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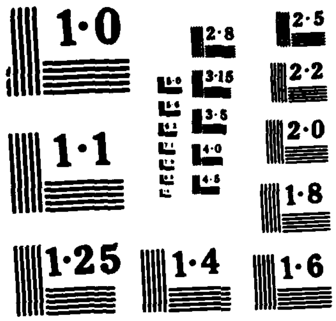

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REPORT NO. T8/85

CONVERSION UNITS COMMON TO BIOMEDICAL RESEARCH ON MILITARY CLOTHING

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

APRIL 1985

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Special conversion units familiar to personnel working in the general area of biophysical properties of clothing and thermal physics are arranged so that they can be easily transposed into metric units. Some of the basic units also found in the System International d'unites' (SI) have been defined and categorized to help the reader have a faster access towards metrification. Keywords:

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TECHNICAL REPORT
NO. T8/85

CONVERSION UNITS COMMON TO BIOMEDICAL RESEARCH ON MILITARY CLOTHING

by

Richard R. Gonzalez, Ph.D.

U.S. Army Research Institute of Environmental Medicine
Natick MA 01760

A. FOREWORD

This glossary is one written for an appendix chapter in support of a NATO Research Study Group (RSG - VII) handbook on Biomedical Effects of Combat Clothing and Personal Life Support Equipment. During the preparation and reading of the handbook it was apparent that many chapters were filled with familiar units (like kcal, Btu, etc.) which authors were reluctant to transpose to metric. The intention of this report is to clarify and readily allow persons to transpose many familiar units to the modern metric system, Systeme International d' unties (SI).

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B. ABSTRACT

Several conversion units familar to personnel working in the general area of biophysical properties of clothing and thermal physics are arranged so that they can be easily transposed into metric units. Some of the basic units also found in the System International d'unites' (SI) have been defined and categorized to help the reader have a faster access towards metrification.

C. INTRODUCTION

This appendix chapter is set up slightly different from regular glossaries using SI in that conversion factors for familiar units and some obsolete terms (i.e. mm Hg) are also included. In SI one and only one unit is acceptable for each physical quantity. It is hoped that this chapter clarifies for readers most of the conversions from common to SI. The glossary does not include conversion units for the luminous flux (lumen, SI) or sound pressure level. More extensive guides are found in references 1,2,3.

In the SI, approved units are as follows:

Angle. The correct unit for the plane angle is the radian. The degree (^{o}) and its decimal fractions may be used but use of minute and second is discouraged.

Area. The SI unit of area is the square meter (m^2). Large areas are expressed as hectares (ha) or square kilometers (km^2). The hectare is restricted to land or sea area and is equal to 10000 m^2.

Energy. The correct unit in SI is the Joule (J). The kilowatt hour (3.6 megajoules) is widely used as a measure of electric energy. However, kilowatt hour will be replaced by megajoules or gigajoule so kwh is discouraged in new applications.

Force. The correct SI unit of force is the newton (N). Do not use the word weight or kilogram force. The newton is used also in combination units which also encompass units of force such as:

pressure or stress, $N \cdot m^{-2}$ = Pa (pascal)

work, $N \cdot m$ = J (joule)

power, $N \cdot m \cdot s^{-1}$ = W (watt)

Mass. This unit in SI is the kilogram (kg). Among the base and derived units of SI this unit is the only one with a prefix. Names of decimal multiples or sub multiples of the unit mass are formed by attaching prefixes to the word gram. The word weight should not be used as this could be confused with force.

Pressure. The correct unit of stress or pressure (which is force per unit area) is the newton per square meter. This unit has been given the special name pascal (Pa). No other units are acceptable in SI.

Temperature. The correct unit of temperature is kelvin (K, not degK or ^oK) which is equal to degree Celsius (formerly, and now redundant, degree centigrade). The thermodynamic temperature (called absolute temperature) is related to Celsius as follows:

$t = T - T_o$, where t = degrees Celsius (^oC)

T = thermodynamic temperature (^oK); note that this unit is degK or ^oK.

T_o = 273.15 K by definition; note that this unit is not ^oK.

Time. In SI the correct unit of time is second. Do not use minute or hour. In some cases of long cycles day, week, month or year are used.

Exceptions: revolution per min may be used but revolution per second is the SI unit; beats per min may be used but frequency (cardiac) s^{-1} is the SI unit.

Volume. The correct SI unit for volume is the cubic meter (m^3). The cubic decimeter which has a special name--- liter (l) is a regularly used submultiple of m^3. This is the correct SI unit to replace gallon or cubic foot. Liter per second thus replaces gpm or cfm. A s :aller correct SI unit is the milliliter per second ($ml \cdot s^{-1}$). The liter is restricted for use only with liquids and gases and for volume of a vessel.

Finally, in SI complex unit symbols are written with either parentheses or with exponents interchangeably.

Example: for oxygen consumption ($\dot{V}O_2$) the correct SI might be expressed as cubic meter per kilogram per second $m^3/(kg \cdot s)$ or $m^3 \cdot kg^{-1} \cdot s^{-1}$. Both forms are equally acceptable.

D. CONVERSION FACTORS

TO CONVERT	MULTIPLY BY	TO OBTAIN
	1. LENGTH OR AREA	
acre (a)	0.405	hectare (ha)
foot (ft)	0.3048	meter (m) exact conversion
inch	25.4	mm
mile	1.61	kilometer (km)
mile, nautical	1.85	km
yd	0.9144	m
square (100 sq ft)	9.29	m^2
yd^2	0.836	m^2
yd^3	0.765	m^3
bolt (U.S. cloth)	36.58	m
centimeter (cm)	1×10^{-5}	km
centimeter (cm)	1.09×10^{-2}	mile
centimeter (cm)	10000	micron
centimeter (cm)	1.0×10^{8}	angstrom unit
hand	10.16	cm
	2. TEMPERATURE	
$^oC + 273.15$	1.0	absolute (^oK)
^oC	(^oC * 1.8)+ 32	temperature (^oF)
$^oF-32$	5/9	^oC
$^oF + 460$	1.0	absolute (^oR)
^oC	1	K (this unit is not ^oK)

TO CONVERT	MULTIPLY BY	TO OBTAIN
	3. FORCE	
kilogram force (kgf)	9.807	Newton (N)
kilopond force (kpf)	9.807	N
pound force (lbf)	4.45	N
	4. POWER	
Btu per min ($Btu \cdot min^{-1}$)	17.57	watt (W)
calorie per second ($cal \cdot s^{-1}$)	4.187	W
horsepower (550 ft·lb/s)	0.746	kW
kilocalorie per h ($kcal \cdot h^{-1}$)	1.163	W
kilopond meter per min ($kpm \cdot min^{-1}$)	0.1634	W
$Btu \cdot h^{-1}$	0.2931	W
$Btu \cdot h^{-1}$	0.07	$g \cdot cal \cdot s^{-1}$
$Btu \cdot h^{-1}$	0.2162	$ft \cdot lb \cdot s^{-1}$
ft·lbf/min	0.0226	W

TO CONVERT	MULTIPLY BY	TO OBTAIN
	5. PRESSURE	
bar	100	kPa (exact conversion)
in Hg	3386.4	$N \cdot m^{-2}$
in H_2O	248.8	$N \cdot m^{-2}$
mmHg, (20°C)	133.3	$N \cdot m^{-2}$
mmHg, (20°C)	0.13332	kPa
mm H_2O (20°C)	9.79	Pa
millibar	0.100	kPa
m H_2O	9.79	kPa
atmospheres	76	cm Hg (at 0°C)
atmospheres	29.92	in Hg (0°C)
atmospheres	1.058	$ton \cdot ft^{-2}$
atmospheres	14.7	$lb \cdot in^{-2}$
atmospheres	1.0333	$kg \cdot cm^{-2}$
bar	0.9869	atmospheres
bar	1×10^{6}	$dynes \cdot cm^{-2}$
bar	1.02×10^{-4}	$kg \cdot m^{-2}$
bar	14.5	$lb \cdot in^{-2}$
centimeter-dynes	1.02×10^{-3}	cm-g
centimeter-dynes	7.233×10^{-5}	lb-ft
cm Hg	1.316×10^{-2}	atmosphere
psi	6.89	kPa
Torr (1mmHg at 0°C)	133.322	Pa
Torr (1 mm Hg at 0°C)	1.33×10^{-3}	bar
$dyne \cdot cm^{-2}$	0.100	Pa
Pa	7.5×10^{-3}	Torr (name of unit is torr)
kPa	7.5	Torr

TO CONVERT	MULTIPLY BY	TO OBTAIN
	6. ENERGY	
British thermal unit (Btu)	1055.9	joule (J)
Calorie (cal)	4.187	joule (J)
foot-pound (ft-lb)	1.3558	J
kilocalorie	4.187	kJ
Btu	1.055×10^{10}	ergs
Btu	7.7816×10^{2}	foot-pound
Btu	252	g-cal
Calorie	3.9685×10^{-3}	Btu
ft·lbf/lb (specific energy)	2.99	$J \cdot kg^{-1}$
therm (U.S.)	105.5	MJ
horsepower	10.68	kg·cal/min
horsepower	0.7457	kW
horsepower	745.7	W
g-cal	1.162×10^{-3}	W·h
ft·lb (work)	1.36	J
W·s	1	J
W·h	3600	J
joule(J)	2.778×10^{-4}	W·h
	7. TORQUE OR MOMENT	
ft·lbf (torque)	1.36	N·m

TO CONVERT	MULTIPLY BY	TO OBTAIN
	8. SPEED OR VOLUME FLOW RATE	
foot per min, fpm	0.00508	$m \cdot s^{-1}$
foot per sec, fps	0.3048	$m \cdot s^{-1}$
kilometer per hour, $km \cdot h^{-1}$	0.2778	$m \cdot s^{-1}$
mile per hour, mph	0.447	$m \cdot s^{-1}$
mph	0.8684	knots
ft^3	28.3	l
ft^3	0.0283	m^3
ft^3/h,(cfh)	7.87	$ml \cdot s^{-1}$
ft^3/min (cfm)	0.472	$l \cdot s^{-1}$
gal per h (gph) U.S.	1.05	$ml \cdot s^{-1}$
gal per min (gpm) U.S.	0.0631	$l \cdot s^{-1}$
knots	1.8532	$km \cdot h^{-1}$
knots	51.48	$cm \cdot s^{-1}$

TO CONVERT	MULTIPLY BY	TO OBTAIN
	9. VOLUME OR CONCENTRATION	
m^3	2.642×10^2	gal
m^3	1000	l
gal	3.785×10^{-3}	m^3
gal	3.785	l
gal H_2O	8.337	pounds H_2O
gal (British)	1.20095	gal (U.S.)
l	0.2642	gal(U.S)
l	1.057	quarts
$mg \cdot l^{-1}$	1.0	ppm
$mg \cdot kg^{-1}$	1.0	ppm
tablespoon	15	ml
teaspoon	5	ml
pint (liquid)	473	ml
in^3 (volume)	16.4	ml
quart (liquid)	0.946	l
oz	29.6	ml
m^3/s	60	$l \cdot min^{-1}$ ($\dot{V}O_2$)

TO CONVERT	MULTIPLY BY	TO OBTAIN
	10. MASS	
gram	0.03527	ounce (avdp)
gram	0.03215	oz (troy)
gram	2.205×10^{-3}	pound
ounce (mass, avoir)	28.3	g
lb	453.5	g

TO CONVERT	MULTIPLY BY	TO OBTAIN
	11. ENERGY/(AREA·TIME)	
Btu per sq foot and hr. (Btu/(ft^2·h)	3.1525	W·m^{-2}
kcal/(m^2·h)	1.163	W·m^{-2}
Btu/(ft^2·min)	1.22 x 10^{-1}	W·in^{-2}

12. HEAT FLUX (q/A)

TO CONVERT	MULTIPLY BY	TO OBTAIN
$Btu \cdot ft^{-2} \cdot h^{-1}$	3.154×10^{-4}	$W \cdot cm^{-2}$
$kcal \cdot h^{-1} \cdot m^{-2}$	1.163×10^{-4}	$W \cdot cm^{-2}$
$cal \cdot s^{-1} \cdot cm^{-2}$	4.1868	$W \cdot cm^{-2}$
$W \cdot cm^{-2}$	8600	$kcal \cdot h^{-1} \cdot m^{-2}$
$W \cdot cm^{-2}$	3170.75	$Btu \cdot ft^{-2} \cdot h^{-1}$
$W \cdot cm^{-2}$	0.2389	$cal \cdot s^{-1} \cdot cm^{-2}$
$Btu \cdot ft^{-2} \cdot h^{-1}$	3.15	$W \cdot m^{-2}$

13. HEAT TRANSFER COEFFICIENT (h)

TO CONVERT	MULTIPLY BY	TO OBTAIN
$Btu \cdot ft^{-2} \cdot h^{-1} \cdot {}^{o}F^{-1}$	5.6785×10^{-4}	$W \cdot cm^{-2} \cdot K^{-1}$
$kca \cdot h^{-1} \cdot ,^{-2} \cdot {}^{o}C^{-1}$	1.163×10^{-4}	$W \cdot cm^{-2} \cdot K^{-1}$
$cal \cdot s^{-1} \cdot cm^{-2} \cdot {}^{o}C^{-1}$	4.186	$W \cdot cm^{-2} \cdot K^{-1}$
$Btu \cdot ft^{-2} \cdot h^{-1} \cdot {}^{o}F^{-1}$	4.8826	$kcal \cdot h^{-1} \cdot m^{-2} \cdot {}^{o}C^{-1}$
$W \cdot cm^{-2} \cdot K^{-1}$	8600	$kcal \cdot h^{-1} \cdot m^{-2} \cdot {}^{o}C^{-1}$
$Btu \cdot ft^{-1} \cdot h^{-1} \cdot F^{-1}$	5.68	$W \cdot m^{-2} \cdot K^{-1}$

TO CONVERT	MULTIPLY BY	TO OBTAIN
14. THERMAL CONDUCTIVITY (k)		
$Btu \cdot h^{-1} \cdot ft^{-1} \cdot {}^{o}F^{-1}$	0.0173	$W \cdot cm^{-1} \cdot K^{-1}$
$Btu \cdot in \cdot h^{-1} \cdot ft^{-1} \cdot {}^{o}F^{-1}$	1.442×10^{-3}	$W \cdot cm^{-1} \cdot K^{-1}$
$kcal \cdot h^{-1} \cdot m^{-1} \cdot {}^{o}C^{-1}$	0.01171	$W \cdot cm^{-1} \cdot K^{-1}$
$cal \cdot s^{-1} \cdot cm^{-1} \cdot {}^{o}C^{-1}$	4.186	$W \cdot cm^{-1} \cdot K^{-1}$
15. DYNAMIC VISCOSITY (u)		
$lb \cdot ft^{-1} \cdot h^{-1}$	0.413	mPa·s
$lbf \cdot s \cdot ft^{-1}$	47900	mPa·s
centipoise	2.42	$lb \cdot ft^{-1} \cdot h^{-1}$
centipoise	3.6	$kg \cdot m^{-1} \cdot h^{-1}$
centipoise	1.00	mPa·s
16. KINEMATIC VISCOSITY (υ)		
$ft^{2} \cdot s^{-1}$	92900	$mm^{2} \cdot s^{-1}$
$ft^{2} \cdot h^{-1}$	0.092903	$m^{2} \cdot h^{-1}$
stokes	0.3599	$m^{2} \cdot h^{-1}$

TO CONVERT	MULTIPLY BY	TO OBTAIN
	17. CLOTHING RESISTANCE	
tog	0.645	clo
clo	1.55	tog
clo	0.155	$m^2 \cdot K/W$
tog	0.1	$m^2 \cdot K/W$
clo	200	$s \cdot m^{-1}$
clo	2	$s \cdot m^{-1}$
	OTHER	
radians	57.296	degrees
radians	3.438×10^3	minutes
radians/s	57.296	$deg \cdot s^{-1}$
radians/s	9.549	$rev \cdot min^{-1}$
steradians	3.283×10^3	square degree

E. Constants

1. GAS CONSTANTS

$R = 8.314$ kJ/(kg·mol·K) = 0.0821 (atm)(l)/(g·mole)(K)

air (R_a) = 0.287 kJ/(kg·°C)

water vapor (R_w) = 0.462 kJ/(kg·°C)

2. SPECIFIC HEAT OF AIR

dry air

constant pressure $c_p = 1.005$ kJ/(kg·°K)

constant volume $c_v = 0.717$ kJ/(kg·°K)

moist air = 1.024 kJ/(kg·°C)

3. SPECIFIC HEAT OF WATER

heat of vaporization at 101.325 kPa (760 Torr) and 100°C

2257 kJ/kg

0.68 W·h/g

heat of fusion at 0°C

335 kJ/kg

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G. REFERENCES

1. Lowe, D.A. A guide to international recommendations on names and symbols for quantities and on units of measurement. WHO (ISO) Geneva, 1975 314 pp..

2. Bligh, J and K.G. Johnson Glossary of terms for thermal physiology. J. Appl. Physiol. 35: 941, 1973.

3. American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Metric Guide, 1978.

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