COMPUTATION STANDARDS

FOR

ENGINEERING WORK

PREPARED BY

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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 blunders 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. Blunders in addition, subtraction, division, and multiplication are the causes of far greater losses of time, effort, materials, and money than mistakes in theory.

The computer should form the habit of checking and rechecking all his figuring as he goes along.

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 USASI (United States of America Standards Institute), formerly American Standards Institute. (See Appendix.)

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

MAKE IT YOUR RULE
TO DATE EVERYTHING

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

C. THE PROBLEM

The problem must be defined clearly. One must understand the statement of the problem and perceive its central question before one can plan the attack.

When one has pinpointed the problem, collected data, gathered the mathematical tools, and considered methods of attack, he is ready to start the solution.

Remember the old adage: *A problem well defined is half solved.*

D. PROBLEM ANALYSIS

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, you may not have broken the problem down sufficiently and are attempting to solve it in too large "bites." 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.

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

E. 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.

1. Fill in every space and line at the top of the sheet. Be very meticulous and fill each sheet of your computations.

2. Divide the sheet into two columns. For slide rule work make the left column two inches wide, for logarithms and longhand make it three inches wide.

3. Reserve the wide, right-hand column for diagrams, analysis, and solution of the problem. All arithmetical figuring belongs in the left-hand column. References may also be shown in this column.

4. *Do not use scratch paper.* Leave a plain trail for the checker 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 the user's mind and is a careless habit.

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

9. *Be careful with spelling and use of English.*

10. *Avoid crowding.* Use more paper if necessary.

    Where repetitive computations are numerous, columnar forms SCS-344 and SCS-347 may be used. Space is available at the top of the sheet for job identification and descrition of the work, date, and computer's initials.

F. 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.

G. UNITS

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

H. 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:

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

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 quantity.

<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 centimeters 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.

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

$$1.63 \text{ km} = \frac{(1.63)(100{,}000 \text{ ft})}{(2.54)(12)}$$

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

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:

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

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

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

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

$$= 1.983 \text{ ac-ft}$$

Usually called 2 ac-ft

I. HOLMAN'S RULES FOR NUMERICAL CALCULATIONS

Since it is misleading as well as time wasting to carry needless figures through a calculation, the engineer should know how to round off values properly and also know what the true results will be where values of varied precision are brought together in a series of calculations. The precision of a result depends upon the precision of both the various factors and the mathematical operations performed. It is necessary, therefore, for one to become familiar with the facts that are summed up in Holman's rules of calculation. In all the following instructions and examples the doubtful figures are the smaller numbers.

1. Addition or Subtraction - The result cannot be accurate beyond the column having the first doubtful value. Note the loss of significant figures in the third example.

ADDITION	SUBTRACTION	SUBTRACTION
128$_3$	645.3$_6$	736.8$_3$
+23.8$_7$	-219.$_4$	-727.$_5$
+ 1.94$_2$	425.9$_6$	9.$_{33}$
1308.$_{812}$		

IN THESE EXAMPLES THE DOUBTFUL FIGURES ARE PRINTED SMALLER.

It should be noted from the examples above that when the total must be correct to a specified column of digits it may be necessary to calculate the separate items to varying numbers of significant figures. The precision of all factors leading to the items must be adjusted to the precision desired in the result.

2. Multiplication or Division - The result will be accurate only to same number of figures as the least precise factor involved. This will be true regardless of the number of factors involved. Note the precision in the examples below.

MULTIPLICATION

```
  1473.6
     2.53
  ------
   442 08
  7368 0
 29472
 ------
 3728.208
```

DIVISION

```
        18.5153
37.4)692.473
     374
     ---
     318 4
     299 2
     -----
      19 27
      18 70
      -----
        573
        374
        ---
        1990
        1870
        ----
         1200
         1122
         ----
          780
```

IN THESE EXAMPLES THE DOUBTFUL FIGURES ARE PRINTED SMALLER.

3. Carrying Doubtful Figures - In general, carry through all intermediate calculations one more figure than is wanted in the end result of a chain of calculations. That is, carry two, but only two, doubtful figures through the intermediate steps; then cut back to one doubtful digit in the final answer. Remember, however, that one doubtful figure will always be left when any rounding off is done. Dropping it merely makes the one to its left doubtful. Refer to section below for the rules for rounding numerical values.

When measured values are to be used in connection with constants such as π or conversion constants that are known to many places, time will be saved if the constants are cut back to the same number of significant figures as the measured values.

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 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 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.

J. OTHER ITEMS

Formula Worshipping is a time-wasting and at times dangerous method of solving problems. The formula worshippers make a fetish 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 Blunders - 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.

Blunders are defined as stupid mistakes. Men in position to know have stated repeatedly that fully 90 percent of the mistakes in figuring are due to careless arithmetical blunders. They are the source of constant delay and expense. Nearly all the mistakes that bedevil engineering offices are due to carelessness in calculations, not to troubles in theory or higher mathematics. Wrong answers due to blunders 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 Blunders

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 consuming blunder, because an internal transposition of digits is one of the most difficult mistakes to detect.

SO—MAKE IT A RULE TO DATE AND INITIAL EVERYTHING.
AND TRAIN THOSE UNDER YOU TO DO THE SAME.

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.

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 275 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 ft 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.

Since Brown has an agreement with the Soil Conservation District, you, Bill Young, the district conservationist, and the area engineer study Brown's soil map and come to the conclusion that the peak consumptive use requirement for the alfalfa, that will determine the irrigation storage requirement of the reservoir, is a 5-inch application every 14 days.

A study of the reservoir site shows that a 9 ft dam will create a 12 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. Power rates are lower if pump operates only 10 hours per day.

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

Note: One of my draftsmen who copied the problem computations in ink (for a sharper reproduction) came in one morning and asked where I got the information about the dam and reservoir, and wouldn't Mr. Brown want to know how much the job will cost.

So I went through the various steps a technician or an engineer would go through to obtain the data for the problem. Field surveys, locating and testing soil for the dam, cost estimates and specifications, and possibly preparing a benefit: cost ratio for Mr. Brown. My draftsman friend would like to see the problem developed in those details. I admit that might be a good idea, but the Service field personnel would know how to handle these steps. Basically the function of the problem is to illustrate the method of Problem Analysis and to set up the format for computations.

COMPUTATION SHEET
SCS-523A REV 5-58

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

STATE: EWP Unit, Portland | PROJECT: Computation Standards for Engineering Work
BY: FKM | DATE: 7-8-69 | CHECKED BY: ESL REG HWF | DATE: 7-10-68 | JOB NO.
SUBJECT: Illustrative Problem | SHEET 1 OF 6

After your trip to the Brown Farm you summarize the problem and problem data

Problem: Mr Brown would like to know:

1. Storage in ac-ft in the reservoir to supply water for a 5 inch application every 14 days (to satisfy the peak irrigation demand of the 16 acre alfalfa field).

2. The number of ac-ft available for fish in the 12 ac-ft reservoir.

3. The size of electric motor for the pump.

4. The number of days required to irrigate the 16 acres of alfalfa by the border method.

5. Size of channel to deliver water from reservoir to field.

Problem Data

1. A 9 ft high earth dam will store 12 ac-ft of water.

2. 16 acres of alfalfa to be irrigated by the border method with a 1.67 cfs stream-intake rate from Irrigation Guide.

3. Brown will irrigate 12 hr per day.

4. Capacity of well 275 gpm - pump to operate 10 hr per day.

5. Electric power for pump.

6. Well is located 30 ft below reservoir surface, and 380 ft away.

7. Pump discharge line will be a 4 in. dia 14 ga steel pipe 380 ft long.

8. Canal to deliver water from reservoir is 860 ft long with an estimated grade of 0.002 ft per ft.

COMPUTATION SHEET
SCS-523A REV 5-58

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

STATE	PROJECT	
BY EWP Unit, Portland	Computation Standards for Engineering Work	
FKM — DATE 7-8-69	CHECKED BY REG HWF — DATE 7-10-69	JOB NO.
SUBJECT Illustrative Problem		SHEET 2 OF 6

Problem Analysis

1. Compute ac-ft of water required to apply 5 in. irrigation to 16 acres of alfalfa.

2. Compute no. 12 hr days to irrigate the 16 acres by the border method with a 1.67 cfs stream.

3. Calculate no. 10 hr pump days to fill reservoir - 12 ac-ft rate of pumping 275 gpm.

4. Calculate no. 10 hr pump days to pump water for one irrigation.

5. Calculate ac-ft in reservoir Brown can have for fish. Equation: 12 ac-ft minus ac-ft for irrigation plus ac-ft pumped to reservoir during the days irrigated.

6. Compute horse-power of electric motor for pump. Pump head is 30 ft static head + head loss in 4 in. dia 14 ga steel pipe 380 ft long.

7. Design earth channel to deliver irrigation water to alfalfa.

COMPUTATION SHEET
SCS-520A REV 5-58

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

STATE	PROJECT			
FWP Unit, Portland	Computation Standards for Engineering Work			
BY: EKM	DATE: 7-8-69	CHECKED BY: EBL REG HWE	DATE: 7-10-69	JOB NO.
SUBJECT: Illustrative Problem				SHEET 4 OF 6

4. Number 10 hr days to pump water for one irrigation

$$(6.67 \text{ ac-ft}) \frac{(\text{day})}{(0.51 \text{ ac-ft})} = \underline{\underline{13 \text{ days}}}$$

5. Number of ac-ft that can be used for fish

Full reservoir - irrigation application + quantity pumped to reservoir during 4 day irrigation

$$(12 \text{ ac-ft}) - (6.67 \text{ ac-ft}) + (4 \text{ days}) \frac{(0.51 \text{ ac-ft})}{(\text{day})}$$

$$(5.33 \text{ ac-ft}) + (2.04 \text{ ac-ft}) = \underline{\underline{7.37 \text{ ac-ft for fish}}}$$

$$\begin{array}{r} 12.00 \\ -\ 6.67 \\ \hline 5.33 \\ +\ 2.04 \\ \hline 7.37 \end{array}$$

6. HP of electric motor to pump 275 gpm against a static head of 30 ft + head loss in 380 ft of 4 in dia 14 ga welded steel pipe

NEH Sec 15, chap 11 table 11-9

Head loss in 4 in pipe = 6.0 ft per 100 ft = 22.8 ft
Static head = 30.0 ft
52.8 ft

$$\begin{array}{r} 3.8 \\ \times\ 6 \\ \hline 22.8 \\ +\ 30.0 \\ \hline 52.8 \end{array}$$

Use 53.0 ft

Water horsepower = $\frac{(Q\,H)(HP)}{3960} = \frac{(\overset{2}{275})(\overset{1}{53.0})}{\underset{3}{3960}} = \underline{\underline{3.68 \text{ HP}}}$

Refer to NEH Sec 15 chap 8 page 8-59

Assume pump efficiency 70%
" motor " 84%

$$\text{Motor HP} = \frac{(\overset{2}{275})(\overset{1}{53.0})(HP)}{(\underset{3}{3960})(\underset{-1+1}{0.70})(\underset{-1+1}{0.84})} = 6.27 \text{ HP}$$

Use 7.5 HP motor

COMPUTATION SHEET
SCS-52JA REV 5-58

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

STATE	PROJECT		
EWP Unit, Portland	Computation Standards for Engineering Work		
BY FKM	DATE 7-8-69	CHECKED BY REG HWF	DATE 7-10-69
SUBJECT Illustrative Problem			JOB NO.
			SHEET 5 OF 6

Note that in the pump formula the only units is HP, all other units were cancelled in arriving at the constant 3960

For those not acquainted with this formula we will develop it.

$$HP = \frac{\left(275 \frac{gal}{min}\right)\left(53.0\ ft\right)\left(8.33 \frac{lb}{gal}\right)}{33{,}000 \frac{ft\text{-}lb}{min} / HP}$$ at 100% efficiency

$$\text{Water } HP = \frac{(275)(53)\,HP}{3960} = 3.68\ HP \text{ at 100\% efficiency.}$$

$$\text{Motor } HP = \frac{(275)(53)\,HP}{(3960)(0.70)(0.84)} = 6.27\ HP$$

7. Design earth channel 860 ft long to deliver 1.67 cfs

$Q = 1.67$ cfs, $n = 0.03$, $s = 0.002$, $b = 2$, $z = 1.5$

King's Handbook 5th edition table 7-11, 7-17, 7-19

$$K' = \frac{Qn}{b^{8/3} s^{1/2}} = \frac{(1.67)(0.03)}{(2)^{8/3}(0.002)^{1/2}} = \frac{0.05}{(6.35)(0.0447)} = 0.176$$

4th edition Table 92, 95, 97

$$\frac{d}{b} = 0.26 \qquad d = (0.26)(2\ ft) = 0.52\ ft$$

$D = d + Fb$ where $Fb = 0.2\ H_o$ or 0.5 ft min

$D = 0.52\ ft + 0.5\ ft = 1.02\ ft$ use $1.0\ ft$

Construct ditch 2.0 ft wide and 1.0 ft deep

COMPUTATION SHEET
SCS-5.2A REV 5-58

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

STATE: EWP Unit, Portland
PROJECT: Computation Standards for Engineering Work
BY: FKM
DATE: 7-8-69
CHECKED BY: REG HWF
DATE: 7-10-69
JOB NO.:
SUBJECT: Illustrative Problem
SHEET 6 OF 6

Irrigation and pump record
(assume reservoir full on June 1)

Date	Daily Irrigation	Daily Pumping	Daily Net Withdrawal	Volume in reservoir
June	←	Units: Ac-ft	→	12.00
1	1.67	0.51	1.16	10.84
2	1.67	0.51	1.16	9.68
3	1.67	0.51	1.16	8.52
4	1.67	0.51	1.16	7.36 *
5		0.51		7.87
6		0.51		8.38
7		0.51		8.89
8		0.51		9.40
9		0.51		9.91
10		0.51		10.42
11		0.51		10.93
12		0.51		11.44
13		0.51	Full reservoir	11.95

* Note slight difference with computed value on sheet 4.

APPENDIX

Abbreviations from USA Standards Institute

acre	spell out *
acre-foot	acre-ft *
alternating-current (as adjective)	a-c
ampere	amp
ampere-hour	amp-hr
antilogarithm	antilog
atmosphere	atm
average	avg
avoirdupois	avdp
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	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

* *Since in the SCS accepted abbreviations for acre and acre feet are ac and ac-ft, we recommend their use.*

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

* *ft^2 or $in.^3$ for sq ft or cu in. not a permissible American Standard, is used in metric system.*

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

A USA Standard is a specification for . .

portland cement
wrought-iron pipe
electrical wire and cable
mica
lampblack
and hundreds of other materials and products.

More than 3000 USA Standards exist, affecting practically all sectors of the American economy — manufacturers, distributors, sellers, consumers, users, insurance companies, safety organizations, employers and employees, federal, state, and local governments, and many others.

(A complete index and price list of USA Standards can be obtained from the USA Standards Institute, 10 East 40th Street, New York, N. Y. 10016.)

A USA Standard is a voluntary national standard, arrived at by common consent, and available for voluntary use.

A USA Standard can be developed under the auspices of the USA Standards Institute. In such case, every group substantially concerned with the proposed standard has the right to participate in its development and be heard on every detail of its scope and provisions and to cast a ballot of approval or disapproval.

Trade associations and professional societies which have developed their own standards can submit these to the Institute for approval as USA Standards.

Approval of a standard as a USA Standard — no matter how or where developed — is given only if two basic requirements are fulfilled:

1. The standard must be accepted by a consensus of all national groups substantially concerned with its scope and provisions.
2. It must be of interest to more than one organization or group.

A USA Standard is reviewed at regular intervals, as a result of which it may be either reaffirmed, revised, or withdrawn.

USA What is...

STANDARDS INSTITUTE

a Standard?

the USA Standards Institute?

a USA Standard?

For further information and literature write to:

USA STANDARDS INSTITUTE

10 East 40th St., New York, N.Y. 10016 • 683-3058

Permission to reprint this leaflet was graciously given by the United States of America Standards Institute.

WHAT IS A STANDARD?

The inch is a standard of measurement.

Money is a standard of exchange.

Words are standards of communication.

Traffic lights are safety standards.

Octane numbers of gasoline are quality standards.

"No more than 1% shrinkage" is a performance standard.

A housewife's recipe is a production standard.

Standards insure that a fitting fits the pipe, that a lamp screws into a socket, and that the bolt matches the nut. A standard specifies the exact composition of a particular grade of steel or the safety requirements for portable ladders. A standard establishes uniform test methods for the washability of a woman's slip or for the tensile strength of hydraulic cement. Standard interchangeable component parts are the basis of all mass production.

Arts, crafts, science, engineering, and production — in fact, the entire fabric of a civilization — cannot exist without standards.

How Do We Get Standards?

Until the time of the industrial revolution, most standards, from the shape of a mason's trowel to the form and size of our tableware, came about by a slow process of evolution. What after many years of custom and experience was found to be the most practical in use became a standard. When the standard was no longer practical, it changed or fell into disuse.

After James Watt had invented the steam engine, however, industrial progress became so fast that the slow evolutionary process of developing the most practical and economical standard fell behind.

So in the 19th century, manufacturers, trade associations, professional societies, government departments, and others began to make planned efforts to speed up the standard-making process. The 20th century has seen many thousands of individual companies and hundreds of trade and professional organizations participate in standards making. Through an exchange of information and by voluntary agreement they formulated standards — for use within a conpany, within a trade, among different industries and trades, for an entire nation, or for international use.

WHAT IS THE USA STANDARDS INSTITUTE?

During World War I, to avoid duplication and waste in war production, efforts were made to coordinate some of the standards activities carried on separately by different engineering branches.

As a result, a forerunner of the present USA Standards Institute — the American Engineering Standards Committee — was founded in 1918 by five leading engineering societies.

Expansion of the work of the AESC led to its reorganization in 1928 and to the birth of the American Standards Association. In 1966 ASA became the United States of America Standards Institute. This action was part of the continuing process of improving the voluntary standardization system and making it fully responsive to the needs of the economy.

USASI is a federation of 150 trade associations and professional societies. It has more than 800 company members

The main functions of the Institute are:

1. To provide systematic means for the development of USA Standards
2. To promote the development and use of national standards in the United States
3. To approve standards as USA Standards provided they are accepted by a consensus of all national groups substantially concerned with their scope and provisions
4. To coordinate standardization activities in the United States
5. To serve as a clearinghouse for information on American and foreign standards
6. To represent American interests in international standardization work

Development and use of USA Standards are voluntary. So is the financial support of USASI. Its income is derived mainly from membership fees and the sale of USA Standards. However, USASI's facilities are available to all — members and non-members alike.

International Work

U.S. interests in international standards work are represented through USASI, the recognized channel through which American industry and other groups can participate on international standards projects. USASI accredits delegates to international meetings, notably those of the

International Organization for Standardization (ISO)

International Electrotechnical Commission (IEC)

Pan American Standards Commission (COPANT)

"ABC" Conference on Unification of Engineering Standards (participating countries America, Britain, Canada)

The Standards Institute is a source of information on foreign standardization work, and, as an aid to foreign trade, it promotes knowledge of USA Standards in foreign countries.

WHAT IS A USA STANDARD?

A USA Standard is a standard approved by the USA Standards Institute. Because USASI's procedures are based upon a consensus of all parties substantially concerned, a USA Standard is accepted as the one national authoritative standard in its immediate field of application.

A USA Standard is...
- a dictionary for nuclear terms
- a manual for engineering drawings
- the National Electrical Code
- the photographic speed and exposure index
- the safety requirements for elevators
- the test methods for textile fabrics.

A USA Standard covers...
- safety glass in American automobiles
- gas ranges in American homes
- floor space of American offices
- lighting in American plants
- the road and paving materials used on American highways.

Minimize Your Mistakes

ROBERT W. RICHARDS
Howard, Needles, Tammen & Bergendoff

WHEN HE WAS chairman of the board of U. S. Steel, Judge Elbert H. Gary said, "All men who do things make an occasional mistake. The only people who do not make mistakes are people who never do anything . . . the man who profits by his mistakes rises highest on the ladder called 'success'."

Scott B. Lilly, an eminent educator and former chairman of the engineering division, at Swarthmore College, counseled his students and younger faculty colleagues with an adaptation of Judge Gary's logic. "All engineers make mistakes," he would say, "but the difference between a good engineer and a bad engineer is that a good engineer finds most of his own mistakes." To Professor Lilly, a mistake was not evidence of failure but an opportunity to find the truth. His admonitions inspired all with whom he dealt to minimize mistakes.

If an engineering student makes a mistake in solving a problem, the consequence is a lower mark on the examination and possibly a lower grade for the course. Practicing engineers, however, have much more at stake. Of greatest importance is the possibility of endangering the public. There are, all too frequently, collapses of buildings, bridges, or dams as the result of engineering errors. Unknown to the public are the countless engineering mistakes that are detected and corrected during design or construction. Sometimes these errors are discovered only after some preliminary physical failure or partial collapse. Sometimes construction workers are killed, and even where there is no loss of life, the economic loss resulting from engineering errors is frequently significant and sometimes staggering.

Because most consulting engineers practice as individuals or as partnerships, they are personally liable when they err. Many engineers and their firms have sought to protect themselves against suit for errors and omissions through professional

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liability insurance. Yet, this insurance does not excuse inferior engineering any more than a fire insurance policy permits arson.

Engineering errors, however, can be of several types and of varying degree. In mathematics, an error is the difference between a calculated, or measured, value and its true, or exact, value. Slide rule error is commonly understood as the difference between a slide rule reading and the absolute value. These are expected. Mistakes, on the other hand, are unintentional, unknown errors. Blunders are gross mistakes. Suppose a surveyor were using a tape that had been calibrated under known conditions of temperature and tension and found to be 100.003 feet long. If he measures five lengths with that tape and records it as 500 feet, and if conditions of temperature and tension were the same as when the tape had been standardized, he would have a known error of 0.015 feet, which he might or might not consider negligible, depending on the job. On the other hand, had the surveyor incorrectly recorded a measured distance as 46.84 feet instead of 46.48 feet, he would have made a mistake. Had he overlooked an entire tape length or had he chained to the wrong point, he would have committed a blunder.

Mistakes, and especially blunders, have no place in engineering work, yet they must be expected with some frequency. Since economic loss through undetected errors is tremendous, and the hazard to life immeasurable, it becomes a management function within the consulting engineer firm to establish a system of having each man's work checked by a second person, with all corrections of errors back-checked by the first. A system of this type is widely used in some parts of Europe, the checking being done by a different firm of engineers. In Germany, for example, this outside checking is required for certain types of structural design. A special license is required for engineers doing this type of checking of calculations. Their job is not to criticize or change the design, but simply to confirm that it is safe and that all calculations are mathematically correct.

This system of checking and rechecking, even though done within the firm, is expensive. It becomes prohibitively expensive if the checker quibbles over inconsequential differences or matters of opinion, or if the original calculator is so stubborn that he tries to defend his mistakes. But neither can the original designer afford to be careless in the knowledge that whatever he does wrong will be caught and corrected, for the time required to make an independent check depends much on the accuracy and organization of the original calculation or drawing. It is essential, therefore, that the firm's management establish certain fundamental work habits which, if rigorously followed, will enable an engineer to detect most of his own mistakes and facilitate the checking of his work by another.

Name and Data — Have every employee identify his work with name or initials and date. This should appear on all calculations, drawings, memos, or engineering analyses. This may seem obvious, but too often it is overlooked or neglected. It also is important, even in a small firm, to put "Revision A" or some other identifying designation on the drawings if changes or additions are made. Conversely, superseded work should be marked "Void."

Periodic inspection reports from field engineers can be valueless if not dated. Moreover, the engineer reporting should identify himself with his work so that it can be discussed with him by telephone without long delays.

References — An engineer should give the source of every formula or solution that is not original or obvious. This permits the person checking the work to verify an analysis in the least possible time. When a particular formula has been taken from a text or handbook, the title, author, edition, page number, and case number should be cited. In like manner, engineering reports should not include general statements such as "from statistical analysis, the average compressive strength was found to be . . ." unless a reference is given to permit the checker to satisfy himself that the method of analysis is valid and has been handled correctly. Some engineering reports require special handling to permit rapid reading by some and thorough checking by others. A happy solution is to keep the main report brief, but include full references in appendices. Then, the reader can read, or the checker can check.

Assumptions — The finest solution is worthless if based on incorrect data. All basic data such as physical constants, conversion factors, and mathematical relationships should be checked by the designer if there is the slightest doubt. Every engineering firm should have a good, up-to-date reference library, and all technical employees should learn to use it. This is not a plea for cookbook engineering; it is simply an assertion of a fact — good original thinking and careful calculation cannot compensate for erroneous basic data.

Original Data — Whenever possible, work from first premises. There is less chance of incorporating or compounding errors. A simple example will illustrate this point. Assume a piece of equipment costs $1250, and it is to be depreciated over a 10-year period on a straight line basis. To find the value of the end of one year, we subtract $125, and we