GHANA CIVIL AVIATION

(AIR NAVIGATION SERVICES)

DIRECTIVES

PART 22 - UNITS OF MEASUREMENTS TO BE USED IN AIR AND GROUND OPERATIONS

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Introduction

Part 22 is about units of measurement to be used in international civil aviation. It makes use of the metric system as the primary international standard.

This part contains table of units based essentially on the metric system, but it also contains four additional interim tables of units for use by States unable to use the primary table. The unit of measurement covers all aspects of air and ground operations and not just air-ground communications. The Part has the International System of Units, known as SI from the "Système International Unités", as the basic standardized system to be used in civil aviation.

The SI units recognize a number of non-SI units which may be used permanently in conjunction with SI units in aviation. These include the litre, the degree Celsius, the degree for measuring plane angle, etc
There are some non-SI units which have a special place in aviation and which have been retained, at least temporarily. These are the nautical mile and the knot, as well as the foot when it is used in the measurement of altitude, elevation or height only.

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22.1 DEFINITIONS

When the following terms are used in the Standards and Recommended Practices concerning the units of measurement to be used in all aspects of international civil aviation air and ground operations, they have the following meanings:

Ampere (A). The ampere is that constant electric current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2 $x10^{-7}$ newtons per metre of length.

Becquerel (Bq). The activity of a radionuclide having one spontaneous nuclear transition per second.

Candela (cd). The luminous intensity, in the perpendicular direction, of a surface of 11600 000 square metre of black body at the temperature of freezing platinum under a pressure of 101 325 newtons per square metre.

Celsius temperature (t°C). The Celsius temperature is equal to the difference t°C = T - To between two thermodynamic temperatures T and To where To equals 273.15 Kelvin.

Coulomb (C). The quantity of electricity transported in 1 second by a current of 1 ampere.

Degree Celsius ("C). The special name for the unit Kelvin for use in stating values of Celsius temperature.

Farad (F). The capacitance of a capacitor between the plates of which there appears a difference of potential of 1 volt when it is charged by a quantity of electricity equal to 1 coulomb.

Foot (ft). The length equal to 0.304 8 metre exactly.

Gray (Gy). The energy imparted by ionizing radiation to a mass of matter corresponding to 1 joule per kilogram.

Henry (H). The inductance of a closed circuit in which an electromotive force of 1 volt is produced when the electric current in the circuit varies uniformly at a rate of 1 ampere per second.

Hertz (Hz). The frequency of a periodic phenomenon of which the period is 1 second.

Human performance. Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.

Joule (J). The work done when the point of application of a force of 1 newtons is displaced a distance of 1 metre in the direction of the force.

Kelvin (K). A unit of thermodynamic temperature which is the fraction 11273.16 of the thermodynamic temperature of the triple point of water.

Kilogram (kg). The unit of mass equal to the mass of the international prototype of the kilogram

Knot (kt). The speed equal to 1 nautical mile per hour.

Litre (L). A unit of volume restricted to the measurement of liquids and gases which is equal to 1 cubic decimetre.

Lumen (Im). The luminous flux emitted in a solid angle of 1 steradian by a point source having a uniform intensity of 1 candela.

Lux (Ix). The illuminance produced by a luminous s flux of 1 lumen uniformly distributed over a surface of 1 square metre.

Metre (m). The distance travelled by light in a vacuum during 11299 792 458 of a second.

Mole (mol). The amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12. (When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles or specified groups of such particles.

Nautical mile (NM). The length equal to 1 852 metres 22.1 exactly.

Newton (N). The force which when applied to a body having a mass of 1 kilogram gives it an acceleration of 1 metre per second squared.

Ohm (Ω). The electric resistance between two points of a conductor when a constant difference of potential of 1 volt, applied between these two points, produces in this conductor a current of 1 ampere, this conductor not being the source of any electromotive force.

Pascal (Pa). The pressure or stress of 1 newtons per square metre.

Radian (rad). The plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius

***Second* (s).** The duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium- 133 atom

Siemens (S). The electric conductance of a conductor in which a current of 1 ampere is produced by an electric potential difference of 1 volt.

Sievert (Sv). The unit of radiation dose equivalent corresponding to 1 joule per kilogram.

Steradian (sr). The solid angle which, having its vertex in the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere

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Tesla (T). The magnetic flux density given by a magnetic flux of 1 Weber per square metre.

Tonne (t). The mass equal to 1 000 kilograms.

Volt (V). The unit of electric potential difference and electromotive force which is the difference of electric

potential between two points of a conductor carrying a constant current of 1 ampere, when the power dissipated between these points is equal to 1 watt.

Waft (W). The power which gives rise to the production of energy at the rate of 1 joule per second.

Weber (Wb). The magnetic flux which, linking a circuit of one turn, produces in it an electromotive force of 1 volt as it is reduced to zero at a uniform rate in 1 second.

22.2 APPLICABILITY

These Directives contain specifications for the use of a Standardized system of units of measurement in international and domestic civil aviation. It is based on the International System of Units (SI) and certain non-SI units considered necessary to meet the specialized requirements of international civil aviation.

22.3 STANDARD APPLICATIONS OF UNITS OF MEASUREMENT

22.3.1 SI Units

The International System of Units developed and maintained by the General Conference of Weights and Measures (CGPM) shall, subject to the provisions of 22.3.2 and 22.3.3, be used as the standard system of units of measurement for all aspects of international civil aviation air and ground operations.

22.3.2 Prefixes

The prefixes and symbols listed in Table 3-1 shall be used to form names and symbols of the decimal multiples and sub-multiples of SI units.

TABLE 3-1 – SI UNIT PREFIXES

Multiplication factor			*Prefix*	*Symbol*
1 000 000 000 000 000 000	=	10^{18}	exa	E
1 000 000 000 000 000	=	10^{15}	peta	P
1 000 000 000 000	=	10^{12}	tera	T
1 000 000 000	=	10^{9}	giga	G
1 000 000	=	10^{6}	mega	M
1 000	=	10^{3}	kilo	k
100	=	10^{2}	hecto	h
10	=	10^{1}	deca	da
0.1	=	10^{-1}	deci	d
0.01	=	10^{-2}	centi	c
0.001	=	10^{-3}	milli	m
0.000 001	=	10^{-6}	micro	μ
0.000 000 001	=	10^{-9}	nano	n
0.000 000 000 001	=	10^{-12}	pico	p
0.000 000 000 000 001	=	10^{-15}	femto	f
0.000 000 000 000 000 001	=	10^{-18}	atto	a

22.3.3 Non-SI Units

22.3.3.1 Non-SI units for permanent use with the SI

The non-SI units listed in Table 3-2 shall be used either in lieu of, or in addition to, SI units as primary units of measurement but only as specified in Table 3-4.

TABLE 3-2 – NON-SI UNITS FOR USE WITH THE SI

Specific quantities in Table 3-4 related to	*Unit*	*Symbol*	*Definition (in terms of SI units)*
mass	tonne	t	1 t = 10^3 kg
plane angle	degree	°	1° = (π/180) rad
	minute	'	1' = (1/60)° = (π/10 800) rad
	second	"	1" = (1/60)' = (π/648 000) rad
temperature	degree Celsius	°C	1 unit °C = 1 unit K[a)]
time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min = 3 600 s
	day	d	1 d = 24 h = 86 400 s
	week, month, year	—	
volume	litre	L	1 L = 1 dm^3 = $10^{-3}m^3$

a) See Attachment C, Table C-2 for conversion.

22.3.3.2 Non-SI alternative units permitted for temporary use with the SI

The non-SI units listed in Table 3-3 shall be permitted for temporary use as alternative units of measurement but only for those specific quantities listed in Table 3-4.

22.3.3 Application of specific units

(1) The application of units of measurement for certain quantities used in international civil aviation air and ground operations shall be in accordance with Table 3-4.

(2) Means and provisions for design, procedures and training should be establish for operations in environments involving the use of standards and non-SI alternatives of specific units of measurement, or the transition between environments using different units, with due consideration to human performance.

TABLE 3-3 – NON-SI ALTERNATIVE UNITS PERMITTED FOR TEMPORARY USE WITH THE SI

Specific quantities in Table 3-4 related to	*Unit*	*Symbol*	*Definition (in terms of SI units)*
distance (long)	nautical mile	NM	1 NM = 1 852 m
distance (vertical)[a)]	foot	ft	1 ft = 0.304 8 m
speed	knot	kt	1 kt = 0.514 444 m/s

a) altitude, elevation, height, vertical speed.

Table 3-4. Standard application of specific units of measurement

Ref. No.	*Quantity*	*Primary unit (symbol)*	*Non-SI alternative unit (symbol)*
1.	***Direction/Space/Time***		
1.1	altitude	m	ft
1.2	area	m^2	
1.3	distance (long)[a)]	km	NM
1.4	distance (short)	m	
1.5	elevation	m	ft
1.6	endurance	h and min	
1.7	height	m	ft
1.8	latitude	° ′ ″	
1.9	length	m	
1.10	longitude	° ′ ″	
1.11	plane angle (when required, decimal subdivisions of the degree shall be used)	°	
1.12	runway length	m	
1.13	runway visual range	m	
1.14	tank capacities (aircraft)[b)]	L	

Ref. No.	*Quantity*	*Primary unit (symbol)*	*Non-SI alternative unit (symbol)*
1.15	time	s min h d week month year	
1.16	visibility[c)]	km	
1.17	volume	m^3	
1.18	wind direction (wind directions other than for a landing and take-off shall be expressed in degrees true, for landing and take-off wind directions shall be expressed in degrees magnetic)	°	
2.	***Mass-related***		
2.1	air density	kg/m^3	
2.2	area density	kg/m^2	
2.3	cargo capacity	kg	
2.4	cargo density	kg/m^3	
2.5	density (mass density)	kg/m^3	
2.6	fuel capacity (gravimetric)	kg	
2.7	gas density	kg/m^3	
2.8	gross mass or payload	kg t	
2.9	hoisting provisions	kg	
2.10	linear density	kg/m	
2.11	liquid density	kg/m^3	
2.12	mass	kg	
2.13	moment of inertia	$kg \cdot m^2$	
2.14	moment of momentum	$kg \cdot m^2/s$	
2.15	momentum	$kg \cdot m/s$	

Ref. No.	*Quantity*	*Primary unit (symbol)*	*Non-SI alternative unit (symbol)*
3.	***Force-related***		
3.1	air pressure (general)	kPa	
3.2	altimeter setting	hPa	
3.3	atmospheric pressure	hPa	
3.4	bending moment	$kN \cdot m$	
3.5	force	N	
3.6	fuel supply pressure	kPa	
3.7	hydraulic pressure	kPa	
3.8	modulus of elasticity	MPa	
3.9	pressure	kPa	
3.10	stress	MPa	
3.11	surface tension	mN/m	
3.12	thrust	kN	
3.13	torque	$N \cdot m$	
3.14	vacuum	Pa	

4. *Mechanics*

4.1	airspeed[d)]	km/h	kt
4.2	angular acceleration	rad/s^2	
4.3	angular velocity	rad/s	
4.4	energy or work	J	
4.5	equivalent shaft power	kW	
4.6	frequency	Hz	
4.7	ground speed	km/h	kt
4.8	impact	J/m^2	
4.9	kinetic energy absorbed by brakes	MJ	
4.10	linear acceleration	m/s^2	
4.11	power	kW	
4.12	rate of trim	°/s	
4.13	shaft power	kW	
4.14	velocity	m/s	
4.15	vertical speed	m/s	ft/min
4.16	wind speed	km/h	kt

5. *Flow*

5.1	engine airflow	kg/s
5.2	engine waterflow	kg/h
5.3	fuel consumption (specific)	
	piston engines	kg/(kW · h)
	turbo-shaft engines	kg/(kW · h)
	jet engines	kg/(kN · h)
5.4	fuel flow	kg/h
5.5	fuel tank filling rate (gravimetric)	kg/min
5.6	gas flow	kg/s
5.7	liquid flow (gravimetric)	g/s
5.8	liquid flow (volumetric)	L/s
5.9	mass flow	kg/s
5.10	oil consumption	
	gas turbine	kg/h
	piston engines (specific)	g/(kW · h)

Ref. No.	*Quantity*	*Primary unit (symbol)*	*Non-SI alternative unit (symbol)*
5.11	oil flow	g/s	
5.12	pump capacity	L/min	
5.13	ventilation airflow	m^3/min	
5.14	viscosity (dynamic)	Pa · s	
5.15	viscosity (kinematic)	m^2/s	
6.	***Thermodynamics***		
6.1	coefficient of heat transfer	$W/(m^2 \cdot K)$	
6.2	heat flow per unit area	J/m^2	
6.3	heat flow rate	W	
6.4	humidity (absolute)	g/kg	
6.5	coefficient of linear expansion	$°C^{-1}$	
6.6	quantity of heat	J	
6.7	temperature	°C	
7.	***Electricity and magnetism***		
7.1	capacitance	F	
7.2	conductance	S	
7.3	conductivity	S/m	
7.4	current density	A/m^2	
7.5	electric current	A	
7.6	electric field strength	C/m^2	
7.7	electric potential	V	
7.8	electromotive force	V	
7.9	magnetic field strength	A/m	
7.10	magnetic flux	Wb	
7.11	magnetic flux density	T	
7.12	power	W	
7.13	quantity of electricity	C	
7.14	resistance	Ω	
8.	***Light and related electromagnetic radiations***		
8.1	illuminance	lx	
8.2	luminance	cd/m^2	
8.3	luminous exitance	lm/m^2	
8.4	luminous flux	lm	
8.5	luminous intensity	cd	
8.6	quantity of light	lm · s	
8.7	radiant energy	J	
8.8	wavelength	m	
9.	***Acoustics***		
9.1	frequency	Hz	
9.2	mass density	kg/m^3	
9.3	noise level	dB[e)]	
9.4	period, periodic time	s	
9.5	sound intensity	W/m^2	
9.6	sound power	W	
9.7	sound pressure	Pa	
9.8	sound level	dB[e)]	

Ref. No.	*Quantity*	*Primary unit (symbol)*	*Non-SI alternative unit (symbol)*
9.9	static pressure (instantaneous)	Pa	
9.10	velocity of sound	m/s	
9.11	volume velocity (instantaneous)	m^3/s	
9.12	wavelength	m	
10.	***Nuclear physics and ionizing radiation***		
10.1	absorbed dose	Gy	
10.2	absorbed dose rate	Gy/s	
10.3	activity of radionuclides	Bq	
10.4	dose equivalent	Sv	
10.5	radiation exposure	C/kg	
10.6	exposure rate	C/kg · s	

a) As used in navigation, generally in excess of 4 000 m.
b) Such as aircraft fuel, hydraulic fluids, water, oil and high pressure oxygen vessels.
c) Visibility of less than 5 km may be given in m.
d) Airspeed is sometimes reported in flight operations in terms of the ratio MACH number.
e) The decibel (dB) is a ratio which may be used as a unit for expressing sound pressure level and sound power level. When used, the reference level must be specified.

22.3.4 TERMINATION OF USE OF NON-SI ALTERNATIVE UNITS

The use in international civil aviation operations of the alternative non-SI units listed in Table 3-3 shall be terminated on the dates listed in Table 4-1.

Introductory Note .— The non-SI units listed in Table 3-3 have been retained temporarily for use as alternative units because of their widespread use and to avoid potential safety problems which could result from the lack of international coordination concerning the termination of their use. Any special procedures associated with specific unit termination will be circulated separately from this Part.

Table 4-1. Termination dates for non-SI alternative units

Non-SI alternative unit	*Termination date*
Knot Nautical	not
Foot	not established[b]

a) No termination date has yet been established for use of nautical mile and knot.
b) No termination date has yet been established for use of the foot.

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