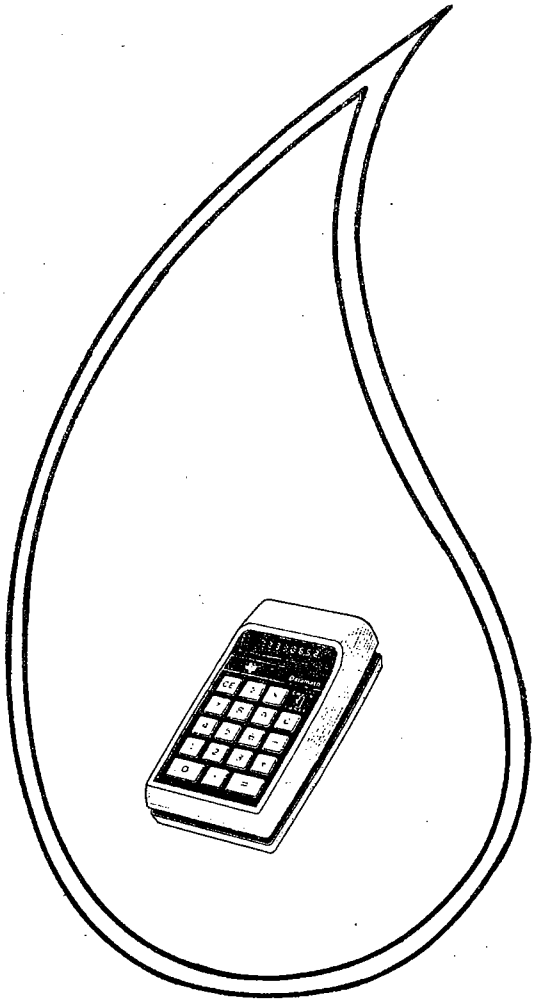
COMPUTATION STANDARDS FOR IDAHO



U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE

USDA-SCS-PORTLAND, OREG. 1975

F O R E W O R D

This standard has been prepared to achieve uniformity of computations in Idaho. It should be used by all personnel providing technical assistance in Soil Conservation Service programs.

The reference was developed by adopting materials from West Technical Service Center and private industry. Displaying and using a strong professional attitude in our technical assistance program is an essential key to Service operations. Quality of planning and application is dependent on logical, neat and orderly computations.

COMPUTATION STANDARDS

A. INTRODUCTION

In engineering practice there is one reason and only one reason for making computations--utility. They are made for use in reaching a specific goal. There are no truly unimportant calculations in any practical situation, since each "minor" result is a link in the series that leads from the given data to the final answer.

To be useful, calculations must be accurate and as precise as the data specify. Thus every effort must be made to prevent errors and to discover and correct those that do occur.

Checking must be done before the work is submitted for action.

Accuracy in simple arithmetic is the most important of the required skills. Mistakes in addition, subtraction, division, and multiplication are the causes of far greater losses of time, effort, materials, and money than mistakes in theory or judgement.

A technician should form the habit of checking and rechecking all his figuring as he goes along. He should also ask himself, is the answer reasonable?

B. THE PRINCIPAL ELEMENTS INVOLVED IN THE PREPARATION OF CALCULATIONS

There are four things that should be considered if one is to prepare clear, concise, professional-type calculation sheets. Such records should be easy to follow, easy to check, and easy to use.

1. Record the analysis and solution of the problem breaking it into a series of simple and logical steps; avoid the use of unfamiliar short cuts. Be sure that the chain of reasoning from data through to the final result is complete and easy to follow.

2. Use the mechanical arrangement and sheet rulings specified in this pamphlet.

3. Consider the quality and neatness of the work. It should be of high quality but not fussy.

4. Symbol codes, standards, and abbreviations should be those generally accepted. The codes in this paper are of the USAI (United States of America Standards Institute), formerly American Standards Institute. See Appendix I.

   Note: Use the same abbreviations for both singular and plural. No periods used except where specifically shown as in. for inch.

Avoid the indiscriminate use of initial letters. Spell the words in full unless a recognized abbreviation is found.

C. PROBLEM ANALYSIS OF A PRACTICE

This simply is a method of thinking a problem through and writing down step by step how you propose to solve it. This series of steps numbered in sequence is the problem analysis. On the computation sheet it should follow the statement of the problem and the sketch you may have drawn.

Please underscore this - Don't make an English theme of the Problem Analysis.

Each step of the problem analysis can usually be stated in one sentence. If much longer, the problem may not have been broken down sufficiently. Again, the statements in the problem analysis should be brief, concise, and complete in their meaning.

Use narrative to relate specific computations to the total design. The use of a few sentences scattered through the computations often facilitates the review of the problem solution.

Explain or justify the method chosen for solution. Alternates that have been examined and eliminated should be described briefly and concisely.

D. FORMAT OF THE COMPUTATION SHEETS

Use Computation Sheet SCS-522, Rev. 5-58, 4 squares to the inch, or SCS-523, Rev. 5-58, 5 squares to the inch, (Exhibits 1 and 2).

1. Use the identification block at the top of the sheet to identify the job, its location and who worked on it. The "Checked By" block may be the same as the designer or that of another checker. The "Job No." block may be used to indicate the SCD the job is located in.

2. Divide the sheet into two columns. The left one should be a minimum of one inch wide. Use it for calculations, documentation, listing references, etc. Calculator tapes may be stapled to this margin.

3. Reserve the wide, right-hand column for diagrams, analysis, and solution of the problem. All secondary figuring belongs in the left-hand column.

4. Do not use scratch paper. Leave a plain trail for a reviewer to follow.

5. Draw a horizontal line from edge to edge of the page to separate each step in a series from the one to follow. Omit the line if nothing follows on that page.

6. Use standard engineering lettering. Do not scribble or use script.

7. Never mark one figure over another. It leaves doubt in user's mind and is a careless habit.

8. Use a ruler or triangle for all rulings, diagrams or other straight lines.

9. Be careful with spelling and use of English.

10. Avoid crowding. Use more paper if necessary.

E. MATHEMATICAL

1. Always show the proper location of the decimal point and be sure it is distinct. Decimal point errors are common but are inexcusable.

2. Place a zero in front of the decimal point for all numbers less than 1. This helps to prevent errors.

3. Point off large numbers in blocks of three digits both ways from the decimal point. Thus 94,500. and 0.006,56.

4. Use parentheses or brackets to indicate multiplication. Do not use the center dot, as it becomes confused with the decimal point in hand work. Do not use the letter x since it is confusing in many situations and it takes no more effort to use parentheses.

5. Indicate division with a horizontal bar fraction. Do not use the symbol ÷ or the inclined bar. The first is largely obsolete; the second is a prolific source of mistakes.

6. Show proportions in fractional form with the unknown in the first numerator.

A problem illustrating the format and problem analysis is included.

F. UNITS

The units in which numerical values are measured have as much bearing on the usefulness of the answers as do the numbers. The answer is no better than the units that describe it. Write the unit with every quantity used.

G. CALCULATION AND CONVERSION OF UNITS

First and most important, write the units with every quantity used and write every conversion constant needed in its proper units. Conversion constants are usually given in a form such as

$$\frac{1000 \text{ meters}}{1 \text{ kilometer}} = 1, \quad \frac{12 \text{ inches}}{1 \text{ foot}} = 1, \quad \text{or} \quad \frac{27 \text{ cu ft}}{1 \text{ cu yd}} = 1$$

These constants are read as "1000 meters per kilometer," "twelve inches per foot" and "twenty-seven cubic feet per cubic yard." The word per in this sense always means there are units in both numerator and denominator and it is the equivalent of a division sign. Since the quantity is a ratio that equals 1, it may be used as a multiplier or divisor without altering the value of another quality. Engineering conversion factors by American Institute of Steel Construction, are shown in Appendix II. Appendix III gives conversion tables for Metric and U.S. Weights and Measures. Exhibit 3-1, page 3-71, Engineering Field Manual, provides conversion factors for hydraulics.

<u>Example 1</u>

Convert 1.63 km into feet. To do this four conversion factors are needed, as follows:

$\frac{1000 \text{ meters}}{1 \text{ kilometer}} = 1$ Read as "1000 meters per kilometer."

$\frac{100 \text{ centimeters}}{1 \text{ meter}} = 1$ Read as "100 centimeter per meter."

$\frac{12 \text{ inches}}{1 \text{ foot}} = 1$ Read as "12 inches per foot."

$\frac{2.54 \text{ centimeters}}{1 \text{ inch}} = 1$ Read as "2.54 centimeters per inch."

Start with the 1.63 kilometers and set the work up as a product of successive fractions, using the conversion ratios so that the unwanted units cancel out, ultimately leaving only feet.

$$1.63 \text{ km} = 1.63 \text{ km} \left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{100 \text{ cm}}{1 \text{ m}}\right)\left(\frac{1 \text{ in.}}{2.54 \text{ cm}}\right)\left(\frac{1 \text{ ft}}{12 \text{ in.}}\right)$$

$$1.63 \text{ km} = \frac{(1.63)(100000)\text{ft}}{(2.54)(12)}$$

$$1.63 \text{ km} = 5350 \text{ ft}$$

Remember, units may be cancelled when multiplying or dividing the same as numbers. In addition or subtraction, however, the units must be the same.

Example 2

Convert a flow of 1 cfs (cubic feet per second) per day into a volume of acre feet.

To do this two conversion factors are needed, as follows:

$$\frac{86{,}400 \text{ sec}}{\text{day}} = 1$$

$$\frac{43{,}560 \text{ cu ft}}{\text{ac ft}} = 1$$

$$\frac{\frac{1 \text{ cu ft}}{\text{sec}}}{\text{day}} = \left(\frac{1 \text{ cu ft}}{\text{sec}}\right) \left(\frac{\text{day}}{1}\right) \left(\frac{86{,}400 \text{ sec}}{\text{day}}\right) \left(\frac{\text{ac ft}}{43{,}560 \text{ cu ft}}\right)$$

$$= \frac{86{,}400 \text{ ac ft}}{43{,}560}$$

$$= 1.983 \text{ ac ft}$$ Usually called 2 ac ft

MATERIAL IN THESE STANDARDS IS FROM THE BOOK "ENGINEERING PROBLEMS MANUAL," BY FOREST C. DANA, C. E., AND LAWRENCE R. HILLYARD, M.S., BY PERMISSION OF McGRAW-HILL BOOK COMPANY PUBLISHERS.

Rules for Rounding off Numerical Values

The following instructions, including the numbering of the rules, are taken from USA Standard Institute Code No. Z25.1-1940, "Rules for Rounding Off Numerical Values." They should be followed whenever it is necessary to round off values that have more figures than can be used in the final answers.

In setting up rules for rounding off decimals there are three general cases that should be considered. They may be stated as follows:

Case 1 - When the figure next beyond the last figure or place to be retained is less than 5, the figure in the last place retained should be kept unchanged.

Example:

1.2342 1.234 1.23 1.2

Case 2 - When the figure next beyond the last figure or place to be retained is more than 5, the figure in the last place retained should be increased by 1.

Example:

1.6789	1.679	1.68	1.7

Case 3 - When the figure next beyond the last figure or place to be retained is 5 and

(a) there are no figures, or only zeros, beyond this 5, if the figure in the last place to be retained is odd, it should be increased by 1; if even, it should be kept unchanged;

Example:

1.35	1.4
1.3500	1.4
1.45	1.4
1.4500	1.4

(b) if the 5 next beyond the figure in the last place to be retained is followed by any figures other than zero, the figure in the last place retained should be increased by 1, whether odd or even.

Example:

1.3501	1.4
1.3599	1.4
1.4501	1.5
1.4599	1.5

The above rules for rounding off decimals may be restated as follows:

The figure in the last place to be retained should be kept unchanged

(a) when the figure in the next place is less than 5,

(b) when the figure in the next place is 5 followed by no other figures or only by zeros, and the figure in the last place retained is even.

The figure in the last place to be retained should be increased by 1

(a) when the figure in the next place is more than 5,

(b) when the figure in the next place is 5, followed by no other figures or only by zeros, and the figure in the last place retained is odd,

(c) when the figure in the next place is 5, followed by any figure or figures other than zero.

The final rounded value should be obtained from the most precise value available and not from a series of successive roundings. For example, 0.5499 should be rounded off successively to 0.550, 0.55, and 0.5 (not 0.6), since the most precise value available is less than 0.55. Similarly, 0.5501 should be rounded off as 0.550, 0.55, and 0.6, since the most precise value available is more than 0.55.

I. OTHER ITEMS

Formula Worshipping is a time-wasting and at times dangerous method of solving problems. The formula worshippers make a fettish of formulas, especially in fields where they are inexperienced and, consequently, not sure of themselves. As a result they spend much time in hunting a magic formula that will give a result without the labor of thinking. They hope it is correct but cannot know. If they would break the problem down into a series of simple, familiar steps, each one easy to understand and solve, they would save time and make fewer blunders. Results obtained by formulas are results obtained by secondhand thinking unless the formula is clearly understood and its derivation known. At best formulas are a symbolic shorthand.

Errors and Mistakes - Errors are defined as the difference between the true value and the one measured or computed. The error is positive or negative depending on whether the computed value is larger or smaller than the true value. The magnitude and sign of the error are determined from this equation:

$$\text{Error} = \begin{pmatrix} \text{the measured} \\ \text{or} \\ \text{computed value} \end{pmatrix} - (\text{the true value})$$

Thus, if a line is computed as being 173.5 feet long and the true value is 173.7 feet, the error is 173.5 - 173.7 = -0.2 foot or 0.2 foot too short.

Mistakes are costly, about 90 percent of all mistakes are due to careless arithmetic. They are the source of constant delay and expense. Nearly all the mistakes that bedevil Service operation are due to carelessness in calculations, not to troubles in theory or higher mathematics. Wrong answers due to errors in arithmetic cannot be brushed aside lightly with an offhand remark about misplaced decimal points or mistakes in arithmetic. Accuracy is a mark of competence.

Source of Errors

1. Unvoiced feeling that this phase of the work is relatively unimportant.

2. Sometimes momentary lapse of attention. A bit of mind wandering while the pencil moves mechanically.

3. Transposing of digits when copying values from scratch paper, which is one of the reasons for forbidding its use. This is a time comsuming blunder, because an internal transposition of digits is one of the most difficult mistakes to detect.

The Illustrative Problem

Karl Brown, a cooperator, came to the district office for assistance in planning an irrigation system for a 16 acre alfalfa field he is seeding.

Brown has a well that has been tested at 250 gpm. He also has a good reservoir site that can be developed by constructing a low earth dam across a narrow draw. The reservoir is located about 30 feet above the well. Brown doesn't have a pump in the well at the present time. He would use electric power for the pump. He will also need a canal from the reservoir to the alfalfa field.

If it is at all possible, Brown would like a reservoir that will serve as an irrigation storage reservoir and also provide him a place to raise some fish.

You are assigned to work with Mr. Brown on this project - you make an appointment with him to come out and look the project site over.

You review Mr. Brown's conservation plan and from the soils map and the irrigation guide come to the conclusion, based on the peak consumptive use requirements of alfalfa, that a 5-inch application of water every 18 days would be feasible for Mr. Brown's field.

A study of the reservoir site shows that a 10-12 ft dam will create a 9 acre-foot reservoir.

While you were out on the farm, Brown told you he had learned from the power company that electric power for a pump would be easy to bring to the well.

The alfalfa field will be irrigated with gravity flow from the reservoir. He will use the border method and irrigate 12 hours per day.

A study of the irrigation guide and chapter 4, NEH 15 indicates that a 1.67 cfs stream will be required for the proposed method of operation.

STATE Idaho		PROJECT Karl Brown Irrigation System	
BY WLR	DATE 4 Mar 75	CHECKED BY	DATE	~~JOB NO~~ Valley SCD
SUBJECT Basic Data For System			SHEET 1 OF 4

After your trip to the Brown Farm you summarize from your field notes the problem & problem data.

Problem:
Mr. Brown would like to know:

1. The size of the electric motor for the pump.
2. The storage in acre-feet of the reservoir to furnish irrigation water for a 5 inch application every 18 days. (To satisfy the peak irrigation use for the alfalfa.)
3. The number of days required to irrigate the 16 acres by the border method
4. The size of canal to deliver water from the reservoir to the alfalfa field.

Problem data

1. Field to be irrigated, 16 acres of alfalfa.
2. Irrigation water to be applied 12 hrs. per day.
3. Capacity of the well — 250 gpm
4. Electric power for pump motor.
5. Water level in well 30 ft. below proposed reservoir surface.
6. A four inch dia. steel pump discharge line will be used.
7. Pump will be operated 10 hrs. per day.
8. Well is located 380 ft. from reservoir.
9. Canal to deliver water from reservoir is 860 ft long with an estimated slope of 0.002 ft per ft.

COMPUTATION SHEET
SCS-523 REV 5-58

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STATE Idaho		PROJECT Karl Brown Irrigation System		
BY WP	DATE 4 Mar 75	CHECKED BY	DATE	JOB NO. Valley SCD
SUBJECT Design Computations				SHEET 2 OF 4

1. Determine acre-ft required for 5-inch irrigation of 16 acres.

$$\left(\frac{5\ \cancel{in}}{\frac{\cancel{12}\ \cancel{in}}{3\ ft}}\right) \cancel{16}^{4}\ ac = \frac{20}{3}\ ac\text{-}ft = \underline{\underline{6.67\ ac\text{-}ft}}$$

The reservoir site will store 9 ac-ft with a 10 ft dam. This would provide a minimum of 2⅓ ac-ft for fish. Borrow excavation for the fill will provide extra depth for fish.

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2. Determine number of 12 hr-days required to irrigate the 16 acres using the 1.67 cfs stream size.

EFM, Ex. 3-1

1 cfs = 1.983 ac-ft per 24 hr. day (Use 2 ac. ft/24 hrs)

1 cfs for 12 hrs = 1 ac-ft

$$\text{No. 12 hr-days} = \frac{6.67\ \cancel{ac\text{-}ft}}{\frac{1.67\ \cancel{ac\text{-}ft}}{day}} = \underline{\underline{4\ days}}$$

---

3. Determine time required to pump 6.67 ac-ft at the rate of 250 gpm per 10 hr day.

EFM, Ex 3-1

1 cfs = 448.8 gpm (use 450 gpm)

$$\cancel{(250\ gpm)}^{5}\left(\frac{1\ cfs}{\cancel{450\ gpm}_{9}}\right) = \frac{5}{9}\ cfs = 0.56\ cfs$$

0.56 cfs per 24 hr = 1.12 ac-ft

ac-ft per 10 hr day = $1.12\ ac\text{-}ft\left(\frac{10}{24}\right) = 0.47\ ac\text{-}ft$

$$\frac{6.67\ ac\ ft}{0.47\ \frac{ac\ ft}{day}} = \underline{\underline{14\ days}}$$

STATE Idaho		PROJECT Karl Brown Irrigation System	
BY WLR	DATE 4 Mar 75	CHECKED BY	DATE
			~~JOB NO~~ Valley SCD
SUBJECT Design Computations			SHEET 3 OF 4

Time required to initially fill reservoir – pump 9 ac-ft

$$\left(\frac{9}{6.67}\right)(14 \text{ days}) = \underline{\underline{19}} \text{ days}$$

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4. Determine size of electric motor required
Q = 250 gpm, static head = 30 ft
380 ft of 4" diam steel pipe.

Total pumping head = static head + head loss in pipe due to friction.

NEH-2, 432F — Use mannings $n = 0.012$

EFM, Exh. 3-5 — friction slope = 0.075 ft per ft

Friction loss = 380(0.075) = 28.5 ft

Total head loss = 30 + 28.5 = 58.5 ft

Note: 28.5 ft is high for pipe friction – however Mr. Brown specifically wishes to use 4" pipe.

NEH-15, Chap. 8 p. 8-60 — Req b.hp of motor = $\frac{(\text{gpm})(\text{total dynamic head})}{3960(\text{pump effic.})(\text{drive effic.})}$

(Note: Electric motors are rated at output h.p.. It is not necessary to use motor efficiency in determining motor size.)

Assume pump will be directly coupled to motor, so drive efficiency = 100%

Called Burp pump co. for estimated pump effic. of 70% — $b.hp = \frac{250(58.5)}{3960(0.70)} = \underline{\underline{5.28}}$

Use 5 HP Motor

STATE Idaho	PROJECT Karl Brown Irrigation System		
BY WLR / DATE 4 Mar 75	CHECKED BY	DATE	JOB NO.
SUBJECT Design Computations			SHEET 4 OF 4

5. Design earth canal to convey water to field

$Q = 1.67$ cfs

NEH-2, 320 — use Mannings $n = 0.025$ for velocity computation.

$S = 0.002$ ft. per ft.

soils map — $z = 1\frac{1}{2}$ to 1 (sandy clay)

Exh. 15-1, EFM — Use this chart to size ditch - it is set up for "n" values of 0.03 & 0.04 so table values of V will need to be adjusted.

Use $b = 1$ ft (less than this is not practical)

Find:

$n=0.03$ $d = 1.0$ ft, $V = 1.47$ ft/sec $Q = 3.7$ cfs

$n=0.04$ $d = 1.0$ ft, $V = 1.10$ " " $Q = 2.8$ cfs

check V for $n=0.025$ by using ratio of "n" values

For $n = 0.025$, $V = 1.47\left(\frac{0.030}{0.025}\right) = 1.76$ ft/sec

EFM, Table 9-2 — Safe velocity = 2.0 ft/sec

Ditch has safe velocity.

Ditch is actually oversized, however it will be adequate with ageing ($n=0.04$)

Use:

$b = 1$ ft

$z = 1\frac{1}{2}$

$d + F = 1.5$ ft

COMPUTATION SHEET
SCS-523 REV 5-58

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SOIL CONSERVATION SERVICE

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STATE		PROJECT		
BY	DATE	CHECKED BY	DATE	JOB NO.
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Exhibit No. 1

COMPUTATION SHEET

SCS-522 REV 5-58

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SOIL CONSERVATION SERVICE

GPO 1958 O—470868

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SUBJECT

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Exhibit No. 2

APPENDIX I

Abbreviations from USA Standards Institute

acre-foot	acre-ft
acre	spell out
alternating-current (as adjective)	a-c
ampere	amp
ampere-hour	amp-hr
antilogarithm	antilog
atmosphere	atm
average	avg
avoirdupois	advp
azimuth	az or a
barrel	bbl
board feet (feet board measure)	fbm
brake horsepower	bhp
brake horsepower-hour	bhp-hr
Brinell hardness number	Bhn
British thermal unit[1]	Btu or B
bushel	bu
calorie	cal
candle	c
candle-hour	c-hr
candlepower	cp
cent	c or ¢
center to center	c to c
centigram	cg
centiliter	cl
centimeter	cm
centimeter-gram-second (system)	cgs
circular	cir
circular mills	cir mils
coefficient	coef
cologarithm	colog
concentrate	conc
constant	const
cosecant	csc
cosine	cos
cost, insurance, and freight	cif
cotangent	cot
coulomb	spell out
cubic	cu
cubic foot	cu ft
cubic feet per minute	cfm
cubic feet per second	cfs
cubic inch	cu in.
cubic meter	cu m or m^3
cubic yard	cu yd
cylinder	cyl
diameter	diam
dozen	doz

elevation	el
equation	eq
external	ext
feet board measure (board feet)	fbm
feet per minute	fpm
feet per second	fps
foot	ft
foot-candle	ft-c
foot-pound	ft-lb
foot-pound-second (system)	fps
gallon	gal
gallons per minute	gpm
gallons per second	gps
horsepower	hp
horsepower-hour	hp-hr
hour	hr
hundredweight (112 lb)	cwt
inch	in.
inch-pound	in-lb
inches per second	ips
indicated horsepower	ihp
indicated horsepower-hour	ihp-hr
inside diameter	ID
internal	int
kilogram	kg
kilowatt	kw
kilowatthour	kwhr
latitude	lat or ϕ
least common multiple	lcm
linear foot	lin ft
liquid	liq
logarithm (common)	log
logarithm (natural)	log. or ln
longitude	long. or λ
mass	spell out
mathematics (ical)	math
maximum	max
melting point	mp
meter	m
mile	spell out
miles per hour	mph
miles per hour per second	mphps
million gallons per day	mgd
minimum	min
minute	min
month	spell out

ounce	oz
ounce-foot	oz-ft
ounce-inch	oz-in.
outside diameter	OD
parts per million	ppm
peck	pk
penny (pence)	d
pennyweight	dwt
pint	pt
pound	lb
pound-foot	lb-ft
pound-inch	lb-in.
pounds per cubic foot	lb per cu ft
pounds per square foot	psf
pounds per square inch	psi
power factor	spell out or pf
quart	qt
revolutions per minute	rpm
revolutions per second	rps
rod	spell out
shaft horsepower	shp
sine	sin
specific-gravity	sp gr
square	sq
square centimeter	sq cm or cm^2
square foot	sq ft
square inch	sq in.
square kilometer	sq km or km^2
square meter	sq m or m^2
square root of mean square	rms
standard	std
tangent	tan
temperature	temp
tensile strength	ts
thousand	M
thousand foot-pounds	kip-ft
thousand pound	kip
ton	spell out
ton-mile	spell out
versed sine	vers
volt	v
volt-ampere	va

watt	w
watthour	whr
watts per candle	wpc
week	spell out
weight	wt
yard	yd
year	yr

APPENDIX II

ENGINEERING CONVERSION FACTORS

Multiply	by	To obtain
acres	.404687	hectares
"	4.04687×10^{-3}	square kilometers
ares	1076.39	square feet
board feet	144 sq. in. x 1 in.	cubic inches
" "	.0833	cubic feet
centimeters	3.28083×10^{-2}	feet
"	.3937	inches
cubic centimeters	3.53145×10^{-5}	cubic feet
" "	6.102×10^{-2}	cubic inches
cubic feet	2.8317×10^{4}	cubic centimeters
" "	2.8317×10^{-2}	cubic meters
" "	6.22905	gallons, British Imperial
" "	28.3170	liters
" "	2.38095×10^{-2}	tons, British Shipping
" "	.025	tons, U.S. Shipping
cubic inches	16.38716	cubic centimeters
cubic meters	35.3145	cubic feet
" "	1.30794	cubic yards
cubic yards	.764559	cubic meters
degrees, angular	.0174533	radians
degrees Fahrenheit (less 32 F.)	.5556	degrees, Centigrade
degrees Centigrade	1.8	degrees, Fahrenheit (less 32 F.)
foot pounds	.13826	kilogram meters
feet	30.4801	centimeters
"	.304801	meters
"	304.801	millimeters
"	1.64468×10^{-4}	miles, nautical
gallons, British Imperial	.160538	cubic feet
" " "	1.20091	gallons, U.S.
" " "	4.54596	liters
gallons, U.S.	.832702	gallons, British Imperial
" "	.13368	cubic feet
" "	231.	cubic inches
" "	3.78543	liters
grams, metric	2.20462×10^{-3}	pounds, avoirdupois
hectares	2.47104	acres
"	1.076387×10^{5}	square feet
"	3.86101×10^{-3}	square miles
horse-power, metric	.98632	horse-power, U.S.
horse-power, U.S.	1.01387	horse-power, metric
inches	2.54001	centimeters
"	2.54001×10^{-2}	meters

Multiply	by	To obtain
inches	25.4001	millimeters
kilograms	2.20462	pounds
"	9.84206×10^{-4}	long tons
"	1.10231×10^{-3}	short tons
kilogram meters	7.233	foot pounds
kilograms per meter	.671972	pounds per foot
kilograms per square centimeter	14.2234	pounds per square inch
kilograms per square meter	.204817	pounds per square foot
" " " "	9.14362×10^{-5}	long tons per square foot
kilograms per square millimeter	1422.34	pounds per square inch
kilograms per square millimeter	.634973	long tons per square inch
kilograms per cubic meter	6.24283×10^{-2}	pounds per cubic foot
kilometers	.62137	miles, statute
"	.53959	miles, nautical
liters	.219975	gallons, British Imperial
"	.26417	gallons, U.S.
"	3.53145×10^{-2}	cubic feet
meters	3.28083	feet
"	39.37	inches
"	1.09361	yards
miles, statute	1.60935	kilometer
" "	.8684	miles, nautical
miles, nautical	6080.204	feet
" "	1.85325	kilometers
" "	1.1516	miles, statute
millimeters	3.28083×10^{-3}	feet
"	3.937×10^{-2}	inches
pounds, avoirdupois	453.592	grams, metric
" "	.453592	kilograms
" "	4.464×10^{-4}	tons, long
" "	4.53592×10^{-4}	tons, metric
pounds per foot	1.48816	kilograms per meter
pounds per square foot	4.88241	kilograms per square meter
pounds per square inch	7.031×10^{-2}	kilograms per square centimeter
" " " "	7.031×10^{-4}	kilograms per square millimeter
pounds per cubic foot	16.0184	kilograms per cubic meter
radians	57.29578	degrees, angular
square centimeters	.1550	square inches
square feet	9.29034×10^{-4}	ares
" "	9.29034×10^{-6}	hectares
" "	.0929034	square meters

APPENDIX II (Continued)

Multiply	by	To obtain
square inches	6.45163	square centimeters
" "	645.163	square millimeters
square kilometers	247.104	acres
" "	.3861	square miles
square meters	10.7639	square feet
" "	1.19599	square yards
square miles	259.0	hectares
" "	2.590	square kilometers
square millimeters	1.550×10^{-3}	square inches
square yards	.83613	square meters
tons, long	1016.05	kilograms
" "	2240.	pounds
" "	1.01605	tons, metric
" "	1.120	tons, short
tons, long, per square foot	1.09366×10^{4}	kilograms per square meter
tons, long, per square inch	1.57464	kilograms per square millimeter
tons, metric	2204.62	pounds
" "	.98421	tons, long
" "	1.10231	tons, short
tons, short	907.185	kilograms
" "	.892857	tons, long
" "	.907185	tons, metric
tons, British Shipping	42.00	cubic feet
" " "	.952381	tons, U.S. Shipping
tons, U.S. Shipping	40.00	cubic feet
" " "	1.050	tons, British Shipping
yards	.914402	meters

APPENDIX III

CONVERSION TABLES FOR METRIC AND U.S. WEIGHTS AND MEASURES

L E N G T H

Centi-meters	cm or in	Inches	Meters	m or ft	Feet	Meters	m or yd	Yards	Kilo-meters	Km or mi	Miles
2.540	1	0.394	0.305	1	3.281	0.914	1	1.094	1.609	1	0.621
5.080	2	0.787	0.610	2	6.562	1.829	2	2.187	3.218	2	1.243
7.620	3	1.181	0.914	3	9.842	2.743	3	3.281	4.827	3	1.864
10.160	4	1.575	1.219	4	13.123	3.658	4	4.374	6.436	4	2.486
12.700	5	1.969	1.524	5	16.404	4.572	5	5.468	8.045	5	3.107
15.240	6	2.362	1.829	6	19.685	5.486	6	6.562	9.654	6	3.728
17.780	7	2.756	2.134	7	22.966	6.401	7	7.655	11.263	7	4.350
20.320	8	3.150	2.438	8	26.246	7.315	8	8.749	12.872	8	4.971
22.860	9	3.543	2.743	9	29.527	8.230	9	9.843	14.481	9	5.593
25.400	10	3.937	3.048	10	32.808	9.144	10	10.936	16.09	10	6.214
50.800	20	7.874	6.096	20	65.616	18.288	20	21.872	32.18	20	12.428
76.200	30	11.811	9.144	30	98.424	27.432	30	32.808	48.27	30	18.642
101.600	40	15.748	12.192	40	131.232	36.576	40	43.745	64.36	40	24.856
127.000	50	19.685	15.240	50	164.040	45.720	50	54.681	80.45	50	31.070
152.400	60	23.622	18.288	60	196.848	54.864	60	65.617	96.54	60	37.284
177.800	70	27.559	21.336	70	229.656	64.008	70	76.553	112.63	70	43.498
203.200	80	31.496	24.384	80	262.464	73.152	80	87.489	128.72	80	49.712
228.600	90	35.433	27.432	90	295.272	82.296	90	98.425	144.81	90	55.926
254.000	100	39.370	30.480	100	328.080	91.444	100	109.361	160.90	100	62.140

APPENDIX III (Continued)

CONVERSION TABLES FOR METRIC AND U.S. WEIGHTS AND MEASURES

A R E A

Square centi-meters	Square cm or inch	Square inches	Square meters	Square m or ft	Square feet	Square meters	Square m or yd	Square yards
6.452	1	0.155	0.093	1	10.764	0.836	1	1.196
12.904	2	0.310	0.186	2	21.528	1.672	2	2.392
19.356	3	0.465	0.279	3	32.292	2.508	3	3.588
25.808	4	0.620	0.372	4	43.056	3.344	4	4.784
32.260	5	0.775	0.465	5	53.820	4.181	5	5.980
38.712	6	0.930	0.557	6	64.584	5.017	6	7.176
45.164	7	1.085	0.650	7	75.348	5.853	7	8.372
51.616	8	1.240	0.743	8	86.112	6.689	8	9.568
58.068	9	1.395	0.836	9	96.876	7.525	9	10.764
64.52	10	1.55	0.929	10	107.64	8.361	10	11.96
129.04	20	3.10	1.858	20	215.28	16.722	20	23.92
193.56	30	4.65	2.787	30	322.92	25.083	30	35.88
258.08	40	6.20	3.716	40	430.56	33.444	40	47.84
322.60	50	7.75	4.645	50	538.20	41.805	50	59.80
387.12	60	9.30	5.574	60	645.84	50.166	60	71.76
451.64	70	10.85	6.503	70	753.48	58.527	70	83.72
516.16	80	12.40	7.432	80	861.12	66.888	80	95.68
580.68	90	13.95	8.361	90	968.76	75.249	90	107.64
645.2	100	15.50	9.29	100	1076.4	83.61	100	119.6

APPENDIX III (Continued)

CONVERSION TABLES FOR METRIC AND U.S. WEIGHTS AND MEASURES

A R E A

Square kilo-meters	Square km or mi	Square miles 0.386	Hectares	ha or ac	Acres	Hectares	ha or sq. mi	Square miles
2.59	1	0.386	0.405	1	2.471	258.99	1	0.00386
5.18	2	0.772	0.809	2	4.942	517.98	2	0.00772
7.77	3	1.158	1.214	3	7.413	776.97	3	0.01158
10.36	4	1.544	1.619	4	9.884	1,035.96	4	0.01544
12.95	5	1.931	2.023	5	12.355	1,294.95	5	0.01930
15.54	6	2.317	2.428	6	14.826	1,553.94	6	0.02316
18.13	7	2.703	2.833	7	17.297	1,812.93	7	0.02702
20.72	8	3.089	3.237	8	19.769	2,071.92	8	0.03088
23.31	9	3.475	3.642	9	22.240	2,330.91	9	0.03474
25.90	10	3.861	4.047	10	24.711	2,258.9	10	0.0386
51.8	20	7.772	8.094	20	49.421	5,179.8	20	0.0772
77.7	30	11.583	12.140	30	74.132	7,769.7	30	0.1158
103.6	40	15.444	16.187	40	98.842	10,359.6	40	0.1544
129.5	50	19.305	20.234	50	123.553	12,949.5	50	0.1930
155.4	60	23.166	24.281	60	148.263	15,539.4	60	0.2316
181.3	70	27.027	28.328	70	172.794	18,129.3	70	0.2702
207.2	80	30.888	32.375	80	197.684	20,719.2	80	0.3088
233.1	90	34.749	36.422	90	222.395	23,309.1	90	0.3474
259	100	38.61	40.469	100	247.105	25,899	100	0.386

APPENDIX III (Continued)

CONVERSION TABLES FOR METRIC AND U.S. WEIGHTS AND MEASURES

W E I G H T

Grams	Gr or grain	Grains	Grams	gr or oz	Ounces	Kilo-grams	Kg or lb	Pounds	Metric tons	mt or t	Net tons (2,000 lbs)
0.0648	1	15.432	28.35	1	0.0352	0.454	1	2.205	0.9072	1	1.1023
0.1296	2	30.864	56.70	2	0.0704	0.907	2	4.409	1.8144	2	2.2046
0.1944	3	46.296	85.05	3	0.1056	1.361	3	6.614	2.7216	3	3.3069
0.2592	4	61.728	113.40	4	0.1408	1.814	4	8.819	3.6288	4	4.4092
0.3240	5	77.160	141.75	5	0.1760	2.268	5	11.023	4.5360	5	5.5115
0.3888	6	92.592	170.10	6	0.2112	2.722	6	13.228	5.4432	6	6.6138
0.4536	7	108.024	198.45	7	0.2464	3.175	7	15.432	6.3504	7	7.7161
0.5184	8	123.456	226.80	8	0.2816	3.629	8	17.637	7.2576	8	8.8184
0.5832	9	138.888	255.15	9	0.3168	4.082	9	19.842	8.1648	9	9.9207
0.648	10	154.320	283.50	10	0.352	4.536	10	22.046	9.072	10	11.023
1.296	20	308.64	567.0	20	0.704	9.072	20	44.092	18.144	20	22.046
1.944	30	462.96	850.5	30	1.056	13.608	30	66.139	27.216	30	33.069
2.592	40	617.28	1,134.0	40	1.408	18.144	40	88.185	36.288	40	44.092
3.240	50	771.60	1,417.5	50	1.760	22.680	50	110.231	45.360	50	55.115
3.888	60	925.92	1,701.0	60	2.112	27.216	60	132.277	54.432	60	66.138
4.536	70	1,080.24	1,984.5	70	2.464	31.752	70	154.324	63.504	70	77.161
5.184	80	1,234.56	2,268.0	80	2.816	36.287	80	176.370	72.576	80	88.184
5,832	90	1,388.88	2,551.5	90	3.168	40.823	90	198.416	81.648	90	99.207
6.48	100	1,543.2	2,835.0	100	3.52	45.369	100	220.462	90.72	100	110.23

APPENDIX III (Continued)

CONVERSION TABLES FOR METRIC AND U.S. WEIGHTS AND MEASURES

W E I G H T

Kilogram/ square centimeter	kg/sq cm or lb/sq in	Pounds/ square in	Kilograms/ meter	Kg/m or lb/ft	Pounds/ foot	Kilograms/ square meter	kg/sq m or lb/sq ft	Pounds/ square foot	Kilograms/ cubic meter	kg/cu m or lb/cu ft	Pounds/ cubic feet
0.070	1	14.223	1.488	1	0.672	4.883	1	0.205	16.019	1	0.062
0.141	2	28.446	2.976	2	1.344	9.765	2	0.410	32.038	2	0.125
0.211	3	42.669	4.465	3	2.016	14.648	3	0.614	48.058	3	0.187
0.281	4	56.892	5.953	4	2.688	19.530	4	0.819	64.077	4	0.250
0.352	5	71.115	7.441	5	3.360	24.413	5	1.024	80.096	5	0.312
0.422	6	85.338	8.928	6	4.032	29.295	6	1.229	96.115	6	0.374
0.492	7	99.561	10.417	7	4.704	34.178	7	1.434	112.134	7	0.437
0.562	8	113.784	11.906	8	5.376	39.060	8	1.638	128.154	8	0.499
0.633	9	128.007	13.394	9	6.048	43.943	9	1.843	144.173	9	0.562
0.703	10	142.230	14.882	10	6.720	48.825	10	2.048	160.192	10	0.624
1.406	20	284.46	29.764	20	13.440	97.650	20	4.096	320.384	20	1.248
2.109	30	426.69	44.646	30	20.160	146.475	30	6.144	480.576	30	1.872
2.812	40	568.92	59.528	40	26.880	195.300	40	8.192	640.768	40	2.496
3.515	50	711.15	74.410	50	33.600	244.125	50	10.240	800.960	50	3.120
4.218	60	853.38	89.292	60	40.320	292.950	60	12.288	961.152	60	3.744
4.921	70	995.61	104.174	70	47.040	341.775	70	14.336	1,121.344	70	4.368
5.624	80	1,137.84	119.056	80	53.760	390.600	80	16.384	1,281.536	80	4.992
6.327	90	1,280.07	113.938	90	60.480	439.425	90	18.432	1,441.728	90	5.616
7.030	100	1,422.3	148.82	100	67.20	488.25	100	20.48	1,601.92	100	6.24

APPENDIX III (Continued)

CONVERSION TABLES FOR METRIC AND U.S. WEIGHTS AND MEASURES

V O L U M E A N D C A P A C I T Y

Cubic centi-meters	cu cm or cu in	Cubic inches	Cubic meters	cu m or cu ft	Cubic feet	Cubic meters	cu m or gal	Cubic yards
16.39	1	0.061	0.028	1	35.314	0.765	1	1.308
32.78	2	0.122	0.057	2	70.628	1.529	2	2.616
49.17	3	0.183	0.085	3	105.942	2.294	3	3.924
65.56	4	0.244	0.113	4	141.256	3.058	4	5.232
81.95	5	0.305	0.142	5	176.570	3.823	5	6.540
98.34	6	0.366	0.170	6	211.884	4.587	6	7.848
114.73	7	0.427	0.198	7	247.198	5.352	7	9.156
131.12	8	0.488	0.226	8	282.512	6.116	8	10.464
147.51	9	0.549	0.255	9	317.826	6.881	9	11.772
163.9	10	0.61	0.283	10	353.14	7.645	10	13.08
327.8	20	1.22	0.566	20	706.28	15.290	20	26.16
491.7	30	1.83	0.849	30	1,059.42	22.935	30	39.24
655.6	40	2.44	1.132	40	1,412.56	30.580	40	52.32
819.5	50	3.05	1.415	50	1,765.70	38.225	50	65.40
983.4	60	3.66	1.698	60	2,118.84	45.870	60	78.48
1,147.3	70	4.27	1.981	70	2,471.98	53.515	70	91.56
1,311.2	80	4.88	2.264	80	2,825.12	61.160	80	104.64
1,475.1	90	5.49	2.547	90	3,178.26	68.805	90	117.72
1,639	100	6.1	2.83	100	3,531.4	76.45	100	130.8

1 liter equals 61.023 cu. in.

28.32 liters equals 1 cu. ft.

APPENDIX III (Continued)

CONVERSION TABLES FOR METRIC AND U.S. WEIGHTS AND MEASURES

V O L U M E A N D C A P A C I T Y

Liters	1 or qt	Quarts	Liters	1 or gal	Gallons	Cubic meters	cu m or gal	Gallons
0.946	1	1.057	3.785	1	0.264	0.004	1	264.17
1.893	2	2.113	7.571	2	0.528	0.008	2	528.34
2.839	3	3.170	11.356	3	0.793	0.011	3	792.51
3.785	4	4.227	15.142	4	1.057	0.015	4	1,056.68
4.732	5	5.284	18.927	5	1.321	0.019	5	1,320.85
5.678	6	6.340	22.712	6	1.585	0.023	6	1,585.02
6.624	7	7.397	26.498	7	1.849	0.027	7	1.849.19
7.570	8	8.454	30.283	8	2.114	0.030	8	2,113.36
8.517	9	9.510	34.069	9	2.378	0.034	9	2,377.53
9.463	10	10.567	37.854	10	2.642	0.038	10	2,641.7
18.926	20	21.134	75.708	20	5.284	0.076	20	5,283.4
28.389	30	31.701	113.562	30	7.926	0.114	30	7,925.1
37.852	40	42.268	151.416	40	10.568	0.152	40	10.556.8
47.315	50	52.835	189.270	50	13.210	0.190	50	13,208.5
56.778	60	63.402	227.124	60	15.852	0.228	60	15,850.2
66.241	70	73.969	264.978	70	18.494	0.266	70	18,481.9
75.704	80	84.536	302.832	80	21.136	0.304	80	21,133.6
85.167	90	95.10	340.686	90	23.778	0.342	90	23,775.3
94.63	100	105.67	378.540	100	26.42	0.38	100	26,417