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METRIC MANUAL FOR SOLDIERS

The Soldier's Primer of the Metric System—An International Decimal System of Weights and Measures Adopted as the Legal Standard by France and Thirty-three Other Nations and in World-Wide Use

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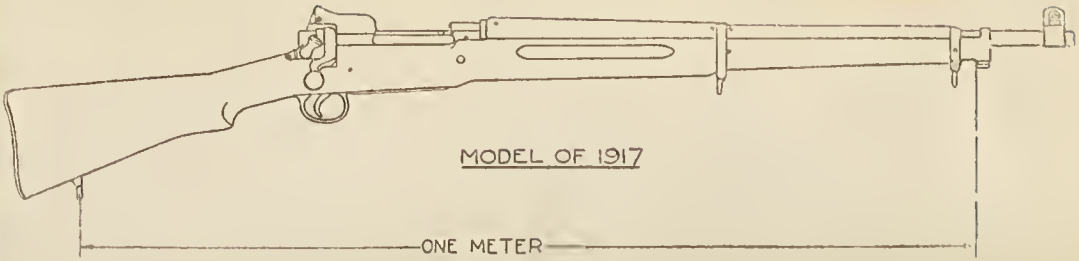

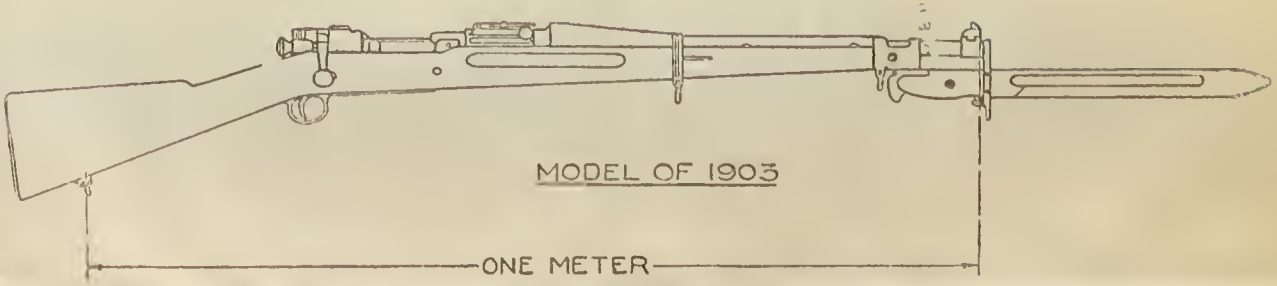

FIGS. 1 and 2.—*U. S. Rifles (pictured one-tenth actual length)*

METRIC MANUAL FOR SOLDIERS

This Manual aims to give the American soldier now in France or Italy, or in training for service abroad, a practical grasp of the metric system of weights and measures. When an American soldier reaches France he will meet with the metric system everywhere, not only in the civil life of the French and other European peoples, but also in the military operations. Our War Department early in the war decided to adopt the metric system for use in France in connection with maps and gunfiring. This makes it doubly important that every soldier know the metric system.

The rapid progress of the metric system in the United States is caused by the growing recognition of its merits and the need for an international system especially in science and commerce. Many industries are using it without special legislation. The necessity for efficiency in warfare has accelerated its progress in this country and resulted in its wide use in radiotelegraphy, military map making, firing data, gunnery, making up war supplies, and especially the manufacture of guns and shells.

Fortunately, the metric system is very easy for an American to learn and use, because all of its tables are made up by multiples of 10 like our system of money, e. g., 10 mills equal 1 cent, 10 cents equal one dime, and so on. In measurement a unit is used and fractions expressed in tenths, hundredths, or thousandths of that unit. Thus, "$12.75" is read (not 1 eagle, 2 dollars, 7 dimes, 5 cents) in dollars and hundredths of a dollar as "12 dollars, 75

cents." Measurements of length may likewise be expressed in meters and thousandths of a meter; that is, in millimeters.

A language of 10 words.—The metric system is a universal language of measure. It is a language of 10 words, as shown in the table following.

The 10 Metric Terms

[4 basic units, 6 numeral[1] prefixes.]

Name	Value	Meaning	Pronounced	Abbreviation
METER	1.	"the unit of length"	meeter	m
LITER	1.	"the unit of volume"	leeter	l
GRAM	1.	"the unit of weight"	gram	g
ARE	1.	"the unit of area"	air	a
MILLI-	.001	"the thousandth part of"	milly	m-
CENTI-	.01	"the hundredth part of"	senti	c-
DECI-	.1	"the tenth part of"	dessy	d-
DEKA-	10.	"ten times"	decka	dk-
HECTO-	100.	"one hundred times"	heckto	h-
KILO-	1000.	"one thousand times"	killo	k-

Familiar terms.—Of these 10 words 7 are well known. "*Mill*" (.001) is our smallest unit of money, being 1 thousandth part of a dollar. "*Cent*" (.01) is our smallest coin, meaning 1 hundredth part. Correspondingly, "*deci*" (.1) is part of "decimal" meaning "tenth." "*Deka-*" (10) is found in "decade." "*Hecto-*" (100) occurs in "hectograph," meaning "100 writings." Again, "meter," meaning "measure," is in common use, and "*are*" is part of the word "area." The remaining three words, *liter*, *gram*, and *kilo-*, are easily remembered.

[1] It is interesting to know that the submultiple prefixes milli-, centi-deci- are from the Latin, while the multiple prefixes deka-, hecto-, kilo- are from the Greek.

A self-explanatory system.—When the meaning of these 10 words is known, the whole metric system is learned. The design of the system makes it self-explanatory. The tables of derived units form themselves automatically. No tables need be or should be memorized.

Smaller and larger units are named by combining the proper numeral prefix with the name of the basic unit. The new term is self-defining—for example, "centi-meter." Here "centi" means "the one-hundredth part of," and "meter" means "the unit of length," so that "centimeter" expresses precisely its meaning, "the one-hundredth part of the unit of length." Every other metric term is as easily formed and expresses as clearly its own definite meaning.

LENGTH

The basic unit of length is the "meter." An idea of the length of the meter may be easily gained. Graphic examples are given to afford a clear idea of the units as shown by familiar lengths. The top of the hip bone of an average man is a meter from the ground; with a little effort a man can step 1 meter; the distance is 1 meter from the butt swivel to rear edge of bayonet lug in the United States 1917 Army rifle; it is also 1 meter from the butt swivel of the 1903 model to the front edge of the fixed stud (of the front sight). (See Figs. 1 and 2, page 2.)

The boy scout official staff is just 2 meters long.

The meter is used to measure cloth, the dimensions of houses and city lots, and in other surveying; in excavation, construction, and general engineering; and in measuring the heights of hills and mountains. In Europe and other places, hills are often identified by numbers which give their height in meters, e. g., "204-meter hill."

A good idea of 100 meters is given by the length of a football field which is 100 meters (almost exactly), while

the circuit of the baseball diamond is 110 meters. An idea of 10 meters may be had by pacing off 13 military paces, quick time. The dekameter (10 meters) and the hectometer (100 meters) as units are seldom used, their place being taken by expressing their dimensions in meters.

One kilometer (1000 meters) is used in measuring distances on roads and maps, and to indicate distances and speeds of travel. An American soldier marches a kilometer in 10 minutes in standard quicktime military pace.

The tenth of a meter (called the "decimeter," or more usually expressed as "10 centimeters") is illustrated by the length of the rule pictured in Fig. 3. The width of a man's hand is practically 10 centimeters—the "hand" unit used in measuring the height of horses. The grip of the bolo knife and of the bayonet—in fact most convenient handles for seizing objects—are 10 centimeters (1 decimeter) long. The height of a canteen cup is 10 centimeters. The standard first-aid package of the soldier is just 10 centimeters long. A French 5-franc note measures 10 by 15 centimeters, or approximately the size of this booklet. The cover of the mess tin is just 30 centimeters long. The bayonet of a Springfield rifle is 40 centimeters long. The seat of a chair is usually 50 centimeters (half a meter) from the floor. The "centimeter" is illustrated by the width of the rule shown in Fig. 3, as well as by the divisions of the rule. The centimeter is used in measuring the dimensions of books, cards, sizes of paper, in scientific measurements, and to denote sizes of articles of apparel, collars, cuffs, etc.

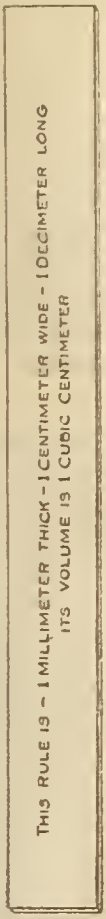

FIG. 3.—*A 10-cm rule*

The tenth of a centimeter is called a "millimeter." The smallest divisions of the rule pictured in Fig. 5 (see p. 15) are millimeters. The millimeter is used in dimensions of machines, in machine design and construction, and in expressing the heights of the mercury column in barometer readings.

AREA

The units of area are merely the squares of the units of length. Only a few of these are used. The square meter is used for measuring floor, wall, and roof areas, also airplane wing surfaces. The square centimeter and square millimeter are used in technical work in measuring pressures and tensile strength. The square millimeter is used to express the areas of cross section of wires. The square kilometer is used to express the areas of countries and continents and of lakes and drainage areas.

For convenience in land measurements an area having a surface of 100 square meters is called an "are." An "are of land" would suffice for a small workman's house and yard in a city. The hectare is 100 ares (or 10 000 square meters). This is the area of a square having a side of 100 meters. The hectare would suffice to make a moderate sized city block.

VOLUME

Likewise the units of volume are merely the cubes of the units of length. Here, again, only a few units are required. The cubic meter is used for measuring earth and excavations, stone, wood in logs, lumber, boards. The cubic meter is used to express register and displacement tonnage of ships. The fact that a cubic meter of water weighs a metric ton makes it a useful unit for that purpose.

The cubic decimeter (1000 cubic centimeters) is called the "liter," which is the unit of capacity. The cubic centimeter illustrated in Fig. 4 is the one-thousandth part of a liter and is used in chemistry, medicine, and in the sciences and industries.

CAPACITY

The primary unit of capacity is the liter or cubic decimeter (=1000 cubic centimeters). As the hand is a decimeter wide the closed fist easily fits in a hollow cube of 1 liter capacity. Such a cube has an edge of $\frac{1}{10}$ of a meter, or the approximate width of this booklet. The volume, therefore, is just a cubic decimeter. If milk were delivered in liter bottles (instead of in quarts) no one would suspect it, unless informed of the change. A liter of tea would fill 4 common tea cups. The soldier's canteen has nearly a liter capacity, and the canteen cup nearly $\frac{3}{4}$ of a liter. The mess tin, if filled to the brim without cover, holds just $\frac{3}{4}$ of a liter. If filled separately, the bottom and top of the bacon tin hold a liter.

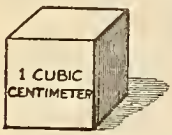

FIG. 4

The milliliter is in world-wide use in pharmacy, and is equal to the cubic centimeter. The dekaliter is used to measure dry commodities and in marketing. The hectoliter is used as a larger volume in farm statistics.

WEIGHT

The unit of weight is the gram, 1000 of which give the market unit, the kilogram. The kilogram is exactly the weight of a liter of water.[2]

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[2] There is a minute distinction between the liter and cubic decimeter which is used only in work of extreme precision.

The weight of a soldier's helmet with padding and straps is about a kilogram. A half kilogram is the weight of a dummy hand grenade marked "1." A light baseball bat weighs a kilogram. The kilogram is used in the markets for weighing meat, ice, sugar, etc. A light sadiron weighs 2 kilograms, a heavy one 3 kilograms.

The gram is the scientific unit of weight used in chemistry, medicine, coinage, and for other purposes. In rationing the gram is commonly used. An excellent idea of the gram as a weight may be gained from American coins. Our nickel 5-cent piece weighs 5 grams, 1 cent for each gram. Ten dollars in nickels weigh 1000 grams, or 1 kilogram. Our silver coins are worth 4 cents for each gram, so that 20 cents in silver weighs 5 grams. This is exactly the weight of the silver French franc. Thus, we have gram weights in our purses in both France and America, and the handling of American nickels or French francs will quickly give a clearer idea of the "5-gram" weight and its multiples than the average man ever gets of the ounce weights.

The metric ton (1000 kilograms) is the weight of a cubic meter of water, and is employed in weighing large quantities of products, such as coal, iron, hay, and heavy freight.

DERIVING THE METRIC SYSTEM FROM A DECIMETER RULE

The simplicity of the metric system is such that the entire system may be derived from the rule pictured in Fig. 5. The "meter" is 10 times this length. The "liter" is the volume of a cube with an edge equal to the length of the rule. The "kilogram" is the weight of this volume of water. All subdivisions and multiples in the metric system are formed by using 10 to multiply or divide. Note the metric dimensions of the rule. (See Figs. 3 and 5.)

The weight of water is equal to its volume, as numerically expressed by appropriate units. A cubic meter of water weighs a ton; 11 cubic meters weigh 11 tons, 31 liters of water weigh 31 kilograms, 53 cubic centimeters of water (i. e., 53 milliliters) weigh 53 grams. A similar equality holds for any other weight or volume of water.

The weight of any material is equal to its volume times its specific gravity. The specific gravity of a solid or liquid is its weight compared with the same volume of water taken as 1.

The volume of this rule (10 by 1 by 0.1 centimeters) is 1 cubic centimeter. Since steel is 7.8 times heavier than water (that is, its specific gravity is 7.8), a rule this size made of steel would weigh 7.8 grams.

STORY OF THE METRIC SYSTEM

When commerce spread, the chaos of units in trading countries became intolerable. A world system was desired alike in science and commerce. An ideal system must be practical and scientific, adapted to measure anything and suited to all people, for all purposes, and for all time. Men of affairs urged that such a system be devised. The vision was realized in the metric system, now the legal standard in 34 countries and in use for scientific purposes throughout the world.

Many features desirable in a world system had been separately suggested prior to the actual proposal in the French National Assembly which resulted in the metric system. Decimals, introduced into Europe by Stevinus, became part of the new system. Self-defining names were suggested by Abbé Mouton, and improved as now found in the system. James Watt suggested that all units of weight and measure be derived from the single unit of length. This was made a basic principle of the metric system. Several had also proposed that this unit of length

be taken from an invariable dimension found in nature. In fixing the metric unit of length, it was decided to make the "meter" equal to one ten-millionth of the quadrant of the earth.

When the plan was approved, the development of the details of the system was begun. Surveyors measured an arc of the meridian passing through Dunkirk as a basis for fixing the length of the meter. Scientists in their laboratories derived precisely the units of volume and of weight from the unit of length. Chemists purified the platinum. Mechanicians perfected form and finish of the standards of length and mass—the meter and kilogram.

The system spread rapidly from nation to nation. The need for international custody of the standards and an international bureau was realized, and in 1875 the leading nations signed the treaty of Paris establishing the International Bureau of Weights and Measures, providing for new standards of the meter and kilogram and for their international custody. The treaty resulted from a series of international conferences in Paris, beginning in 1870, interrupted by the Franco-Prussian War, resumed in 1872, and completed in 1875. The treaty realized the suggestion of John Quincy Adams made years before that a council of nations be called to fix a single invariable and an international system for all peoples and all times. The results of the treaty assured the permanency and final success of the metric system which is now the legal standard in 34 nations and the world standard for all the sciences.

Under the terms of this treaty, the leading nations now jointly maintain the International Bureau of Weights and Measures in the Parc du St. Cloud, at Sèvres, a little northwest of Paris, on neutral territory dedicated for the purpose by the French Government. At this Bureau are preserved the international meter and the international

kilogram—the world's metric standards of length and weight (or mass). The same nations are represented by an International Committee of Weights and Measures, the highest tribunal on the subject of measurement, which officially represents the governments of 26 nations.

TABLES

A knowledge of the metric system is not gained best by memorizing equivalents but by learning to think, measure, and compute directly and entirely in metric units. The best method of learning is to use only these units and learn their values direct without reference to English equivalents. This avoids confusing the English system with the metric system, which was designed for simplicity and ease of use. Where translation is strictly required, the equivalents given below will be useful. The extended values are not usually needed but are given for accuracy of redu tion as shown in problems such as those given below.

1. Convert 27.3 millimeters to inches. (Refer to table.)

2 mm=.0748 inch, hence	20.	mm=	.7874 inch
	7.	mm=	.27559 inch
	.3	mm=	.01181 inch
	27.3	mm=	1.0748 inches

2. Convert 1.0748 inches to millimeters. (See table.)

1 inch					=25.400 mm
7 inches=177.8	mm,	hence	.07	inch=	1.778 mm
4 inches=101.6	mm,	hence	.004	inch=	.102 mm
8 inches=203.2	mm,	hence	.0008	inch=	.020 mm
			1.0748	inch=	27.300 mm

Inches (in.)	Millimeters (mm)	Feet (ft.)	Meters (m)
0.039 37	= 1		1 = 0.304 801
0.078 74	= 2		2 = 0.609 601
0.118 11	= 3		3 = 0.914 402
0.157 48	= 4		4 = 1.219 202
0.196 85	= 5		5 = 1.524 003
0.236 22	= 6		6 = 1.828 804
0.275 59	= 7		7 = 2.133 604
0.314 96	= 8		8 = 2.438 405
0.354 33	= 9		9 = 2.743 205
	1 = 25.4001	3.280 83	= 1
	2 = 50.8001	6.561 67	= 2
	3 = 76.2002	9.842 50	= 3
	4 = 101.6002	13.123 33	= 4
	5 = 127.0003	16.404 17	= 5
	6 = 152.4003	19.685 00	= 6
	7 = 177.8004	22.965 83	= 7
	8 = 203.2004	26.246 67	= 8
	9 = 228.6005	29.527 50	= 9

Yards (yd.)	Meters (m)	U. S. miles (mi.)	Kilometers (km)
	1 = 0.914 402	0.621 370	= 1
	2 = 1.828 804	1.242 740	= 2
	3 = 2.743 205	1.864 110	= 3
	4 = 3.657 607	2.485 480	= 4
	5 = 4.572 009	3.106 850	= 5
	6 = 5.486 411	3.728 220	= 6
	7 = 6.400 813	4.349 590	= 7
	8 = 7.315 215	4.970 960	= 8
	9 = 8.229 616	5.592 330	= 9
1.093 611	= 1		1 = 1.609 347
2.187 222	= 2		2 = 3.218 694
3.280 833	= 3		3 = 4.828 042
4.374 444	= 4		4 = 6.437 389
5.468 056	= 5		5 = 8.046 736
6.561 667	= 6		6 = 9.656 083
7.655 278	= 7		7 = 11.265 431
8.748 889	= 8		8 = 12.874 778
9.842 500	= 9		9 = 14.484 125

U. S. liquid quarts (qt.)	Liters (l)	U. S. bushels (bu.)	Hectoliters (hl)
1	0.946 33	1	0.352 38
2	1.892 67	2	0.704 77
3	2.839 00	3	1.057 15
4	3.785 33	4	1.409 53
5	4.731 67	5	1.761 92
6	5.678 00	6	2.114 30
7	6.624 33	7	2.466 68
8	7.570 66	8	2.819 07
9	8.517 00	9	3.171 45
1.056 71	1	2.8378	1
2.113 42	2	5 6756	2
3.170 13	3	8.5135	3
4.226 84	4	11.3513	4
5.283 55	5	14.1891	5
6.340 26	6	17.0269	6
7.396 97	7	19.8647	7
8.453 68	8	22.7026	8
9.510 39	9	25.5404	9

Avoirdupois ounces (oz. av.)	Grams (g)	Avoirdupois pounds (lb. av.)	Kilograms (kg)
0.035 274	1	1	0.453 59
0.070 548	2	2	0.907 18
0.105 822	3	3	1.360 78
0.141 096	4	4	1.814 37
0.176 370	5	5	2.267 96
0.211 644	6	6	2.721 55
0.246 918	7	7	3.175 15
0.282 192	8	8	3.628 74
0.317 466	9	9	4.082 33
1	28.350	2.204 62	1
2	56.699	4.409 24	2
3	85.049	6.613 87	3
4	113.398	8.818 49	4
5	141.748	11.023 11	5
6	170.097	13.227 73	6
7	198.447	15.432 36	7
8	226.796	17.636 98	8
9	255.146	19.841 60	9

SYNOPSIS OF METRIC SYSTEM

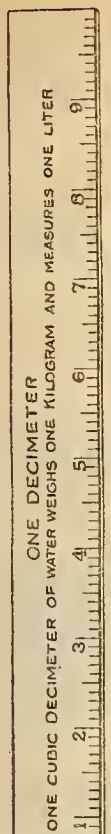

FIG. 5.—*A key to the metric system*

The fundamental unit of the metric system is the METER *(the unit of length) From this the units of mass* (GRAM) *and capacity* (LITER) *are derived. All other units are the decimal subdivisions or multiples of these. These three units are simply related, so that, for all practical purposes the volume of one kilogram of water (one liter) is equal to one cubic decimeter.*

PREFIXES	MEANING			UNITS
MILLI-	= *one thousandth*	$\frac{1}{1000}$	.001	
CENTI-	= *one hundredth*	$\frac{1}{100}$	.01	
DECI-	= *one tenth*	$\frac{1}{10}$	1	METER *for length*
unit	= *one*		1.	GRAM *for mass*
DEKA-	= *ten*	$\frac{10}{1}$	10.	LITER *for capacity*
HECTO-	= *one hundred*	$\frac{100}{1}$	100.	
KILO-	= *one thousand*	$\frac{1000}{1}$	1000	

The metric terms are formed by combining the words "METER," "GRAM," and "LITER" with the six numerical prefixes

			LENGTH		
10	milli-meters	mm	=	1 centi-meter	cm
10	centi-meters		=	1 deci-meter	dm
10	deci-meters		=	1 METER (*about 40 inches*)	m
10	meters		=	1 deka-meter	dkm
10	deka-meters		=	1 hecto-meter	hm
10	hecto-meters		=	1 kilo-meter (*about ⅝ mile*)	km
			MASS		
10	milli-grams	mg	=	1 centi-gram	cg
10	centi-grams		=	1 deci-gram	dg
10	deci-grams		=	1 GRAM (*about 15 grains*)	g
10	grams		=	1 deka-gram	dkg
10	deka-grams		=	1 hecto-gram	hg
10	hecto-grams		=	1 kilo-gram (*about 2 pounds*)	kg
			CAPACITY		
10	milli-liters	ml	=	1 centi-liter	cl
10	centi-liters		=	1 deci-liter	dl
10	deci-liters		=	1 LITER (*about 1 quart*)	l
10	liters		=	1 deka-liter	dkl
10	deka-liters		=	1 hecto-liter (*about a barrel*)	hl
10	hecto-liters		=	1 kilo-liter	kl

The square and cubic units are the squares and cubes of the linear units. The ordinary unit of land area is the HECTARE (about 2½ acres).

[Hyphen indicates prefix, or prefix initial.]

are=100 square meters.
area=surface measured in squares of length units.
c-=centi-.
capacity=space in a container, expressed in cubes of linear units.
centi-=.01.
d-=deci-.
deka-=10.
dk-=deka-.
gram=the unit of weight or (more strictly) of mass.
h-=hecto-.
hecto-=100.
k-=kilo-.
length=direct distance between two points.
l-=liter (volume of 1 kg of water).
liter=the unit of capacity, or volume.
m=meter.
m-=milli-.
mass=amount of material, measured by weighing.
mega-=one million (1 000 000).
meter=the unit of length.
micro-=one-millionth (.000001).
micron=term applied to one-millionth of a meter. (micron is abbreviated by the Greek letter micron μ).
mil=(1) infantry unit of vertical angle (elevation), 1 millimeter at 1 meter distance, 1 meter at 1 kilometer distance, subtend 1 infantry mil; (2) artillery unit of horizontal angle (azimuth) approximately the same as the infantry mil.
milli-=.001.
stère=trade name for a cubic meter.
ton=trade name for 1000 kilograms (weight of 1 cubic meter of water).
volume=cubical contents expressed in cubes of length units.
weight=(1) a mass of metal used in weighing and (2) the pull of gravity on a mass of material.