Induced Velocities etc.

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
U_A	UA	Axial velocity induced by propeller		m/s
U_{AD}	UADU	Axial velocity induced by duct of ducted propeller		m/s
U_{RP}	URP	Radial velocity induced by propeller of ducted propeller		m/s
U_{RD}	URDU	Radial velocity induced by duct of ducted propeller		m/s
U_{AP}	UAP	Axial velocity induced by propeller of ducted propeller		m/s
U_R	UR	Radial velocity induced by propeller		m/s
U_{TD}	UTDU	Tangential velocity induced by duct of ducted propeller		m/s
U_{TP}	UTP	Tangential velocity induced by propeller of ducted propeller		m/s
U_T	UT	Tangential velocity induced by propeller		m/s
β	BETB	Advance angle of a propeller blade section	arctg ($V_A / r\,\omega$)	rad
β_I	BETI	Hydrodynamic flow angle of a propeller blade section	Flow angle taking into account induced velocity	rad
β^*	BETS	Effective advance angle	arctg (V_A/ (0.7 $R\,\omega$))	rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.3.4 Unsteady Propeller Forces

2.3.4.1 Basic Quantities

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
C_{uv}	SI(U,V)	Generalized stiffness		
D_{uv}	DA(U,V)	Generalized damping		
F_u	FG(I)	Generalized vibratory force	u = 1,.., 6 u = 1, 2, 3: force u = 4, 5, 6: moment	N N Nm
F_i	F(I)	Vibratory force	i = 1, 2, 3	N
K_{Fu}	KF(U)	Generalized vibratory force coefficients	According to definitions of K_{Fi} and K_{Mi}	1
K_{Fi}	KF(I)	Vibratory force coefficients	$F_i / (\rho n^2 D^4)$	1
K_{Mi}	KM(I)	Vibratory moment coefficients	$M_i / (\rho n^2 D^5)$	1
K_p	KPR	Pressure coefficient	$p / (\rho n^2 D^2)$	1
M_i	M(I)	Vibratory moment	i = 1, 2, 3	Nm
M_{uv}	MA(U,V)	Generalized mass		
p	PR	Pressure		Pa
R_u	R(U)	Generalized vibratory bearing reaction	u = 1,.., 6 u = 1, 2, 3: force u = 4, 5, 6: moment	N N Nm
V_i	V(I)	Velocity field of the wake	i = 1, 2, 3	m/s
x y z	X Y Z	Cartesian coordinates	Origin O coinciding with the centre of the propeller. The longitudinal x-axis coincides with the shaft axis, positive forward; the transverse y-axis, positive to port; the third, z-axis, positive upward	m m m
X a r	X ATT R	Cylindrical coordinates	Cylindrical system with origin O and longitudinal x-axis as defined before; angular a-(attitude)-coordinate , zero at 12 o'clock position, positive clockwise looking forward; r distance measured from the x-axis	m 1 m
δ_u	DP(U)	Generalized vibratory displacement	u = 1,.., 6 u = 1, 2, 3: linear u = 4, 5, 6: angular	m m rad
$\dot{\delta}_u$	DPVL(U)	Generalized vibratory velocity	u = 1,.., 6 u = 1, 2, 3: linear u = 4, 5, 6: angular	m/s m/s rad/s
$\ddot{\delta}_u$	DPAC(U)	Generalized vibratory acceleration	u = 1,.., 6 u = 1, 2, 3: linear u = 4, 5, 6: angular	m/s^2 m/s^2 rad/s^2

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.3.5 Water Jets

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
C_p	CP	Local pressure coefficient	$(p-p_0)/(\rho\ V^2/2)$	1
C_{Tn}		Thrust loading coefficient:viscous pressure	$\dfrac{T_{\mathrm{net}}}{\frac{1}{2}\rho U_0^2 A_{\mathrm{n}}}$	1
c_{es}		Energy velocity coefficient at station s		1
c_{ms}		Momentum velocity coefficient at station s		1
Dp		Pressure differential of flow rate transducer		Pa
E_j	EJ	Energy flux at station j	$E_j = (\rho/2)\int_{Q_J} V_{Ej}^2 dQ_j$	W
E_{s}		Total energy flux at station s (kinetic + potential + pressure)	$\iint_{A_s} \rho \left(\frac{1}{2}\boldsymbol{u}^2 + \frac{p}{\rho} - g_j x_j \right) u_i n_i dA$	W
$E_{\mathrm{s}\xi}$		Total axial (in ξ direction) energy flux at station s	$\iint_{A_s} \rho \left(\frac{1}{2}u_\xi^2 + \frac{p}{\rho} - g_j x_j \right) u_i n_i dA$	W
F_D		Skin friction correction in a self propulsion test carried out at the ship self-propulsion point		N
H_1	HT1	Local total head at station 1		m
H_{35}	H35	Mean increase of total head across pump and stator or several pump stages		m
I_{VR}	IVR	Intake velocity ratio	VI/V	1
J_{VR}	JVR	Jet velocity ratio	VJ/V	1
K_Q		Impeller torque coefficient:	$\dfrac{Q}{\rho n^2 D^5}$	
K_{QJ}		Flow rate coefficient:	$\dfrac{Q_{\mathrm{J}}}{nD^3}$	1
$\overline{M}_{is}$		Momentum flux at station s in i direction	$\iint_{A_s} \rho u_i \left(u_j n_j \right) dA$	N
NVR		Nozzle velocity ratio:	$\dfrac{\overline{u_{6\xi}}}{U_0}$	1
T_{jx}	TJX	Jet thrust (can be measured directly in bollard pull condition)		N
n		Impeller rotation rate		Hz
n_i		Unit normal vector in i direction		1
P_{D}		Delivered Power to pump impeller		W
P_{E}		Effective power:	$R_{\mathrm{TBH}} U_0$	W
P_{JSE}		Effective Jet System Power	$Q_{\mathrm{J}} H_{1A7}$	W
P_{PE}		Pump effective power:	$Q_{\mathrm{J}} H_{35}$	W
P_{TE}		Effective thrust power		W

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
p_0	PR0	Ambient pressure in undisturbed flow		Pa
p_s		Local static pressure at station *s*		Pa
Q		Impeller torque		Nm
Q_{bl}		Volume flow rate inside boundary layer		m³/s
Q_J		Volume flow rate through water jet system		m³/s
R_{TBH}		Total resistance of bare hull		N
$T_{jet\,x}$		Jet thrust (can be measured directly in bollard pull condition)		N
T_{net}		Net thrust exerted by the jet system on the hull		N
t		Thrust deduction fraction	$(1-t)=\dfrac{R_{TBH}}{T_{net}}$	1
U_0		Free stream velocity		m/s
$\bar{u}_{eis}$		Mean energy velocity in *i* direction at station s	$\sqrt{\dfrac{1}{Q_J}\iint u_\xi^3 dA}$	m/s
$\bar{u}_{es}$		Mean (total) energy velocity at station *s*	$\sqrt{\dfrac{1}{Q_J}\iint \boldsymbol{u}^3 dA}$	m/s
u_{is}		Velocity component in *i*-direction at station *s*		m/s
u_s		Velocity at station s		m/s
$u_{7\varphi}$	UJFI	Local tangential velocity at station 7		*m/s*
w_1		Geometric intake width at station 1		m
w_{1A}		Width of capture area measured over hull surface at station 1A		m
z_6		Vertical distance of nozzle centre relative to undisturbed surface		m
ΔM	DMF	Change of momentum flux		N
$\Delta\overline{M}_x$		Change in Momentum Flux in *x* direction		N
η_D		Overall propulsive efficiency:	$\dfrac{P_E}{P_D}$	1
η_{duct}		Ducting efficiency:	$\dfrac{P_{JSE}}{P_{PE}}$	1
η_{eI}		Energy interaction efficiency:	$\dfrac{P_{JSE0}}{P_{JSE}}$	1
η_I		Ideal efficiency, equivalent to jet efficiency in free stream conditions	$\dfrac{P_{TE0}}{P_{JSE0}}$	1
η_{inst}		Installation efficiency to account for the distorted flow delivered by the jet intake to the pump		1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
η_{INT}		Total interaction efficiency:	$\frac{\eta_{\mathrm{eI}}}{\eta_{\mathrm{mI}}}(1-t)$	1
η_{jet}		Momentum or jet efficiency:	$\frac{P_{\mathrm{TE}}}{P_{\mathrm{JSE}}}$	1
η_{JS}		Jet system efficiency:	$\frac{P_{\mathrm{JSE}}}{P_{\mathrm{D}}}$	1
η_{mI}		Momentum interaction efficiency:	$\frac{T_{\mathrm{net0}}}{T_{\mathrm{net}}}$	1
η_{P}	ETAP	Pump efficiency	$\frac{P_{\mathrm{PE}}}{P_{\mathrm{D}}}$	1
η_{P0}		Pump efficiency from a pump loop test		1
η_0		Free stream efficiency:	$\eta_{\mathrm{P}}\eta_{\mathrm{duct}}\eta_{\mathrm{I}}$	1
θ_{n}		Jet angle relative to the horizontal at the nozzle (station 6)		rad
ρ		Mass density of fluid		kg/m³
ζ_{ij}		Energy loss coefficient between station *i* and *j*		1
ζ_{13}	ZETA13	Inlet duct loss coefficient:	$\frac{E_3 - E_1}{\frac{1}{2}\rho U_0^2}$	1
ζ_{57}	ZETA57	Nozzle duct loss coefficient:	$\frac{E_7 - E_5}{\frac{1}{2}\rho \overline{u}_{\mathrm{e6}}^{2}}$	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.4 Manoeuvrability and Seakeeping
2.4.1 Manoeuvrability
2.4.1.1 Geometrical Quantities
see also Section 1.3.1 and Section 1.3.3

A_{FB}	AFBO	Projected area of bow fins		m^2
A_{HL}	AHLT	Lateral area of the hull	The area of the profile of the underwater hull of a ship when projected normally upon the longitudinal centre plane	m^2
A_{LV}	AHLV	Lateral area of hull above water		m^2
A_R	ARU	Total lateral area of rudder		m^2
A_{Rmov}	ARMV	Lateral area of movable part of rudder		m^2
A_{RN}	ARNO	Nominal lateral area of rudder	$(A_R + A_{Rmov}) / 2$	m^2
b_R	SPRU	Rudder span	Maximum distance from root to tip	m
b_{RM}	SPRUME	Mean span of rudder		m
C_{AL}	CAHL	Coefficient of lateral area of ship	$A_{HL} / (L\ T)$	1
h	DE	Water depth		m
h_M	DEME	Mean water depth		m
x_R	XRU	Longitudinal position of rudder axis		m
δ	ANRU	Rudder angle, helm angle		rad
Λ_R	ASRU	Aspect ratio of rudder	b_R^2 / A_R	1

2.4.1.2 Motions and Attitudes

p	OX, P	Roll velocity, rotational velocity about body x-axis		1/s
q	OY, Q	Pitch velocity, rotational velocity about body y-axis		1/s
r	OZ, R	Yaw velocity, rotational velocity about body z-axis		1/s
$\dot{p}$	OXRT, PR	Roll acceleration, angular acceleration about body x-axis	dp / dt	$1/s^2$
$\dot{q}$	OYRT, QR	Pitch acceleration, angular acceleration about body y-axis	dq / dt	$1/s^2$
$\dot{r}$	OZRT, RR	Yaw acceleration, angular acceleration about body z-axis	dr / dt	$1/s^2$
u	UX, U	Surge velocity, linear velocity along body x-axis		m/s
v	UY, V	Sway velocity, linear velocity along body y-axis		m/s
w	UZ, W	Heave velocity, linear velocity along body z-axis		m/s
$\dot{u}$	UXRT, UR	Surge acceleration, linear acceleration along body x-axis	du / dt	m/s^2
$\dot{v}$	UYRT, VR	Sway acceleration, linear acceleration along body y-axis	dv / dt	m/s^2
$\dot{w}$	UZRT, WR	Heave acceleration, linear acceleration along body z-axis	dw / dt	m/s^2
V	V	Linear velocity of origin in body axes		m/s
V_A, V_0	VA, V0	Approach speed		m/s
V_u	V(URT)	Generalized velocity		m/s

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$\dot{V}_u$	V(URT)	Generalized acceleration		m/s^2
V_F	VF	Flow or current velocity		m/s
V_{WR}	VWREL	Relative wind velocity		m/s
V_{WT}	VWABS	True wind velocity		m/s
ψ	YA	Course angle or heading		rad
χ	YX	Yaw angle		rad
$d_{t\psi}$	YART	Rate of change of course	$d\psi / dt$	rad/s
Ψ_O	YA0R	Original course		rad
θ	PI	Pitch angle		rad
ϕ	RO	Roll angle		rad

2.4.1.3 Flow Angles etc.

α	AAPI	Pitch angle	Angle of attack in pitch on the hull	rad
β	AADR	Drift angle	Angle of attack in yaw on the hull	rad
β_{WR}	ANWIRL	Angle of attack of relative wind		rad
δ	ANCS	Angle of a control surface, rudder angle, helm angle		rad
δ_0	ANRU0	Neutral rudder angle		rad
δ_{EFF}	ANRUEF	Effective rudder inflow angle		rad
δ_{FB}	ANFB	Bow fin angle		rad
δ_{FS}	ANFS	Stern fin angle		rad
δ_R	ANRU	Rudder angle		rad
δ_{RO}	ANRUOR	Rudder angle, ordered		rad
ψ_C	COCU	Course of current velocity		rad
ψ_{WA}	COWIAB	Absolute wind direction	see also section 3.4.2, Wind	rad
ψ_{WR}	COWIRL	Relative wind direction		rad

2.4.1.4 Forces and Derivatives

K	MX	Roll moment on body, moment about body x-axis		Nm
M	MY	Pitch moment on body, moment about body y-axis		Nm
N	MZ	Yaw moment on body, moment about body z-axis		Nm
N_r	NR	Derivative of yaw moment with respect to yaw velocity	$\partial N / \partial r$	Nms
$N_{\dot{r}}$	NRRT	Derivative of yaw moment with respect to yaw acceleration	$\partial N / \partial \dot{r}$	Nms^2
N_v	NV	Derivative of yaw moment with respect to sway velocity	$\partial N / \partial v$	Ns
$N_{\dot{v}}$	NVRT	Derivative of yaw moment with respect to sway acceleration	$\partial N / \partial \dot{v}$	Nms^2
N_δ	ND	Derivative of yaw moment with respect to rudder angle	$\partial N / \partial \delta$	Nm
Q_{FB}	QFB	Torque of bow fin		Nm
Q_R	QRU	Torque about rudder stock		Nm
Q_{FS}	QFS	Torque of stern fin		Nm
X	FX	Surge force on body, force along body x-axis		N
X_R	XRU	Longitudinal rudder force		N
X_u	XU	Derivative of surge force with respect to surge velocity	$\partial X / \partial u$	Ns/m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$X_{\dot{u}}$	XURT	Derivative of surge force with respect to surge acceleration	$\partial X / \partial \dot{u}$	Ns^2/m
Y	FY	Sway force, force in direction of body axis y		N
Y_r	YR	Derivative of sway force with respect to yaw velocity	$\partial Y / \partial r$	Ns
Y_R	YRU	Transverse rudder force		N
$Y_{\dot{r}}$	YRRT	Derivative of sway force with respect to yaw acceleration	$\partial Y / \partial \dot{r}$	Ns^2
Y_v	YV	Derivative of sway force with respect to sway velocity	$\partial Y / \partial v$	Ns/m
$Y_{\dot{v}}$	YVRT	Derivative of sway force with respect to sway acceleration	$\partial Y / \partial \dot{v}$	Ns^2/m
Y_δ	YD	Derivative of sway force with respect to rudder angle	$\partial Y / \partial \delta$	N
Z	FZ	Heave force on body, force along body z-axis		N

2.4.1.5 Linear Models

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
C_r	CRDS	Directional stability criterion	$Y_v (N_r - mux_G) - N_v (Y_r - mu)$	N^2s^2
L_b , l_b	LSB	Static stability lever	N_v / Y_v	m
L_d , l_d	LSR	Damping stability lever	$(N_r - mux_G) / (Y_r - mu)$	m
T	TIC	Time constant of the 1st order manoeuvring equation		s
T_1	TIC1	First time constant of manoeuvring equation		s
T_2	TIC2	Second time constant of manoeuvring equation		s
T_3	TIC3	Third time constant of manoeuvring equation		s
K	KS	Gain factor in linear manoeuvring equation		1/s
P_n	PN	P-number, heading change per unit rudder angle in one ship length		1

2.4.1.6 Turning Circles

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
D_C	DC	Steady turning diameter		m
D_C'	DCNO	Non-dimensional steady turning diameter	D_C / L_{PP}	1
D_0	DC0	Inherent steady turning diameter $\delta_R = \delta_0$		m
D_0'	DC0N	Non-dimensional inherent steady turning diameter	D_0 / L_{PP}	1
l_r	LHRD	Loop height of r-δ curve for unstable ship		rad/s
l_δ	LWRD	Loop width of r-δ curve for unstable ship		rad
r_C	OZCI	Steady turning rate		1/s
r_C'	OZCINO	Non-dimensional steady turning rate	$r_C L_{PP} / U_C$ or $2 L_{PP} / D_C$	m
R_C	RCS	Steady turning radius		m
t_{90}	TI90	Time to reach 90 degree change of heading		s
t_{180}	TI180	Time to reach 180 degree change of heading		s

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
U_C	UC	Speed in steady turn		m/s
x_{090}	X090	Advance at 90° change of heading		m
x_{0180}	X0180	Advance at 180° change of heading		m
x_{0max}	XMX	Maximum advance		m
y_{090}	Y090	Transfer at 90° change of heading		m
y_{0180}	Y0180	Tactical diameter (transfer at 180° change of heading)		m
y_{0max}	Y0MX	Maximum transfer		m
β_C	DRCI	Drift angle at steady turning		rad

2.4.1.7 Zig-Zag Manoeuvres

t_a	TIA	Initial turning time		s
t_{c1}	TIC1	First time to check yaw (starboard)		s
t_{c2}	TIC2	Second time to check yaw (port)		s
t_{hc}	TCHC	Period of changes in heading		s
t_r	TIR	Reach time		s
y_{0max}	Y0MX	Maximum transverse deviation		m
δ_{max}	ANRUMX	Maximum value of rudder angle		rad
ψ_S	PSIS	Switching value of course angle		rad
ψ_{01}	PSI01	First overshoot angle		rad
ψ_{02}	PSI02	Second overshoot angle		rad

2.4.1.8 Stopping Manoeuvres

s_F	SPF	Distance along track, track reach		m
x_{0F}	X0F	Head reach		m
y_{0F}	Y0F	Lateral deviation		m
t_F	TIF	Stopping time		s

2.4.2 Seakeeping

Related information is to be found in Chapter 3 on General Mechanics in Sections 3.1.2 on Time and Frequency Domain Quantities, 3.1.3 on Stochastic Processes, 3.2.1 on Inertial Properties,, 3.2.2 on Loads, 3.2.3 on Rigid Body Motions, and 3.4.1 on Waves.

2.4.2.1 Basic Quantities

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
A_{FS}	AFS	Projected area of stern fins		m^2
a_i	AT(I)	Attitudes of the floating system	i = 1, 2, 3, e.g. Euler angles of roll, pitch, and yaw, respectively	rad
f	FR	Frequency	$1 / T$	Hz
f_{E}	FE	Frequency of wave encounter	$1 / T_{\mathrm{E}}$	Hz
f_z		Natural frequency of heave	$1 / T_z$	Hz
f_θ		Natural frequency of pitch	$1 / T_\theta$	Hz
f_φ		Natural frequency of roll	$1 / T_\varphi$	Hz
F_{L}	FS(2)	Wave excited lateral shear force	Alias horizontal!	N
F_{N}	FS(3)	Wave excited normal shear force	Alias vertical!	N
M_{L}	MB(3), FS(6)	Wave excited lateral bending moment	Alias horizontal!	Nm
M_{N}	MB(2), FS(5)	Wave excited normal bending moment	Alias vertical!	Nm
M_{T}	MT(1), FS(4)	Wave excited torsional moment		Nm
n_{AW}	NAW	Mean increased rate of revolution in waves		1/s
P_{AW}	PAW	Mean power increased in waves		W
Q_{AW}	QAW	Mean torque increased in waves		Nm
R_{AW}	RAW	Mean resistance increased in waves		N
$S_\eta(f)$, $S_{\eta\eta}(f)$, $S_\eta(\omega)$, $S_{\eta\eta}(\omega)$	EWSF, EWSC	Wave elevation auto spectral density	see also section 1.4.1, Waves	$\mathrm{m}^2\mathrm{s}$
x_i	X(I)	Absolute displacement of the ship at the reference point	i = 1, 2, 3 :surge, sway, and heave respectively	m
x_u	X(U)	Generalized displacement of a ship at the reference point	u = 1...6 surge, sway, heave, roll, pitch, yaw	m, rad
T_{AW}	TAW	Mean thrust increase in waves		N
T	TC	Wave period		s
T_{e}	TE	Wave encounter period		s
T_z	TNHE	Natural period of heave		s
T_θ	TNPI	Natural period of pitch		s
T_φ	TNRO	Natural period of roll		s
$Y_z(\omega)$, $A_{z\zeta}(\omega)$		Amplitude of frequency response function for translatory motions	$z_a(\omega) / \zeta_a(\omega)$ or $z_a(\omega) / \eta_a(\omega)$	1
$Y_{\theta\zeta}(\omega)$, $A_{\theta\zeta}(\omega)$		Amplitude of frequency response function for rotary motions	$\Theta_a(\omega) / \zeta_a(\omega)$ or $\Theta_a(\omega) / (\omega^2/ (g\zeta_a(\omega)))$	1
Λ		Tuning factor	$L_z = \frac{w_E}{w_Z}$ $L_q = \frac{w_E}{w_q}$ $L_f = \frac{w_E}{w_j}$ or $L_Z = \frac{T_Z}{T_E}$ $L_q = \frac{T_q}{T_E}$ $L_f = \frac{T_j}{T_E}$	
μ		Wave encounter angle	Angle between ship positive x axis and positive direction of waves (long crested) or dominant wave direction (short crested)	rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

2.4.3 Large Amplitude Motions Capsizing

A		Assumed centre of gravity above keel used for cross curves of stability - I99/1.2.4.1		1
$\overline{AB}$	XAB	Longitudinal centre of buoyancy from aft perpendicular - I99/1.2.4.2	Distance of centre of buoyancy from aft perpendicular	m
A_{C}		Area of deck available to crew		m²
$\overline{AF}$	XAF	Distance of the centre of flotation from after perpendicular		m
$\overline{AG}_{\mathrm{L}}$	XAG	Longitudinal centre of gravity from aft perpendicular	Distance of centre of gravity from aft perpendicular	m
$\overline{AG}_{\mathrm{T}}$	YAG	Transverse distance from assumed centre of gravity A, to actual centre of gravity G		m
$\overline{AG}_{\mathrm{V}}$	ZAG	Vertical distance from assumed centre of gravity A, to actual centre of gravity G		m
A_{LV}	AHLV	Lateral area of hull above water		m²
A_{RL}		Positive area under righting lever curve		m²
A_{SI} I_{AS}	ASI	Attained subdivision index		1
A_{S}	AS	Area of sails in profile according to ISO 8666		m²
A_{V}	AV	Projected lateral area of the portion of the ship and deck cargo above the waterline - IMO/IS, IMO/HSC'2000		m²
$\overline{AZ}$	YAZ	Righting arm based on horizontal distance from assumed centre of gravity A, to Z	Generally tabulated in cross curves of stability	m
B		Centre of buoyancy	Centroid of the underwater volume	
B_{CB}		Breadth between centres of buoyancy of side hulls		m
$\overline{BM}$	ZBM	Transverse metacentre above centre of buoyancy	Distance from the centre of buoyancy CB to transverse metacentre M $\overline{BM} = \frac{I_T}{\nabla} = \overline{KM} - \overline{KB}$	m
$\overline{BM}_L$	ZBML	Longitudinal metacentre above centre of buoyancy	$\overline{BM}_L = \overline{KM}_L - \overline{KB}$	m
b		Centre of flotation of added buoyancy layer or centre of lost buoyancy of the flooded volume		
b		Maximum tank breadth		m
C_{D}		Crew density	Proportion of boat plan needed for crew	
C_H		Height coefficient, depending on the height above sea level of the structural member exposed to the wind		1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
C_{Lcpi}		Crew limit	Maximum number of persons on board	
C_{MTL}	CMTL	Longitudinal trimming coefficient - I99/1.2.4.3	Trimming moment divided by change in trim which approximately equals $\overline{BM}_L / L$	1
C_{s}		Shape coefficient, depending on the shape of the structural member exposed to the wind		1
d	T	Draught, moulded, of ship hull - I99/1.2.1		m
d		Density coefficient for submerged test weights		1
F		Centre of flotation of the water plane		
F		Wind force - IMO/IS		
f	FREB	Freeboard	From the freeboard markings to the freeboard deck, according to official rules	m
$\overline{FB}$	XFB	Longitudinal centre of buoyancy, L_{CB}, from forward perpendicular	Distance of centre of buoyancy from forward perpendicular	m
$\overline{FF}$	XFF	Longitudinal centre of flotation, L_{CF}, from forward perpendicular	Distance of centre of floatation from forward perpendicular	m
$\overline{FG}$	XFG	Longitudinal centre of gravity, from forward perpendicular	Distance of centre of gravity from forward perpendicular	m
G		Centre of gravity of a vessel		
g		Centre of gravity of an added or removed weight (mass)		1
$\overline{GG}_1$	GGV	Vertical stability lever caused by a weight shift or weight addition	$\overline{KG}_1 = \overline{KG}_0 + \overline{GG}_1$	m
$\overline{GG}_{\mathrm{H}}$	GGH	Horizontal stability lever caused by a weight shift or weight addition		m
$\overline{GG}_{\mathrm{L}}$	GGL	Longitudinal stability lever caused by a weight shift or weight addition		m
$\overline{GG}_{\mathrm{V}}$	GGV	Vertical stability lever caused by a weight shift or weight addition	$\overline{KG}_1 = \overline{KG}_0 + \overline{GG}_1$	m
$\overline{GM}$	GM	Transverse metacentric height	Distance of centre of gravity to the metacentre $\overline{GM} = \overline{KM} - \overline{KG}$ (not corrected for free surface effect)	m
$\overline{GM}_{\mathrm{EFF}}$	GMEFF	Effective transverse metacentric height	$\overline{GM}$ Corrected for free surface and/or free communication effects	m
$\overline{GM_L}$	GML	Longitudinal metacentric height	Distance from the centre of gravity G to the longitudinal metacentre M_{L} $\overline{GM}_L = \overline{KM_L} - \overline{KG}$	m
$\overline{GZ}$	GZ	Righting arm or lever	$\overline{GZ} = \overline{AZ} - \overline{AG}_{\mathrm{V}} \sin\varphi - \overline{AG}_{\mathrm{T}} \cos\varphi$	m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$\overline{GZ}$		Arm of static stability corrected for free surfaces - IMO/table		m
$\overline{GZ}_{\mathrm{MAX}}$	GZMAX	Maximum righting arm or lever		m
h		Maximum tank height		m
h_{CE}		Height of centre of area of A_{SP} above waterline at SSM		m
HL		Heeling lever (due to various reasons) - IMO/HSC'2000		m
h_{LP}		Height of waterline above centre of area of immersed profile		m
K		Keel reference		
$\overline{KA}$	ZKA	Assumed centre of gravity above moulded base of keel	Distance from the assumed centre of gravity A to the moulded base of keel or K	m
$\overline{KB}$	ZKB	Centre of buoyancy above moulded base of keel	Distance from the centre of buoyancy B to the moulded base of keel or K	m
$\overline{KG}$	ZKG	Centre of gravity above moulded base of keel	Distance from the centre of gravity G to the moulded base of keel or K	m
$\overline{Kg}$	ZKAG	Vertical centre of gravity of added or removed weight above moulded base of keel	Distance from the assumed centre of gravity, g, to the moulded base of keel or K	m
$\overline{KM}$	ZKM	Transverse metacentre above moulded base of keel	Distance from the transverse metacentre M to the moulded base of keel or K	m
$\overline{KM}_{\mathrm{L}}$	ZKML	Longitudinal metacentre above moulded base of keel	Distance from the longitudinal metacentre M_{L} to the moulded base of keel or K	m
k		Roll damping coefficient expressing the effect of bilge keels		1
L		Length of the vessel on the waterline in maximum load condition - IMO/IS		m
l		Arm of dynamic stability corrected for free surfaces - IMO/table		m
l	XTA	Longitudinal trimming arm	$X_{\mathrm{CG}} - X_{\mathrm{CB}}$	m
l		Maximum tank length		m
l_{s}		Actual length of enclosed superstructure extending from side to side of the vessel		m
l_{w}		Wind heeling lever		m
M		Metacentre of a vessel	See subscripts for qualification	
m	SHIPMA	Ship mass	W/g	kg
M_{C}		Maximum offset load moment due to crew		Nm
M_{c}		Minimum capsizing moment as determined when account is taken of rolling		Nm
M_{FS}		Free surface moment at any inclination		Nm
m_{LCC}		Mass in light craft condition		kg

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
m_{LDC}		Mass in loaded displacement condition according to …		kg
m_{MTL}		Maximum total load (mass)		kg
M_{R}		Heeling moment due to turning		Nm
M_{S}	MS	Moment of ship stability in general	$\Delta\,\overline{GZ}$. Other moments such as those of capsizing, heeling, etc. will be represented by M_{S} with additional subscripts as appropriate.	Nm
m_{SSC}		Mass in standard sailing conditions according to …		kg
M_{TC}	MTC	Moment to change trim one centimetre		Nm/cm
M_{TM}	MTM	Moment to change trim one meter	$\Delta\ C_{MTL}$	Nm/m
M_{W}		Maximum heeling moment due to wind		Nm
M_{v}		Dynamically applied heeling moment due to wind pressure		Nm
$\overline{OG}$		Height of centre of gravity above waterline		m
P_{V}		Wind pressure		Pa
r		Effective wave slope coefficient		1
R_{SI}	RSI	Required subdivision index		1
s		Wave steepness		1
$STIX$	STIX	Actual stability index value according to …		1
$\overline{STIX}$	STIXR	Required stability index value, see …		1
T	YHA	Equivalent transverse heeling arm	Heeling moment/Δ	m
TL		Turning lever		m
t_{s} t_{KL}	TRIM	Static trim	T_{A} - T_{F} - d_{KL}	m
V v		Tank total capacity		m³
V_0		Speed of craft in the turn - IMO/HSC'2000 Service speed - IMO/IS		m/s
v_{W}		Wind speed used in calculation		m/s
W	SHIPWT	Ship weight	$m\ g$	N
x_{CB}	XACB	Longitudinal centre of floatation of added buoyant layer	Longitudinal distance from reference point to the centre of the added buoyant layer, b	m
X_{CB} L_{CB}	XCB	Longitudinal centre of buoyancy (L_{CB})	Longitudinal distance from reference point to the centre of buoyancy, B	m
X_{CF} L_{CF}	XCF	Longitudinal centre of flotation (L_{CF})	Longitudinal distance from reference point to the centre of flotation, F	m
x_{CG}	XACG	Longitudinal centre of gravity of added weight (mass)	Longitudinal distance from reference point to the centre of gravity, g, of an added or removed weight (mass)	m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
X_{CG} L_{CG}	XCG	Longitudinal centre of gravity (L_{CG})	Longitudinal distance from reference point to the centre of gravity, G	m
X_1, X_2		Roll damping coefficients		1
x_D		Distance of down flooding opening from end of boat		m
Y_{CG}, y_{CG}	YCG	Lateral displacement of centre of gravity (Y_{CG})	Lateral distance from a reference point to the centre of gravity, G	m
y_D		Distance of down flooding opening from gunwale		m
y_D'		Distance of down flooding opening off centreline		m
Z	ZRA	Intersection of righting arm with line of action of the centre of buoyancy		
Z		Vertical distance from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught - IMO/IS		m
Z, h		Vertical distance from the centre of A to the waterline		m
z_D		Height above waterline of down flooding opening		m
z_{SA}	ZSA	Static sinkage at AP	Caused by loading	m
z_{SF}	ZSF	Static sinkage at FP	Caused by loading	m
z_S	ZS	Mean static sinkage	$(z_{SF}+z_{SA})/2$	m
δ		Tank block coefficient		1
δt_{KL}	DTR	Change in static trim		m
Δ	DISPF	Displacement (buoyant) force	$g\ \rho\ \nabla$	N
Δ_m	DISPM	Displacement mass	$\rho\ \nabla$	kg
∇	DISPVOL	Displacement volume	$\Delta / (\rho g)$	m³
∇_{fw}	DISVOLFW	Displacement volume of flooded water	$\Delta_{fw} / (\rho g)$	m³
ϕ	HEELANG	Heel angle		rad
ϕ_0		Heel angle during offset load tests		rad
$\phi_{0(REQ)}$		Maximum permitted heel angle during …		rad
ϕ_D		Actual down flooding angle according to …		rad
$\phi_{D(REQ)}$		Required down flooding angle, see…		rad
ϕ_{DC}		Down flooding angle to non-quick draining cockpits		rad
ϕ_{DH}		Down flooding angle to any main access hatchway		rad
ϕ_F	HEELANGF	Heel angle at flooding		rad
ϕ_{GZMAX}		Angle of heel at which maximum righting moment occurs		rad
ϕ_R		Assumed roll angle in a seaway		rad
ϕ_{VS}	HEELANGV	Heel angle for vanishing stability		rad
ϕ_W		Heel angle due to calculation wind		rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
μ	PMVO	Volumetric permeability	The ratio of the volume of flooding water in a compartment to the total volume of the compartment	1
θ_c		Capsizing angle under the action of a gust of wind IMO/IS		rad
ϕ_m		Heel angle corresponding to the maximum of the statical stability curve		rad
θ_S	TRIMS	Static trim angle	$\tan^{-1}((z_{SF}-z_{SA})/L)$	rad
ρ	RHO	(Liquid) mass density		kg/m³
ρ_A	RHOA DNA	(Air) mass density		kg/m³
$\rho_{\otimes}$	DNWA	(Water) mass density		kg/m³

2.4.4 Symbols for Attributes and Subscripts

A	Aft
E	Entrance
F	Fore
R	Run
Z	Heave
θ	Pitch
φ	Roll

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3. SPECIAL CRAFT
3.1 Planing and Semi-Displacement Vessels
3.1.1 Geometry and Hydrostatics

See also Section 1.2.1, Hull Geometry and Section 1.2.2 Propulsor Geometry

A_{P}	APB	Planing bottom area	Horizontally projected planing bottom area (at rest), excluding area of external spray strips	m^2
B_{LCG}	BLCG	Breadth at longitudinal position of the centre of gravity	Breadth over spray strips measured at transverse section containing centre of gravity	m
B_{PC}	BPC	Breadth over chines	Breadth over chines, excluding external spray strips	m
B_{PA}	BPA	Mean breadth over chines	$A_{\mathrm{P}} / L_{\mathrm{P}}$	m
B_{PT}	BPT	Transom breadth	Breadth over chines at transom, excluding external spray strips	m
B_{PX}	BPX	Maximum breadth over chines	Maximum breadth over chines, excluding external spray strips	m
L_{SB}	LSB	Total length of shafts and bossings		m
L_{PR}	LPRC	Projected chine length	Length of chine projected in a plane parallel to keel	m
β	BETD	Deadrise angle of planing bottom	Angle between a straight line approximating body section and the intersection between basis plane and section plane	rad
β_{M}	BETM	Deadrise angle at midship section		rad
β_{T}	BETT	Deadrise angle at transom		rad
$\varepsilon_{\mathrm{SH}}$	EPSSH	Shaft angle	Angle between shaft line and reference line (positive, shaft inclined downwards)	rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.1.2 Geometry and Levers, Underway

3.1.2.1 Geometry, Underway

d_{TR}	DTRA	Immersion of transom, underway	Vertical depth of trailing edge of boat at keel below water surface level	m
h_P	HSP	Wetted height of strut palms (flange mounting)		m
h_R	HRU	Wetted height of rudders		m
L_C	LC	Wetted chine length, underway		m
l_{CP}	LCP	Lever of resultant of pressure forces, underway	Distance between centre of pressure and aft end of planing surface	m
L_K	LK	Wetted keel length, underway		m
L_M	LM	Mean wetted length, underway	$(L_K + L_C) / 2$	m
S_{WHP}	SWHP	Wetted area underway of planing hull	Principal wetted area bounded by trailing edge, chines and spray root line	m^2
S_{WB}	SWB	Wetted bottom area, underway	Area bounded by stagnation line, chines or water surface underway and transom	m^2
S_{WHE}	SWHE	Wetted hull area, underway	Total wetted surface of hull underway, including spray area and wetted side area, w/o wetted transom area	m^2
S_{WHS}	SWSH	Area of wetted sides	Wetted area of the hull side above the chine or the design water line	m^2
S_{WS}, S_S	SWS	Area wetted by spray	Wetted area between design line or stagnation line and spray edge	m^2
α_B	ALFSL	Angle of stagnation line	Angle between projected keel and stagnation line in a in plane normal to centre plane and parallel to reference line	rad
α_{BAR}	ALFBAR	Barrel flow angle	Angle between barrel axis and assumed flow lines	rad
ε_{WL}	EPSWL	Wetted length factor	L_M / L_{WL}	1
ε_{WS}	EPSWS	Wetted surface area factor	S / S_0	1
θ_{DWL},	TRIMDWL	Running trim angle based on design waterline	Angle between design waterline and running waterline (positive bow up)	rad
θ_S, θ_0	TRIMS	Static trim angle	Angle between ship design waterline and actual water line at rest (positive bow up) $\tan^{-1}((z_{SF} - z_{SA}) / L)$	rad
θ_V , θ_D	TRIMV	Running (dynamic) trim angle	Angle between actual water line at rest and running water line (positive bow up) $\tan^{-1}((z_{VF} - z_{VA}) / L)$	rad
λ_W	LAMS	Mean wetted length-breadth ratio	$L_M / (B_{LCG})$	1
τ	TRIMDWL	Running trim angle based on design waterline	Angle between design waterline and running waterline (positive bow up)	deg
τ_{DWL}	TAUDWL	Reference line angle	Angle between the reference line and the design waterline	rad
τ_R	TAUR	Angle of attack relative to the reference line	Angle between the reference line and the running waterline	rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
φ_{SP}	PHISP	Spray angle	Angle between stagnation line and keel (measured in plane of bottom)	rad
δ_{λ}	DLAM	Dimensionless increase in total friction area	Effective increase in friction area length-breadth ratio due to spray contribution to drag	1

3.1.2.2 Levers, Underway

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
e_{A}	ENAPP	Lever of appendage lift force N_{A}	Distance between N_{A} and centre of gravity (measured normally to N_{A})	m
e_{B}	ENBOT	Lever of bottom normal force N_{B}	Distance between N_{B} and centre of gravity (measured normally to N_{B})	m
e_{PN}	ENPN	Lever of propeller normal force N_{PN}	Distance between propeller centre-line and centre of gravity (meas-ured along shaft line)	m
e_{PP}	ENPP	Lever of resultant of propeller pressure forces N_{PP}	Distance between N_{PP} and centre of gravity (measured normally to N_{PP})	m
e_{PS}	ENPS	Lever of resultant propeller suc-tion forces N_{PS}	Distance between N_{PS} and centre of gravity (measured normal to N_{PS})	m
e_{RP}	ENRP	Lever of resultant of rudder pres-sure forces N_{RP}	Distance between N_{RP} and centre of gravity (measured normal to N_{RP})	m
f_{AA}	FRAA	Lever of wind resistance R_{AA}	Distance between R_{AA} and centre of gravity (measured normal to R_{AA})	m
f_{AP}	FRAP	Lever of appendage drag R_{AP}	Distance between R_{AP} and centre of gravity (measured normal to R_{AP})	m
f_{F}	FRF	Lever of frictional resistance R_{F}	Distance between R_{F} and centre of gravity (measured normal to R_{F})	m
f_{K}	FRK	Lever of skeg or keel resistance R_{K}	Distance between R_{K} and centre of gravity (measured normal to R_{K})	m
f_{R}	FDRR	Lever of augmented rudder drag ΔR_{RP}	Distance between ΔR_{RP} and centre of gravity (measured normal to ΔR_{RP})	m
f_{S}	FSL	Lever of axial propeller thrust	Distance between axial thrust and centre of gravity (measured nor-mal to shaft line)	m
f_{T}	FRT	Lever of total resistance R_{T}	Distance between R_{T} and centre of gravity (measured normal to R_{T})	m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.1.3 Resistance and Propulsion

See also Sections 2.3.1 on Hull Resistance

C_{L0}	CL0D	Lift coefficient for zero deadrise	$\Delta / (B_{CG}^2\ q)$	1
$C_{L\beta}$	CLBET	Lift coefficient for deadrise surface	$\Delta / (B_{CG}^2\ q)$	1
C_V	CSP	Froude number based on breadth	$V / (B_{CG}\ g)^{1/2}$	1
C_Δ	CDL	Load coefficient	$\Delta / (B_{CG}^3\ \rho\ g)$	1
L_{VHD}	LVD	Vertical component of hydrodynamic lift		N
L_{VS}	LVS	Hydrostatic lift	Due to buoyancy	N
F_{TA}	FTAPP	Appendage drag force (parallel to reference line)	Drag forces arising from appendages inclined to flow, assumed to act parallel to the reference line	N
F_{TB}	FTBOT	Bottom frictional force (parallel to reference line)	Viscous component of bottom drag forces assumed acting parallel to the reference line	N
F_{TK}	FTKL	Keel or skeg drag force (parallel to reference line)	Drag forces arising from keel or skeg, assumed to act parallel to the reference line	N
F_{TRP}	FTRP	Additional rudder drag force (parallel to reference line)	Drag forces arising from influence of propeller wake on the rudder assumed to act parallel to the reference line	N
N_A	NAPP	Appendage lift force (normal to reference line)	Lift forces arising from appendages inclined to flow, assumed to act normally to reference line	N
N_B	NBOT	Bottom normal force (normal to reference line)	Resultant of pressure and buoyant forces assumed acting normally to the reference line	N
N_{PP}	NPP	Propeller pressure force (normal to reference line)	Resultant of propeller pressure forces acting normally to the reference line	N
N_{PS}	NPS	Propeller suction force (normal to reference line)	Resultant of propeller suction forces acting normally to the reference line	N
N_{RP}	NRP	Rudder pressure force (normal to reference line)	Resultant of rudder pressure forces acting normally to the reference line	N
R_K	RKEEL	Keel drag		N
R_π	RPI	Induced drag	$g\ \rho\ \nabla \tan\tau$	N
R_{PAR}	RPAR	Parasitic drag	Drag due to inlet and outlet openings	N
R_{PS}	RSP	Pressure component of spray drag		N
R_T	RT	Total resistance	Total towed resistance	N
R_{VS}	RSV	Viscous component of spray drag	$C_F\ S_{WS}\ q_S$	N
V_{BM}	VBM	Mean bottom velocity	Mean velocity over bottom of the hull	m/s
V_{SP}	VSP	Spray velocity	Relative velocity between hull and spray in direction of the spray	m/s

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.2 Multi-Hull Vessels

3.2.1 Geometry and Hydrostatics

See also Section 2.2.1, Hull Geometry

A_I	AIA	Strut-hull intersection area		m^2
B_B	BB	Box breadth	Breadth of main deck	m
B_S	BS	Hull spacing	Distance between hull centre lines	m
B_{TV}	BTUN	Tunnel width	Minimal distance of the demihulls at the waterline	m
D_H	DHUL	Hull diameter	Diameter of axis symmetric submerged hulls	m
D_X	DX	Hull diameter at the longitudinal position "X"		m
H_{DK}	HCLDK	Deck clearance	Minimum clearance of wet deck from water surface at rest	m
H_{SS}	HSS	Strut submerged depth	Depth of strut from still water line to strut-hull intersection	m
i_{EI}	ANENIN	Half angle of entrance at tunnel (inner) side	Angle of inner water line with reference to centre line of demihull	rad
i_{EO}	ANENOU	Half angle of entrance at outer side	Angle of outer water line with reference to centre line of demihull	rad
L_{CH}	LCH	Length of centre section of hull	Length of prismatic part of hull	m
L_{CS}	LCS	Length of centre section of strut	Length of prismatic part of strut	m
L_H	LH	Box length	Length of main deck	m
L_{NH}	LNH	Length of nose section of hull	Length of nose section of hull with variable diameter	m
L_{NS}	LNS	Length of nose section of strut	Length of nose section of strut with variable thickness	m
L_S	LS	Strut length	Length of strut from leading to trailing edge	m
L_{SH}	LSH	Length of submerged hull		m
t_S	TSTR	Maximum thickness of strut		m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.2.2 Resistance and Propulsion

3.2.2.1 Resistance Components

See also Section 2.3.1 on Hull Resistance

R_{FMH}	RFMH	Frictional resistance of multi-hull vessel		N
R_{FINT}	RFINT	Frictional resistance interference correction	R_{FMH} - Σ R_{F}	N
R_{RMH}	RRMH	Residuary resistance correction of multi-hull	R_{TMH} - R_{FMH}	N
R_{RI}	RRINT	Residuary resistance interference correction	R_{RMH} - Σ R_{R}	N
R_{TMH}	RTMH	Total resistance of multi-hull vessel		N
R_{TI}	RTINT	Total resistance interference correction	R_{TMH} - Σ R_{T}	N

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.3 Hydrofoil Boats

3.3.1 Geometry and Hydrostatics

See Sections 2.2.1 and 2.2.4

A_{F}	AFO	Foil area (general)	Foil area in horizontal plane	m^2
A_{FT}	AFT	Total foil plane area		m^2
B_{FOA}	BFOA	Maximum vessel breadth including foils		m
b_{S}	BST	Span of struts		m
b_{ST}	BSTT	Transverse horizontal distance of struts		m
c_{C}	CHC	Chord length at centre plane		m
c_{F}	CFL	Chord length of flap		m
c_{M}	CHM	Mean chord length		m
c_{S}	CSTR	Chord length of a strut		m
c_{SF}	CHSF	Chord length of strut at intersection with foil		m
c_{T}	CHTI	Chord length at foil tips		m
W_{F}	WTF	Weight of foil		N
α_{c}	ALFTW	Geometric angle of twist		rad
θ_{DH}	DIHED	Dihedral angle		rad
∇_{F}	DISVF	Foil displacement volume		m^3

3.3.1.1 Geometry, Underway

A_{FE}	AFE	Emerged area of foil		m^2
A_{FF}	ASFF	Submerged area of front foil		m^2
A_{FR}	ASFR	Submerged area of rear foil		m^2
$A_{\mathrm{F}S}$	AFS	Submerged foil area		m^2
A_{FST0}	AFSTO	Submerged foil plan area at take-off speed		m^2
A_{SS}	ASS	Submerged strut area		m^2
b_{w}	BSPW	Foil span wetted		m
c_{PF}	CPFL	Distance of centre of pressure on a foil or flap from leading edge		m
Fr_L	FNFD	Froude number based on foil distance	$V / (g\ L_{\mathrm{F}})^{1/2}$	1
Fr_c	FNC	Froude number based on chord length	$V / (g\ c_{\mathrm{M}})^{1/2}$	1
h_{CG}	HVCG	Height of centre of gravity foilborne	Distance of centre of gravity above mean water surface	m
h_{F}	HFL	Flight height	Height of foil chord at foilborne mode above position at rest	m
h_{K}	HKE	Keel clearance	Distance between keel and mean water surface foilborne	m
l_{F}	LEFF	Horizontal distance of centre of pressure of front foil to centre of gravity		m
l_{FR}	LEFR	Horizontal distance between centres of pressure of front and rear foils	$l_{\mathrm{F}} + l_{\mathrm{R}}$	m
l_{R}	LERF	Horizontal distance of centre of pressure of rear foil to centre of gravity		m
T_{F}	TFO	Foil immersion	Distance between foil chord and mean water surface	m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
T_{FD}	TFD	Depth of submergence of apex of a dihedral foil	Distance between foil apex and mean water surface	m
T_{FM}	TFOM	Mean depth of foil submergence		m
α_{IND}	ALFIND	Downwash or induced angle		rad
α_{M}	ALFM	Angle of attack of mean lift coefficient for foils with twist		rad
α_{s}	AFS	Angle of attack for which flow separation (stall) occurs		rad
α_{TO}	ATO	Incidence angle at take-off speed		rad

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.3.2 Resistance and Propulsion

See also **Section 2.3.1 Hull Resistance**

3.3.2.1 Basic Quantities

D_{F}	DRF	Foil drag	Force in the direction of motion of an immersed foil	N
D_{FR}	DFA	Drag force on rear foil	$C_{D\mathrm{F}}\, A_{\mathrm{FR}}\, q$	N
D_{FF}	DFF	Drag force on front foil	$C_{D\mathrm{F}}\, A_{\mathrm{FF}}\, q$	N
D_{I}	DRIND	Induced drag	For finite span foil, the component of lift in the direction of motion	N
D_{INT}	DRINT	Interference drag	Due to mutual interaction of the boundary layers of intersecting foil	N
D_{P0}	DRF0	Profile drag for angle of attack equal to zero lift	Streamline drag	N
D_{S}	DRSP	Spray drag	Due to spray generation	N
D_{ST}	DRST	Strut drag		N
D_{W}	DRWA	Wave drag	Due to propagation of surface waves	N
D_{V}	DRVNT	Ventilation drag	Due to reduced pressure at the rear side of the strut base	N
L_{F}	LF	Lift force on foil	$C_L\, A_{\mathrm{FT}}\, q$	N
L_{FF}	LFF	Lift force on front foil	$C_L\, A_{\mathrm{FF}}\, q$	N
L_{FR}	LFR	Lift force on rear foil	$C_L\, A_{\mathrm{FR}}\, q$	N
L_0	LF0	Profile lift force for angle of attack of zero	$C_{L0}\, A_{\mathrm{FT}}\, q$	N
L_{TO}	LT0	Lift force at take off	$C_{L\mathrm{TO}}\, A_{\mathrm{FT}}\, q$	N
M	MSP	Vessel pitching moment		Nm

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.3.2.2 Derived Quantities

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
$C_{D\mathrm{F}}$	CDF	Drag coefficient of foil	$D_\mathrm{F} / (A_\mathrm{FS}\ q)$	1
$C_{D\mathrm{I}}$	CDI	Induced drag coefficient	$D_\mathrm{I} / (A_\mathrm{FS}\ q)$	1
$C_{D\mathrm{INT}}$	CDINT	Interference drag coefficient	$D_\mathrm{INT} / (A_\mathrm{FS}\ q)$	1
C_{D0}	CDO	Section drag coefficient for angle of attack equal to zero	$D_\mathrm{P} / (A_\mathrm{FS}\ q)$	1
$C_{D\mathrm{S}}$	CDSP	Spray drag coefficient	$D_\mathrm{S} / (A_\mathrm{FS}\ q)$	1
$C_{D\mathrm{VENT}}$	CDVENT	Ventilation drag coefficient	$D_\mathrm{V} / (A_\mathrm{FS}\ q)$	1
$C_{D\mathrm{W}}$	CDW	Wave drag coefficient	$D_\mathrm{W} / (A_{F\mathrm{S}}\ q)$	1
$C_{L\mathrm{F}}$	CLF	Foil lift coefficient	$L_\mathrm{F} / (A_\mathrm{FS}\ q)$	1
C_{L0}	CLO	Profile lift coefficient for angle of attack equal to zero	$L_0 / (A_\mathrm{FS}\ q)$	1
$C_{L\mathrm{TO}}$	CLTO	Lift coefficient at take-off condition	$L_\mathrm{TO} / (A_\mathrm{FS}\ q)$	1
$C_{L\mathrm{X}}$	CLA	Slope of lift curve	$dC_L / d\alpha$	1
C_M	CM	Pitching moment coefficient	$M / ((A_\mathrm{FF} + A_\mathrm{FR}) (l_\mathrm{F} - l_\mathrm{R})\ q)$	1
M_F	MLF	Load factor of front foil	L_FF / Δ	1
M_R	MLR	Load factor of rear foil	L_FR / Δ	1
ε_F	EPSLDF	Lift/ Drag ratio of foil	L / D	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.4 ACV and SES

3.4.1 Geometry and Hydrostatics

See also Section 1.2.1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
A_{C}	CUA	Cushion area	Projected area of ACV or SES cushion on water surface	m^2
B_{C}	BCU	Cushion breadth	SES cushion breadth measured between the side walls	m
B_{WLT}	BWLT	Total waterline breadth of SES	At the water line	m
H_{CG}	HVCG	Height of centre of gravity above mean water plane beneath craft		m
h_{BS}	HBS	Bow seal height	Distance from side wall keel to lower edge of bow seal	m
H_{SK}	HSK	Skirt depth		m
h_{SS}	HSS	Stern seal height	Distance from side wall keel to lower edge of stern seal	m
L_{B}	LB	Deformed bag contact length		m
L_{C}	LAC	Cushion length		m
L_{E}	LACE	Effective length of cushion	$A_{\mathrm{C}} / B_{\mathrm{C}}$	m
S_{H0}	SSH0	Wetted area of side hulls at rest off cushion	Total wetted area of side walls under way on cushion	m^2
S_{SHC}	SSHC	Wetted area of side hulls under way on cushion	Total wetted area of side walls under way on cushion	m^2
S_{SH}	SSH	Wetted area of side hulls under way off cushion	Total wetted area of side walls under way off cushion	m^2
X_{H}, L_{H}	XH, LH	Horizontal spacing between inner and outer side skirt hinges or attachment points to structure	needs clarification	m
X_{S}, L_{S}	XS, LS	Distance of leading skirt contact point out-board or outer hinge of attachment point to structure	needs clarification	m
Z_{H}, H_{H}	ZH, HH	Vertical spacing between inner and outer side skirt hinges or attachment points to structure	needs clarification	m
δB_{C}	DBCV	Increase in cushion breadth due to water contact		m
ε_{WS}	EPSWS	Wetted surface factor	$S_{\mathrm{SHC}} / S_{\mathrm{SH0}}$	1
θ_{B}	TETB	Bag contact deformation angle		rad
θ_{F}	TETF	Finger outer face angle		rad
θ_{W}	TETW	Slope of mean water plane for surface level beneath cushion periphery		rad
ρ_{A}	DNA	*(ACV and SES)* Mass density of air	Mass of air per unit volume	$\mathrm{kg/m}^3$
ζ_{C}	ZETAC	Height of cushion generated wave above mean water plane at leading edge side of the skirt		m

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.4.2 Resistance and Propulsion

See also Section 2.3.1 on Hull Resistance

C_{Δ}	CLOAD	Cushion loading coefficient	$\Delta / (g \rho_{A} A_{C}^{3/2})$	1
C_{PR}	CPR	Aerodynamic profile drag coefficient	$R_0 / (\rho_A V_R^2 A_C / 2)$	1
C_{WC}	CWC	Cushion wave making coefficient		1
p_B	PBM	Mean bag pressure		Pa
p_{BS}	PBS	Bow seal pressure	Pressure in the bow seal bag	Pa
p_{CE}	PCE	Mean effective skirt pressure		Pa
p_{CU}	PCU	Cushion pressure	Mean pressure in the cushion	Pa
p_{FT}	PFT	Fan total pressure		Pa
p_{LR}	PLR	Cushion pressure to length ratio	P_{CU} / L_C	Pa/m
p_{SK}	PSK	Skirt pressure in general		Pa
p_{SS}	PSS	Stern seal pressure	Pressure in the stern seal bag	Pa
P_{FCU}	PFCU	Power of lift fan		W
P_{FSK}	PFSK	Power of skirt fan		W
Q_{BS}	QBS	Bow seal air flow rate	Air flow rate to the bow seal	m^3/s
Q_{CU}	QCU	Cushion air flow rate	Air flow rate to cushion	m^3/s
Q_{SS}	QSS	Stern seal air flow rate	Air flow rate to the stern seal	m^3/s
Q_T	QT	Total air volume flow		m^3/s
Q_{TS}	QTS	Total air volume flow of skirt		m^3/s
R_{AT}	RAT	Total aerodynamic resistance	$R_M + R_0$	N
R_H	RH	Hydrodynamic resistance	$R_W + R_{WET}$	N
R_M	RM	Intake momentum resistance in general	$\rho_A Q_T V_A$	N
R_{MCU}	RMCU	Intake momentum resistance of cushion	$\rho_A Q_{CU} V_A$	N
R_{ASK}	RASK	Intake momentum resistance of skirt	$\rho_A Q_{TS} V_A$	N
R_{WET}	RWET	Resistance due to wetting		N
T_C	TC0	Cushion thrust		N

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.5 Ice Going Vessels

3.5.1 Resistance and Propulsion

(See Figure 3.4, p 225 and Figure 3.8, p 231 of Vol. 1 of the *Proceedings of the 21st ITTC*)

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit
C_I	CI	Coefficient of net ice resistance	$R_I / (\rho_I g h^2 B)$	1
C_{IW}	CIW	Coefficient of water resistance in the presence of ice	$R_{IW} / (S q_{IW})$	1
F_{IN}	FNIC	Normal ice force on a body	Projection of hull - ice interaction force on the external normal	N
F_{IT}	FTIC	Tangential ice force on a body	Projection of the hull - ice interaction force on the direction of motion	N
Fr_I	FNIC	Froude number based on ice thickness	$V / (g h_I)^{1/2}$	1
F_{XI} F_{YI} F_{ZI}	FXIC FYIC FZIC	Components of the local ice force		N N N
f_{ID}	CFRD	Coefficient of friction between surface of body and ice (dynamic)	Ratio of tangential force to normal force between two bodies (dynamic condition)	1
f_{IS}	CFRS	Coefficient of friction between surface of body and ice (static)	The same as above (static condition)	1
h_I	HTIC	Thickness of ice		m
h_{SN}	HTSN	Thickness of snow cover		m
K_{QIA}	KQICMS	Average coefficient of torque in ice	$Q_{IA} / (\rho_W n_{IA}^2 D^5)$	1
K_{TIA}	KTICMS	Average coefficient of thrust in ice	$T_{IA} / (\rho_W n_{IA}^2 D^4)$	1
n_{IA}	FRICMS	Average rate of propeller revolution in ice		Hz
P_{DI}	PDI	Delivered power at propeller in ice	$2 \pi Q_{IA} n_{IA}$	W
Q_{IA}	QIMS	Average torque in ice		Nm
R_I	RI	Net ice resistance	R_{IT} - R_{IW}	N
R_{IT}	RIT	Total resistance in ice	Ship towing resistance in ice	N
R_{IW}	RIW	Hydrodynamic resistance in presence of ice	Total water resistance of ship in ice	N
T_{IA}	TIMS	Average total thrust in ice		N
η_{ICE}	ERIC	Relative propulsive efficiency in ice	η_{ID} / η_D	1
η_{ID}	EFDIC	Propulsive efficiency in ice	$R_{IT} V / (2 \pi n_{IA} Q_{IA})$	1

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.6 Sailing Vessels

3.6.1 Geometry and Hydrostatics

See also Section 2.2.1 on Hull Geometry

A_J	ASJ	Area of jib or genoa		m^2
A_{LK}	ALK	Lateral area of keel		m^2
A_{LT}	ALT	Total lateral area of yacht		m^2
A_m	ASM	Area of mainsail		m^2
A_N	ASN	Normalized sail area		m^2
A_{SP}	ASSP	Area of spinnaker		m^2
A_S, S_A	AS	Sail area in general	$(P E + I J) / 2$	m^2
B_{OA}	BOA	Breadth, overall		m
C_{pi} E	CPI EM	Center of pressure for A_i Main-sail base		m
I	I	Fore triangle height		m
J	J	Fore triangle base		m
P	P	Mainsail height		m
L_{EFF}	LEFF	Effective length for Reynolds Number		m
S_C	SC	Wetted surface area of canoe body		m^2
S_K	SK	Wetted surface area of keel		m^2
S_R	SR	Wetted surface area of rudder		m^2
T_C	TCAN	Draught of canoe body		m
T_{EFF}	TEFF	Effective draught	$F_H / (\rho V_B^2 R)^5$	m
Z_{CE}	ZCE	Height of centre of effort of sails above waterline in vertical centre plane		m
∇_C	DVCAN	Displaced volume of canoe body		m^3
∇_K	DVK	Displaced volume of keel		m^3
∇_R	DVR	Displaced volume of rudder		m^3
Δ_C	DFCAN	Displacement force (weight) of canoe body		N
Δ_K	DFK	Displacement force (weight) of keel		N
Δ_R	DFR	Displacement force (weight) of rudder		N

ITTC Symbol	Computer Symbol	Name	Definition or Explanation	SI-Unit

3.6.2 Resistance and Propulsion

C_{FU}	CFU	Frictional resistance coefficient (upright)	R_{FU} / (S q)	1
C_{RU}	CRU	Residuary resistance coefficient (upright)	R_{RU} / (S q)	1
C_{TU}	CTU	Total resistance coefficient (upright)	R_{TU} / (S q)	1
C_{WU}	CWU	Wave resistance coefficient (upright)		1
$C_{T\varphi}$	CTPHI	Total resistance coefficient with heel and leeway	$R_{T\varphi}$ / (S q)	1
C_{I}		Induced resistance coefficient		1
C_x, C_y, C_z		Force coefficients		1
F_{H}		Heeling force of sails		N
F_{R}		Driving force of sails		N
F_{V}		Vertical force of sails		N
H		Side force		N
L_{HY}		Hydrodynamic lift force		N
R_{AW}		Mean added resistance in waves		N
R_{FU}		Friction resistance (upright)		N
R_{RU}		Residuary resistance (upright)		N
R_{I}		Resistance increase due to side (induced resistance)		N
R_{TU}	RTU	Total resistance (upright)		N
$R_{T\varphi}$	RTUH	Total resistance when heeled	$R_{TU} + R_{\varphi}$	N
R_{φ} , R_{H}	RTUHA	Resistance increase due to heel (with zero side force)		N
X,Y,Z		Components of resultant force along designated axis		N
V	V	Vessel velocity		m/s
V_{WR}	VWR	Apparent wind velocity		m/s
V_{WT}	VWT	True wind velocity		m/s
V_{mc}	VMC	Velocity made good on course		m/s
V_{mg}	VMG	Velocity made good to windward (contrary to wind direction)		m/s
β_{L}	BETAL	leeway angle		rad
β_{aw}	BETWA	apparent wind angle (relative to boat course)		rad
β_{tw}	BETWT	true wind angle (relative to boat course)		rad

4. BACKGROUND AND REFERENCES

4.1 Symbols and Terminology Group

The tasks of the former Symbols and Terminology Group (SaT) have been handed over to the Quality Systems Group in 2002.

4.2 Description of the List of Symbols

4.2.1 Classification

The prime concern of the QS Group was to revise and try to complement the list of ITTC Standard Symbols sticking to the system for the classification of concepts.

With this regard, the following design requirements and goals have been maintained:

1. a coherent document, meeting the present and possibly the future requirements of the ITTC community in general and particular user groups
2. an open ended matrix structure that can be easily expanded as requirements arise, without the need of restructuring and repetition or too many explicit cross-references
3. minimized departures from the well established and widely accepted previous list of symbols

On the other hand, to facilitate the practical use of the list, a second version in which the symbols are arranged in alphabetic order was prepared. Symbols which have been listed several times in the matrix structured document have been maintained and for each symbol the field in which it is used is given in italic letters prior to the meaning of the symbol.

4.2.2 Structure of the Lists

The concepts related to a given subject area or model are designated by the ITTC Symbol and called by their Name. Their meaning can in principle only be concluded from the context of the model. The logically consistent, so called 'implicit' definition is derived from a definitely defined statement of the model, ideally a generally accepted system or an equivalent, e.g. a drawing.

The problem is that traditionally in lists of symbols, as in dictionaries, these explicit models are missing for various reasons. One reason is that many subject areas under discussion are far from being developed and understood to the extent necessary. A consequence of this situation is that the symbols proposed are not always as coherent as would be necessary for advanced and systematic work, for which explicit models and adequate notations are essential.

The problem under discussion is of course the same in national and international standards. However there is an accepted international standard which deals with the general principles concerning physical quantities, equations, quantity and unit symbols, and coherent unit systems for general use within the various fields of science and technology (ISO 31.

4.2.3 Organization of the matrix structured list

As has been emphasized the development of symbols is a continuing process and as the subject develops, further amendments and additions, as approved by the Conference, will be included in future editions of the list.

In order to avoid any extra problems the symbols are arranged in alphabetical order in each subject area as in previous lists. Continuous page numbering was discarded in earlier versions. The idea was to establish a loose leaf organization as the most appropriate, in view of new draughts to be incorporated.

In view of the tremendous effort which explicit mathematical models, explanations, and sketches take for their preparation, the present QS Group can only follow the former SaT Group and state that the Technical Committees and other interested parties are urged to provide further material for review by the QS Group and future inclusion into the list.

It has been noted that some users dislike the disruption of the list of symbols by lengthy explanations. The present QS Group feels that the subject and the sensible use of the symbols require such explanations, also as the fundamentals of the theory of science and terminology often are not taught to students of naval architecture and marine engineering. However the arrangement has been changed so that these explanations can be visited by using hyperlinks and the list is not disrupted any more.

5. PRINCIPLES OF NOTATION

In Figure 5 the principles of notation in according to ISO 31 are shown.

Symbols representing physical quantities normally are one Latin or Greek letter with Subscripts for further identification. They are written in ***italic*** style letters.

Numbers are normally written in **roman** style letters. For more details, look at the list below or in the Excerpts of ISO 31 below or in standard itself.

Superscripts signify **operators** e.g.

- exponentiation
- the various aspects of complex quantities
- the various aspects of spectra and
- the various aspects of random quantities and stochastic processes e.g. probability operators.

Subscripts signify **identifiers**

- matrix components,
- identifiers tested, e.g. ship S or model M, appendages (App)or the various bodies in a multi-body problem,
- identifiers of coordinate systems and of the reference points, quantities(L_{PP})

Symbols for physical units	italic, one letter, except dimensionless quantities	A (e.g. Area in m²)
Symbols for characteristic numbers	2 letters italic	*Re, Fr*
Numbers	roman, generally	10^3
Symbols representing numbers	italic	x_{ij}
Units	roman, lower case unless derived from name	m, Pa
Prefix of units	roman	**µ**m
Symbols for chemical elements	roman	H_2O
Symbols for universal constants	italic	g = 9,80665 m/s²

Superscripts signify **Operators**
Numbers in **roman** (power of *n*)
Symbols representing numbers (*n* = 1, 2, 3 etc.) in ***italic***

SYMBOLS in *italic*

$$K_{T\mathrm{M}}^{2} \times 10^{n}$$

NUMBERS in roman

Subscripts signify **Identifiers**:
Symbol for **physical quantity** in ***italic*** (*T* = Thrust)
Other symbols in **roman** (M = Model)

Figure 5

5.1 Excerpts of ISO 31

1 Scope

This part of ISO 31 gives general information about principles concerning physical quantities, equations, quantity and unit symbols, and coherent unit systems, especially the International System of Units, SI.

The principles laid down in this part of ISO 31 are intended for general use within the various fields of science and technology and as a general introduction to the other parts of ISO 31.

2. Quantities and units

2.1 Physical quantity, unit and numerical value

In ISO 31 only physical quantities used for the quantitative description of physical phenomena are treated. Conventional scales, such as the Beaufort scale, Richter scale and colour intensity scales, and quantities expressed as the results of conventional tests, e.g. corrosion resistance, are not treated here, neither are currencies nor information contents.

Physical quantities may be grouped together into categories of quantities which are mutually comparable. Lengths, diameters, distances, heights, wavelengths and so on would constitute such a category. Mutually comparable quantities are called "quantities of the same kind".

If a particular example of a quantity from such a category is chosen as a reference quantity, called the ***unit***, then any other quantity from this category can be expressed in terms of this unit as a product of this unit and a number. This number is called the ***numerical value*** of the quantity expressed in this unit.

In formal treatments of quantities and units, this relation may be expressed in the form

$$\mathrm{A}=\{\mathrm{A}\}\cdot[\mathrm{A}]$$

where A is the symbol for the physical quantity, [A] the symbol for the unit and {A} symbolizes the numerical value of the quantity A expressed in the unit [A]. For vectors and tensors the components are quantities which may be expressed as described above.

If a quantity is expressed in another unit which is k times the first unit, then the new numerical value becomes $1/k$ times the first numerical value; the physical quantity, which is the product of the numerical value and the unit, is thus independent of the unit.

REMARK ON NOTATION FOR NUMERICAL VALUES

It is essential to distinguish between the quantity itself and the numerical value of the quantity expressed in a particular unit. The numerical value of a quantity expressed in a particular unit could be indicated by placing braces (curly brackets) around the quantity symbol and using the unit as a subscript. It is, however, preferable to indicate the numerical value explicitly as the ratio of the quantity to the unit.

2.2 Quantities and equations

2.2.1 Mathematical operations with quantities

Two or more physical quantities cannot be added or subtracted unless they belong to the same category of mutually comparable quantities.

Physical quantities are multiplied or divided by one another according to the rules of algebra; the product or the quotient of two quantities, A and B, satisfies the relations

$AB = \{A\}\{B\} - [A][B]$

Thus, the product $\{A\}\{B\}$ is the numerical value $\{AB\}$ of the quantity AB, and the product $[A][B]$ is the unit $[AB]$ of the quantity AB. Similarly, the quotient $\{A!/\{B\})$ is the numerical value $\{A/B\}$ of the quantity A/B, and the quotient $[A]/[B]$ is the unit $[A/B]$ of the quantity A/B.

2.2.2 Equations between quantities and equations between numerical values

Two types of equation are used in science and technology: ***equations between quantities***, in which a letter symbol denotes the physical quantity (i.e. numerical value × unit), and ***equations between numerical values***. Equations between numerical values depend on the choice of units, whereas equations between quantities have the advantage of being independent of this choice. Therefore the use of equations between quantities should normally be preferred.

2.2.3 Empirical constants

An empirical relation is often expressed in the form of an equation between the numerical values of certain physical quantities. Such a relation depends on the units in which the various physical quantities are expressed.

An empirical relation between numerical values can be transformed into an equation between physical quantities, containing one or more empirical constants. Such an equation between physical quantities has the advantage that the form of the equation is independent of the choice of the units. The numerical values of the empirical constants occurring in such an equation depend, however, on the units in which they are expressed, as is the case with other physical quantities.

2.2.4 Numerical factors in quantity equations

Equations between quantities sometimes contain ***numerical factors***. These numerical factors depend on the definitions chosen for the quantities occurring in the equations.

EXAMPLE

$$E_k = \frac{1}{2} m v^2$$

2.2.5 Systems of quantities and equations between quantities; base quantities and derived quantities

Physical quantities are related to one another through equations that express laws of nature or define new quantities.

For the purpose of defining unit systems and introducing the concept of dimensions, it is convenient to consider some quantities as mutually independent, i.e. to regard these as ***base quantities***, in terms of which the other quantities can be defined or expressed by means of equations; the latter quantities are called ***derived quantities.***

It is a matter of choice how many and which quantities are considered to be base quantities.

The whole set of physical quantities included in ISO 31 is considered as being founded on seven base quantities: **length L, mass M, time T, electric current I, thermodynamic temperature Θ, amount of substance N and luminous intensity J**.

In the field of mechanics a system of quantities and equations founded on three base quantities is generally used. In ISO 31-3, the base quantities used are length, mass and time.

In the field of electricity and magnetism a system of quantities and equations founded on four base quantities is generally used. In ISO 31-5, the base quantities used are length, mass, time and electric current.

In the same field, however, systems founded on only three base quantities, length, mass and time, in particular the "Gaussian" or symmetric system, have been widely used. (See ISO 31-5:1992, annex A.)

2.2.6 Dimension of a quantity

Any quantity Q can be expressed in terms of other quantities by means of an equation. The expression may consist of a sum of terms. Each of these terms can be expressed as a product of powers of base quantities $A, B, C,$ ... from a chosen set, sometimes multiplied by a numerical factor ξ, i.e. $\xi A^\alpha B^\beta C^\gamma \ldots$, where the set of exponents (α, β, γ ...) is the same for each term.

The ***dimension*** of the quantity Q is then expressed by the dimensional product

$\dim Q = \mathrm{A}^\alpha \mathrm{B}^\beta \mathrm{C}^\gamma$ ..

where A, B, C, ... denote the dimensions of the base quantities $A, B, C,$ ..., and where α, β, γ .... are called the ***dimensional exponents***.

A quantity all of whose dimensional exponents are equal to zero is often called a ***dimensionless*** **quantity**. Its dimensional product or dimension is $A^0 B^0 C^0 ... = 1$. Such a quantity *of* ***dimension one*** *is* expressed as a number.

In the system founded on the seven base quantities length, mass, time, electric current, thermodynamic temperature, amount of substance and luminous intensity, the base dimensions may be denoted by L, M, T, I, O, N and J respectively and the dimension of a quantity Q becomes in general

dim $Q = L^{\alpha} M^{\beta} T^{\gamma} I^{\delta} \Theta^{\varepsilon} N^{\zeta} J^{\eta}$.

EXAMPLES

Quantity	**Dimension**
velocity	LT^{-1}
angular velocity	T^{-1}
force	LMT^{-2}
energy	L^2MT^{-2}
relative density	1

2.3 Units

2.3.1 Coherent unit systems

Units might be chosen arbitrarily, but making an independent choice of a unit for each quantity would lead to the appearance of additional numerical factors in the equations between the numerical values.

It is possible, however, and in practice more convenient, to choose a system of units in such a way that the equations between numerical values have exactly the same form (including the numerical factors) as the corresponding equations between the quantities. A unit system defined in this way is called ***coherent*** with respect to the system of quantities and equations in question. The SI is such a system. The corresponding system of quantities is given in ISO 31-1 to ISO 31-10 and in ISO 31-12 and ISO 31-13.

For a particular system of quantities and equations, a coherent system of units is obtained by first defining units for the base quantities, the ***base units***. Then for each derived quantity, the definition of the corresponding ***derived unit*** in terms of the base units is given by an algebraic expression obtained from the dimensional product (see 2.2.6) by replacing the symbols for the base dimensions by those of the base units. In particular, a quantity of dimension one acquires the unit 1. In such a coherent unit system no numerical factor other than the number 1 ever occurs in the expressions for the derived units in terms of the base units.

2.3.2 SI units and their decimal multiples and sub-multiples

The name *International System of Units* (Système International d'Unités), with the international abbreviation SI was adopted by the 11th *General Conference on Weights and Measures* (Conférence Générale des Poids et Mesures, CGPM) in 1960.

This system includes

- base units
- derived units including supplementary units

which together form the coherent system of *SI units.*

2.3.2.1 Base units

The seven base units are listed in Table 1.

Table 1 - SI base units

Base quantity	SI base unit	
	Name	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

2.3.2.2 Derived units including supplementary units

The expressions for the coherent derived units in terms of the base units can be obtained from the dimensional products by using the following formal substitutions:

L → m	I → A
M → kg	Θ → K
T → s	N → mol
	J → cd

In 1960, the CGPM classified the SI units radian, rad, and steradian, sr, for plane angle and solid angle respectively as "supplementary units".

In 1980, the *International Committee for Weights and Measures* (Comité International des Poids et Mesures, CIPM) decided to interpret the class of supplementary units in the SI as a class of dimensionless derived units for which the CGPM allows the freedom of using or not using them in expressions for SI derived units.

Although, as a consequence of this interpretation, the coherent unit for plane angle and for solid angle is the number 1, it is convenient to use the special names radian, rad, and steradian, sr, instead of the number 1 in many practical cases.

Table 2 - SI derived units with special names, including SI supplementary units

Derived quantity	SI derived unit		
	Special name	Symbol	Expressed in terms of SI base units and SI derived units
plane angle	radian	rad	1 rad = 1 m/m = 1
solid angle	steradian	sr	1 sr = 1 m^2 /m^2 = 1
frequency	hertz	Hz	1 Hz = 1 s^{-1}
force	newton	N	1 N = 1 kg . m/s^2
pressure, stress	pascal	Pa	1 Pa = 1 N/m^2
energy, work, quantity of heat	joule	J	1 J = 1 N - m
power, radiant flux	watt	W	1 W = 1 J/s
electric charge, quantity of electricity	coulomb	C	1 C = 1 A - s
electric potential, potential difference, tension, electromotive force	volt	V	1 V = 1 W/A
capacitance	farad	F	1 F = 1 C/V
electric resistance	ohm	S2	1Ω = 1 V/A
electric conductance	siemens	S	1 S = 1 $Ω^{-1}$
magnetic flux	weber	Wb	1 Wb = 1 V . s
magnetic flux density	tesla	T	1 T = 1 Wb/m^2
inductance	henry	H	1 H = 1 Wb/A
Celsius temperature	degree Celsius')	°C	1 °C = 1 K
luminous flux	lumen	Im	1 lm = 1 cd . sr
illuminance	lux	Ix	1 lx = 1 lm/m^2

1) Degree Celsius is a special name for the unit kelvin for use in stating values of Celsius temperature. (See also ISO 31-4:1992, items 4-1.a and 4-2.a.)

EXAMPLES

Quantity	Symbol for SI unit expressed in terms of the seven base units (and the supplementary units in some cases)
velocity	m/s
angular velocity	rad/s or s^{-1}
force	kg . m/s^2
energy	kg . m^2/s^2
relative density	1

For some of the SI derived units, special names and symbols exist; those approved by the CGPM are listed in tables 2 (and 3).

It is often of advantage to use special names and symbols in compound expressions for units.

2.3.2.3 SI prefixes

In order to avoid large or small numerical values, decimal multiples and sub-multiples of the SI units are added to the coherent system within the framework of the SI. They are formed by means of the prefixes listed in Table 4.

Table 4 - Sl prefixes

Factor	Prefix	
	Name	Symbol
10^{24}	yotta	Y
10^{21}	zetta	z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

For information about the use of the prefixes, see 3.2.4.

The SI units and their decimal multiples and submultiples formed by use of the prefixes are specially recommended.

2.3.3 The unit one

The coherent SI unit for any quantity of dimension one is the unit one, symbol 1. It is generally not written out explicitly when such a quantity is expressed numerically.

EXAMPLE

Refractive index $n = 1{,}53 \times 1 = 1{,}53$

In the case of certain such quantities, however, the unit 1 has special names that could be used or not, depending on the context.

EXAMPLES

Plane angle $\alpha = 0{,}5$ rad = 0,5 ,

Solid angle $\Omega = 2{,}3$ sr = 2,3

Decimal multiples and sub-multiples of the unit one are expressed by powers of 10. They shall not be expressed by combining the symbol 1 with a prefix.

In some cases the symbol % (per cent) is used for the number 0,01.

NOTES

3 In some countries the symbol %o ("per mill", or per thousand) is used for the number 0,001. This symbol should be avoided.

4 Since per cent and per mill are numbers it is in principle meaningless to speak about percentage by mass or percentage by volume. Additional information, such as % (m/m) or % (V/V), should not therefore be attached to the unit symbol. The preferred way of expressing a mass fraction is: "the mass fraction is 0,67" or "the mass fraction is 67 %", and the preferred way of expressing a volume fraction is: "the volume fraction is 0,75" or "the volume fraction is 75 %". Mass and volume fractions can also be expressed in the form 5 µg/g or 4,2 ml/m3.

Abbreviations such as ppm, pphm and ppb shall not be used.

2.3.4 Other unit systems and miscellaneous units

The CGS system of mechanical units is a coherent system the base units of which are centimetre, gram and second for the three base quantities length, mass and time.

In practice this system was enlarged by adding the kelvin, the candela and the mole as base units for the base quantities thermodynamic temperature, luminous intensity and amount of substance.

Units used in electricity and magnetism have been defined in the CGS system in several ways depending on the system of quantities and equations chosen. The "Gaussian" or symmetric CGS system, coherent with the "Gaussian" or symmetric system of quantities and equations founded on three base quantities, has been widely used. For further information on this system, see ISO 31-5:1992, Annex A.

The special names and symbols for derived CGS units such as dyne, erg, poise, stokes, gauss, oersted and maxwell shall not be used together with the Sl.

Table 5 - Units used with the SI

Quantity	**Unit**		
	Name	**Symbol**	**Definition**
time	minute hour day	min h d	1 min= 60s 1 h = 60 min 1 d = 24 h
plane angle	degree minute second	° ' "	1 ° = (π/180)rad = (n/l80) rad 1' = (1/60)° 1" = (1/60)'
volume	litre	I, L [1)]	11 = 1 dm^3 = 1 dm
mass	tonne[2)]	t	1 t = 10^3 kg
[1)] The two symbols for litre are on an equal footing. The CIPM will, however, make a survey on the development			

of the use of the two symbols in order to see if one of the two may be suppressed.
[2)] Also called the metric ton in the English language.

Table 6 - Units used with the SI, whose values in SI units are obtained experimentally

Quantity	Unit		
	Name	**Symbol**	**Definition**
energy	electronvolt	eV	The electronvolt is the kinetic energy acquired by an electron in passing through a potential difference of 1 volt in vacuum: 1 eV ≈ 1,602 177 $\times 10^{-19}$ J.
mass	unified atomic mass unit	u	The unified atomic mass unit is equal to (1 /12) of the mass of an atom of the nuclide ^{12}C: 1u ≈ 1,660 540 $\times 10^{-27}$kg.

In other parts of ISO 31, the special names for the derived CGS units are given in informative annexes which are not integral parts of the standards.

There are certain units outside the SI which are recognized by the CIPM as having to be retained for use together with the SI, e.g. minute, hour and electronvolt. These units are given in Tables 5 and 6.

Other coherent systems of units have been defined, e.g. a system based on the units foot, pound and second and a system based on the units metre, kilogram-force and second.

Apart from these, other units have been defined which do not belong to any coherent system, e.g. the atmosphere, **the nautical mile** and the curie.

3 Recommendations for printing symbols and numbers

3.1 Symbols for quantities

3.1.1 Symbols

The symbols for physical quantities are generally single letters of the Latin or Greek alphabet, sometimes with subscripts or other modifying signs. These **symbols** are printed in ***italic*** (sloping) type (irrespective of the type used in the rest of the text).

The symbol is not followed by a full stop except for normal punctuation, e.g. at the end of a sentence.

NOTES

5 Symbols for quantities are given in ISO 31-1 to ISO 31-10 and in ISO 31-12 and ISO 31-13.

6 Notations for vectorial and other non-scalar quantities are given in ISO 31-11, on mathematical signs and symbols.

7 Exceptionally, symbols made up of two letters are sometimes used for combinations of dimension one of quantities (e.g. Reynolds number, *Re*). If such a two-letter symbol appears as a factor in a product, it is recommended that it be separated from the other symbols.

3.1.2 Rules for the printing of subscripts

When, in a given context, different quantities have the same letter symbol or when, for one quantity, different applications or different values are of interest, a distinction can be made by use of subscripts.

The following principles for the printing of subscripts are recommended:

A subscript that represents a symbol for a physical quantity is printed in italic (sloping) type.

Other subscripts are printed in roman (upright) type.

EXAMPLES

Upright subscripts		**Sloping subscripts**	
$\boldsymbol{C}_{\mathrm{g}}$	(*g* gas)	C_p	(*p*: pressure)
g_{n}	(n: normal)	$\sum_n a_n \delta_n$	(*n:* running number)
μ_{r}	(r: relative)	$\sum_x a_x b_x$	(*x:* running number)
$\boldsymbol{E}_{\mathrm{k}}$	(k: kinetic)	g_{ik}	(*i, k:* running numbers)
χ_{e}	(e: electric)	p_x	(*x*:*x*-coordinate)
$T_{1/2}$	(1/2: half)	l_λ	(λ wavelength)

NOTES

8 Numbers as subscripts should be printed in roman (upright type. However, letter symbols representing numbers are generally printed in italic (sloping) type.

3.1.3 Combination of symbols for quantities; elementary Operations with quantities

When symbols for quantities are combined in a product, this process of combination may be indicated in one of the following ways:

ab, $a\ b$, $a \cdot b$, $a \times b$

NOTES

10 In some fields, e.g. in vector analysis, distinction is made between $\boldsymbol{a} \cdot \boldsymbol{b}$ and $\boldsymbol{a} \times \boldsymbol{b}$.

11 For multiplication of numbers, see 3.3.3.

12 In systems with limited character sets a dot on the line may be used instead of a half-high dot.

Division of one quantity by another may be indicated in one of the following ways:

$\frac{a}{b}$, a/b or by writing the product of $\boldsymbol{a}$ and $\boldsymbol{b^{-1}}$,

e.g. $a \cdot\cdot\, b^{-1}$

3.2 Names and symbols for units

3.2.1 International symbols for units

When international symbols for units exist, they, and no other, shall be used. They shall be printed in roman (**upright**) type (irrespective of the type used in the rest of the text), shall remain unaltered in the plural shall be written without a final full stop (period) except for normal punctuation, e.g. at the end of a sentence.

Any attachment to a unit symbol as a means of giving information about the special nature of the quantity or context of measurement under consideration is incorrect.

EXAMPLE

$U_{\mathrm{max}} = 500$ V (not $U = 500$ $\mathrm{V_{max}}$)

The unit symbols shall in general be printed in lower case letters except that the first letter is printed in upper case when the name of the unit is derived from a proper name.

EXAMPLES

m	metre
s	second
A	ampere
Wb	weber

3.2.2 Combination of symbols for units

When a compound unit is formed by multiplication of two or more units, this should be indicated in one of the following ways:

N·m, N m

NOTES

13 In systems with limited character sets a dot on the line may be used instead of a half high dot.

14 The latter form may also be written without a space, provided that special care is taken when the symbol for one of the units is the same as the symbol for a prefix.

EXAMPLE

mN means millinewton, not metre newton.

When a compound unit is formed by dividing one unit by another, this should be indicated in one of the following ways:

$\frac{\mathrm{m}}{\mathrm{s}}$ m/s $\mathrm{m{\cdot}s^{-1}}$

A solidus (/) shall not be followed by a multiplication sign or a division sign an the same line unless parentheses are inserted to avoid any ambiguity. In complicated cases negative powers or parentheses shall be used.

3.2.3 Printing of symbols for units

No recommendation is made or implied about the font of upright type in which symbols for units are to be printed.

NOTE 15 In this series of publications the font used in such cases is generally that of the associated text, but this does not constitute a recommendation.

3.2.4 Printing and use of prefixes

Symbols for prefixes should be printed in roman (upright) type without a space between the symbol for the prefix and the symbol for the unit.
Compound prefixes shall not be used.

EXAMPLE

Write nm (nanometre) for 10^{-9} m, not mμm.

The symbol of a prefix is considered to be combined with the single unit symbol to which it is directly attached, forming with it a new symbol (for a decimal multiple or sub-multiple) which can be raised to a positive or negative power, and which can be combined with other unit symbols to form symbols for compound units (see 3.2.2).

EXAMPLES

$1\mathrm{cm}^3 = (10^{-2}\mathrm{m})^3 = 10^{-6}\,\mathrm{m}^3$

$1\ \mu\mathrm{s}^{-1} = (10^{-6}\ \mathrm{s})^{-1} = 10^{6}\ \mathrm{s}^{-1}$

$1\ \mathrm{kA/m} = (10^{3}\mathrm{A})/\mathrm{m} = 10^{3}\ \mathrm{A/m}$

NOTE 16 For historical reasons the name of the base unit or mass, the kilogram, contains the name of the SI prefix ,"kilo". Names of the decimal multiples and sub-multiples of the unit of mass are formed by adding the prefixes to the word „gram“, e.g. milligram (mg) instead of microkilogram (μkg).

3.3 Numbers

3.3.1 Printing of numbers

Numbers should generally be printed in roman (upright) type.

To facilitate the reading of numbers with many digits, these may be separated into suitable groups, preferably of three, counting from the decimal sign towards the left and the right; the groups should be separated by a small space, and never by a comma or a point, or by any other means.

3.3.2Decimal sign

The decimal sign is a comma on the line.

If the magnitude of the number is less than unity, the decimal sign should be preceded by a zero.

NOTE 17 In documents in the English language. a dot is often used instead of a comma. If a dot is used, it should be on the line. In accordance with an ISO Council decision, the decimal sign is a comma in ISO documents.

3.3.3 Multiplication of numbers

The sign for multiplication of numbers is a cross (×) or a dot half-high (·).

NOTES

18 If a dot half-high is used as the multiplication sign, a comma should be used as the decimal sign. If a dot is used as the decimal sign, a cross should be used as the multiplication sign.

19. In ISO documents, the dot is not used directly between numbers to indicate multiplication.

3.4 Expressions for quantities

The symbol of the unit shall be placed after the numerical value in the expression for a quantity, leaving a space between the numerical value and the unit symbol. It should be noted that, in accordance with this rule, the symbol °C for degree Celsius shall be preceded by a space when expressing a Celsius temperature.

The only exceptions to this rule are for the units degree, minute and second for plane angle, in which case there shall be no space between the numerical value and the unit symbol.

If the quantity to be expressed is a sum or a difference of quantities then either parentheses shall be used to combine the numerical values, placing the common unit symbol after the complete numerical value, or the expression shall be written as the sum or difference of expressions for the quantities.

EXAMPLES

l = 12 m - 7 m= (12 - 7) m = 5m
t = 28.4 °C ± 0,2 °C = (28,4 ± 0,2) °C
(not 28,4 ± 0,2 °C)
λ.=220 × (1 ± 0,02) W/(m·K)

3.5 Symbols for chemical elements and nuclides

Symbols for chemical elements shall be written in roman (upright) type (irrespective of the type used in the rest of the text). The symbol is not followed by a full stop except for normal punctuation, e.g. at the end of a sentence.

EXAMPLES

H He C Ca

A complete list of the symbols for the chemical elements is given in ISO 31-8:1992, annex A, and 150 31-9:1992, annex A.

The attached subscripts or superscripts specifying a nuclide or molecule shall have the following meanings and positions.

The nucleon number (mass number) of a nuclide is shown in the left superscript position, e.g.
^{14}N

The number of atoms of a nuclide in a molecule is shown in the right subscript position, e.g.
$^{14}N_2$

The proton number (atomic number) may be indicated in the left subscript position, e.g.
$_{64}Gd$

If necessary, a state of ionization or an excited state may be indicated in the right superscript position.

EXAMPLES

State of ionization:	Na^+
	PO_4^{3-} or $(PO_4)^{3-}$
Electronic excited state:	$He^{*\bullet}$, $N0^{*\bullet}$
Nuclear excited state:	$^{110}Ag^{*\bullet}$, $^{110}Ag^m$

3.6 Mathematical signs and symbols

Mathematical signs and symbols recommended for use in the physical sciences and technology are given in 1S031-11.

3.7 Greek alphabet (upright and sloping types)

alpha	Α	a	A	a
beta	Β	β	B	β
gamma	Γ	γ	$\mathit{\Gamma}$	γ
delta	Δ	δ	$\mathit{\Delta}$	δ
epsilon	Ε	ε	E	ε
zeta	Ζ	ζ	Z	ζ
eta	Η	η	H	η
theta	Θ	θ, ϑ	$\mathit{\Theta}$	θ, ϑ
iota	Ι	ι	I	ι
kappa	Κ	κ	K	κ
lambda	Λ	λ	$\mathit{\Lambda}$	λ
mu	Μ	μ	M	μ
nu	Ν	ν	N	ν
xi	Ξ	ξ	$\mathit{\Xi}$	ξ
omicron	Ο	ο	O	o
pi	Π	π	$\mathit{\Pi}$	π
rho	Ρ	ρ	P	ρ,
sigma	Σ	σ	$\mathit{\Sigma}$	σ
tau	Τ	τ	T	τ
upsilon	Υ	υ	$\mathit{\Upsilon}$	υ
phi	Φ	φ	$\mathit{\Phi}$	φ
chi	Χ	χ	X	χ
psi	Ψ	ψ	$\mathit{\Psi}$	ψ
omega	Ω	ω	$\mathit{\Omega}$	ω

5.2 Computer Symbols

Wherever possible the symbols in the second column of the tables have been chosen so that their meaning is readily apparent. They have been constructed from the CCITT International Telegraph Alphabet, restricted character set. They are therefore suitable for use in a wide range of situations e. g.: Telex messages, letters, computer printouts etc.

To ensure that the symbols can be used in a wide range of programming languages they currently have been kept to less than six characters long. The symbols should be used as defined, and, in accordance with modern programming practice, should have their type explicitly declared before use. The following rules were applied in the derivation of the symbols:

1. Only upper case letter A - Z and digits 0 - 9 have been used.
2. Formerly Greek letters have been spelled out, if necessary in abbreviated form or with changed spelling. This practice is considered obsolete.
3. The Froude 'circular' symbols are defined by the prefix CIRC.
4. All symbols start with a letter.
5. Qualifiers and operators, preferably two characters, are currently suffixed to the main symbol line, without spacing.
6. No one computer compatible symbol should be used for different concepts in a given context. This goal has not been completely achieved for the whole list. Ad hoc solutions have been attempted but discarded as unsatisfactory.
7. Since the computer compatible symbols have been proposed as the basis of attribute names for data exchanges, the above rules will probably be further developed in the near future.

A final remark on the Computer Symbols: in the computer, the letter O and figure 0 (zero) have fundamentally different meanings, but owing to their resemblance they can be easily confused. Thus it is necessary to distinguish rigorously between them. As a matter of fact there are contradictory conventions being widely used.

5.3 Documentation

5.3.1 ITTC Documents

1. International Towing Tank Conference, Standard Symbols 1971, BSRA Technical Memorandum No.400, August 1971.
2. International Towing Tank Conference, Standard Symbols 1976. BSRA T.M. No.500, 1976.
3. ITTC Dictionary of Ship Hydrodynamics. RINA Maritime Technology Monograph No.6, 1978.
4. Translation of Overall Index of Titles of Dictionary of Ship Hydrodynamics., Vol. 1: CETENA, Genova, 1984,
   Vol. 2: University of Tokyo, 1984.
5. Bibliography and Proposed Symbols on Hydrodynamic Technology as Related Model Tests of High Speed Marine Vehicles. Prep. by 17th ITTC High-Speed Marine Vehicle Committee. SPPA Maritime Research and Consulting. Rep. No.101, 1984.

5.3.2 Translations

A number of translations of the List of ITTC Standard Symbols into languages other than English have been made including French, German, Italian, Japanese, Russian, Spanish and Chinese. For obvious reasons these translations are no longer up-to-date as the present accepted list in English and the Russian one.

1. French Translation of ITTC Standard Symbols 1971., Association Francaise de Normalisation (AFNOR).
2. International vereinbarte Buchstabensymbole und Bezeichnungen auf dem Gebiet der Schiffshydrodynamik. Collatz, G. Schiff und Hafen 27 (1975) No.10.
3. Italian Translation of ITTC Standard Symbols 1971. Luise E. Appendix II, Report of Presentation Committee.
   Proceedings 14th ITTC, Vol. 4, Ottawa 1975.
4. Japanese Translation of ITTC Standard Symbols. Transactions of the Society of Naval Architects of Japan, No.538, April 1974.
5. Russian Translation of ITTC Standard Symbols 1971. Brodarski Institute Publication No.28, Zagreb 1974.
6. Simbolos Internacionales en Arquitectura Naval. Asociacion de Investigacion de la Construccion Naval,
   Publication 7/75, Juli 1975, Madrid.
7. Report of Information Committee, Proc. 17th ITTC, Göteborg 1984.
8. Chinese Translation of ITTC Standard Symbols. China Ship Scientific Research Centre, Wuxi.

5.3.3 Other References

Apart from the organizations represented on the ITTC these symbols have been recommended for use in technical writing on naval architecture by a number of organizations concerned with marine matters including The Royal Institution of Naval Architects, the American Society of Naval Architects and Marine Engineers and the American, British, Canadian, Australian, and Italian Navies. Where possible, the symbols for Section 3.4.1, Waves are consistent with the IAHR/PIANC List of Sea State Parameters, Supplement to Bulletin No 52, January 1986.

In 1985 the Draught International Standard ISO/DIS 7463 Shipbuilding - Symbols for Computer Applications - has been published. The symbols are based on the list approved by the ITTC in Ottawa 1975 and a related list produced by the ISSC in 1974, inconsistencies having been removed. The ISO/TC8/SC15 has been notified that major changes of the ITTC Symbols are under discussion. Subsequently processing of ISO/DIS 7463 has not been postponed, but the standard has been published as ISO 7463 in 1990.