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Symbols and Abbreviations

For symbols of chemical elements, see Sec. 6; for abbreviations applying to metric weights and measures and SI units, Sec. 1; SI unit prefixes are listed on p. 1–19.

Pairs of parentheses, brackets, etc., are frequently used in this work to indicate corresponding values. For example, the statement that "the cost per kW of a 30,000-kW plant is $86; of a 15,000-kW plant, $98; and of an 8,000-kW plant, $112," is condensed as follows: The cost per kW of a 30,000 (15,000) [8,000]-kW plant is $86 (98) [112].

In the citation of references readers should always attempt to consult the latest edition of referenced publications.

A or Å	Angstrom unit = 10^{-10} m; 3.937×10^{-11} in
A	mass number = N + Z; ampere
AA	arithmetical average
AAA	Am. Automobile Assoc.
AAMA	American Automobile Manufacturers' Assoc.
AAR	Assoc. of Am. Railroads
AAS	Am. Astronautical Soc.
ABAI	Am. Boiler & Affiliated Industries
abs	absolute
a.c.	aerodynamic center
a-c, ac	alternating current
ACI	Am. Concrete Inst.
ACM	Assoc. for Computing Machinery
ACRMA	Air Conditioning and Refrigerating Manufacturers Assoc.
ACS	Am. Chemical Soc.
ACSR	aluminum cable steel-reinforced
ACV	air cushion vehicle
A.D.	anno Domini (in the year of our Lord)
AEC	Atomic Energy Commission (U.S.)
a-f, af	audio frequency
AFBMA	Anti-friction Bearings Manufacturers' Assoc.
AFS	Am. Foundrymen's Soc.
AGA	Am. Gas Assoc.
AGMA	Am. Gear Manufacturers' Assoc.
ahp	air horsepower
AIChE	Am. Inst. of Chemical Engineers
AIEE	Am. Inst. of Electrical Engineers (see IEEE)
AIME	Am. Inst. of Mining Engineers
AIP	Am. Inst. of Physics
AISC	American Institute of Steel Construction, Inc.
AISE	Am. Iron & Steel Engineers
AISI	Am. Iron and Steel Inst.
Al. Assn.	Aluminum Association
a.m.	ante meridiem (before noon)
a-m, am	amplitude modulation
Am. Mach.	Am. Machinist (New York)
AMA	Acoustical Materials Assoc.
AMCA	Air Moving & Conditioning Assoc., Inc.
amu	atomic mass unit
AN	ammonium nitrate (explosive); Army-Navy Specification
AN-FO	ammonium nitrate-fuel oil (explosive)
ANC	Army-Navy Civil Aeronautics Committee
ANS	Am. Nuclear Soc.
ANSI	American National Standards Institute
antilog	antilogarithm of
API	Am. Petroleum Inst.
approx	approximately
APWA	Am. Public Works Assoc.
AREA	Am. Railroad Eng. Assoc.
ARI	Air Conditioning and Refrigeration Inst.
ARS	Am. Rocket Soc.
ASCE	Am. Soc. of Civil Engineers
ASHRAE	Am. Soc. of Heating, Refrigerating, and Air Conditioning Engineers
ASLE	Am. Soc. of Lubricating Engineers
ASM	Am. Soc. of Metals
ASME	Am. Soc. of Mechanical Engineers
ASST	Am. Soc. of Steel Treating
ASTM	Am. Soc. for Testing and Materials
ASTME	Am. Soc. of Tool & Manufacturing Engineers
atm	atmosphere
Auto. Ind.	Automotive Industries (New York)
avdp	avoirdupois
avg, ave	average
AWG	Am. Wire Gage
AWPA	Am. Wood Preservation Assoc.
AWS	American Welding Soc.
AWWA	American Water Works Assoc.
b	barns
bar	barometer
B&S	Brown & Sharp (gage); Beams and Stringers
bbl	barrels
B.C.	before Christ
B.C.C.	body centered cubic
Bé	Baumé (degrees)
B.G.	Birmingham gage (hoop and sheet)
bgd	billions of gallons per day
BHN	Brinnell Hardness Number
bhp	brake horsepower
BLC	boundary layer control
B.M.	board measure; bench mark
bmep	brake mean effective pressure
B of M, BuMines	Bureau of Mines

BOD	biochemical oxygen demand
bp	boiling point
Bq	bequerel
bsfc	brake specific fuel consumption
BSI	British Standards Inst.
Btu	British thermal units
Btub, Btu/h	Btu per hr
bu	bushels
Bull.	Bulletin
Buweaps	Bureau of Weapons, U.S. Navy
BWG	Birmingham wire gage
c	velocity of light
°C	degrees Celsius (centigrade)
C	coulomb
CAB	Civil Aeronautics Board
CAGI	Compressed Air & Gas Inst.
cal	calories
C-B-R	chemical, biological & radiological (filters)
CBS	Columbia Broadcasting System
cc, cm^3	cubic centimetres
CCR	critical compression ratio
c to c	center to center
cd	candela
c.f.	centrifugal force
cf.	confer (compare)
cfh, ft^3/h	cubic feet per hour
cfm, ft^3/min	cubic feet per minute
C.F.R.	Cooperative Fuel Research
cfs, ft^3/s	cubic feet per second
cg	center of gravity
cgs	centimetre-gram-second
Chm. Eng.	Chemical Eng'g (New York)
chu	centrigrade heat unit
C.I.	cast iron
cir	circular
cir mil	circular mils
cm	centimetres
CME	Chartered Mech. Engr. (IMechE)
C.N.	cetane number
coef	coefficient
COESA	U.S. Committee on Extension to the Standard Atmosphere
col	column
colog	cologarithm of
const	constant
cos	cosine of
$\cos^{-1}$	angle whose cosine is, inverse cosine of
cosh	hyperbolic cosine of
$\cosh^{-1}$	inverse hyperbolic cosine of
cot	cotangent of
$\cot^{-1}$	angle whose cotangent is (see $\cos^{-1}$)
coth	hyperbolic cotangent of
$\coth^{-1}$	inverse hyperbolic cotangent of
covers	coversed sine of
c.p.	circular pitch; center of pressure
cp	candle power
cp	coef of performance
CP	chemically pure
CPH	close packed hexagonal
cpm	cycles per minute
cycles/min	
cps, cycles/s	cycles per second
CSA	Canadian Standards Assoc.
csc	cosecant of
$\csc^{-1}$	angle whose cosecant is (see $\cos^{-1}$)
csch	hyperbolic cosecant of
csch^{-1}	inverse hyperbolic cosecant of
cu	cubic
cyl	cylinder
db, dB	decibel
d-c, dc	direct current
def	definition
deg	degrees
diam. (dia)	diameter
DO	dissolved oxygen
D_2O	deuterium (heavy water)
d.p.	double pole
DP	Diametral pitch
DPH	diamond pyramid hardness
DST	daylight saving time
d^2 tons	breaking strength, d = chain wire diam. in.
DX	direct expansion
e	base of Napierian logarithmic system (= 2.7182+)
EAP	equivalent air pressure
EDR	equivalent direct radiation
EEI	Edison Electric Inst.
eff	efficiency
e.g.	exempli gratia (for example)
ehp	effective horsepower
EHV	extra high voltage
El. Wld.	Electrical World (New York)
elec	electric
elong	elongation
emf	electromotive force
Engg.	Engineering (London)
Engr.	The Engineer (London)
ENT	emergency negative thrust
EP	extreme pressure (lubricant)
ERDA	Energy Research & Development Administration (successor to AEC; see also NRC)
Eq.	equation
est	estimated
etc.	et cetera (and so forth)
et seq.	et sequens (and the following)
eV	electron volts
evap	evaporation
exp	exponential function of
exsec	exterior secant of
ext	external
°F	degrees Fahrenheit
F	farad
FAA	Federal Aviation Agency
F.C.	fixed carbon, %
FCC	Federal Communications Commission; Federal Constructive Council
F.C.C.	face-centered-cubic (alloys)
ff.	following (pages)
fhp	friction horsepower
Fig.	figure
F.I.T.	Federal income tax
f-m, fm	frequency modulation
F.O.B.	free on board (cars)
FP	fore perpendicular
FPC	Federal Power Commission
fpm, ft/min	feet per minute
fps	foot-pound-second system
ft/s	feet per second
F.S.	Federal Specifications
FSB	Federal Specifications Board
fsp	fiber saturation point
ft	feet
fc	foot candles
fL	foot lamberts
ft·lb	foot-pounds
g	acceleration due to gravity
g	grams
gal	gallons

gc	gigacycles per second
GCA	ground-controlled approach
g · cal	gram-calories
gd	Gudermannian of
G.E.	General Electric Co.
GEM	ground effect machine
GFI	gullet feed index
G.M.	General Motors Co.
GMT	Greenwich Mean Time
GNP	gross national product
gpcd	gallons per capita day
gpd	gallons per day, grams per denier
gpm, gal/min	gallons per minute
gps, gal/s	gallons per second
gpt	grams per tex
H	henry
h	Planck's constant $= 6.624 \times 10^{-27}$ org-sec
$\hbar$	Planck's constant, $\hbar = h/2\pi$
HEPA	high efficiency particulate matter
h-f, hf	high frequency
hhv	high heat value
horiz	horizontal
hp	horsepower
h-p	high-pressure
HPAC	Heating, Piping, & Air Conditioning (Chicago)
hp · hr	horsepower-hour
hr, h	hours
HSS	high speed steel
H.T.	heat-treated
HTHW	high temperature hot water
Hz	hertz = 1 cycle/s (cps)
IACS	International Annealed Copper Standard
IAeS	Institute of Aerospace Sciences
ibid.	ibidem (in the same place)
ICAO	International Civil Aviation Organization
ICC	Interstate Commerce Commission
ICE	Inst. of Civil Engineers
ICI	International Commission on Illumination
I.C.T.	International Critical Tables
I.D., ID	inside diameter
i.e.	id est (that is)
IEC	International Electrotechnical Commission
IEEE	Inst. of Electrical & Electronics Engineers (successor to AIEE, *q.v.*)
IES	Illuminating Engineering Soc.
i-f, if	intermediate frequency
IGT	Inst. of Gas Technology
ihp	indicated horsepower
IMechE	Inst. of Mechanical Engineers
imep	indicated mean effective pressure
Imp	Imperial
in., in	inches
in · lb, in · lb	inch-pounds
INA	Inst. of Naval Architects
Ind. & Eng. Chem.	Industrial & Eng'g Chemistry (Easton, PA)
int	internal
i-p, ip	intermediate pressure
ipm, in/min	inches per minute
ipr	inches per revolution
IPS	iron pipe size
IRE	Inst. of Radio Engineers (see IEEE)
IRS	Internal Revenue Service
ISO	International Organization for Standardization
isoth	isothermal
ISTM	International Soc. for Testing Materials
IUPAC	International Union of Pure & Applied Chemistry
J	joule
J&P	joists and planks
Jour.	Journal
JP	jet propulsion fuel
k	isentropic exponent; conductivity
K	degrees Kelvin (Celsius abs)
K	Knudsen number
kB	kilo Btu (1000 Btu)
kc	kilocycles
kcps	kilocycles per second
kg	kilograms
kg · cal	kilogram-calories
kg · m	kilogram-metres
kip	1000 lb or 1 kilo-pound
kips	thousands of pounds
km	kilometres
kmc	kilomegacycles per second
kmcps	kilomegacycles per second
kpsi	thousands of pounds per sq in
ksi	one kip per sq in, 1000 psi (lb/in^2)
kts	knots
kVA	kilovolt-amperes
kW	kilowatts
kWh	kilowatt-hours
L	lamberts
l, L	litres
£	Laplace operational symbol
lb	pounds
L.B.P.	length between perpendiculars
lhv	low heat value
lim	limit
lin	linear
ln	Napierian logarithm of
loc. cit.	loco citato (place already cited)
log	common logarithm of
LOX	liquid oxygen explosive
l-p, lp	low pressure
LPG	liquified petroleum gas
lpw, lm/W	lumens per watt
lx	lux
L.W.L.	load water line
lm	lumen
m	metres
M	thousand; Mach number; moisture, %
mA	milliamperes
Machy.	Machinery (New York)
max	maximum
MBh	thousands of Btu per hr
mc	megacycles per second
m.c.	moisture content
Mcf	thousand cubic feet
mcps	megacycles per second
Mech. Eng.	Mechanical Eng'g (ASME)
mep	mean effective pressure
METO	maximum, except during take-off
me V	million electron volts
MF	maintenance factor
mhc	mean horizontal candles
mi	mile
MIL-STD	U.S. Military Standard
min	minutes; minimum
mip	mean indicated pressure
MKS	metre-kilogram-second system
MKSA	metre-kilogram-second-ampere system
mL	millilamberts
ml, mL	millilitre = 1.000027 cm^3
mlhc	mean lower hemispherical candles
mm	millimetres

mm-free	mineral matter free
mmf	magnetomotive force
mol	mole
mp	melting point
MPC	maximum permissible concentration
mph, mi/h	miles per hour
MRT	mean radiant temperature
ms	manuscript; milliseconds
msc	mean spherical candles
MSS	Manufacturers Standardization Soc. of the Valve & Fittings Industry
mu	micron, micro
MW	megawatts
MW day	megawatt day
MWT	mean water temperature
n	polytropic exponent
N	number (in mathematical tables)
N	number of neutrons; newton
N_s	specific speed
NA	not available
NAA	National Assoc. of Accountants
NACA	National Advisory Committee on Aeronautics (see NASA)
NACM	National Assoc. of Chain Manufacturers
NASA	National Aeronautics and Space Administration
nat.	natural
NBC	National Broadcasting Company
NBFU	National Board of Fire Underwriters
NBS	National Bureau of Standards (see NIST)
NCN	nitrocarbonitrate (explosive)
NDHA	National District Hearing Assoc.
NEC®	National Electric Code® (National Electrical Code® and NEC® are registered trademarks of the National Fire Protection Association, Inc., Quincy, MA.)
NEMA	National Electrical Manufacturers Assoc.
NFPA	National Fire Protection Assoc.
NIST	National Institute of Standards and Technology
NLGI	National Lubricating Grease Institute
nm	nautical miles
No. (Nos.)	number(s)
NPSH	net positive suction head
NRC	Nuclear Regulator Commission (successor to AEC; see also ERDA)
NTP	normal temperature and pressure
O.D., OD	outside diameter (pipes)
O.H.	open-hearth (steel)
O.N.	octane number
op. cit.	opere citato (work already cited)
OSHA	Occupational Safety & Health Administration
OSW	Office of Saline Water
OTS	Office of Technical Services, U.S. Dept. of Commerce
oz	ounces
p. (pp.)	page (pages)
Pa	pascal
P.C.	propulsive coefficient
PE	polyethylene
PEG	polyethylene glycol
P.E.L.	proportional elastic limit
PETN	an explosive
pf	power factor
PFI	Pipe Fabrication Inst.
PIV	peak inverse voltage
p.m.	post meridiem (after noon)
PM	preventive maintenance
P.N.	performance number
ppb	parts per billion
PPI	plan position indicator
ppm	parts per million
press	pressure
Proc.	Proceedings
PSD	power spectral density, g^2/cps
psi, lb/in^2	lb per sq in
psia	lb per sq in. abs
psig	lb per sq in. gage
pt	point; pint
PVC	polyvinyl chloride
Q	10^{18} Btu
qt	quarts
q.v.	quod vide (which see)
r	roentgens
R	gas constant
R	deg Rankine (Fahrenheit abs); Reynolds number
rad	radius; radiation absorbed dose; radian
RBE	see rem
R-C	resistor-capacitor
RCA	Radio Corporation of America
R&D	research and development
RDX	cyclonite, a military explosive
rem	Roentgen equivalent man (formerly RBE)
rev	revolutions
r-f, rf	radio frequency
RMA	Rubber Manufacturers Assoc.
rms	square root of mean square
rpm, r/min	revolutions per minute
rps, r/s	revolutions per second
RSHF	room sensible heat factor
ry.	railway
s	entropy
s	seconds
S	sulfur, %; siemens
SAE	Soc. of Automotive Engineers
sat	saturated
SBI	steel Boiler Inst.
scfm	standard cu ft per min
SCR	silicon controlled rectifier
sec	secant of
$\sec^{-1}$	angle whose secant is (see $\cos^{-1}$)
Sec.	Section
sech	hyperbolic secant of
sech^{-1}	inverse hyperbolic secant of
segm	segment
SE No.	steam emulsion number
SEI	Structural Engineering Institute
sfc	specific fuel consumption, lb per hphr
sfm, sfpm	surface feet per minute
shp	shaft horsepower
SI	International System of Units (Le Systéme International d'Unites)
sin	sine of
$\sin^{-1}$	angle whose sine is (see $\cos^{-1}$)
sinh	hyperbolic sine of
$\sinh^{-1}$	inverse hyperbolic sine of
SME	Society of Manufacturing Engineers (successor to ASTME)
SNAME	Soc. of Naval Architects and Marine Engineers
SP	static pressure
sp	specific
specif	specification
sp gr	specific gravity
sp ht	specific heat
spp	species unspecified (botanical)
SPS	standard pipe size
sq	square
sr	steradian
SSF	sec Saybolt Furol
SSU	seconds Saybolt Universal (same as SUS)
std	standard

SUS	Saybolt Universal seconds (same as SSU)
SWG	Standard (British) wire gage
T	tesla
TAC	Technical Advisory Committee on Weather Design Conditions (ASHRAE)
tan	tangent of
$\tan^{-1}$	angle whose tangent is (see $\cos^{-1}$)
tanh	hyperbolic tangent of
$\tanh^{-1}$	inverse hyperbolic tangent of
TDH	total dynamic head
TEL	tetraethyl lead
temp	temperature
THI	temperature-humidity (discomfort) index
thp	thrust horsepower
TNT	trinitrotoluol (explosive)
torr	= 1 mm Hg = 1.332 millibars (1/760) atm = (1.013250/760) dynes per cm^2
TP	total pressure
tph	tons per hour
tpi	turns per in
TR	transmitter-receiver
Trans.	Transactions
T.S.	tensile strength; tensile stress
tsi	tons per sq in
ttd	terminal temperature difference
UHF	ultra high frequency
UKAEA	United Kingdom Atomic Energy Authority
UL	Underwriters' Laboratory
ult	ultimate
UMS	universal maintenance standards
USAF	U.S. Air Force
USCG	U.S. Coast Guard
USCS	U.S. Commercial Standard; U.S. Customary System
USDA	U.S. Dept. of Agriculture
USFPL	U.S. Forest Products Laboratory
USGS	U.S. Geologic Survey
USHEW	U.S. Dept. of Health, Education & Welfare
USN	U.S. Navy
USP	U.S. pharmacopoeia
USPHS	U.S. Public Health Service
USS	United States Standard
USSG	U.S. Standard Gage
UTC	Coordinated Universal Time
V	volt
VCF	visual comfort factor
VCI	visual comfort index
VDI	Verein Deutscher Ingenieure
vel	velocity
vers	versed sine of
vert	vertical
VHF	very high frequency
VI	viscosity index
viz.	videlicet (namely)
V.M.	volatile matter, %
vol	volume
VP	velocity pressure
vs.	versus
W	watt
Wb	weber
W&M	Washburn & Moen wire gage
w.g.	water gage
WHO	World Health Organization
W.I.	wrought iron
W.P.A.	Western Pine Assoc.
wt	weight
yd	yards
Y.P.	yield point
yr	year(s)
Y.S.	yield strength; yield stress
z	atomic number, figure of merit
Zeit.	Zeitschrift
Δ	mass defect
μc	microcurie
σ, s	Boltzmann constant
μ	micro (= 10^{-6}), as in μs
μm	micrometre (micron) = 10^{-6} m (10^{-3} mm)
Ω	ohm

MATHEMATICAL SIGNS AND SYMBOLS

+	plus (sign of addition)
+	positive
−	minus (sign of subtraction)
−	Negative
±(∓)	plus or minus (minus or plus)
×	times, by (multiplication sign)
·	multiplied by
÷	sign of division
/	divided by
:	ratio sign, divided by, is to
∷	equals, as (proportion)
<	less than
>	greater than
≪	much less than
≫	much greater than
=	equals
≡	identical with
∼	similar to
≈	approximately equals
≅	approximately equals, congruent
≤	equal to or less than
≥	equal to or greater than
± ≠	not equal to
→ ≐	approaches
∝	varies as
∞	infinity
$\sqrt{\ }$	square root of
$\sqrt[3]{\ }$	cube root of
∴	therefore
∥	parallel to
() [] { }	parentheses, brackets and braces; quantities enclosed by them to be taken together in multiplying, dividing, etc.
$\overline{AB}$	length of line from A to B
π	pi (= 3.14159+)
°	degrees
′	minutes
″	seconds
∠	angle
dx	differential of x
Δ	(delta) difference
Δx	increment of x
$\partial u/\partial x$	partial derivative of u with respect to x
$\int$	integral of

$\int_b^a$	integral of, between limits a and b
$\oint$	line integral around a closed path
Σ	(sigma) summation of
$f(x)$, $F(x)$	functions of x
$\exp x = e^x$	[$e = 2.71828$ (base of natural, or Napierian, logarithms)]
∇	del or nabla, vector differential operator
∇^2	Laplacian operator
£	Laplace operational symbol
$4!$	factorial $4 = 4 \times 3 \times 2 \times 1$
$\lvert x \rvert$	absolute value of x
$\dot{x}$	first derivative of x with respect to time
$\ddot{x}$	second derivative of x with respect to time
$\mathrm{A} \times \mathrm{B}$	vector product; magnitude of A times magnitude of B times sine of the angle from A to B; $AB \sin \overline{AB}$
$\mathrm{A} \cdot \mathrm{B}$	scalar product; magnitude of A times magnitude of B times cosine of the angle from A to B; $AB \cos \overline{AB}$

The Editors

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Preface to the Eleventh Edition

The evolutionary trends underlying modern engineering practice are grounded not only on the tried and true principles and techniques of the past, but also on more recent and current advances. Thus, in the preparation of the eleventh edition of "Marks'," the Editors have considered the broad enterprise falling under the rubric of "Mechanical Engineering" and have added to and/or amended the contents to include subject areas that will be of maximum utility to the practicing engineer. That said, the Editors note that the publication of this eleventh edition has been accomplished through the combined and coordinated efforts of contributors, readers, and the Editors.

First, we recognize, with pleasure, the input from our many contributors—past, continuing, and those newly engaged. Their contributions have been prepared with care, and are authoritative, informative, and concise.

Second, our readers, who are practitioners in their own wise, have found that the global treatment of the subjects presented in the "Marks'" permits of great utility and serves as a convenient ready reference. The reading public has had access to "Marks'" since 1916, when Lionel S. Marks edited the first edition. This eleventh edition follows 90 years later. During the intervening years, "Marks'" and "Handbook for Mechanical Engineers" have become synonymous to a wide readership which includes mechanical engineers, engineers in the associated disciplines, and others. Our readership derives from a wide spectrum of interests, and it appears many find the "Marks'" useful as they pursue their professional endeavors.

The Editors consider it a given that every successive edition must balance the requests to broaden the range or depth of subject matter printed, the incorporation of new material which will be useful to the widest possible audience, and the requirement to keep the size of the Handbook reasonable and manageable. We are aware that the current engineering practitioner learns quickly that the revolutionary developments of the recent past soon become standard practice. By the same token, it is prudent to realize that as a consequence of rapid developments, some cutting-edge technologies prove to have a short shelf life and soon are regarded as obsolescent—if not obsolete.

The Editors are fortunate to have had, from time to time, input from readers and reviewers, who have proffered cogent commentary and suggestions; a number are included in this edition. Indeed, the synergy between Editors, contributors, and readers has been instrumental in the continuing usefulness of successive editions of "Marks' Standard Handbook for Mechanical Engineers."

The reader will note that a considerable portion of the tabular data and running text continue to be presented in dual units; i.e., USCS and SI. The date for a projected full transition to SI units is not yet firm, and the "Marks'" reflects that. We look to the future in that regard.

Society is in an era of information technology, as manifest by the practicing engineer's working tools. For example: the ubiquitous personal computer, its derivative use of software programs of a vast variety and number, printers, computer-aided design and drawing, universal access to the Internet, and so on. It is recognized, too, that the great leaps forward which

are thereby enhanced still require the engineer to exercise sound and rational judgment as to the reliability of the solutions provided.

Last, the Handbook is ultimately the responsibility of the Editors. The utmost care has been exercised to avoid errors, but if any inadvertently are included, the Publisher and Editors will appreciate being so informed. Corrections will be incorporated into subsequent printings.

Ardsley, NY EUGENE A. AVALLONE
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