FM 5-34

DEPARTMENT OF THE ARMY FIELD MANUAL

ENGINEER FIELD DATA

HEADQUARTERS, DEPARTMENT OF THE ARMY
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HEADQUARTERS
DEPARTMENT OF THE ARMY
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This manual supersedes FM 5–34, 27 June 1962.

CHAPTER 1
INTRODUCTION

Section I. Purpose and Scope

1. PURPOSE

This manual provides a convenient pocket reference for officers and noncommissioned officers at the platoon level. The continuing requirement of readily accessible field data, when library facilities are not available, will be fulfilled to a great extent by this manual.

2. SCOPE

a. *Content.* This manual contains condensed data on a wide variety of subjects pertinent to the field duties of engineer officers and noncommissioned officers. Information is presented in tables, diagrams, formulas, written matter, and illustrations.

b. *Application.* The information in this manual is applicable to both nuclear and nonnuclear warfare.

c. *Comments.* Users of this manual are encouraged to submit comments or recommendations for changes to improve this manual. Comments should be keyed to the specific page, paragraph, and line of text in which the change is recommended. Reasons should be provided for each comment to insure understanding and proper evaluation. Comments should be forwarded directly to the Commandant, U.S. Army Engineer School, Fort Belvoir, Virginia, 22060.

Section II. References

3. MANUALS

Pertinent manuals and other military publications are listed in appendix I.

4. STANDARD AGREEMENTS

Information in this manual reflects, where appropriate, North Atlantic Treaty Organization (NATO) agreements in the form of standard agreements.

CHAPTER 2
EXPLOSIVES AND DEMOLITIONS

Section 1. General Information

5. CHARACTERISTICS OF EXPLOSIVES AND SAFETY

See table 1 for the principal types of U.S. explosives commonly used for military purposes.

Note. Safety regulations will be observed in all situations to the fullest extent permitted by time, by materials available, and by requirements of the mission.

a. Always handle explosives carefully.

b. Responsibility for the preparation, placement, or firing of charges is never to be divided; one person should be responsible to supervise all phases of a demolition mission.

c. See table 2 for minimum safe distances.

d. For further information, see AR 385–63.

6. FIRING SYSTEMS

Firing systems for explosives are illustrated in figure 1. A non-electric detonating assembly is shown in figure 2.

Table I: Characteristics of Principal U.S. Explosives

Name	Principal use	Smallest cap required for detonation	Relative effectiveness as external charge	Velocity of detonation, fps	Value as cratering charge	Intensity of poisonous fumes	Water resistance	Packaging
TNT	Main charge, booster charge; cutting and breaching charge, general and military use in forward areas	Special blasting cap, electric or nonelectric	1.00	21,000	Good	Dangerous	Excellent	1 lb, 50 to box
Tetrytol, M1, M2			1.20	23,000	Fair	Dangerous	Excellent	2½ lb blocks wooden box
Composition C3			1.34	26,000	Excellent	Dangerous	Good	16 2¼-lb blocks in wooden box
Composition C4			1.34	26,000	Excellent	Slight	Excellent	24 2½-lb blocks in wooden box
Ammonium nitrate	Cratering and ditching	Special blasting cap, electric or nonelectric	0.42	11,000	Excellent	Dangerous	Poor	40-lb charge in metal can
M118 charge demolition	(See C-4)	(See C-4)	1.34	23,000	Poor	Slight	Excellent	4 ea, ½ lb sheets/container
Military dynamite M1	Quarrying stumping-ditching	(See C-4)	0.92	20,000	Good	Dangerous	Good	½-lb 100 to box

Table 1.—Continued

Name	Principal use	Smallest cap required for detonation	Relative effectiveness as external charge	Velocity of detonation, fps	Value as cratering charge	Intensity of poisonous fumes	Water resistance	Packaging	
Straight dynamite (Commercial) 40%	Land clearing, cratering, quarrying, and general use in rear areas, such as ditching and stumping.	No. 6 commercial cap, electric or nonelectric	0.65	11,600	Good	Dangerous	Poor	102	Sticks per 50 lb box
Straight dynamite (Commercial) 50%			0.79	15,000			Good	103	
Straight dynamite (Commercial) 60%			0.83	18,200			Excellent	106	
Ammonia dynamite (Commercial) 40%			0.41	10,200	Excellent	Dangerous	Good	110	Sticks per 50 lb box
Ammonia dynamite (Commercial) 50%			0.46	11,000			Good	110	
Ammonia dynamite (Commercial) 60%			0.53	12,700			Good	110	
Gelatin dynamite 40%			0.42	8,000	Good	Slight	Good	130	Sticks per 50 lb Box
Gelatin dynamite 50%			0.47	9,000	Good		Very Good	120	
Gelatin dynamite 60%			0.76	16,000	Good		Very Good	110	
PETN	Detonating cord	Special blasting cap, electric or nonelectric	1.00	21,000	NA	Slight	Good		
	Blasting cap	NA							
Tetryl	Booster charge	Special blasting cap, electric or nonelectric	1.25	23,400	NA	Dangerous	Excellent		

Table 1.—Continued

Name	Principal Use	Smallest Cap required far detonation	Relative effective-ness as external charge	Velacity af detona-tion, fps	Value as cratering charge	Intensity af poison-aus fumes	Water restist-ance	Packaging
Campositian B	Bangalare tarpeda	Special blasting cap, electric ar nanelectric	1.35	25,000	Good	Dangeraus	Excel-lent	Bulk
Amatal 80/20	—do—		1.17	16,000	Excellent	Dangeraus	Paar	
Black Pawder	Time blasting fuze	NA	0.55	1310 Max. Depends on Confinement	Fair	Dangeraus	Paar	Bulk
Nitrastarch	Substitute for TNT	Special blasting cap, electric or nanelectric	0.80	15,000	Good	Dangeraus	Satis-factory	1-lb blacks

Table 2. Minimum Safe Distance for Personnel in the Open

Pounds of explosive	Safe distance in feet	Pounds of explosive	Safe distance in feet	Pounds of explosive	Safe distance in feet
1–27	900	46	1065	90	1344
28	910	48	1080	95	1365
30	930	50	1104	100	1400
32	951	55	1141	125	1500
34	965	60	1170	150	1600
36	990	65	1200	200	1750
38	1000	70	1225	300	2000
40	1020	75	1260	400	2200
42	1030	80	1290	500	2400
44	1050	85	1310		

NOTE. MINIMUM distance for personnel in a missile-proof shelter is 300 feet.
For charges over 500 lbs, use

$$\text{Distance} = 300 \sqrt[3]{\text{Pounds of explosives}}$$

7. RELATIVE EFFECTIVENESS FACTOR

a. The formulas given in paragraphs 9 through 14 give the weight of explosive required for a demolition task (P), in pounds of TNT.

b. For external charges only, where a type of explosive other than TNT is used, the correct weight of explosive is obtained by dividing P by the relative effectiveness factor for the explosive used. See table 1, column 4.

c. *Example.* For a steel cutting charge, P is found to be 21 lbs of TNT. Composition C–4 is to be used. Therefore, the correct weight of C–4 required is $21 \div 1.34 = 15.7$ lbs of C–4. Use 16 lbs of C–4.

d. This adjustment is not used for internal charges or rules of thumb.

e. For further details see FM 5–25.

8. ROUNDING-OFF RULE

a. When using explosives always attempt to use the amount calculated. However, at times it may be difficult to use the exact amount calculated due to the size of the explosive package. Use the amount

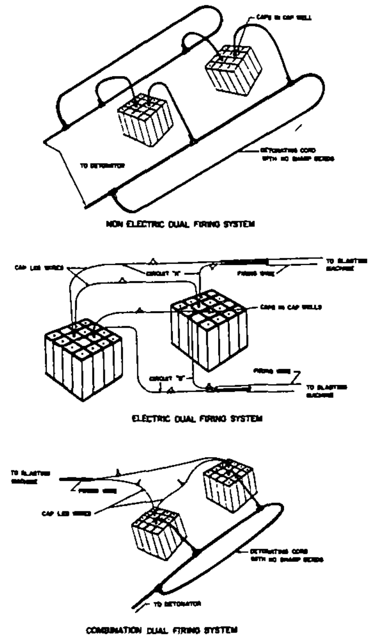

Figure 1. Firing systems for explosives.

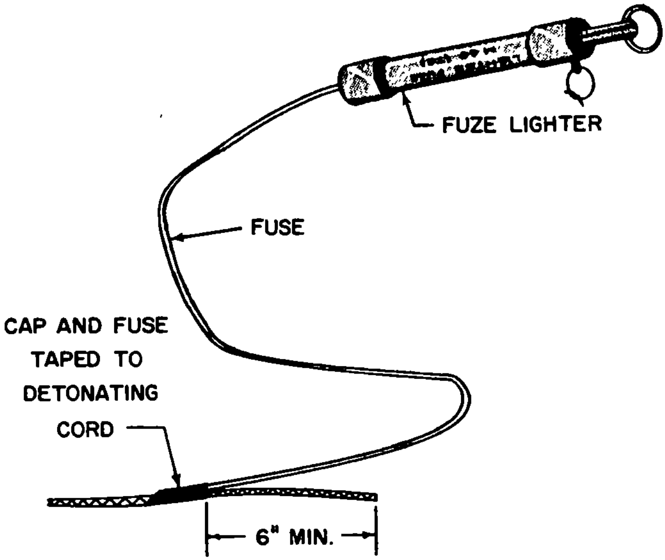

Figure 2. Nonelectric detonating assembly.

of explosive as close to the calculated amount as possible, but never use *less than the calculated* amount. Some explosives like C–4 and M118 can be cut to the desired amount, while with other types the ability to size explosives is limited.

b. For charges calculated by formula, use the following round-off steps:

(1) Calculate one (1) charge for TNT using a demolition formula to at least two decimals.

(2) Use the relative effectiveness factor, if required.

(3) Round off answer for one charge to next package size or pound.

(4) Multiply answer for one charge by the number of charges to obtain the total explosives required.

Section II. Calculation of Charges

9. STEEL CUTTING CHARGES

a. *Formula for Structural Steel Sections.* This is the type of steel used in buildings, bridges, and other steel structures. The following formula is applicable to this steel (such as I-beams, girders, and plates) except slender bars of 2-inch diameter or less:

$P = \frac{3}{8} A$ where P = pounds of TNT required and

A = cross sectional area, in square inches, of the steel member to be cut.

b. *Formula for Other Steel Sections.* The following formula is recommended for use with all high-carbon steel, alloy steel, armor plate, strong forgings, machine parts, cables, chains, and high-strength tools. It is also recommended for structural steel rods and bars of 2-inch diameter or less:

$P = D^2$ where P = pounds of TNT and

D = diameter, in inches, of section to be cut, or the smallest cross section dimension.

c. *Railroad Rails.* The size of a railroad rail is expressed by the weight of 1 yard of rail: an 80-pound rail weighs 80 pounds per yard. To cut this size rail, ½ pound of TNT is set against its web. For a heavier rail, use 1 pound of TNT. (As a rule of thumb, a rail over 5 inches high weighs more than 80 pounds per yard.)

d. *Example:*

(1) Calculate the amount of TNT required to cut the steel wide-flange section (fig. 3).

Calculation: $P = \frac{3}{8} A$ (See a above)

Area in flanges $= 2 \times \frac{1}{2}$ in. $\times 5$ in. $= 5$ sq. in.
Area in web $= \frac{3}{8}$ in. $\times 11$ in. $= 4\frac{1}{8}$ sq. in.
Total area $= 9\frac{1}{8}$ sq. in.

$P = \frac{3}{8} A$

$P = \frac{3}{8} \times 9\frac{1}{8} = 3.42$, therefore, use 4 lbs. TNT

(2) Plastic explosive is best suited for cutting steel. How much composition C–4 explosive is required to cut the wide-flange section shown in figure 3? Since the amount of TNT required is 3.42 pounds and composition C–4 has a relative effectiveness factor of 1.34 (column 4 of table 1), the amount of C–4 $= \frac{3.42}{1.34} = 2.55$ pounds. Use 3 pounds of C–4.

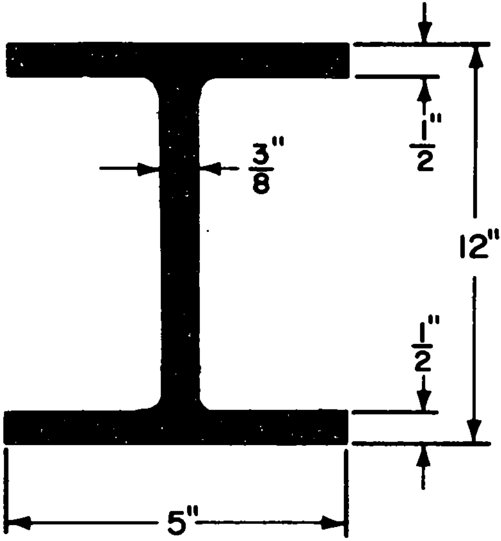

Figure 3. Wide flange section.

e. *Example.* How much TNT is required to cut the steel chain in figure 4?

Calculation: $P = D^2$

$P = 1 \text{ in.} \times 1 \text{ in.}$

$P = 1$ lb of TNT

Use 1 pound of TNT at A and 1 pound at B to destroy the chain link.

f. *Table.* See table 3 for amount of TNT required to cut different rectangular steel sections.

10. TIMBER-CUTTING CHARGES

a. *Requirements.* Different types of timber in various localities require varying amounts of explosive to cut them. Test shots should be made to determine the specific amount of explosive required for a specific type of timber.

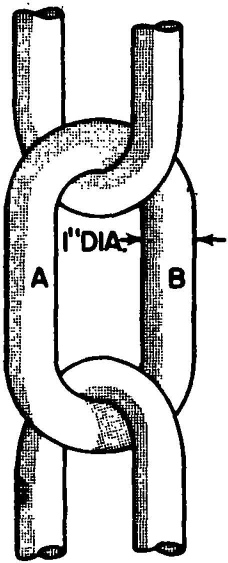

Figure 4. Steel chain.

Table 3. Cutting Charges For Rectangular Steel Section

Thickness of Section in Inches	Pounds of TNT P = 3/8 A, Structural Steel												
	Width of Section in Inches												
	2	3	4	5	6	8	10	12	14	16	18	20	24
¼	.2	.3	.4	.5	.6	.8	1.0	1.2	1.3	1.5	1.7	1.9	2.3
⅜	.3	.5	.6	.7	.9	1.2	1.4	1.7	2.0	2.3	2.6	2.8	3.4
½	.4	.6	.8	1.0	1.2	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.5
⅝	.5	.7	1.0	1.2	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.7	5.7
¾	.6	.9	1.2	1.4	1.7	2.3	2.8	3.4	4.0	4.5	5.1	5.7	6.8
⅞	.7	1.0	1.4	1.7	2.0	2.7	3.3	4.0	4.6	5.3	6.0	6.6	7.9
1	.8	1.2	1.5	1.9	2.3	3.0	3.8	4.5	5.3	6.0	6.8	7.5	9.0

To use table:

1. Measure rectangular sections of member separately.
2. Using table, find charge for each section.
3. Add charges for sections to find total charge.
4. Never use less than calculated charge.
5. If dimension is not in the table, use next higher dimension.

b. For Untamped External Charges. To cut trees, piles, posts, beams, or other timber, the following formula gives a test shot.

$$P = \frac{D^2}{40}$$ where P = pounds of TNT required and

D = diameter of timber in inches

For other explosives, adjustments for P are made according to paragraph 7.

c. *For Tamped Internal Charges.* The following formula gives a test shot:

$$P = \frac{D^2}{250}$$ where p = pounds of *any type* explosive and

D = diameter or least cross sectional dimension in inches of dressed timber.

d. Table. Use table 4 as a guide for both internal and external timber cutting test charges.

e. *For Cutting Trees to Create an Obstacle.* To cut trees and leave them attached to their stumps, the following formula gives a test shot.

$$P = \frac{D^2}{50}$$ where P = pounds of TNT needed for external charges and

D = diameter of timber in inches

For other explosives, adjustments are made according to paragraph 7.

f. Placement. See figure 5 for placement of charges.

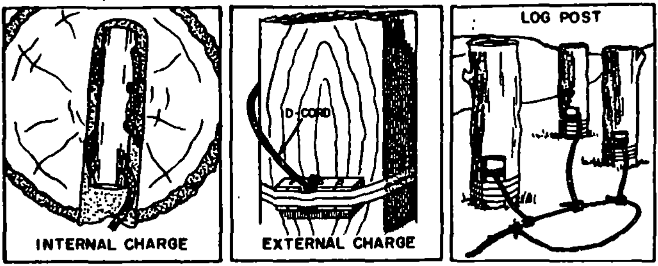

Figure 5. Placement of charges.

Table 4. Timber Cutting Test Shot Charges

Type of Charge	Explosive	Least dimension of timber in inches									
		6	8	10	12	15	18	21	24	30	36
		Pounds of explosive									
Internal	Any	½	½	½	1	1	1½	2	2½	4	6
External	TNT	1	2	2½	4	6	8½	11½	14½	22½	32½
Abatis External	TNT	1	1½	2	3	4½	6½	9	11½	18	26

11. PRESSURE CHARGES

a. Use. Pressure charges are effective against simple span, reinforced concrete T-beam bridges.

b. For Tamped Pressure Charges. Use the following formula:

$P = 3H^2T$ where P = pounds of TNT required for each stringer
H = height of stringer (including thickness of roadway) in feet, and
T = thickness of stringer in feet.

If H and T are not whole numbers, round them off to the next higher *quarter-foot* dimension. Neither is ever considered to be less than 1 in the formula. A minimum of 10 inches of tamping surrounding the charge is required. For other explosives, adjustments are made according to paragraph 7.

c. For Untamped Pressure Charges. Increase the calculated value of P by one-third in the formula, (*b* above), if the pressure charge is not tamped.

d. Example. How much TNT is required to destroy the bridge span in figure 6? The amount is calculated in figure 6.

e. Continuous Bridge Spans. For concrete stringer bridges of continuous spans, charges are calculated by the breaching formula (para 12*b*). Charges should be so placed and calculated to insure that the breaching radius or radii will cause a complete severance of the cross concrete section. The steel probably will not be cut by the explosion.

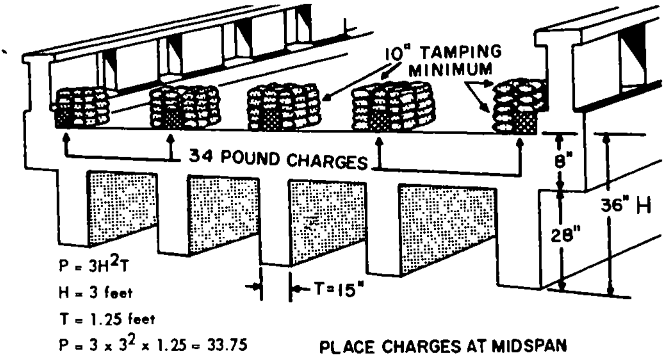

Figure 6. Calculation and placement of pressure charges.

f. Table. Use table 5 for calculation of pressure charges for simple span reinforced concrete T-beams.

12. BREACHING CHARGES

a. *Use.* Breaching charges have their most important use in the destruction of bridge piers, bridge abutments, and field fortifications of a permanent type, or in breaching walls and blowing holes in concrete slabs or roadways.

b. Formula. $P = R^3KC$

where P = pounds of TNT required

R = breaching radius in feet, to nearest highest ½ foot increment

K = material factor (table 6) which indicates strength and hardness of material to be demolished. (When it is not known whether or not concrete is reinforced, it is assumed to be reinforced.)

C = tamping factor (fig. 7).

NOTE. To breach walls 1 foot thick and under, increase the total calculated charge by 50 percent. Add 10 percent for charges under 50 pounds. For external charges, use at least 5 pounds for reinforced concrete and at least 3 pounds for dense concrete.

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Table 5. Tamped Pressure Charges—Increase by 1/3 if Untamped

Height of Beam in Feet	Pounds of TNT for Each Beam (Tamped Charges)								
	Thickness of Beam in Feet								
	1	1¼	1½	1¾	2	2¼	2½	2¾	3
	12 in.	15 in.	18 in.	21 in.	24 in.	27 in.	30 in.	33 in.	36 in.
1 (12 in.)	3								
1¼ (15 in.)	5	6							
1½ (18 in.)	7	9	11						
1¾ (21 in.)	10	12	14	16					
2 (24 in.)	12	15	18	21	24				
2¼ (27 in.)	16	19	23	27	31	35			
2½ (30 in.)	19	24	29	33	38	43	47		
2¾ (33 in.)	23	29	34	40	46	51	57	63	
3 (36 in.)	27	34	41	48	54	61	68	75	81
3¼ (39 in.)	32	40	48	56	64	72	80	88	95
3½ (42 in.)	37	46	56	65	74	83	92	101	111
3¾ (45 in.)	43	53	64	74	85	95	106	116	127
4 (48 in.)	48	60	72	84	96	108	120	132	144
4¼ (51 in.)	55	68	82	95	109	122	136	149	163
4½ (54 in.)	61	76	92	107	122	137	152	169	183
4¾ (57 in.)	68	85	102	119	136	153	170	187	203
5 (60 in.)	75	94	113	132	150	169	188	207	225

c. *Tables.* For reinforced concrete breaching, see table 7. See table 8 for the breaching of masonry items other than reinforced concrete.

d. *Number of Charges.* To demolish a pier, slab, or wall, use this formula:

$N=\frac{W}{2R}$ where N = number of charges,

W = width of pier, slab, or wall, in feet, and
R = breaching radius in feet.

Table 6. Values of Material Factor K for Use in Calculating Breaching Charges

Material	R (breaching radius)*	K
Ordinary earth	All values	0.05
Poor masonry, shale, and hard-pan, good timber and earth construction	All values	0.23
Good masonry, ordinary concrete, rock	Less than 3 ft 3 ft to less than 5 ft 5 ft to less than 7 ft 7 ft or more	0.35 .28 .25 .23
Dense concrete, first-class masonry	Less than 3 ft 3 ft to less than 5 ft 5 ft to less than 7 ft 7 ft or more	0.45 .38 .33 .28
Reinforced concrete (for concrete only; will not cut reinforcing steel)	Less than 3 ft 3 ft to less than 5 ft 5 ft to less than 7 ft 7 ft or more	0.70 .55 .50 .43

*Distance (in feet) from the explosive, within which all material is displaced or destroyed. For external charges, the thickness of the mass to be breached may be taken. For internal charges, take one-half of thickness of mass to be breached if charge is placed midway into mass. If holes are drilled less than halfway into mass, the breaching radius is the longer distance from center of drill hole to outside of mass, e.g., to breach 4-foot wall by internal charge placed 1 foot into mass; breaching radius is 3 feet.

NOTE: FOR WATER, IF THE BREACHING RADIUS IS GREATER THAN THE DEPTH OF WATER USE 2.5; IF EQUAL TO OR LESS USE 1.25

Figure 7. Values of tamping factor "C."

When the calculated value of N contains a fraction less than ½, the fraction is disregarded; if ½ or more, round off to next higher figure. Exception: in N values between 1 and 2, fractions less than ¼ are disregarded; ¼ or more is rounded off to whole number of 2.

e. *Examples.*

(1) Find the size and number of TNT charges required to breach a reinforced concrete wall that is 25 feet long and 4 feet thick. Use external charges placed at ground level and untamped.

Size of charges:

$P = R^3KC, \quad R = 4, \quad K = .55, \quad C = 4.5$

$P = (4)^3 \times (.55) \times (4.5) = 158.4$ pounds, use 159 pounds of TNT

Number of charges:

$N = \frac{W}{2R} \quad W = 25, \quad R = 4,$

$N = \frac{25}{(2)(4)} = 3\frac{1}{8}$ Use 3 charges.

(2) A timber and earth wall 6½ feet thick and an explosive charge placed at the base of the wall without tamping. The conversion factor is 0.5 (table 8). If this wall were made of reinforced concrete, 618 pounds of TNT would be required to breach it (table 7). Multiply 618 pounds of TNT by 0.5 and the result is 309 pounds of TNT required to breach the wall.

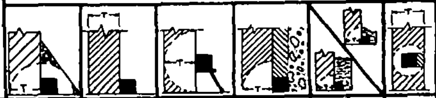
f. *Breaching Hard-Surface Pavements.*

(1) A hard-surface pavement is breached so that holes can be dug for cratering charges. Use a 1-pound charge of explosives for each 2 inches of pavement thickness, with tamping twice as thick as the pavement.

(2) Pavement may be breached by charges placed in boreholes drilled or blasted through the pavement. A shaped charge readily blasts a small diameter borehole through the pavement and into the subgrade. Concrete should not be breached at an expansion joint because the concrete will then shatter on only one side of the joint.

g. *Shaped Charges.* Table 9 shows the size of boreholes obtained by using the standard shaped charges.

Table 7. Breaching Charges, Reinforced Concrete Only



THICKNESS OF CONCRETE IN FEET	METHODS OF PLACEMENT: TNT						ANY	DISTANCE BETWEEN CHARGES IN FEET: INTERNAL	DISTANCE BETWEEN CHARGES IN FEET: EXTERNAL
COLUMN	1	2	3	4	5	6	7	8	9
2	16	28	15	8	8	16	1	2	4
2½	31	55	28	16	16	31	2	2½	5
3	41	67	38	21	21	41	4	3	6
3½	59	107	55	33	33	59	6	3½	7
4	88	159	81	49	49	88	8	4	8
4½	126	226	116	63	63	126	11	4½	9
5	157	282	144	79	79	157	16	5	10
5½	208	375	192	104	104	208	20	5½	11
6	270	486	249	135	135	270	21	6	12
6½	344	618	316	172	172	344	26	6½	13
7	369	664	340	185	185	369	33	7	14
7½	454	817	418	227	227	454	40	7½	15
8	551	991	507	276	276	551	49	8	16

NOTES:

1. 10% HAS BEEN ADDED TO THE TABLE FOR CHARGES LESS THAN 50 LBS
2. FOR BEST RESULTS PLACE CHARGE IN SHAPE OF A SQUARE
3. FOR THICKNESS OF CONCRETE OF 4' OR LESS USE CHARGE THICKNESS OF 2" (ONE BLOCK THICK), OVER 4' THICK USE CHARGE THICKNESS OF 4" (ONE HAVERSACK OF TETRYTOL OR PLASTIC).

TO USE TABLE:

1. MEASURE THICKNESS OF CONCRETE.
2. DECIDE HOW YOU WILL PLACE THE CHARGE AGAINST THE CONCRETE. COMPARE YOUR METHOD OF PLACEMENT WITH THE DIAGRAMS AT THE TOP OF THE PAGE IF THERE IS ANY QUESTION AS TO WHICH COLUMN TO USE, ALWAYS USE THE COLUMN THAT WILL GIVE YOU THE GREATER AMOUNT OF TNT.

*FOR OTHER TYPES OF CONSTRUCTION, SEE TABLE 8

*Table 8. Breaching Charges for Material Other Than Reinforced Concrete**

Conversion Factors For Material Other Than Reinforced Concrete		
Earth	Ordinary Masonry, Hard-pan Shale, Ordinary Concrete, Rock, Good Timber and Earth Construction	Dense Concrete First Class Masonry
0.1	0.5	0.7

To use table:

1. Determine the type of material in the object you plan to destroy if in doubt, assume the material to be of the stronger type—e.g.—Unless you know differently, assume concrete to be reinforced.
2. Using the above table, determine the appropriate conversion factor.
3. Using table 7, determine the amount of explosive that would be required if the object were made of reinforced concrete.
4. Multiply the number of pounds of explosives (from table 7) by the conversion factor from the table above.

Example:

A timber and earth wall 6½ ft. thick and an explosive charge placed at the base of the wall without tamping. The conversion factor is 0.5 (see table above). If this wall were made of reinforced concrete, 618 lbs of TNT would be required to breach it (see table 7).

Multiply 618 lbs of TNT by 0.5 and the result is 309 lbs of TNT required to breach it.

*For reinforced concrete see table 7.

Table 9. Sizes of Boreholes Produced By Shaped Charges

Material	Information needed		M3 (40-lb) shaped charge	M2A3 (15-lb) shaped charge
Reinforced concrete	Maximum wall thickness which can be perforated		60 in	36 in
	Depth of penetration in thick walls		60 in	30 in
	Diameter of hole	Entrance	5 in	3½ in
		Average	3½ in	2¾ in
		Minimum	2½ in	2 in
	Depth of hole with second charge placed over first hole		84 in	45 in
Armor-plate	Perforation		At least 20 in	12 in
	Average diameter of hole		2½ in	1½ in
Permafrost	Depth of hole with 50-in standoff		72 in	NA
	Depth of hole with 30-in standoff		NA	72 in
	Depth of hole with 42-in standoff		NA	60 in
	Diameter of hole with average (30 in) standoff		NA	6 to 1½ in
	Diameter of hole with 50-in standoff		8 to 5	NA
	Diameter of hole with normal standoff		26-30 to 7 in	26-30 to 4 in
Ice	Depth with average (42 in) standoff		12 ft	7 ft
	Diameter with average (42 in) standoff		6	3½ in

13. CRATERING CHARGES

a. *Requirements.* Road craters, to be effective obstacles, must be too wide for spanning by track-laying vehicles and too deep and steep-sided for any vehicle to pass through them. They must also be large enough to tie into natural or manmade obstacles at each end. Antitank and antipersonnel mines are often placed at the site to hamper repair operations and thus increase the effectiveness of the crater. Road craters angled at about 45° to the roadway are more effective obstacles than craters blasted perpendicular to the roadway.

b. *Deliberate Road Crater.* See figure 8.

c. *Hasty Road Crater.* Hasty road craters blasted with boreholes less than 5 feet deep and loaded with less than 50-lb explosive charges

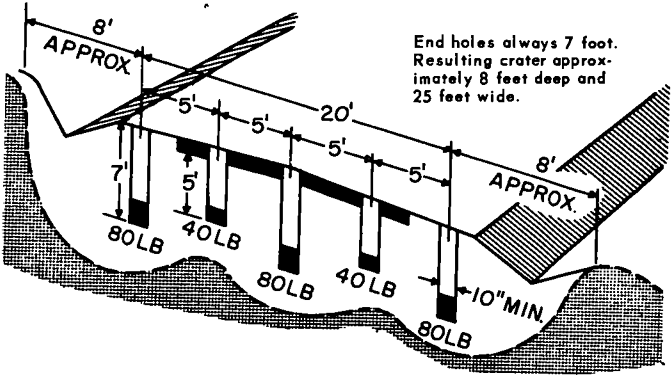


Figure 8. Placement af charges far deliberate raad crater.

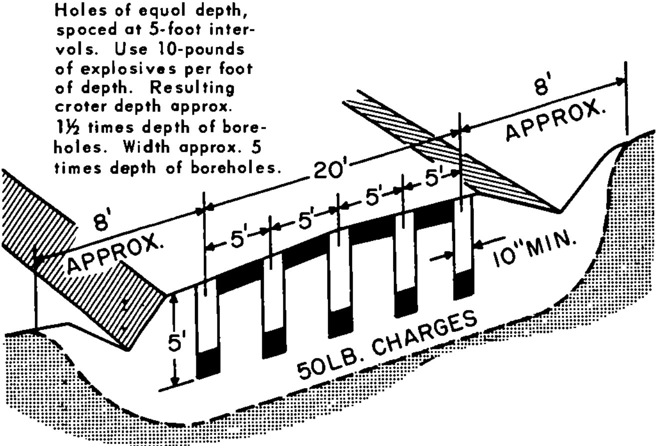


Figure 9. Placement af charges for hasty raad crater.

are ineffective against modem tanks. For placement and size of charges see figure 9.

d. Relieved Face Crater. Crater will be approximately 7 feet deep and 30 feet wide. Instantaneous delay caps must be used to get desired delay detonation. The greatest improvement over the other types of craters is the resulting trapezoidal shape. For replacement and size of charge, see figure 10.

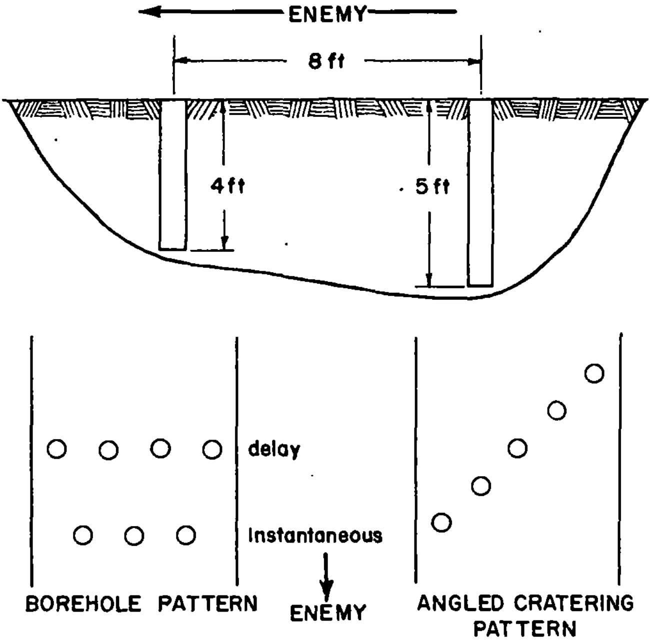


Figure 10. Relieved face crater.

e. *Antitank Ditch Cratering.* In open country, antitank ditches are constructed to strengthen prepared defensive positions. As they are costly in time and effort, much is gained if the excavation can be made by means of the cratering methods described above. To be effective, an antitank ditch must be wide enough and deep enough to stop an enemy tank. It may be improved by placing a log hurdle on the enemy side, by placing the spoils in the friendly side, and by digging the face in the friendly side vertical.

f. Rules of Thumb.

(1) To ensure against misfires, all ammonium nitrate cratering charges must have an additional primer, a one-pound charge placed on top of each can and incorporated into a dual firing system (figs. 1 and 2).

(2) Rule of thumb for number of holes:

$$N = \frac{L-11}{5}$$

Where L is the total length of the blown crater.

14. BRIDGE ABUTMENT DEMOLITION

Placing charges in the fill behind an abutment is economical in explosives and conceals the charges from the enemy.

a. *Abutments 5 Feet Thick or Less and 20 Feet or Less in Height.* See figure 11 for details.

b. *Abutments More Than 5 Feet Thick and 20 Feet or Less in Height.* Place breaching charges in contact with rear face of abutment (fig. 12). Calculate the size and number of charges by the formula in figure 12. Charges are placed at a depth greater than or equal to R. The spacing between charges and number of charges are determined by the calculations explained in paragraph 12.

c. *Abutments Over 20 Feet High.* Place a combination of external breaching charges (along bottom of the river face of the abutment) and fill charges (behind the abutment) to destroy abutments more than 20 feet high. Fire them simultaneously. The fill charges may be calculated according to paragraph 12b, or placed as in figure 11, depending on the thickness of the abutment.

Beginning 5 feet in from the side of the road, place 40-pound cratering charges in holes 5 feet deep, 5 feet on centers and 5 feet behind the river face of the abutment.

Formula: $N = \frac{W}{5} - 1$

where N = no. boreholes
W = width of abutment

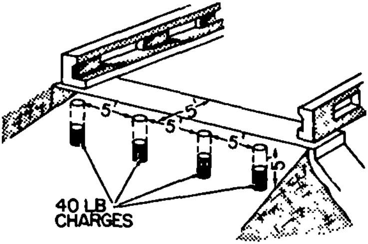


Figure 11. Charge placed in the fill behind a reinforced concrete abutment less than 5 feet thick and 20 feet or less in height.

Size of Charge Formula:

$P = R^3KC$

where R = abutment thickness
K = material factor
C = tamping factor

Number of Charges Formula:

$N = \frac{W}{2R}$

(This formula may also be used for concrete and masonry piers.)

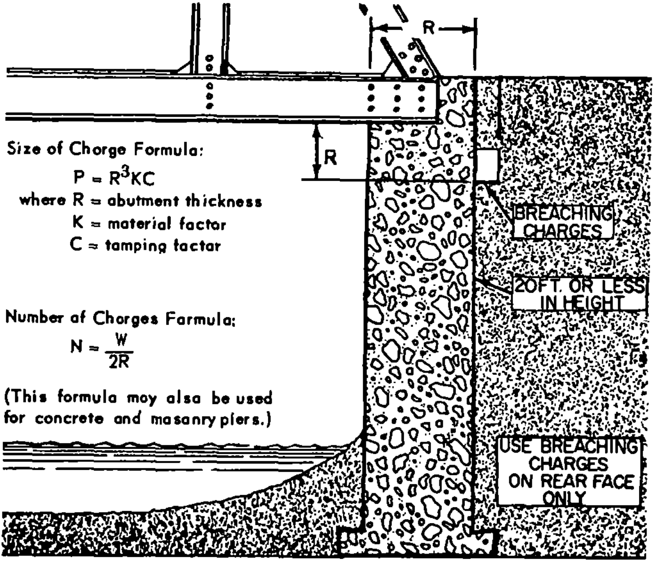


Figure 12. Charges in a fill behind a reinforced concrete abutment more than 5 feet thick and 20 feet or less in height.

Section III. Destruction of Obstacles

15. CONCRETE OBSTACLES

a. *Small Obstacles*. For small obstacles (100 ft^3 or less), such as those found on beaches, use hand-placed charges. As shown in figure 13, use 1 pound of military explosive, tetrytol or greater, per cubic foot of reinforced concrete.

b. *Large Obstacles*. For large obstacles (greater than 100 ft^3), use breaching formula or bar or castle charge (fig. 14) according to the size of the charge.

16. STEEL AND LOG OBSTACLES

a. *Placement*. The illustrations in figure 15 show several obstacles and the placement and sizes of charges to destroy or cut them.

b. *Charges for Log Obstacles*. Generally, the charge should be placed at a joint where the obstacle is weakest. Against log cribs, place 30 to 40 pounds of explosives in the center of the earth fill two-thirds the depth of the crib and tamp thoroughly. Similar charges are placed on 8-foot centers for the full length of wooden posts. Log scaffolding (often under water) is destroyed by tying three 15-foot lengths of bangalore torpedo together and placing them at right angles to the line of scaffolding. This clears a lane 12 feet wide. Charges placed on obstacles driven into the ground should be attached below or as close to the surface of the ground as possible.

17. WALLS

a. *Concrete Walls Not Backfilled*. On walls up to 6 feet high and 6 feet thick, use 160 pounds of explosive per foot of thickness. For larger walls, add 80 pounds of explosive for each additional foot of height and thickness. Example: For a wall 8 feet thick and 10 feet high, $(6 \times 160) + (4 \times 80) + (2 \times 80) = 1{,}440$ pounds. The positions, amounts, and patterns of charges are shown in figure 14.

NOTE : SATCHEL CHARGES ARE USED TO DESTROY THESE OBSTACLES. IN COMPUTING THE NUMBER OF SATCHELS REQUIRED, ROUND UP TO THE NEXT FULL 20LB. SATCHEL.

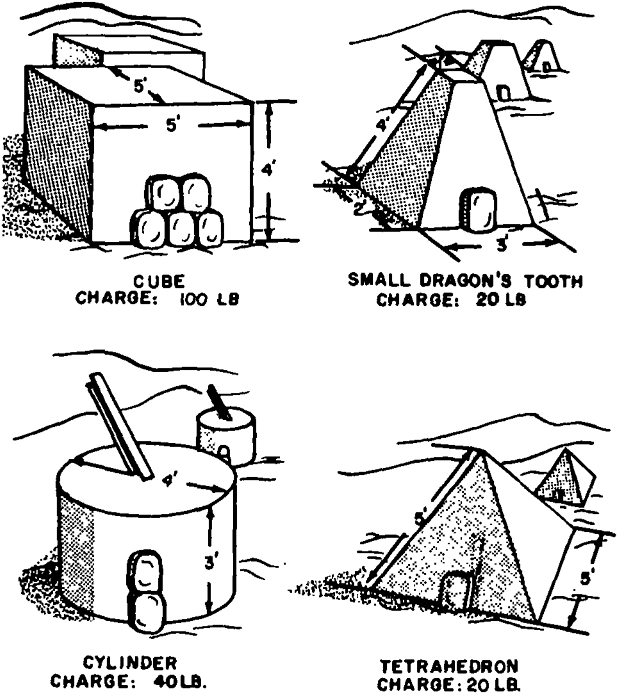
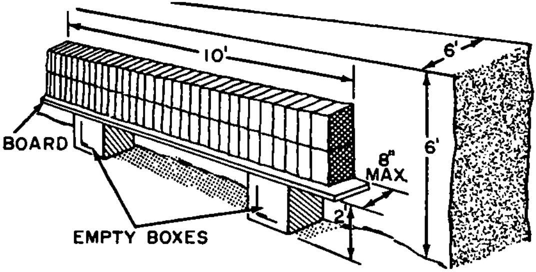
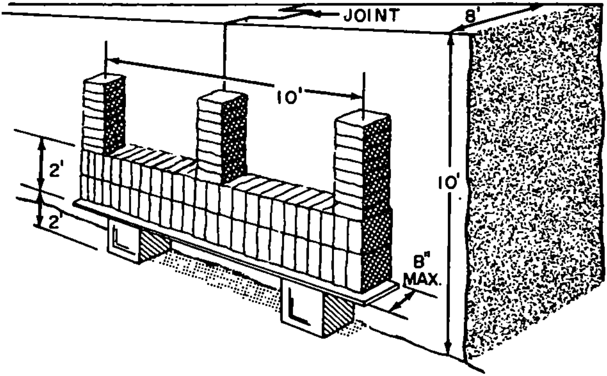


Figure 13. Explosive packs needed to destroy typical small concrete obstacles.



(1) CHARGE: 1000 LB.



(2) CHARGE: GREATER THAN 1000 LB.

Figure 14. Placement of charges for a wall 6 feet thick and for a wall over 6 feet thick.

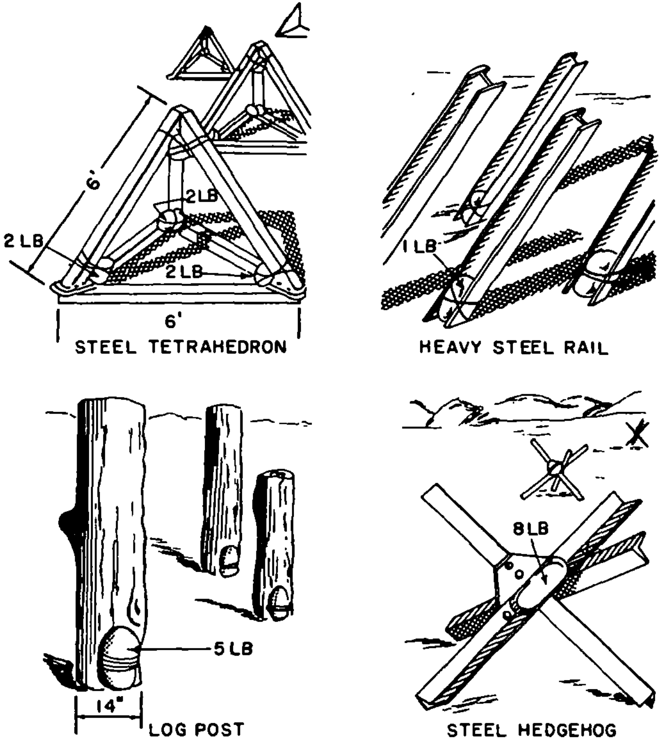


Figure 15. Placement of charges for destruction of steel and log obstacles.

b. Backfilled Walls.

(1) Concrete. Increase by 20 percent the charges specified for walls not backfilled. On some walls, where this may not be enough, use a second shot or clear with dozers or hand labor.

(2) Logs. Place a 500-pound charge 10 feet long on top of the wall 2 feet from the face (fig. 16).

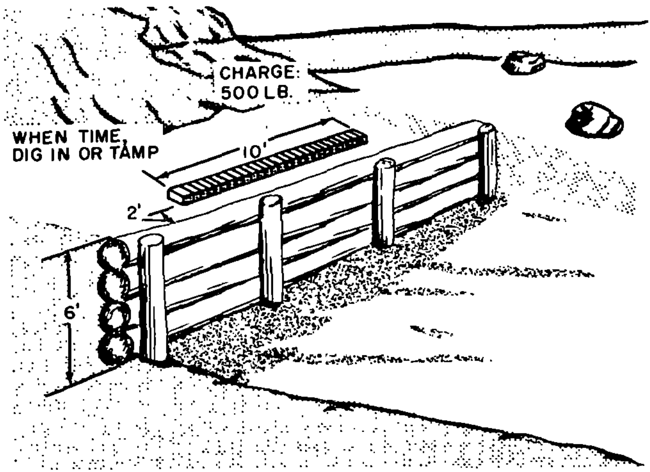


Figure 16. Breaching a backfilled log wall.

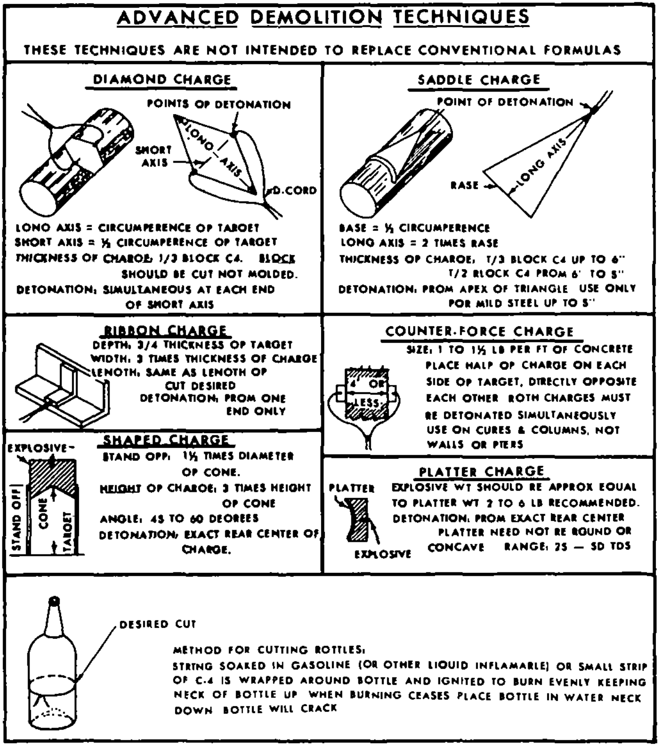


Figure 17. Advanced demolition techniques.

18. MINIMUM EXPLOSIVE CHARGES

The demolition techniques shown in figure 17 provide the desired results with a minimum of explosives. These techniques are not intended to replace conventional formulas. The diamond, saddle, and ribbon charges are used on structural steel and similar materials. Use C-4 as the explosive in these charges and the improvised shaped charge.

Section IV. Constructive Uses of Explosives

19. QUARRYING

a. *Methods.* Military quarries can be developed as either single or multiple benches. The method is determined by the drilling depth capability of the equipment available. Figure 18 shows a multiple bench quarry.

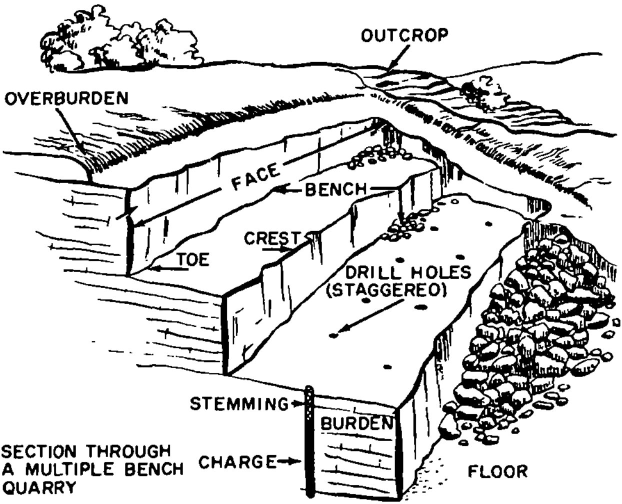


Figure 18. Multiple-bench quarry.

b. Spacing Barehales. There is a relotianship between the burden, which is the distonce from the raw of borehales to the face, measured ot the battam of the foce (fig. 19), and the spacing af barehales in o row. This spocing olso depends upan the type af borehales, of which there are twa—

(1) *Verticol holes.* The depth of verticol hales is limited by depth af rock, the length of drill, ond drilling equipment. Spocing is equal to, or o little more thon, the burden. When several rows are drilled in preporotian far instantaneous blosting, the burden af the rear rows is 10 percent less than the burden of the frant row (fig. 19).

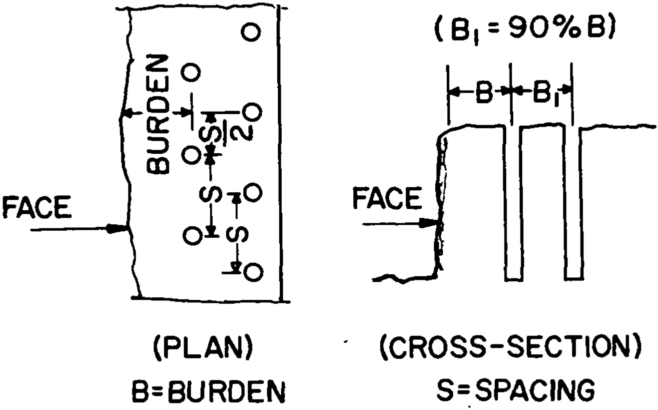


Figure 19. Arronging porallel rows of vertical borehales.

(2) *Snokeholes.* Drill at bose of quorry foce and begin from 2 ta 4 feet obove the flaor. Slope eoch hale downword ot the some angle so thot the end af the hale is level with the quorry floar. Burden will equol ane-holf the height of foce, with spacing between 8 and 10 feet (fig. 20). Snokehales are sprung by drilling to the desired depth, then firing a small charge ot the bottom of the borehale ta form o chamber in which the lorger chorge is ploced. The omaunt of explasives ar initiol ond successive springing must be determined by test.

c. *Amount of Explosives.* An approximate amount of explosives per foot of borehole is shown in table 10 for vertical holes and in table 11 for snakeholes.

20. ROCK EXCAVATION

a. *Overburden.* After the layout has been decided upon, the work of removing the overburden should be started as soon as possible.

b. *Blasting.*

(1) *Drill holes.* Use drill holes to bring through cuts or sidehill cuts to grade with one shot by drilling ahead of power shovel. When the whole cut cannot be blasted at once, drill boreholes 100 to 150 feet ahead of the shovel and blast four or five rows at a time (fig. 21).

(2) *Snakeholes.* Use snakeholes to widen cuts (fig. 20). Drill them on 5-foot centers and wherever possible fire them simultaneously.

c. *Explosive Charge.* Determine weight of explosive charge required per borehole by test shots. Table 10 gives the explosive capacity per foot of borehole of various sizes.

Table 10. Recommended Trail Shots for Vertical Boreholes

Height of bench (in ft.)	4	7	10	16	22
Depth of holes (in ft.)*	5	8	12	18	24
*Includes depth of subdrilling					
Explosives per borehole (lb)					
Hard rock	4	6	12	18	23.5
Medium rock	3	5	9.5	14	19
Soft rock	2	3	6	9	12
Pattern dimension burden and spacing (in ft.)—	4.5	4.5	5.0	5.0	5.0
Borehole diameter (in in.)	1.75	1.75	2	2	2

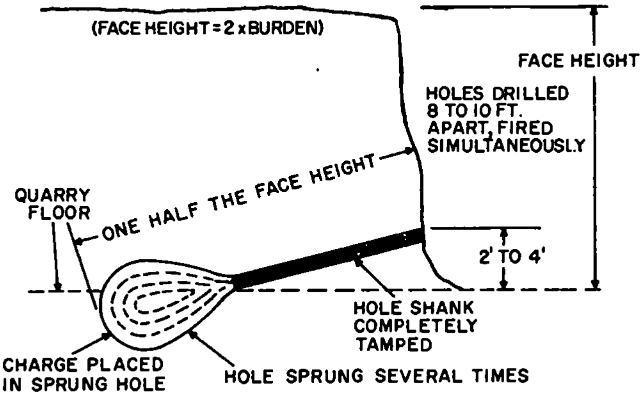


Figure 20. Snakeholes

21. BLASTING BOULDERS

a. *Size of Charge.* See table 12.

b. *Methods of Blasting.* See figure 22 for details.

Table 11. Explosives Required in Snakeholes

Bench height (ft)	Explosives per hole (lb)
5	5
10	20
15	40
20	75
25	115
30	170

NOTES

1. The amounts of explosives are based on military dynamite in hard rock, with maximum hole spacing of 8 feet. Depth of holes equals ½ bench height.
2. For medium rock, multiply amount of explosive by 0.8.
3. For soft rock, multiply amount of explosive by 0.5.
4. Holes normally are sprung to accommodate charge.

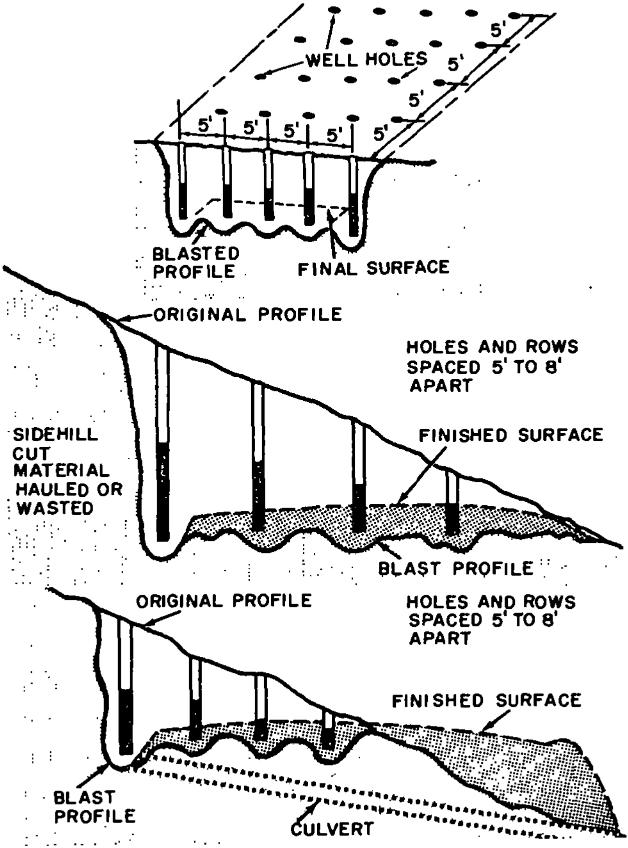


Figure 21. Benching.

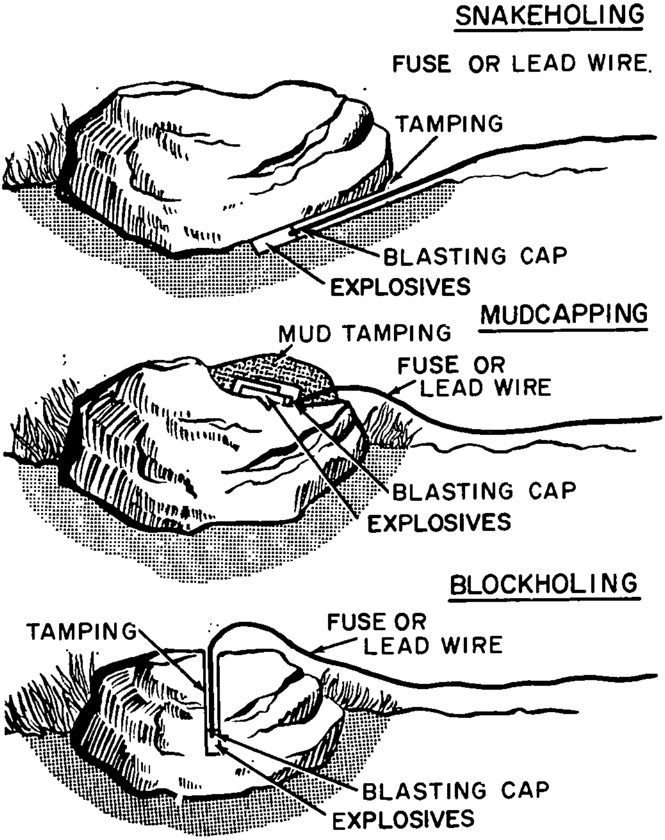


Figure 22. Methods of blasting boulders.

22. DITCHING

a. Conditions. Rough, open ditches 2½ to 12 feet deep and 4 to 40 feet wide can be blasted in most types of soil, except in gravel and sand. Trees, stumps, and large boulders are charged separately, but are fired simultaneously with the ditching charges.

b. Test Shots. Before beginning the ditching, run test shots to determine the proper depth, spacing, and weight of charges for desired results. Begin with holes 2 feet deep and 18 inches apart for small ditches and increase in charges and depth as required (fig. 23 and table 13).

c. Alinement and Grade. Mark ditch centerlines by chalk or transit line, and by drilling holes along it.

Table 12. Charges for Blasting Boulders

Boulder diameter, ft	Lbs of TNT required		
	Blockholing	Snakeholing	Mudcapping
1½	1/8	½	1
2	1/8	½	1½
3	¼	¾	2
4	3/8	2	3½
5	1/2	3	6

When a transit is used, the grade of the ditch can be accurately controlled by checking the hole depth every 5 or 10 holes and at each change in grade. Drill holes in soft ground with sharp punch or quick-

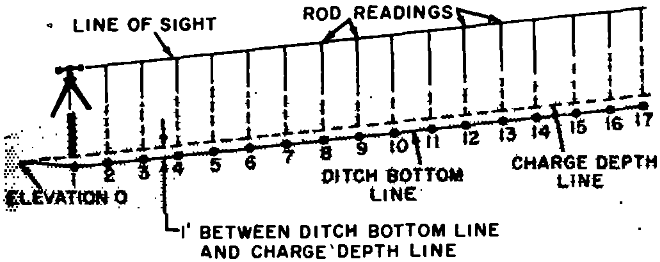


Figure 23. Charge holes set by transit line.

sand punch (fig. 24). Load and tamp them immediately to prevent cave-ins and insure charge is at proper depth. Table 13 shows example of method to determine depth of holes.

Table 13. Example Charge Points (See fig. 23)

(1) Charge point	(2) Ditch-bottom line elevation, ft	(3) Charge-depth-line elevation, ft	(4) Line-of-sight elevation, ft	(5) ROD reading, ft	(6) Ground elevation (4)-(5)=(6), ft	(7) Depth of hole (6)-(3)=7, ft
1	0	1	9	5.0	4.0	3.0
5	1	2	10	4.8	5.2	3.2
9	2	3	11	6.7	4.3	1.3
13	3	4	12	7.0	5.0	1.0
17	4	5	13	5.0	8.0	3.0

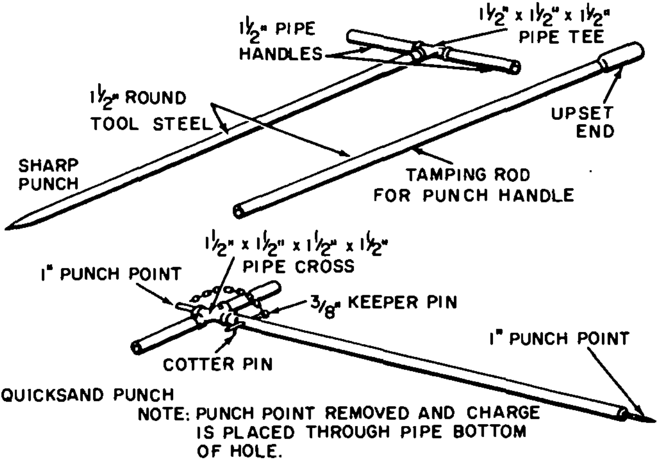


Figure 24. Punches used to place charges at proper depths in soft ground.

d. Detonation Methods.

(1) *Propagation methods.* Prime the hole, or holes, at one end of the proposed ditch; concussion will set off the succeeding charges. Use straight dynamite. It works only in moist soils, particularly with the ground under several inches of water (fig. 25). If more than one line of charges is used to obtain a wide ditch, each line is primed. Overcharge the prime hole 1 or 2 pounds.

NOTE. The propagation method can only be used with 50% straight, or greater, commercial dynamite.

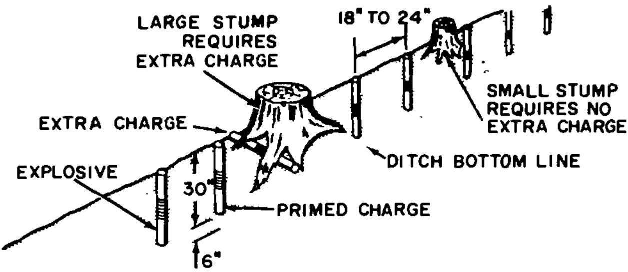


Figure 25. Propagation method of detonation.

(2) *Electrical method.* Use any high explosive in this method of ditching, and in any soil except sand regardless of moisture. Prime each charge with an electric cap. Blow all charges simultaneously.

(3) *Detonating cord method.* Use any high explosive with this method. This method is effective in any soil except sand and gravel, regardless of the amount of moisture. Each charge is primed with detonating cord and connected to a ring main.

e. *Loading Methods.*

(1) The method of loading for a deep, narrow ditch is pictured in figure 26.

(2) The relief method of loading for shallow ditches is depicted in figure 27. Ditches 1 and 3 are blasted first to relieve the charge in ditch 2.

(3) Figure 28 shows the posthole method of loading for shallow ditches in the mud.

(4) The cross section method of loading to clean and widen ditches is explained graphically in figure 29.

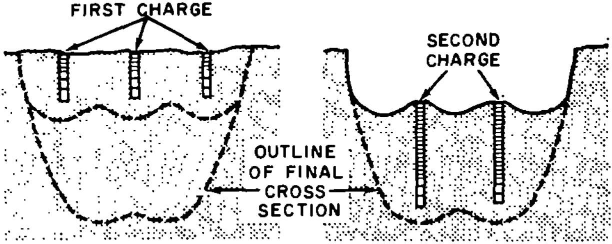


Figure 26. Method of loading a deep narrow ditch.

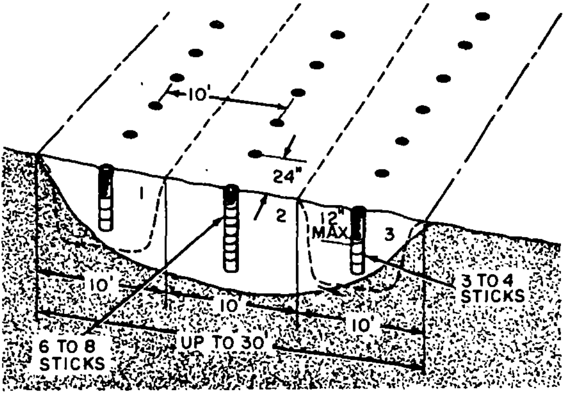


Figure 27. Relief method of loading for shallow ditches.

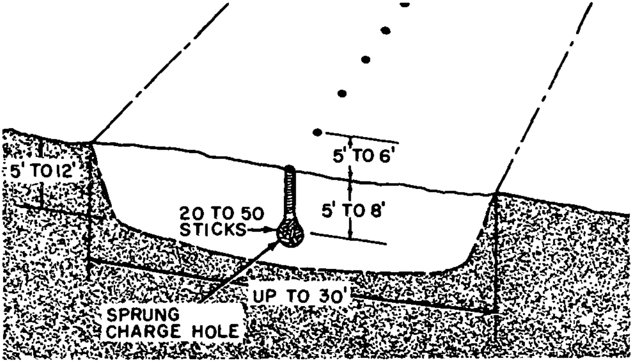


Figure 28. Post-hole method of loading for shallow ditches in mud.

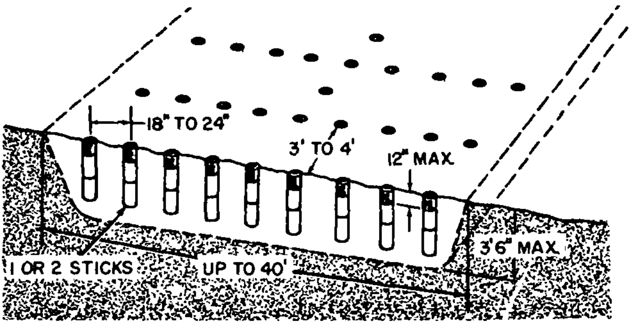
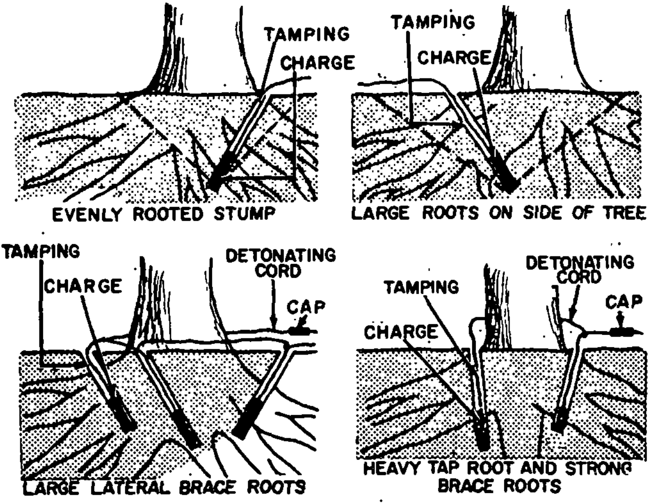


Figure 29. Cross section method of looding to clean and widen ditches.

23. BLASTING TREES AND STUMPS

a. *Size of Charge Required.* The size of the charge required varies with the size, variety, and age of the tree or stump, and with the soil conditions. The rule of thumb (fig. 30) shows how the size of charge varies with the size and age of the tree, using military dynamite. To remove stumps properly, test shots are required.

b. *Drilling Holes for Charge.* In drilling holes for the charge, follow illustrations in figure 30.



Rules of Thumb. Use dynamite as follows:

(1) For dead stumps -- 1 pound per foot of diameter.

(2) For live stumps -- 2 pounds per foot of diameter.

(3) For standing timber -- add 50 percent for standing timber.

Figure 30. Stump blasting methods for various root structures.

CHAPTER 3
LAND MINE WARFARE

Section I. General Data

24. MINEFIELDS

a. *Types.* Data on the various types of minefields is covered in table 14.

b. *Siting.* In the siting of minefields the following factors must be considered:

(1) Overall plan of operation.

(2) Nature of enemy threat (mechanized, infantry, etc.).

(3) Terrain.

(4) Location of other obstacles.

(5) Likely avenues of enemy approach.

(6) Possibility of later expansion of the field.

(7) Site should compel channeling of an attacking force into an area covered by massed fires.

(8) On large scale, site in patterns so that penetration of the foremost field will be contained by subsequent fields.

(9) Enemy capabilities for breaching, harassing, or interfering with mine laying.

(10) Availability of mines and restrictions on use of certain types.

(11) Troops and material available for mine laying, and their experience.

25. TYPES OF MINES

a. *Live Service Mines.*

(1) *Antitank mines.* Standard antitank (AT) mines are listed and described in table 15.

(2) *Antipersonnel mines.* Standard antipersonnel (APers) mines are listed in table 15.

b. *Training Mines.* Training mines are of two types:

(1) *Practice.* Practice mines (blue with white lettering) may resemble a specific model of service mine or a basic type of service mine. They produce a report and a puff of smoke to simulate detonation and are used on maneuvers and in training.

(2) *Inert*. Inert mines (painted black with white letters or O.D. with black letters) are service mines that have no explosive components added. They may be inert-loaded with sand, plaster, concrete, and so forth, and are used to familiarize troops with the live service mine.

26. PERSONNEL PROTECTION

Troops laying toxic chemical mines should be provided with field protective masks, impermeable protective clothing, protective gloves and hood, chemical agent detector kits, decontaminating materials, protection and treatment set, and boots treated with vesicant gas-resistant leather dressing. This clothing and equipment is also required by troops engaged in breaching and clearing an area that is uncontaminated but is suspected of containing toxic chemical mines.

27. CAMOUFLAGE

The principles written in FM 20–32 apply to all phases of installing a minefield, whether by manual or mechanical means. All traces of mine laying activity should be removed, such as boxes, crates, and wrappings. If mines are laid on the surface, they should be lightly covered with local natural materials to blend in with the surroundings. Don't overdo this because too much will give away each mine location.

Section II. Minefield Installation

28. PLATOON ORGANIZATION

The organization of the platoon as the basic unit for installing a standard pattern minefield is presented in table 16.

29. STANDARD PATTERN MINEFIELD

a. *Pattern*. The standard pattern is illustrated in figures 31 and 32 and statistical details are given in table 14.

b. *Clusters*. The mine cluster (fig. 33) is the basic unit of the standard pattern minefield. A cluster may contain from one to five mines. Two rows of clusters make up a minestrip, as shown in figure 32.

c. *Numbering*. The clusters in each strip are numbered from the right end of the strip when facing the enemy (fig. 34). Cluster number 1 is the first cluster on the right when looking down the strip.

Table 14. Consolilated Minefield Data Sheet

Type of Field [1]	Required Authority [2]	Tactical Employment [3]	Type of Mines [3]	Marking Required
Protective	Battalion or higher. Not delegated lower than commanders of company size units.	1. Temporary position protection a. Forward and rear areas or in isolated locations b Examples· outpost, working parties, roadblock defense parties. 2. Static installation protection Part of perimeter security of depots, airfields, static missile sites and other installations normally located to rear of zone of contact.	Antitank, antipersonnel, flares, flame mines of detectable type. Toxic chemical mines seldom employed. Booby traps and complex fuzeing systems are not extensively used.	Marked and/or guards posted to protect friendly troops.
Defensive	Division and higher commanders may not be delegated lower than brigade and comparable commanders.	Defeat or limit penetration into or between positions of company, battalion, or brigade defense areas and to strengthen the defenses in accordance with a tactical plan employed to delay and disorganize enemy attacks; to disrupt, channelize and assist in the destruction of enemy mobility and to strengthen manned weapons and obstacle systems.	All types of mines, booby trapping devices and flares. Chemical mines are not to be used unless field to be included into a barrier system at least 5% of antitank mines. Booby trapped warning devices such as flares, noisemakers, and smoke streamers should he laid to warn of enemy breaching attempts.	As required to protect friendly troops. Normally the standard marking fence w/markers is used.

See notes at end of table.

Table 14.—Continued

Removal Required	Reports Required	Records Required	Density	Patterns	Remarks
Yes, removal required by laying unit unless relieving unit commander specifically requests them to be left in place. Certificate of transfer sent to lowest commander having command over both units involved.	1. Intention to lay. 2. Initiation of laying. 3. Completion of laying. 4. Report of change, if any. Forward all reports to div. hq. or equivalent hq.	Standard form with at least minimum information. Exception: Urgency of tactical situation may sometimes preclude recording at time of laying. Forward to division.	One per meter of front by mine type. (Minimum requirements.)	Hand laid by the method best suited to the situation.	1. Locate within small arms range of the defenders but beyond hand grenade range of the enemy to defenders position. 2. Normally laid on short notice with mines laid from basic loads and local stocks.
No, if responsibility is transferred, certificate will be completed as for a protective minefield.	1. Intention to lay. 2. Initiation of laying. 3. Completion of laying. 4. Progress (if large field). 5. Report of change. Forward completion report to army hq. or comparable hq's. level.	Standard form with at least minimum information. A record of change is required if field is altered. Forward to army hq's.	One A.T. and two Apers. per meter of front.	Standard, nonstandard patterns, and scattered mining is authorized.	1. Minimum depth—100 meters. 2. Location coordinated w/division and corps fire support plans. 3. Cover by artillery, machinegun and antitank weapons and when possible by all forms of fire support.

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Table 14.—Continued

Type of Field [1]	Required Authority [2]	Tactical Employment [3]	Types of Mines [3]	Marking Required
Barrier	Corps and higher commanders. May not be delegated lower than division or comparable commanders.	Employed to black enemy attack formation in selected areas, especially to the flanks and rear areas and to channel his approach into selected battle areas. Usually preplanned and integrated into field army, corps and division barrier plans. Employed to channelize, disrupt and delay enemy attack. To provide the defender to concentrate fire and reserves. Also used to direct the enemy attack which enables the defender to attack with blocking or counter attacking forces.	All types of mines, booby trapping devices, and flares may be used. Extensive use of complex fusing. Toxic chemical mines may be used if autharlzed. 20% of A.T. mines booby trapped.	As required to protect friendly troops and civilians. Normally the standard marking fence with markers is used.
Nuisance	Army commander or higher. May be delegated division or comparable commanders.	To delay, disorganize and lower morale, of advancing enemy; to hinder his use of an area or route. Particularly effective in reterograde movement, denial operations and during evacuation.	All types of A.T. and A.P. mines, booby traps and dirty trick devices. If time permits all A.T. mines should be booby trapped	None unless initially to protect friendly troops.

See notes at end of table.

Table 14.—Continued

Removal Required	Reports Required	Records Required	Density	Patterns	Remarks
No	1. Intention to lay. 2. Initiation of laying. 3. Progress of laying. 4. Completion of laying. 5. Change of field. Completion report to army hq.	Standard form with at least minimum information. Forward to army hq. Record of change is required.	Three A.T., four fragmentation Apers., and eight Apers. blast mines per linear meter of front.	Normally the cluster pattern will be used.	1. Minimum depth—300 meters. 2. Cover by observation and plans made to bring down artillery and/or air attacks, and to move out direct fire elements to provide fire cover at threatened points.
No	1. Intention to lay. 2. Initiation of laying. 3. Progress (if large field). 4 Completion of laying. 5. Change of field Completion report to army hq.	Standard form. Forward to army hq.	None specified	None specified	1. Abandoned fields become nuisance fields. 2. May or may not be covered by fire. 3. A booby trapped area is considered a nuisance minefield.

Table 14.—Continued

Type of Field [1]	Required Authority [2]	Tactical Employment [3]	Types of Mines [3]	Marking Required
Phony	The commander who has the authority to employ the type field simulated.	Used when lack of time, personnel, or materiel prevents laying a live mine field. Used to deceive the enemy into thinking area is mined. Used to extend or supplement live fields. (Camouflage gaps in live fields.)	Phony mines only. Ground disturbed to simulate live mines. Metal (cans, scrap, etc.) used to give false signals on detector sets.	
Enemy (any minefield that the enemy laid or has an opportunity to influence the disposition of mines therein)			All types of mines, special fuses and booby traps.	Marked and/or guards posted to protect friendly troops, by first unit discovering the field.

[1] The basic classification of minefields is in accordance with the tactical purpose of their employment. Minefields are also categorized according to the type of enemy movement being obstructed. This includes the antipersonnel, antitank, antiamphibious and antiairborne minefields. Another category also describes the type of terrain in which the minefield is installed. It includes route mining, beach mining, river mining and field mining. Thus a barrier minefield may consist solely of or include segments of route mining, field mining, river mining, etc.; or antiamphibious minefields may be protective, defensive, barrier or nuisance depending on its tactical purpose.

Table 14.—Continued

Removal Required	Reports Required	Records Required	Density	Patterns	Remarks
Same as *for the type field simulated*					1 *Planning and coordination for laying and fire coverage must be done with same care as for type field being simulated*
No	Location (include apparent boundaries and known bypasses). Forward to army hq by unit locating field.	Standard record form with as much information as is available. Forward to army hq. by unit discovering field. Mark at top with "enemy mine field."			When additional information becomes available, another record form is prepared and forwarded through channels.

[2] Commanders may limit the employment of mines by subordinate units by restraining or revoking authority to lay certain types of mines or their use in specified areas.

[3] Mine employment at each command echelon must be consistent with the overall concept of operation, probable future mission and all available resources.

NOTE. All minefield reports are classified "SECRET."

Table 15. Mine Data

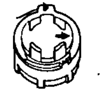
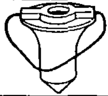
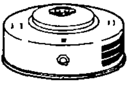
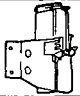
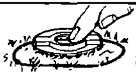
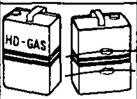
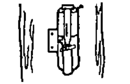
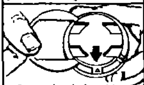
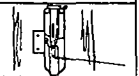
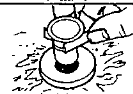
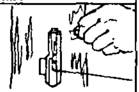
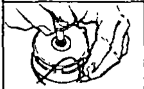
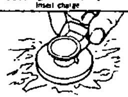
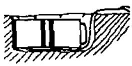
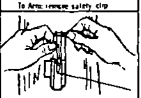
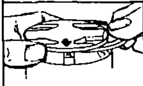
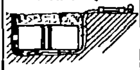
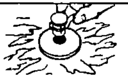
M14 BLAST ANTIPERSONNEL MINE	M25 BLAST ANTIPERSONNEL MINE (ELSIE)	M23 AND M1 1-GALLON CHEMICAL LANDMINES	M49A1 TRIP FLARE
			
Wt. 3⅓ oz Expl 1 oz TETRYL Fuze Integral with Belleville Spring Functioning 20 to 35 lb.	Wt 3½ oz Expl ⅓ oz shaped charge Fuze Integral, with ball release Functioning 17 to 22 lb press	When armed for pressure detonation, emplace in same manner as the M15 antitank mine	Has 55 to 70 sec surface burning period and an illumination radius of approximately 330 yds. Initiates by taut or loose trip wire
 Unscrew shipping plug from bottom of mine. Turn pressure plate to ARMED position with arming tool	 Push mine into ground. If ground is hard, dig hole with bayonet		 Attach flare
 Remove safety clip & check for malfunctioning	 Remove dust cap	Wt. 11 lb loaded, has an 8-ft length of detonating cord for burster charge. May be armed for electric or trip wire actuation	 Attach trip wire to anchor, then to trigger. Pull trigger to vertical position and secure
 Replace safety	 Insert charge	Electric Firing  Attach burster charge — 8 ft. length of detonating cord — to side of mine	 To Arm: remove safety clip
 Screw detonator into detonator well	 Remove safety clip	 Bury mine 4 in. and attach detonating cord to controlled firing system	 To Disarm: insert safety pin
 Bury mine & remove safety clip	The M25 will penetrate a soldier's boot and foot or puncture a 12 ply tire and tube	Non-Electric Firing  Bury mine as above and attach non-electric detonator to burster	 Check both ends then cut taut trip wire
Buried: Pressure plate slightly above ground level To Disarm: Insert safety clip and remove detonator Caution: Do not turn pressure plate back to safe position as it creates excess wear	 To Disarm: Replace safety clip and lift charge container from mine	Warning: SOLDIERS PREPARING, LAYING, and REMOVING CHEMICAL LAND MINES, MUST WEAR PROTECTIVE MASK and PROTECTIVE CLOTHING	Caution: NEVER LOOK DIRECTLY AT BURNING FLARE Note: For loose wire operation Attach wire to eye of Safety Pin

Table 15.—Continued

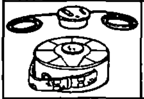
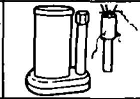
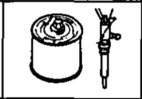
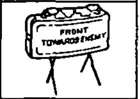
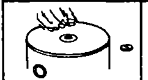
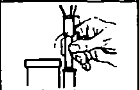
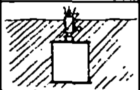
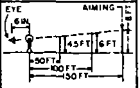
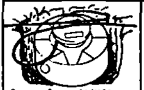
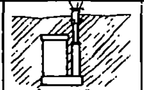
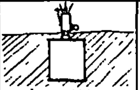
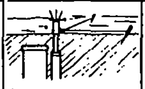
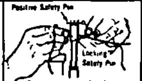
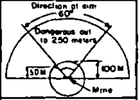
M612 FUZE USED WITH M21 ANTITANK MINE	M2 SERIES BOUNDING ANTIPERSONNEL MINE	M16 SERIES BOUNDING ANTIPERSONNEL MINE	M18A1 FRAGMENTATION ANTIPERSONNEL MINE
			
Has two 9-ft pneumatic blasts safety latch, and arming lever	Wt .. 5.3 lb. Projectile . Steel Fuze M605 combination Function Pressure 8 to 20 lb. Pull 3 to 10 lb.	Wt . . . 8.25 lb. Projectile Steel Fuze M605 combination Function- Pressure 8 to 20 lb Pull 3 to 8 lb.	Wt . 3.5 lb Expl. 1.5 lb. C-4 Missiles 700 steel balls Equipment 1 electric cap with 100 ft leg wires per mine 1 circuit tester per 6 mines 1 electric firing device per mine Mine is control fired
 Remove closure plug and insert 120 booster	 Remove shipping cap	 Remove shipping plug and install fuze	 Test Circuit Mate firing device circuit tester, and blasting cap Depress handle, spark should show in window Separate test components
 Remove shipping plug from mine. Screw in fuze	 Screw on fuze	 Pressure installation	 Position and aim mine
 Bury mine Cross and extend hoses	 Pressure installation	 Trip wire installation	 Remove shipping plug – priming adapter and secure cap
 Lift safety latch and turn arming lever to ARMED Recross hoses	 Trip wire (and pressure) installation	 Attach trip wires – first to anchor then to pull ring	 Unroll firing wire and connect directly to "Safed" firing device
 Complete camouflage	 Remove locking safety first then positive safety	 Remove locking safety first, then positive safety	
Timer provides a 35 ± 5 minute safe separation period Both leads must be depressed for initiation To Disarm Reverse arming procedure	Shell is propelled to height of 6 to 8 ft. and detonated. Mine has 10-yd. casualty radius. To Disarm Reverse arming procedure	Mine bounds into air and explodes at height of 2-4 ft. Has 35 ft casualty radius To Disarm Reverse arming procedure	Firing Position Min. of 16M to rear or to side Friendly troops at side and rear should be under cover at min. of 100 M To Fire Offset safety bail and depress handle To Disarm Reverse arming procedure

Table 15.—Continued

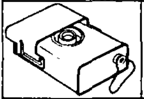
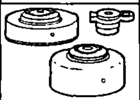
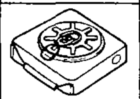
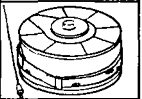
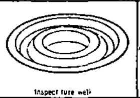
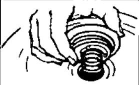
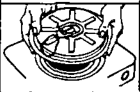
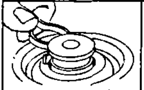
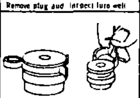
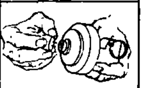
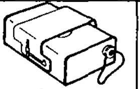
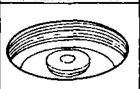
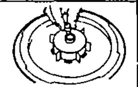
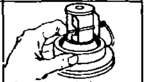
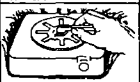
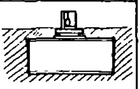
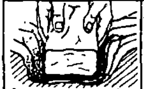
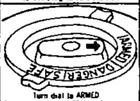
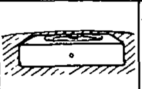
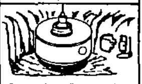
M7A2 METALLIC LIGHT ANTITANK AND ANTIVEHICULAR MINE	M6A2 MEDIUM AND M15 HEAVY METALLIC ANTITANK MINES	M19 PLASTIC HEAVY ANTITANK MINE	M21 METALLIC (KILLER) ANTITANK MINE
			
Wt 4 9 lb Expl 3 5 lb Fuze M603 Act Wells 1 Functioning 140 to 240 lb press	M15 / M6A2 Wt 30 lb / 20 lb Expl 22 lb / 12 lb Fuze M603 / M603 Act Wells 2 / 2 Functioning 300 to 400 lb press / 300 to 400 lb press	Wt 28 lb Expl 21 lb Fuze M606 Act Wells 2 Functioning 350 to 500 lb press	Wt 18 lb Expl 10.5 lb. Fuze M607 Act Wells None Functioning 290 lb press on fuze or 20° deflection of tilt rod blows concave steel plate into target
 Inspect fuze well	 Remove plug and inspect fuze well	 Remove pressure plate	 Remove closing plug. Insert M 120 booster in bottom. Replace closing plug
 Remove safety and insert fuze	 Inspect fuze and remove safety	 Remove shipping plug. Inspect position of striker (offset). Remove safety fork and turn dial to ARMED. Check position of striker (center). Turn to SAFE and replace safety fork	 Remove closure assembly from fuze
 Replace plate	 Insert fuze	 Screw detonator into detonator well	 Remove shipping plug from mine. Screw in fuze
 Sandbag cover	 Replace plug in safe position	 Place mine in hole. Remove safety fork and turn dial to ARMED	 Bury mine
 Bury mine and complete camouflage	 Turn dial to ARMED	 Complete camouflage	 Remove safety (pull ring assembly) and complete camouflage
Burial: Pressure plate at ground level or slightly above To Disarm: Reverse arming procedure Note: Sandbag prevents earth, gravel, etc. from getting under pressure plate and causing misfire	Burial: Pressure plate at ground level or slightly above To Disarm: Reverse arming procedure Note: Additional 8 lb expl charge buried with the M6A2 to improvise a heavy antitank mine	Burial: Pressure plate at ground level or slightly above To Disarm: Reverse arming procedure	Burial—Pressure fuze cap flush with ground surface Tilt Rod: Seat mine firmly in snug fitting hole. Most effective in brush, weeds, etc. To Disarm: Reverse arming procedure

Table 16. Plataon Organizatian ta Install Minefield

Personnel	Officer	NCO	EM	Equipment
Supervisary personnel	1	1	....	Officer: Map, lensatic campass, natebook, and minefield record forms. NCO: Map, natebook, and lensatic campass.
Siting party	...	1	3	Stakes or pickets, sledges, hammers, tracing tape on reels, and nails ta peg tape.
Marking party	..	1	2	Barbed wire an reels, marking signs, lane signs, wire cutters, gloves, sledges, pickets.
Recording party	...	1	2	Sketching equipment, lensatic campass, minefield record farms, map, and metric tape.
1st laying party	....	1	6 ta 8	Natebook far squad leader, picks, shavels, and sandbags.
2d laying party	....	1	6 ta 8	—do—
3d laying party	...	1	6 ta 8	—do—
Total	1	7	25 to 31	

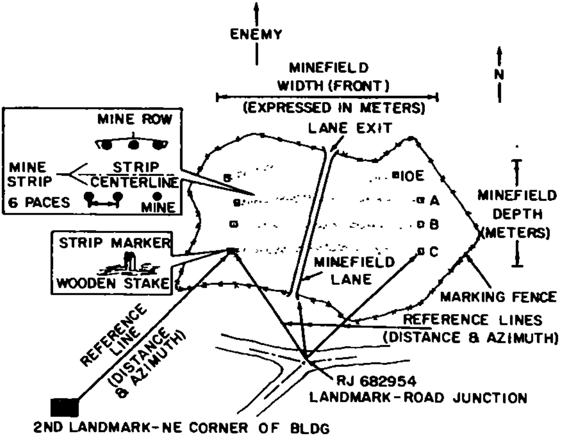


Figure 31. Standard minefield, fenced, marked, and referenced.

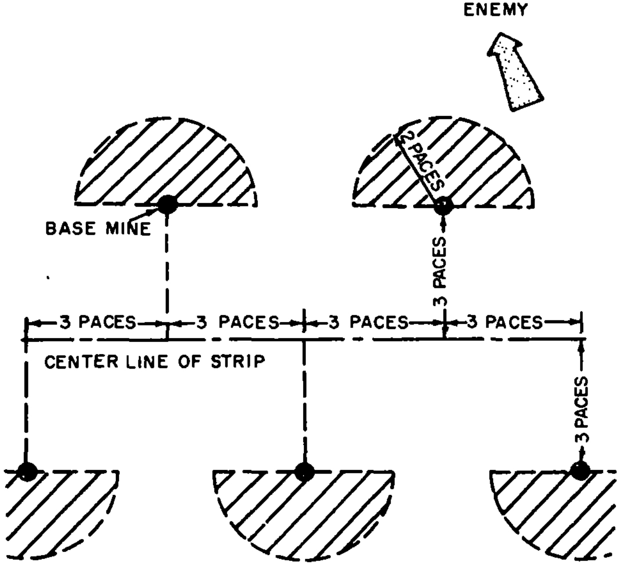
d. Tripwires. If tripwires are used, they are placed on selected antipersonnel mines in the row on the enemy side of the strip centerline with not more than one trip-wire-activated mine to a cluster, and no closer than every third cluster (fig. 35).

e. *Arrangement.* The strips are not parallel, but their centerlines must be at least 18 paces apart at all points. A centerline may have as many turning points as desired (fig.36).

30. INSTALLATION PROCEDURE

a. *Limitations.* The procedure described here may be varied according to the personnel, terrain, materials, and proximity of the enemy.

b. Laying Out the Field and Installing Mines. When the OIC arrives at the site with his siting and marking parties, the OIC proceeds to lay the minefield as shown in figures 37 through 42.



CLUSTERS ARE LAID ON BOTH SIDES OF STRIP ℄

THE CENTRAL MINE IN EACH CLUSTER MAY BE EITHER ANTITANK OR ANTIPERSONNEL FRAGMENTATION

ADDITIONAL MINES, ANTIPERSONNEL ONLY, ARE PLACED WITHIN EACH CLUSTER (SHADED AREA) IF DESIRED

Figure 32. Mine strip.

A CLUSTER MAY CONSIST OF ONE ANTITANK MINE	
OR ONE ANTITANK MINE PLUS SEVERAL ANTIPERSONNEL MINES WITHIN A 2-PACE SEMICIRCLE FROM THE ANTITANK MINE	
OR ONE ANTIPERSONNEL MINE	
OR SEVERAL ANTIPERSONNEL MINES WITHIN A 2-PACE SEMICIRCLE OF THE BASE ANTIPERSONNEL MINE	

Figure 33. Mine clusters.

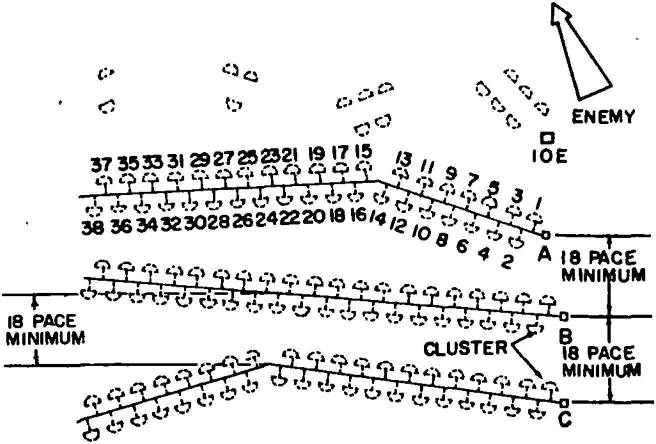


Figure 34. Method of numbering clusters in mine strips.

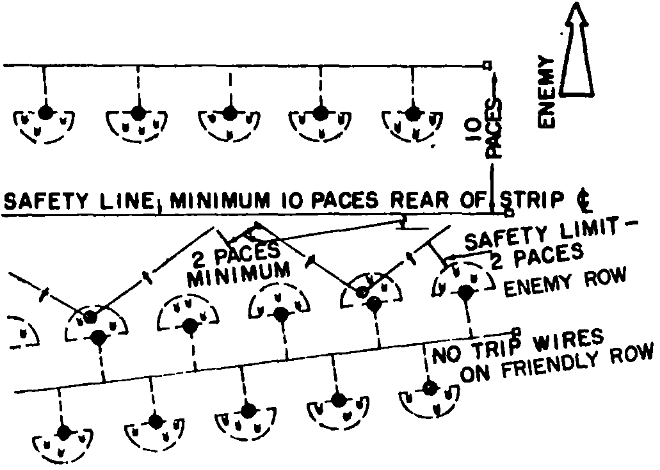


Figure 35. Use of trip-wires on front row of mine strip.

31. MINEFIELD MARKING

o. *Rear Areo Minefields.* Completely fence o rear-area minefield with two stronds of borbed wire ot the time of loying (fig. 43). As figure 31 depicts, the fence does not follow the exoct boundary of the field, but is placed where it does not indicote the boundary. It is no closer than 20 paces from the neorest mine. Standord markers (fig. 44) are hung on the upper strand so that the words "MINES," "BOOBY TRAPS," or, in the case of o toxic chemicol minefield, the word "GAS" face away from the field. If o minefield hos been contominated with toxic chemicol agents (chemicol mines previously detonated or other means), the standord chemical contamination morker (fig. 44) with word "gos" facing away from minefield, is used olong with standord mine morker. Lanes ore morked os shown in figure 45.

CLUSTER #3 IS LAST CLUSTER OF A STRIP SECTION

CLUSTER #4 IS FIRST CLUSTER OF A STRIP SECTION

THE LAST BASE MINE WILL NEVER BE LAID CLOSER THAN 3 PACES TO END OF A STRIP SECTION

THE FIRST MINE LAID ON A SECTION OF A STRIP WILL ALWAYS BE 3 PACES FROM THE TURNING POINT AND ON THE OPPOSITE SIDE OF STRIP CENTERLINE FROM PREVIOUS CLUSTER LOCATION

IF NECESSARY TO TURN ANGLES SHARPER THAN THOSE SHOWN, OMIT A CLUSTER TO ASSURE BASE MINES BEING 6 PACES APART, AND NO CLUSTER AREA CLOSER THAN 3 PACES FROM ANY CENTERLINE TAPE

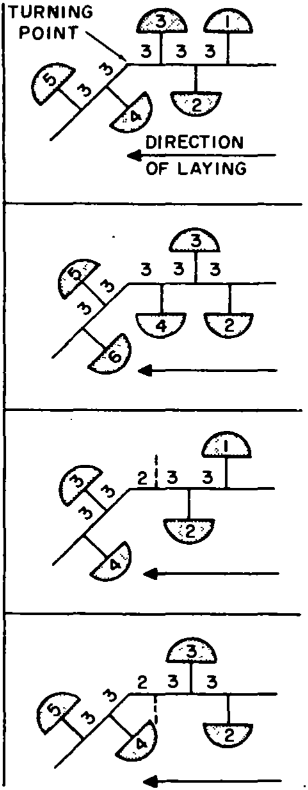


Figure 36. Turning points in a mine strip.

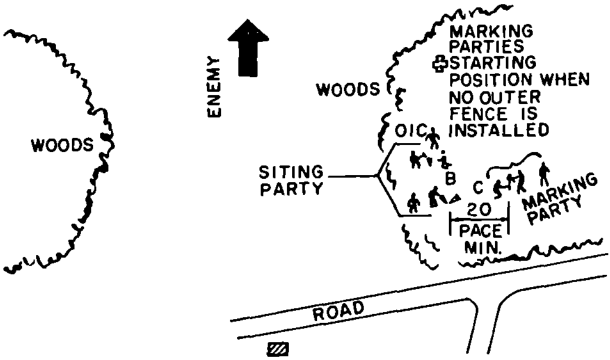


Figure 37. Initial steps in laying minefield.

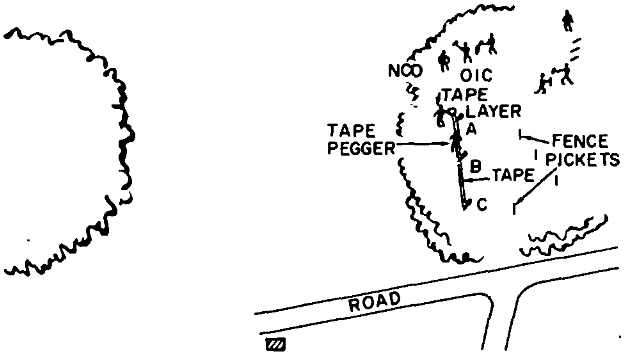


Figure 38. Establishing the right hand boundary stakes of a minefield.

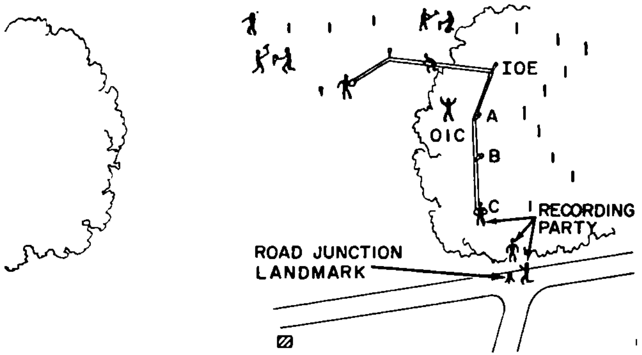


Figure 39. Laying out the IOE strip.

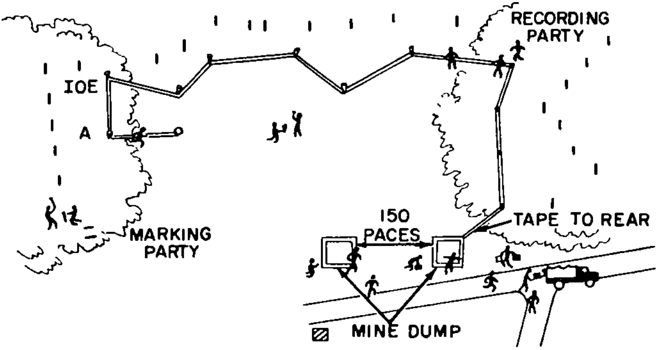


Figure 40. Laying out strip A and establishing mine dumps.

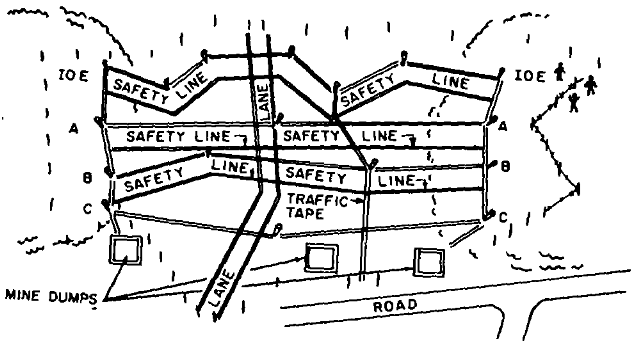


Figure 41. Minefield completely taped.

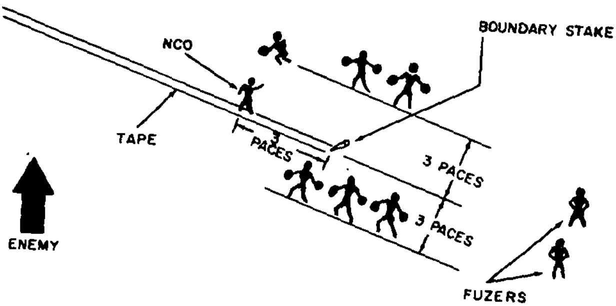


Figure 42. Laying mines on a section of a regular strip.

b. Forward Area Minefields. Mark forward area minefields the same as just described in *a*, with these exceptions:

(1) Minefields forward of the FEBA are sometimes fenced only on the friendly side, or on the friendly side and flanks.

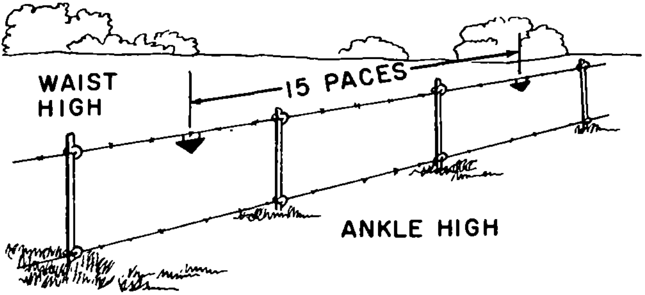


Figure 43. Standard minefield marking fence.

(2) Lanes in forward areas are marked inconspicuously by placing wire, tape, or closely spaced objects on the ground on each side of the lane, with the lane entrance identified by markers such as pickets marked with tape or piles of stones, and the like. Do not mark lane exits on enemy side. Fencing, marking, and camouflaging of minefields must be carefully maintained.

32. LANES AND GAPS

a. *Lanes.* A minefield lane is a safe path or route through a minefield. Lanes through friendly fields are 8 meters wide for one-way vehicle traffic and 16 meters wide for two-way vehicle traffic.

b. *Gaps.* A minefield gap is that portion of a minefield in which no mines have been laid. The purpose of a gap is to enable a friendly force to pass through the field in a tactical formation. Gaps are of a specified width seldom less than 100 meters.

c. *Siting and Location.* Site the lanes and gaps so that the unit protecting the field, and adjacent units, may carry out operational plans such as patrolling, attacking, and counterattacking. The tactical commander gives the general location of lanes and gaps to the commander of the laying unit. Skillful siting of the lanes and gaps will prevent the enemy from easily determining their location. Change the location of lanes and gaps frequently to prevent detection and subsequent ambush of friendly patrols. Tactical commanders must always be consulted regarding future locations of lanes and gaps.

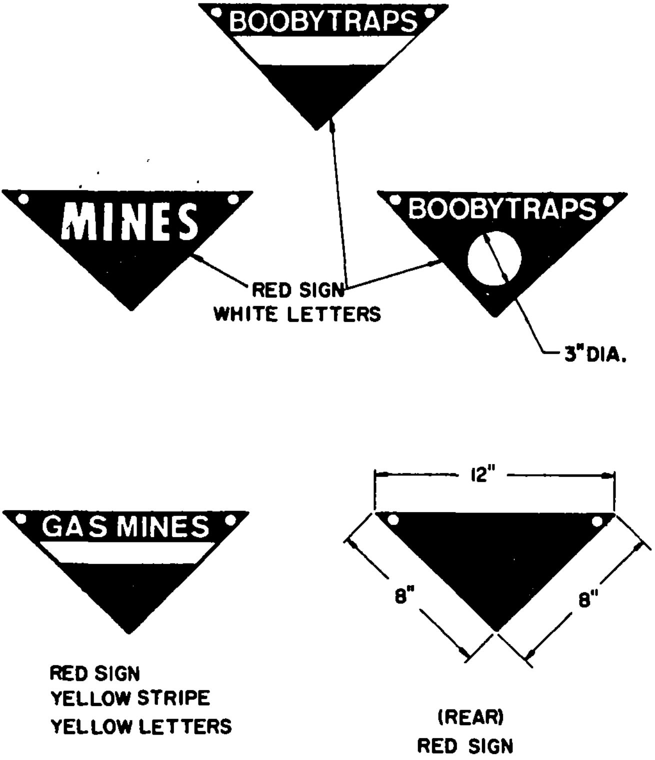


Figure 44. Standard marking signs.

Table 17. Minefield Requirements for $\frac{\text{100 Yards}}{\text{100 Meters}}$ of Front

Density AT	Density APF	Density APB	Strips Req.	AT	AP Frag	AP Blast	Mines Crated Wt. Tons	Mines Crated Cu. Ft.	Veh. w/Mines Crated 5T Cgo	Veh. w/Mines Crated 5T Dump	Man Hours	Fencing Yards Wire	Fencing Yards Post	Fencing Yards Tons
1	1	1	3	153	153	153	4.67	212.44	.41	1.57	115	1200	30	.32
				164	164	164	4.98	226.85	.44	1.68	124			
1	2	2	3	153	291	291	5.48	241.92	1.1	1.79	184	1200	30	.32
				164	312	312	5.86	258.74	1.17	1.92	197			
1	4	8	8	153	581	1131	7.32	313.53	1.46	2.32	467	2000	50	.54
				164	623	1213	7.84	335.8	1.57	2.49	500			
2	4	8	9	291	581	1131	10.7	475.99	2.16	3.53	501	2400	60	.65
				312	623	1213	11.46	508.96	2.3	3.77	537			
3	4	8	9	428	581	1131	14.06	635.28	2.81	4.70	535	2400	60.	.65
				459	623	1213	15.06	680.95	3.0	5.04	574			

NOTES.

1. Calculation of mines strips:
   a. 3 x Density of AT mines = number of strips.
   b. 3/5 x Sum of desired density = number of strips.

Use a or b, whichever is greater.

2. Total mines by type include mines in strips plus IOE and 10% safety factor.
3. Calculation of mine requirements when frontage is expressed in yards or meters.
   a. Mines required per pace of front = frontage (yards) ÷ .80 equals number of mines for main field. Divide this number by 9 for clusters in the IOE. Add 10% of combined total for grand total of mines required for field.
   b. Mines required per pace of front = frontage (meters) ÷ .75 equals number of mines per pace for main field. Divide this number by 9 for clusters in the IOE. Add 10% of combined totals for grand total of mines required for field.
   c. Cluster composition of IOE 1-2-2.

Table 17.—Continued

4. Mine weights based on the following (Reference TM 9-1345-200):

M-15 AT Mine	M-16 AP Frag Mine	M-14 AP Blast Mine
1 mine per crate	4 mines per crate	90 mines per crate
49 lbs per crate	45 lbs per crate	44 lbs per crate

5. Mine cubage based on the following (Reference FM 101-10):

M-15 AT Mine	M-16 AP Frag Mine	M-14 AP Blast Mine
1.17 cu ft per mine crated	.77 cu ft per crate (4-M16)	1.7 cu ft per crate (0-M14)

6. Vehicles required based on off-road tonnage capacity and/or cargo space.

7. Vehicle payload capacity (Reference FM 101-10):

Type	*Off-Road (Tons)*	*Cargo Space (Cu Ft)*
2½ ton dump	2½	67.5
2½ ton cargo	2½	408
5 ton dump	5	135
5 ton cargo	5	513

8. Time Requirements:

Based on a laying rate of 4 mines per hour per man in an A/T and A/Pers minefield

9. Fencing Requirements:

Based on 2 strand fence with posts every 25 yards. For each additional 100 yards of front add 250 yards wire and 6 posts. For meter of front add 10% to table.

Table 18. Land Mine Logistical Data Table

Mine Model & type	Wt. (lbs.) per mine	Mine packaging data: No. of mines, etc., per crate	Wt. (lbs) per crate	Crate dimensions (ins): Lgth.	Width	Hgt.	Capacity of indicated army vehicles (Note: figures in parentheses indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space) — M-35 2½ ton cargo truck (Cargo space: 147 x 88 x 60 ins): No of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)
M-6 AT	20	a uncrated mines	—	13 13 ins diam.		2.25	—	flat	4	250 (264)	2.5 (2.64)
		b 1, w/fuze & activator	31	13.5	13.5	3.75	162 (322)	(on end) flat	1 (6)	162 (322)	2.51 (4.99)
		c. 2, w/fuzes & activator	60	18.13	16	9.75	84 (160)	flat	2 (4)	168 (320)	2.52 (4.8)
*M-7 AV	5	a. 8, w/fuzes	56	19.25	11	8.25	90 (178)	flat	2 (4)	720 (1424)	2.52 (4 98)
		b. 12, w/fuzes	71.5	23.5	11.75	9 5	70 (140)	flat	2 (4)	840 (1680)	2 5 (5)
M-15 AT	31	a. uncrated mines	—	13 13 ins diam.		5	—	flat (flat, 11 on end)	3 — (3)	162 (209)	2.51 (3.24)
		b 1, w/fuze & activator	49	18	15.13	7.5	103 (200)	flat	3 (5)	103 (200)	2.53 (4.9)
M-19 AT	28	2, w/fuzes & activators	80	16.25	10.5	16	63 (125)	on end (on side)	1 (3)	126 (250)	2.52 (5)

Table 18.—Continued

Capacity of indicated army vehicles (Note: figures in parentheses indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space)														
M-105 1½ ton trailer (Cargo Space: 133 x 87 x 71 ins)					M-47 2½ Ton Dump Truck (Cargo Space: 108 x 70 x 15+ ins) (Volume determines capacity)					M-51 5 Ton Dump Truck (Cargo Space: 125 x 82 x 23 ins) (Volume determines capacity)				
No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)	No. of crates	How carried	No. of Tiers of crates	Total No. mines	Total wt. (tons)	No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tns)
—	flat (on edge)	3 (2)	150 (300)	1.5 (3)	—	on edge	1	165	1.65	—	flat	10	500	5
96 (195)	flat	2 (4)	96 (195)	1.48 (3 02)	140	on end	1	140	2.17	324	flat	6	324	5
50 (100)	flat	2 (4—)	100 (200)	1.5 (3)	42	on end	1	84	1.26	60	flat (or on end)	2 (1)	120	1.8
56 (110)	flat	2 (3)	448 (880)	1.56 (3.08)	72	on end	1	576	2 01	105	on end	1	840	3
41 (85)	flat (on end)	2 (1)	492 (1020)	1 46 (3.02)	63	on end	1	756	2.25	78	on end	1	936	2.78
—	flat (on edge)	3 (2)	100 (200)	1.55 (3.1)	—	on end (or flat)	1 (3)	105	1.62	—	flat	5	270	4.1
61 (122)	flat	2 (4)	61 (122)	1.49 (2.98)	56	on end	1	56	1.37	90	flat	3	90	2.2
37 (75)	flat	1— (2)	74 (150)	1.48 (3)	40	on end	1	80	1.6	98	flat	2	196	3.9

Table 18.—Continued

Mine Model & type	Wt (lbs) per mine	Mine packaging data: No. of mines, etc., per crate	Wt. (lbs) per crate	Crate dimensions (ins): Lgth.	Width	Hgt.	Capacity of indicated army vehicles (Note: figures in parenthesis indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space) — M-35 2½ ton cargo truck (Cargo space· 147 x 88 x 60 ins): No. of crates	How carried	No. of tiers of crates	Total No mines	Total wt (tons)
M-21 AT	18.75	4, w/M-607 fuzes	90	29.2	13.5	12.5	56 (111)	flat	2 (34)	224 (444)	2 51 (4.98)
M-2 AP	5	6, w/fuzes & trip wire	50	15	10 25	9.5	100 (200)	flat	2 (3)	600 (1200)	2.5 (5)
M-3 AP	9 6	6, w/fuzes & trip wire	72	18	8.75	9.5	70 (138)	flat	2— (2+)	420 (828)	2.52 (4.96)
M-14 AP	0.2	90, w/dets & wrenches	44	19	18	8 75	114 (227)	flat (on end)	4 (3)	10,260 (20,430)	2.5 (4.99)
M-16 AP	8	4, w/fuzes & trip wire	45	15.75	10.13	8.5	112 (222)	flat	2 (4)	448 (888)	2.52 (4.99)
M-18 AP	2.5	a. 1, (M-68 kit) w/elec cap, 50′ firing wire, 1 btry hldr	3.2	8.75	3	5 5	1562 (3125)	upright	3+ (6)	1562 (3125)	2.5 (5)
		b. 5 (M-69 kit) w/elec caps, 500′ firing wire	21.5	13.5	10.5	5.5	233 (466)	upright	2+ (5+)	1165 (2330)	2.52 (5+)

Table 18.—Continued

Capacity of indicated army vehicles (Note: figures in parentheses indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space)														
M-105 1½ ton trailer (Cargo space 133 x 87 x 71 ins)					M-47 2½ Ton Dump Truck (Cargo Space: 108 x 70 x 15+ins) (volume determines capacity)					M-51 5 Ton Dump Truck (Cargo Space. 125 x 82 x 23 ins) (volume determines capacity)				
No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)	No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt (tns)	No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)
33 (66)	flat	1+ (3−)	132 (264)	1.48 (2 96)	40	on end	1	160	1.79	48 (60)	flat (on end)	2 (1)	192 (240)	2 1 (2.7)
60 (120)	flat	1 (2)	360 (740)	1.5 (3)	70	on end (or flat)	1 (2)	420	1.75	128	flat	2	768	3.2
41 (83)	flat	1 (2−)	246 (498)	1 47 (2.98)	70	on end (or flat)	1− (2−)	420	2.52	108	flat	2	648	3 5
68 (136)	flat	3 (5)	6120 (12,240)	1.49 (2.99)	48	on end	1	4320	1 05	72	flat	3	6480	1 5
66 (133)	flat	1+ (2+)	264 (532)	1.48 (2.99)	80	on end (or flat)	1 (2)	320	1 80	168	flat	3	672	3.7
938 (1875)	upright	3− (5)	938 (1875)	1.5+ (3)	864	on end	2	864	1 38	1782	on end	3	1782	2.8
140 (280)	upright	2 (3+)	700 (1400)	1 5+ (3+)	96	on end	2	480	1.03	252	flat	4	1260	2 7

Table 18.—Continued

Mine Model & type	Wt. (lbs) per mine	Mine packaging data: No. of mines, etc. per crate	Wt. (lbs) per crate	Crate dimensions (ins): Lgth	Width	Hgt.	Capacity of indicated army vehicles (Note: figures in parentheses indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space) — M-35 2½ ton cargo truck (Cargo space 147 x 88 x 60 ins): No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)
M-23 Chem	24.7	3, w/fuzes & activators	a. 110 (1 drum)	17 5 ins diam (stnd shipping drum)		22	46 (80)	on side (on end)	2 (2)	138 (240)	2.53 (4.4)
			b. 1,840 (pallet of 16 drums)	52	46	48	3 pallets	flat	1	144	2.76
M-24 AP	2.3	a. 3 in cardbd tube	8.12	18	3 5 diam.		615 (1230)	flat	3+ (6)	1845 (3690)	2.5 (5)
		b. 18 (6 tubes in a wooden box)	70±	21.25	12 5	10	70 (140)	flat	1+ (3+)	1260 (2520)	2.5 (5)
M-25 AP	0.21	96 (12 per bag; 8 bags per crate)	40	18.75	9.25	12 5	125 (250)	flat	2 (4)	12,000 (24,000)	2.5 (5)

Table 18.—Continued

Capacity of indicated army vehicles (Note: figures in parentheses indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space)														
M-105 1½ ton trailer ((Cargo space: 133 x 87 x 71 ins)					M-47 2½ Ton Dump Truck (Cargo Space: 108 x 70 x 15+ in) (Volume determines capacity)					M-51 5 Ton Dump Truck (Cargo Space: 125 x 82 x 23 ins) (Volume determines capacity)				
No. of crates	How carried	No of tiers of crates	Total No. mines	Total wt. (tons)	No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)	No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)
27 (54)	flat	2— (3)	71 (142)	1.48 (2.97)	24	on end	1	72	1.32	28	on end	1	84	1.5
2 pallets	flat	1	96	1.84	2	flat	1	96	1.84	3	flat	1	144	2.7
370 (706)	flat	3— (5—)	1110 (2118)	1.51 (3)	600	on end	1	1800	2.42	864	flat	6	2592	3.5
43 (86)	flat	1+ (2+)	774 (1548)	1.5 (3)	50	on end	1	900	1.75	80	on end	1	1440	2.8
75 (150)	flat	2 (3)	7200 (14,400)	1.5 (3)	70	flat	2	6720	1.4	86	flat	2	9216	2

Table 18.—Continued

Mine Model & type	Wt (lbs) per mine	Mine packaging data: No. of mines, etc., per crate	Wt. (lbs) per crate	Crate dimensions (ins): Lgth.	Width	Hgt.	Capacity of indicated army vehicles (Note: figures in parentheses indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space) — M-35 2½ ton cargo truck (Cargo space: 147 x 88 x60 ins): No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)
M-48 parachute flare	5	4. w/fuzes & trip wire	41	14.7	13.13	11	122 (244)	flat	2+ (4+)	488 (976)	2.5 (5)
M-49 static flare	1.4	a. 16, w/fuzes & trip wire	45	21.25	14.5	11	111 (180)	flat	3+ (5)	1776 (2880)	2.49 (4.04)
		b. 25, w/fuzes & trip wire	59	21.25	14.5	11	84 (170)	flat	3— (5)	2100 (4250)	2.47 (5)

NOTES.

1. Loads limited to: 16,000 lbs on roads; 6,500 lbs (3.25 tons) cross-country.
2. Maximum payload: 1,024 lbs (0.5 ton) internal; 3,000 lbs (1.5 tons) external
3. Maximum payload: 4,182 lbs (2.09 tons)

Table 18.—Continued

Capacity of indicated army vehicles (Note: figures in parentheses indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space)														
M-105 1½ ton trailer (Cargo Space: 133 x 87 x 71 ins)					M-47 2½ Ton Dump Truck (Cargo Space 100 x 70 x 15+ ins) (Volume determines capacity)					M-51 5 Ton Dump Truck (Cargo Space: 125 x 82 x 23 in) (Volume determines capacity)				
No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)	No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)	No. of crates	How carried	No. of tiers of crates	Total No. mines	Total wt. (tons)
73 (146)	flat	2+ (1—)	292 (584)	1.49 (2.98)	70	flat	2	280	1.43	96	flat	2	384	2
66 (132)	flat	2 (4—)	1056 (2112)	1.48 (2.96)	42	on end	1	672	0.94	50	flat	2	800	1.1
50 (101)	flat	2 (3—)	1250 (2525)	1.47 (2.97)	42	on end	1	1050	1.23	50	flat	2	1250	1.5

4. Mines are transported unarmed and w/o being assembled with firing chain components. These tables also are applicable to crated mines only
5. Safety in transporting mines and explosive items must be observed for all modes of transportation.

Table 19. Minefield Breaching/Clearing Average Time and Materiel Requirements

Method	Width of cleared lane (in meters)	Man-hours req'd per 100 meters	Remarks
Manual			
Location by probing	1 (footpath)	16–22	See note.
Removal by rope or explosives	8 oneway (vehicle lane)	38–44	See note.
Location by detector, assisted by probing	8 oneway (vehicle lane)	27–33	See note.
Removal by rope or explosives	8	220–247	See note.
Explosive			
Demolition snakes, M3A1	6	40–100	
Demolition snake M157 (Diamond Lil)	3.5–4.5	6–8	+6 – 8 manhours to assemble
Bangalore torpedo.	1 (footpath)	3.5–4.5	See note.

NOTE. Based upon average conditions of visibility and moderate enemy activity and normal U.S. countermeasures, i.e. screening of enemy observation and counter-battery fires against hostile artillery or other weapons covering the field.

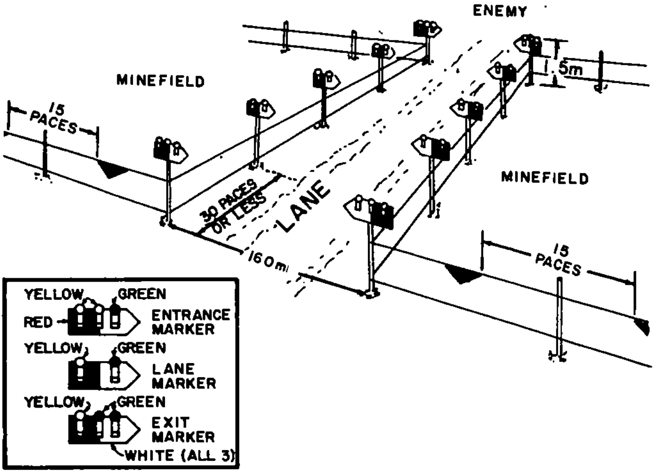


Figure 45. Standard minefield lane marking in rear area.

33. LOGISTICAL DATA

a. Logistical and Planning Data. See tables 17 and 18.

b. Material and Manpower Requirements. See table 19.

Section III. Reports and Records

34. REPORTING AND RECORDING

a. Reports.

(1) Three reports are required for every minefield laid. First is the report of intention to lay, which is made as soon as it is decided to install the minefield. The second report is the initiation of laying and is made when the laying unit is ready to begin. Third is the report of the completion of laying. All reports are classified SECRET. See FM 20-32.

(2) In addition, there is the written report of transfer made to the relieving commander by the commander of the unit responsible for the field when the transfer of responsibility is effected.

SECRET (WHEN COMPLETED) SHEET 1 OF 1

CO B, 15th Engr Combat Bn	30 Aug 00 June 63	Thomas Jones 2nd Lt 0?7?90	15-B-3C
LAYING UNIT	COMPLETION DATE AND TIME	OFFICER IN CHARGE (RANK, NAME, SERIAL NO)	MINEFIELD NUMBER

LANDMARKS

NO	COORDINATES	DESCRIPTION
1	302677	RJ
2	303070	SW Corner Building
3		
4		

INTERMEDIATE MARKERS

NO	DESCRIPTION
1	Three Steel Pickets Wrapped W/wire
2	
3	
4	

DESCRIPTION OF BOUNDARY FENCE: Standard

NO. OF STRIPS: 3 DESCRIPTION OF STRIP MARKERS: Stakes Driven Flush

LANES

NO	WIDTH	HOW MARKED (GENERAL INFORMATION)	MINES IN LANE: TYPE M15 NO	TYPE NO	TYPE NO
1	8m	Field Wire Pegged Down on ℄	4		
2					
3					

MAP SHEET: Talbotville

SHEET NO: E561 SCALE: 1/25000

RECORDER: John C Jones, Sgt

NOTES

Lane Entrance marked by 3 turns of tracing tape wrapped around bottom of fence picket

Lane Exit marked by one wooden stake driven flush alongside fence picket

4 M-15 mines laid in lane where it crosses strip A

ANTI-TANK MINES

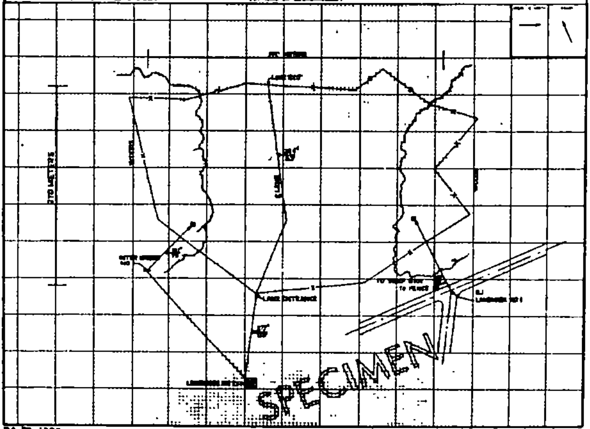
	TYPE M15 NO	TYPE NO	TYPE NO	TYPE NO	TOTAL AT MINES NO	[illegible] NO
TOTAL [illegible]	315				313	34
[illegible]	17				17	0
STRIP A						
B						
C						
D						
E						
F						

ANTIPERSONNEL MINES

	TYPE M16 NO	TYPE M2A4 NO	TYPE NO	TYPE NO	TOTAL AP MINES NO
TOTAL [illegible]	622	313			939
[illegible]	0	51			51
STRIP A					
B					
C					
D					
E					
F					

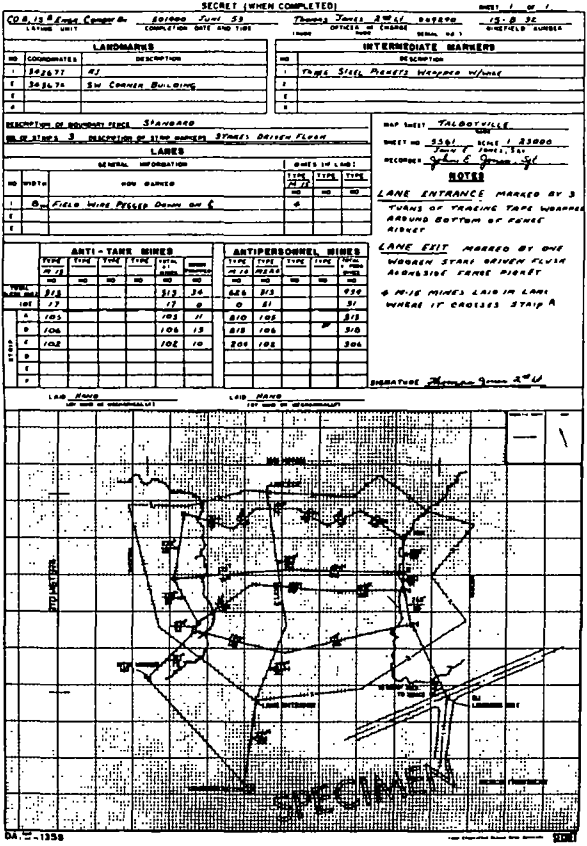
LAID: Hand (BY HAND OR MECHANICALLY) LAID: Hand (BY HAND OR MECHANICALLY)

SIGNATURE: Thomas Jones 2d Lt



DA FORM 1355 SECRET

Figure 46. Minefield record with minimum information.



SECRET (WHEN COMPLETED) SHEET 1 OF 1

CO B, 13th Engr Combat Bn — LAYING UNIT | 201900 June 53 — COMPLETION DATE AND TIME | Thomas Jones 2nd Lt 049290 — OFFICER IN CHARGE (NAME, GRADE, SERIAL NO.) | 15-B 32 — MINEFIELD NUMBER

LANDMARKS

NO	COORDINATES	DESCRIPTION
1	342677	RJ
2	343674	SW Corner Building
3		
4		

INTERMEDIATE MARKERS

NO	DESCRIPTION
1	Three Steel Pickets Wrapped W/wire
2	
3	
4	

DESCRIPTION OF BOUNDARY FENCE Standard

NO. OF STRIPS 3 DESCRIPTION OF STRIP MARKERS Stakes Driven Flush

LANES

NO	WIDTH	HOW MARKED	MINES IN LANE: TYPE M 15 NO	TYPE NO	TYPE NO
1	8m	Field Wire Pegged Down on ℄	4		
2					
3					

MAP SHEET Talbotville

SHEET NO 5561 SCALE 1 25000

RECORDER John E Jones, Sgt

NOTES

LANE ENTRANCE marked by 3 turns of tracing tape wrapped around bottom of fence picket

LANE EXIT marked by one wooden stake driven flush alongside fence picket

4 M-15 mines laid in lane where it crosses strip A

	Anti-tank: Type M 15 NO	Type NO	Type NO	Type NO	Total AT mines NO	Booby-trapped NO	Antipersonnel: Type M 16 NO	Type M2A4 NO	Type NO	Type NO	Total AP mines NO
TOTAL	313				313	34	626	313			939
IOE	17				17	0	0	51			51
STRIP A	105				105	11	210	105			315
STRIP B	106				106	13	212	106			318
STRIP C	102				102	10	204	102			306
STRIP D											
STRIP E											
STRIP F											

SIGNATURE Thomas Jones 2nd Lt

LAID Hand LAID Hand

SPECIMEN

DA FORM 1355

Figure 47. Minefield record with maximum information.

785-094 O-66—6

(3) A report of removal is made to the next higher commander immediately when friendly mines are removed.

(4) When any changes are made in a friendly minefield, a report of change is sent by the commander responsible for the minefield to the headquarters which maintains the written mine record.

(5) Progress reports are initiated according to unit SOP.

b. Records.

(1) The standard minefield record form is a single printed sheet as shown in the samples in figures 46 and 47. A standard minefield record form is prepared by the commander of the laying unit, signed by him, and sent to the next higher headquarters. It is classified SECRET. The number of copies prepared depends on the type of minefield and SOP. Normally one copy is forwarded to higher headquarters. The SOP should provide for dissemination of records up, down, and laterally. For this purpose, the record is photographically reproduced.

(2) When changes are made to a friendly minefield, a completely new record must be prepared on the standard form. It is marked REVISED, but retains the same minefield number.

(3) Boobytrapped areas are recorded as nuisance type minefields.

35. MINE SYMBOLS

Type unknown 

AT, boobytrapped 

Apers 

AT, double or multiple 

AT 

Boobytraps 

Toxic chemical 

Section IV. Enemy Minefields

36. RECONNAISSANCE

a. *Types.*

(1) Ground reconnaissance.

(2) Aerial reconnaissance.

(3) Reconnaissance by fire.

(a) Artillery, mortar, or rocket.

(b) Bombing.

b. *Reconnaissance Patrol.*

(1) A minefield reconnaissance patrol is normally comprised of an experienced officer or senior NCO, four to six trained men, and a security element armed with light automatic weapons and grenades (fig. 48).

(2) Depending upon the patrol's mission and types of mines it may encounter, equipment may include compasses, wirecutters, probes, mine detectors, disarming implements (wires, safety pins, and the like), tape and protective body armor. If secrecy is not essential, it may include prepared demolition charges, grapnels, light lines, and similar means for mine removal. Where toxic chemical mines may be encountered,

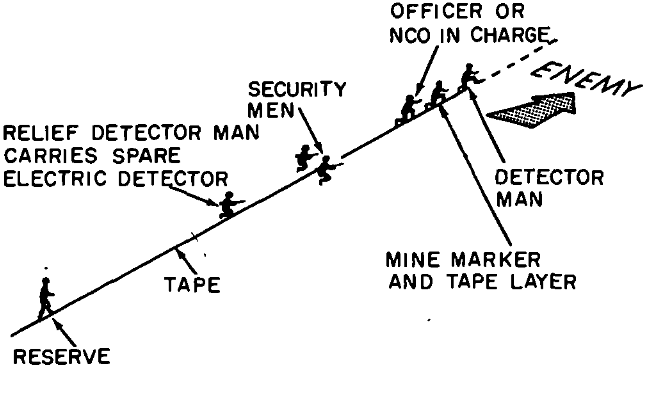


Figure 48. Minefield reconnaissance patrol.

take such equipment as protective clothing, chemical agent detector set, first aid supplies, and decontamination equipment.

(3) Where reconnaissance is preliminary to breaching, the patrol records information by a tape laid on the centerline of the path. Indicate location of tripwires or types of mines by knots tied on tape as follows:

Type	*No. of knots*
Apers mine	1
AT mine	2
Tripwire	3
New type mine	4
Toxic chemical mine	5

37. REPORTING AND RECORDING

a. *Reporting.* Report any knowledge or suspicion of the existence of an enemy minefield to the next higher commander immediately. This report is forwarded to Army headquarters and should include as much of the following information as is obtainable:

(1) Location and apparent boundaries of the enemy minefield.
(2) Bypasses around the field, if any.
(3) Type and density of mines.
(4) Patterns.
(5) Enemy defenses, fortifications, fire coverage, and observation.

A unit encountering an enemy minefield erects temporary warning signs, pending installation of standard markings as prescribed in paragraph 31 for friendly rear area minefields. A report is made to the next higher headquarters whenever enemy mines are removed.

b. *Recording.* Use the standard NATO, if available, or the U.S. minefield record form when preparing a record of an enemy field. This record contains the identity of the unit preparing it and is identified at the top by the words ENEMY MINEFIELD. Include a full description of the markings, a sketch or overlay showing location, and other information as outlined in paragraph 34. Whenever additional information becomes available, another record is prepared and submitted to higher headquarters.

Section V. Breaching and Clearing Operations

38. MINE DETECTION METHODS

a. *Visual.* Visual search is an important method of locating mines. Experience with the mine habits of an enemy is often of great help in locating his mines.

b. *Probing.* In this method, the earth is penetrated with a sharp instrument such as a mine probe, a bayonet, or a stiff wire. Probing is the best way to locate buried nonmetallic mines, particularly the small anti-personnel type similar to the M14. When probing, the soldier moves on hands and knees with sleeves rolled up to locate tripwires and pressure prongs.

c. *Electrical Detection.* When used in connection with visual inspection and probing, mine detectors (metallic and nonmetallic) are effective aids in locating mines. Both types of detectors, metallic or nonmetallic, may give a signal when items other than mines are detected; experience in operating each type enables the user to recognize the characteristics of the signal to be expected for each type of mine. For the soldier assigned to this task, it is an exacting job, and he must constantly watch for boobytraps and tripwires. Twenty minutes at a time should be the maximum period for each soldier.

39. METHODS OF BREACHING MINEFIELDS

a. *Hasty and Deliberate Methods.* Breaching is the use of any means available to open a lane through a mined area for the passage of vehicles or personnel. It is either hasty or deliberate.

(1) Hasty breaching requires speed with a minimum of planning. Leading combat units must often clear a lane of all mines. Special mechanical or explosive devices, artillery or aerial bombardment, or specially trained teams accomplish this. See table 19, Minefield Breaching/Clearing Average Time and Material Requirements.

(2) Deliberate breaching requires extensive planning, and is normally done by engineers or other trained personnel, supported by combined arms. Deliberate breaching is usually made in the following phases:

(a) Reconnaissance
(b) Plans and preparations.
(c) Breaching and attack.
(d) Passage of forces.

b. *Explosive Methods.* The use of explosives is the easiest method of removing mines. One pound of explosive, with a standard firing assembly, placed on top of a mine will detonate most mines. A detonating cord firing system may connect a group of mines to fire them simultaneously. Several different rigid and flexible line charges are available for breaching foot and vehicle lanes through minefields. They range in size from the man-carried bangalore torpedo to the tank pushed "snakes". The various models available are described in TM 9-1375-200, *Demolition Materials.*

c. *Mechanical Methods.* The term, mechanical methods, refers to use of rollers, flails, derelict vehicles, etc., pushed by armored vehicles.

d. *Platoon Organization and Equipment for Manual Breaching.* Table 20 and figure 49 show the organization of this platoon and the operation of a breaching party, respectively.

Table 20. Platoon Organization and Equipment for Manual Breaching

Personnel	Officer	NCO	EM	Equipment
Officer in charge .	1	. . .	. . .	Lensatic compass, map, radio, and individual weapon.
Platoon sergeant .	. . .	1	. . .	Same as OIC, except no radio.
No. 1 breaching party	. .	1	7	2 portable detectors, 2 probes, mine markers, marking tape or wire on reels, safety pins, clips, smooth wires (18" lengths), 1-lb. blocks of explosive, blasting caps, detonating cord, safety fuze, fuze lighters, crimpers, and portable radio.
No. 2 breaching party. . . .	. . .	1	7	Same as No. 1 breaching party.
No. 3 breaching party	. . .	1	7	Same as No. 1 breaching party.
Support party. . .	.	1	10	Same as No. 1 party, plus: sledges or mauls, hammers, pliers, wirecutters, 2" by 4" stakes at least 6' long, individual weapons, litters, lanemarking signs, gauntlets, barbed wire, stakes and pickets.
Total	1	5	31	

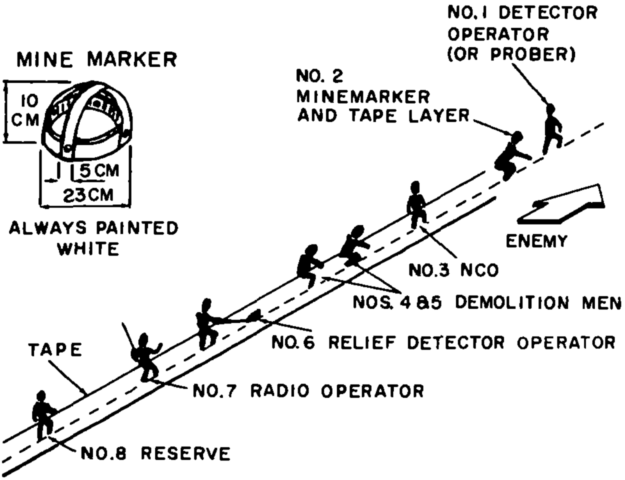


Figure 49. Minefield breaching party.

40. METHODS OF CLEARING MINEFIELDS

a. *Introduction.* To clear a minefield is to remove or destroy all mines, enemy or friendly, in the field. The methods used in mine clearance are similar to those in breaching, but are more deliberate and carefully applied. Minefield records are used to the maximum. Brush and other cover in the minefield area may be removed by burning.

b. *By Probing.* To clear mines from an enemy field or a friendly field for which records are unavailable, the procedure described here is to be considered as a guide only. The platoon is used as the basic unit, and mines are blown in place or removed by rope.

(1) The platoon is organized as shown in table 21. The clearing parties operate as depicted in figure 50.

(2) The use of explosive is described in paragraph 39.

(3) Rope removal is safer than removing mines by hand. Proceed as follows:

(a) Uncover top of mine.

(b) Attach rope or wire at least 45 meters long to mine.

Table 21. Platoon Organization and Equipment for Manual Clearing

Personnel	Officer	NCO	EM	Equipment
Officer in charge	1	. . .	. .	Map, lensatic compass, portable radio, and all available information on mines in area.
No. 1 clearing party	. . . .	1	10	Mine probes, tracing tape on reels, mine markers, grapnels, rope or wire in 45 meters lengths, 45-cm lengths of 10-and 16-gage wire, demolition equipment, shovels or entrenching tools, and portable radios
No. 2 clearing party	. . . .	1	10	Same as No. 1 clearing party
No. 3 clearing party	. . . .	1	10	Same as No. 1 clearing party
Control party	. . . .	1	2	Map, lensatic compass, portable radio (2 preferably, 1 for platoon and 1 for company net)
TOTAL	1	4	32	

(c) Make sure all personnel nearby have taken cover.

(d) Take cover at least 45 meters from mine and pull it from hole. (Make sure the place of cover, such as a foxhole, is checked for enemy boobytraps prior to this action.)

(e) Wait 30 seconds before approaching mine.

(f) Recheck hole for additional mines.

(g) Remove fuze or cut the firing chain.

(h) Carry mine to a dump for disposal or reuse.

c. *By Use of Detectors.*

(1) The platoon is organized the same as for probing, except that each clearing party has three electrical mine detectors and is reduced by one man. The duties and procedures are basically the same as for probing.

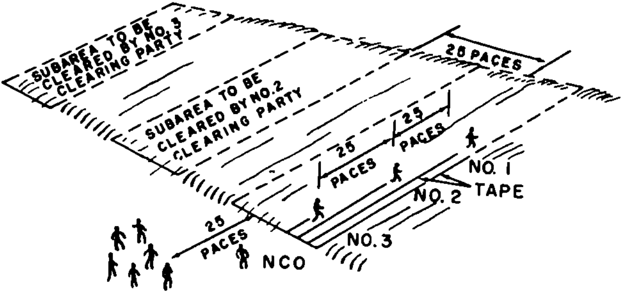


Figure 50. Number 1 clearing party in operation.

(2) Figure 51 shows the clearing party in action, using electrical detectors.

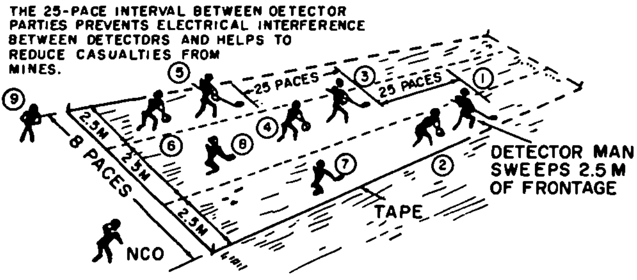


Figure 51. Clearing party using electrical detectors.

CHAPTER 4
FIELD FORTIFICATIONS

Section I. General Data

41. PRIORITY OF TASKS

Many of the jobs involved in preparing a defensive position are carried on concurrently, but some will be executed in priority. The commander, therefore, specifies the sequence for the preparation of the position and any special precautions to be taken regarding camouflage. The following is a recommended sequence.

a. Establish security.

b. Position weapons.

c. Clear fields of fire, remove objects, mask observation and determine ranges to probable target locations.

d. Provide for signal communications and observation systems.

e. Prepare weapons emplacements and individual positions to include overhead cover, and camouflage them concurrently.

f. Lay minefields and prepare important demolitions.

g. Prepare obstacles (other than minefields) and less vital demolitions.

h. Prepare routes for movement and for supply and evacuation.

i. Prepare alternate and supplementary positions.

j. Prepare CBR protective shelters as required.

k. Prepare deceptive installations in accordance with deceptive plans of higher headquarters.

42. CLEARING FIELDS OF FIRE

a. Principles. There is little opportunity to clear fields of fire when a unit is in contact with the enemy. Individual riflemen and weapons crews must select the best natural positions available. Usually, there is only time to clear areas in the immediate vicinity of the position. However, in preparing defensive positions for expected contact with the enemy, suitable fields of fire are cleared in front of each position. The following principles are pertinent:

(1) Excess of careless clearing will disclose firing positions.

(2) In areas organized for close defense, clearing should start near the position and work forward for at least 100 meters or to the maximum effective range of the weapon if time permits.

(3) A thin natural screen of vegetation should be left to hide defensive positions.

b. Procedure.

(1) Remove the lower branches of large scattered trees in sparsely wooded areas.

(2) In heavy woods, fields of fire may neither be possible nor desirable within the time available. Restrict work to thinning the undergrowth and removing the lower branches of large trees. Clear narrow lanes of fire for automatic weapons.

(3) Thin or remove dense brush since it is never a suitable obstacle and obstructs the field of fire.

(4) Cut weeds when they obstruct the view from firing positions.

(5) Remove brush, weeds, and limbs that have been cut to areas where they cannot be used to conceal enemy movements or disclose the position.

(6) Do only a limited amount of clearing at one time. Overestimating the capabilities of the unit in this respect may result in a field of fire improperly cleared which would afford the enemy better concealment and cover than the natural state.

(7) Cut or burn grain, hay, and tall weeds.

c. *Manhours Required.* The manhours required to clear 100 square meters are tabulated in table 22.

Table 22. Manhours Required to Clear 100 Square Meters

Description of clearing	Tools used	Manhours required*
Medium clearing: Clearing undergrowth and trees less than 12" in diameter	Saws, axes	5
Light clearing: Clearing small brush	Axes, brush-hooks, machetes, and hatchets	2.5

* Figures are for daylight; for work at night, increase labor by 50 percent

Section II. Emplacements

43. TYPES

a. *Requirements.* Emplacements shauld be so constructed as to permít each individual or weapon crew ta meet the following requirements:

(1) Permit each individual ar eoch weapons crew to occomplish ossigned fire missions.

(2) Be simple ond easily constructed.

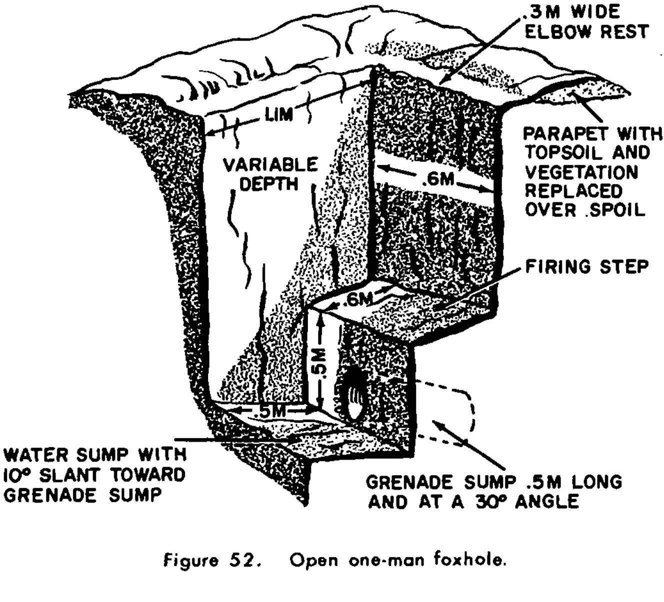


Figure 52. Open one-man foxhole.

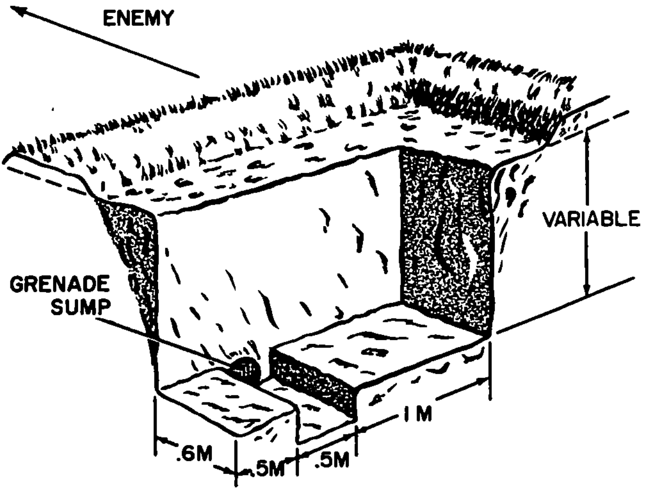


Figure 53. Open two-man foxhole.

(3) Provide maximum protection with minimum time and labor.
(4) Be camouflaged and concealed.
(5) Provide protection against mechanized attack.
(6) Provide protection against nuclear attack.

b. *Types.* See figures 52 through 57 for different types.

c. *Labor Requirements for Emplacements.* See tables 23 and 24.

44. REVETMENTS

a. *Retaining-Wall Type.* This type of revetment is used in relatively unstable soils. The horizontal layers of the wall are tied together so

Table 23. Time and Material Requirements for Personnel and Individual Weapons Emplacement

Type of emplacement or shelter	Total construction time in man hours for construction with D-handle shovels and ordinary carpentry tools					Weight and volume of materials							
	Revetment materials for cover support only		Complete revetment		No revetment materials used	Revetment materials for cover support only				Complete revetment			
						Corrugated metal construction		Sized lumber construction		Corrugated metal construction		Sized lumber construction	
	Corrugated metal constr.	Sized lumber constr.	Corrugated metal constr.	Sized lumber constr		Weight (lb.)	Volume (cu. ft.)	Weight (lb.)	Volume (cu. ft)	Weight (lb.)	Volume (cu. ft.)	Weight (lb.)	Volume (cu. ft.)
Improved crater	N/A	N/A	N/A	N/A	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Skirmishers trench	N/A	N/A	N/A	N/A	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Prone emplacement	N/A	N/A	N/A	N/A	1.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Open one man foxhole	N/A	N/A	3.5	4.5	2.0	N/A	N/A	N/A	N/A	190	3.5	240	8
Open one man foxhole with offset	9.0	14.0	10.0	16.0	N/A	50	0.6	180	5 5	240	4.0	420	13.0
One man foxhole with half cover	2.5	3 0	4 5	5.5	N/A	10	0.1	20	0.6	200	3.5	260	8.0
One man foxhole with half cover and offset	10 0	14.0	12.0	18.0	N/A	60	0.7	200	6.0	250	4.0	440	14.0
Open two man foxhole	N/A	N/A	6.0	8.0	3.0	N/A	N/A	N/A	N/A	280	5.0	320	10.0
Deepened two man foxhole	N/A	N/A	8 0	10.0	5.0	N/A	N/A	N/A	N/A	300	5.5	375	12.0
Two man foxhole with half cover.	4.0	4.0	8.0	10.0	N/A	15	0.2	32	1.0	280	5.0	350	11.0
Two man foxhole with half cover and two offsets.	20.0	30.0	22.0	35.0	N/A	120	1.5	400	12.0	380	6.0	700	22.0
Two man foxhole with half cover and adjoining shelter.	11.0	17.0	13.0	22.0	N/A	100	1 2	560	18.0	460	7.0	880	28.0
Open fighting trench (25′ length)	N/A	N/A	28.0	32.0	21.0	N/A	N/A	N/A	N/A	490	8 0	710	22.0
Fighting trench with full cover (25′ length).	27.0	29.0	35.0	40.0	N/A	240	4.0	360	11.0	730	12.0	1060	33.0

Table 24. Characteristics of Crew Served Infantry and Artillery Weapons Emplacements

Type of emplacement or shelter	Total construction time in man hours for construction with 0-handle shovels and ordinary carpentry tools					Weight and volume of materials							
						Revetment materials for cover support only				Complete revetment			
	Revetment materials for cover support only		Complete revetment		No revetment materials used	Corrugated metal construction		Sized lumber construction		Corrugated metal construction		Sized lumber construction	
	Corrugated metal constr	Sized lumber constr.	Corrugated metal constr.	Sized lumber constr.		Weight (lb.)	Volume (cu. ft.)	Weight (lb.)	Volume (cu. ft.)	Weight (lb.)	Volume (cu. ft.)	Weight (lb.)	Volume (cu. ft)
CHARACTERISTICS of CREW SERVED WEAPONS EMPLACEMENTS													
Open automatic rifle emplacement	N/A	N/A	7.0	8.0	4.0	N/A	N/A	N/A	N/A	170	3 0	200	6.0
Automatic rifle emplacement with 18" of cover.	4.0	5 0	6.0	7.0	N/A	45	0.5	70	2 0	220	4.0	270	10.0
Open horseshoe type .30 cal machinegun emplacement	N/A	N/A	5.0	7.0	2 0	N/A	N/A	N/A	N/A	280	5.0	450	14.0
Open 2 one-man foxhole type fight machinegun emplacement.	N/A	N/A	6.0	7.0	4 0	N/A	N/A	N/A	N/A	530	10 0	640	20.0
Horseshoe type light machinegun emplacement with full cover	9.0	11 0	11.0	14.0	N/A	190	4.0	250	7 0	720	13.0	890	27.0
2 one-man foxhole type lt. machinegun type emplacement with ½ cover and adjoining shelter	15.0	22.0	19 0	28.0	N/A	250	2.5	630	20.0	520	7 5	850	30.0
Circular type 50 cal machinegun emplacement	N/A	N/A	14.5	16.5	10.0	N/A	N/A	N/A	N/A	300	5.0	420	13.0
Pit type emplacement for 3.5 rocket launcher.	N/A	N/A	5.0	6 0	3.0	N/A	N/A	N/A	N/A	110	1.0	160	5.0

Table 24.—Continued

Type of emplacement or shelter	Total construction time in man hours for construction with D-handle shovels and ordinary carpentry tools					Weight and volume of materials							
	Revetment materials for cover support only		Complete revetment		No revetment materials used	Revetment materials for cover support only				Complete revetment			
						Corrugated metal construction		Sized lumber construction		Corrugated metal construction		Sized lumber construction	
	Corrugated metal constr	Sized lumber constr.	Corrugated metal constr.	Sized lumber constr.		Weight (lb.)	Volume (cu. ft.)	Weight (lb.)	Volume (cu. ft.)	Weight (lb.)	Volume (cu. ft.)	Weight (lb.)	Volume (cu ft.)
81-mm mortar emplacement	N/A	N/A	12.0	N/A	N/A	N/A	N/A	N/A	N/A	210	3.0	N/A	N/A
4.2-inch mortar emplacement.	N/A	N/A	29 0	N/A	N/A	N/A	N/A	N/A	N/A	370	6.0	N/A	N/A
Recoilless rifle position (mounted)	N/A	N/A	N/A	N/A	30 0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Recoilless rifle position (dismounted).	N/A	N/A	N/A	N/A	17.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CHARACTERISTICS of ARTILLERY WEAPONS EMPLACEMENTS													
105-mm howitzer emplacement ...	N/A	N/A	N/A	N/A	100 0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
155-mm howitzer emplacement.	N/A	N/A	N/A	N/A	170 0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

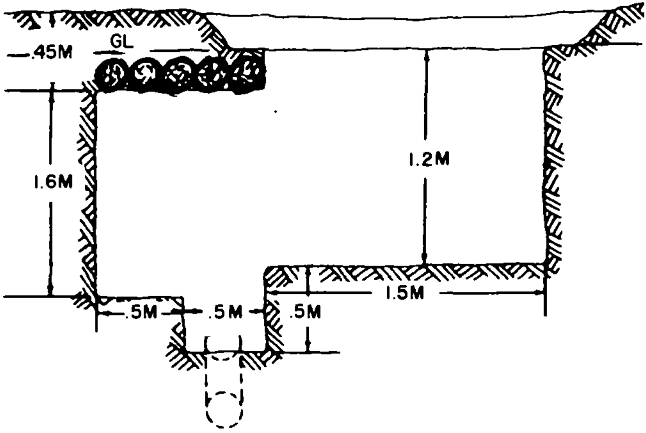


Figure 54. Two-man foxhole with half cover.

that the wall acts as a structural unit without any sliding of one part upon another. This type of revetment (fig. 58) may be constructed of sandbags, sod blocks, and various expedients as described below. The methods of building with these construction materials are as follows:

(1) Sandbags are useful for temporary revetments. Lay them as follows:

(a) Fill to three-fourths of full capacity (5" × 10" × 20").

(b) Place a double row of alternate headers and stretchers as shown in figure 58.

(c) Place about 800 sandbags per 25 square meters of revetted surface.

(d) Stabilize bags to prolong their life by filling them with 1 part cement to 10 parts dry earth; in a sand-gravel mixture, increase ratio to 1 to 6.

(e) Tuck in bottom corner of bags after filling.

(f) Slope the wall toward revetted face at slope of 1 to 4.

(g) With stabilized sandbags the foundation should be about 15 centimeters below floor level.

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(h) Place bags perpendicular to slope.
(i) Place all bags on bottom row as headers (fig. 58).
(j) Alternate intermediate rows as headers and stretchers.
(k) Have top row consist of headers.
(l) Place side seams and choked ends on inside.

(2) Sod blocks of thick sod with good roots provide satisfactory revetting material. Cut sod blocks into 20- by 45-centimeter sections and lay them flat, using the alternate stretcher-method as with sandbags ((1) above). Lay sod grass-to-grass and soil-to-soil except for the top layer which is placed with grass upward for camouflage purposes. Drive two wooden pegs through each section of every layer as it is completed. Lay this sod revetment at a slope of 1 to 3.

(3) Expedients may be used, such as ice blocks in cold weather. They are stacked the same as sandbags or sod. Water is run over them

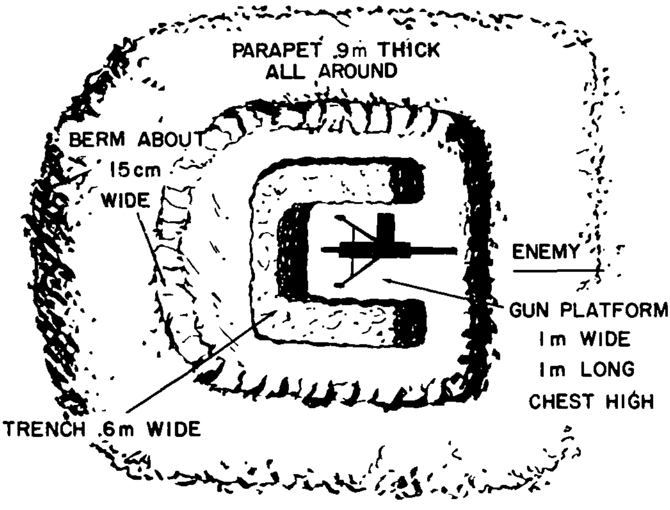


Figure 55. Horseshoe type emplacement.

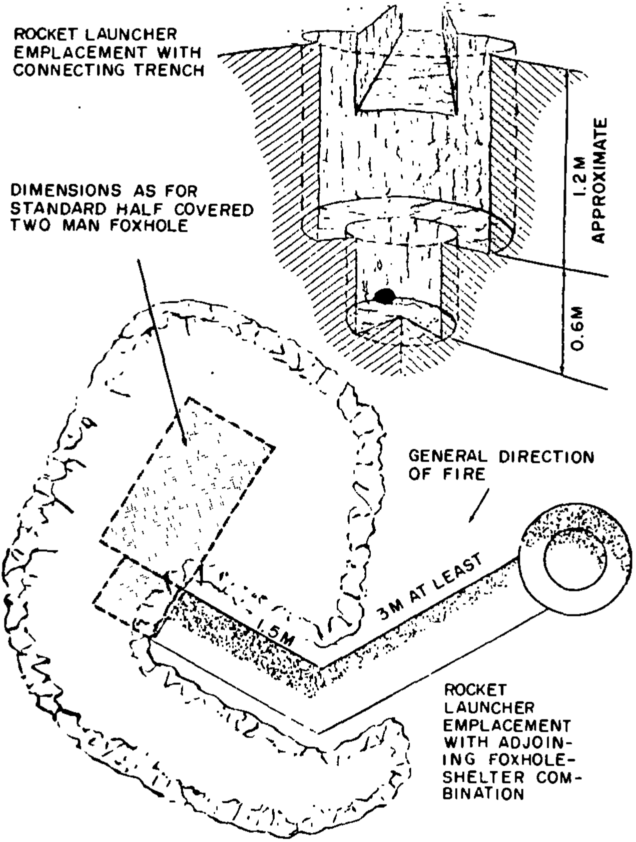


Figure 56. Rocket launcher emplacement.

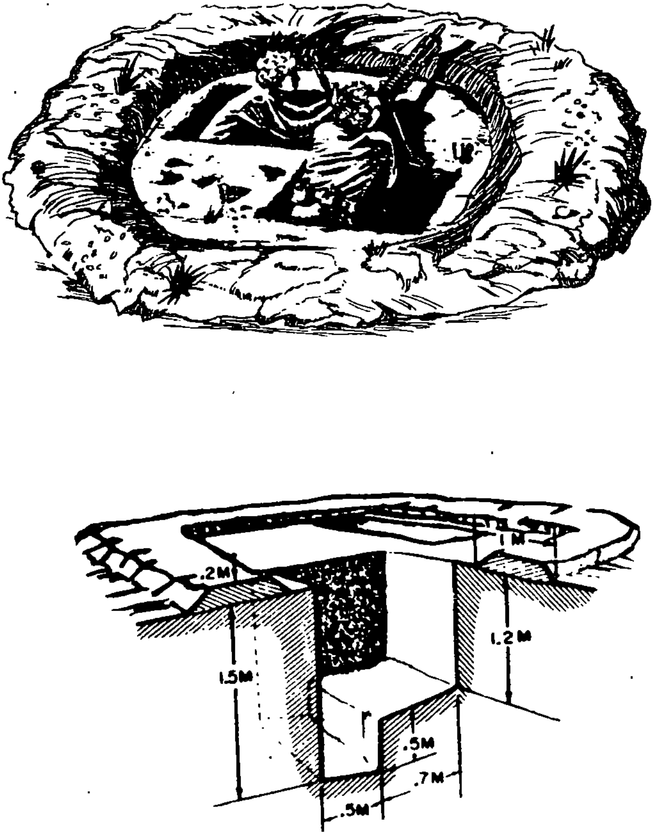


Figure 57. Two one-mon foxhole types.

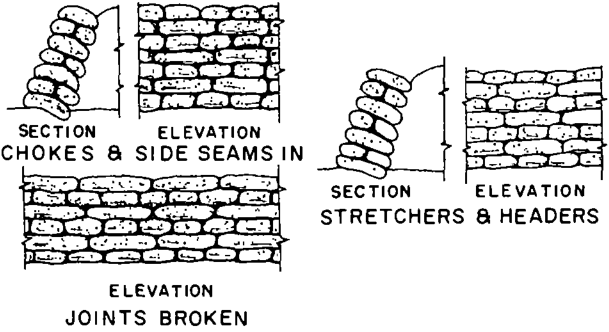


Figure 58. Retaining wall type of revetment.

to bind by freezing. Another expedient is earth-filled packing cases or ammunition boxes, which are placed in position and nailed to the layer below. The boxes are then filled with earth or rock. In wooded areas, small timber may be used as revetting material.

b. *Facing Type.* This type of revetment serves mainly to protect revetted surfaces from weather and damage caused by occupation. This revetment consists of facing (revetting) material and support which hold this material in place. The top of the facing is set below ground level so that the revetting is not damaged by tanks crossing the emplacement.

(1) Materials used in facing may be brushwood bundles, continuous brush, pole and dimensional timbers, corrugated metal, or burlap and chicken wire. Construction methods of each type are described in (3) below.

(2) Methods of support.

(a) Timber frames of dimensioned timber are built to fit the bottom and sides of the position and hold the facing material apart. This insures that the excavated width remains stable.

(b) Pickets are driven into the ground on the position side of the facing material and held tightly against the facing by bracing the pickets apart or fastening their tops to stakes or holdfasts (fig. 59).

(3) Methods of constructing facing type revetments.

(a) The size of pickets depends upon the soil type and the kind

of facing material, but timber pickets should *not* be smaller than 7.6 centimeters in diameter. Maximum spacing between pickets should be 1.8 meters. Steel wire fence U-shaped pickets are excellent for revetting. Pickets are driven at least 0.46 meters into the floor of the position. Where the pickets are anchored at the top, proceed as shown in figure 59.

(b) A brushwood bundle (hurdle) is a woven revetment unit usually 1.8 meters long and of required height.

(c) The pole revetment is similar to the continuous brush revetment, except that a layer of small horizontal round poles cut to wall length is used. If available, boards or planks are used.

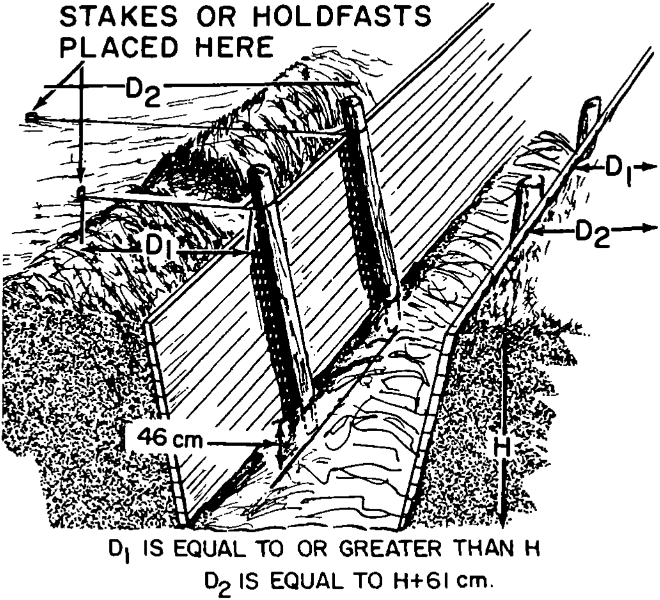


Figure 59. Method of anchoring pickets.

(d) Corrugated metal sheets or pierced steel planks ore strong, durable, and rapidly installed. They may be used for any height or length of revetment. Smear metal surfaces with mud to eliminate possible reflection of thermal radiation and to aid comouflage.

45. BUNKERS

o. For protection against shells and bombs, see tobles 25 and 26.

Table 25. Material Thicknesses in Centimeters Needed Against Projectiles and Bombs Exploding 15 Meters Awoy

Material	High-explosive shells and rockets			General-purpose bombs			
	75-mm	105-mm	155-mm	100-lb	250-lb	500-lb	1,000-lb
Solid Walls:							
Brick masonry.	10	15	20	20	25	33	43
Concrete, ploin	10	13	15	20	25	38	46
Concrete, reinforced. . . .	8	10	13	18	23	30	38
Timber. . . .	20	25	36	38	46	60	76
Walls of loose material between boards:							
Brick rubble. .	23	25	30	45	60	71	76
Gravel, small stones. . . .	23	25	30	45	60	71	76
Earth[1]. . .	38	45	60	60	76	...	...
Sandbags filled with:							
Brick rubble. .	25	25	50	50	50	76	100
Gravel, small stones . . .	25	25	50	50	50	76	100
Sand[1]	25	25	50	76	76	100	100
Earth[1]	50	50	76	76	100	100	127
Poropets of:[2]							
Sond[1]	30	45	60	60	90	90	120
Earth[1]	60	90	120	90	120	152	....

[1] Figures based on dry material. If wet moterial, double figures.

[2] Figures given to nearest 15 cm.

Table 26. *Material Thicknesses in Centimeters Needed for Protection Against Direct Hits by Direct-Fire Weapons*

Material	Small-arms and machine-gun (7.92-mm) fire at 100 m[1]	Antitank rifle (7.92 mm) fire at 100 m.	20-mm antitank fire at 200 m	37-mm antitank fire at 400 m.	50-mm. antitank fire at 400 m.	75-mm. direct fire, 500 to 1,000 m.	88-mm direct fire, 500 to 1,000 m	Remarks
Solid walls.[2]								
Brick masonry	45	60	76	152	....	....	....	
Concrete, not reinforced[3]	30	45	60	107	120	137	198	Plain, formed-concrete walls.
Concrete, reinforced	15	30	45	90	107	120	198	Structurally reinforced
Stone masonry	30	45	76	107	137	152	....	These figures can be taken as guides only.
Wood	60	90	120	....	....	....	....	These figures can be taken as guides only.
Timber	90	152	....	....	....	....	....	These figures can be taken as guides only
Walls of loose material packed between boards[2]								
Brick rubble	30	60	76	152	180	....	....	
Clay, dry	90	120	....	....	....	....	....	Add 100 % if wet
Loam, dry	60	90	120	....	....	....	....	Add 50 % if wet
Gravel or small crushed rock	30	60	76	152	180	....	....	
Sand, dry	30	60	76	152	180	....	....	Add 100 % if wet.
Sandbags filled with								
Brick rubble	51	76	76	152	178	....	....	
Clay, dry	102	152	....	....	....	....	....	Add 100 % if wet
Loam, dry	76	127	152	....	....	....	....	Add 50 % if wet
Concrete, gravel or small crushed rock	51	76	76	152	178	....	....	
Sand, dry	51	76	76	152	178	....	....	Add 100 % if wet.
Loose parapets of[2]								
Clay	107	152	....	....	....	....	....	Add 100 % if wet.
Loam	90	120	152	....	....	....	....	Add 50 % if wet.
Sand	60	90	120	....	....	....	....	Add 100 % if wet.

NOTE. Protective thicknesses given are for a single shot only (except [1]) Where direct fire weapons are able to get five or six hits in the same area, the required protective thickness is approximately twice that indicated

[1] One burst of five shots.

[2] Thicknesses given to nearest 15 cm.

[3] For 3,000 psi concrete.

b. The protective cover and at least the roof of the supporting structure of an emplacement should be a design unity that freely moves in unison. That is, the overall cover and roof must be rigid enough to displace as a unit, yet the construction must be able to absorb or dampen the shock of an exploding shell.

c. Practical fulfillment of this design unity is a sandwich construction in which the two outer layers, burster course, and roof structure, possess a certain amount of both rigidity and resiliency, and the middle layer is a cushion of porous consistency.

d. The most effective test example of the design unity for resistance to direct hits of 155-mm, fuze-delay shells was the following design (see fig. 60)·

(1) Burster course — 1 foot (30½ cm) of 6 inches (15 cm)—to 8 inches (20 cm) rock.

(2) Cushion layer — 1 foot (30½ cm) thick of dry uncompacted soils.

(3) Structure roof—10 inches (25 cm) thick of 2 inch (5 cm) by 12 inch (30½ cm) planks laid in five layers, each layer 90° to adjacent layers.

Figure 60. Bunker.

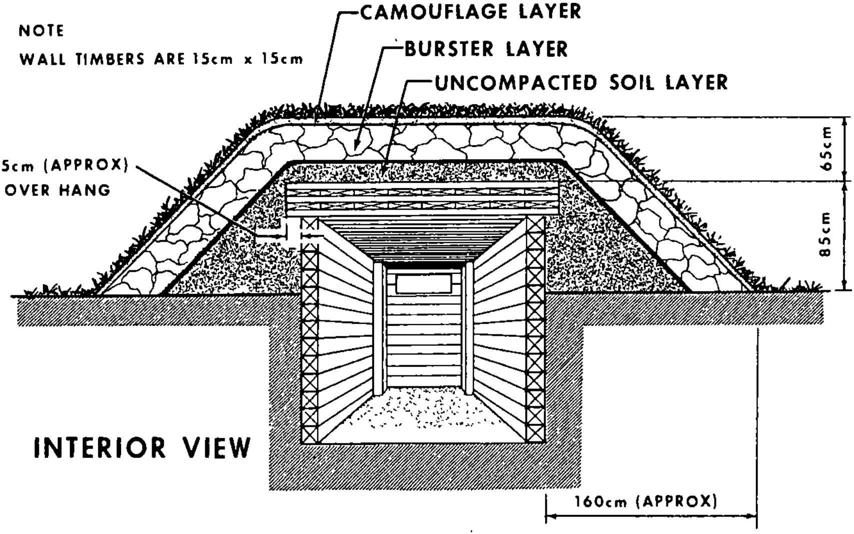
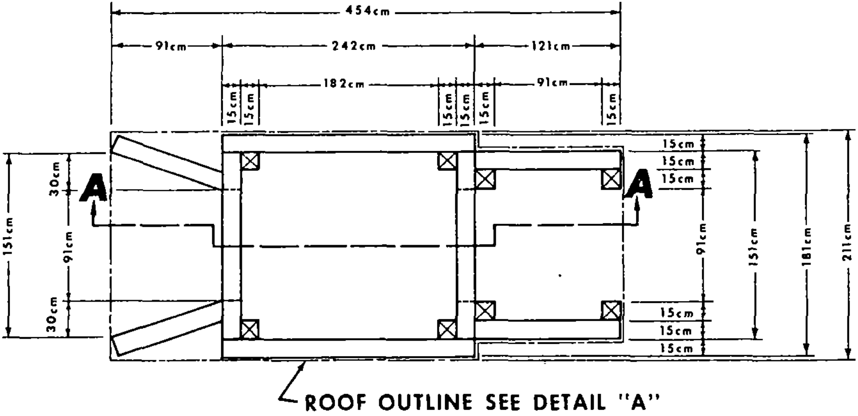


Figure 60—Continued.



PLAN VIEW

Figure 60—Continued.

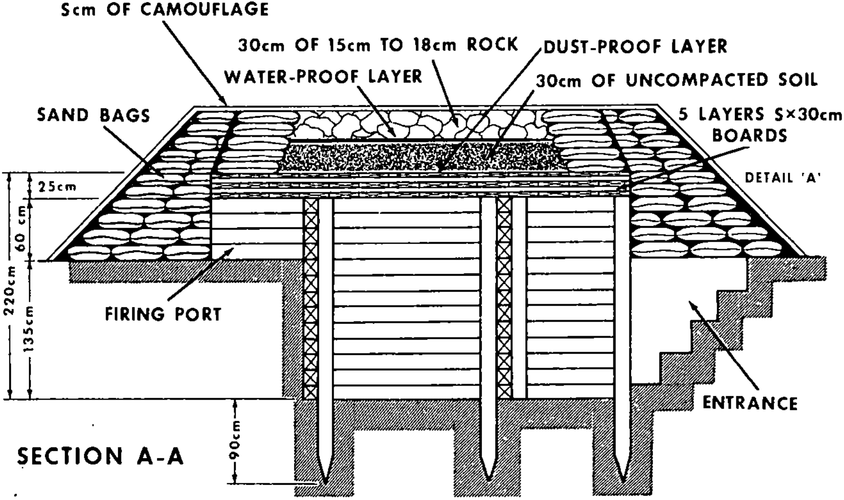


Figure 60—Continued.

ITEM	DESCRIPTION	NO. PCS
ROOF	5cm × 30cm × 2.11m Long — Wood	48pcs
	5cm × 30cm × 4.54m Long	14pcs
SIDE WALLS	15cm × 15cm × 2.42m Long — Wood	26pcs
ENTRANCE WALL	15cm × 15cm × 1.21m Long — Wood	26pcs
FIRING PORT AND ENTRANCE DOOR	15cm × 15cm × 30cm Long — Wood	26pcs
FRONT AND REAR WALLS	15cm × 15cm × 1.51m Long — Wood	13pcs
FIRING PORT AND RETAINING WALL	15cm × 15cm × 1.00m Long — Wood	8pcs
SIDE POST	15cm × 15cm × 2.85m Long — Wood	6pcs
SIDE POST	15cm × 15cm × 1.95m Long — Wood	2pcs

Figure 60—Continued.

e. In obtaining protection from direct hits of deloyed-fuze shells, it is importont thot the burster course be thick and rigid enough to effect detonation before the shell has passed through it. A 1-foat (30½ cm) thickness of 6-inch (15 cm) —to 8-inch (10 cm) stone seems to be optimum for ammunition up through 155 mm.

f. The camouflage loyer of soil over the burster course should be obout 2 inches (5 cm) thick.

g. In timber construction, notching or grooving should be ovoided.

h. Timber field fortificotions with solid walls are undoubtedly stronger than the post, cap, and stringer type but require considerably more timber.

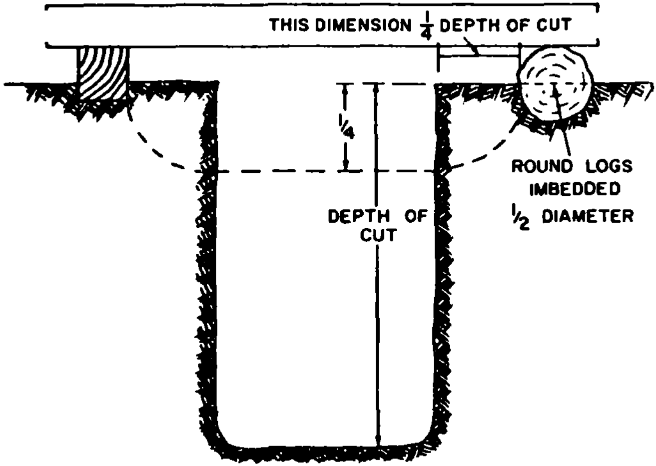


Figure 61. Support of overheod cover on eorth bonks.

i. It is preferoble thot o field fortificotion structure be bosed on the excovation floor, insteod of the ground-up type. If bosed on the ground-up type, columns (post) should extend down into the ground ot the four corners for the purpose of onchoring ond supporting the structure.

j. See figures 60 ond 61.

46. IMPROVISED OBSTACLES

See figures 62 through 66.

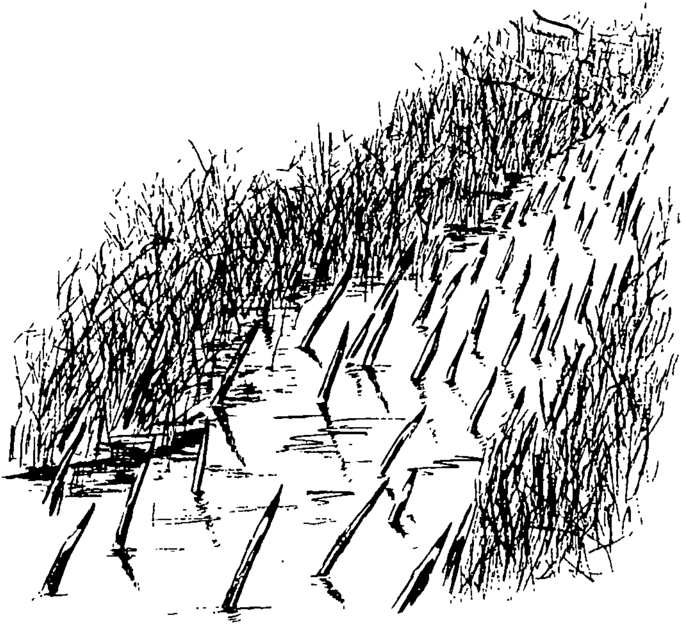


Figure 62. Belt of imbedded sharpened stakes.

Figure 63. Panji jungle trap.

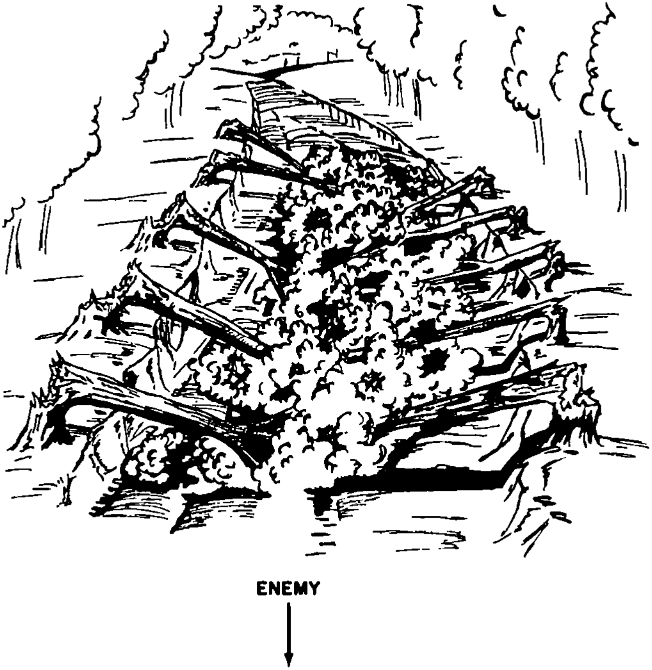


Figure 64. Abatis used as roadblock.

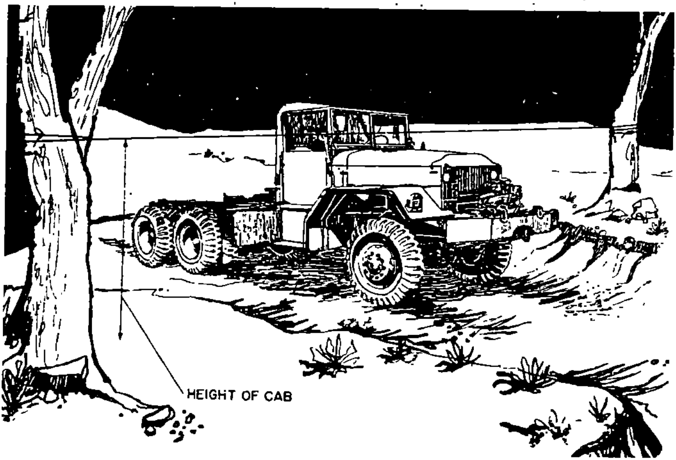


Figure 65. *Wire-rope roadblock.*

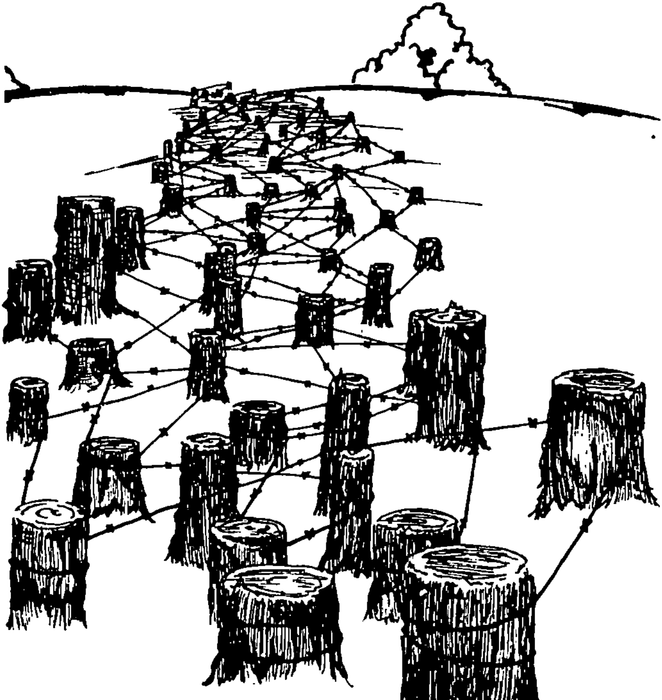


Figure 66. Belt of log post obstacles.

Section III. Wire Obstacles

47. ESTIMATING BARBED WIRE REQUIREMENTS

When the length of front is taken as straight line distance between limiting points, the total length of wire obstacles may be estimated as follows:

a. *Tactical Wire.* Length of tactical wire is 1¼ times the length of front times number of belts. This can be either three belts of 4- and 2-pace double apron fence or two belts of triple standard concertino.

b. *Protective Wire.* Length of protective wire entanglement for a defensive position is 5 times the length of the platoon front times number of belts, times the number of platoons. Because protective wire usually encircles each platoon, the length of entanglement per individual platoon is 2½ times the platoon frontage. This can be 1 belt of 4- and 2-pace double apron fence or 1 belt of triple standard concertino.

c. *Supplementary Wire.* Supplementary wire in front of the FEBA breaks up the line of tactical entanglements. It is 1¼ times the unit frontage, times the number of belts, times the number of platoons. Behind the FEBA, it is 2½ times the unit depth, times the number of belts. Supplementary wire should be of identical construction to the wire it supplements.

d. *Supply and Labor.* For construction estimates of manhours and materials, see tables 27 and 28.

Table 27. Wire Entanglement Materials

Material		Approx weight, Kg	Approx length, M	No. carried by 1 man	Approx weight of man-load, Kg
Reel		47.5	366	½	24
Bobbin		3.5-4.0	27.5	4-6	14.5-24.5
Standard barbed-wire concertina		25	15.2	1	25
Expedient barbed-wire concertina		13.5	6.1	1	13.5
Screw pickets	Long	4	1.6	4	16.3
	Medium	2.7	0.81	6	16.3
	Short	1.8	0.53	8	14.5
U-shaped pickets	Extra Long	7.25	2.4	3-4	21.8-29.0
	Long	4.5	1.5	4	18.1
	Medium	2.7	0.81	6	16.3
	Short	1.8	0.61	8	14.5
Wooden pickets	Extra Long	7.7-10.5	2.13	2	15.4-20.8
	Long	5.4-7.25	1.5	3	16.3-21.7
	Short	1.4-2.7	0.75	8	11.0-21.7

Table 28. Material and Labor Requirements for 300-meter Sections of Various Barbed-Wire Entanglements

Type of entanglement	Pickets				Barbed wire, no. of 400 m, 47.5-Kg reels[1]	No. of concertinas[4]	Staples	Kgs of materials per lin m of entanglement[2]	Man-hours to erect 300 m of entanglement[3]
	Extra long	Long	Medium	Short					
Double-apron, 4- and 2-pace	-	100	-	200	14-15	-	-	4.9	59
Double-apron, 6- and 3-pace	-	66	-	132	13-14	-	-	3.5	49
High wire (less guy wires)	-	198	-	-	17-19	-	-	5.9	79
Low wire, 4- and 2-pace	-	-	100	200	11	-	-	3.7	49
4-strand fence	-	100	-	2	5-6	-	-	1.9	20
Double expedient concertina	-	101	-	4	3	100	295	6.9	40
Triple expedient concertina	51	101	-	7	4	148	295	10.4	99
Triple standard concertina	-	160	-	4	3	59	317	7.9	30

[1] Lower number of reels applies when screw pickets are used; high number when U-shaped pickets are used. Add difference between the two to the higher number when wood pickets are used.

[2] Average weight when any issue metal pickets are used.

[3] With the exception of the triple-standard concertinas, man-hours are based on the use of screw pickets. When driven pickets are used, add 20 percent to man-hours. With experienced troops, reduce man-hours by one-third. Increase man-hours by 50 percent for night work.

[4] Based on concertinas being made up in rear areas and ready for issue. One expedient concertina opens to 6-meter length, as compared with 15 meters for a standard concertina; it requires 92 meters of standard barbed wire, also small quantities of No. 16 smooth wire for ties.

48. BARBED WIRE TIES

See figure 67.

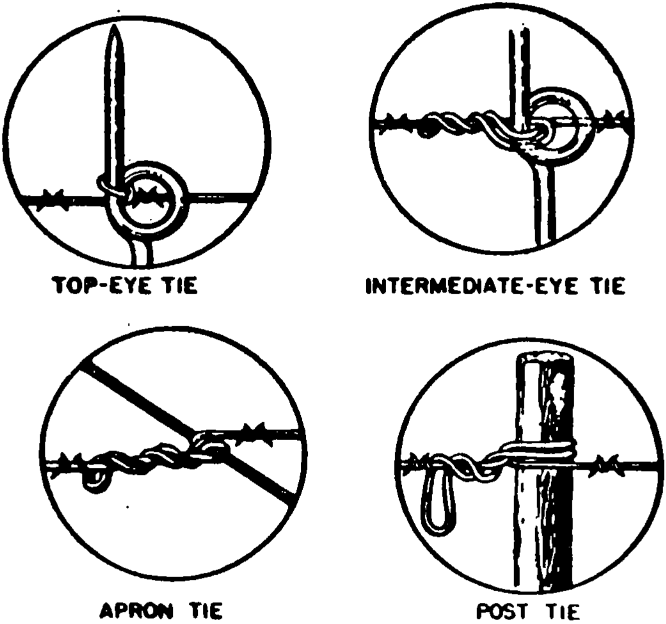


Figure 67. Barbed wire ties.

49. FOUR AND TWO PACE DOUBLE APRON FENCE

a. Erect from right to left (as you face the enemy).

b. Spacing of pickets.

(1) Long pickets are four paces apart.

(2) Anchor pickets are placed two paces from the line of center pickets and opposite the midpoint of the space between the center pickets.

(3) Anchor pickets are also placed on ends of fence, four paces from the first and last long pickets.

c. See figure 68.

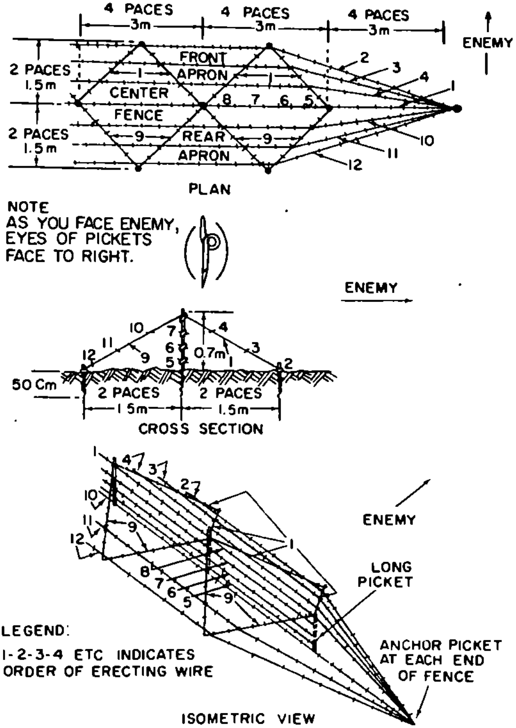


Figure 68. Double apron fence.

50. SIX AND THREE PACE DOUBLE APRON FENCE

a. Erect from right to left (as you face the enemy).

b. Spacing of pickets.

(1) Long pickets are six paces apart.

(2) Anchor pickets are placed three paces from the line of center pickets and opposite the midpoint of the space between the center pickets.

(3) Anchor pickets are also placed on ends of fence, six paces from the first and last long pickets.

51. CONSTRUCTION PROCEDURE FOR DOUBLE APRON FENCES

a. *First operation*—layout and installation of pickets (3 crews).

(1) First crew lays out long pickets.

(2) Second crew lays out short pickets.

(3) Third crew installs all pickets.

b. *Second operation*—layout and installation of wire (men are broken into 2–4 man crews to install wire).

(1) First wire, enemy diagonal.

(2) Second wire, enemy trip wire (5–10 cm off ground).

(3) Third and fourth wire, enemy apron.

(4) Fifth, sixth, seventh, eighth, center fence (install from bottom up).

(5) Ninth wire, friendly diagonal.

(6) Tenth and eleventh wire, friendly apron.

(7) Twelfth wire, friendly trip wire.

52. TRIPLE STANDARD CONCERTINA

a. Erect from right to left (as you face the enemy).

b. Space pickets as follows:

(1) Long pickets are five paces apart.

(2) Anchor pickets are placed two paces from end long pickets.

(3) Enemy and friendly rows of pickets are 3 feet (.9M) apart.

(4) Friendly picket row is offset from enemy row.

c. See figure 69.

53. CONSTRUCTION PROCEDURE—TRIPLE STANDARD CONCERTINA

a. *First operation (3 crews).*

(1) First crew lays out all pickets.

(2) Second crew installs all pickets.

(3) Third crew lays out concertinas.

(a) One concertina in front of third picket on enemy side.

(b) Two concertinas to rear of third picket on friendly side.

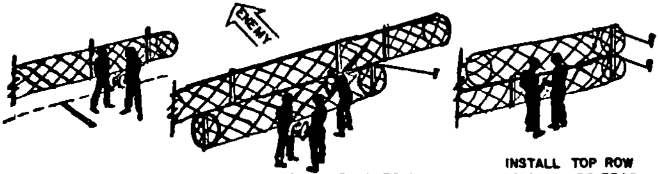


Figure 69. *Installing cancertinos.*

(*c*) Remove binding wire and place on hondles.

(*d*) Repeot same perfarmonce every faurth picket thereafter.

b. Second aperation (All personnel).

(1) Instoll frant row concertina ond harizantol wire.

(*a*) Drap concertinas over pickets.

(*b*) Method of jaining (fig. 70).

1. Battom of old concertina on jaining picket.
2. Battom and top af new cancertino on jaining picket.
3. Tap af ald concertino on joining picket.

(2) Install reor row concertina ond horizontal wire.

(3) Install top raw concertina and rock to the reor horizantal wire.

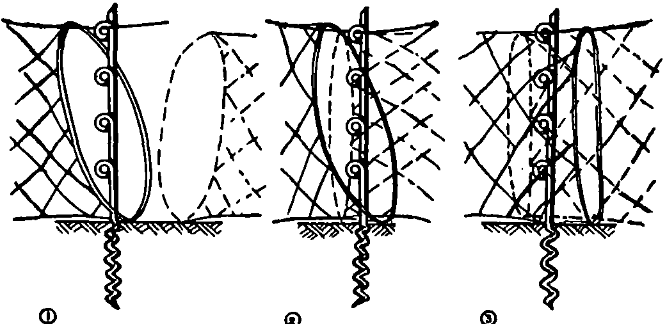


Figure 70. *Joining cancertinos.*

54. LOW WIRE FENCE

This is like a 4- and 2-poce dauble apran fence, except that medium pickets instead of lang pickets are used in the centerline. The Nas. 5, 6, and 7 wires ore not used, which results in all opran ond diagonol wires being much closer ta the graund. Being law ta the graund, this obstocle is easily hidden in tall grass ar shallow woter. For best results, it should be used in depth.

55. FOUR-STRAND CATTLE FENCE

This is the four-strand center section of a double-opran fence. In farm cauntry, such an obstacle blends with the landscape. Waoden pickets at 2- ta 4-pace intervals ore set up. If guy wires are used, they should be added separately when estimating because this material is nat included in the amaunts listed in table 28.

a. Use eight men an short sectians of this fence. On 300-meter sectians, use up ta 17 men.

b. In the first operatian the working party is divided into two appraximately equal graups. The first graup lays aut lang pickets at 3-meter intervals. It begins ond ends the section with an anchar picket, including anchor pickets for guys, if needed. The secand graup installs the pickets.

c. As each man campletes the first aperatian, he moves to the fence. These teams af twa ar faur men are organized ta instoll wires. In four-man teoms, twa men carry the reel, and twa makes ties and tighten the wire. In the twa-man teams, the wire is unralled far 50 ta 100 meters, then the men make the ties. The first team installs the battom wire, and succeeding teoms instoll the next wires in order.

56. COMBINATION BANDS

Many types af fence may be combined in bonds ta form abstacles mare difficult ta breach thon single belts. Other voriatians moy be readily develaped.

57. PORTABLE BARBED-WIRE OBSTACLES

Standord concertinas are in this category becoase they ore reodily maved. Other portable barbed-wire obstacles are listed belaw.

a. Spirols of laose wire ore used to fill open spoces in and between wire entanglements. Prepore them by driving faur 1-meter posts into the graund ta form a diamond 1 meter by 0.5 meter. Wind 75 meters of wire araund them from bottam ta tap. Remove wire from the frame, tie it ot the quorter points, then corry the spirals ta the site where they are apened and used.

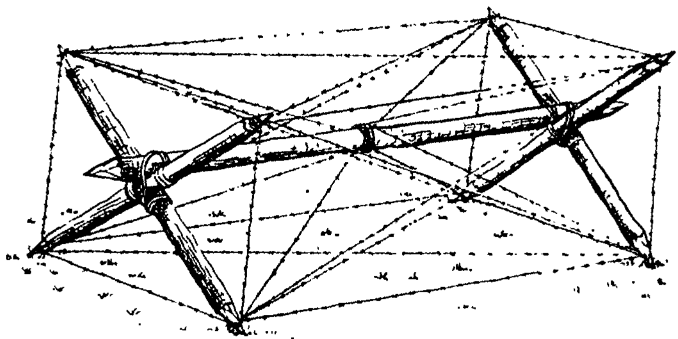


Figure 71. Knife rest.

b. The knife rest (fig. 71) is a portable wooden or metal frame strung with barbed wire. It is about 4.5 meters long and 1.2 meters high. It must be securely fixed in position.

c. Right after a defensive position is occupied and before protective wire is erected, trip wires should be placed just outside of grenade range (about 40 meters). Stretch the wires about 25 centimeters above the ground and stretch on pickets at 1.5-meter intervals. Conceal them in long grass, on the side of a path, or at the edge of a field. Place them in depth in an irregular pattern.

d. Tanglefoot is used where concealment is needed (fig. 72). Use it in a minimum depth of 9 meters. Place pickets at irregular intervals of from 0.75 to 3 meters. Height of the barbed wire varies from 0.25 to 0.75 meters. Site this wire in scrub, if possible. Use bushes as supports for part of the wire and short pickets in open ground.

e. The trestle apron fence (fig. 73) has inclined cross-pieces spaced at 5- to 6-meter intervals to carry wires on the enemy side.

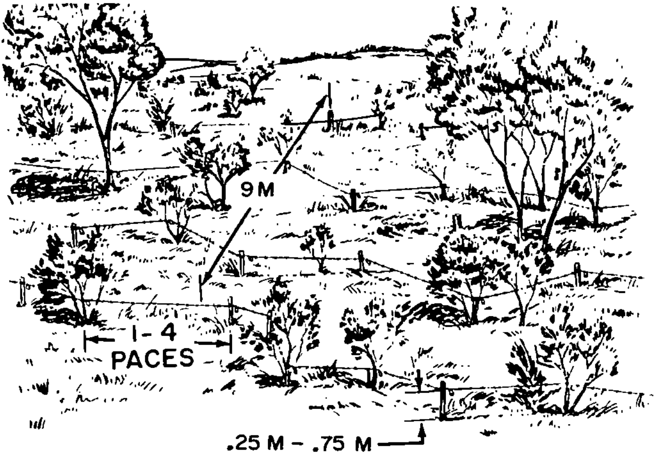


Figure 72. Tanglefoot.

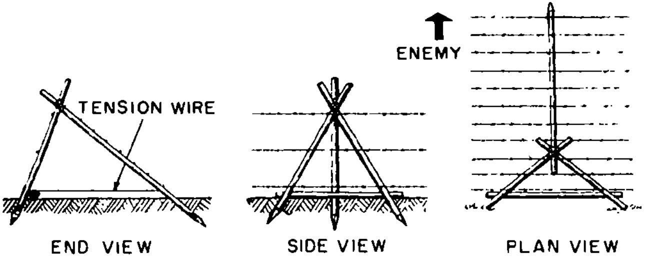


Figure 73. Trestle apron fence.

CHAPTER 5

MARKING OF BRIDGES AND VEHICLES

58. MARKING OF BRIDGES

a. *Classification.*

(1) The class number of a bridge represents the safe load-carrying capacity of a single-lane bridge, or a single lane of a multilane bridge under normal crossing conditions. The bridge class number may be a single class number, which will permit either a wheeled or tracked vehicle to cross if the vehicle class number is equal to or less than the bridge class number. The bridge class number may be a dual class number, which indicates one normal class number for wheeled vehicles and another normal class number for tracked vehicles. Dual classification may be used for bridges with a capacity greater than Class 30. For reconnaissance reports and tables, dual class numbers are written (70)/50, (80)/60, (50)/70, and so on, with the wheeled class number in parentheses above the tracked vehicle class number.

(2) The normal class number is the largest bridge class number (single or dual) which permits the normal crossing of vehicles whose vehicle class numbers are equal to or less than the bridge class number.

(3) A special class number represents the load-carrying capacity of a bridge under special crossing conditions. These numbers are not posted on standard bridge marking signs, but on supplementary signs.

(4) Width requirements. See table 29.

b. *Bridge Signs.*

(1) For prefabricated bridges and ferries, bridge signs indicate the class number given in technical manuals. For bridges fixed in place or for nonstandard fixed bridges designed in the field, bridge signs shall indicate the class number found by methods shown in chapter 7.

(2) All single-lane bridge signs are a minimum of 16 inches in diameter. For multilane and dual class bridges, the signs are at least 20 inches in diameter. Numerals are black on a yellow background, with a black border 1 ½ inches wide.

Table 29. Bridge Width Requirements

Bridge class	4 - 12	13 - 30	31 - 60	61 - 100
One-lane width	9'0"	11'0"	13'2"	14'9"
Two-lane width	18'0"	18'0"	24'0"	27'0"

(3) A multilane bridge has a roadway wide enough to carry at least two lanes of traffic simultaneously. If each lane has the same class, the signs are the same as for single-lane bridges. If the lanes are of different classes, each lane has a class sign. Two-lane bridges may carry a combination circular sign (fig. 74), which gives the normal two-way classification on the left and the computed, one-way classification on the right.

(4) Dual classification is used for bridges with a capacity greater than class 30. Two numbers are then shown on the sign: the upper one for wheeled vehicles, the lower one for tracked vehicles (fig. 74). Dual-class two-lane bridges may be designated by a composite sign indicating both dual-class and combination classes (fig. 74).

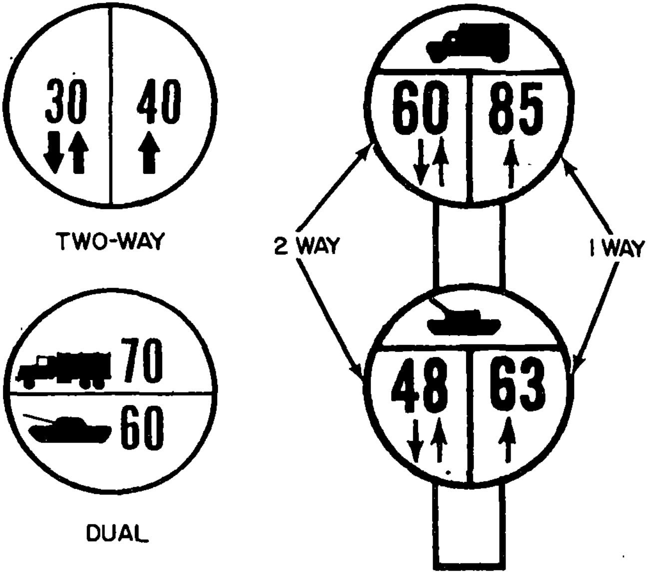


Figure 74. Bridge classification signs.

c. *Traffic Control.* To expedite passage of vehicles and to prevent damage to the bridge, rigid control of bridge traffic must be maintained. This is done by the following control measures wherever possible.

(1) A traffic park is set up where vehicles can be halted and dispersed so as to avoid congestion.

(2) A turnout area is provided for vehicles to turn off the road and out of the line of traffic. It is meant primarily for vehicles having mechanical troubles, but it can be used as a limited traffic park.

(3) Telltales are provided for bridges having overhead framing, trolley wires, or other features which limit overhead clearance (fig. 75).

(4) A normal crossing is defined as one in which the vehicle class number is equal to or less than the bridge classification number, where vehicles maintain 30-yard gaps, and where speed is restricted to 25 miles per hour. On floating bridges, sudden stopping or acceleration is forbidden.

(5) Special crossings are authorized by the local tactical commander under exceptional operating conditions in the field to permit a vehicle to cross a bridge, or other crossing means, whose class number

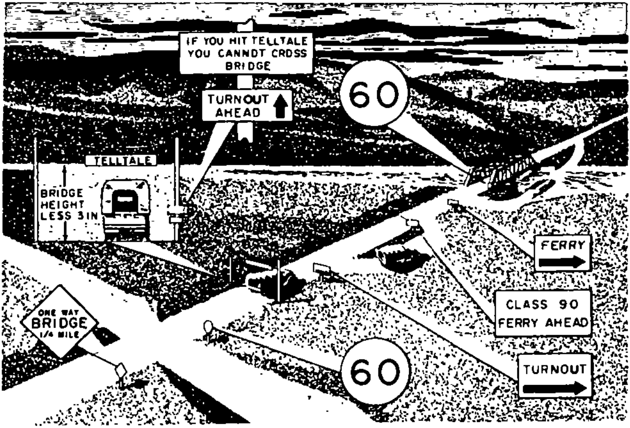


Figure 75. Example of telltale, turnout, and sign arrangement for single-lane bridges.

is less than that of the vehicle. Special crossings are either caution crossings or risk crossings.

(a) In a caution crossing of a bridge, vehicles with a classification up to 25 percent above the capacity of the nonstandard bridge are allowed to cross under strict traffic control. Caution crossings also require that the vehicle remain on the centerline, maintain a 50-yard distance from other vehicles, not exceed 8 miles per hour, not stop, not accelerate, and not have its gears shifted on the bridge.

(b) A risk crossing may be made only on standard prefabricated fixed and floating bridges. Risk crossings are made only in the greatest emergencies. The vehicle moves on the centerline, does not exceed 3 miles per hour, is the only vehicle on the bridge, does not stop, is not accelerated, and does not shift gears on the bridge. The vehicle class number must not exceed the published risk class. After the crossing, and before other traffic is permitted, the engineer officer should reinspect the entire bridge.

59. MARKING OF VEHICLES

a. *Weight Classification.* All vehicles with a gross weight over 3 tons and all trailers with rated payload over 1½ tons are assigned classification numbers. These numbers indicate a relationship between the load carrying capacity of a bridge and the effect produced on it by a vehicle (fig. 76).

b. *Vehicle Signs.*

(1) Classification numbers assigned to vehicles are whole numbers ranging from 4 through 150. Front signs on a vehicle are 9 inches in diameter and the side signs are 6 inches in diameter. The signs have black numerals on a yellow background, and the numerals are as large as the sign will permit. Place the front sign above the bumper to the driver's right and below his line of vision; and the side sign on the right side of the vehicle in a place where normal use of the vehicle does not conceal it from view.

(2) With a combination vehicle (two or more single vehicles spaced less than 30 yards apart), the front sign shows the normal vehicle class for the combination with the letter "C" in red above the class number. Each vehicle in the combination carries a side sign which shows its class as a single vehicle.

(3) If one vehicle is towing another, they are considered separate. However, if they are both on the same span and the distance between them is less than 30 yards, they are considered as a combination vehicle with a temporary front sign showing the class number. If the sum of the class numbers of the two vehicles is 60 or less, use the formula

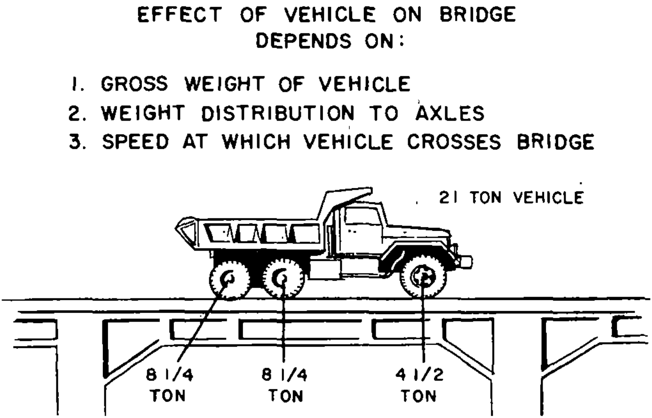


Figure 76. Effect of vehicle on bridge.

9/10(A + B) to obtain the combination class, where A is class of the first vehicle, and B is the class of the second vehicle. If the class numbers add to more than 60, use the sum as the combination class.

60. DIMENSIONS, WEIGHTS, AND CLASSIFICATION OF VEHICLES

For information concerning specific vehicles see appendix II.

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CHAPTER 6
FLOATING EQUIPAGE

Section 1. Bridges

61. ANCHORAGE SYSTEMS

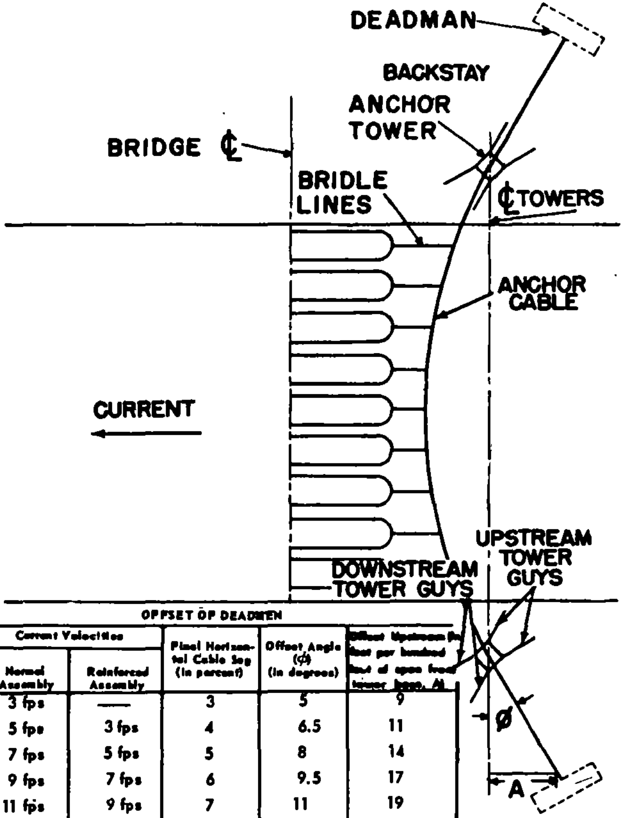
a. Ancharages must be pravided ta secure the bridge between the abutments and ta insure cantinued alinement. The selectian of an anchorage system is influenced by the width af the river; its velacity, turbulence, variatians in stage; debris flaw; nature af material in the river bed and embankments; and the time, materials, and persannel available. The ancharage system is designed ta withstand the warst canditians anticipated. The basic ancharage systems used are: averhead cable-bridle line systems, share guys, kedge anchars, and a cambinatian af kedge anchars and share guys. The mast satisfactary methad af ancharing a flaating bridge is the averhead cable bridle-line system supplemented by share guys. Flaat suppcrted cables, share guys, and kedge anchars shauld nat be used as the final ancharage system except when it is nat passible ta install an averhead cable system. Althaugh cambinatians af the basic ancharage systems may be used during assembly and far reinfarcement, the laad cannat be praperly divided between twa systems; ane system must supplement the ather. Overhead cable systems can hald in currents up ta 11 fps; cambinatian kedge anchors and share guys up ta 5 fps; and kedge anchars ar share guys alane up ta 3 fps. Kedge anchars are used an every bay upstream and every ather bay dawnstream. Share guys are used an every sixth bay upstream and every tenth bay dawnstream. When an averhead cable system is used, a bridle line is used an every panton.

b. See figure 77 far a typical layaut of an averhead cable-bridle line system. Table 30 can be used ta select the required size ar the required number af averhead cables for a particular situatian.

Example: a 400-faat span reinfarced M4T6 bridge in a maximum current af 9 fps wauld require 1 each 1¼-inch-diameter cable, ar 2 each 1-inch-diameter cables, ar 3 each ¾-inch-diameter cables (fram table 30).

62. ALUMINUM FLOATING FOOTBRIDGE

a. The aluminum faatbridge is the standard means af crassing foot traaps. This faatbridge set furnishes 472 feet 6 inches af bridge, and



OFFSET OF DEADMEN

Current Velocities		Final Horizontal Cable Sag (in percent)	Offset Angle (ϕ) (in degrees)	Offset Upstream (in feet per hundred feet of span from tower base, A)
Normal Assembly	Reinforced Assembly			
3 fps	——	3	5	9
5 fps	3 fps	4	6.5	11
7 fps	5 fps	5	8	14
9 fps	7 fps	6	9.5	17
11 fps	9 fps	7	11	19
——	11 fps	8	13	23

Figure 77. Typical anchor cable system.

can be used in currents up to 11 feet per second. One bay of bridge consists of one panton, one treadway, and four handrail posts, which provides 11 feet 3 inches of bridging. The bridge is erected by successively connecting individual bays to the near share end and pushing the entire bridge toward the far shore. Capacity, in men per minute with a current velocity up to 8 feet per second, is: day—75; moonlight—40; blackout—25. This is based on troops crossing single file at a 2-pace interval in daylight and moonlight at double time. Reduce the capacities by 20 percent in currents of 9–11 fps.

Table 30. Anchor Cable Requirements

BRIDGE SPAN (ft.)	BRIDGE TYPE & ASSY		SIZE (IN.) AND NUMBER OF CABLES FOR SPECIFIED STREAM VELOCITIES											
			5 FPS			7 FPS			9 FPS			11 FPS		
			SINGLE	DUAL	TRIPLE	SINGLE	DUAL	TRIPLE	SINGLE	DUAL	TRIPLE	SINGLE	DUAL	TRIPLE
200	M4	N	3/8	3/8	3/8	5/8	5/8	3/8	1/2	5/8	5/8	1/2	1/2	5/8
		R	1/2	3/8	3/8	1/2	5/8	3/8	5/8	1/2	5/8	5/8	1/2	1/2
	M4T6 & CL 60	N	1/2	5/8	5/8	5/8	1/2	1/2	3/4	5/8	1/2	7/8	3/4	5/8
		R	5/8	1/2	5/8	3/4	5/8	1/2	7/8	3/4	5/8	1 1/8	7/8	3/4
400	M4	N	1/2	3/8	3/8	1/2	1/2	5/8	5/8	1/2	3/8	3/4	5/8	1/2
		R	5/8	1/2	3/8	5/8	1/2	1/2	3/4	5/8	1/2	7/8	3/4	5/8
	M4T6 & CL 60	N	5/8	1/2	1/2	3/4	5/8	1/2	1	7/8	5/8	1 1/4	1	3/4
		R	3/4	5/8	1/2	1	3/4	5/8	1 1/4	1	3/4	1 1/2	1 1/4	7/8
600	M4	N	5/8	1/2	3/8	5/8	1/2	3/8	3/4	5/8	1/2	7/8	3/4	5/8
		R	3/4	1/2	1/2	3/4	5/8	1/2	7/8	3/4	5/8	1	7/8	3/4
	M4T6 & CL 60	N	3/4	5/8	1/2	1	3/4	5/8	1 1/4	1	3/4	1 1/2	1 1/4	7/8
		R	1	3/4	5/8	1 1/8	1	3/4	1 1/2	1 1/4	7/8		1 1/2	1 1/8
800	M4	N	5/8	1/2	5/8	3/4	5/8	1/2	7/8	3/4	5/8	1	7/8	3/4
		R	3/4	5/8	1/2	7/8	3/4	5/8	1	7/8	3/4	1 1/8	1	7/8
	M4T6 & CL 60	N	7/8	3/4	5/8	1 1/8	7/8	3/4	1 5/8	1 1/8	7/8		1 1/2	1 1/8
		R	1 1/8	7/8	3/4	1 5/8	1 1/8	7/8		1 3/8	1	..	.	1 1/4
1000	M4	N	3/4	5/8	1/2	7/8	5/8	1/2	1	3/4	5/8	1 1/8	7/8	3/4
		R	7/8	3/4	5/8	1	3/4	5/8	1 1/8	7/8	3/4	1 1/4	1 1/8	7/8
	M4T6 & CL 60	N	1	7/8	3/4	1 1/4	1	7/8	1 1/2	1 3/8	1	.....	...	1 1/4
		R	1 1/4	1	3/4	1 1/2	1 1/4	1	.		1 1/8	....	......	1 3/8

b. Construction and transportation data are found in table 31.

c. As an expedient vehicle bridge, the aluminum footbridge can be assembled with pontons butted next to one another and offset alternately left and right of the centerline. Two treadways are used as vehicle tracks. One-quarter ton vehicles with trailers can be crossed on this bridge. Use appropriate anchorage system. See paragraph 61 and figure 78.

Table 31. Aluminum Floating Footbridge Data

Bridge set	Basis of issue	Suggested working party		
		Detail	NCO	EM
Normal Assembly: 472 ft 6 in.	One set to each engineer float bridge company*	Near-shore anchor cable..		6
Light vehicle bridge: 100 ft.	Vehicles required for transportation of bridge set:	Far-shore anchor cable..	1	7
Expedient rafts: 3	Two, 2½-ton 6 x 6 cargo trucks with 2½-ton pole-type trailers or 3, 2½-ton cargo trucks.	Bridle line............		2
Major items:		Guy line...:..........		5
Ponton 42		Shore assembly.........	1	6
Treadways 42		Assembly carrying.. ...		6
		River assembly...	1	4
		Handrail............. .		3
		Plus 2 EM per 100 ft of bridge.		

* Also one set to each Airborne Engineer Bn.

63. LIGHT TACTICAL BRIDGE

a. The light tactical floating bridge is assembled from the light tactical raft equipment. Both raft and bridge consist of a deck built of aluminum sections supported on aluminum pontons. With a trained crew, during daylight hours, and in still water, this bridge can be hand erected at a rate of 3½ feet per minute. Each bay provides 11 feet of bridging with a deck width of 9 feet. This equipment is issued as a light tactical raft set.

b. See table 32, for bridge capacities. Organization of assembly crews is given in table 32.

64. M4 FLOATING BRIDGE

a. The M4 bridge bay consists of two M4 aluminum half pontons joined stern to stern with a deck of hollow aluminum balk. The deck balk pattern is so designed that a "continuous beam" action results which distributes the load over more than one ponton. With 18 balk across the deck, the roadway width is 166 inches. The effective length of one bay is 15 feet.

b. The M4 bridge is currently stocked as a Standard B item and may be requisitioned against existing needs by length of bridging needed rather than by bridge sets.

c. For a layout of the M4 bridge see figure 79 and for construction and transportation data see table 34. Capacities may be found in table 32.

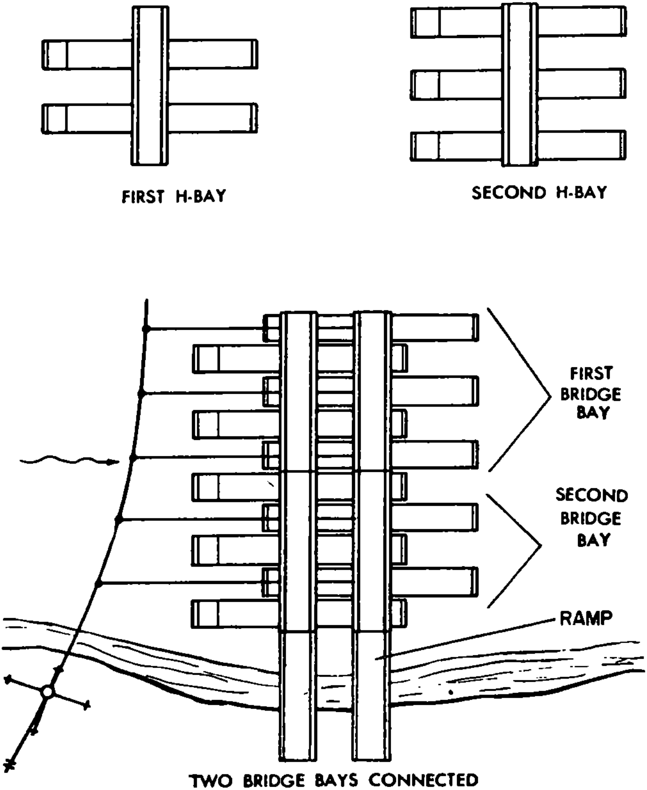


Figure 78. Assembly of light vehicle bridge.

Table 32. Floating Bridge Capacities

Type of bridge	Type of crossing	Stream velocities in feet per second for specified assembly[1]						Stream velocities in feet per second for specified assembly[1]					
		Normal[2]						Reinforced[3]					
		3	5	7	8	9	11	3	5	7	8	9	11
M4[5]	Normal	60	60	(45)[4] 50	(45) 45	(30) 35	(18) 20	95	95	(75) 80	(60) 65	(45) 50	(24) 27
	Caution	68	65	(58) 59	(52) 53	(44) 46	(29) 31	100	(100) 99	(88) 85	(75) 74	62	(35) 37
	Risk	72	68	(61) 62	(58) 59	(53) 54	(37) 39	(105) 100	(105) 100	(101) 96	(88) 85	(74) 73	(45) 46
Class 60[6]	Normal	(60) 65	(55) 65	(45) 55	(40) 50	(35) 45	(22) 25	65	65	65	65	65	(30) 35
	Caution	(65) 70	(62) 67	(56) 61	(52) 56	(45) 49	(34) 37	75	75	75	75	75	(47) 51
	Risk	(75) 79	(72) 77	(67) 72	(62) 67	(57) 62	(46) 50	85	85	85	85	85	(70) 74
M4T6[5]	Normal	(50) 55	(45) 55	(40) 50	(35) 45	(30) 40	(25) 30	75	75	(70) 75	(65) 70	(55) 60	(27) 30
	Caution	(60) 61	(58) 59	(54) 55	(49) 51	(45) 47	(35) 37	80	80	79	73	(66) 67	(43) 45
	Risk	(68) 69	(66) 67	(62) 63	(59) 60	(54) 56	(43) 45	90	90	90	87	81	(59) 60

See footnotes at end of table.

Table 32.—Continued.

Type of bridge	Type of crossing	Stream velocities in feet per second for specified assembly [1]						Stream velocities in feet per second for specified assembly [1]					
		Normal [2]						Reinforced [3]					
		3	5	7	8	9	11	3	5	7	8	9	11
Light tactical raft floating bridge	Normal	16	16	13	11	8	2						
	Caution	18	18	15	12	9	3						
	Risk	21	21	17	14	11	5						

[1] Use 2-space distance for 3fps only; 1-bay distance for 4 and 5 fps; 2-bay distance for 6 and 7 fps.

[2] Based upon abutment deck level within 10 inches of floating bridge deck level, except for hinged or other special end spans. Where limitations are exceeded, capacities must be reduced.

[3] Reinforced by placing 3 floating supports under 2 bays of decking. 50 percent reinforced.

[4] (Wheeled vehicle classification)/Tracked vehicle classification. Single classification indicates both classifications are the same.

[5] Capacities based on roadway widths of 18 balk and deck width of 22 balk. Reinforced assembly requires a 38′4″ superimposed end span.

[6] Reinforced bridge capacities up to 9 fps are controlled by end span limitations.

65. CLASS 60 FLOATING BRIDGE

a. The Class 60 bridge bay consists of two steel deck-tread panels, two curbs, and one filler panel with an effective bridging length of 15 feet and a roadway width of 162 inches. The floating support for one bay consists of two pneumatic half floats joined stern to stern and, when properly saddled with the equipment provided, it is rated at 24 tons capacity. The bridge requires cranes and air compressors for assembly.

b. Construction and transportation data are listed in table 35, and capacities are given in table 32.

c. Two trestle assemblies are furnished with each set. See paragraphs 69 through 79.

66. M4T6 FLOATING BRIDGE

a. Through the use of deck balk stiffeners and saddle adapters, the deck balk from the M4 floating bridge and the pneumatic floats from the class 60 floating bridge can be combined to build a hand erected

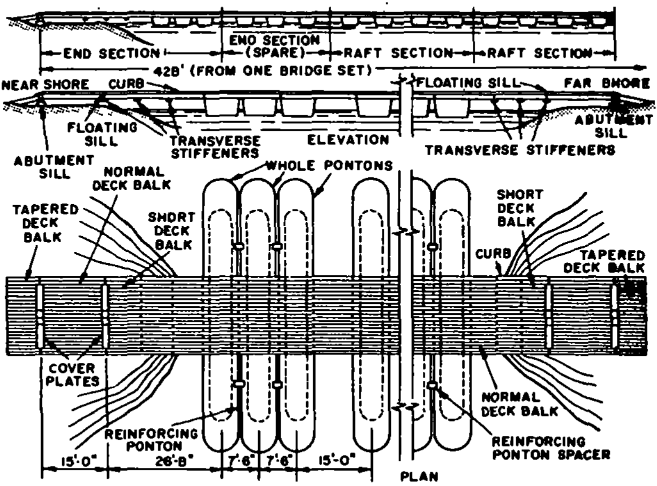


Figure 79. Floating bridge, M4.

high capacity bridge. An air compressor is required for assembly. The deck farms a continuous beam action over the pontons and provides an effective bridging length of 15 feet per bay with a roadway width of 166 inches. See figure 80 for deck balk layout.

b. Construction and transportation data are listed in table 36 and capacities are given in table 32.

c. Two trestle assemblies are furnished with each set. See section II, this chapter.

d. For information about connection of the M4T6 bridge to the M4 and class 60 floating bridges, see TM 5–210.

Table 33. Organization for Assembly of Light Tactical Bridge by Successive Pontons

Details	NCO	EM	Summary of Tasks
Pontan	1	10	Unload, launch, and join half pontons.
Deck	1	10	Unload and place deck panels, curbs and filler panels on pontons.
Ponton delivery	. . .	2	Deliver complete bays to bridge-connecting site.
Bridge connecting . . .	1	4	Connect assembled bays to the bridge.
Near-shore abutment.	1	8	Construct near-shore abutment; connect articulator and ramps; and maintain bridge alinement.
Far-shore abutment . .	1	8	Construct far-shore abutment, install end section articulator and ramps.
Anchorage	2	12	Install anchar cable, bridle lines, and shore guys (see TM 5–210 and para 61 FM 5–34)

Table 34. Construction and Transportation Data of M4

Bridge set	Standard B Stock Basis of Issue	Suggested working party		
	Class IV	Detail	NCO	EM
Floating bridge:	Vehicles required for	Near-shore abutment ..	1	8
608 ft 4 in.	transportation of	Ponton outfitting (2 crews).	4	36
	bridge set:	Ponton delivery (2 crews)..	2	10
Fixed bridges:		Anchorage	2	12
2-23 ft	¾-ton cargo truck	Balk carrying....	2	88
2-30 ft	2½-ton cargo truck	Balk laying.......	1	8
2-38 ft	2½-ton truck, bolster	Far-shore abutment.. ...	1	16
2-45 ft	2½-ton bolster trailer	Pin checking	1	3
	2½-ton pole type trailer			
Rafts:	5-ton dump truck	Total....	14	181
4-4-ponton	Transported by			
4-6-ponton	organic vehicles of			
4-7-ponton	the using unit.			

Table 35. Construction and Transportation Data of Class 60

Bridge set	Basis of issue*	Suggested working party		
		Detail	NCO	EM
Floating bridge:	Class IV	Supervisory..	2	
135 ft.		Crane crew......... ..	1	1
Fixed bridges:	Vehicles required for	Saddle assembly—2 crews .	2	20
4, 30 ft	transportation of	Float inflation.		9
3, 45 ft	bridge set:	Deck panel.............. .	1	6
2, 60 ft		Float handling......... ..		8
1, 75 ft	9 ea. 5-ton 6 x 6 military	Single bay, connecting......	1	6
1 multispan	bridging trucks carry	Boat crew		4
from 85 to	one complete bay each.	Bridge assembly	1	8
92 ft	3 ea. carry accessories	Anchorage............. .	1	10
Rafts:		Trestle	1	8
1 4, 5, or 6	Allocation same as			
float.	M4T6 see table 36.	Total..	10	80

*May be partial issue of M4T6 bridge sets. See table 36.

Table 36. Construction and Transportation Data of M4T6

Bridge set	Basis of issue*	Suggested working party: Detail	NCO	EM per crew
Normal floating bridge, 141 ft. 8 in. One 4-float and one 5-float reinforced raft, 2 floating bridges, 75 ft., one without reinforcing balk on end float, 3 38 ft. 4 in. span fixed bridges.	Divisional Engr. 4 sets. Abn. Div. Engr. none. Engineer float bridge company (5 bridge sets of 141′ 8″ each for a float bridge company at full strength, and 3 sets for a company at reduced strength).	Float inflation.	1	8
		Saddle assembly	2	20
		Assembled float delivery . . .	2	4
		Balk-carrying from shore .	2	40
		Balk-laying.	1	12
		Anchorage.	2	12
		Near-shore abutment	1	8
		Far-shore abutment.	1	8

*May be partial issue of class 60 steel treadway bridge transportation same as class 60 bridge set. See table 35.

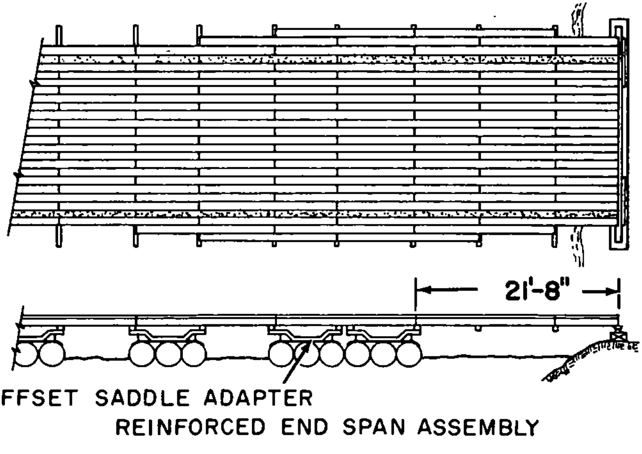


Figure 80. Bridge, floating, aluminum deck-balk superstructure (M4T6).

67. AMPHIBIOUS RIVER CROSSING EQUIPMENT (ARCE-FRENCH)

a. *Description.*

(1) This amphibious river-crossing equipment consists of these two major items: the amphibious bridge vehicle, class 60 (ABV–60); the amphibious ramp vehicle, class 60 (ARV–60).

(2) The basic unit of each amphibious vehicle is a welded steel-plate water-tight hull mounted on a four-wheel drive chassis.

(3) To insure stability and buoyancy during navigation, each vehicle is equipped with two pneumatic floats about 36 feet in length and 4½ feet in diameter, attached to the sides. A compressor is kept in operation during water travel to maintain a constant pressure on the floats.

(4) An integral part of each ABV–60 is 26 feet 3 inches of decking, folded for road transport, and pivoted and widened for bridge construction. After entering the water, the deck section is rotated 90°, widened to 13 feet 2 inches, and deck-filler panels are added.

(5) The effective length of the ramp of he ARV–60 is 26 feet 3 inches. It is 13 feet 2 inches wide.

(6) See table 37 for vehicle specifications.

b. *Capacity.* The French ARCE is classified as a class 60 bridge in currents up to 9.8 fps.

c. *Operation.*

(1) A four-man crew, consisting of a driver, pilot, and two crewmen, is required to operate the vehicle on land, in the water, and during bridge construction.

(2) The ABV–60 enters the water, ready for incorporation onto a bridge or raft, as a 26 foot 3 inch floating section. All movements of the decking during construction are hydraulically controlled. As successive units enter the water they are joined until the required length of bridge or raft has been built, then ramps are added to each end.

(3) The end ramp is transported by the ARV–60. The carrier unit positions the ramp for connection to the bridge or raft and is disengaged when the connection has been made. All movement of the ramp during construction and operation is done by the hydraulic system of the carrier and bridge vehicle to which it is connected.

68. MOBILE FLOATING ASSAULT BRIDGE/FERRY (MFAB/F–U.S.)

a. *Description.*

(1) This amphibious river crossing equipment consists of a basic hull of aluminum plate with either an intermediate superstructure or an

Table 37. Mobile Floating Assault Bridge Vehicles

Specification	U.S.	French
Vehicle length	42′-3″	36′-0″
Vehicle width—Land travel	12′-0″	10′-0″
—Intermediate	—	13′-0″
—Water travel	12′-0″	19′-8″
Vehicle height—Interior bay	10′-6″	12′-10″
—End bay	11′-9″	12′-10″
Draft-unloaded		
Atmospheric wheel well	2′-7″	—
Air pressure wheel well	2′-0″	2′-0″
Weight—Tons—Interior bay	23.75	29.70
—End bay	25.13	30.20
Turning radius	40′-0″	57′-5″
Vehicle speed—Land travel—MPH	35	37
Fuel tank capacity—U.S. gallons	100	132
Engine horsepower	335	222
Superstructure dimensions		
Length—Interior bay	26′-0″	26′-3″
—End bay	37′-0″	26′-3″
Width	13′-6″	13′-2″
Ramp articulation—Above horizontal	6′-3″	10′-0″
—Below horizontal	6′-3″	1′-0″

articulating ramp end section mounted on top of it. The hull alone provides all the buoyancy for the vehicle and the bridge load.

(2) The four wheels which propel the MFAB/F unit on land retract in the water and the wheel wells can be air-pressurized for added buoyancy.

(3) Similar to the French ARCE, the U.S. MFAB/F has a superstructure which is rotated 90° to form one bay of bridge decking.

(4) See table 37 for vehicle specifications.

(5) Effective length of the ramp is 37 feet, and the interior bay is 26 feet.

b. Capacity. The U.S. MOFAB is classified as a class 60 bridge.

c. Operation. A three man crew operates the bridge unit on land and in the water, rotating the superstructure and maneuvering to connect the unit to another interior bay or ramp unit. The ramp does not disconnect from the ramp vehicle as with the French ARCE.

69. RAFT POWER AND PERSONNEL

All standard rafts built from standard bridge sets may be powered by properly rigged 19-foot or 27-foot bridge erection power boats. One 19-foot boat may be used in currents not over 5 fps. In currents over 5 fps, normally two 19-foot boats may be substituted for one 27-foot boat. Rafts built from the light tactical raft set are normally powered with from one to four outboard motors. All standard rafts require approximately one squad of men for operation plus power boat operators. Where stream velocities are so high as to prevent available power sources from pushing a raft straight across the stream, the unloading point must be down stream from the loading point. Use steel pickets in hard soil and wood pickets in softer soils to form holdfasts to secure rafts for loading and unloading.

70. EXPEDIENT RAFTS USING ALUMINUM FOOTBRIDGE

Expedient personnel or vehicle rafts may be constructed by placing one or three widths of aluminum footbridge treadway, side by side across a row of two, three, or five pontons from the same set, also butted side by side. Treadways connected to the two outside deck treadways will form a ramp for vehicle loading. A single ¼-ton truck or a single ¼-ton trailer (securely blocked or tied down) is the maximum load that should be attempted with the vehicular raft. The rafts are propelled by poles, paddles, or outboard motors (fig. 81).

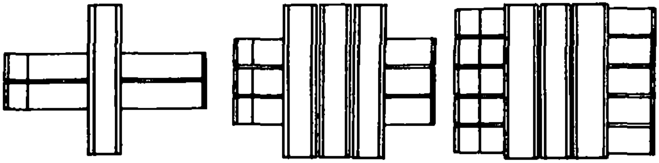


Figure 81. Expedient rafts built from the aluminum footbridge set.

Table 38. Raft Capacities

Type of raft	No. of pontons or floats	Type of crossing	Class of raft — Stream Velocity, fps: 5	7	9	11	Length: Overall, including ramps	Available for loading*
Class 60	4, normal	Normal	(40) 45	(40) 45	(35) 40	(25) 30	92'-5"	51'-0"
		Risk	(50) 55	(50) 55	(45) 50	(35) 40		
	4, reinforced	Normal	(45) 55	(40) 45	(35) 40	(25) 30	83'-1"	40'-0"
		Risk	(55) 60	(50) 55	(45) 50	(35) 40		
	5, normal	Normal	(50) 55	(50) 55	(40) 45	(30) 35	107'-5"	66'-0"
		Risk	(60) 65	(60) 65	(50) 55	(40) 45		
	5, reinforced	Normal	(55) 60	(55) 55	(45) 50	(35) 40	92'-5"	54'-6"
		Risk	(60) 70	(60) 65	(55) 60	(45) 50		
	5, with one short deck bay reinforced	Normal	(60) 65	(55) 60	(50) 55	(45) 50	83'-1"	43'-9"
		Risk	(65) 75	(65) 70	(60) 65	(55) 60		
	6, reinforced	Normal	(65) 75	(65) 75	(60) 65	(50) 55	92'-5"	57'-0"
		Risk	(80) 90	(80) 90	(70) 80	(60) 70		
	6, with one short deck bay reinforced	Normal	(60) 70	(60) 70	(55) 60	(45) 50	98'-9"	50'-10"
		Risk	(75) 85	(75) 85	(65) 75	(55) 65		
M4	4, normal	Normal	(50) 55	(50) 55	(50) 55	(40) 45	87'-0"	51'-8"
		Risk	(55) 60	(55) 60	(55) 60	(45) 50		
	6, partially reinforced	Normal	(70) 75	(70) 75	(65) 70	(50) 55	87'-0"	51'-8"
		Risk	(75) 80	(75) 80	(75) 80	(55) 60		

	7, fully reinforced	Normal	(85) 90	(85) 90	(80) 85	(55) 60	87′-0″	51′-8″
		Risk	(90) 95	(90) 95	(90) 95	(65) 70		
M4T6	4, normal	Normal	(50) 55	(45) 50	(35) 40	(30) 35	87′-1″	51′-8″
		Risk	(60) 65	(55) 60	(45) 50	(35) 40		
	5, reinforced •	Normal	(60) 65	(60) 65	(55) 60	(45) 50	88′-9″	50′-1″
		Risk	(70) 75	(70) 75	(65) 70	(55) 60		
Light tactical raft w/ articulators	4 pontons	Normal	12	12	8	0	58	
	3 bays	Risk	14	14	12	4		
	5 pontons	Normal	9	9	8	2	80	
	5 bays	Risk	11	11	11	6		
	6 pontons	Normal	13	13	13	5	69	
	4 bays	Risk	15	15	15	11		

Operating characteristics of rafts	Stream width ft.		
	250	500	1,000
No. of round trips per hr in currents of 5 fps in daylight (reduce 50% for night or adverse conditions)	10	6	4
No. of rafts which can be used efficiently at one site	1	2	3

•Measured from outside edge to outside edge of end pontons or float saddle beams.

NOTES.

1. Numerals in parentheses represent wheeled vehicle class; numerals without parentheses represent tracked vehicle class.

2. Capacities are based on loading rafts with center of gravity of loads 6″ downstream from top of raft and on properly inflated floats.

3. Extreme caution is required in loading and unloading vehicles weighing more than 70 tons.

4. Roadway width consists of 18 balk between curbs with 22 balk overall (M4 & M4T6). M4T6).

5. Capacities of LTR may be increased by 4 if no articulators are used.

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71. LIGHT TACTICAL RAFT

o. The deck of the light tactical raft consists of two aluminum deck treads and filler panels. The unit of issue of this raft provides components of one 4-ponton normal raft.

b. See toble 38 for roft classification by construction and stream velocity. See table 39 for classes of French-ARCE rafts.

c. Construction transportation, ond operation is as follows:

(1) The construction time for assembly of the light toctical raft is given in toble 40.

(2) The light tactical roft components are normolly transported on two 2½-ton corgo trucks and one 2½-ton pole-type trailer. With each raft set there ore four chain slings, four binders, and one crodle. The chain slings and binder secure the raft sets on vehicles, and the crodle nests the half pontons on troilers. The eight deck panels, eight filler panels, ond eight long curbs of the superstructure are transported on the 2½-ton truck used to houl the trailer. Another 2½-ton truck transports the articulating ossemblies, ramps, ponels, orticulator ond romp curbs, orticulator and ramp fillers, onchors, and holdfasts.

(3) The party operating the roft is normolly under the supervision of an NCO ond comprises o roft crew, o nearshore crew, and a forshore crew. Toble 41 outlines their duties.

72. M4 RAFT

o. The M4 roft (fig. 82) can be assembled from the components of the M4 floating bridge set, (para. 64). The basic 4-ponton roft con be converted to a reinforced roft with greoter lood capacity by adding reinforcing pontons. The other recommended types of rafts ossembled from M4 bridge equipment ore the 6-ponton and 7-ponton, both reinforced (fig. 82).

Table 39. ARCE Raft Copacities

Raft construction	Current velocity fps		
	0–4.9	5.0–6.6	6.7–8.2
2—Bay	55	49.5	4.4
3—Bay	88	80.3	71.5
4—Bay	121	110	99

Copacities are given in short tons.

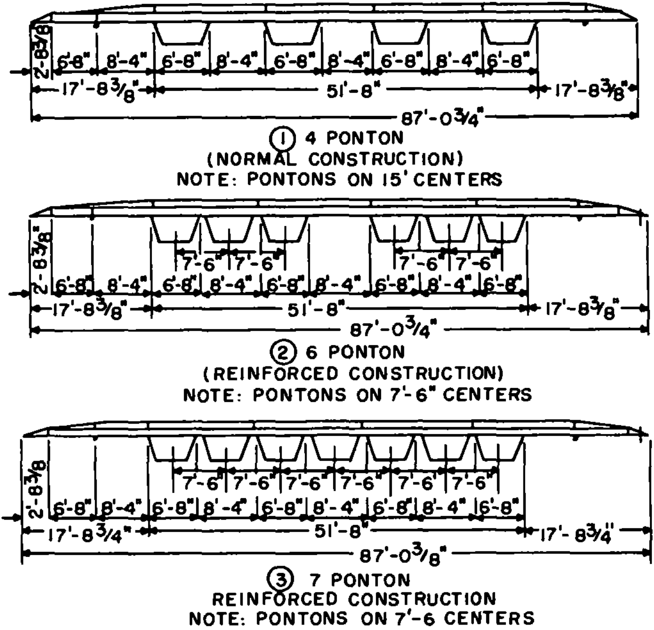


Figure 82. M4 raft.

b. The amount of time and the number of trained men required for the assembly of M4 rafts are given in table 42. Raft classifications are given in table 38.

73. CLASS 60 RAFT

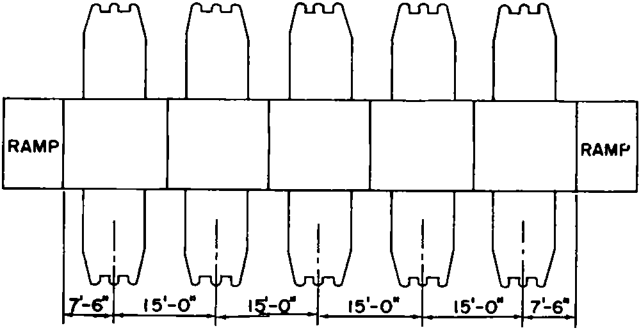
a. The class 60 raft (fig. 83) can be assembled from the components of the class 60 floating bridge set, (para. 65).

b. Raft classifications are given in table 38.

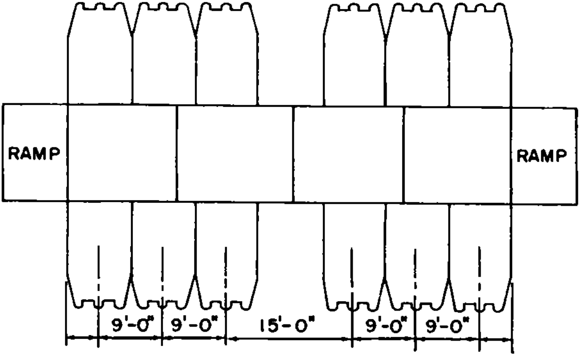
74. M4T6 RAFT

a. The M4T6 raft (fig. 84) can be assembled from components of the M4T6 floating bridge set, (para. 66).

b. Raft classifications are given in table 38.



NORMAL 5-FLOAT RAFT



REINFORCED 6-FLOAT RAFT WITH FOUR NORMAL DECK BAYS

Figure 83. Class 60 raft.

Table 40. Construction Time for Light Tactical Raft

Type of assembly	NCO	EM	Time required, minutes
4-ponton, 3-bay. . . .	3	27	15
5-ponton, 5-bay. . . .	3	27	20
6-ponton, 4-bay. . . .	3	27	30

75. ARCE RAFT (FRENCH)

a. For rafting, the construction procedure for 2-, 3-, 4-, and 5-unit rafts is similar to that used for the bridge. Time required varies from 15 minutes (2-unit) to 25 minutes (5-unit). In each case, about 10 minutes are required for connection of the ramps.

b. See table 39 for raft construction and classification.

76. MFAB/FERRY (U.S.)

a. For rafting, the construction procedure is similar to that used for the bridge. A four-unit ferry consisting of two end bays and two interior bays and capable of carying a class 62 vehicle or a total of 72 tons payload, at 8 mph can be assembled by its crew of three men per unit in about 12 minutes.

b. Tentative MFAB/Ferry classifications are given in table 43. These classifications are subject to change with further development of the units.

Table 41. Duties of Party Operating Light Tactical Raft

Crew	No. of men	Duties
Raft	8	4 men operate outboard motors; 4 men place and remove chocks from wheels of vehicles.
Near shore	1	1 man guides vehicles onto raft and instructs drivers in proper operation of vehicles while being loaded and unloaded.
Far shore	1	1 man guides vehicle off raft.
Guy line	4	Handle guy lines.

Table 42. Time and Labor to Assemble M4 Raft

Type of assembly[1]	Time, hr.[2]
4-ponton raft, 15-ft. spacing	2
4-ponton raft, short deck	2
Reinforced rafts	
5-ponton	2½
6-ponton	3
7-ponton	3½
5-ponton raft, short deck	2½

[1]One platoon is required for each type of assembly.
[2]For night assembly, increase time 50 percent.

The larger rafts (5-, 6-, or 7-ponton) are assembled by adding one, or more, pontons to this 4-ponton raft. The reinforcing ponton(s) is centered between the center pontons and fastened to them by four reinforcing ponton spacers. From five to seven bolster-body trucks, depending upon the number of added pontons, are required for transportation.

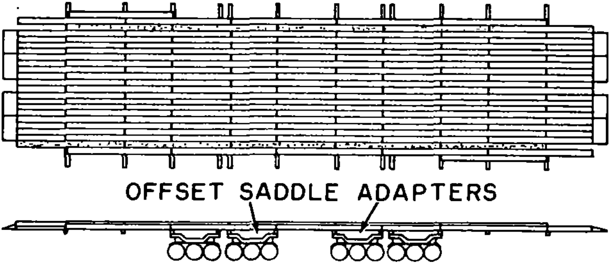


Figure 84. M4T6 reinforced raft.

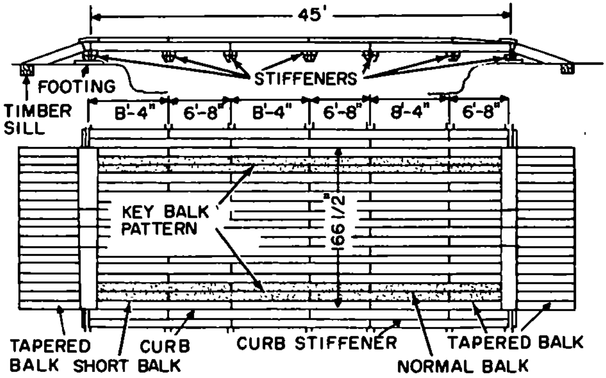


Figure 85. Loyout of deck-bolk fixed bridge.

77. EXPEDIENT AVLB RAFT

The ormored vehicle lounched bridge moy be lounched in the usual monner from o suitable embankment onto four fully saddled 24-ton pneumatic floats from the closs 60 flooting bridge set or the M4T6 flooting bridge set to build on expedient roft. The bridge is centered lengthwise across the floats ond offset downstreom from the roft centerline enough so os not to rest on the treodwoy holddown lugs. Four roller choin rachet hoists are used to tie the bridge down to the floats. They are connected to the hook rings on eoch side of the bridge ond to the outermost saddle beoms on the end floats. The floots are tied together securely with rope before the bridge is lounched. Power is supplied by bridge erection boots. The roft should not be used in fost currents ond should be used only os o necessory expedient. Four hinge pins must be ploced in the top center connectors when the AVLB is used as o raft. These pins ore not kept with the bridge becouse they serve no function in the normol use of the bridge.

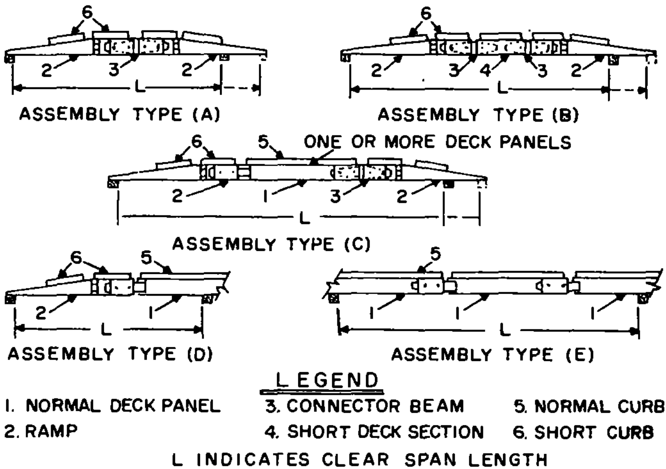


Figure 86. Class 60 fixed bridge.

Toble 43. MFAB/Ferry Classification (Tons)

Raft construction	Type crossing	
	Narmol	Risk
2 end bays	25	
3 boys	47	55
4 boys	72*	81
5 bays	90*	
6 bays	108*	115

*Provided that no single vehicle in the payload exceeds class 62. All classes are tentatively designated.

Table 44. Deck Balk Fixed Bridges (Span Capacities)

Type of Crossing	Capacity for Specified Span Lengths (feet) and Ratio of Deck/Roadway Widths[1]														
	23'4"	30'0"			38'4"				45'0"						
	22 18	22 18	22 16	24 18	22 18	22 16	24 18	26 18	20 16	22 18	22 16	24 18	24 16	26 18	26 16
Normal	[3](120)[2] 100	(85) 65	(90) 70	(90) 70	(45) 35	(50) 40	(55) 45	(65) 50	(24) 25	(24) 25	(30) 30	(30) 30	(40) 35	(40) 35	(45) 40
Caution	(120)[2] 100[2]	(100) 80	(100) 80	(105) 85	(70) 51	(70) 51	(75) 55	(82) 50	(40) 35	(46) 40	(46) 40	(51) 43	(51) 43	(56) 46	(56) 46
Risk	(120)[2] 100[2]	(110) 90	(110) 90	(115) 95	(78) 57	(78) 57	(85) 62	(90) 67	(47) 40	(54) 45	(54) 45	(60) 49	(60) 49	(66) 53	(66) 53

[1]Deck width (number of balk) - - - - - - - - 22 / 18 Roadway width (number of balk)

[2]Limited by roadway width

[3]Wheeled vehicle classification - - - - - - - (45) / 50 Tracked vehicle classification

78. FIXED SPAN CONSTRUCTION

a. The decks from either the class 60 floating bridge sets or the M4 and M4T6 bridge sets can be assembled as fixed bridges to cross small gaps. Two trestle sets are furnished with each class 60 and M4T6 bridge set. These must be used as sets of two and cross braced to each other to attain the proper classification.

b. Tables 44 and 45 and figures 85 and 86 list the classifications for various spans of M4 balk and class 60 fixed spans. The span is the clear distance between abutments, trestles, or suitable expedient supports.

79. LIGHT STEAM CROSSING EQUIPMENT

Data on the characteristics of engineer stream-crossing equipment is compiled in table 46.

Table 45. Classes of Fixed-Span Assemblies Shown in Figure 86

Clear span (feet)	Type of assembly	Classes		
		Normal	Caution	Risk
24	ABCDE . .	(120*) 100	(120*) 100*	(120*) 100*
26	ABCD . . .	(120*) 95	(120*) 100	(120*) 100*
	E	(120*) 100	(120*) 100	(120*) 100*
28	ABCD .	(115) 80	(120*) 87	(120*) 100
	E	(120) 85	(120*) 92	(120*) 100*
30	ABCD . . .	(105) 65	(110) 65	(120*) 90
	E	(110) 70	(120) 80	(120*) 95
32	BCDE . . .	(95) 60	(105) 70	(120) 85
34	BCDE . . .	(85) 55	(90) 63	(110) 75
36	BCDE . .	(75) 50	(81) 58	(100) 68
38	CDE	(65) 45	(75) 53	(90) 65
40	CDE	(60) 40	(68) 50	(83) 60
50	CDE	(30) 30	(36) 36	(50) 45
60	CDE	(20) 22	(22) 25	(28) 30

*Limited by roadway widths.

NOTES.

1. Figures in parentheses represent wheeled vehicle class and other figures represent tracked vehicle class.
2. These capacities are for most critical position of abutments.
3. For symmetrical erection of type B, with respect to abutments, the stated capacities may be increased 10 tons.
4. Number of normal deck panels utilized depends on span length desired.

Table 46. Engineer Light Stream-Crossing Equipment Data

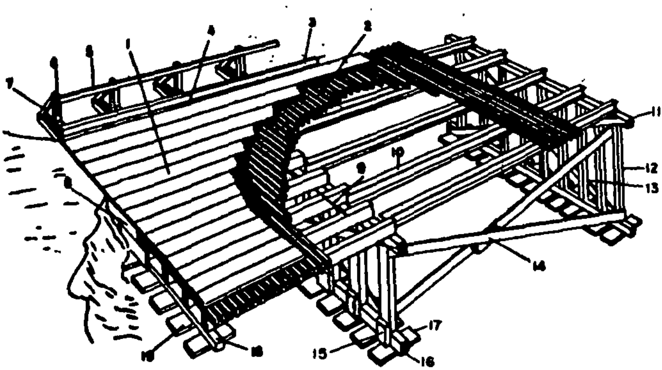
Item	Use	Description	Capacity	Remarks
Three-man reconnaissance boat	Reconnaissance	Canvas w/5 compartments Issued w/towline and 3 paddles. Total wgt 30 pounds.	3 men in current Speeds up to 4 KMPH.	Boat is breath-inflated or hand pumped. Easily carried by one man when deflated and packed in case.
Plastic assault boat	Initial crossing	Plastic, hand paddled Weight 300 pounds Length 16'5" Width 5'4"	12 Infantrymen w/full equipment or equivalent in current speeds up to 4 KMPH.	Normal crew, three engineers. Maximum capacity w/no current is 3300 pounds. Can be propelled by one 25-HP outboard motor at speed of 12.8 KMPH w/o a load reduction.
Storm boat	Speed crossing	Plywood, double-bottomed. Weight 440 lbs. w/o motor.	7 Infantry w/full equipment	Normal crew, two engineers. Power supplied by two 25-HP motors Maximum speed 32 to 40 KMPH. Capable of crash-landing at full speed. Engr CL IV Supply.
Plastic assault boat Employed as storm boat	Speed crossing	See plastic assault boat above.	5 Riflemen w/full equipment and 1-man crew.	Maximum speed 32 KMPH. Capable of crash-landing at full speed. Can be used in currents up to 12 KMPH. Power supplied by one 25-HP motor.
Light tactical raft (alum)	Ferry high-priority vehicles	4 alum pontons and solid alum deck. 33 foot loading area.	Class 16 load in current velocity of 8 KMPH. Class 8 load in current velocity of 9.6 KMPH.	Two rafts organic to Div. Engr. Bn.
Assault boat pneumatic	Assault crossing	Neoprene coated nylon, pneumatic, weight 250 lbs. length 17 feet, width 5'8"	12 fully equipped Infantrymen, crew 3 engr..	18 in Div. Engr. Bn. Can be paddled or power supplied by 25-BHP motor. 13 KMPH in current of 7-KMPH.

CHAPTER 7
FIXED BRIDGES

Section I. Timber Trestle Bridge

80. INFORMATION

A timber trestle bridge (fig. 87) is one of the simplest types of bridge built in a theater of operations. Steel or timber stringers rest on near and far-shore abutments and intermediate supports. The intermediate supports may be timber bents, timber piers, pile bents, or a combination of these supports. Spans are usually limited to 25 feet when using timber stringers. Deep water, swift current, or adverse footing conditions demand the use of piles (fig. 88). The load carrying component of the superstructure is the stringer system, which may be rectangular timber, round timber, or steel beams. Steel stringers are either I-beams, wide-flange beams, channel beams, or built-up beams. Maximum span will depend on the size beam and capacity required. See figures 88–92 and table 47 for nomenclature. See chapter 5 for posting of classification signs. See TM 5–312 for further reference.



(NUMBERS REFER TO TABLE 47)

Figure 87. Timber trestle bridge.

Table 47. Bridge Components of Timber Trestle Bridge

No.	Bridge Components	Common Sizes of References
1	Tread	2" x 10" x Random Length
2	Open-laminated deck	Variable Size
3	Curb	6" x 6" x Random Length
4	Curb riser block	6" x 10" x Random Length
5	Handrail	2" x 4" x Random Length
6	Handrail post	4" x 4" x 3'-0"
7	Handrail kneebrace	2" x 4" x Length to Suit
8	End dam	Use tread material (1)
9	Timber stringers	See paragraph 82a
10	Steel stringers	See paragraph 82b
11	Cap	See paragraph 82c
12	Posts.	See paragraph 82c
13	Transverse bracing	2" x 10" or 3" x 8"
14	Longitudinal bracing	4" x 6" or 3" x 8"
15	Scabs	Use tread material (1)
16	Sill	Same size as cap (11)
17	Footings	See paragraph 82c
18	Abutment sill	Same size as cap (11)
19	Abutment footings	Same size as footings (17)

See figures 87 through 92

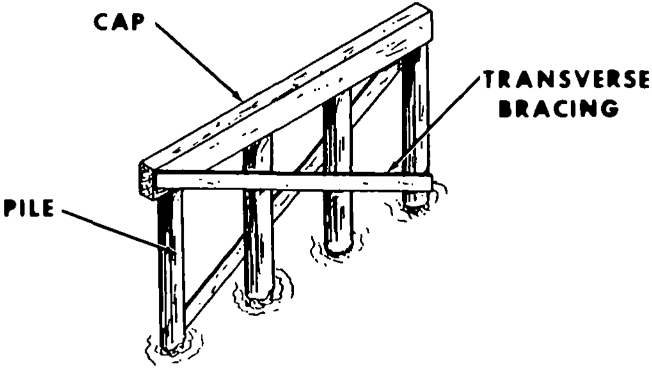


Figure 88. Pile bent.

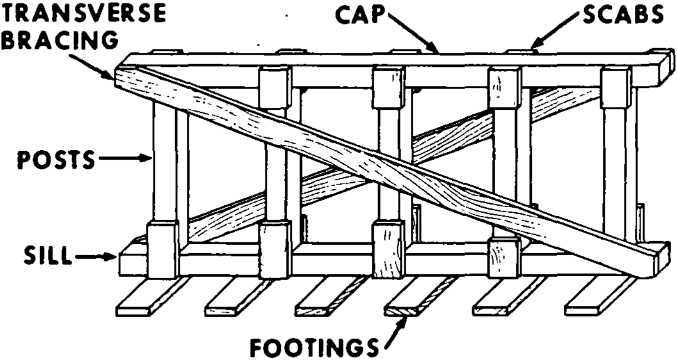


Figure 89. Timber trestle bent.

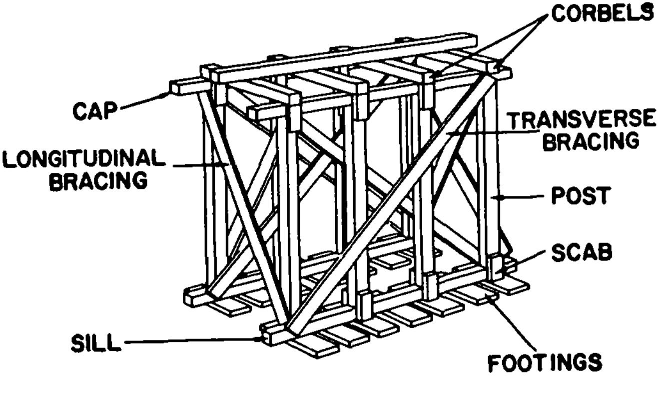


Figure 90. Timber trestle pier.

81. TIMBER TRESTLE FIELD CLASSIFICATION

a. *Highway Bridge With Timber Stringers.*

(1) Count number of stringers (N) in one lane of weakest span. (If weakest is unknown, use procedure for each span.)

(2) Measure width and depth of stringers in inches and span length in feet.

NOTE. Span length (L) measured from center to center of caps.

(3) Entering table 48 with the width (b) of the stringer and the depth (d), read "m" which is the resisting moment of one stringer. Determine "M," the total resisting moment, by the formula.

$$M = Nm$$

If the stringer size is not listed, compute "M" by the formula—

For rectangular sections $M = \frac{Nbd^2}{30}$ or For circular sections $M = \frac{N\pi d^3}{160}$

(4) Mark this value of "M" on the left side of the graph in figure 93 and draw a horizontal line through this point.

(5) Draw a vertical line on the graph along span length (see bottom of graph).

(6) The intersection of the lines drawn in steps 4 and 5 gives the bridge class based on moment. If intersection falls between the two class curves, estimation should be used to determine class.

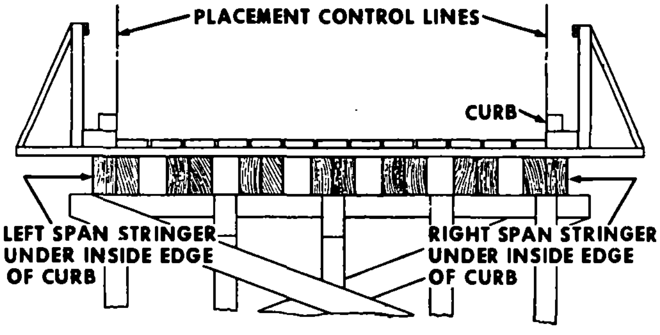


Figure 91. Placement of stringers on trestle bent.

Table 48. Properties of Timber Stringers

Actual size, in. (breadth and depth)	m**	v	Maximum span length, ft.	Actual size, in. (breadth and depth)	m**	v	Maximum span length, ft.
4 x 8	8.53	1.42	12	12 x 20	160.0	10.67	30
*4 x 10	13.33	1.78	15	12 x 22	193.6	11.73	33
*4 x 12	19.20	2.13	18	12 x 24	230.0	12.80	36
6 x 8	12.80	2.13	12	14 x 14	91.5	8.71	21
6 x 10	20.0	2.67	15	14 x 16	119.5	9.96	24
6 x 12	28.8	3.20	18	14 x 18	151.2	11.20	27
*6 x 14	39.2	3.73	21	14 x 20	186.7	12.44	30
*6 x 16	51.2	4.27	24	14 x 22	226.0	13.69	33
*6 x 18	64.8	4.80	27	14 x 24	269.0	14.93	36
8 x 8	17.07	2.84	12	16 x 16	136.5	11.38	24
8 x 10	26.7	3.56	15	16 x 18	172.8	12.80	27
8 x 12	38.4	4.27	18	16 x 20	213.0	14.22	30
8 x 14	52.3	4.98	21	16 x 24	307.0	17.07	36
8 x 16	68.3	5.69	24	18 x 18	194.4	14.40	27
*8 x 18	86.4	6.40	27	18 x 20	240.0	16.00	30
*8 x 20	106.7	7.11	30	18 x 22	290.0	17.60	33
*8 x 22	129.1	7.82	33	18 x 24	346.0	19.20	36
*8 x 24	153.6	8.53	36	8φ	10.05	2.51	12
10 x 10	33.3	4.44	15	9φ	14.31	3.18	13.5
10 x 12	48.0	5.33	18	10φ	19.63	3.93	15
10 x 14	65.3	6.22	21	11φ	26.1	4.75	16.5
10 x 16	85.3	7.11	24	12φ	33.9	5.65	18
10 x 18	108.0	8.00	27	13φ	43.1	6.64	19.5
10 x 20	133.3	8.89	30	14φ	53.9	7.70	21
*10 x 22	161.3	9.78	33	16φ	80.4	10.05	24
*10 x 24	192.0	10.67	36	18φ	114.5	12.72	27
12 x 12	57.6	6.40	18	20φ	157.1	15.71	30
12 x 14	78.4	7.47	21	22φ	209.0	19.00	33
12 x 16	102.4	8.53	24	24φ	271.0	22.6	36
12 x 18	129.6	9.60	27				

* Lateral braces required at midpoint and ends of span.

** Section modulus may be found by solving S = 5m.

φ Diameter at butt end.

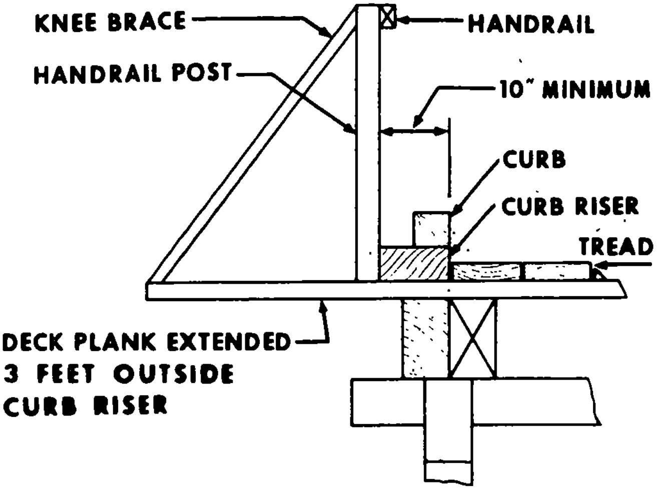


Figure 92. Curb and handrail system.

(7) Entering table 48 with the width (b) of the stringer and the depth (d), read "v" which is the resistance to shear for one stringer. Determine V, the total shear resistance, by the formula.

$$V = Nv$$

If the stringer size is not listed, compute V by the formula—

For rectangular sections $V = \frac{2Nbd}{45}$ or For circular sections $V = \frac{N\pi d^2}{80}$

(8) Mark this value of V on the left side of the graph in figure 94 and draw a horizontal line through this point.

(9) Draw a vertical line on graph along span length.

(10) The insection of the lines drawn in steps 8 and 9 gives the bridge class based on shear.

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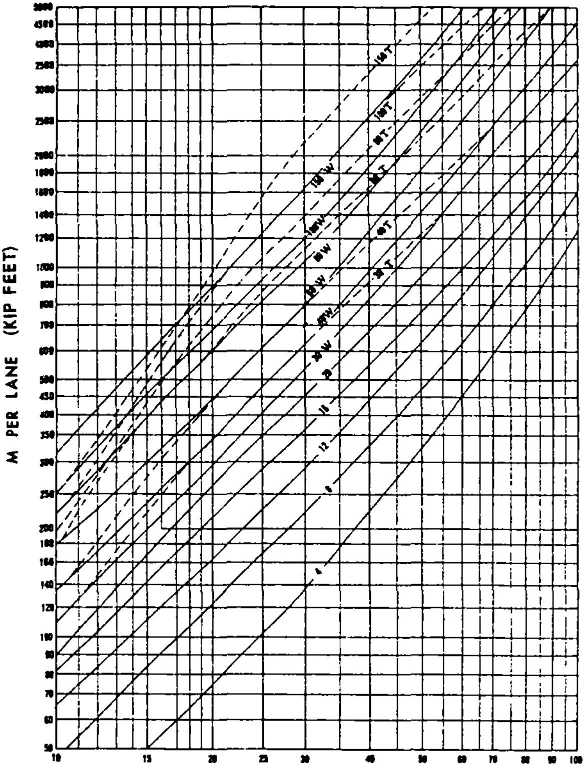

Figure 93. Moment graph for rapid field design method.

(11) The lower of the classes obtained in steps 6 and 10 is the class of the bridge. Check capacity of intermediate supports.

NOTE. The class found above is the only number necessary for a one-lane bridge sign. For a two-lane bridge this is the two-way class number placed on the left side of the sign.

To determine the one-way class number for a two-lane bridge, change steps 1 and 2 as follows:

Step 1. Count TOTAL number of stringers in the weakest span. Measure width and depth of stringers, the span length and the width of roadway (table 29).

Step 2. Multiply total number of stringers by

$$\frac{15}{\text{roadway width in feet}}$$ to obtain "N," the effective number of stringers.

Steps 3 to 11. No change.

Example 1.

Given: One-lane bridge; wood stringers; 16-ft span; 7 stringers, each 6" x 12" (actual dimensions); 10-ft roadway width. To find bridge class: since there is only one lane, all seven stringers are effective in that lane. From table 48 for $b = 6''$ and $d = 12''$, read $m = 28.8$. Therefore, $M = 7(28.8) = 201.6$. Mark this "M" on the left side of the graph in figure 93 and draw a line horizontally to intersect the vertical 16-ft span length line. Read class 25 from curve. From table 48 read $v = 3.20$. Therefore, $V = 7(3.20) = 22.4$. Mark "V" on the left side of the graph in figure 94 and draw a line horizontally to intersect the vertical 16-ft-span line. Read class 31 wheeled and tracked from curve. Bridge is class 25, but because width is less than 11'-0" (table 29), a width restriction sign must be posted directly under the class sign (see chapter 5).

NOTE. If bridge specifications do not comply with paragraph 82c, or if members are damaged, reinforcement or repair will be necessary prior to final classification.

b. Highway Bridge With Steel Stringers. Use same method as for timber stringers, a above, except change steps 2, 3, and 7 as follows:

Step 2. Measure width, depth, average flange thickness, and web-thickness of stringers in inches and span length in feet.

Step 3. If the stringer is a beam listed in table 49, read "m" from the table. Determine "M" by the formula

$$M = Nm$$

If the stringer is not listed or if doubt exists, compute "M" by the formula

$M = 2Nd_1 \left(A_f + \frac{A_w}{6}\right)$ (see example 2 below)

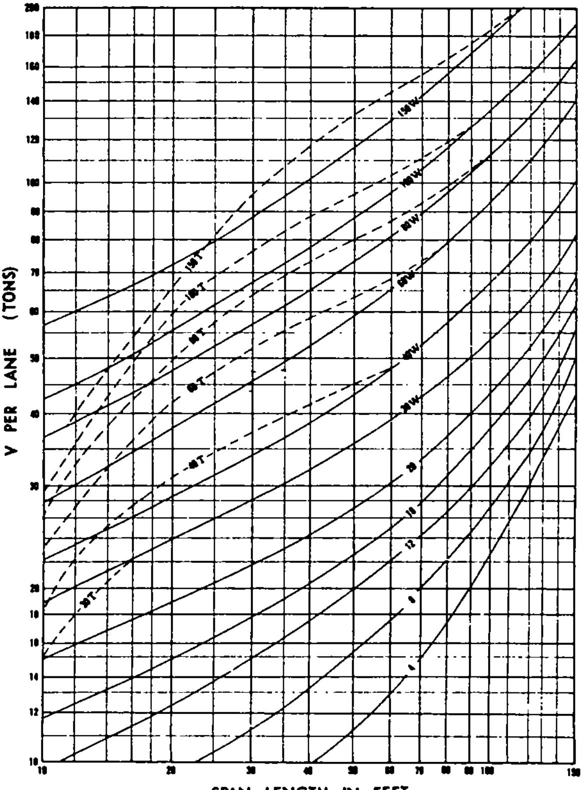

Figure 94. Shear graph for rapid field design method.

Step 7. If the stringer is a beam listed in table 49, read "v" from the table. Determine "V" by the formula

$$V = Nv$$

If the stringer is not listed or if doubt exists, compute "V" by the formula

$$V = 5Ndt_2$$

Example 2.

Given: Two-lane bridge: steel stringers; 43-ft-span; 4 stringers, each 30¼" deep, 10½" wide flange, 1" thick flange, and ⅝" thick web; 24-ft roadway width.

To find bridge class: roadway width limits two-way class to classes 4 to 60. Number of stringers per lane = 2. Since table 49 does not list this stringer, find "M" and "V" as follows (fig. 95):

$$M = 2Nd_1\left(A_f + \frac{A_w}{6}\right)$$

$d_1 = d - 2t_1 = 28.25$

$A_f = b \times t_1 = 10.5$

$A_w = d_1 \times t_2 = 17.66$

$$M = (2)(2)(28.25)\left(10.5 + \frac{17.66}{6}\right) = 1519$$

$V = (5)(2)(30.25)(⅝) = 189$

Two-way class: bridge is class 60 wheeled and class 48 tracked.

One-way class: effective no. of Str.

$$= \frac{15}{\text{roadway width in feet}} \times \text{no. of Str.}$$

$$= \frac{15}{24} \times 4 = 2.5$$

$$M = 2(2.5)(28.25)\left(10.5 + \frac{17.66}{6}\right) = 1899$$

$V = 5(2.5)(30.25)(⅝) = 236$

Bridge is class 85 wheeled and class 63 tracked. Check capacity of intermediate supports.

NOTE. If the bridge specifications do not comply with paragraph 82c, or if members are damaged, reinforcement or repair will be necessary prior to final classification.

c. *Capacity of Trestle Bents.* In almost all cases the stringer is the most critical member of the bridge (figure 91). However, a check of the capacity of the posts may be made. To check post capacity of the weakest support:

(1) Count posts and measure size of posts.

(2) Use table 50 and determine maximum load per post, or use this formula:

$$\text{Max. Load (in tons)} = \frac{A_p}{4}$$

A_p = Cross sectional area of post (sq. in.)

Table 49. Properties of Steel Beams

Nominal size	Actual depth d	Actual width b	Flange thickness t_1	Web thickness t_2	m[1]	v	Max span length	Max bracing space
[2]51BU278	51-1/4	14	1-5/8	3/4	2727	192	128	15
[3]39WF211	39-1/4	11-3/4	1-7/16	3/4	1574	147	98	15
[3]37WF206	37-1/4	11-3/4	1-7/16	3/4	1472	140	93	15
36WF300	36-3/4	16-5/8	1-11/16	15/16	2210	172	92	25.5
36WF194	36-1/2	12-1/8	1-1/4	13/16	1327	148	91	14
36WF182	36-3/8	12-1/8	1-3/16	3/4	1242	136	91	13
36WF170	36-1/8	12	1-1/8	11/16	1158	124	90	12
36WF160	36	12	1	11/16	1082	124	90	11.5
36WF230	35-7/8	16-1/2	1-1/4	3/4	1671	134	90	19.5
[2]36WF150	35-7/8	12	15/16	5/8	1006	112	90	10.5
[3]36WF201	35-3/8	11-3/4	1-3/16	3/4	1374	132	88	16
[3]33WF196	33-3/8	11-3/4	1-3/16	3/4	1274	125	83	17
33WF220	33-1/4	15-3/4	1-1/4	13/16	1481	135	83	20
33WF141	33-1/4	11-1/2	15/16	5/8	894	104	83	11
33WF130	33-1/8	11-1/2	7/8	9/16	810	93	83	10
33WF200	33	15-3/4	1-1/8	3/4	1339	124	83	18.5
[3]31WF180	31-1/2	11-3/4	1-5/16	11/16	118	108	79	16.5
30WF124	30-1/8	10-1/2	15/16	5/8	709	94	75	11
30WF116	30	10-1/2	7/8	9/16	656	84.5	75	10
30WF108	29-7/8	10-1/2	3/4	9/16	598	84	75	9
[3]30WF175	29-1/2	11-3/8	1-5/16	11/16	1028	102	74	17.5
[3]27WF171	27-1/2	11-3/4	1-5/16	11/16	942	94.5	69	18.5
27WF102	27-1/8	10	13/16	1/2	533	68	68	10
[2]27WF94	26-7/8	10	3/4	1/2	486	67	67	9
[3]26WF157	25-1/2	11-3/4	1-1/4	5/8	814	79.5	64	19
24WF94	24-1/4	9	7/8	1/2	442	60.5	61	11
24WF84	24-1/8	9	3/4	1/2	393	60	60	9.5
24WF100	24	12	3/4	1/2	498	60	60	13
24 I 120	24	8	1-1/8	13/16	502	97.5	60	12.5
24 I 106	24	7-7/8	1-1/8	5/8	469	75	60	12
24 I 80	24	7	7/8	1/2	348	60	60	8.5
24WF76	23-7/8	9	11/16	7/16	351	52	60	8.5

Table 49—Continued

Nominal size	Actual depth d	Actual width b	Flange thickness t_1	Web thickness t_2	m^1	v	Max span length	Max bracing space
[3]24WF153	23-5/8	11-3/4	1-1/4	5/8	736	74	59	20.5
[3]24 I 134	23-5/8	8-1/2	1-1/4	13/16	564	96	59	15
[3]22 I 75	22	7	13/16	1/2	274	55	55	8.5
[3]21WF139	21-5/8	11-3/4	1-3/16	5/8	622	67.5	54	24.5
[3]21 I 112	21-5/8	7-7/8	1-3/16	3/4	440	81	54	14.5
21WF73	21-1/4	8-1/4	3/4	1/2	301	53	53	9.5
21WF68	21-1/8	8-1/4	11/16	7/16	280	46.5	53	9
21WF62	21	8-1/4	5/8	3/8	253	39.5	53	8
20 I 85	20	7-1/8	15/16	11/16	300	69	50	11
[3]20 I 65	20	6-1/2	13/16	7/16	218	44	50	9
[3]20WF134	19-5/8	11-3/4	1-3/16	5/8	552	61.5	49	23.5
18WF60	18-1/4	7-1/2	11/16	7/16	216	40	46	9.5
[3]18 I 86	18-1/4	7	1	11/16	290	62.5	46	13
18WF55	18-1/8	7-1/2	5/8	3/8	196	34	45	8.5
[3]18 I 80	18	8	15/16	1/2	260	45	45	14
18WF50	18	7-1/2	9/16	3/8	178	34	45	8
18 I 55	18	6	11/16	1/2	177	45	45	7.5
[3]18WF122	17-3/4	11-3/4	1-1/16	9/16	576	50	44	23.5
[3]18 I 62	17-3/4	6-7/8	3/4	3/8	212	33	44	9.5
[3]18 I 77	17-3/4	6-5/8	15/16	5/8	250	55.5	44	11.5
[3]16WF112	16-3/4	11-3/4	1	9/16	400	47	42	23.5
[3]16 I 70	16-3/4	6-1/2	15/16	5/8	212	52.5	42	12
16WF50	16-1/4	7-1/8	5/8	3/8	161	30.5	41	9
16WF45	16-1/8	7	9/16	3/8	145	30	40	8
16WF64	16	8-1/2	11/16	7/16	208	35	40	12.5
16WF40	16	7	1/2	5/16	129	25	40	7.5
[3]16 I 50	16	6	11/16	7/16	138	35	40	8.5
16WF36	15-7/8	7	7/16	5/16	113	25	40	6.5
[3]16WF110	15-3/4	11-3/4	1	9/16	307	44.5	39	25
[3]16 I 62	15-3/4	6-1/8	7/8	9/16	178	44.5	39	11.5

See footnotes at end of table.

Table 49—Continued

Nominal size	Actual depth d	Actual width b	Flange thickness t_1	Web thickness t_2	m[1]	v	Max span length	Max bracing space
[3]16 I 45	15-3/4	5-5/8	5/8	7/16	134	34.5	39	7.5
[3]15WF103	15	11-3/4	15/16	9/16	328	42	38	24.5
[3]15 I 56	15	5-7/8	13/16	1/2	154	37.5	38	10.5
15 I 43	15	5-1/2	5/8	7/16	118	33.5	38	7.5
[3]14WF101	14-1/4	11-3/4	15/16	9/16	306	40	36	26
[3]14 I 40	14-1/4	5-3/8	5/8	3/8	106	26.5	36	8
[3]14 I 51	14-1/8	5-5/8	3/4	1/2	134	35.5	35	10
[3]14 I 70	14	8	15/16	7/17	182	30.5	35	18
[3]14 I 57	14	6	7/8	1/2	136	35	35	12.5
[3]14 I 40	14	5-1/2	5/8	3/8	108	26	35	8
14WF34	14	6-3/4	7/16	5/16	97	22	35	7.5
14WF30	13-7/8	6-3/4	3/8	1/4	84	17.5	35	6
[3]14WF92	13-3/8	11-3/4	7/8	1/2	264	33.5	33	25.5
[3]14 I 46	13-3/8	5-3/8	11/16	1/2	112	33.5	33	9
[3]13 I 35	13	5	5/8	3/8	76	24.5	33	8
[3]13 I 41	12-5/8	5-1/8	11/16	9/16	96	35.5	32	9.5
12WF36	12-1/4	6-5/8	9/16	5/16	92	19	31	9.5
[3]12 I 65	12	8	15/16	7/16	162	26	30	21
12WF27	12	6-1/2	3/8	1/4	68	15	30	7
12 I 50	12	5-1/2	11/16	11/16	101	41	30	10
12 I 32	12	5	9/16	3/8	72	22.5	30	7.5
[3]12 I 34	11-1/2	4-3/4	5/8	7/16	72	25	29	8.5
[3]11WF76	11	11	13/16	1/2	108	27.5	28	27
[3]10 I 29	10-5/8	4-3/4	9/16	5/16	60	16.5	27	8.5
10WF25	10-1/8	5-3/4	7/16	1/4	53	12.5	25	8
[3]10 I 40	10	6	11/16	3/8	82	19	25	14
10 I 35	10	5	1/2	5/8	58	31	25	8
10 I 25	10	4-5/8	1/2	5/16	49	15.5	25	7.5
10WF21	9-7/8	5-3/4	5/16	1/4	43	12.5	25	6.5
[3]10WF59	9-1/2	9-1/2	11/16	7/16	118	21	24	23

Table 49—Continued

Nominal size	Actual depth d	Actual width b	Flange thickness t_1	Web thickness t_2	m[1]	v	Max span length	Max bracing span
[3]9 I 25	9-1/2	4-1/2	1/2	3/16	46	15	24	8
[3]9 I 50	9	7	13/16	3/8	92	17	23	21
[3]8 I 35	8	6	5/8	5/16	58	12.5	20	15.5
[3]8 I 28	8	5	9/16	5/16	44	12.5	20	11.5
8WF31	8	8	7/16	5/16	55	12.5	20	14.5
[3]8WF44	7-7/8	7-7/8	5/8	3/8	72	15	20	21
[3]7WF35	7-1/8	7-1/8	9/16	3/8	52	13.5	18	18.5
[3]6WF31	6-1/4	6-1/4	9/16	3/8	40	11.5	16	18.5

LEGEND

[1]Section modulus may be found by solving S = 1/2 m.

[2]Functional component beams (TM 5 - 302).

[3]These nominal sizes have no U. S. equivalent.

(3) Multiply maximum load per post by number of posts. (Result is maximum load support will carry.)

(4) Add the lengths of the spans which are supported by the trestle bent.

(5) For a one-lane bridge or the one-way class of a two-lane bridge, use the values obtained in steps (3) and (4) in the graph in figure 94, to determine the class of the trestle bent. For the two-way class of a two-lane bridge, divide the value obtained in step (3) by two and use this value in the graph in figure 94.

(6) Compare this result with the stringer class and use the smaller value as the bridge class. See chapter 5 for classification signs.

NOTE. If bridge specifications do not comply with paragraph 82c, or if members are damaged, reinforcement and/or repair will be necessary prior to final classification.

Table 50. Capacities of Posts and Piles

Rectangular			Round		
Size, in.	Max. Load, tons	Height,* ft.	Size, in.	Max. Load, tons	Height,* ft.
6 x 6	9	18	8	12	22
6 x 8	12	18	9	15	24
8 x 8	16	24	10	19	27
8 x 10	20	24	11	23	30
10 x 10	25	30	12	28	32
10 x 12	30	30	13	33	35
12 x 12	36	36	14	36	38

*Maximum unbraced height—see page 82d.

82. TIMBER TRESTLE DESIGN

a. Design *Procedure* for *Timber Stringers.*

(1) *Moment design.*

(a) Determine the value of M from the moment graph (fig. 93) by entering the graph with the span length and drawing the line vertically to the desired class curve. From there draw a line horizontally to the left and intersect the value of M.

(b) Determine "m" from table 48 by entering the table with the stringer dimensions b and d.

(c) Compute the total number of stringers required from the formula:

$$N_s = \frac{M}{m} \times N_L$$

where N_L is the number of lanes.

NOTE. If the stringer size is nonstandard, and "m" cannot be obtained from table 48, then the total number of stringers can be computed from the following formula for rectangular sections:

$$N_S = \frac{30\ M}{bd^2} \times N_L \text{ (M in kip-feet)}$$

(2) *Shear design.*

(a) If the ratio $\frac{L \times 12}{d}$ is less than 13, shear will probably be critical. If $\frac{L \times 12}{d} > 13$, then shear design is omitted.

(b) Compute the value of shear (V) that will occur in the span by entering the shear chart (fig. 94) with the span length and draw a line vertically to the desired class curve. From this point draw a line horizontally to the left, intersecting the value of shear (tons) occurring in a lane of the bridge.

(c) Determine the value of "v" from table 48 for the particular size of stringer being used.

(d) Compute the total number of stringers required from the formula:

$$N_S = \frac{V}{v} \times N_L$$

NOTE. If the stringer is a nonstandard size and cannot be obtained from table 48, then compute the number of stringers from:

For rectangular sections $N_S = \frac{22.5V}{bd} \times N_L$ (V in tons)

For circular sections $N_S = \frac{80V}{\pi d^2}$

b. Design Procedure for Steel Stringers

(1) *Moment design.*

(a) Determine the value of M_R from the moment graph (fig. 93) in the same manner as for timber stringers.

(b) Determine "m" by extracting the value from table 49. If the stringer size is not listed in table 49, then the value of "m" can be computed from the formula:

$$m = 2S \quad (S = \text{section modulus} = \tfrac{1}{2}\, m)$$

(c) Compute the total number of stringers required in the same way as for timber stringers (a(1)(c) above).

(2) *Shear design.*

(a) If the ratio $\frac{L \times 12}{d} < 10$, then shear will probably be critical rather than moment. If the ratio is equal to or greater than 10, the shear design is omitted.

(b) Determine the value of shear (V) in the span by following the procedure for the timber stringers (a(2)(b) above).

(c) Determine "v" by taking the proper value from table 49 for the stringer size being used.

(d) To compute the number of stringers required, follow the procedure for timber stringers (a(2)(d) above).

NOTE. Should the stringer in question not be listed in table 49, then the total number of stringers required is computed from the formula:

$$N_S = \frac{V \times N_L}{5dt_2} \quad t_2 = \text{web thickness}$$

$$d = \text{depth of beam}$$

c. *Rules of Thumb.*

(1) *Posts.* Maximum c-to-c spacing is 5 times depth of cap or sill. C-to-c distance of outside posts equals the distance face-to-face between curbs. Maximum unsupported length of rectangular posts is 36 times least dimension. Maximum unsupported length of a round post is 32 times its diameter. The total number of posts required is computed as follows (fig. 96):

$$N_{post} = \frac{V}{\text{cap/post} \times N_L}$$

V is taken from figure 94 after computing $L_e = L_1 + L_2$. In figure 96 this would be 35 feet. By using figure 94, V would be 47 tons. The value of cap/post is taken from table 50.

(2) *Caps and Sills.* With round timber, diameter must be at least 2 inches greater than that of post. Hew timber to fit at top and joints. With rectangular timber, use at least same size timber as posts with larger dimensions vertical, 6 inches x 8 inches minimum.

(3) *Bracing.* If bents are more than 4 feet high, use transverse cross bracing on all bents and longitudinal bracing between bents in every other span. Transverse bracing on pile bents may be omitted if pile is exposed less than 11 feet above ground line. The minimum size of bracing material is 2 inches x 10 inches (see table 50).

(4) *Footings.* Maximum length is 8 times thickness for SBC less than or equal to 4 tons per square foot and 6 times thickness for SBC over 4 tons per square foot (see table 51 for SBC).

(5) *Flooring.* Thickness exclusive of tread is c-to-c stringer spacing divided by 8. Use a minimum of 3 inches.

(6) *Tread.* At least 2 inches thick.

(7) Curb and *handrail.* For specification, see figure 92.

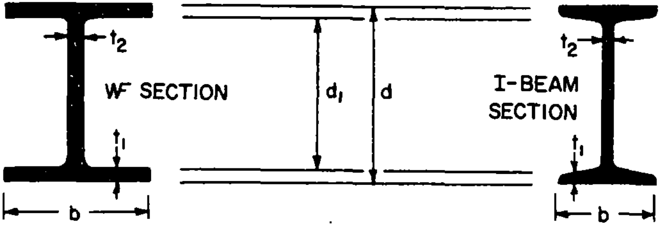

Figure 95. Beam cross section dimensions.

d. Substructure Design With a Pile Bent.

(1) Use horizontal braces at midpoint of piles when pile height exceeds that shown in table 50.

(2) For a bent under adjacent spans, add the adjacent span lengths to find the effective span length (Le). Using "Le" find "V" from the shear graph figure 94.

(3) Determine capacity of one post from table 50. If post is not listed,

$$\text{cap/post} = \frac{A_p}{4} \text{ (tons)}$$

where A_p = cross section of post, square inches.

Table 51. Soil Bearing Capacities (SBC)

Soil description	Bearing values, tons per sq ft.
Hardpan overlaying rock	12
Very compact sandy gravel	10
Loose gravel and sandy gravel, compact sand and gravelly sand, very compact sand-inorganic silt soils	6
Hard, dry consolidated clay	5
Loose coarse-to-medium sand; medium compact fine sand	4
Compact sand clay	3
Loose fine sand, medium compact sand-inorganic silt soils	2
Firm or stiff clay	1.5
Loose saturated sand-clay soils, medium soft clay	1

(4) Determine the allowable load (P) for a skin friction pile by one of the following:

For piles driven by

	Drophammer	Single-acting pneumatic or steam hammer	Double-acting pneumatic, steam, or closed end diesel hammer
Timber	$P = \dfrac{2W_dh}{(S+1)}$	$P = \dfrac{2W_rH}{(S+0.1)}$	$P = \dfrac{2E}{(S+0.1)}$
Steel	$P = \dfrac{3W_dh}{(S+1)}$	$P = \dfrac{3W_rH}{(S+0.1)}$	$P = \dfrac{3E}{(S+0.1)}$

Where:
$P =$ estimated safe capacity of pile (lb)
$W_d =$ weight of drophammer (lb)
$W_r =$ weight of ram of steam or pneumatic hammer (lb)
$h =$ average height of fall of drophammer for last 6 blows (ft)
$H =$ stroke of ram (ft)
$S =$ average pile penetration, in inches per blow, for last 6 blows of a drophammer or last 20 blows of steam or pneumatic hammer
$E =$ driving energy (ft-lbs/blow), steam or pneumatic

(5) Determine number of effective piles required

$$Np.e. = \frac{V \times 2000 \times N_L}{\text{capacity per pile}} \quad \text{where} \quad \frac{\text{capacity}}{\text{pile}}$$ is the smallest of the values found in d(3) and d(4).

(6) Determine $\dfrac{S_p}{D} = \dfrac{W_R \times 12}{(Np.e. - 1)D}$

$W_R =$ width of roadway—ft
$D =$ diameter of pile

(7) Using the pile chart, figure 97, determine Np. (Minimum number of piles per bent = 4.)

(8) Maximum pile Sp. = 5 x d_{cap} is depth of cap, in.

Example 3.

Given: $L_1 = 20'$, $L_2 = 30'$, Class 60, $Hp = 15'$, cap 12″ x 12″, 10″ Ø pile, = 10′; $W_d = 2000$ lbs., penetration for last 6 blows = 6″, $W_R = 14'$.

(1) $H_p = 15'$ which is less than 27', therefore no mid-point bracing is required.

(2) $Le = L_1 + L_2 = 20' + 30' = 50'$; $V = 63$

(3) Capacity/pile = 19.6 x 2000 = 39,200

(4) $P = \frac{2W_dh}{S+1} = \frac{2 \times 2000 \times 10}{(\frac{6}{6} + 1)} = 20{,}000$ lbs.

(5) $Np.e. = \frac{V \times 2000 \times N_L}{cap/pile} = \frac{63 \times 200 \times 1}{20{,}000} = 6.3$

(6) $\frac{S_p}{d} = \frac{W_R \times 12}{(Np.e. - 1)d} = \frac{14 \times 12}{(6.3 - 1)10} = 3.2$

(7) $N_p = 8$

(8) Actual $S_p = \frac{W_R \times 12}{(N_p - 1)} = \frac{14 \times 12}{(8 - 1)} = 24''$

(9) $5 \times d_{cap} = 5 \times 12 = 60$ Therefore, S_p is all right.

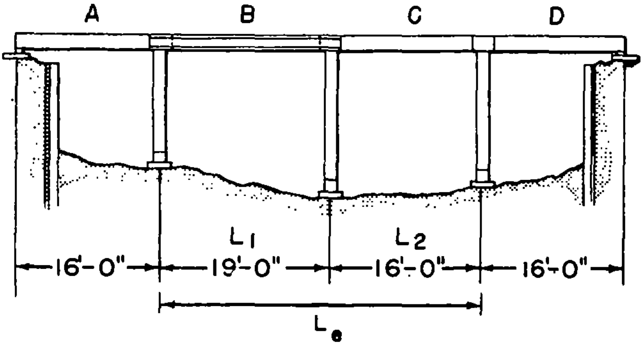

Figure 96. Example bridge spans.

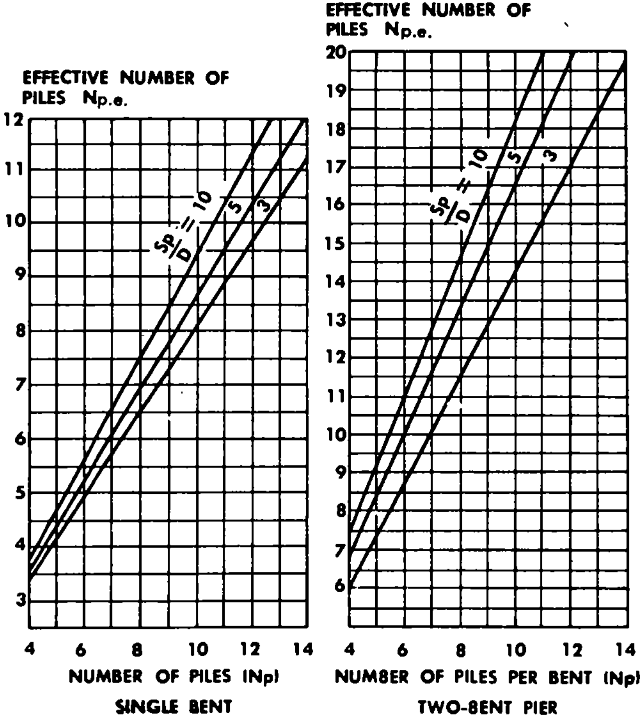

Figure 97. Pile design charts.

Section II. Panel Bridge, Bailey Type, M2

83. INTRODUCTION

a. The panel bridge, Bailey type, M2 (fig. 98) is a through-truss bridge supported by two main trusses formed from 10-foot steel "panels."

b. Panel bridge parts may be transported on twenty-five 5-ton dump trucks and 8 pole trailers. The loading plan is based on the experience that the double-single truss assembly provides for most bridging problems which require the panel bridge, Bailey type, M2. The loads have been arranged on the basis of the above vehicles capable of carrying all parts issued for a 130-foot DD bridge, including spares. The engineer panel bridge company is the TOE unit designated to carry one bridge set and provide technical personnel and equipment to transport and supervise erection of panel bridging. Two 80-foot DS bridges or one 130-foot DD bridge may be constructed from one bridge set. Each bridge set has 126 panels (weighing 577 pounds each), 56 transoms (618 pounds each), 96 stringers (260 to 267 pounds each), 48 ribands (215 pounds each), 48 ramps (338 to 349 pounds each), and chess, end posts, bracing and erection equipment.

84. CONSTRUCTION DATA

a. Organization of assembly crews is given in table 52.

b. Figures 99 and 104 depict roller layout and suggested equipment layout.

c. Other data is shown in tables 53 through 58.

85. CLASSIFICATION

Table 59 gives the dual classification, by type of construction, type of crossing, and span length of the M2 panel bridge.

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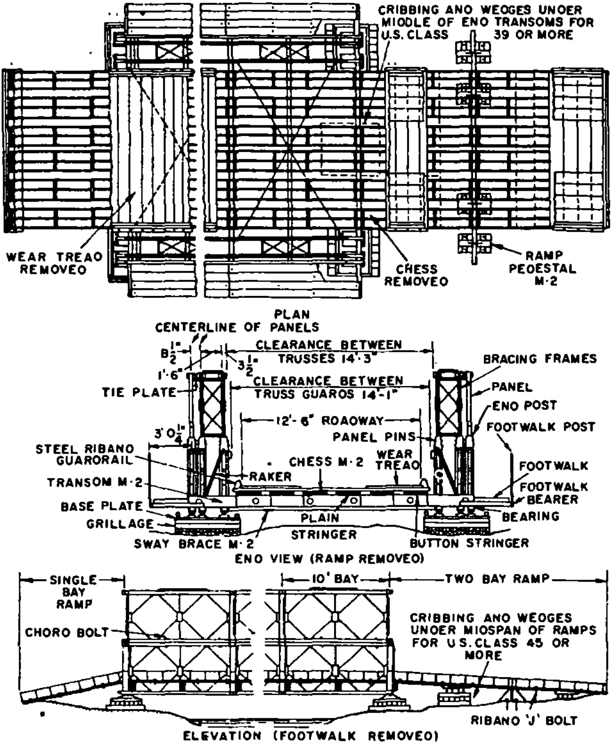

Figure 98. Steel panel fixed bridge, Bailey type, M2

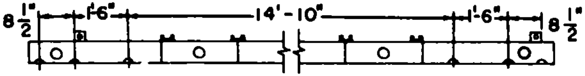

Figure 99. Transam used as templote.

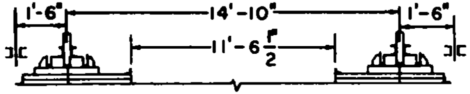

Figure 100. Plain roller, SS, DS, bridges.

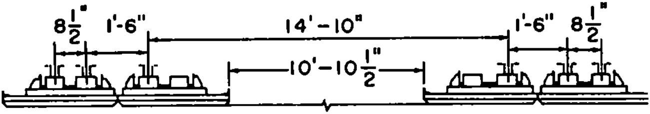

Figure 101. Ploin raller, TS, DD, TD, DT, TT, bridges.

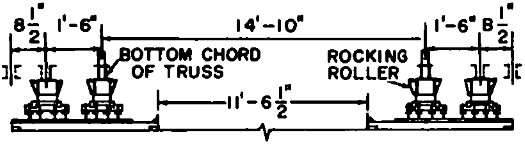

Figure 102. Layout af rocking raller template.

Table 52. Organization of Assembly Crews—Bailey Bridge

	NO. OF NCOs AND EM								
	Type of bridge								
	Single-single	Double-single	Triple-single	Double-double	Triple-double	Double-triple	Triple-triple	Double-triple	Triple-triple
	Construction by manpower only							Using 1 crane*	
CRANE	...	...	...	...	...	...	...	0–3	0–3
Truck driver	...	...	...	...	...	...	...	(1)	(1)
Crane operator	...	...	...	...	...	...	...	(1)	(1)
Hook man	...	...	...	...	...	...	...	(1)	(1)
PANEL	1–14	1–14	2–28	2–32	3–50	3–50	3–68	3–30	3–30
Carrying	(12)	(12)	(24)	(28)	(44)	(44)	(60)	(24)	(24)
Pin	(2)	(2)	(4)	(4)	(6)	(6)	(8)	(6)	(6)
TRANSOM	1–9	1–10	1–10	1–10	1–10	2–28	2–28	2–20	2–20
Carrying	(8)	(8)	(8)	(8)	(8)	(24)	(24)	(16)	(16)
Clamp	(1)	(2)	(2)	(2)	(2)	(4)	(4)	(4)	(4)
BRACING	1–4	1–6	1–8	1–12	1–20	1–32	1–40	1–32	1–38
Sway brace	(2)	(2)	(2)	(2)	(2)	(6)	(6)	(6)	(6)
Raker	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Bracing frame	...	(2)	(2)	(4)	(4)	(8)	(8)	(10)	(8)
Chord bolt	...	...	...	(4)	(8)	(10)	(14)	(10)	(14)
Tie plate	...	...	(2)	...	(4)	...	(4)	...	(4)
Overhead supp't	...	...	...	...	...	(6)	(6)	(4)	(4)
DECKING	1–12	1–12	1–12	1–12	1–12	1–12	1–12	1–12	1–12
Stringer	(8)	(8)	(8)	(8)	(8)	(8)	(8)	(8)	(8)
Chess and riband	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Total	4–39	4–42	5–58	5–66	6–92	7–122	7–148	7–97	7–103

*Normally, a crane is not used for single- or double-story assembly.

Table 53. Bailey Bridge Launching Construction

Bridge Type	Span ft.	No. of bays in nose SS	No. of bays in nose DS	No. of bays in nose DD	Distance of links from tip of nose ft.	Required distance behind rocking rollers, ft
SS	30	2			—	35
	40	3			—	43
	50	3			—	47
	60	4			10	55
	70	5			20	63
	80	5			20	67
	90	6			30	75
	*100	*6			30	76
DS	50	3			—	45
	60	4			10	52
	70	4			10	57
	80	5			20	64
	90	6			20	71
	100	6			20	76
	100	7			30	83
	120	8			40	90
	130	8			10 & 40	95
	*140	*8			10 & 40	96
TS	80	5			20	63
	90	6			20	70
	100	6			20	74
	110	7			30	81
	120	7			30	86
	130	8			40	93
	140	9			10 & 40	100
	*150	*9			20 & 40	101
	*160	*9			20 & 40	106
DD	100	6			20	74
	110	7			20	81
	120	7			30	86
	130	8			30	93
	140	7	2		40	100

Bridge Type	Span ft.	No. of bays in nose SS	No. of bays in nose DS	No. of bays in nose DD	Distance of links from tip of nose ft.	Required distance behind rocking rollers, ft.
DD (*)	150	6	3		40	106
	*160	*6	*3		40	106
	*170	*7	*3		10 & 40	113
	*180	*7	*3		20 & 40	117
TD	110	6			20	77
	120	7			20	84
	130	6	2		30	90
	140	5	3		30	96
	150	5	4		40	103
	*160	*5	*4		40	106
	*170	*6	*4		10 & 40	112
	*180	*7	*4		10 & 40	125
	*190	*7	*4		20 & 40	126
DT	130	5	3		30	91
	140	5	3		30	96
	150	5	4		30	102
	160	5	5		40	109
	*170	*5	*5		40	112
	*180	*5	*5		40	116
	*190	*6	*5		10 & 40	131
	*200	*7	*5		20 & 40	132
	*210	*7	*5		30 & 40	135
TT	*160	*5	*5		40	94†
	*170	*5	*6		40	96†
	*180	*6	*2	*2	40	102†
	*190	*6	*6	*2	10 & 40	112†
	*200	*6	*6	*4	20 & 40	115†
	*210	*7	*5	*6	30 & 40	117†

*Spans launched incomplete. See following table.
†Estimated.

LAUNCHING TT BRIDGES 1 Launch until near-bank rocking rollers are under last TT bay of initial construction. 2 Add up to six bays TT bays to tail of initial construction. This completes all but 210-foot span. 3. Continue launching until near-bank rocking rollers are under last TT bay added in step 2. 4. Add remainder of TT bays to complete bridge (210-foot span only). 5. Add five bays DS nose-type construction to tail of bridge. 6 Launch forward until first three DT bridge bays are beyond far-bank rollers. 7. Complete first three bridge bays by converting to TT and adding transoms. 8. Pull bridge back to final position, remove DS tail, add decking where needed, and jack down.

Table 54. Bailey Bridge Spans Launched Incomplete

Type	Span, ft.	No. of bays, decking & stringers	Omitted of top story
SS	100	4	
DS	140	6	
TS	150	6	
	160	10	
DD	160	7	
	170	7	
	180	12	2
TD	160	3	
	170	10	
	180	All	
	190	All	3 1/3
DT	170	3	
	180	8	
	190	All	
	200	All	3
	210	All	5
			No. of bridge bays in initial construction *
TT	160	3	14
	170	6	14
	180	6	14
	190	All	15
	200	All	14
	210	All	13

* First three bridge bays are constructed DT with only one transom per bay. Last bridge bay is constructed DT because of staggered construction necessary when adding subsequent bays.

Table 55. Number of Jacks Needed at Each End of Bailey Bridge

Type	Span, ft.	No. of jacks needed at each end of
SS	30-100	2
DS	50-140	4
TS	80-140	4
	150-160	6
DD	100-120	4
	130-180	6
TD	110-140	6
	150-190	8
DT	130	6
	140-180	8
	190-210	10
TT	160-170	10
	180-210	12

Table 56. Number of Racking Rollers Needed for Bailey Bridge

Type	Span, ft.	Near bank	Far bank
SS	30-100	2	*
	50-80	2	*
DS	90-100	2	2
	110-140	4	2
TS	80-160	4	2
DD	100-130	4	2
	140-180	4	4
TD	110-120	4	2
	130-190	4	4
DT	130-210	4	4
TT	160-210	4	4

* Use two plain rollers

Table 57. Weight per Bay of Bailey Bridge

Construction	Weights per bay, tons
BRIDGE	
SS	2.76
DS	3.41
TS	4.01
DD	4.66
TD	5.88
DT	6.46
TT	8.29
LAUNCHING NOSE	
SS	1.00
DS	1.64
DD	2.90
DECKING	
Stringers only	0.79
Chess and steel ribands	0.66
FOOTWALKS	0.17
OVERHEAD BRACING	
Supports, transoms, sway bracing, and chord bolts	0.54
WEAR TREAD AND TRUSS GUARDS	0.35

NOTE: Footwalks, wear treads, and truss guards not included. Overhead bracing included on DT and TT.

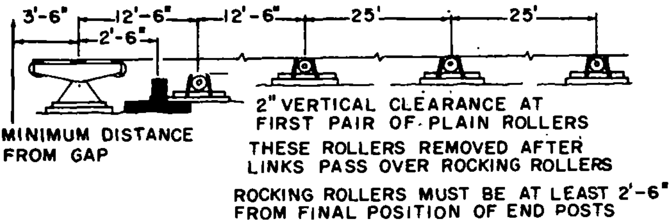

Figure 103. Vertical clearance necessary for removing first pair of near shore plain rollers after links pass rocking rollers.

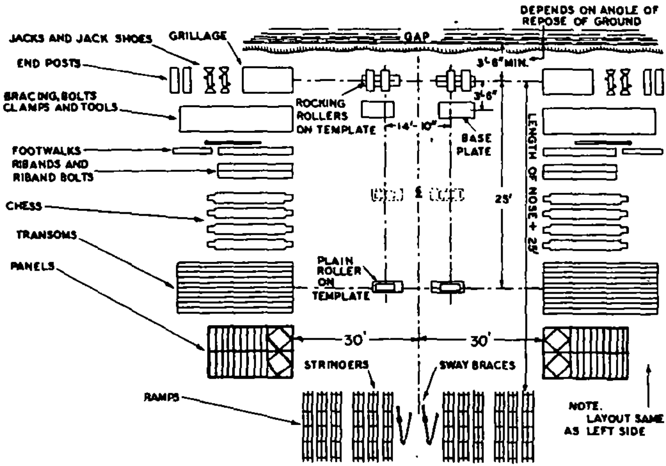

Figure 104. Layout of equipment at bridge site for training purposes.

Table 58. Critical Dimensions of Bailey Bridge

Road width between steel ribands	12' 6"
Road width between timber truss guards	13' 9"
Lateral distance between centerlines of trusses:	
Inner trusses	14' 10"
Middle trusses	17' 10"
Outer trusses	19' 3"
Lateral distance between centerlines of base plates:	
S truss bridge	14' 10"
D truss bridge	16' 4"
T truss bridge	17' 3½"
Lateral distance between outside edges of base plates:	
S truss bridge	19' 5"
D truss bridge	20' 11"
T truss bridge	21' 10½"
Lateral distance between measuring lugs of rocking roller templates	11' 6½"
Lateral distance between measuring lugs of plain roller templates:	
SS, DS bridges	11' 6½"
TS, DD, TD, DT, TT bridges	10' 10½"
Longitudinal spacing between plain rollers	25'
Height from base of base plate to top of chess	28 5/16"
Height from base of rocking roller template to top of rocking roller	16 5/16"
Height from base of plain roller templated to top of plain roller	8 15/16"
Height from base of ramp pedestal to top of ramp chess	17 ¼"
Height from bottom of half round lug under sloping end of ramp to top of ramp chess	5 7/8"
Height from top of chess to overhead bracing:	
Normal	14' 7"
Expedient	12' 3"
Height from base of bearing to bottom of panel	5 17/32"
Height from bottom of panel to top of chess	20 11/16"
Height from bottom of half round lug of end post to top of chess	22 13/32"
Height from base of rocking roller bearing to top of rocking roller	13 5/16"

Table 59. Dual Classification by Type of Construction and Crossing-Bailey Bridge

SPAN IN FEET	SINGLE SINGLE			DOUBLE SINGLE			TRIPLE SINGLE			DOUBLE DOUBLE			TRIPLE DOUBLE			DOUBLE TRIPLE			TRIPLE TRIPLE		
	N	C	R	N	C	R	N	C	R	N	C	R	N	C	R	N	C	R	N	C	R
30	30/30	42/37	47/42																		
40	24	38/34	40/38																		
50	24	33/31	36/35	75/70	83/86	88/84															
60	20	30/29	33/32	65/65	77/73	85/78															
70	20	24	30/30	60/60	68/69	78/75															
80	16	20	24	50/55	60/60	66/64	65/80	95/90	100*/90*												
90	12	16	19	40/45	50/50	55/55	65/65	74/75	82/82												
100	8	12	14	30/30	37/39	42/44	50/55	57/60	84/66	80/80	86/90	96/90									
110				20	30/32	34/36	35/40	47/49	52/54	65/70	72/76	80/83	80/90*	100*/90*	100*/90*						
120				16	23	27/30	30/35	38/41	43/45	45/55	57/61	64/68	75/80	83/90*	91/90*						
130				12	18	21	20	31/33	35/38	35/45	47/50	53/56	55/60	65/72	74/80	70/80	80/90*	90/90*			
140				8	14	17	16	24	29/31	30/35	39/42	44/48	45/55	57/62	84/70	70/70	80/90*	88/90*			
150							12	18	22	24	32/35	36/40	35/45	47/51	54/58	60/60	77/85	85/90*			
160							8	15	17	16	25	30/33	30/35	37/41	45/48	55/55	69/78	80/89	80/75	100/90*	100*/90*
170							4	10	13	12	19	24	20	31/34	36/40	45/50	57/64	84/74	70/70	80/90*	90/90*
180										8	15	18	16	24	29/32	35/45	48/53	55/60	55/60	66/75	77/87
190													12	18	22	30/33	39/43	48/51	45/55	59/68	68/77
200																20	32/38	36/43	35/40	48/52	55/82
210																16	25	31/33	24	38/43	48/51

* Limited by roadway width.

86. MASONRY ARCH BRIDGE

To obtain the bridge classification number for a masonry arch bridge, a pravisianal closs number based an the crawn thickness and span length is determined; this provisianal class number is then adjusted by applying factors based an the moteriols ond the condition of the bridge.

Step 1. Provisianal class number.

(a) Mark span length (S in fig. 105) on col. A of figure 106.

(b) Mark totol crown thickness (t + D in fig. 105) on col. B of figure 106.

(c) Drow o stroight line through the points marked in steps *(a)* ond *(b)*, and where this line intersects col. C, read the provisionol closs number.

Step 2. Profile factor.

(o) Divide spon length (S in fig. 105) by the rise (R in fig. 105) ond mark the result at the bottam af figure 107. If the result is 4 ar less, profile factor is 1. Otherwise—

(b) Draw a vertical line fram the mark made in *(o)* obave ond mork the paint where it intersects the curved line.

(c) Draw a harizontol line from the mork mode in *(b)* obove to the left edge of figure 107 and read the profile factor at this point.

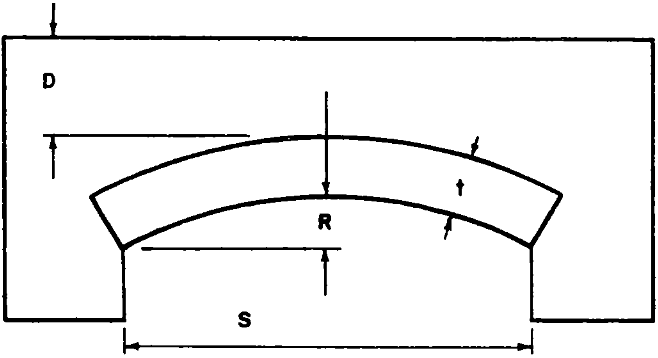

Figure 105. Mosonry orch bridge.

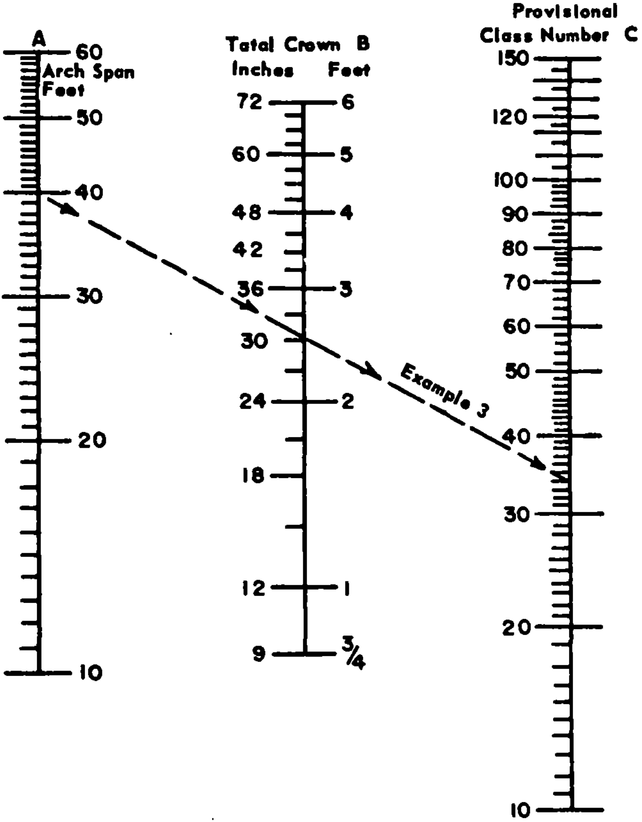

Figure 106. Chart for determining provisional load class of arch bridges.

Step 3. Other factors (see table 60). Select the material, joint, deformation, crack, abutment size, and abutment fault factors from the table. Use only those factors which apply.

Step 4. Actual class number. Multiply the provisional class number by each of the various factors found above. The result is the bridge classification number.

Example 4.

Given: Masonry arch bridge; span (S), 40 ft; rise (R), 8 ft; arch ring thickness (t), 18 in.; depth of fill at crown (D), 12 in.; roadway width, 15 ft; material, limestone in good condition; joints, mortar, some deterioration, small voids, close joints; cracks—large longitudinal crack in arch under one parapet wall; abutments—one approach up a narrow embankment.

Find Bridge Class—Solution: Roadway width limits bridge to one lane. Total crown thickness (t = D, see fig. 105) = 18 in. + 12 in. = 2.5 ft. Using figure 106, line up straight edge at span of 40 ft. (Col. A) and total crown thickness of 2.5 ft. (col. B). At the intersection of straight edge and Col. C, read provisional class number, 34. Determine the profile factor. Span /rise ratio = 40/8 = 5. Enter the bottom of figure 107 with the span-rise ratio and draw a vertical line. At the intersection of this vertical line and the curved line on the graph, pivot (going horizontally) to the left edge of the chart. Read the profile factor as 0.86.

Material factor for limestone in good condition is 1.0. Joint factor is between 0.80 and 0.70, say 0.75. Crack factor for one crack at the edge of the ring is 0.90. Abutment factor for one unsatisfactory abutment is 0.95 (table 60).

Determine actual class number by multiplying provisional class number by factors found above.

Actual class number = 34 X 0.86 X 1.0 X 0.75 X 0.90 $\times$ 0.95 = Class 19.

87. REINFORCED CONCRETE BRIDGE

a. *Introduction.* Due to wide variations in design criteria, it is not possible to calculate the exact capacity of a reinforced concrete bridge based only on the measurable external dimensions. Therefore, when information is available pertaining to the design loading or civil load rating for the bridge (from a local agency or from intelligence reports), the class will be obtained by correlation if charts are available.[1] Civilian design load is equated to the military class for various span lengths. When the necessary information is not available for classification by correlation, the expedient methods shown may be used.

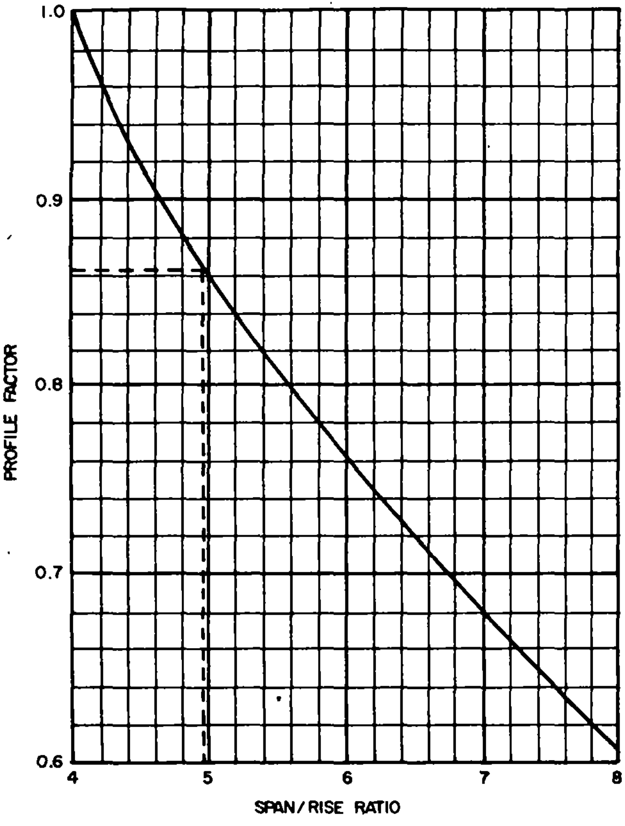

Figure 107. Profile factors for arch bridges.

Table 60. Arch Factors.

Material Factor		
1. Granite, whitestone, and built-in-course masonry		–1.5
2. Concrete or blue engineering bricks		–1.2
3. Good limestone masonry and building bricks		–1.0
4. Poor masonry or brickwood (of any kind)	–0.7	–0.5
Joint Factors		
1. Thin joints, 1/10 in. or less in width		–1.25
2. Normal joints, with width up to ¼ in.		–1.00
3. Ditto, but with mortar unpointed		–0.90
4. Joints over ¼ in. wide, irregular good mortar		–0.80
5. Ditto, but with mortar containing voids deeper than 1/10 of the ring thickness		–0.70
6. Joints ½ in. or more wide, poor mortar		–0.50
Deformation Factors		
1. The rise over the affected portion is always positive	Apply span-rise ratio of affected portion to the whole arch.	
2. Flat section of profile	Max class: 12	
3. A portion of the ring is sagging	Max class: 5, if fill at crown exceeds 18 in.	
Crack Factors		
1. Small cracks within 2 ft of the edge		–1.0
2. Large cracks within 2 ft of the edge		–1.0
3. Longitudinal cracks in center third of bridge	–0.9	–0.7
one small crack		–1.0
one large crack or several narrow cracks		–0.5
4. Small lateral and diagonal cracks		–1.0
5. Large lateral and diagonal cracks	Max class: 12, or figure derived by using the other factors.	
6. Cracks between the arch ring and parapet wall due to lateral spread of the fill		–0.9
7. Cracks between the ring and spandrel, due to a dropped ring	Reclassify from the nomograph, on assumption that crown thickness is that of ring alone.	
Abutment Size Factors		
1. Both abutments satisfactory		–1.00
2. One unsatisfactory abutment		–0.95
3. Both abutments unsatisfactory		–0.90
4. Both abutments massive, clay fill suspected		–0.70
5. Arch supported on 1 abutment and 1 pier		–0.90
6. Arch supported on 2 piers		–0.80
Abutment Fault Factors		
1. Inward movement of 1 abutment	–0.75	–0.50
2. Outward spread of abutments	–1.00	–0.50
3. Vertical settlement of 1 abutment	–0.90	–0.50

b. Slab Bridges. Measure the span length from center-to-center of supports in feet, the roadway width (W) in feet, and the depth (D) of the concrete slab, exclusive of any wearing surface or fill, in inches (fig. 108). Enter figure 109 with the span length, drawing a vertical line until it intersects the curve representing the depth (D) of the slab and estimating when necessary where this point should be. From this intersection draw a horizontal line to read the value of "m." Determine "M" by the formula

$$M = W_L m,$$

in which W_L equals the width of one lane in feet. Enter the graph in figure 93 with this value of "M" and the span length to obtain the class of the bridge.

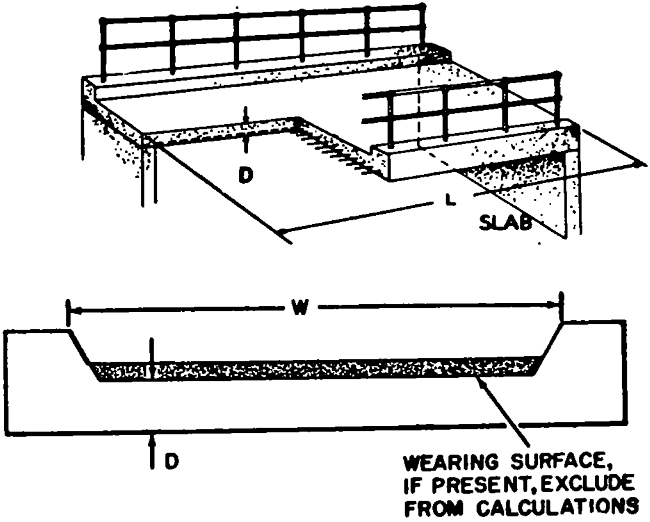

Figure 108. Concrete slab bridge.

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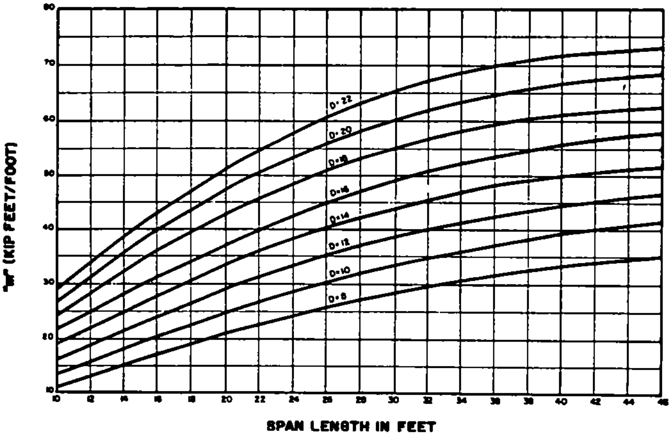


Figure 109. Moment for reinforced concrete slab bridges.

Example 5.

Given: Two-lane concrete slab bridge; 20-ft span length; D = 16"; 22-ft roadway width. To find bridge class: roadway width limits two-way class to classes 4 to 30. From chart in figure 109, m = 37. The width of one lane is 11 feet, therefore, $M = W_L m = 11\ (37) = 407$. With this value of "M" and the span length, obtain class 52 wheeled and class 36 tracked from the graph in figure 93.

Two-way Class: Bridge is class 30 as limited by roadway width.

One-way Class: Effective width of roadway is 15'. Therefore, $M = 15\ (37) = 555$. Bridge is class 75 wheeled and class 54 tracked.

c. *T-Beam Bridges.* Make the necessary measurements as shown in figure 110 and find L, the span length from center-to-center of supports. All dimensions are in inches except L which is in feet. Calculate "M" by formula:

$$M = N\ 158 + D(1.07T + 0.34L + 0.77b - 24.1) + 0.08L^2$$

Enter the graph in figure 93 with this value of "M" and the span length to obtain the class of the bridge.

Example 6.

Given: Two-lane concrete T-beam bridge; 32-ft span length; 7 T-beams, S=48″, D=30″, b=12″, T=6″; 24-ft roadway (see fig. 110).

To find bridge class: Roadway width limits two-way classes 4 to 60. Number of stringers per lane=3.5.

$$M=3.5\ [158+30\ (107\ \{6\}\ +0.34\ \{32\}+ 0.027\ \{48\}\ +\ 0.77\ \{12\}\ -24.1)]+0.08\ (32)^2$$

$$M=3.5\ [158+30\ (6.42+10.88+1.30+9.24 -24.1)]+82$$

$$M=3.5\ [158+30\ (3.74)]+82=3.5\ (158+112.2)+82=1028$$

With this value of "M" and the span length, obtain the class from the graph in figure 93.

Two-way class: bridge is class 60 wheeled as limited by roadway width and class 50 tracked.

One-way class:

$$\text{Effective No. of Str.}=\frac{15}{\text{roadway width in feet}}\times$$

$$\text{No. of Str.}=\frac{15}{24}\times 7=4.375$$

$$M=4.375\ (158+112.2)\ +82=1264$$

Bridge is class 95 wheeled and class 63 tracked.

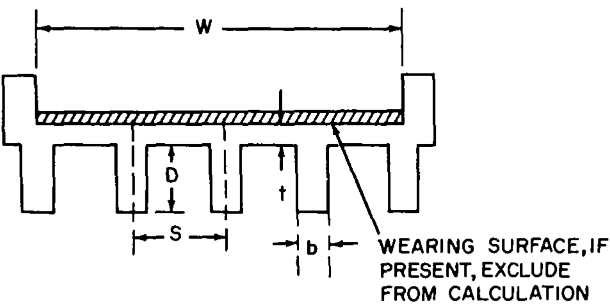


Figure 110. Cross section of RC T-beam bridge.

88. LIGHT SUSPENSION BRIDGE DESIGN

The suspension bridge (fig. 111) is used for long spons high above obstacles. The floor system is suspended fram cables, which ore supported on towers ond onchored ta obutments.

a. Doto. See information in table 61 ond figure 111.

b. Exomple of Moin Cable Design. Determine tensian in main cobles for o 200-faat-spon suspension bridge with a suspended weight of 10 tons. Assume a 10-percent sag rotio ond o 4-ton line laad.

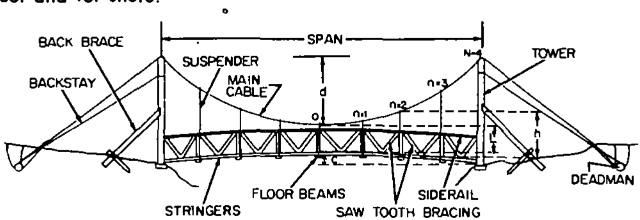
Suspended weight	20,000 lb
Line lood	8,000 lb
Impact	8,000 lb
Totol	36,000 lb

Maximum totol tensian in moin cobles for o 10-percent sag rotio= $36{,}000 \times 1.35 = 48{,}600$ pounds. If two moin cobles are used, each must have o tensile strength of 24,300 pounds.

89. THREE-ROPE BRIDGE

The three-rape bridge is used to carry personnel with full field pock; maximum of 7 men ot 5-poce intervol. Maximum length is 150 feet. Canstruction procedures fallow:

a. Canstruct stringers or support for treod rope ond hond ropes on neor and for shore.



h = EFFECTIVE SUSPENDER LENGTH
L = EFFECTIVE LENGTH OF CENTER SUSPENDER
n = PANEL POINT OF SUSPENDER
N = PANEL POINT OF TOWER
C = CAMBER
d = DIP

Figure 111. Light suspension bridge.

Table 61. Light-Suspension Bridge Design Data

Item	Data		
Panel length	10 to 15 ft.		
Camber	Approximately 2 ft.		
Stringer design	See paragraph 82*a*		
Floor beams	4″ x 4″ for foot troops or pack animals. 6″ x 6″ for ¼-ton truck. 8″ x 8″ for ¾-ton truck.		
Stress in suspenders	Design for dead load of one panel, live load and 100% of live load for impact. See table 81 for cable strength.		
Length of suspenders	$h = L + \left(\frac{n}{N}\right)^2 (C + d)$ See figure 111 for meaning of symbols.		
Sag ratio	5% for foot bridges to 10% for animal and light vehicle bridges.		
Main-cable design	Sag ratio %	Max total tension in main cables, in parts of total suspended weight of bridge and load	Length of cable between towers, in parts of span length
	7	1.94	1.012
	8	1.57	1.018
	9	1.46	1.022
	10	1.35	1.026
	11	1.23	1.033
	12½	1.12	1.041
	16⅔	0.90	1.070
Towers	12″ x 12″ posts and caps will take loads, including a 2½-ton truck. 6″ to 8″ timber side, back, and forebraces. ½″ wire-rope side and back guys. 1 to 1 slope for side guys; 2½ horizontal to 1 vertical slope for back guys.		
Anchorage	Deadman or other anchorage must hold maximum tension of main cable.		
Factor of safety	Wire rope = 2 Cordage = 3.5		

b. Lay out tread rope and hand ropes parallel and one pace apart on near shore. Minimum diameters = 1" for tread ropes and ¾" for hand ropes.

c. Cut suspender rope 12 feet long, center on tread rope (two paces apart) and tie with a clove hitch on bottom.

d. Lift hand rope elbow high and tie suspenders with girth hitch on inside.

e. Haul bridge over gap with small diameter (½ inch) rope and secure on far shore with a round turn and a bowline.

f. Pull near shore rope tight (5 percent sag) and secure.

g. Send one man onto bridge to make final adjustments of suspender ropes.

h. Complete details are given in TM 5–270.

90. FOUR-ROPE BRIDGE

The four-rope bridge is used to carry pack animals and personnel. Maximum length is 100 feet. Maximum capacity is 5 men with full field packs spaced 5 paces apart or one pack animal with handler. The bridge is constructed the same as the three rope bridge (para 89) except:

a. Cross members (minimum 3" diameter) are tied to tread ropes, one pace apart, with suspender ropes using clove hitches.

b. After erection, decking is lashed to the cross members and covered with twigs, leaves, and light brush to provide a walking surface.

91. TRUSS BRIDGE CLASSIFICATION

For expedient classification of truss bridges, assume that the stringers are the critical members. Consider the c-to-c distance between panel points (fig. 112) is the span length of the stringers and calculate stringer capacity as for the trestle bridge. If, on inspection, damage to a truss section or obvious damage to the substructure is indicated, the expedient classification should be drastically reduced pending complete analysis.

92. ARMORED VEHICLE LAUNCHED BRIDGE

This bridge is a class 60 bridge which is designed to be transported, launched, and retrieved by a modified turretless medium tank. The bridge folds at midspan and is transported on top of the launcher by means of a launching mechanism and carrying rack. It is a conventional, girder type bridge of aluminum alloy and may be launched or retrieved from either end. Its length, while being transported, is 31 feet 6 inches; when unfolded, it is 63 feet. The bridge has a clear span of 60 feet. Each clear treadway width is 4 feet 11 inches, and

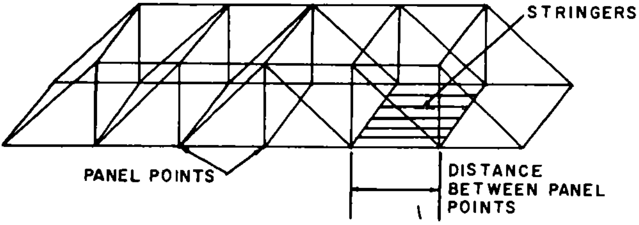


Figure 112. Truss bridges.

a single treadway will cross a ¼-ton vehicle. With both treadways, larger vehicles (including medium tanks) can cross this bridge. The usable tread width is 12 feet 6 inches; the overall width is 13 feet 5½ inches with tie rods. In launching this bridge, bank conditions must support the launching vehicle and provide sufficient bearing to allow the bridge to support its rated load after launching. The bridge can be launched and recovered on a maximum uphill grade of 28 percent, maximum downhill grade of 19 percent and maximum transverse grades of 11 percent. The method used to assemble the bridge depends on the state of disassembly of the bridge for transporting; i.e., it would be completely disassembled for transporting on bridge trucks, or it may be separated lengthwise for rail or low-bed trailer shipment (TM 5–216). For a normal span up to 60 feet, the bridge has a normal rating of class 60, a caution rating of class 65, and a risk rating of class 75. With the bridge in travel position, the launcher has the mobility approximately that of a medium tank and can maintain the rate of march of both administrative and tactical movements. However, in planning a route, the added weight (class 60), width (13 feet 6 inches), and overhead clearance (13 feet 3 inches) required must be considered. An escort reconnaissance vehicle should precede the launcher and bridge through built-up areas.

93. EXPEDIENT LOG BRIDGES

Figure 113 illustrates six suggested configurations for expedient wooden bridges. Capacities cannot be accurately determined, as with standard bridges. They depend on the size and condition of the timber and the strength of the lashings.

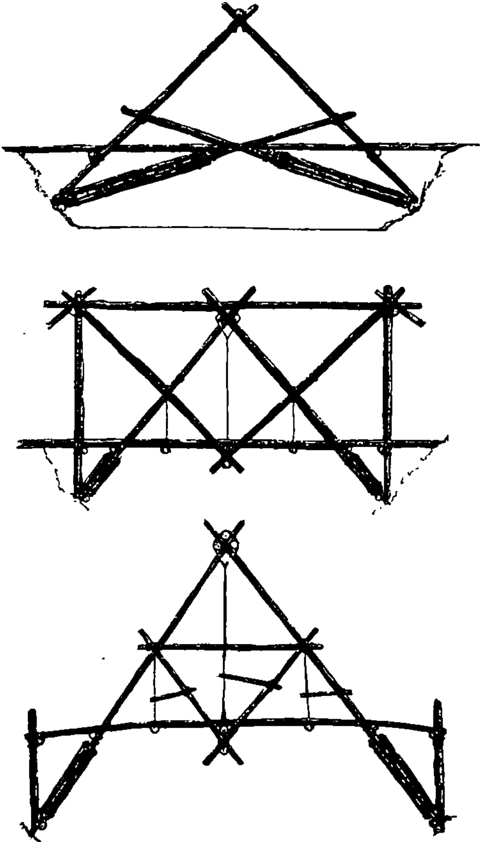


Figure 113. Expedient wooden bridges.

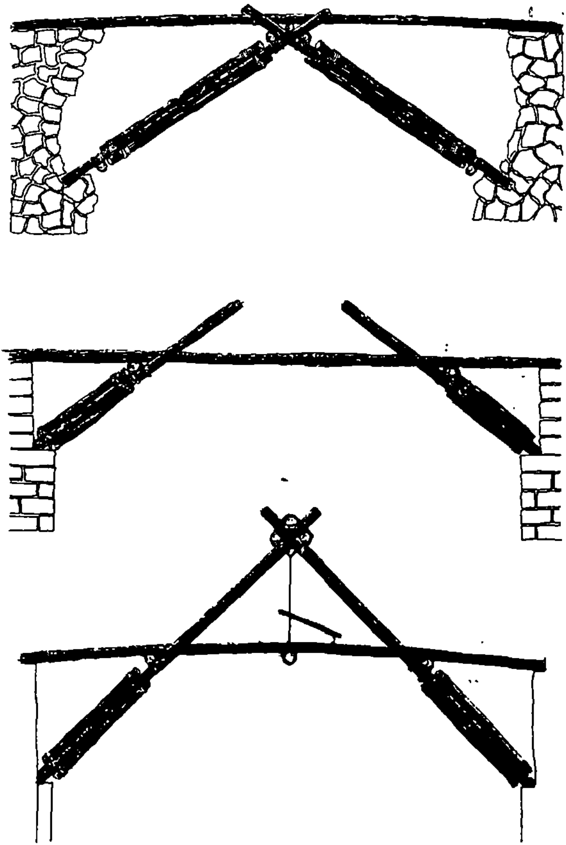


Figure 113 — Continued.

CHAPTER 8
CONCRETE CONSTRUCTION

94. EXCAVATION

Final excavation should be done by hand. If too much material is removed, it is recommended that the material removed never be put back. Fill the void with concrete or rock. See table 62 for time estimates by hand.

95. FORMING

a. The average carpenter can erect about 10 square feet of wooden forms per hour.

b. Steel road forms can be set by 4-man teams at the rate of approximately 50 linear feet per hour.

c. Wooden forms (see fig. 114).

(1) *Sheathing*. Sheathing forms the surface of the concrete. It should be watertight and as smooth as possible, especially if the finished surface is to be exposed. Since the concrete is in a plastic state when placed into the form, the sheathing must be free from cracks or holes. Tongue and groove sheathing gives a smooth watertight surface. Plywood or masonite can be used for special work.

Table 62. Earth excavation by hand

Type of material	Cubic yords per man-hour					
	Excavation with pick and shovel to depth indicated				Loosening earth—man with pick	Loading in trucks or wagons—one man with shovel and loose soil
	0 to 3 feet	0 to 5 feet	0 to 8 feet	0 to 10 feet		
Sand	2.0	1.8	1.4	1.3	.	1.8
Silty sand	1.9	1.6	1.3	1.2	6.0	2.4
Gravel, loose	1.5	1.3	1.1	1.0	....	1.7
Sandy silt-clay	1.2	1.2	1.0	.9	4.0	2.0
Light clay	.9	.7	.6	.7	1.9	1.7
Dry clay	.6	.6	.5	.5	1.4	1.7
Wet clay	.5	.4	.4	.4	1.2	1.2
Hardpan	.4	.4	.4	.3	1.4	1.7

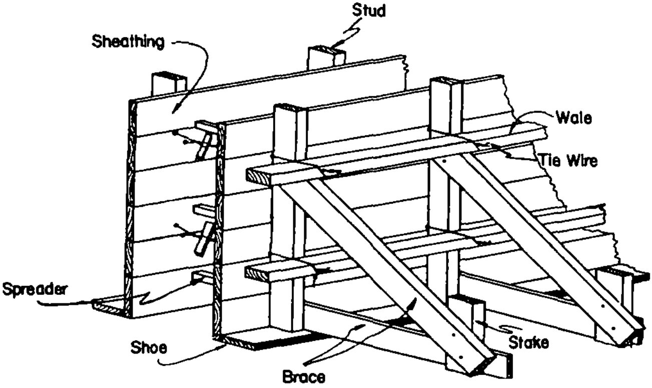


Figure 114. Form for a concrete wall.

(2) *Studs.* The weight of the plastic concrete would cause sheathing to bulge. Studs run vertically and add rigidity to the wall form. They are made from 2-inch × 4-inch or 3-inch × 6-inch material as a rule.

(3) *Wales.* Studs also require reinforcing when they extend over four or five feet. This reinforcing is supplied by wales. Wales also serve to tie prefabricated panels together and keep them in a straight line. They run horizontally and are lapped at the corners of the forms to add rigidity. They are usually the same material as the studs.

(4) *Braces.* There are many types of braces which can be used to hold forms in place. The most common types are diagonal members nailed from a stake to a stud or wale. They should make a 30° angle with the horizontal. Additional bracing may be added to the form itself by placing vertical members behind the wales (strongbacks) or by placing vertical members in the corner formed by intersecting wales.

(5) *Shoe plates.* The shoe plate is nailed into the foundation or footing and is placed carefully so as to give the correct wall dimension. The studs are tied into the shoe and spaced according to the correct design.

(6) *Spreoders.* In order to mointoin proper distonce between farms, smoll pieces of wood ore cut to the some length as the thickness of the woll ond are ploced between the forms. These ore called spreaders. When the concrete is placed into the form, enough pressure is opplied on the form by the plastic concrete to allow the spreoders to be remaved. The spreoders must be removed before the concrete hardens.

(7) *Tie wires.* Tie wires hold the ponels agoinst the spreaders. Use No. 9 anneoled wire or similor.

(8) *Calumn yokes ond sheathing.* In calumn farms, sheathing runs verticolly to sove an the number af sow cuts required. Use only harizontal bracing.

d. All forms shauld be oiled befare concrete is ploced. This is to aid in removing farms after the concrete has hordened.

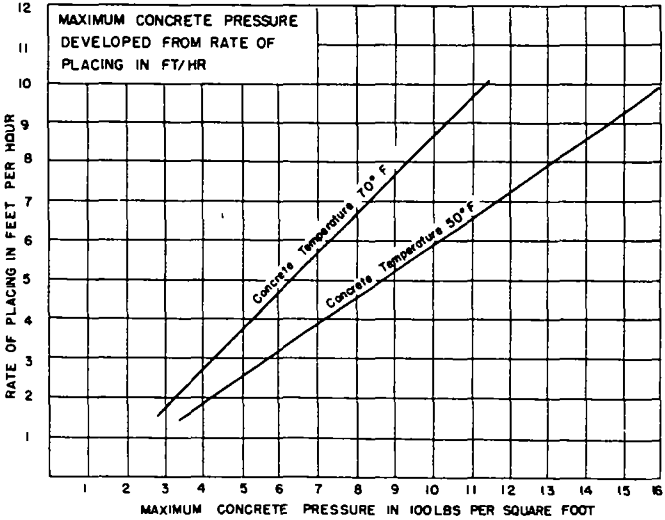


Figure 115. Moximum concrete pressure graph.

96. FORM DESIGN

a. Determine Rate af Placing Cancrete. Rate af placing cancrete in farm equals mixer capacity (cu ft/hr) divided by the area that the farm cavers:

$$\text{Rate af placing (ft/hr)} = \frac{\text{mixer capacity (cu ft/hr)}}{\text{farm area (sq ft)}}$$

b. Determine Maximum Cancrete Pressure. Enter figure 115 with the rate af placing cancrete and the temperature at which the cancrete will be placed. Determine the maximum cancrete pressure.

c. *Determine Maximum Stud Spacing.* Ta determine the maximum stud spacing, enter figure 116 with the maximum cancrete pressure. Draw a line vertically up until it intersects the carrect sheathing curve. Read harizantally ta the side af the chart and determine the maximum stud spacing.

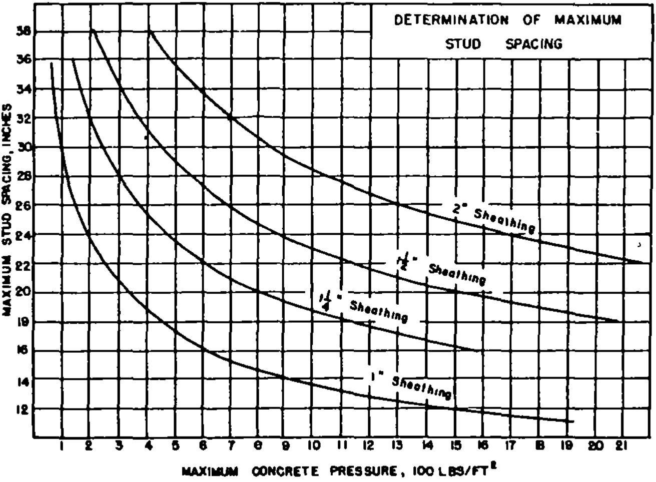


Figure 116. Maximum stud spacing graph.

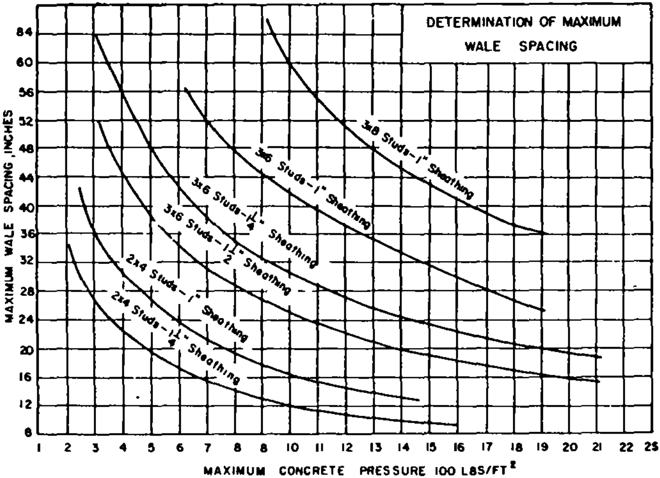


Figure 117. Maximum wale spacing graph.

d. Determine Maximum Wale Spacing. Enter figure 117 with the known maximum concrete pressure and read up until the stud-sheath curve is intersected. Read to the left for the maximum wale spacing.

e. *Column Forms (see fig. 118).* Enter table 63 with the height of the column desired. Read across to the largest cross-sectional dimension of the form. This is shown as L in the sketch. This will give the vertical distance between each yoke, starting from the bottom of the form to the top.

Example: What is the yoke spacing for a 9-foot column whose largest cross-sectional dimension is 36 inches?

Answer: starting from bottom of form to the first yoke 8″-10″—11″-12″—15″-17″—17″-17″.

97. IMPORTANT FACTORS

The important considerations in mixing good concrete are:

a. *Plastic Mixtures.* For plastic mixtures, use sound, clean sand, coarse aggregate, and adequate placement procedures. The strength

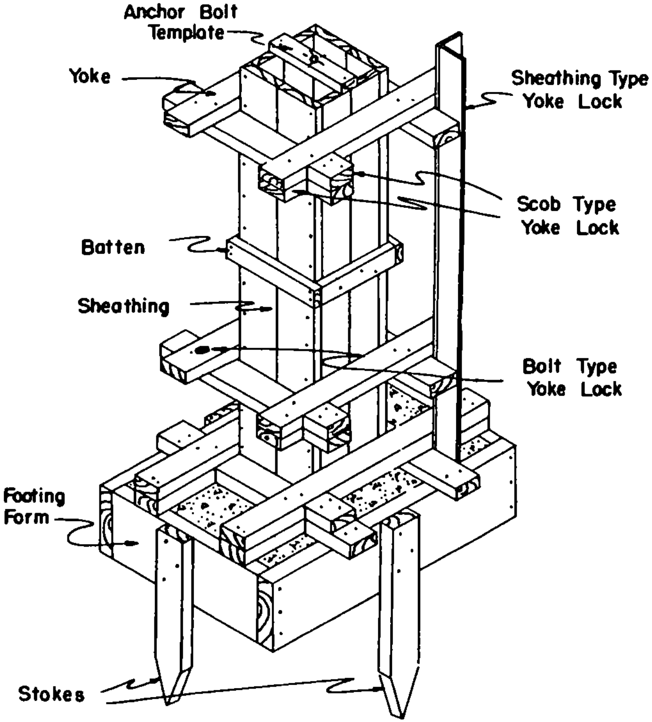


Figure 118. Form for a concrete column.

of concrete under given job conditions depends upon the net quantity of mixing water used per sack of cement.

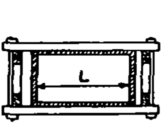
b. Sand and Aggregate. Assuming that proper cement is available the first item of importance for a concrete job is the availability of suitable sand and coarse aggregate. The sand should be free of clay and silt and the aggregate should be hard and strong.

Table 63. Column Yoke Spacing

LARGEST DIMENSION OF COLUMN IN INCHES–'L'

Rows 1'–20' (height of column); yoke spacings read from top down in each column:

L	Yoke spacings (from top)
16"	31", 31", 30", 29", 21", 20", 18", 15", 14", 13", 13", 12"
18"	29", 28", 28", 26", 20", 18", 16", 15", 13", 12", 12", 11", 11"
20"	27", 26", 26", 24", 19", 16", 15", 14", 12", 11", 11", 10", 10", 9"
24"	23", 23", 23", 22", 16", 14", 13", 12", 11", 10", 9", 9", 9", 8", 8", 8"
28"	21", 21", 20", 18", 15", 13", 12", 10", 9", 9", 9", 8", 8", 8", 7", 6"
30"	20", 20", 19", 18", 18", 12", 12", 10", 9", 8", 8", 8", 7", 7", 7", 6"
32"	19", 19", 18", 17", 13", 12", 10", 10", 8", 8", 8", 7", 7", 7", 6", 6"
36"	17", 17", 17", 15", 12", 11", 10", 8", 8", 7", 7", 7", 6", 6", 6", 6"



c. *Strength.* Factors affecting the strength of a concrete mix depend on the water-cement ratio. The type, gradation, cleanliness, and shape of the aggregate particles definitely aid in strength, but not to the extent that the water-cement ratio does.

d. *Mix.* The amount of sand and coarse aggregate required for each batch should be carefully measured by weight or volume.

e. *Water.* Water for mixing concrete should be free of foreign matter such as silt, decayed matter, alkali, sulphates, or salt.

98. ESTIMATING VOLUMES OF MATERIALS STORAGE

a. *Formulas.*

(1) A good formula by which to estimate the weight and volume of aggregate in a cone shaped pile is:

$$\text{volume} = 0.2618 \times \text{height} \times \text{diameter (squared)}.$$

(2) The graph in figure 119 gives the method of estimating both volume and weight of aggregate in a pile or storage.

b. *Storage Capacity.* An explanation for using above three pairs of curves in figure 119 considers the following:

(1) The capacity of the conical-shaped piles is determined from the two curves on the far right and the vertical column on the outside right. It could be determined for example, that a stackpile of crushed stone 30 feet high has a capacity of 2,010 tons.

(2) In determining the capacities per lineal foot of tent-shaped piles, note that the two ends of these are equivalent to one conical pile, and their capacity can be determined in the manner described in a above. The capacity of the intermediate section for various heights is determined by using either of the two curves in the middle of the chart and the vertical column on the inside right. For example, a stockpile of gravel 19 feet high has a capacity of 24 tons per lineal foot. The capacity of the two end sections is 630 tons, therefore the total capacity of a stockpile with a 50-foot-long intermediate section would be $24 \times 50 + 630$, or 1,830 tons.

(3) The vertical column of figures on the left gives the diameter or width (B) of conical or tent shaped stockpiles of various heights. For example, a 17-foot high tent-shaped pile of crushed stone has a base width of only 41 feet.

99. CONCRETE MIXING BY HAND

a. *Hand-Mixing Concrete.* Hand mixing must be carefully and thoroughly done. It is efficient only for a few, small batches of no larger than 1 cubic yard each.

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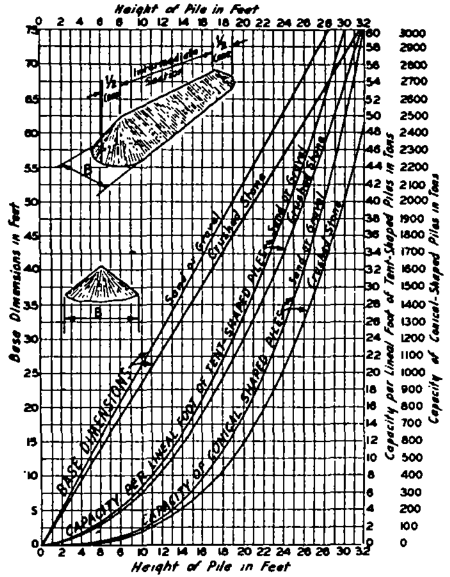

Curves based on:

Unit weight of aggregate of 100 pounds per cubic foot. Angle of repose of sand and gravel of 37°. Angle of repose of crushed stone of 40°.

Figure 119. Storage capacity curves.

b. Equipment. Equipment required includes a watertight metal or wooden platform (about 10 feet × 12 feet) two shovels, 1-cubic-foot measuring boxes, mortar hoes, and pails for measuring water.

c. Mix Sand and Cement Dry First. If the batch consists of two sacks of cement, 5.5 cubic feet of sand, and 6.4 cubic feet of coarse aggregate, 3 cubic feet of sand is dumped on the platform first. Lay the sand out flat, and spread a sack of cement evenly over it. Then lay the rest of the sand and the other sack of cement similarly on the pile. Turn this mix two or three times until the material is a uniform color. After the cement and fine aggregate are mixed, the pile is leveled off and the 3 cubic feet of coarse aggregate is measured and spread over it. Then turn this batch two or three times and "trough" the center. Pour water, carefully measured, into the trough. Turn the dry materials, into the water and mix *until* consistency is *uniform*.

100. DESIGN OF CONCRETE MIXES

a. *Water-Cement Ratio.*

(1) The amount of water in mixing concrete is of major importance. It can be expressed in terms of gallons per sack of cement, or in terms of weight of water per sack of cement. Table 64 gives the quantities of water for concrete of given strengths.

(2) Where strength and economy are important, tests for strength should be made with materials under job conditions. These tests should include at least three different water contents. The 15 percent safety factor used with table 64 should be used here.

(3) The gallons of water per sack of cement to make durable concrete for various conditions is shown in table 64.

b. *Slump (Consistency).*

(1) Consistency is measured by slump test.

(2) The procedure for determining the slump of concrete is as follows:

(a) Construct slump cone as shown in figure 120.

(b) Moisten cone and place on a waterproof surface such as a piece of tin or plastic. Do not place on concrete or wood unless thoroughly moistened.

(c) Completely fill cone in three layers, each layer consisting of approximately 1/3 of the volume of the cone.

*Table 64. Relations Between Mixing Water and Compressive Strength of Concrete**

Water—gal per sack of cement	Probable average strength, psi	
	7-day strength	28-day strength
4	4,400	6,000
5	3,500	5,000
6	2,800	4,000
7	2,200	3,300
8	1,800	2,800

*A safety factor of 15 percent should be allowed when selecting the water content required. If 2,800-psi concrete at 28 days is required, a water content corresponding to a strength of 3,200 psi should be selected.

(d) As each layer is placed it must be rodded with a ⅝-inch tamping rod 25 times. Each stroke of the rod should penetrate the layer of concrete below the layer being tamped, with the bottom layer being rodded throughout its entire depth.

(e) When the cone is full, strike off excess concrete.

(f) Carefully remove the cone and place next to the concrete. Measure the slump of the concrete as shown in figure 120.

101. CONCRETE ESTIMATION (3/2 RULE)

a. Determine volume of concrete needed in cubic feet.

b. Multiply volume of concrete needed by 3/2. This gives the total amount of dry loose material needed.

c. Assume a volumetric proportion of cement, sand and gravel. This can be done by actual test or by assuming a 1-2-3 mix.

d. Compute total volume of each material needed. Take the desired proportional mix decided on in paragraph c above and add up (i.e

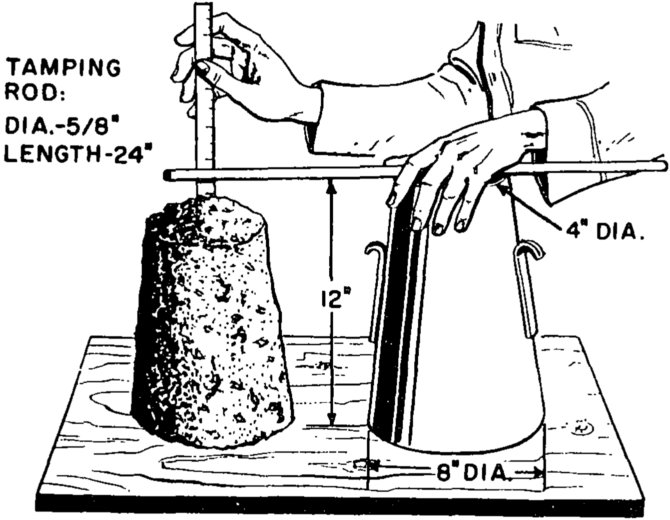

Figure 120. Measurement of slump.

1-2-3 = 6). Determine the amount of cement, sand and gravel needed by multiplying the volume of dry material needed, found in paragraph *b* by the proportional amount of the total mix.

Example: Cement = 1/6 x total volume
Sand = 2/6 x total volume
Gravel = 3/6 x total volume

e. Add loss factor due to handling by using rule of thumb: 10% loss for jobs up to 200 cubic yards of dry loose material needed and 5% loss for jobs over 200 cubic yards. (Note: Round off to nearest whole number.)

f. Example: Determine the amount of material needed to place a concrete wall. The size has been determined to be 10 feet long, 3 feet high and 1 foot thick.

Volume (cubic feet) = 10 feet x 3 feet x 1 foot = 30 cu ft
Dry loose material required = 30 cu ft x 3/2 = 45 cu ft
Assumed proportional mix = 1-2-3 = 6
Amount of material required:
Cement = 45 cu ft x 1/6 = 7.5 cu ft = 7.5 bags
Sand = 45 cu ft x 2/6 = 15 cu ft
Gravel = 45 cu ft x 3/6 = 22.5 cu ft
Amount required is less than 200 cubic yards.
Assume 10% handling loss.
Therefore, total amount required equals:
Cement = 7.5 bags + 10% = .75 + 7.5 = 9 bags
Sand = 15 cu ft + 10% = 1.5 + 15 = 17 cu ft
Gravel = 22.5 cu ft + 10% = 2.25 + 22.5 = 25 cu ft

102. CONCRETE MIX DESIGN (TRIAL BATCH METHOD)

a. It is recommended, that to properly design a concrete mix, the testing equipment and procedures outlined in TM 5–742 be used. If this is not available, the procedure given in this manual will be satisfactory. For large projects, it may be more convenient to use a mixer for trial batch, but for small projects mixing by hand may be better. The method given here, is for trial mixing done by hand.

b. Construct a measuring box which has the inside dimensions of 6-inches x 6-inches x 6-inches. This will give a container which will hold 0.125 (⅛) cubic foot of material.

c. Determine the amount of water that is to be added to the cement by using table 64.

d. Determine the slump required by referring to table 65. Be sure to pick one particular slump instead of a range.

*Table 65. Recommended Slumps for Various Types of Construction**

Type of Construction	Slump	
	Maximum	Minimum
Reinforced foundation walls and footings......	5	2
Plain footings, caissons, and substructure walls..	4	1
Slabs, beams, reinforced wall............	6	3
Building columns..................	6	3
Pavements....................	3	2
Heavy mass construction...	3	1

*With high-frequency vibrators, reduce the table values by one-third.

e. Using the measuring box, measure out one box of cement, two boxes of sand and three boxes of gravel. Place on a surface which will not absorb moisture. Mix the cement, sand and gravel until evenly mixed. Place the mixture in a mound and form a depression in the middle.

f. Measure out $\frac{1}{8}$ of the required water for one sack of cement and pour slowly into the cement-sand-gravel mixture. Mix well until all sand and gravel is coated with cement.

g. Test slump to compare against what is required.

h. If slump is more than required repeat the trial mix using more sand-gravel. If slump is less than what is desired, it is permissible to reduce the sand-gravel content. Caution: Never increase only water content to get more slump.

i. After the proper trial mix has been determined, multiply the amounts used by 8. This will give the amount of sand and gravel to mix with one bag of cement.

j. Example: It is required to place concrete which will have a 7-day strength of 3,500 psi. The concrete will be used for footings.

(1) Water to be added equals 4 gallons.

(2) Slump required is 3 inches.

(3) After the trial batch it was found that to obtain a 3 inch slump 1 box ($\frac{1}{8}$ cu ft) of cement, 2 boxes ($\frac{1}{8}$ cu ft each) of sand and 4 boxes ($\frac{1}{8}$ cu ft each) of gravel were needed.

Therefore for a one bag mix:

Cement $= 1 \times \frac{1}{8}$ cu ft $\times 8 = 1$ cu ft $= 1$ bag
Sand $= 2 \times \frac{1}{8}$ cu ft $\times 8 = 2$ cu ft
Gravel $= 4 \times \frac{1}{8}$ cu ft $\times 8 = 4$ cu ft

103. BATCHING

a. Once a design mix has been determined and a one sack mix is computed the project site must be laid out and organized to facilitate quality control of the batch (charge) which will go into the mixer.

b. A recommended layout is to place cement, sand, gravel and water as close to skip (load bucket) of the mixer as possible. When the charge is being placed in the skip, gravel should be placed in the skip first. This allows the material to flow freely and keep the skip clean. Cement is placed next and covered with sand. This prevents the cement from being blown away. The exact amount can be controlled by constructing measuring boxes which have an inside dimension of 1 foot x 1 foot x 1 foot and all sand and gravel being measured as it is placed in the skip. Water can be placed into the mixer either by the use of a metering device which may be a part of the mixer, or by hand. If the water is placed by hand it should be measured into containers which will not leak and care should be taken that the water is not spilled as it is placed into the mixer. Water may be added through the discharge end of the mixer (discharge chute up) after the dry materials are in the drum. Avoid spilling water into the skip as it has a tendency to make the materials stick.

104. MIXING

The actual mixing time will depend on the means available to discharge the mixer. If discharge is direct into the form, the mixing time should be at least one minute for any mix or one minute for each cubic yard of mix. The time is increased by 15 seconds for each additional ½ cubic yard. If discharged into small containers, the mixing time will be longer due to the additional time required to empty the mixer drum.

105. CONCRETE PLACING

a. Concrete should not be allowed to fall into forms at heights greater than three to five feet unless suitable drop chute, baffles, or vertical pipes are provided.

b. As concrete is being placed, it should be compacted by vibration, spades or rods. Care should be taken not to over vibrate. This will cause the concrete to segregate, making the concrete weaker. (Segregation is when the large stones sink to the bottom of the mix.)

c. Curing and protection methods are as follows:

(1) *Moist curing.* The loss of moisture must be prevented during hydration. Keep the exposed surface moist by spraying or ponding, or covering with earth, sand, or burlap, maintained in a moist condition.

(2) *Curing compaunds.* Sproy on the compound in one caot. Do not use the campounds if the air temperoture is above 100°F and the oir is dry.

(3) *Protectian against law temperatures.* Da not let fresh cancrete drop belaw 40°F in temperoture.

106. MIXER CLEANING

Cleaning of the mixer should be perfarmed after every use. Ta clean o mixer, all cement paste shauld be washed aff the outside af the mixer. The inside af the drum shauld be cleaned. This can be dane by plocing water and small stanes in the drum and allawing the mixer ta ratate to dean and flush aut oll cancrete from the drum. After cleaning, a light caot af ail on the autside of the mixer will prevent cement and cancrete from sticking ta the mixer during the next aperatian.

CHAPTER 9

MILITARY ROAD CONSTRUCTION

107. MINIMUM DESIGN REQUIREMENTS

Table 66 gives a summary of military road specifications.

108. TYPES OF SURFACES

a. Earth Roads. Earth roads consist of native fine-grained soils, graded and drained to form a surface for carrying traffic. Their use is limited to dry weather and light traffic. In combat areas, these roads are used where necessity demands speed of construction with limited equipment and personnel.

b. Oiled Earth Roads. Oil is spread on earth roads to prevent dust and help waterproof the surface. It is successful with silt or clay. The amount of oil used varies from about ½ to 1 gallon per square yard applied in two or three increments, depending upon the soil and the type of oil used.

c. *Soil-Stabilized Surfaces.* Bituminous soil-stabilized mixtures and soil cement may be used as road surfaces as an expedient for relatively short periods and to carry light traffic.

d. Sandy-Clay Roads. This type of road has a natural or artificial mixture of sand and clay, graded and drained to form a road surface. Usually fine gravel added to it will give stability. These roads serve well for light traffic, and will carry heavy traffic except in adverse weather, although they withstand such conditions better than earth roads.

Table 66. Military Road Specifications

Characteristic	Specification
Width	
Traveled way (single lane)	Min—11.5 ft (3.5 meters)
Traveled way (two lanes)	Min—23 ft (7.0 meters)
Shoulders (each side)	Min—4 ft (1.5 meters)
Clearing	Min—6 ft (2 meters) on each side of roadway
Grades:	
Absolute maximum	Lowest maximum gradability of vehicles for which road is built
Normal maximum	10%
Desirable maximum	Tangents and gentle curves, less than 6%; sharp curves, less than 4%

Table 66.—Continued

Characteristic	Specification
Horizontal curve radius	Desired min—150 ft (45 m) Absolute min—80 ft (25 m)
Vertical curve length:	
Invert curves	100-ft min (30 m) for each 4% algebraic difference in grades
Overt curves	125-ft min (40 m) for each 4% algebraic difference in grades
Sight distance:	
Nonpassing	Absolute minimum—200 ft (60 m)
Passing	Absolute minimum—350 ft (110 m)
Load capacity	
Road proper	Sustain 18,000 lb wheel load
Bridges	Accommodate using traffic
Slopes	
Shoulders	¾ in per ft to 1½ in per ft
Crown (gravel and dirt)	½ to ¾ in per ft
Crown (paved)	¼ to ½ in per ft
Superelevation	¼ to 1¼ in per ft
Cut	Variable
Fill	Variable
Drainage	
Good	Adequate crown or superelevation with adequate ditches and culverts in good condition. Take full advantage of natural drainage. Try to locate road at least 5 ft above the ground-water table
Miscellaneous	
Overhead clearance	Min—14 ft (4.3 m)
Traffic volume	2,000 vehicles per day
Turnouts (single lane)	Min—every ¼ mile

e. *Gravel Roads.* Gravel roads are a compacted layer of well graded gravelly soil which meets the plasticity requirements for mechanically stabilized soils. Grading requirements for this type of surface are given in table 67. Natural pit- or bank-run gravel may meet these requirements with only screening. Other pit- or bank-run gravel may require both screening and washing. River gravels normally require the addition of binder soil. The capability of gravel roads to carry heavy, sustained traffic depends on the strength and hardness of gravel,

Table 67. Suggested Grading Requirements for Gravel and Composite Type Surface Courses of Processed Materials

Sieve designation	% passing, by weight
1 in	100
3/4 in	85 - 100
3/8 in	65 - 100
No. 4	55 - 85
No. 10	40 - 70
No. 40	25 - 45
No. 200	0 - 10

the cohesiveness of clay binder, the thickness of the layer, and the stability of the subgrade. These surfaces make an excellent base for later pavements.

f. *Roads of Processed Materials.* Processed materials are prepared by crushing and screening rock, gravel, or slag. The information on gravel roads is applicable to these roads. They should meet the grading requirements set forth in table 68.

g. *Use of Calcium Chloride and Sodium Chloride.*

(1) Calcium chloride is widely used in construction (and maintenance) of mechanically stabilized soil surfaces, gravel roads, and roads made with composite type processed materials. Calcium chloride attracts and retains moisture from the air. Use 0.5 pound per square yard per inch of compacted mixture when mixed-in-place construction is used. If the mixture is prepared at a central plant, the mixture should be 10 pounds of calcium chloride per ton of mixture. It is recommended that 1 pound per square yard be applied when the surface is complete.

(2) Sodium chloride (generally rock salt) may be used in much the same way as above. Use about 1 ton per mile per inch of compacted surface 20 feet (6 meters) wide.

Table 68. Suggested Grading Requirements for Fine-Graded Type Surface Course of Processed Materials

Sieve designation	% passing, by weight
¾ in	100
No. 4	70 - 100
No. 10	35 - 80
No. 40	25 - 50
No. 200	8 - 25

h. Other Aggregate Materials.

(1) *Caral.* Caral requires considerable maintenance because it will scar and rut when given hard usage, causing water ta pand and saften the base. Surfaces must be periadically shaped with a grader. Traffic will alsa praduce a fine dust, which requires periadic sprinkling, preferably with salt water.

(2) *Caliche.* The life af caliche (a hard pan, cemented by mineralizing salutians) is greatly increased as a surface when bituminaus treatment is applied.

(3) *Tuff.* Tuff (depasits af fine minerals ejected by valcanaes) is dusty when dry and slippery when wet. Regrade and rall the surface after a rain ta hald surface maisture and close cracks. An asphalt seal caat will prevent infiltratian af water.

i. Ice Surfaces. In narthern latitudes, vehicles and aircraft may use the surfaces af fresh-water ice an lakes and rivers, ar salt-water ice an seas ar alang caastlines.

(1) Fresh-water ice breaks up in the spring. During the winter the strength af this ice exceeds that af yaung sea ice. The strength af sea ice increases with time, and has a use equal ta fresh water ice when thick enaugh.

(2) Ice strength is affected by temperature and its canditian. Inspect the canditian af ice carefully far haneycamb, ratting, ar melting befare impasing heavy laads.

(3) Snaw and ice raads are satisfactary far traffic use where the snawfall reaches a minimum of 2 feet and the temperature falls ta belaw 20°F far at least 3 manths. Faur types af snaw and ice roads are: pianeer, traugh, and wide and narraw rut. See TM 5–349 far their canstructian. A pianeer snaw road carries carga vehicles ar snaw tractars with grass weights up ta abaut 5,000 paunds. A traugh raad suppårts 2½ tan trucks and medium track type tractors with sled trains. A wide-rut raad supparts 6-tan trucks and heavy track type tractars with sled trains. Hawever, aver ice, the beairng capacity depends an the ice thickness. Table 69 is a rule-af-thumb guide ta the laad capacity af ice. Ice recannaissance is mandatary ta determine thickness and canditian af the ice.

j. Partable Raad Surfaces. During aperatians in the field, it is aften necessary ta make temparary use af metal mesh, metal landing mats, waod mats, ar variaus types af treadways. These materials are rapidly transported and assembled aver mud, swamps, beaches, ar ather unstable sails. TM 5–337 gives the details af canstructing partable surfaces.

109. CROSS-SECTIONS

See figures 121 thraugh 125 far typical military raad crass-sectians.

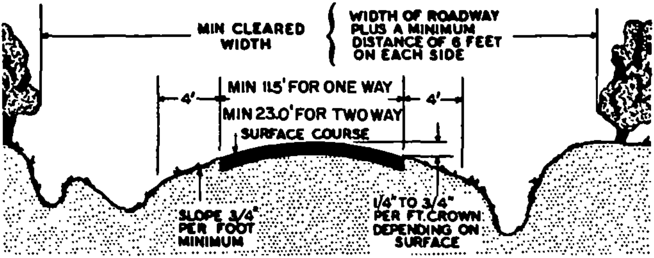

Figure 121. Typical cross section illustrating road specifications.

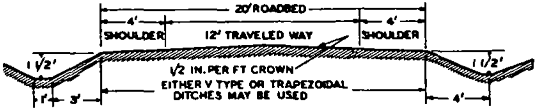

Figure 122. One-way earth road.

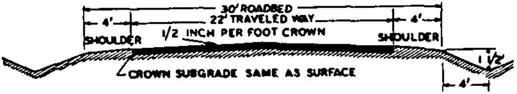

Figure 123. Two-way road using single course construction.

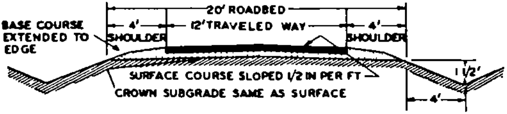

Figure 124. One-woy *rood using dauble-caurse canstructian.*

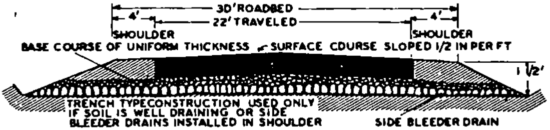

Figure 125. Two-woy rood usıng double-course, trench-type constructian.

110. CENTERLINE STAKES

a. *Generol.* Centerline ar alinement stokes are ploced on the centerline of o raod ar airfield ta indicate its alinement, locotian, ond direction. These stokes are the first stokes to be placed ond ore usuolly placed at 100-foot intervols. On raugh ground ar an sharp harizontol and verticol curves, the stokes ore placed closer together. See figure 126.

b. *Placement and Morking.*

(1) *Plocement.* Stokes ore placed with the brood portian af the stake perpendicular to the centerline. The side af the stoke which foces the starting point (stotion 0+00) is colled the frant of the stake.

(2) *Marking.* The front of the stoke is morked with o ℄ which meons centerline, ond the statian number ar the distonce from the starting paint. As an exaemple 78+00 means 7800 feet from the storting point. On the reverse side, or bock side of the stoke, is placed the omaunt of cut or fill, in feet, required at this stotian.

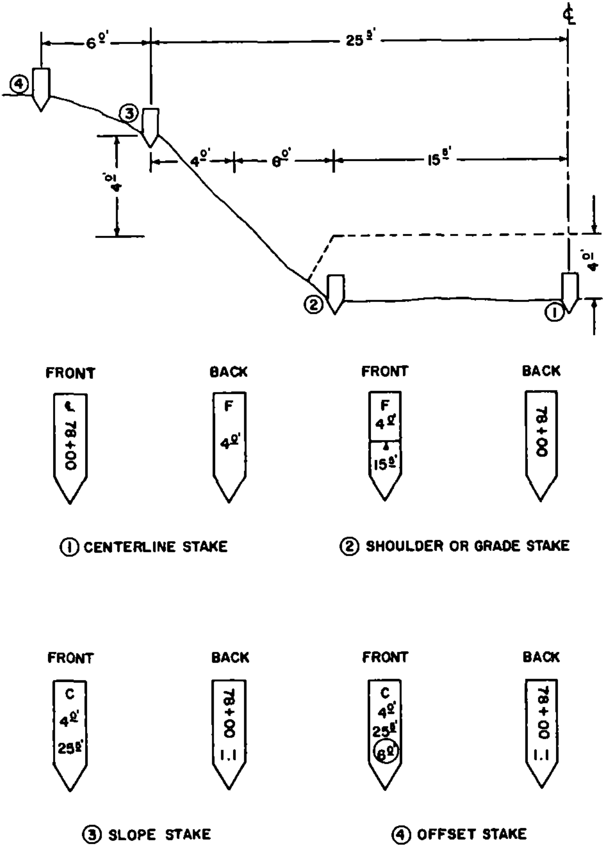

Figure 126. Construction stake markings.

Table 69. Load Capacity of Ice

Lood	Minimum thickness of ice in	Minimum interval ft
Single riflemon on skis or snowshoes.	1½ (40 mm)	16 (5 m)
Troops in single file, 2-poce distonce	3 (80 mm)	*23 (7 m)
Troop column, single horses, motorcycles, unloaded sleds, or motor-toboggons	4 (100 mm)	*33 (10 m)
Single light ortillery piece, ¼-ton truck, 4 x 4	6 (150 mm)	49 (15 m)
Light ortillery, possenger cors, medium 1½-ton trucks with gross weight of 3½ tons	8 (200 mm)	65 (20 m)
2½-ton trucks, light loods	10 (250 mm)	82 (25 m)
Closed columns of oll orms except ormored force ond heovy ortillery	12 (305 mm)	*98 (30 m)
Armored scout cors, light tonks	14 (355 mm)	115 (35 m)
20-ton vehicles	16 (405 mm)	131 (40 m)
45-ton vehicles	24 (60 cm)	164 (50 m)

* Minimum intervol between files or columns.

111. SHOULDER STAKES

a. *General.* Shoulder stakes are set an the inside edge af the shoulder and are used as guides far the operator ta determine the width af the road. See figure 126.

b. *Placement and Marking.*

(1) *Placement.* These stakes are set at right angles ta the centerline opposite each centerline stake.

(2) *Marking.* Markings can be the same as those far raugh grade stakes (par 114) ar the stake can be simply a plain, unmarked piece of wood that marks the inside edge af the shoulder.

112. SLOPE STAKES

a. *General.* Slope stakes define the limits of grading wark. Usually the area ta be cleared extends 6 feet beyond the slope stakes. See figure 126.

b. *Placing and Marking.*

(1) *Placing.* Slope stakes are set an lines perpendicular to the centerline (one an each side), at the points where the cut and fill slopes intersect the natural ground surface. If there is cut or fill to be performed, the stake is placed in the ground at an angle, leaning away from the centerline. Slope stakes are placed at 100-foat intervals on tangents and at 50-foot intervals on horizantal or vertical curves.

(2) *Marking.* The front of the slope stake is the side facing the centerline. This side is marked with the amount of cut or fill to be done, in feet, from the stake to the outside edge of the ditch line at a point even with the final grade of the road at the shoulder. The second figure on the stake represents the distance from the stake to the centerline of the road. The back of the stake contains the station number and the slope required for the cut or fill.

113. OFFSET STAKES

a. *General.* As soon as work is started on a cut or fill, the centerline and slope stakes may be destroyed. In order to eliminate resurveying to replace these stakes, offset stakes are placed beyond the limits of construction for the purpose of relocating the original stakes. See figure 126.

b. *Marking.* The offset stake will contain all the information found on the original slope stake plus the horizontal distance from the original slope stake to the offset stake. This distance is marked on the front of the stake and is circled to indicate that it is an offset distance.

114. GRADE STAKES

a. *Rough Grade Stakes.*

(1) *General.* Rough grade stakes are placed on centerlines, shoulder lines, or slope lines after grading has begun. These stakes are placed to show the operator the amount of cut or fill remaining and are not considered a permanent reference.

(2) *Placement and Marking.*

(a) Placement. The rough grade stake is placed at either a point of cut or a point of fill to show how much earth is left before final grade is obtained.

(b) Marking. The front of the stake (the side of the stake facing the centerline) is marked with the letter F or C, indicating fill or cut, a reference line with a "crow's foot" and the distance from the stake to the centerline. To eliminate confusion, the surveyor who put in the grade stakes should explain how he used the reference line found on the stake. Some surveyors use this line as final grade and others use this line as a reference line (to measure the amount of fill or cut from the back of the stake containing the station number).

b. *Final Grade Stakes.*

(1) *General.* Normally these are 2 x 2-inch wooden stakes driven into the ground until the top of the stake is at a level to represent final elevation.

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(2) *Placement and Marking.*

(a) *Placement.* These stakes are placed wherever it is felt a reference to final grade should be made such as on centerline stations.

(b) *Marking.* There are no markings on these stakes other than the blue or red tops. The setting of the top of the stake could represent the exact finish grade or a certain standard distance above exact grade.

115. SOILS

a. *Field Expedients for Soil Analysis.* The following field tests may be of value in soil analysis. (For complete information see TM 5–530.)

(1) *Feel.* Sand has gritty feel when rubbed between the fingers. Dry silts have a smooth, silky, floury feel. Some wet clays feel slick or soapy.

(2) *Shine.* When rubbed with fingernail or knife blade, inorganic clays remain dull, high plastic clays become shiny.

(3) *Taste.* Fine-grained soil will tend to stick to tongue.

b. *Drainage Characteristics.* Soils may be divided into three general groups on the basis of their drainage characteristics:

(1) *Well-draining soils.* Clean sands and gravels fall into this classification. They may be readily drained by gravity systems. For roads or airfields, open ditches may be used in these soils to intercept and carry water.

(2) *Poorly draining soils.* These are the inorganic and organic fine sands and silts, organic clays of low compressibility, and coarse grained soils having an excess of nonplastic fines. Drainage by gravity alone is difficult in these soils.

(3) *Impervious soils.* Fine-grained, homogeneous, plastic soils, and coarse-grained soils containing plastic fines are in this category. Subsurface drainage is so slow in these soils that it is of little value in improving their condition. Any drainage process may be difficult and expensive.

116. DRAINAGE

a. *Checkdams.* Checkdams are used on sidehill cuts and steep grades, where they are placed in side ditches to slow the water and prevent it from washing out the road. Checkdams are used when the ditchline grade exceeds 5 percent or where erosion is a problem. They are made of timber, sandbags, concrete, rock, or similar materials. Figure 127 shows the method of computing checkdam spacing.

b. *Culverts.* Culverts are required wherever drainage channels are needed to cross roads, to provide ditch relief, and to continue side ditches at the intersections of roads and access routes. In tactical situ-

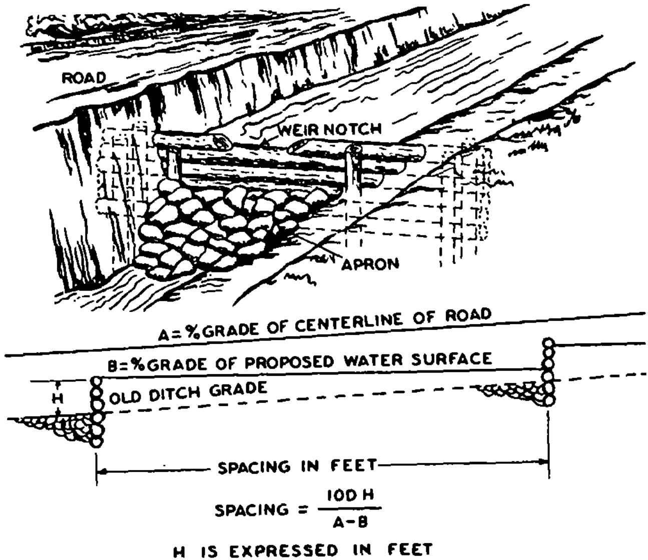


Figure 127. Methods of computing checkdam spacing.

ations where roads will be used only a few weeks, the cross sectional areas of drainage facilities are estimated by hasty methods.

(1) Talbot's formula may be used as an approximate method for computing the cross-sectional area of a proposed culvert. This formula is:

$$A = C\sqrt[4]{D^3} \text{ or } A = CD^{3/4}$$

where A = area of waterway opening in square feet
D = drainage area in acres
C = coefficient of retardation based upon slope and soil characteristics, (see table 70).

Table 70. Surface Runoff Factors

Types of surface	Foctor
Bituminous povements.	0.80 to 0.95
Concrete povements.	0.70 to 0.90
Grovel or mocodom povements . .	0.35 to 0.70
Impervious soils	0.40 to 0.65
Impervious soils, with turf* . . .	0.30 to 0.55
Slightly pervious soils*	0.15 to 0.40
Pervious soils*	0.01 to 0.10
Wooded oreos (depending on surfoce slope ond soil cover)	0.01 to 0.20

* For slopes from 1 to 2 percent.

(2) Toble 71 shows required culvert openings os computed from Talbot's formulo.

(3) An olinement chort for solutions is given in figure 128.

(4) The deliberote method of estimoting runoff combines engineer judgment with colculations bosed on onolysis, measurement, or estimation. It is expressed by:

$$Q = CIA$$

where Q = runoff from o given oreo in cubic feet per second

C = o coefficient thot represents the rotio of runoff to rainfall

I = intensity of rainfoll in inches per hour for the estimated time of concentrotion

A = droinoge areos in ocres.

The volue of C is derived from a study of the soil, the slope, ond conditions of the surface. The more commonly used volues are shown in toble 71. Other formulos may be found in TM 5–330.

c. *Culvert Plocement.*

(1) A woy to prevent erosion is pointed out in figure 129. Suggestions of culvert olinement are shown in figure 130.

(2) Culverts ore normolly at the grode of the natural and artificiol droinoge chonnels which dischorge into them. Grodes of 2 to 4 percent ore desiroble. Velocities should not be over 8 feet per second nor less thon 2.5 feet per second.

(3) Culverts should be ploced wherever natural droinoge channels require cross droinoge. Figure 131 shows the spocing of ditch-relief culverts. The bedding ond spocing of multiple-pipe culverts is equal to ot leost half the diometer of the pipe (fig. 132).

Table 71. Required Culvert Opening, in Square Feet, Computed from Talbot's Formula

Drainage area in acres	Mountainous (C = 1.0)	Hilly (C = 0.7)	Rolling (C = 0.5)	Flat (C = 0.2)
2	1.7	1.2	0.9	0.3
5	3.3	2.3	1.7	0.7
10	5.6	3.9	2.8	1.1
20	9.5	6.7	4.8	1.9
30	12.8	9.0	6.4	2.6
40	15.9	11.1	8.0	3.2
50	17.8	12.5	8.9	3.6
75	25.4	17.8	12.7	5.1
100	31.6	22.1	15.8	6.3
150	42.9	30.0	21.5	8.6
200	53.1	37.2	26.6	10.7
300	72.2	50.5	36.1	14.4
400	88.1	61.7	44.1	17.6
500	106.0	74.2	53.0	21.2
600	121.0	85.0	61.0	24.0
800	151.0	106.0	76.0	30.0
1,000	178.0	125.0	86.0	36.0
1,200	204.0	143.0	102.0	41.0
1,500	241.0	169.0	121.0	48.0
2,000	299.0	209.0	150.0	60.0
2,500	353.0	247.0	177.0	71.0
3,000	(*)	284.0	203.0	81.0
4,000	(*)	352.0	252.0	101.0
5,000	(*)	(*)	298.0	119.0
7,500	(*)	(*)	(*)	161.0
10,000	(*)	(*)	(*)	200.0
15,000	(*)	(*)	(*)	271.0
20,000	(*)	(*)	(*)	336.0

* Formula not to be used for these conditions.

NOTE: Value of C may be reduced where ponding or temporary storage is available, such as in irrigated areas or rice paddies.

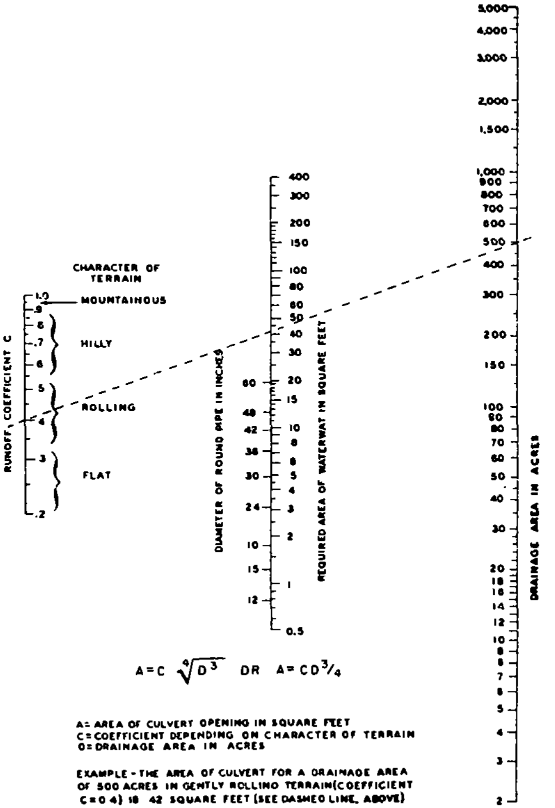


Figure 128. Nomograph for solution of Talbot's formula.

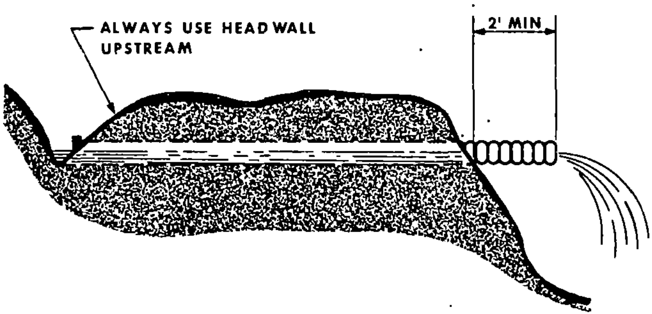


Figure 129. Culvert extended beyond fill to prevent erosion.

d. Box Culverts. There are several types of box culverts: log box, timber box, and concrete box. Examples of each are shown in figures 133 through 135.

e. Nestable Corrugated Pipe Culverts. These culverts are of two types: notched, having a notched edge and plain edges, and flanged, having flanges with slotted holes. The two types are not interchangeable. Figure 136 shows the strutting diagram for elongating the vertical dimension of the larger sizes of corrugated pipe culvert prior to backfilling.

f. *Expedient Culverts.*

(1) One type of this culvert uses oil, gasoline, or asphalt drums. Remove their ends with detonating cord, sharp handtools, or the tool-pneumatic metal drum opener.

CAUTION: Do not use a torch or other tools on gasoline or oil drums unless they are completely empty. Join these drums end to end by tack-welding, bolting, or wiring.

(2) Another type of expedient culvert is illustrated in figure 137. It uses sandbags and pierced metal panels, the latter being placed both above and below the sandbags as shown in figure 137.

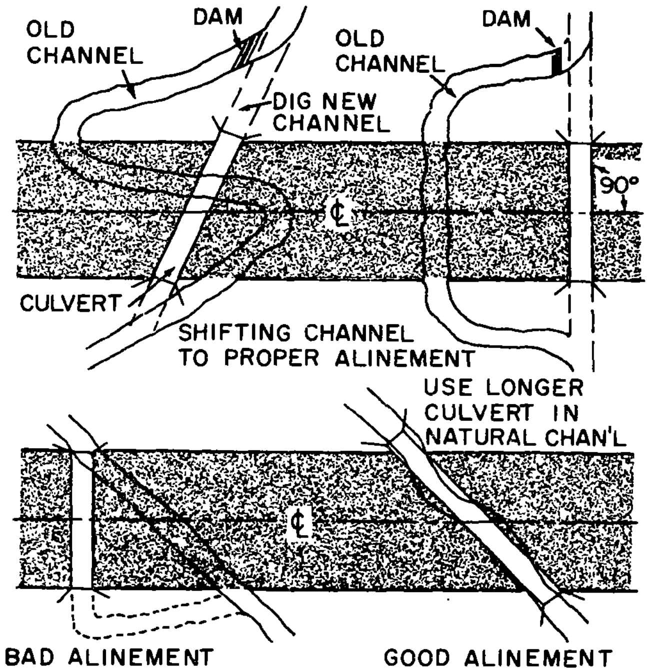


Figure 130. Alinement of culverts.

g. Cover. A minimum caver requirement of ½ the diameter con be used for reinfarced concrete pipe ond corrugated metal pipe culverts. Culverts other than pipe should hove o minimum af 12 inches, preferably 18 inches, af cover. Where heovy equipment is used in construction, odequate caver must be pravided to protect culvert structures from damage.

h. Hasty Culvert Areo Calculotion. See figure 138.

117. IDENTIFICATION OF BITUMINOUS MATERIALS

a. *Asphalt and Tar.* Asphalt and tar products are the principal bituminous materials used for road and airfield construction. Figure 139 is a field guide to identification of unknown bituminous materials. Table 72 shows the few grades which may be manufactured in the field.

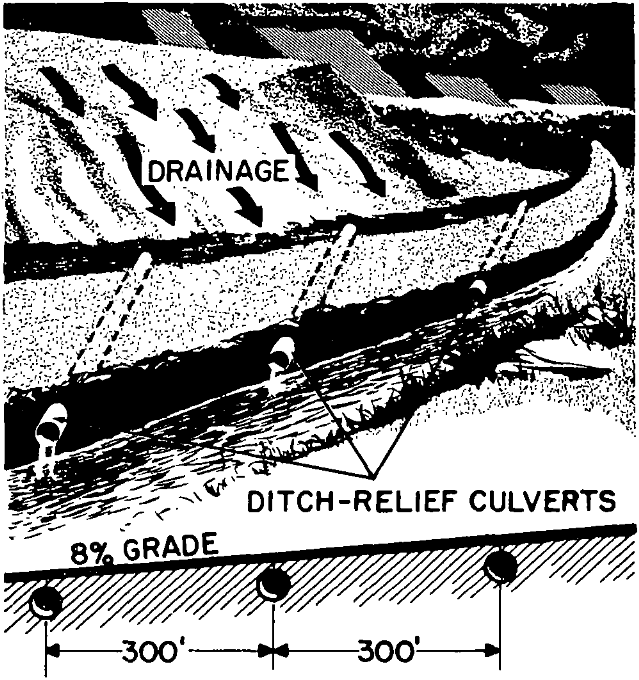


Figure 131. Spacing of ditch-relief culverts.

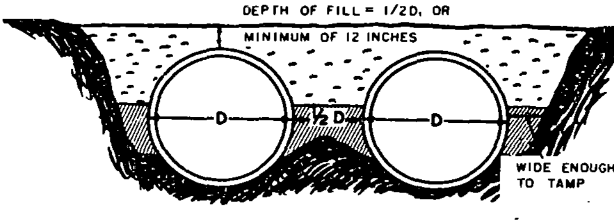


Figure 132. Spacing of multiple-pipe culvert.

b. Asphalt Construction. For emergency use, mixed-in-place surfaces are made of 3.5- to 6-percent bitumen, depending on the fineness of aggregate (see TM 5–337 for procedures.)

118. ROAD CONSTRUCTION IN THE ARCTIC

a. Nonpermafrost Areas. Construction design and procedures are generally the same for nonpermafrost as for northern areas or for any temperate climate. Allowances are made for the conditions of winter frost: in the arctic and subarctic regions, the depth of frost penetration is greater than in temperate zones (TM 5–349).

Table 72. Asphalt Cutback Composition (in percent of total volume)

Type	Components		Grades				
		Solvent	30	70	250	800	3000
Rapid curing RC	Asphalt cement	Gasoline or naphtha		65 35	75 25	83 17	87 13
Medium curing MC	Asphalt cement	Kerosene	54 46	64 36	74 26	82 18	86 14
Slow curing SC	Asphalt cement	Fuel oil		50 50	60 40	70 30	80 20

b. Permafrost Areas. In permafrost areas, site selection is the most important of all construction operations. Construction design depends on the surface and subsurface conditions at the selected site. Prime consideration is given to subgrade soil, ground water, surface ice fields, snow, and surface drainage. If at all possible, locate roads on soil composed of coarse-grained, nonfrost-active materials, e.g., high-bench gravel terraces. Ground with pores filled by ice or water should be avoided. The presence or absence of vegetation and its type, if it is present, provide a hasty indication of soil condition (TM 5-349).

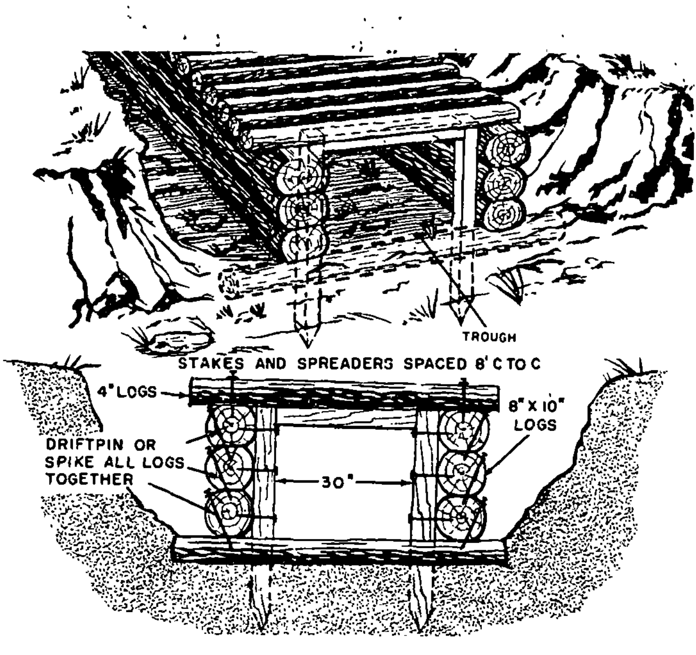


Figure 133. Log box culvert, 30-inch.

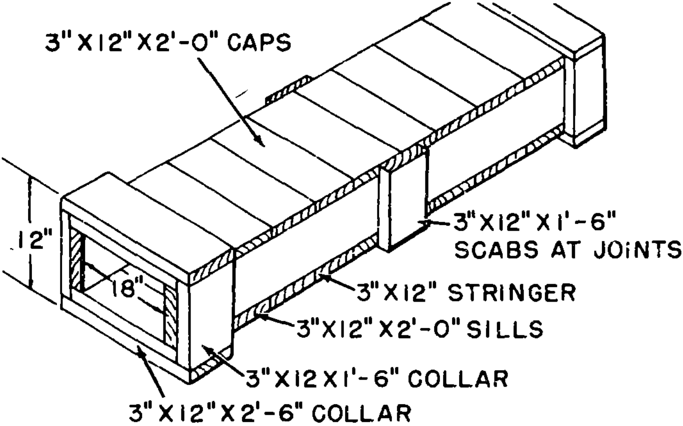


Figure 134. . Timber bax culvert, 18- by 12-inch.

c. *Bridging.* The constructian af bridge faundations in permofrost areas is about the same os for other large structures. Far detailed information an raod ond bridge constructian in the arctic, see TM 5–349.

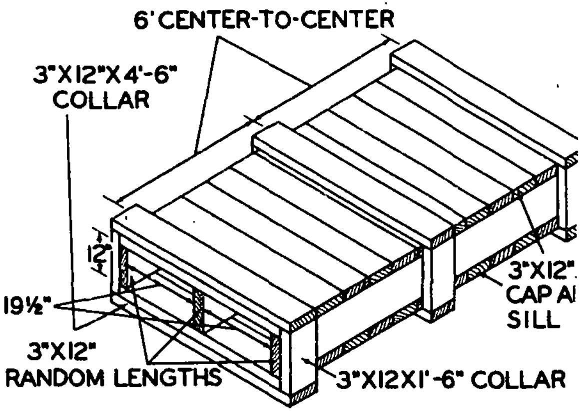


Figure 135. Timber box culvert, 19½- by 12-inch.

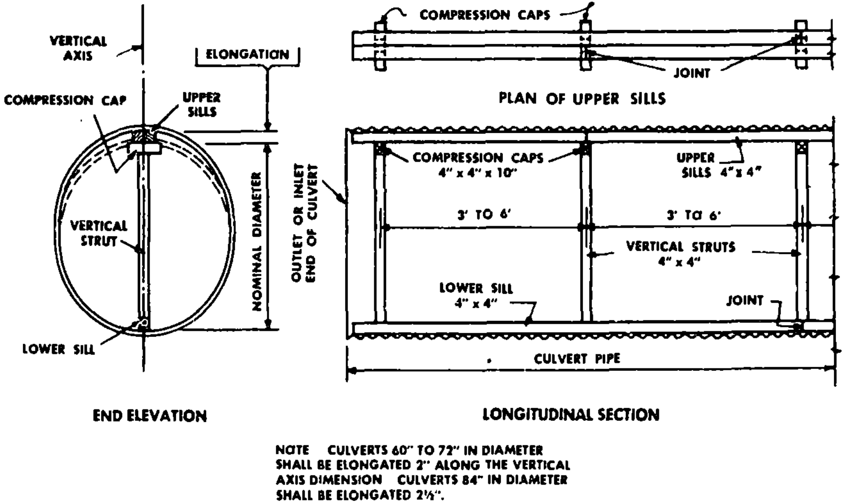


Figure 136. Strutting diagram shawing end and langitudinal views—corrugated culvert pipe.

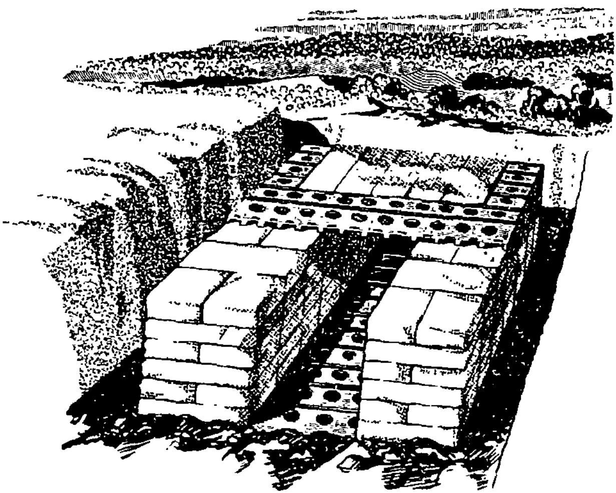
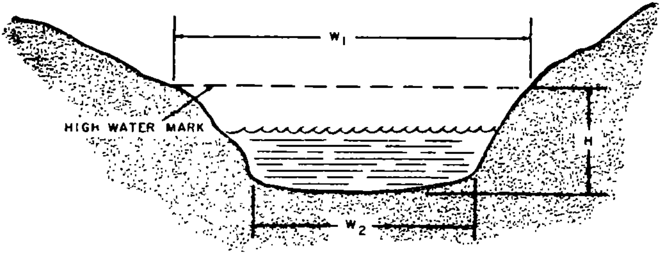


Figure 137. Expedient culvert.



W1 = WIDTH OF CHANNEL AT HIGH WATER MARK
W2 = WIDTH OF CHANNEL AT BOTTOM
H = VERITICAL DISTANCE FROM BOTTOM TO HIGH WATER MARK

$$\left(\frac{W_1 + W_2}{2}\right) H = \text{AREA OF WATERWAY}$$

SIZE OF CULVERT = AREA OF WATERWAY + SAFETY FACTOR 100%

Figure 138. Hasty culvert computation.

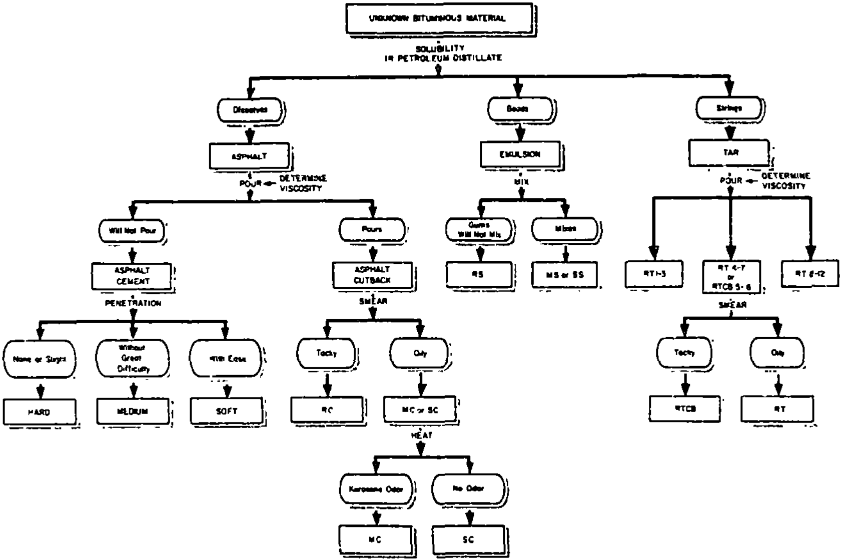


Figure 139. Field identification of unknown bituminous materials.

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CHAPTER 10

ARMY AIRFIELDS AND HELIPORTS

119. STANDARDS OF CONSTRUCTION

Army airfields and heliports are divided into three general classes in relation to construction standards: pioneer, hasty, and deliberate.

a. *Pioneer.* Lowest standard of construction, yet maintaining favorable operating conditions. Safety factors at minimum. Runway surface of soil or sod.

b. *Hasty.* Substandard but operable margin of safety. Reasonably safe and efficient except in prolonged inclement weather. Runway depends on soil, weather, time of year, availability of surfacing material and length of time field is used.

c. *Deliberate.* Safety and efficiency standards observed. Can operate under adverse conditions. Must have good subgrade and well-made flexible or rigid pavement to be all-weather operable.

120. MARKING PIONEER AND HASTY AIRPLANE LANDING AREAS

Pioneer and hasty airplane landing areas are normally marked to aid the aviator in identifying the area and to facilitate landing. Marking is normally accomplished by using ground-to-air signal panels. Marking is standard for all airplane landing areas and can vary from minimum marking (fig. 140) to optimum marking (fig. 141). These markings are only a guide and can be altered, as required, for special situations. The markings should always include the length of the usable areas and a wind indicator (or direction of landing).

a. *Marking Airplane Landing Area by Panels.*

(1) First, place two panels on the left side of the usable landing area as follows:

(a) At the departure end, place one panel perpendicular to the direction of landing.

(b) At the touchdown end, place the other panel parallel to the direction of landing.

(2) At the touchdown end of the landing area, use two additional panels to make a wind "T" to indicate direction of landing and wind information. Point the tail of the wind "T" into the wind. If the tail is on the left side, this indicates right-hand traffic; if on the right side, this indicates left-hand traffic; if centered, right or left traffic is indicated.

(3) If a code letter or identity panel is used, center it on the left side of the landing area.

(4) Remove panel marking after all aviators become familiar with the area, and as soon as practicable, as they are easily seen by the enemy.

CAUTION: Anchor panels securely against both propeller and rotor wash. Exercise extraordinary care in securing panels to ground. Use firmly driven stakes to secure panels tautly; rocks piled on the corners are not adequate.

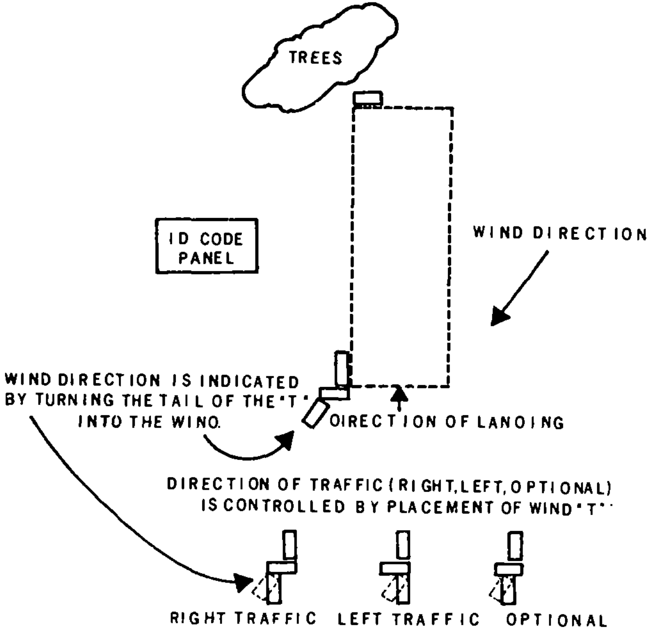
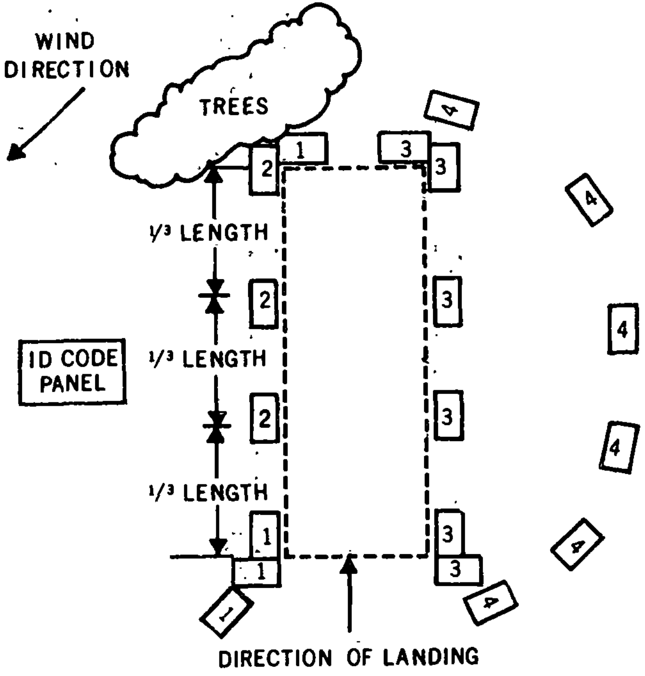


Figure 140. Minimum markings for a landing area.



THE NUMBERS ON THE PANELS INDICATE PRIORITY OF EMPLACEMENT. THE NUMBER 4 PANELS INDICATE TAXIWAY WHEN APPLICABLE.

Figure 141. Maximum markings for a landing area.

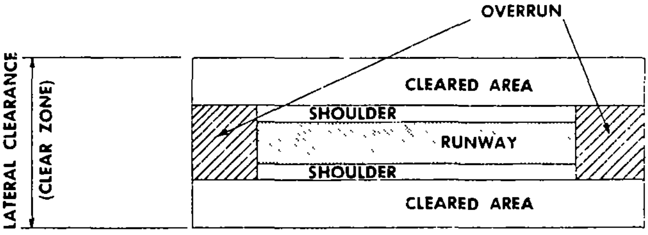


Figure 142. Flightstrip nomenclature.

b. Marking Airplane Landing Area by Smoke. If the tacticol situation permits, smoke used at the proper time will readily identify the exact location of the landing oreo; it will also indicate wind direction and velocity. Smoke is normally used in the same orea designoted for wind indicator. It must be of a color authorized by the signol operation instructions (SOI).

121. GENERAL NOMENCLATURE OF ARMY AIRFIELDS

The generol loyout and nomenclature are shown in figures 142 ond 143.

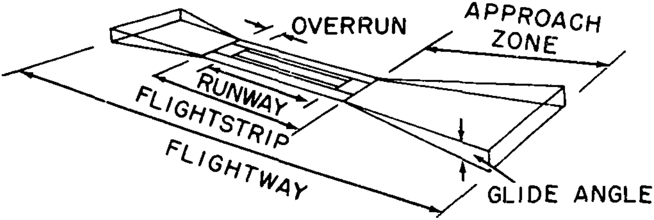


Figure 143. Flightway nomenclature.

122. ARCTIC CONSTRUCTION OF AIRFIELDS

The information on the construction of roads in the arctic is generally pertinent to airfield construction in arctic areas. Runway design over frost-susceptible soils must taken into account frost and permafrost conditions. For detailed information see TM 5–349.

123. ARMY AIRFIELD DESIGN

a. *Specifications of Army Airplanes.* These specifications are listed in table 73.

b. *Runway Length.* Determination of runway length consists of multiplying the minimum takeoff ground run by safety factors to allow for variation in pilot skill; psychological factors; and wind, snow, and other surface conditions.

Step 1. Takeoff ground run for individual aircraft is shown in table 73. Increase figure shown by 7 percent for soft surfaces.

Step 2. Increase result of step 1 by 15 percent for each 1000-foot increase in runway elevation above sea level.

Step 3. Increase result of step 2 by 4 percent for each 10°F increase in temperature above 59°F. (Use highest expected temperature.)

Step 4. Increase result in step 3 by a slope correction of 20 percent for each 1 percent of effective gradient over 2 percent.

Step 5. Multiply result in step 4 by the safety factor for the particular type airfield being planned; pioneer, 1.25; hasty, 1.50; deliberate, 1.75. Round result off to the next larger 100 feet.

c. *Runway Width.* The minimum runway width for a pioneer airfield is 50 feet; for a hasty airfield, 50 feet; and a deliberate airfield, 75 feet. Care should be taken to insure that the shoulders and cleared areas on both sides of the runway are wide enough to provide sufficient clearance for the wings of the airplanes using the runway.

d. *Facilities.* The above methods give the planner a minimum set of length and width for a runway. Shoulders, approach zones, and further sophistications of design require TM 5–330 as a guide.

e. *Coordination.* When possible, the aviation unit commander should be consulted before runway construction begins. Most aircraft models have variations in characteristics which could greatly affect the size of the runway to be constructed.

124. HELICOPTER TAKEOFF AND LANDING AREA

Helicopters are intended to be vertical takeoff aircraft, but under certain conditions of load and atmosphere, require a takeoff ground run for

Table 73. Specifications of Army Airplanes

Aircraft type	Army designation	Gross weight (lbs)	Overall airplane dimensions: Length	Wing-span	Height	Tread	Take-off ground run[1]	Take-off distance to clear 50' ob-stacle[1]	Land-ing ground roll[1]	Land-ing distance to clear 50' ob-stacle[1]
Observation	O-1A	2,100	25'9½"	36'	7'6"	7'7"	355'	580'	305'	605'
	O-1E	2,165	25'9½"	36'	7'6"	7'7"	380'	634'	305'	605'
	TO-1D, O-1F	2,400	25'9½"	36'	7'6"	7'7"	375'	772'	300'	660'
	OV-1A, B, C	Characteristics plus requirements vary from less than 1,000 feet to several thousand feet depending upon model and serial number of aircraft. Consult aviation unit commander for runway requirements.								
Utility	U-6A	5,100	30'5"	48'0"	10'5"	10'2"	815'[2]	1,250'[2]	590'[2]	1,250'[2]
	U-1A	8,000	41'10"	58'0"	12'5"	11'2"	1,045'[2]	1,605'[2]	565'[2]	1,225'[2]
Cargo	CV-2B	28,500	72'7"	95'7½"	31'9"	23'2"	735'	1,205'	665'	1,245'
Command	U-8D	7,300	31'6"	45'4"	11'4"	12'9"	1,430'[3]	2,385'[3]	1,310'[3]	2,135'[3]
	U-8F	7,700	33'4"	45'11"	14'2"	12'9"	1,320'[4]	2,200'[4]	1,345'[5]	2,125'[5]
	U-9C	7,000	35'5"	44'7"	14'6"		1,250'[2]	1,540'[2]	1,058'[2]	1,630'[2]

[1]30° wing flaps for takeoff, 60° wing flaps for landing, sod runway, no wind, 59° F, and at sea level.
[2]Hard surface runway—flaps set for "TAKEOFF."
[3]Hard surface runway—assumes landing weight of 7,000 lbs (300 lbs fuel consumption).
[4]Hard surface runway—0° flaps
[5]Hard surface runway—assumes landing weight of 7,350 lbs (350 lbs fuel consumption)

Table 74. Specifications of Army Helicopters

Aircraft type	Army designation	Maximum allowable gross weight (lbs)	Overall helicopter dimensions: Length	Rotor diameter	Height	Tread	Performance takeoff—[1]	Altitude (feet): Sea level	2,000	4,000	6,000	8,000
Observation	OH-13E, G	2,350	41′5″	35′2″	9′5″	7′6″	ground run	([2])	([2])	([2])	([2])	([2])
							to clear 50 ft.	225	300	550	900	1,450
	OH-13H	2,450	41′5″	35′2″	9′4″	7′6″	ground run	([2])	([2])	([2])	([2])	([2])
							to clear 50 ft.	0	0	0	0	550
	OH-13S	2,850	43′3″	37′2″	9′4″	7′6″	ground run	0	0	0	0	0
							to clear 50 ft.	0	0	0	0	0
	OH23B, C	2,500	40′5″	35′	9′6″	7′6″	ground run	230	299	377	466	....
							to clear 50 ft.	481	672	1,055	3,297	....
	OH-23D	2,700	40′9″	35′5″	10′2″	7′6″	ground run	0	235	325	....	...
							to clear 50 ft.	0	475	670	....	....
Utility	UH-19C	7,500	62′6″	53′	14′7″	11′ (main)	ground run	255	330	565	210[3]	645[3]
						4′8″ (nose)	to clear 50 ft.	520	680	1,050	670[3]	1,840[3]
	UH-19D	7,900	62′3″	53′	15′3″	11′ (main)	ground run	95	230	405	180[3]	260[3]
						4′8″ (nose)	to clear 50 ft.	370	505	705	575[3]	935[3]
	UH-1A	7,200	52′11″	43′9″	13′11″	8′5″	ground run	0	0	0	....	....
							to clear 50 ft.	110	120	970	....	....

Table 74.—Continued

Aircraft type	Army designation	Maximum allowable gross weight (lbs)	Overall helicopter dimensions: Length	Rotor diameter	Height	Tread	Performance takeoff—[1]	Altitude (feet): Sea level	2,000	4,000	6,000	8,000
	UH-1B	8,500	52 11″	44′0″	15′8″	8′5″	ground run	([2])	([2])	([2])	([2])	([2])
							to clear 50 ft.	0[4]	44[4]	50[4]	94[4]	....
	UH-1D	9,000	57′2″	48′3″	14′6″	9′7″	ground run	([2])	([2])	([2])	([2])	([2])
							to clear 50 ft.	0[5]	306[5]	474[5]	...	...
Cargo	CH-21	13,500	86′4″	44′	15′9″	13′4″	ground run	0[6]	0[6]	....	....	....
							to clear 50 ft.	0[6]	0[6]	1,150[6]	2,200[6]	....
	CH-34C	13,500	65′10″	56′0″	15′11″	12′	ground run	0	160	185[3]	345[3]	...
							to clear 50 ft.	0	700	890[3]	1,395[3]	....
	CH-37B	31,000	88′	72′	22′	19′9″	ground run	161	184	414	345[3]	886[3]
							to clear 50 ft.	316	391	771	811[3]	1,846[3]
	CH-47A	33,000	98′4″	59′2″	19′	11′11″	ground run	0[7]	0[7]	0[7]	0[7]	0[7]
							to clear 50 ft.	0[7]	0[7]	0[7]	0[7]	0[7]

[1]At maximum allowable gross weight, firm dry sod, no wind, 59° F, from a dead stop, and disregarding moisture content.

[2]Data not contained in TM 55-Series-10.

[3]Prepared surface required.

[4]-9 or -11 engine.

[5]48′ rotor.

[6]Assumes dewpoint of 32° F.

[7]Using L-7 engines.

required lift. Therefore, runways should be included in a design for a heliport. Efforts should be made to keep dust to a minimum in the runway area.

a. *Runway Length*. The minimum runway length for a pioneer heliport is 100 feet longer than the overall length of the longest helicopter to use the runway. The minimum runway length for a hasty heliport is 300 feet longer than the longest helicopter to use the runway. The minimum runway length for a deliberate heliport is 450 feet longer than the longest helicopter to use the runway. See table 74 for the takeoff run required by each helicopter. Then apply steps 1, 3, 4, and 5, in order given in paragraph 123*b*, to these minimum lengths to obtain runway length requirements.

b. *Runway Width*. The minimum runway width for a pioneer or hasty heliport is 25 feet; for a deliberate heliport, use 40 feet. Care should be taken to insure that the shoulders and cleared areas on both sides of the runway are wide enough to provide sufficient clearance for the rotor blades.

c. *Emergency Sites*. Emergency landing pads can be constructed for helicopters by providing a level, cleared area with a stable surface. This surface may be earth, timber mat, or expedient paving materials. Actual required pad size can be estimated using data in table 74. The pad size is one-half the total length of the helicopter (including rotor blades) by one-half the diameter of the rotor blades.

CHAPTER 11

RECONNAISSANCE

125. TYPES OF RECONNAISSANCE

a. *Route Reconnaissance.*

(1) Route reconnaissance is governed by the same fundamentals that apply to all reconnaissance. It is usually made on the ground, but it should be supplemented by air reconnaissance when practicable. Route reconnaissance provides information to aid in route selection for the movement of troops, equipment, and supplies.

(2) Information sought in this type of reconnaissance includes:

(a) Nature of terrain.

(b) What roads exist and their characteristics, including load-bearing capabilities. See TM 5-330 for more detailed information.

(c) Obstructions.

(d) Bridges and other stream crossing means.

(e) Tunnels.

(3) Route reconnaissance must consider the mission of the parent unit. Reconnaissance factors include the weight, width, and height of the vehicles that will be used; the classification of these vehicles; the approximate number of each class to be moved per hour; and the approximate length of time the route will be used.

(4) A route reconnaissance report should be accurate, concise, and clear. The preferred method of preparation is in simplified map form (fig. 144) or overlay, using symbols (fig. 145) to show the limiting features. A route reconnaissance report is accompanied by a road reconnaissance report and bridge, tunnel, ferry, and ford reconnaissance reports as needed. Military sketches of limiting features, local maps, and photographs of significant factors (terrain, roads, tunnels, bridges, ferries, fords, and so forth) support the route report.

(5) Important features to be shown on an overlay are listed below.

(a) Length (in kilometers) between well marked points.

(b) Curves having radii of less than 30 meters with these radii marked in meters.

(c) Steep grades, with their maximum gradients in percent, and length of any grade of 7 percent or greater.

(d) Road width of constrictions (bridges, tunnels and so forth), with the widths of the traveled ways in meters; their lengths in kilometers.

(e) Underpass limitations, with their limiting heights and widths in meters.

(f) Bridge bypasses, classified as easy, difficult, or impossible (c below).

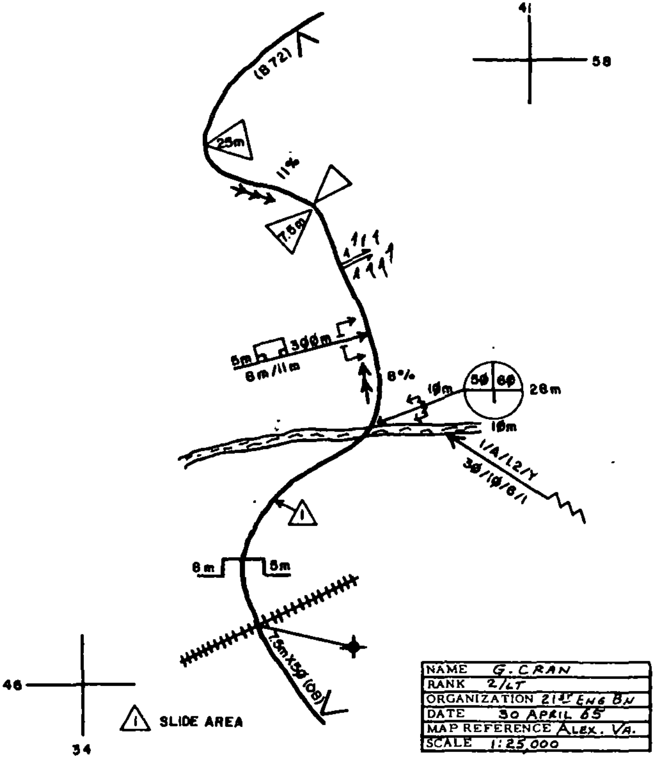


Figure 144. Example of raute recannaissance averlay.

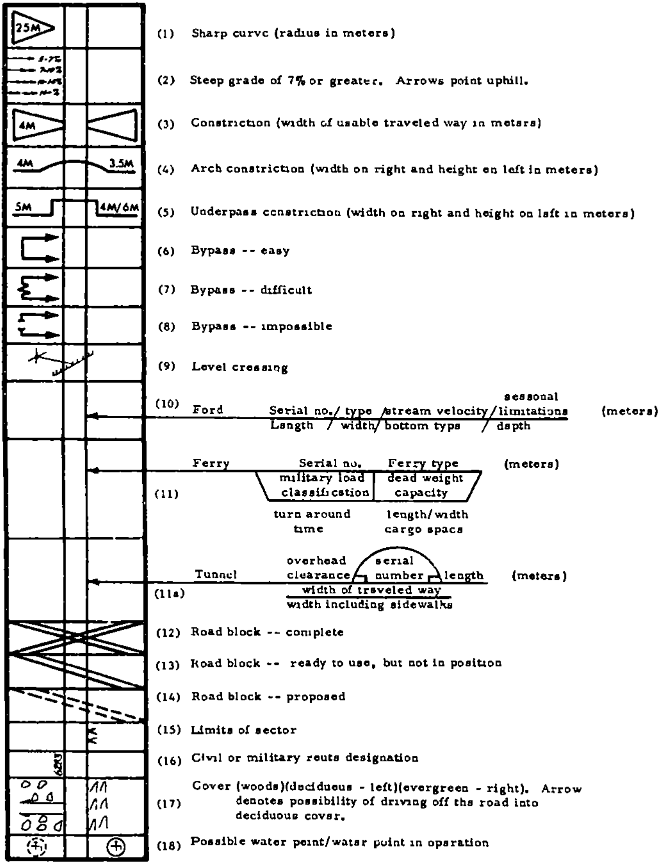


Figure 145. Overlay symbols.

(g) Civil or military road numbers, or other designations.

(h) Feasibility of driving off roads, including shoulders.

(i) Locations of fords, ferries, and tunnels including limiting information.

(6) Route classification formula. Symbols for route reconnaissance maps or overlays are shown in figures 144 and 145. Further symbols are as follows:

(a) Types of roads.

1. (X) All-weather. Any road which, with reasonable maintenance, is passable throughout the year to a volume of traffic never appreciably less than its maximum good weather capacity. This type of road has a waterproof surface and is only slightly affected by rain, frost, thaw, or heat. At no time is it closed to traffic due to weather effects other than snow blockage. The following are examples of this category: concrete; bituminous; brick or stone.

2.(Y) Limited all-weather. Any road which, with reasonable maintenance, can be kept open in bad weather to a volume of traffic which is considerably less than its normal good weather capacity. This type of road does not have a waterproof surface and is considerably affected by rain, frost or thaw. The following are examples of this category: crushed rock or waterbound macadam; gravel or lightly metalled surface.

3. (Z) Fair weather. A road which becomes quickly impassable in bad weather and which cannot be kept open by normal maintenance. This type of road is seriously affected by rain, frost, or thaw. The following are examples of this type: natural or stabilized soil; sand or clay; shell; cinders; disintegrated granite.

(b) Formulas.

1. 6 meter Y 50 describes a route 6 meters wide (minimum), limited all-weather type, and load classification of class 50.

2. 6 meter Y 50 (Ob). "(Ob)" indicates an obstruction along the route.

3. 6 meter Y 50 (T). "(T)" represents snow blockage.

4. 6 meter Y 50 (W). "(W)" represents flooding.

(c) Causeways, snowsheds, and galleries. Although these structures are not often encountered in a route reconnaissance, when they constitute an obstruction to traffic they should be included in the route reconnaissance report. Limit the data to clearances and load-carrying capacity. If possible, support the information with photographs or a sketch of each structure. Also, include enough descriptive information to permit an evaluation concerning the strengthening or removal of these structures.

1. A causeway is a raised way across wet or unstable ground.

2. A snowshed is a shelter protecting something from snow, such as a long structure over an exposed part of a road or railroad.

3. A gallery is a sunken or cut passageway covered overhead as well as the sides. In a combat area, a gallery may be important not only because it may be an obstruction, but because it may afford additional protection.

b. Road Reconnaissance.

(1) Road reconnaissance is performed to get information on road classification, primarily in support of selecting a route, and to report changes to existing maps for dissemination in the theater of operations. Its main concern is with existing road conditions and not for maintenance operations. Its purpose is to find out the quantity and kind of traffic and loads that a road can accommodate in its present condition. It may include estimates of the practicability of improvement and the amount of engineer effort necessary to prepare a route for specified traffic and loads. Obtaining data for complete road classification should be done by an engineer officer. An example of a road reconnaissance (DA Form 1248) is shown in figures 146 and 147.

(2) Information required—

(a) Local name of road.

(b) Local road designation and number.

(c) Location of road by map grid reference.

(d) Obstructions, which include, among other items, underpasses, fords, large tree limbs, craters, projecting buildings, areas subject to inundation, and so forth.

(e) Bridge locations. (Bridge reconnaissance is outlined in c below.

(f) Tunnel locations, together with their lengths, widths, and heights. (Tunnel reconnaissance is described in d below.)

(g) Snowshed locations and estimated coverage.

(h) Gallery locations, together with their lengths, widths, and heights.

(i) Other requirements are listed in a(5) (a) through (e) and (*i*) above.

(3) Road classification formula. Road characteristics are expressed by definition and symbols in the following order: limiting factors, width, construction material, and, if desired, length.

(a) Limiting factors. The symbol "A" is used if there are no limiting factors. The symbol "B" means one or more limiting factors. A question mark in parentheses (?) means an unknown limiting factor. A V-like symbol on a map or overlay represents the terminal points of

ROAD RECONNAISSANCE REPORT
(FM 5-36)

DATE: 25 JUN 65

TO: (Headquarters ordering reconnaissance) 21ST ENGR BN, ATTN: S2

FROM: (Name, grade and unit of officer or NCO making reconnaissance) L.H. DICKEY CAPT. CE Co.A, 21ST ENGR BN

1. MAPS	a. COUNTRY	b. SCALE	c. SHEET NUMBER OF MAPS	2. DATE/TIME GROUP (Of signature)
	VIRGINIA, ALLANDALE	1:25,000	U.S. SHEET 5561 I,S.W. AMS V834	1Ø123ØZ JUN

SECTION I - GENERAL ROAD INFORMATION

3. ROAD GRID REFERENCE FROM	TO	4. ROAD MARKING (Civilian or Military number of road)	5. LENGTH OF ROAD (Miles or kilometers, specify)
1Ø5155	119169	FAIRFAX Co. #644	6.7 MILES

6. WIDTH OF ROADWAY (Feet or meters, specify): 14-20 FEET

7. RECONNAISSANCE — DATE: 10 MAR 65 — TIME: Ø8ØØ-12ØØ

8. WEATHER DURING RECONNAISSANCE (Include last rainfall, if known): COOL, DRY, 61°F LAST RAIN ABOUT 10 JUN 65

SECTION II - DETAILED ROAD INFORMATION (When circumstances permit more detailed information will be shown in an overlay or on the mileage chart on the reverse side of this form. Standard symbols will be used.)

9. ALINEMENT (Check one ONLY)

	(1) FLAT GRADIENTS AND EASY CURVES
	(2) STEEP GRADIENTS (Excess of 7 in 100)
	(3) SHARP CURVES (Radius less than 100 ft (30m))
✓	(4) STEEP GRADIENTS AND SHARP CURVES

10. DRAINAGE (Check one ONLY)

✓	(1) ADEQUATE DITCHES, CROWN/CAMBER WITH ADEQUATE CULVERTS IN GOOD CONDITION
	(2) INADEQUATE DITCHES, CROWN/CAMBER OR CULVERTS. ITS CULVERTS OR DITCHES ARE BLOCKED OR OTHERWISE IN POOR CONDITION

11. FOUNDATION (Check one ONLY)

✓	(1) STABILIZED COMPACT MATERIAL OF GOOD QUALITY
	(2) UNSTABLE, LOOSE OR EASILY DISPLACED MATERIAL

12. SURFACE DESCRIPTION (Complete Items 12a and b)

a. THE SURFACE IS (Check one ONLY)

✓	(1) FREE OF POTHOLES, BUMPS, OR RUTS LIKELY TO REDUCE CONVOY SPEED
	(2) BUMPY, RUTTED OR POTHOLED TO AN EXTENT LIKELY TO REDUCE CONVOY SPEED

b. TYPE OF SURFACE (Check one ONLY)

	(1) CONCRETE
✓	(2) BITUMINOUS (Specify type where known): SEE MILAGE CHART
	(3) BRICK (Pave)
	(4) STONE (Pave)
	(5) CRUSHED ROCK OR CORAL
	(6) WATERBOUND MACADAM
	(7) GRAVEL
	(8) LIGHTLY METALLED
	(9) NATURAL OR STABILIZED SOIL, SAND CLAY, SHELL, CINDERS, DISINTEGRATED GRANITE, OR OTHER SELECTED MATERIAL
	(10) OTHER (Describe):

SECTION III - OBSTRUCTIONS (List in the columns below particulars of the following obstructions which affect the traffic capacity of a road. If information of any factor cannot be ascertained, insert "NOT KNOWN")
(a) Overhead obstructions, less than 14 feet or 4.25 meters, such as tunnels, bridges, overhead wires and overhanging buildings
(b) Reductions in road widths which limit the traffic capacity, such as craters, narrow bridges, archways, and buildings.
(c) Excessive gradients (Above 7 in 100)
(d) Curves less than 100 feet (30 meters) in radius
(e) Fords

SERIAL NUMBER a	PARTICULARS b	GRID REFERENCE c	REMARKS d
1.	STEEP GRADE - 8% UP EASTWD	1Ø8158	
	.02 MILE LONG		
2	SERIES OF SHARP CURVES	1Ø9160 TO	
		11Ø161	
3	STEEP GRADE - 7% DOWN		
	EASTWARD	112165	

DA FORM 1 JUL 60 1248

Figure 146. Road reconnaissance report.

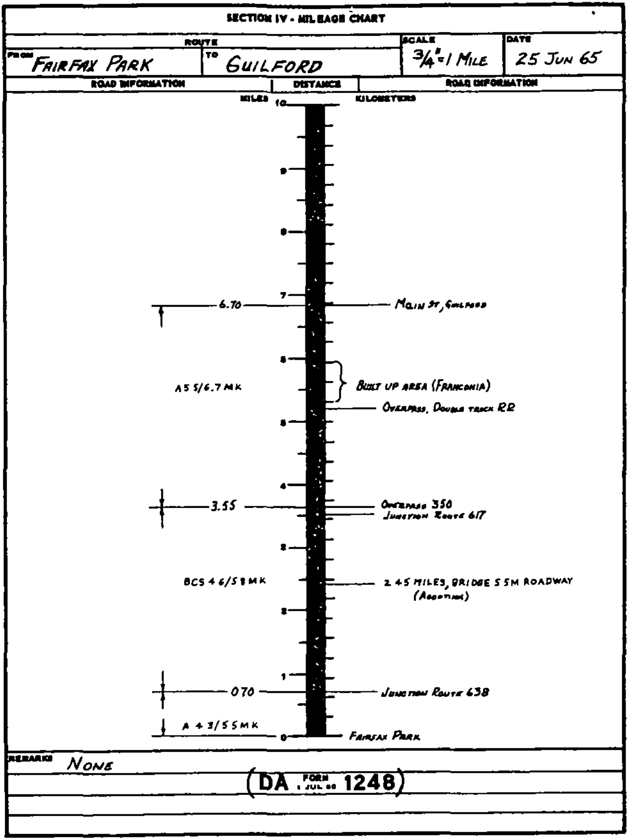


Figure 147. Road reconnaissance report (reverse side).

785-094 O-66—17

the road sector (fig. 144). Table 75 shows limiting factors, their criteria, and symbols representing them.

(b) Width. The traveled way of a road is expressed in feet or meters followed by a slash with the width of traveled way and shoulders combined as 14/16.

Table 75. Criteria for Determinations of Limiting Factors

Limiting Factor	Criteria	Symbol
Sharp curves	Sharp curves with radius less than 100 ft (30 m) cause some slowing of convoy traffic and will in addition be reported as obstructions.	c
Steep gradients	Steep gradients, 7% or steeper, cause some slowing of of convoy traffic. Gradients steeper than 7% and excessive changes in gradients will, also be reported as obstructions.	g
Poor drainage	Inadequate ditches, crown/camber, or culverts; culverts and ditches blocked or otherwise in poor condition.	d
Weak foundation	Unstable, loose or easily displaced material.	f
Rough surface	Bumpy, rutted, or potholed to an extent likely to reduce convoy speeds.	s
Excessive camber or superelevation.	Falling away so sharply as to cause heavy vehicles to skid or drag toward the road side.	l

(c) Construction materials. See table 76 for these symbols.

(d) Length. This may be shown, if desired, in parentheses at the end of a road classification formula.

(e) Examples:

1. A 5.0/6.2 mk-concrete road, 5.0 meters wide; 6.2 meters, including shoulders; no limiting factors.

2. Bgs. 14/16 ft 1 (Ob)—gravel or lightly metalled, 14 feet wide, 16 feet, including shoulders, steep gradients, rough surface; and obstructions.

3. Bg. (f?) 3.2/4.8 m.p. (4.3 km) 1—Paving brick or stone; 3.2 wide, 4.8 meters, including shoulders; sharp curves; foundation unknown; 4.3 kilometers long; and subject to snow blockage.

Table 76. Symbols for Types of Surface Materials

Symbol	Material	Normal road type
k	Concrete	Type (X); generally heavy duty
kb	Bituminous or asphaltic concrete (bituminous plant mix).	Type (X); generally heavy duty
p	Paving brick or stone	Type (X); generally heavy duty
rb	Bitumen-penetrated macadam; waterbound macadam with superficial asphalt or tar cover.	Type (X) or (Y); generally medium duty
r	Waterbound macadam, crushed rock, or coral.	Type (Y); generally light duty
l	Gravel or lightly metalled surface.	Type (Y); generally light duty
nb	Bituminous surface treatment on natural earth, stabilized soil, sand-clay, or other select material.	Type (Y) or (Z); generally light duty
n	Natural earth, stabilized soil, sand-clay, shell, cinders, disintegrated granite, or other select material.	Type (Z); generally light duty
v	Various other types not mentioned above.	(indicate length when this symbol is used.)

NOTE: In addition to the symbols shown above, the symbol "b" (bituminous surface) may be used alone when the type of bituminous construction cannot be determined.

(4) Measuring radii of curves.

(a) A method of determining the radius of a curve is based on the formula—

$$R=C^2/8m+2 \text{ (fig. 148)}$$

where C-length of cord (if C is 19 meters or more, it need not be reported.)

m = perpendicular distance from center of cord to centerline (ᶜL) of road

R = radius of circle

By fixing m at any convenient distance, such as 5 feet, the formula becomes—

$$R=C^2/40=2.5$$

In applying the formula, m is measured from the centerline of the curve toward the estimated center of the circle and then C is measured per-

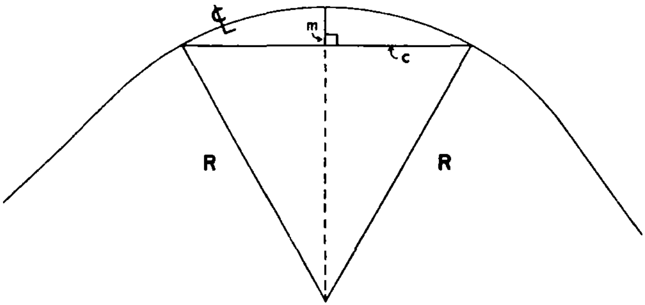


Figure 148. *Measuring a curve using formula* $R = C^2/8m + m/2$.

pendicularly to m, making sure that C is centered on m. If C is measured at 18 meters, R=26.8 meters.

(b) Figure 149 shows an alternate method effective when the chord is impossible to measure due to brush, minefields, or similar obstacles. A compass azimuth is taken at two points along the curve and the centerline distance (between the two points) of the curve paced or measured directly.

1. If A_B is larger than A_A:

$$\gamma = \frac{57c}{A_B - A_A} \quad (\gamma \text{ is in the units of c})$$

2. If A_A is larger than A_B:

$$\gamma = \frac{57c}{360 + A_B - A_A} \quad (\gamma \text{ is in the units of c})$$

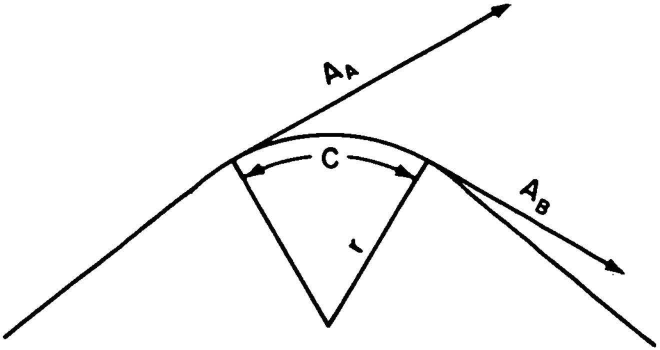
(c) Method *(a)* above is more accurate than method *(b)*. Both have their advantages.

(5) Determining road gradient—

$$\frac{\text{Vertical distance}}{\text{Horizontal distance}} \times 100 = \% \text{ of slope}$$

(or a clinometer may be used).

(6) The road reconnaissance report has the information required for classification of a road. There should be several copies, each covering a selected section of the road. Short forms or worksheets may be designed for rapid field work. (See FM 5–36.)



A_A = AZIMUTH A

A_B = AZIMUTH B

C = DISTANCE ALONG ℄ OF ROAD

r = RADIUS OF CURVE

Figure 149. Alternate method for measuring a curve.

c. *Bridge Reconnaissance.*

(1) The limiting features of bridges are of basic importance to the selection of a route for normal troop movements. See tables 77 and 78.

(2) Bridge reconnaissance has two methods.

(a) Hasty reconnaissance determines immediate trafficability.

(b) Deliberate reconnaissance is done when there is enough time and qualified personnel to make a thorough analysis and classification of the bridge, including necessary repairs or demolition procedures.

(3) Full bridge symbol includes the location of the bridge, the arbitrarily assigned bridge number, the military local classification number, the overall length of the bridge, the roadway width, the vertical

Table 77. General Dimension Data Required for Each of the Seven Basic Types of Bridges

Dimension data	Simple stringer	Slab	T-beam	Truss	Girder	Arch	Suspension
Overall length.	x	x	x	x	x	x	x
No. of spans	x	x	x	x	x	x	x
Length of spans.	x	x	x	x	x	x	x
Panel length	---------	---------	---------	x	---------	---------	x
Height above streambed .	x	x	x	x	x	x	x
Height above estimated normal water level. . .	x	x	x	x	x	x	x
Width of roadway	x	x	x	x	x	x	x
Vertical clearance (over) .	---------	---------	---------	x	---------	---------	x
Horizontal clearance. . .	x	x	x	x	x	x	x

NOTE: The letter "x" indicates that the dimension is required.

clearance, the bridge bypasses, horizontal clearance, under-bridge clearance, number of spans, type of span construction, type of span construction material, and length and condition of spans (fig. 150). Information should be obtained to complete the Bridge Report Form (DA Form 1249), figures 151 and 152.

(4) Bridge bypasses are local detours, which are classified as easy, difficult, or impassable. Figure 145 shows the symbols used for each classification.

(a) Bypass easy is a local detour by road or cross-country movement which all types of traffic can make in 15 minutes or less, or 4 miles (6.5 km) added to the direct route distance. It should require less than 4 hours for 35 men, with proper equipment, to improve or construct.

(b) Bypass difficult differs from bypass easy in that more than 4 hours are required for 35 men, with proper equipment, to improve or construct.

(c) Bypass impassible exists when—

1. No alternative bridge is available within acceptable distance.

2. Terrain prevents off-road movement or temporary road construction.

3. Characteristics of the stream prohibit fording or construction of temporary crossing means.

4. Depth or slope of obstacle prohibits construction of approaches to crossing site.

Table 7B. · Capacity Dimension Data Required for Each of the Seven Basic Types of Bridges

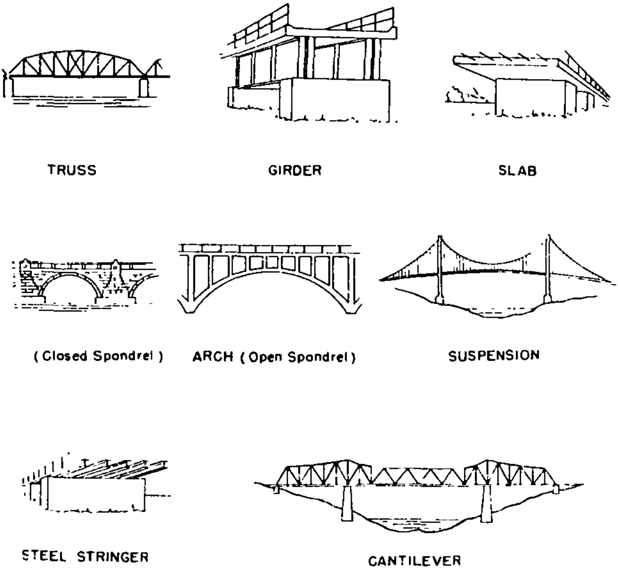
Capacity (1) dimension data	Basic types of bridge										
	Simple stringers					Slab	T-beam	Truss	Girder	Arch	Suspension
Thickness of wearing surface	x					x	x	x	x	x	x
Thickness of flooring, deck, or depth of fill at crown	x					x	x	x	x	x	x
	Timber		Steel								
	Rectang.	Log	I-beam	Channel	Rail						
Distance, c-to-c, between T-beams, stringers, or floor beams	x	x	x	x	x	...	x	x	x	x	x
No. of T-beams or stringers	x	x	x	x	x	...	x	x	x	...	x
Depth of each T-beam or stringer	x	(2)	x	x	x	...	x	x	x	...	x
Width of each T-beam or stringer	x	..	(3)	(3)	(3)	..	x	x	x	..	x
Thickness of web of I-beams, WF-beams, channels, or rails	...	...	x	x	x	...	...	x	x	...	x
Sag of cable	...	...	...	...	...	...	...	...	...	...	x
No. of each size of cable	...	...	...	...	...	...	...	...	...	...	x
Thickness of arch ring	...	...	...	...	...	...	...	...	...	x	...
Rise of arch	...	...	...	...	...	...	...	...	...	x	...
Diameter of each size of cable	...	...	...	...	...	...	...	...	...	...	x
Depth of plate girder	...	...	...	...	...	...	...	...	x	...	...
Width of flange plates	...	...	...	...	...	...	...	...	x	...	...
Thickness of flange plates	...	...	...	...	...	...	...	...	x	...	...
No. of flange plates	...	...	...	...	...	...	...	...	x	...	...
Depth of flange angle	...	...	...	...	...	...	...	...	x	...	...
Width of flange angle	...	...	...	...	...	...	...	...	x	...	...
Thickness of flange angle	...	...	...	...	...	...	...	...	x	...	...
Depth of web plate	...	...	...	...	...	...	...	...	x	...	...
Thickness of web plate	...	...	...	...	...	...	...	...	x	...	...
Average thickness of flange	...	...	x	...	...	...	...	...	...	...	...

Note. "x" indicates required dimension.

1 Capacity is computed by the use of formulas and data in bridge manuals.

2 Diameter.

3 Width of flange.



Bridge Number Symbols

Type of Span	Number Symbol
Truss	1
Girder	2
Beam	3
Slab	4
Arch (closed spandrel) .	5
Arch (open spandrel) .	6
Suspension.	7
Floating	8
Others.	9

Construction Material Symbols

Material of Span Construction	Letter Symbol
Steel, or other metal . .	a
Concrete	k
Reinforced concrete . . .	ak
Prestressed concrete . .	kk
Stone or brick	p
Wood	n

Figure 150. Common types of span construction.

BRIDGE RECONNAISSANCE REPORT (FM 5-36)

DATE	10 JUN 65
SIGNATURE	W. D. Atkinson 2/LT CE
TO: (Headquarters ordering reconnaissance)	21ST ENGR BN ATT: S2
FROM: (Name, grade, and unit of officer or NCO making reconnaissance)	W.D. ATKINSON 2/LT CE CO A, 21ST ENGR BN
MAPS (Country, scale and sheet number or name)	VIRGINIA ALLANDALE 1:25000 SHEET 55W
DATE/TIME GROUP (Of signature)	1Ø153ØZ

ESSENTIAL BRIDGE INFORMATION / ADDITIONAL BRIDGE INFORMATION (Add columns as needed) (Military load class, overall length, roadway width, vertical clearance, bridge by-pass)

Serial No (1)	Location (2)	Clearance: Horizontal (3)	Clearance: Under-bridge (4)	Spans: Number (5)	Spans: Type of construction (6)	Spans: Type of construction material (7)	Spans: Length and condition (8)	Military Load Classification (9)	Overall Length (10)	Travel Width (11)	Overhead Clearance (12)	Bridge By-pass (13)	Remarks (14)
1	LA Ø72687	∞	2 M	1	3	h	13.5 FT	30	42 M	3.5 M	∞	EASY	NONE
2.	LA118759	9.5M	6.5M		4	K	4 M	40 50	25 M	7.5 M	4 M	DIFFICULT	NONE
					1	a	16 M						
					4	K	4 M						
3	LA16565Ø	∞	2.3 M	5	3	aK	25 M	80 60	126 M	12 M	?	IMPOSSIBLE	NONE
4	LA156645	10.5 M	8.5 M	3	6	K	10 M	80 100 60 80	100 M	10 M	10.5 M	IMPOSSIBLE	NONE
				2	2	a	20 M						
				3	6	K	10 M						

DA FORM 1 JUN 60 1249

Figure 151. Bridge report form.

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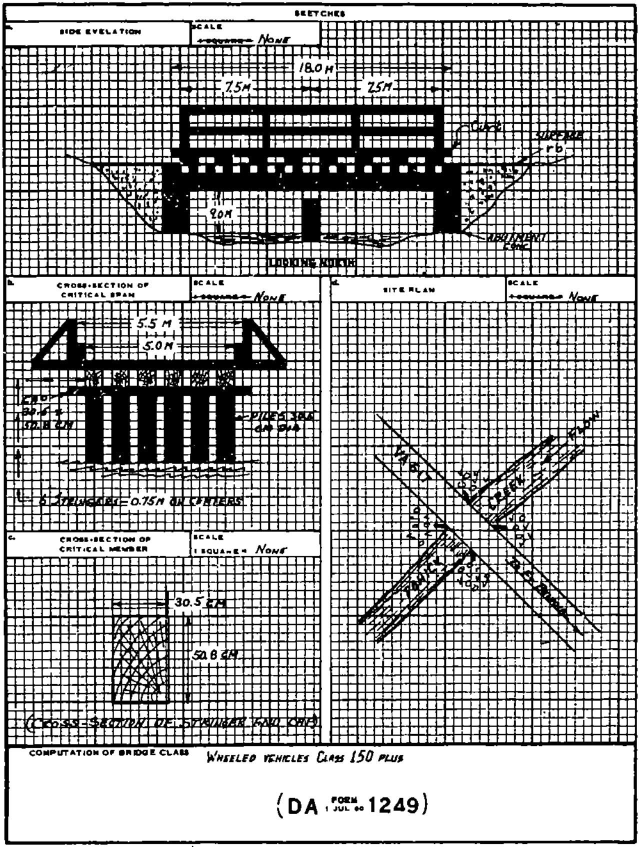


Figure 152. Bridge report form (reverse side).

d. Engineer Reconnaissance Report. DA Form 1711–R, Engineer Reconnaissance Report (figs. 153 and 154) is used along with a map overlay to provide a uniform method of reporting reconnaissance of engineer interest. Examples of information reported would include existing and potential water points, abandoned equipment and supplies, and obstacles or limiting factors on a road being reported on. The reverse side of DA Form 1711–R (fig. 154) is used to indicate the manpower, equipment, and materials to replace, repair, or demolish items reported on the front side of the form. Each work estimate is keyed by number to the appropriate object on the front side of the form (fig. 153). Only those columns which are applicable need be completed. Additional sketches may be drawn if needed to better explain the type work required.

e. *Tunnel Reconnaissance.* Because tunnels are sometimes used for storage, maintenance assembly, or other purpose, their limiting must be known. The required information (DA Form 1250) is pointed out in FM 5–36.

f. Ford Reconnaissance.

(1) Classification of fords. Fords are classified according to their crossing potential for foot, wheeled, or tracked movement.

(a) Their trafficability is indicated for vehicles and foot troops in table 79.

(b) Approaches may be paved with concrete or bituminous material, although they are usually just sand or gravel. The composition and slope of the approach are important; its trafficability in inclement weather depends upon them.

(c) The composition of the stream bottom determines its possability. It is important, therefore, to indicate it.

(d) The stream bottom at a ford may be paved, in some cases, to improve its load-bearing capacity and to reduce the stream's depth. The paved area may be of concrete, gravel, layers of sandbags, steel mats, or wooden planks.

(e) Seasonal floods, excessively dry periods, freezing, and other extreme conditions of weather affect the fordability of a stream.

(f) Swiftness of the current and presence of debris affect possability of a ford. Current is recorded as swift (over 5 feet per second), moderate (1 to 1.5 meters per second), or slow (less than 1 meter per second).

(g) Dimensional data of a ford are pointed out in figure 155.

(2) Stream width.

(a) With a compass, determine the azimuth from a point on the near shore close to the water's edge to a point near the water's edge on the far shore of the stream directly opposite. Then another

ENGINEER RECONNAISSANCE REPORT — PAGE 1 OF 1 PAGES

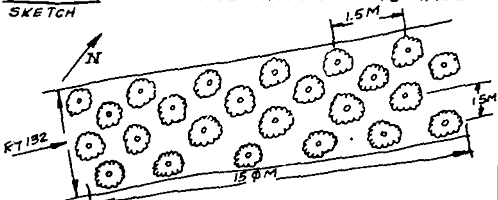
TO: CO, 21ST ENGR BN, ATT: S2	FROM: Co 'A', 21ST ENGR BN

FILE NO.	PARTY LEADER (NAME, GRADE, ORGANIZATION)	PLACE - HOUR - DATE
REPORT NO. 1	W.C. STEVENS, M/SGT, E 8 Co A, 21ST ENG BN	UT 586708 130930 MAR 65

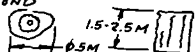
MAPS: QUANTICO, VIRGINIA 1:50,000 SHEET 5561 III

DELIVER TO (Organization, Place, Hour and Date): S-2, 21ST ENGR BN UT556461 131100 MAR 65

KEY	OBJECT	TIME OBSERVED	WORK ESTIMATE?	ADDITIONAL REMARKS AND SKETCH
1	X	0900	YES	UT 058684 - LOG POST OBSTACLE BLOCKING RT 132 SKETCH



(24) LOGS @ 0.5M DIAMETER, C-C 1.5M. ON ALL SIDES, 1.5 TO 2.5 M. ABOVE GROUND



KEY	OBJECT	TIME OBSERVED	WORK ESTIMATE?	ADDITIONAL REMARKS AND SKETCH
2		0940	No	UT 50974 - ABANDONED ENEMY EQPT. QUANTITY & TYPE: (2) 'ZIPLO' MODEL 200 CRAWLER CRANES (OPERATIONAL) CHECKED FOR BOOBY TRAPS - NONE
3	W	1000	No	UT 761432 - EXISTING WATER PURIFICATION PLANT SUPPLYING WATER TO THE CITY OF YUCU OUTPUT 50,000 GAL PER DAY

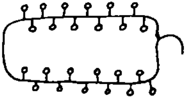
ENGINEER WORK ESTIMATES ON OTHER SIDE

TYPED NAME, GRADE AND ORGANIZATION	SIGNATURES
W.D. ATKINSON, 2/LT, C.E. CoA, 21ST ENGR BN	William D. Atkinson 2/LT. C.E.

DA Form 1711-R, 1 Jun 61

Figure 153. Engineer reconnaissance report.

ENGINEER WORK ESTIMATE

LOCATION KEY	DESCRIPTION OF WORK	UNIT REQ'D	HOURS	EQUIPMENT TYPE	EQUIPMENT NO.	EQUIPMENT HOURS	MATERIALS TYPE	MATERIALS UNIT	MATERIALS QUANTITY
△ 1	REMOVE LOG POST FROM ROUTE 132 BY DEMO	1 SQD	2	DEMO SET #1	1	2	TNT	lbs	240
$P = \frac{D^2}{40} = \frac{(19.2)^2}{40} = 93\#$				D-7 CAT	1	2	D-CORD	FT	140
° ° ° 19#/POST							NON ELECT CAP	EA	25
240# TOTAL							TIME FUSE	FT	4
							M-2 FUSE LIGHTER	EA	1

RECONNAISSANCE REPORT ON OTHER SIDE

Figure 154. Engineer work estimate (reverse side engineer reconnaissance report).

Table 79. *Trafficability of Fords*

Type of traffic	Fordable depth, m[1]	Min width, m	Type of bottom	Max desirable slope on approaches[2]
Foot.	1	1= (single file) 2= (column of 3's).	Firm enough to prevent sinking.	1:1
Trucks and truck-drawn artillery .	.6	3.6		3:1
Light tank	.3 to 1	4.2	Firm	2:1
Medium tanks.	.6 to 1.2	4.2	and	2:1
Heavy tanks	1.2 to 1.8	4.2	smooth.	2:1

[1] Moderate current.

[2] Based on hard, dry surface. If wet and slippery, slope must be less.

point, either upstream or downstream from the previously marked points, is established on the near shore, from which the azimuth to the point on the far shore is 45° at variance with the previously marked azimuth. The distance between the two points on the near shore is equal to the distance across the stream (fig. 156).

(b) Stretch a string across the stream, then measure the distance on the string. A measuring tape may be used if one long enough is available.

(3) Stream velocity. Stream velocity is calculated by measuring a distance along the riverbank, then determining the time it takes a light object to float this measured distance (fig. 156). Velocity is computed as follows:

$$\frac{\text{Measured distance (m)}}{\text{Time (sec)}} = \text{velocity in meters per second.}$$

(4) Ford reconnaissance report. This report is made on DA Form 1251, Ford Reconnaissance Report. Short forms or worksheets may also be used.

g. *Ferry Reconnaissance.* Ferries differ widely in appearance, capacity, propulsion, construction, and so on. For information on ferry reconnaissance, see FM 5–36.

h. *Water Reconnaissance.*

(1) Location of water source. This always involves field reconnaissance, with a brief study of a map.

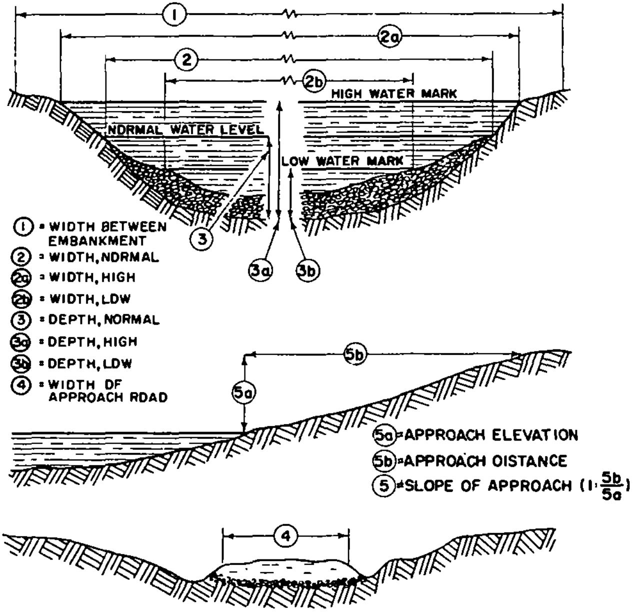


Figure 155. Standard dimensional data for fords.

(2) Sources. When troops are in combat and moving rapidly, usually there isn't time to search for the best water, and units must take whatever is available and purify it with material at hand. The principal sources are:

(a) Surface water (streams, lakes and ponds).

(b) Springs.

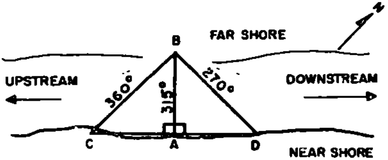
(c) Wells.

(d) Sea water.

(e) Rain.

(f) Snow and ice.

1. MEASURING STREAM WIDTH, USING A COMPASS.



ADD 45° TO AB AZIMUTH TO GET AZIMUTH OF CB

SUBTRACT 45° FROM AB AZIMUTH TO GET AZIMUTH OF BD

WHEN TURNING 90° TO THE LEFT, ADD 45° TO THE A TO B AZIMUTH TO GET THE C TO B AZIMUTH.

WHEN TURNING 90° TO THE RIGHT, SUBTRACT 45° FROM THE A TO B AZIMUTH TO GET THE C TO B AZIMUTH.

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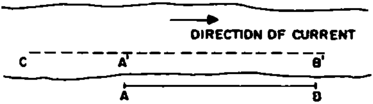
2. DETERMINING STREAM VELOCITY



DISTANCE AB IS MEASURED
FLOATING OBJECT IS THROWN INTO STREAM AT C
TIME REQUIRED FOR FLOATING OBJECT TO FLOAT DISTANCE A'B' IS DETERMINED

$$V(FPS) = \frac{AB\ (FEET)}{\text{TIME TO FLOAT } A'B'\ (SEC)}$$

Figure 156. Methods of measuring stream width and velocity.

(3) Capacity of source (quantity). It is necessary to compute the minimum, average, and maximum flow of streams, wells, or springs, and the dimensions and depths of lakes or ponds, with their rate of outflow. The amount of water that passes a point in one minute is determined as follows:

$$Q = A \times V \times 7.5 \times 0.85$$

Where A = Cross-Section area of stream
V = Flow in ft/min.
7.5 = No. of gals. of water per cu. ft.
0.85 = Friction loss constant

(4) Quality of water. Check the color, turbidity, odor, taste, and possible pollution. In a pollution check, examine the drainage area, as much as time permits, for human wastes, industrial wastes, carrion (dead fish), or poisoning by enemy action.

(5) Tests. Tests are performed by personnel operating water supply and by medical service personnel.

(6) Accessibility. There should be a road system connecting a water supply with the users.

(7) Proposed development. Compute the time, labor, and material necessary to improve the site.

(8) Data from local inhabitants, local records, and soil surveys. If a water source is to be used for some time, information must be obtained on seasonal variations, seasonal floods, seasonal drought, and additional sources.

(9) The above data should be reported on pertinent maps with the conventional military symbols and signs described in FM 21–30.

i. Water Supply. Quantities of water required per man per day are shown in chapter 17.

126. SYMBOLS FOR OVERLAYS

a. Bridge Symbols. See figure 157.

b. Tunnel Symbols. Tunnel data is largely the standard dimensional data written on the report form (DA Form 1250).

c. Ford Symbols. Ford data is mainly the dimensional data given on the report form (DA Form 1251).

d. Ferry Symbols. This data is the type of measurements required by DA Form 1252.

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e. *Water Supply Symbols.* Water-source and water-supply data may be recorded on a map or overlay, using the appropriate symbol as given in FM 21–30.

f. *Airfield Symbols.* Abbreviations, symbols, and notations as used for route reconnaissance are useful in airfield reconnaissance, see FM 21–30.

g. *Minefield Symbols.* The symbols used in the sketches and reports of minefields are as given in chapter 3.

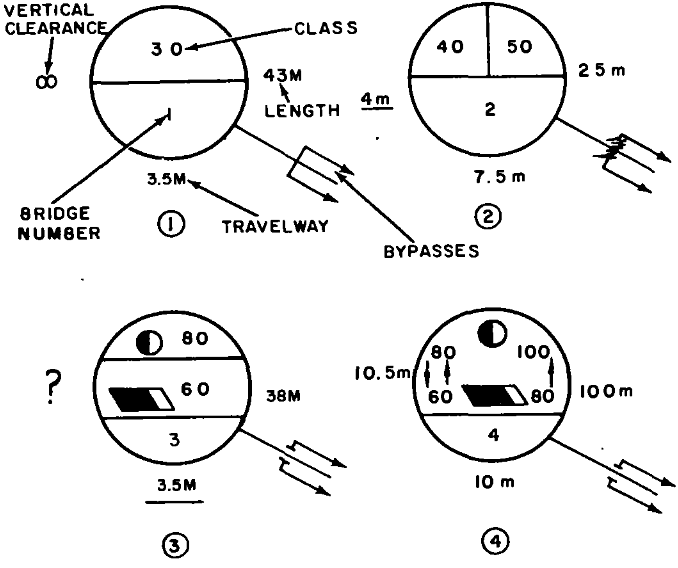


Figure 157. Examples of the full bridge symbol.

127. UNIT DESIGNATIONS

For a complete coverage of military symbols see FM 21-30.

a. *Branch and Duty Symbols.*

Airborne 

Air Force 

Amphibious 

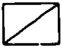
Antiaircraft Artillery 

Antitank 

Armor 

Army Aviation 

Artillery 

Cavalry 

Chemical (CBR) 

Civil Affairs 

Engineer 

Engineer Bridge Unit 

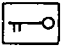
Finance 

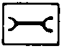
Infantry 

Medical 

Military Police 

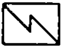
Ordnance 

Quartermaster 

Repair/Maintenance 

Rocket/Guided Missile 

Service 

Signal 

Supply 

Supply and Maintenance 

Transportation 

Topographic 

Veterinary 

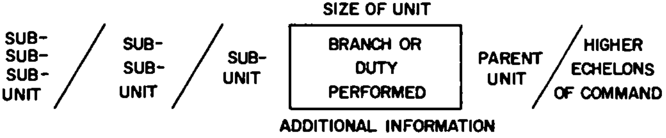
Wheeled Armor 

NOTE. At times, two of the above symbols may be combined. For example, the armored infantry would combine the symbol for armor and infantry.

b. Size and Type of Activity Symbols.

Squad	●	Army	XXXX
Section	● ●	Army Group	XXXXX
Platoon—Detachment	● ● ●		
Company—Troop—Battery	I		
Battalion—Squadron	I I	Unit	□
Regiment—Group	I I I	Unit Hq	
Brigade	X	Observation or Listening Post	△
Division	XX		
Corps	XXX	Logistical Unit	○

c. *Unit Designation and Basic Symbol.* The arrangement of various combinations of symbols to depict specific units is shown in the following diagram:



Exomples using specific engineer units:

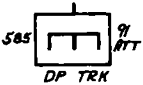
Bridge Co., 50th Engr. Bn.

16th Armored Engr. Bn. 4th Armored Div.

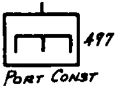
AVLB Plotoon, Bridge Co., 31st Armored Engr. Bn.

1st Sq'd., 2d Plotoon, Co. B., 162d Engr. Bn., 5th Infantry Div (mechonized)

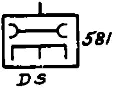
Atomic Demo. Munitions Plotoon, 69th Engr. Bn.



585th Dump Truck Co., Attoched to 91st Engr. Bn.



497th Engr. Port Const. Co.



581st Engr. Moint Co. (Direct Support)

d. Unknown Symbols. When the correct symbol is not known, o symbol moy be mode up ond exploined in o legend to the mop or overloy being drown.

CHAPTER 12
RIGGING

128. KNOTS

See figure 158 and TM 5–725, Rigging.

129. FIBER ROPES, WIRE ROPES, CHAINS, AND HOOKS

a. *Data.* See tables 80 and 82 for data on ropes and chains.

b. *Properties of Hooks.*

(1) *Slip Hook.* Figure 159 shows the slip hook.

(2) *Loads.* Safe loads are given in table 83.

Table 80. Properties of Manila and Sisal Rope

Nominal diameter, in.	Circumference, in.	lbs. per ft.	No. 1 manila		Sisal	
			Breaking strength, tons	Safe load, tons (F.S. = 4)	Breaking strength, tons	Safe load, tons (F.S. = 4)
¼	¾	.020	30.0	0.07	0.24	0.06
⅜	1⅛	.040	0.67	0.16	0.54	0.13
½	1½	.075	1.32	0.33	1.06	0.26
⅝	2	.133	2.20	0.60	1.76	0.44
¾	2¼	.167	2.70	0.67	2.16	0.54
⅞	2¾	.186	3.85	0.96	3.08	0.77
1	3	.270	4.50	1.12	3.60	0.90
1⅛	3½	.360	6.00	1.50	4.80	1.20
1¼	3¾	.418	6.75	1.69	5.40	1.35
1½	4½	.600	9.25	2.31	7.40	1.85
1¾	5½	.895	13.25	3.31	10.60	2.65
2	6	1.08	15.50	3.87	12.40	3.10
2½	7½	1.35	23.25	5.81	18.60	4.65
3	9	2.42	32.00	8.00	25.60	6.40

NOTES.

1. Breaking strength and safe loads given are for new rope used under favorable conditions. As rope ages or deteriorates, progressively reduce safe loads to one-half of values given.

2. Safe working capacity may be computed, with safety factor of 4. When condition of material is doubtful, divide computation by 2.

$$T = D^2$$

where, T = safe working capacity in tons
D = diameter in inches

3. Cordage rope is issued by circumference sizes.

Table 81. Breaking Strength of 6 x 19 Standard Wire Rope [1]

Diameter in.[2]	Approximate weight lb/ft	Iron	Breaking strength, tons of 2000 lbs			
			Traction steel	Plow steel	Improved plow steel	Extra improved plow steel
¼	0.10	1.4	2.6	2.39	2.74	....
⅜	0.23	2.1	4.0	5.31	6.10	7.55
½	0.40	3.6	6.8	9.35	10.7	13.3
⅝	0.63	5.5	10.4	14.5	16.7	20.6
¾	0.90	7.9	14.8	20.7	23.8	29.4
⅞	1.23	10.6	20.2	28.0	32.2	39.8
1	1.60	13.7	26.0	36.4	41.8	51.7
1⅛	2.03	17.2	32.7	45.7	52.6	65.0
1¼	2.50	21.0	40.6	56.2	64.6	79.9
1½	3.60	29.7	56.6	80.0	92.0	114.0
1¾	...	..	..	108.0	124.0	153.0
2	. .	...	...	139.0	160.0	198.0

[1] 6 x 19 means rope composed of 6 strands of 19 wires each.

[2] Breaking Strength of 6 x 7 or 6 x 37 wire rope is 94% of the breaking strength of a 6 x 19 rope of an equal diameter and identical material.

Example:
Find breaking strength of 1¼ inch, 6 x 7, Improved Plow Steel wire rope
Breaking strength of 6 x 19, 1¼ inch, Improved Plow Steel wire rope = 64.6 tons
Breaking strength (6 x 7) = .94 x 64.6 = 60.7 tons

Note. Safe working capacity with a safety factor of 4, $T = 8D^2$ where
T = Safe working capacity in tons
D = Diameter in inches
When condition of material is doubtful, divide T by 2.

130. MECHANICAL ADVANTAGES OF VARIOUS BLOCK ARRANGEMENTS

a. *Blocks and Tackle.* Figure 160 shows examples of typical tackle systems. In a simple tackle with 2 lines (1, fig. 160) leaving the load the mechanical advantage is 2. In a simple tackle with three lines (2, fig. 160) leaving the load, the mechanical advantage is 3. In a simple tackle, using 2 double blocks (3, fig. 160), with 5 lines leaving the load, the mechanical advantage is 5. In a compound system with 5 lines (4, fig. 160) leaving the load, and the fall line of this tackle attached to a traveling block with 2 lines supporting it, the mechanical advantage is 2 times 5, or 10. A more complicated compound system (5, fig. 160)

Table 82. Wire Rope Safety Factors*

Type of service	Minimum safety factor
Track cables	3.2
Guys	3.5
Miscellaneous hoisting equipment	5.0
Haulage ropes	6.0
Derricks	6.0
Small electric and air hoists	7.0
Slings	8.0

* Where age and condition of rope are doubtful, or where human life or expensive equipment may be endangered by rope failures, apply a safety factor of at least 8.

is made up of two simple systems, each of which has 4 lines supporting the load. The traveling block of the first simple system is fastened to the fall line of the second simple system, and the mechanical advantage of this compound system is 4 times 4, or 16.

b. Chain Hoists. With a chain hoist, a load can remain stationary without requiring attention, and the hoist can be operated by one man to raise loads of several tons.

131. PICKET HOLDFAST

a. Picket Holdfast, 1–1–1 Combination (fig. 161).

b. Picket Holdfast, 3–2–1 Combination (fig. 162).

c. Holding Power. Sound wooden pickets 5 ft long driven 3 ft into undisturbed earth, spaced 3 to 6 feet apart and inclined away from the load at 15° should stand the following pulls.

	Pounds
Single picket	700
1–1 picket holdfast combination	1,400
1–1–1 picket holdfast combination	1,800
2–1 picket holdfast combination	2,000
3–2–1 picket holdfast combination	4,000

For wet earth, holding power should be multiplied by the following factors:

Clay and gravel	0.9
River clay and sand	0.5

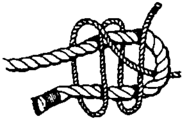
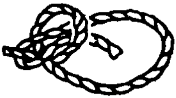
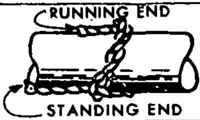
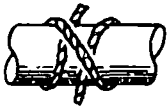
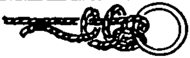
Name	Illustration	Use
Square		Join two ropes of same size. (Will not slip, but will draw tight under strain.) To end block lashing.
Double sheet bend		Join wet ropes, of unequal size, or rope to an eye. (Will not slip or draw tight under strain.)
Bowline		Form a loop. (Will not slip under strain and is easily untied.)
Timber hitch		Lifting or dragging heavy timbers. (Is more easily controlled if supplemented by half hitches.)
Clove hitch		Fasten rope to pipe, timber, or post. (It is used to start and finish all lashings and may be tied at any point in rope.)
Sheep shank		Shorten rope or take load off weak spot in rope.
Fisherman's Bend		To fasten cable or rope to anchor.

Figure 158. Knots

132. DEADMEN

a. *Log Deadman* (fig. 163).

b. *Steel Beam Deadman* (fig. 164).

c. *Holding Power of Deadmen in Ordinary Earth.*

(1) *Log Deadman.*

Legend: for figure 163 and the formulas below—

T = tension (Breaking strength of rope)
MD = mean depth (you select)
SR = slope ratio (1/2, 1/3, 1/4, etc.)
HD = horizontal distance (see formula in (2) below)
VD = vertical depth (Must be at least 1 ft. above water table)
HP = holding power (see table 84)
BAr = bearing area required (see formula in (2) below)
EL = effective length (see formula in (2) below)
WST = width, sloping trench (1 to 2 feet)
Tim D = timber diameter (you select)
Tim L = timber length (see formula in (2) below)

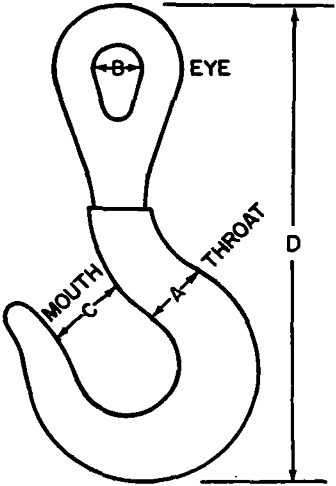


Figure 159. Slip hook.

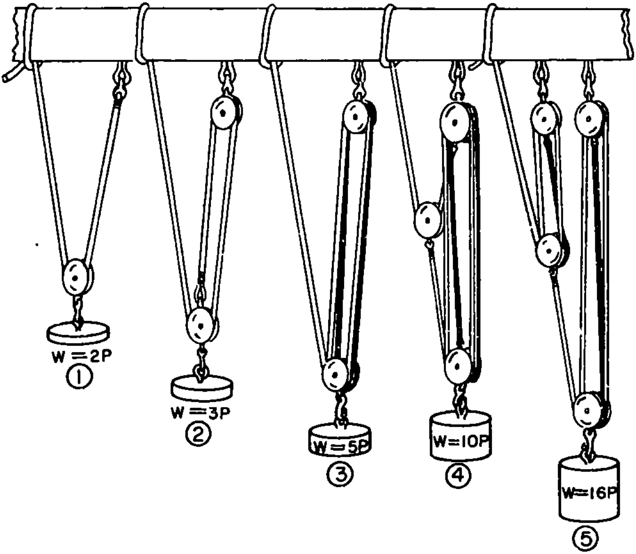


Figure 160. Mechanical advantage of various tackle riggings.

(2) *Formulas.*

(a) $BAr = \frac{T}{HP}$ (in lbs)

(b) $EL = \frac{BAr}{Tim\ D}$

(c) $Tim\ L = EL + WST$

(d) $VD = MD + \left(\frac{Tim\ D}{2}\right)$

(e) $HD = \frac{VD}{SR}$

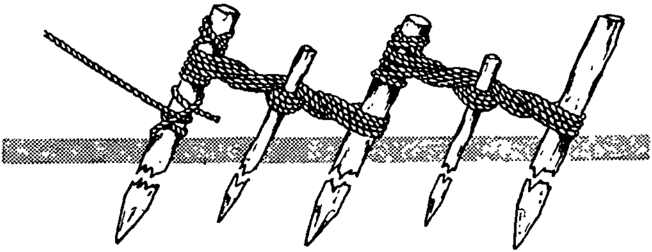


Figure 161. *Picket holdfast 1–1–1 combinotion.*

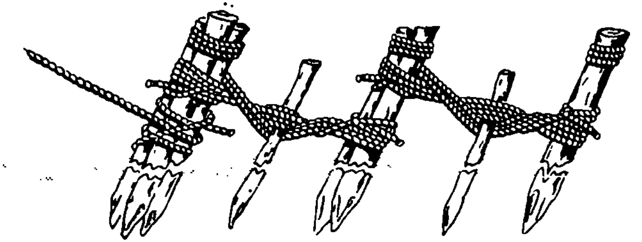


Figure 162. *Picket holdfast, 3–2–1 combination.*

(3) *Problems.*

Given: T = 1 in. wire rope I.P.S. (improved plow steel)

MD = 7 ft.

SR = 1/4

HP = 8,400 lb. (toble 84)

WST = 1 1/2 ft.

Tim D 2 ft.

Find:

BAr

EL

Tim L

VD

HD

Solution: $BAr = \frac{84{,}000}{8{,}400} = 10$ sq. ft.

$$EL = \frac{10}{2} = 5 \text{ ft.}$$

$$\text{Tim } L = 5\text{ft.} + 1\tfrac{1}{2} \text{ ft.} = 6\tfrac{1}{2} \text{ ft.}$$

$$VD = 7 \text{ ft.} + \frac{2 \text{ ft.}}{2} = 8 \text{ ft.}$$

$$HD = \frac{8}{\tfrac{1}{4}} = 32 \text{ ft.}$$

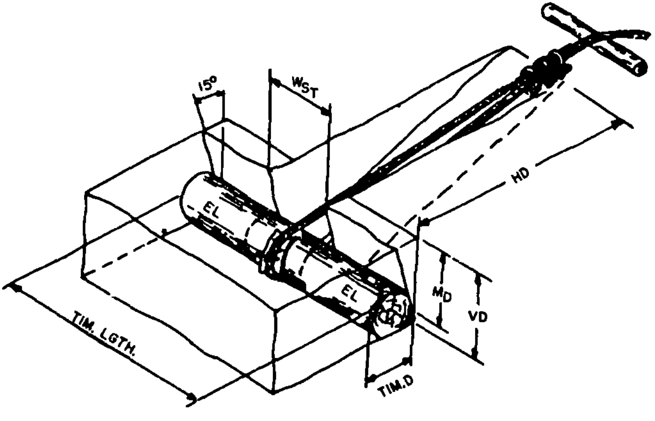


Figure 163. Log deadman.

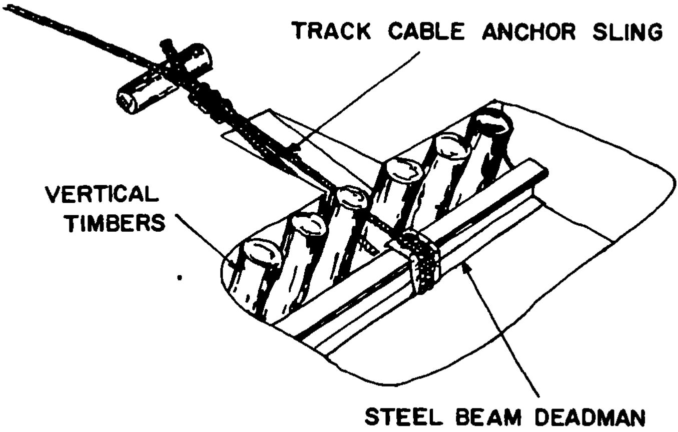


Figure 164. Steel beam deadman.

133. ATTACHMENTS

a. *Clips.* Clips are used in making eyes in wire rope. The correct method of attaching clips is shown in figure 165. The base of each clip should bear against the line, or long rope, end, and the U-bolt should bear against the dead, or short, end. Space the clips at least six rope diameters apart, the number of clips equals three times the rope diameter (in inches) plus one. If this calculation results in a fraction, use the next larger whole number. For example, on a ¾-inch rope:

$$\text{No. of clips} = 3\,D + 1 \quad \text{(minimum of 3 clips)}$$

$$= (3 \times \tfrac{3}{4}) + 1$$

$$= 3\tfrac{1}{4}, \text{ or } 4$$

$$\text{Spacing of clips} = 6D = 6 \times \tfrac{3}{4} = 4\tfrac{1}{2} \text{ in.}$$

Table 83. Safe Loads on Hooks

Diameter of metal A,* in.	Inside diameter of eye B, in.	Width of opening C, in.	Length of hook D, in.	Safe Working Capacity of hooks, lb.
11/16	7/8	1 1/16	4 15/16	1,200
3/4	1	1 1/8	5 13/32	1,400
7/8	1 1/8	1 1/4	6 1/4	2,400
1	1 1/4	1 3/8	6 7/8	3,400
1 1/8	1 3/8	1 1/2	7 5/8	4,200
1 1/4	1 1/2	1 11/16	8 19/32	5,000
1 3/8	1 5/8	1 7/8	9 1/2	6,000
1 1/2	1 3/4	2 1/16	10 11/32	8,000
1 5/8	2	2 1/4	11 27/32	9,400
1 7/8	2 3/8	2 1/2	13 9/32	11,000
2 1/4	2 3/4	3	14 13/16	13,600
2 5/8	3 1/8	3 3/8	16 1/2	17,000
3	3 1/2	4	19 3/4	24,000

*For reference to A, B, C, or D, see figure 159.
NOTE. Formula for safe work load for hooks: T (tons) $= D^2(in^2)$

Table 84. Holding Power of Deadmen in Ordinary Earth

Mean depth of anchorage, ft	Safe resistance for inclination of pull (vertical or horizontal) of projected area of deadman, lbs per sq ft.				
	Vertical	1/1	1/2	1/3	1/4
3	600	950	1,300	1,450	1,500
4	1,050	1,750	2,200	2,600	2,700
5	1,700	2,800	3,600	4,000	4,100
6	2,400	3,800	5,100	5,800	6,000
7	3,200	5,100	7,000	8,000	8,400

b. Clamps. Figure 166 shows how to apply a wire rope clamp. Slip the two end collars of the clamp on the rope, facing each other. Bend the rope, bringing the free end back along the long end. Slip one end collar of the clamp over both parts of the rope. Place the two side pieces of the clamp over both parts of the rope so that the free end of the rope is even with the ends of the two side pieces. Screw the collars on the side pieces, using a wrench to force a snug fit.

c. *Wedge Socket.* This fitting is shown in figure 167. It is used when the fitting must be changed at frequent intervals. This socket has two parts, the socket proper with a tapered opening for the wire rope and a small wedge to go into this socket. Remove the wedge and insert a loop of the wire rope through the tapered opening from the bottom of the socket up. Place the wedge through the loop and pull the ends of the wire rope back through the tapered opening until the wedge forces the wire rope against the sides of the wedge socket. The loop of wire rope must be inserted in the wedge socket so that the running part of the wire rope will form a nearly direct line to the clevis of the fitting. If properly mounted, a wedge socket will tighten when a strain is put on the wire rope.

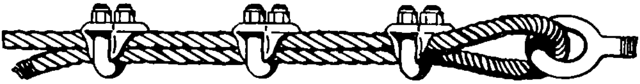


Figure 165. *Wire rope clips.*

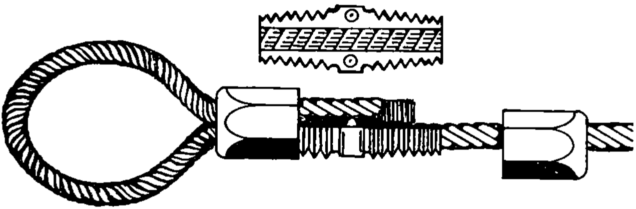


Figure 166. *Wire rope clamp.*

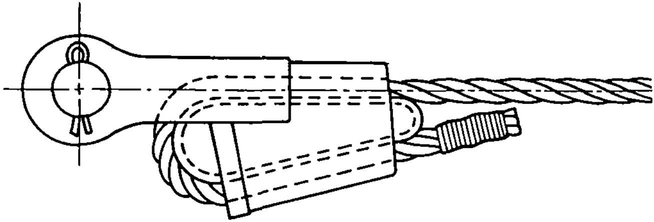


Figure 167. Wedge socket and fitting.

134. SAFE CAPACITY OF SPRUCE TIMBER AS A GIN POLE

See table 85 for these capacities. Weight of timber is 40 pounds per cubic foot.

135. SLINGS

a. Single Slings. See figure 168 for components of a single sling.

(1) A basket hitch has a single sling passed under the load and both ends hooked over the hoisting hook (A, fig. 169).

(2) Single slings with two hooks are sometimes used for lifting stone (B, fig. 169).

Table 85. Safe Capacity of Spruce Timbers as Gin Poles in Normal Operations

Size of timber, in.	Safe capacity for given length of timber, lbs.					
	20 ft (6 m)	25 ft (7.5 m)	30 ft (9 m)	40 ft (12 m)	50 ft (15 m)	60 ft (18 m)
6 dia	5,000	3,000	2,000	----------	----------	----------
8 dia	----------	11,000	8,000	5,000	3,000	----------
10 dia	31,000	24,000	16,000	9,000	6,000	----------
12 dia	----------	----------	31,000	19,000	12,000	9,000
6 x 6	6,000	4,000	3,000	----------	----------	----------
8 x 8	----------	14,000	10,000	6,000	4,000	----------
10 x 10	40,000	30,000	20,000	12,000	8,000	----------
12 x 12	----------	----------	40,000	24,000	16,000	12,000

NOTE: Safe capacity of each leg of shears or tripod is seven-eighths of the value given for a gin pole.

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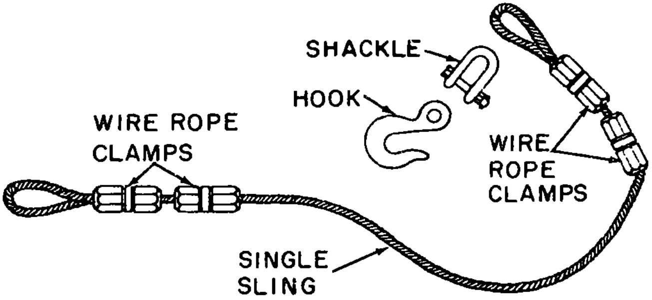


Figure 168. Single sling components.

(3) The double anchor hitch is used sometimes for hoisting cylindricol objects (C., fig. 169).

b. Endless Slings.

(1) The anchor, or choker, hitch is o common method of using an endless sling by costing the sling under the lood ond inserting one loop through the other and over the hoisting hook (D, fig. 169).

(2) For o bosket hitch, the endless sling is possed oround the object ond both remaining loops are slipped on the hook (E, fig. 169).

(3) The toggle hitch is a modification of the basket hitch ond is used only for special opplication (F, fig. 169).

136. SLING LOAD FORMULA

o. Stress. The stress or tension in each leg of o sling depends on the number of legs, the angle of the sling leg, and the totol load.

b. Formula (fig. 170).

$$T = \frac{W}{N} \times \frac{L}{V}$$

where T = tension, in pounds
N = number of legs
W = weight, in pounds
V = vertical distonce, in feet
L = length of leg, in feet

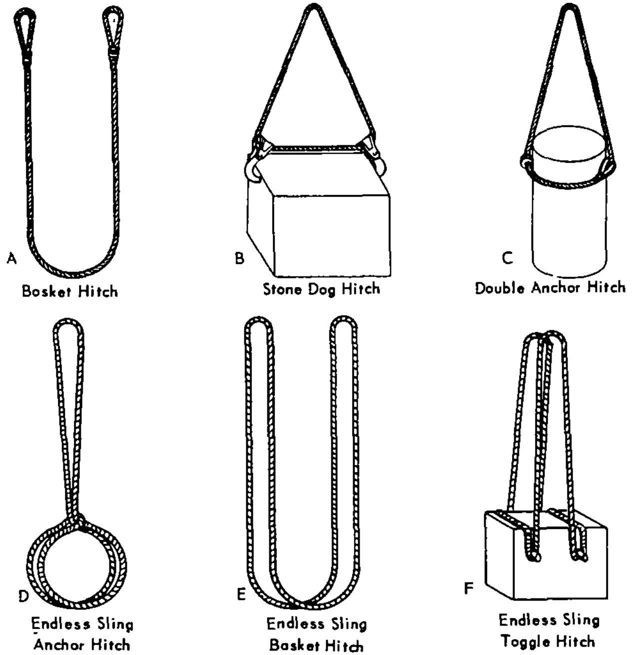


Figure 169. Hitches.

c. *Problem.* Is it safe to use a ¾-inch diameter cordage rope sling to lift a 2,000-pound load with a 4-leg sling which has vertical distances of 6 feet and length of leg of 12 feet?

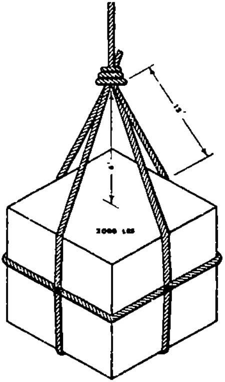


Figure 170. Sling stresses.

$$T = \frac{W}{N} \times \frac{L}{V}$$

$$T = \frac{2{,}000}{4} \times \frac{12}{6} = 1{,}000 \text{ pounds}$$

The tension on each leg will be 1,000 paunds. The sofe working copacity of ¾-inch diometer cordoge rope is $T = D^2 = (3/4)^2 = 9/16$ .5625 ton.

137. SLING LOAD CHART

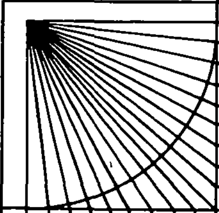
See figure 171.

138. SHEARS

a. *Moteriols.* This device is used ta erect heavy machinery and bulky objects. Figure 172 shows its canstruction. It must be guyed ta hald its position. It is adapted to wark ot an inclinotion from the vertical. Maximum shear leg length is 60 times the least diameter of the leg. This rotio must be reduced far heovy loods.

b. *Erection.* Holes should be dug at the points where the legs are to stond. On hard surface, the legs should be level and lashed to prevent spreading.

Load chart of sling tension at various angles of inclination with a load of 1,000 lb.



Total vertical load (lb)	Total sling-tension (lb)	Angle degrees
		0
1000	11473	5
1000	5759	10
1000	3863	15
1000	2924	20
1000	2366	25
1000	2000	30
1000	1743	35
1000	1555	40
1000	1414	45

Total vertical load (lb)	Total sling-tension (lb)	Angle degrees
1000	1000	90
1000	1003	85
1000	1015	80
1000	1035	75
1000	1064	70
1000	1103	65
1000	1154	60
1000	1220	55
1000	1305	50
1000	1414	45

Tension in each leg of a sling assembly is found by dividing the total sling tension by the number of legs. If the load is over or under 1,000 pounds, divide the load by 1,000 and multiply by the total sling tension found in the table for the corresponding angle.

The chart illustrates the variation of tension on one sling leg when applied to a constant 1000-pound load at various angles.

Example

Problem: 100,000 pounds weight is to be lifted by a four-leg sling assembly with each leg lifting at an angle of 45 degrees. What will be the tension on one leg:

Procedure: From the chart the total sling tension on one leg at 45 degrees for 1000 pounds is 1414 pounds.

Total tension for 100,000 pounds = 141,400 pounds.

Tension on each leg = $\frac{141400}{4}$ = 35,350 pounds.

If all legs lifted vertically, the tension on each leg = $\frac{100000}{4}$ = 25,000 pounds.

Figure 171. Sling Load Chart.

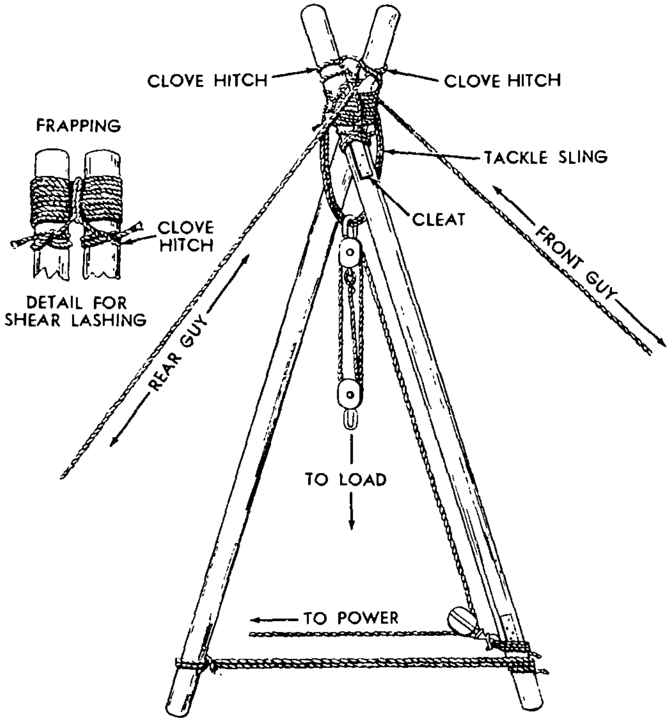


Figure 172. Lashing for shears.

139. GIN POLE

See figures 173 and 174.

a. *Description.* A gin pole is an upright spar, guyed at the top to hold it in a vertical or near-vertical position, and equipped with suitable hoisting tackle. It is easily rigged, moved, and operated.

b. *Erecting.* A gin pole 30 or 40 feet long may be raised easily by hand, but longer poles must be raised by supplementary rigging or power equipment. Figure 173 shows the gin pole in position for operation, while the necessary rigging is illustrated in figure 174. The maximum allowable length is 60 times the minimum diameter. Guys are 3 to 4 times the pole length.

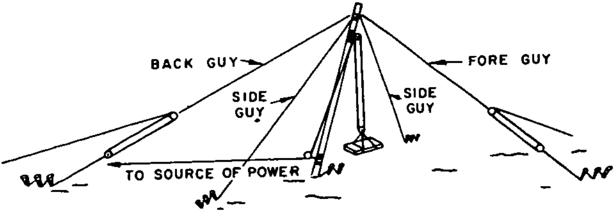


Figure 173. Gin pole ready for operation.

140. BOOM DERRICK

a. *Rigging.* Booms are used on gin poles to lift loads at a distance from the base of the pole. The boom is two-thirds the length of the gin pole. For heavy loads, lower butt of boom to ground; raise it for lighter loads. It must not bear against the upper two-thirds of the pole.

b. *Operation.* Raise the boom into position when the rigging is finished. In operation, it is a convenient means for loading and unloading trucks and flatcars, and for use on docks or piers. Figure 175 shows the boom derrick in position for operation.

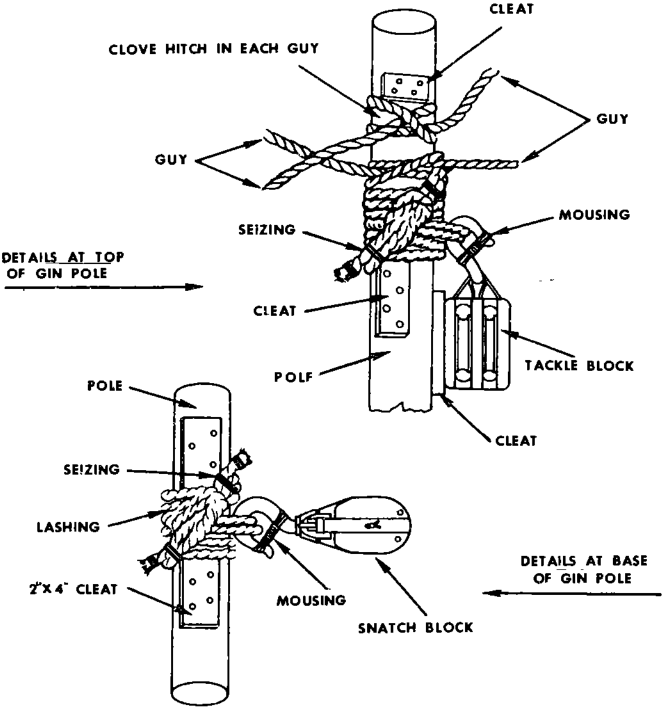


Figure 174. Lashing for a gin pole.

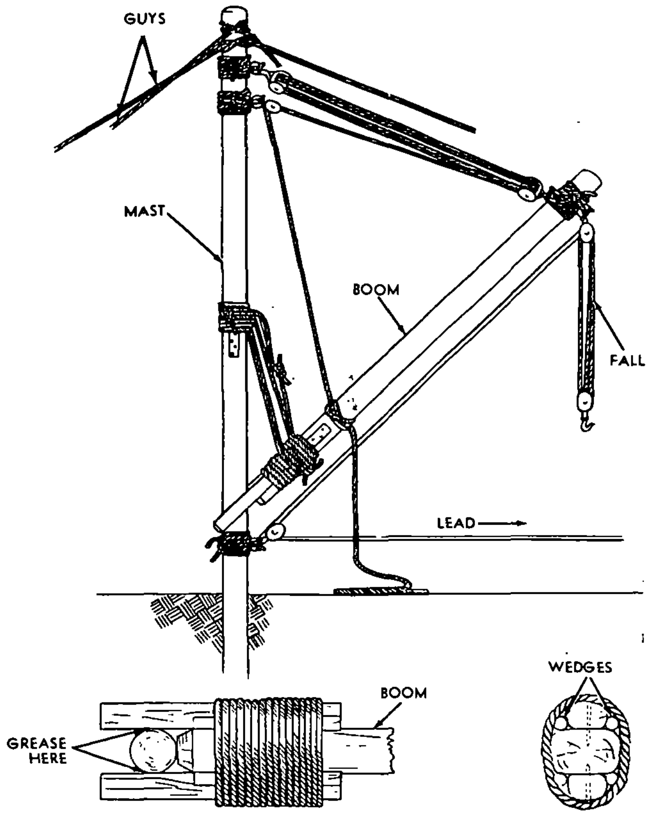


Figure 175. Boom derrick.

141. GUY LINE TENSION FOR SHEARS AND GIN POLES

The most stress on a guy line occurs when a straight line through the load and pole passes through the guy line. To compute the tension, use the formula shown in figure 176.

Problem:

Load	=2,500
Weight of pole	=800 pounds
Drift	=10 feet
y-distance	=20 feet

Therefore, by figure 176, $t = \frac{2{,}900 \times 10}{20} = 1{,}450$

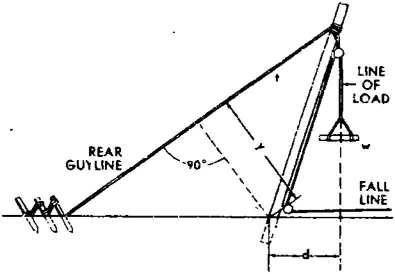


Figure 176. Computing stresses in single guylines.

142. HIGHLINE

The highline is a trolley line passing through a snatch block at each support (fig. 177). It is the type most commonly erected at the platoon level.

a. *Sag.* The sag in the track cable when loaded should be not less than 5 percent of the span.

b. *Formula for Safeload of Highline.*

$$SL = \frac{BS\ (lbs)}{5 \times SF} - \frac{DL\ (lbs)}{2}$$

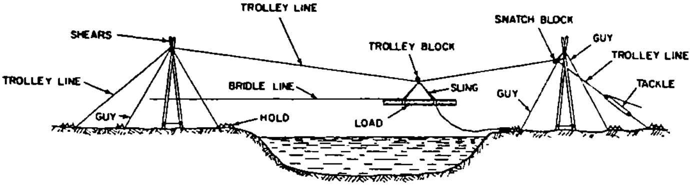


Figure 177. Highline.

. . . .

Where: SL = safelood
BS = breaking strength of line
DL = dead load
SF = sofety factor

Prablem: Span is 400 feet
Trock line is ¾-inch diometer manilo rape
Houl line is ½-inch diometer manilo rape
Sofety factor is 4.0
Trock cable sag is 5 percent

Solution: BS (breoking strength) for ¾-inch diometer-manilo rape= 5,400 pounds.
W (¾-inch rope)= 66.8 pounds/400 feet (table 80)
W(½-inch rape)= 60 pounds/800 feet (table 80)

Therefare:

$$SL = \frac{5,400}{5 \times 4.0} - \frac{66.8}{2}$$

$$SL = 270 - 33.4$$

SL = 236.6 paunds

Far the payload, use the formulo:

PL = SL − (½W af haul rape + W af traveler + W af corrier)

Far this prablem, this wauld mean:

PL = 236.6 − (30 plus the weight af the traveler ond corrier)

NOTE. For information an suspension bridge see chapter 7.

CHAPTER 13
EQUIPMENT PRODUCTION

143. CRAWLER AND RUBBER TIRED TRACTORS

a. The economicol hauling distonce for a dozer ranges from 25 to 300 feet.

b. Dozer output chart. See toble 86.

c. The recommended uses of troctors to increose production are:

(1) *Slot dozing*. This is o method of digging ond pushing material in the some path to reduce blode spilloge. As the dozer cuts into the earth, windrows are built up octing os retoining walls to keep the materıal in front of the blade. Production moy increase up to 30%.

(2) *Blade to blode dozing*. Usıng this method requires close coordinotion by the operators. The mochines have to travel at the same speed and keep the blades together. Blade to blode dozing con produce 1 to 1.5 cubic yords more per pass in a ronge of 50–300 feet.

(3) *Downhill* dozing. Dozer should be operated downhill when possible. The dozer will receive the benefit of gravity and be oble to push o lorger load.

(4) *Ripper otrochments*. Standord militory blades ore equipped with ripper teeth mounted to the back of the blade. On the back up portion of the cycle, these teeth may be lowered into the ground ta loosen hord moterial, making it easier to obtain o full lood on the forword portion of the cycle.

144. SCRAPERS

o. Crawler troctor-scraper combinotions can be efficiently operated from 300 to 1500 feet.

b. Rubber-tired troctor-scroper combinotions con be efficiently operated from 1200 to 5000 feet.

c. Methods of increosing scraper production are:

(1) *Downhill looding*.

(2) *Straddle looding*.

(a) Make two cuts, one on each side of a lane which is slightly smaller than the width of the scroper.

(b) On third cut, strip lone left by cuts one and two.

(3) *Bock track looding*. With this method, o troctor is used to push the loading tractor-scraper. It is good where the pushing troctor hos to bock only a short distance to get into position to push the next troctor-scroper.

Table 86. Dozer Output

Model	Capacity in yards (loose)	Production rate — cu yds/hr		Speeds in miles per hour		Gallons of fuel per hour
		50 ft haul	100 ft haul	Lowest gear	Highest gear	
D-8	5.0	450	250	1.5	5.2	11(DSL)
TD-24		Same data as for D-8		1.7	8.2	11(DSL)
HD-16M		Same data as for D-8		3.47	7.41	11(DSL)
TD-20	3.5	390	215	1.6	7.3	10(DSL)
HD-6M	2.6	284	154	1.5	5.5	9(DSL)
830M	5.0	364*	272	5.7	30.5	12(DSL)
MRS 100	2.6	228*	130	2.2	30.	9(DSL)
D-6S	2.8	250	170	2.0	7.0	. . . .
TD-18		Same data as for TD-20		1.7	5.7	. .
MRS 150	. . . .	. . . .	. . . .	2.46	26.4	. .
MRS 190	. . . .	. . . .	. . . .	2.96	26.4	. . .
DW-20M	. . . .	. . . .	. . . .	2.8	25.1	. . . .
Super "C"	. . . .	. . .	. . . .	2.6	14.3	. . . .

* Depends upon type material and speed.

(4) *Shuttle loading.* With this method, a pusher tractor is used to push a tractor-scraper. However, after the operation is complete, instead of the pusher backing up to get into position to push another tractor-scraper, a tractor-scraper positions itself so that the pusher has only to reverse its direction and push the new tractor-scraper.

(5) *Chain loading.* This method is used where the cut area is fairly long. A pusher initially loads one unit, then moves in behind another unit which is moving parallel to and adjacent to the first unit.

(6) *Traveling.* All loaded units should leave the cut area as fast as possible.

(7) *Grading.* All haul roads should be maintained with a grader to increase the haul speed of earth-movers.

(8) *Rooting.* For ease in scraper loading rip soil prior to loading scraper.

d. Capacities of Scrapers. See table 87.

145. EARTH MOVING PRODUCTION FOR SCRAPERS

a. *Determine Cycle Time.* Cycle time is the total time required for a piece of equipment to complete its entire operation. Cycle time is divided into two types of time. These times are:

(1) *Fixed time.* This is the time spent in operations other than hauling and returning. It includes that time taken for loading, accelerating, decelerating and dumping. This time can be estimated in the field or if no data is available table 88 may be used as a guide.

(2) *Variable time.* Variable time is determined by the formula:

$$\text{Variable time (min.)} = \frac{\text{haul distance (feet)}}{\text{speed (mph)} \times 88}$$

Speed is determined by haul road conditions. This includes grade resistance, rolling resistance, and traction. For detailed calculations see TM 5–331. For an estimation, use table 86. Assume high speed for haul roads with hard surface and slight grades, middle speed for average road surface and medium grades, and lowest speed for poor road surface and steep grades.

b. Determine Load Capacity. See table 87.

c. *Determine Efficiency Factor.* See table 89.

d. Estimate Production. Production is estimated by the formula:

Loose cubic yards per hour

$$= \text{Number of hauling units} \times \text{Capacity} \times \frac{\text{60 min per hour}}{\text{cycle time}} \times \text{efficiency factor}$$

e. *Estimate Job Duration.* This is determined by the formula:

$$\text{Job duration (hours)} = \frac{\text{Soil Conversion Factor} \times \text{Soil to be moved (yds)}}{\text{Loose cubic yards per hour}}$$

See table 90 for soil conversion factor.

f. *Example:* How long will it take to move 500 cubic yards of clay (in place), 5000 feet one way with an 830M rubber-tired tractor pulling a Curtiss-Wright scraper? The haul road is poor, work during daylight, 45-minute working hour.

(1) *Cycle time.* From table 88 fixed time = 1.9 min

$$\text{Variable time (min)} = \frac{5000 \text{ feet}}{5.7 \text{ mph} \times 88 \text{ feet per second}}$$

$$= 10 \text{ min}$$

Speed from table 86.

$$\text{Cycle time} = 1.9 \text{ min} = 10 \text{ min} = 11.9 \text{ min}$$

(2) *Load capacity.* From table 86 assume heaped capacity = 23.6 cu yds

(3) *Efficiency factor.* From table 89 Efficiency factor = 0.75

(4) *Production in cubic yards per hour.*

$$23.6 \text{ cu yds per scraper} \times \frac{60 \text{ min per hour}}{11.9 \text{ min}} \times 0.75 \text{ efficiency factor} =$$

89 cubic yards of material per hour.

Table 87. Scraper Capacity

Make and model	Weight lbs	Capacity struck cu yds	Capacity heaped cu yds
LeTourneau LP closed bowl	19,700	12.0	15.0
Wooldridge OS–122A open bowl	24,140	12.2	15.5
Curtiss-Wright open bowl	38,900	18.2	23.6
Air drop hydraulic	16,000	7.5	9.5
open bowl	12,650		

(5) *Time required to finish job.* From table 90, 1 cubic yard of in place clay equals 1.43 cubic yards of loose material.

$$\text{Job duration} = \frac{1.43 \times 500 \text{ cu yds}}{89 \text{ cubic yards per hour}}$$

$$= 8.05 \text{ hours or about 8 hours.}$$

Table 88. Basic Fixed Time Constants (Use as Guide Only)

Wheel scraper (with pusher)	Fixed time
5th gear haul 4th gear haul 3rd gear haul	3.0 min 2.3 min 1.9 min
Track tractor with scraper	
Self-loaded Push-loaded	2.5 min 2.0 min

Table 89. Efficiency Factor Chart

	Type tractor	Working hours	Eff. factor
Day operation	Track-type Wheel-type	50 min/hr 45 min/hr	0.83 0.75
Night operation	Track-type Wheel-type	45 min/hr 40 min/hr	0.75 0.67

Table 90. Soil Conversion Factors (Estimated)

Soil type	Soil condition initially	In-place	Loose	Compacted
Sand	In place		1.11	0.95
	Loose	.90		.86
	Compacted	1.05	1.17	
Loam	In place		1.25	0.90
	Loose	.80		.72
	Compacted	1.11	1.39	
Clay	In place		1.43	0.90
	Loose	.70		.63
	Compacted	1.11	1.59	
Rock (blasted)	In place		1.50	1.30
	Loose	.67		.87
	Compacted	.77	1.15	
Hard coral (dead) comparable to limestone	In place		1.50	1.30
	Loose	.67		.87
	Compacted	.77	1.15	

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146. EQUIPMENT APPLICATION CHART

See table 91.

147. GRADERS

a. *Methods of Obtaining Maximum Production.*

(1) In working distances up to 1000 feet, back up to beginning of project.

(2) In working distances greater than 1000 feet, turn grader around.

b. *Correct Gear Ranges for Grader Operation.* See table 92.

c. *Steps in Hasty Road Construction.*

(1) *Marking cut.* Place right front wheel in line with ditch staker. Set mold board at outside of right front wheel. Make 3 to 4-in-deep cut along ditch stakes.

(2) *Ditching cut.* Place right front wheel in marking cut. Adjust mold board so leading edge is in line with and behind right front wheel. Make cuts as deep as possible and make as many cuts as needed to give proper ditch depth.

(3) *Moving windrow.* Angle mold board and move windrow, obtained from ditch cut, to center of road.

(4) *Level windrow.* Level windrow to make road surface and crown.

(5) *Slope.* Slope banks to prevent erosion.

(6) *Police.* Clean and clear ditches.

d. *Production Capabilities of Graders.* See table 93.

e. *Efficiency Factor for Graders.* For general grader production estimation, assume a 60-percent efficiency factor.

148. COMPACTION EQUIPMENT

a. *Sheepsfoot Roller.*

(1) The depth of loose lift should not exceed 9 inches when a bond is desired between two lifts of material.

(2) Overlap should be by at least 1 foot.

(3) If the feet of the sheepsfoot roller do not walk themselves out of material, this is an indication that the roller is exceeding the shear stress of the soil and the weight of the roller must be reduced.

b. *13-Wheel, Pneumatic-Tired Roller.*

(1) When operating with a rolling load of 7 tons or less, tire pressure should be 25 psi. Increase the pressure 5 psi for each additional ton up to a maximum of 9 tons.

(2) Compaction is obtained with loads of not more than 7 tons.

(3) Compaction lifts should not exceed 6 inches.

Table 91. Equipment Utilizatian

	clearing			finishing			slaping		haul or doze			spread		cut or ditch	
	very high no trees	heovy	stripping	fine	rough	compaction	hold	finish	short	medium	long	light	heavy	shallow	deep
motorized scraper	fair	nat applicable	excellent	nat applicable	fair	excellent	excellent	fair	excellent	excellent	excellent	excellent	excellent	excellent	excellent
rubber-tired dozer	excellent	fair	excellent	fair	excellent	fair	excellent	fair	excellent	excellent	nat applicable	excellent	excellent	excellent	excellent
track-type tractor	excellent	excellent	excellent	fair	excellent	nat applicable	excellent	fair	excellent	nat applicable	nat applicable	excellent	excellent	excellent	excellent
tractor scraper	fair	nat applicable	excellent	nat applicable	fair	nat applicable	excellent	fair	excellent	fair	nat applicable	excellent	excellent	excellent	excellent

Legend: excellent (hatched) fair (dark) nat applicable (blank)

Table 92. Correct Gear Ranges Used in Grader Operation

Operation	Gear
Maintenance	2d & 3d
Spreading	3d & 4th
Mixing	4th to 6th
Ditching	1st to 2d
Bank sloping	1st
Snow removal	5th to 6th
Finishing	2d to 4th

Table 93. Production Capacities of the Grader

Operation	Rate per hour	Unit	Conditions
Ditching	250	cu yd	"V" ditching, easy digging
	150	cu yd	"V" ditching, medium digging
	85	cu yd	"V" ditching, hard digging
Grading	.2	mile	Digging side ditches and shaping crown, 4 round trips required
Subgrade preparation	400	sq yd	Scarify and shape
Base course production	200	cu yd	Spread material
	450	cu yd	Shaping surface
Surface treatment	150	sq yd	Mixing in place 2-in bituminous material

(4) The 13-wheel roller is best in granular type soils.

(5) The 13-wheel roller is good for finishing asphalt.

c. *50-Ton, Pneumatic-Tired Roller.*

(1) The 50-ton roller will compact down to 18 inches with two passes.

(2) Compaction of material depends on tire pressure and weight of roller.

Table 94. Shovel Dipper Capacity in Cu Yds

CLASS OF MATERIAL	⅜	½	¾	1	1¼	1½	1¾	2	2¼
Moist loam or light sandy clay	3.8′ 85	4.6′ 115	5.3′ 165	6.0′ 205	6.5′ 250	7.0′ 285	7.4′ 320	7.8′ 355	8.4′ 405
Sand and gravel	3.8′ 80	4.6′ 110	5.3′ 155	6.0′ 200	6.5′ 230	7.0′ 270	7.4′ 300	7.8′ 330	8.4′ 390
Good common earth	4.5′ 70	5.7′ 95	6.8′ 135	7.8′ 175	8.5′ 210	9.2′ 240	9.7′ 270	10.2′ 300	11.2′ 350
Clay hard tough	6.0′ 50	7.0′ 75	8.0′ 110	9.0′ 145	9.8′ 180	10.7′ 210	11.5′ 235	12.2′ 265	13.3′ 310
Rock well blasted	— 40	— 60	— 95	— 125	— 155	— 180	— 205	— 230	— 275
Common, with rocks and roots	— 30	— 50	— 80	— 105	— 130	— 155	— 180	— 200	— 245
Clay, wet and sticky	6.0′ 25	7.0′ 40	8.0′ 70	9.0′ 95	9.8′ 120	10.7′ 145	11.5′ 165	12.2′ 185	13.3′ 230
Rock, poorly blasted	— 15	— 25	— 50	— 75	— 95	— 115	— 140	— 160	— 195

Power shovel yardages—conditions:

1. Cu yds bank measurement per 60 min. hour with no delays
2. Suitable depth of cut for maximum effect
3. All materials loaded into hauling units 90° swing

NOTE. Top figures denote optimum depth of cut—bottom figures denote cubic yards per hour.

d. Steel Wheel Roller, 3-Wheel, 10-Ton.

(1) The 3-wheel, 10-ton roller will compact a 10- to 12-inch lift of material.

(2) Passes of roller must overlap at least 50 percent.

(3) The 3-wheel, 10-ton roller can be used to compact rock.

e. *9–14 Ton Roller.* The 9–14 ton roller is used only as a finish roller on materials such as asphalt.

149. EARTH LIFTING EQUIPMENT

a. *Shovel-Dipper Capacity in Cubic Yards.* See table 94.

b. *Short Boom Dragline Performance.* See table 95.

c. *Scoop Loader Production.* See table 96.

Table 95. Short Boom Dragline Performance in Cu Yds

CLASS OF MATERIAL	⅜	½	¾	1	1¼	½	1¾	2	2½
Light, moist clay or loam	5.0′ 70	5.5′ 95	6.0′ 130	6.6′ 160	7.0′ 195	7.4′ 220	7.7′ 245	8.0′ 265	8.5′ 305
Sand or gravel	5.0′ 65	5.5′ 90	6.0′ 125	6.6′ 155	7.0′ 185	7.4′ 210	7.7′ 235	8.0′ 255	8.5′ 295
Good common earth	6.0′ 55	6.7′ 75	7.4′ 105	8.0′ 135	8.5′ 165	9.0′ 190	9.5′ 210	9.9′ 230	10.5′ 265
Clay; hard, tough	7.3′ 35	8.0′ 55	8.7′ 90	9.3′ 110	10.0′ 135	10.7′ 160	11.3′ 180	11.8′ 195	12.3′ 230
Clay; wet, sticky	7.3′ 20	8.0′ 30	8.7′ 55	9.3′ 75	10.0′ 95	10.7′ 110	11.3′ 130	11.8′ 145	12.3′ 175

NOTE. Top figure denotes optimum depth of cut—bottom figure denotes cubic yards per hour (bank measure).

Table 96. Scoop Loader Production in Cubic Yards Per Hour Based on a 50 Minute Hour

SAE rated bucket capacities	Cycle time in seconds											
	20	30	40	50	60	80	100	120	140	160	180	200
1 cu yd	150	100	75	60	50	38	30	25	21	..	..	..
1½ cu yd	220	150	110	90	75	55	45	37	32	28	25	22
2¼ cu yd	338	220	168	132	110	85	68	56	48	42	38	34
2½ cu yd	370	250	185	150	125	94	75	63	54	47	42	37
3½ cu yd	..	342	260	210	175	160	110	86	75	65	58	52
4 cu yd	..	395	300	240	200	150	120	100	85	75	66	60

150. PRODUCTIVE CAPACITY OF ENGINEER EQUIPMENT

When time does not permit calculation of production of engineer equipment table 97 may be used.

Table 97. *Productive Capacity of Equipment*

Equipment	Rate units per hr	*Unit*	*Conditions*
DRAINAGE DITCHES			
Grader, motorized	250	cu yd	V-ditches, easy digging
	150	cu yd	V-ditches, med. hard digging
	85	cu yd	V-ditches, hard digging
Shovel or dragline, ¾ cu yd	60*	cu yd	Hard digging
	125*	cu yd	Easy digging
Hand tools	5 man-hrs	100 ft	V-ditches, 3 ft wide, 1 foot deep, easy digging
	9 man-hrs	100 ft	V-ditches, 3 ft wide, 1 foot deep, medium hard digging
Ditching machine, ladder type	0-8	ft. per min.	Operating speed depends on width (18 or 24 in.), depth (0 to 99 in.), and type of soil
Ditching machine, mobile	0-28	ft. per min.	Same as above, except 24 in. wide
CLEARING AND GRUBBING			
Hand tools	1½ man-hrs	tree	3 man blasting team, good conditions
	125 man-hrs	acre	Light clearing
	350 man-hrs	acre	Medium clearing
	25 man-hrs	100 lin yd	Light clearing, 30 ft wide
	70 man-hrs	100 lin yd	Medium clearing, 30 ft wide
Mower, with tractor, 30 dbhp	2.0	acre	Cutting weeds and grasses
Tractor, 66- to 90-dbhp, with dozer	1.0	acre	Light stripping or clearing
	0.25	acre	Medium clearing
	20 to 50	trees	4 in. to 10 in. diameter
	3 to 12	trees	12 in. to 30 in. diameter

Table 97.—Continued

Equipment	Rate units per hr	Unit	Conditions
		GRADING	
Tractor, 66- to 90-dbhp, with dozer	400	lin ft	Sidehill cut; medium-hard digging, 10° slope
	190	lin ft	Sidehill cut, medium-hard digging, 20° slope
	110	lin ft	Sidehill cut, medium hard digging, 30° slope
	120	cu yd	Sidehill cut, medium hard digging
	90	cu yd	Sidehill cut, hard digging
	130	cu yd	50 ft level haul, medium hard digging
	80	cu yd	100 ft level haul, medium hard digging
Scraper, towed 12 cu yd with tractor	145	cu yd	500 ft level haul, medium hard soil
	121	cu yd	800 ft level haul, medium hard digging
Shovel, power, ¾ cu yd	45	cu yd	Hard digging
	75	cu yd	Easy digging
Grader, motorized	0.2	mile	Digging side ditches and shaping crown, 4 round trips
Hand tools	1.2 to 2.4	cu yd	Loading loose material into truck, 1 man with shovel
	1.5	cu yd	Excavation with pick and shovel, to 5 ft, easy digging
		EMBANKMENT	
Tractor, 70- to 90-dbhp, with angle-dozer	300	cu yd	Spreading material
Roller, sheepsfoot, two drum-in-line, towed by tractor, 70- to 90-dbhp	250	cu yd	9 in loose layers, 8 passes
	200	cu yd	9 in loose layers, 10 passes
	150	cu yd	9 in loose layers, 12 passes

Table 97.—Continued

Equipment	Rate units per hr	Unit	Conditions
SUBGRADE PREPARATION			
Grader, motorized	400	sq yd	Scarify and shape
Roller, sheepsfoot, two drum-in-line, towed by tractor, 70- to 90-dbhp	650	sq yd	6 in layers, 8 passes
	540	sq yd	6 in layers, 10 passes
	450	sq yd	6 in layers, 12 passes
Roller, rubber-tired with tractor, 30-dbhp	3000	sq yd	5 mph, 5 passes
Roller, road, tandem, 5- to 8-ton	1000	sq yd	3 mph, 5 passes
BASE COURSE CONSTRUCTION			
Tractor, 70- to 90-dbhp, with angle-dozer	300	cu yd	Spread material
Grader, motorized	200	cu yd	Spread material
	450	sq yd	Shaping surface
Roller, road, tandem, 5- to 8-ton	300	sq yd	Compacting gravel
Roller, road, tandem, 5- to 8-ton	75	cu yd	Compacting gravel
Roller, rubber-tired, tractor, 30-dbhp	1500	sq yd	Compacting gravel, 10 passes
SURFACE TREATMENTS AND PAVEMENT CONSTRUCTION			
Sweeper, tractor, 30-dbhp	2500	sq yd	Sweeping compact base
Distributor, trailer mounted	2500	sq yd	0.1 gal per sq yd, 24-ft spray
	1250	sq yd	0.2 gal per sq yd, 24-ft spray
Distributor, truck mounted	(See TM 5-1134)		
Spreader, aggregate, traction powered	5000	sq yd	Spread cover aggregates
Roller, road tandem, 5- to 8-ton	3000	sq yd	Rolling aggregate, 3 mph, 3 passes
Roller, rubber-tired, tractor, 30-dbhp	3000	sq yd	Rolling aggregate, 5 mph, 5 passes
Grader, motorized	150	sq yd	Mixed in place, 2-in bituminous material

Table 97.—Continued

Equipment	Rate units per hr	Unit	Conditions
	AGGREGATE PRODUCTION		
Crusher, two-unit, 25 cu yd per hr	15	ton	1-in aggregate, screened
	20	ton	1½-in aggregate, screened
	30	ton	2½-in aggregate, screened
Crusher, (Dj-50) tph	18	ton	1-in aggregate, screened
	30	ton	1½-in aggregate, screened
	43	ton	2-in aggregate, screened
Crusher, 225 tph	110	ton	¼-in aggregate, screened, washed
	220	ton	1¼-in aggregate, screened, washed
Crusher 15 tph, Airborne	15	ton	1-in aggregate, crushed
	25	ton	1½-in aggregate, crushed
	38	ton	2-in aggregate, crushed
Compressor, 210 cfm (Reciprocating)	210	cfm	At sea level
	194	cfm	5000 ft. above sea level
Compressor, 315 cfm (Reciprocating)	315	cfm	At sea level
	310	cfm	5000 ft. above sea level
Compressor, 600 cfm (Rotary)	600	cfm	At sea level
	600	cfm	5000 ft. above sea level
Compressor, 210 cfm (Rotary)	210	cfm	At sea level
	210	cfm	5000 ft. above sea level
Drill, rock, 35-lb class	20	lin ft	1¾-in hole, max depth 8 ft. Requires 40 to 60 cfm of air
Drill, rock, 45-lb class	30	lin ft	1¾-in hole, max depth 12 ft. Requires 70 to 90 cfm of air
Scoop loader, wheel 2 cu yd	200	cu yd	Truck loading

*dbhp—drawbar horsepower

CHAPTER 14
FIELD SANITATION

151 SANITATION FACILITIES

For details on field sanitation see FM 21–10, Military Sanitation.

152. WASHING FACILITIES

a. Hand washing devices should be set up near latrines and kitchens See figure 178.

b. Showers should be set up whenever possible for personal hygiene and morale. See figure 179.

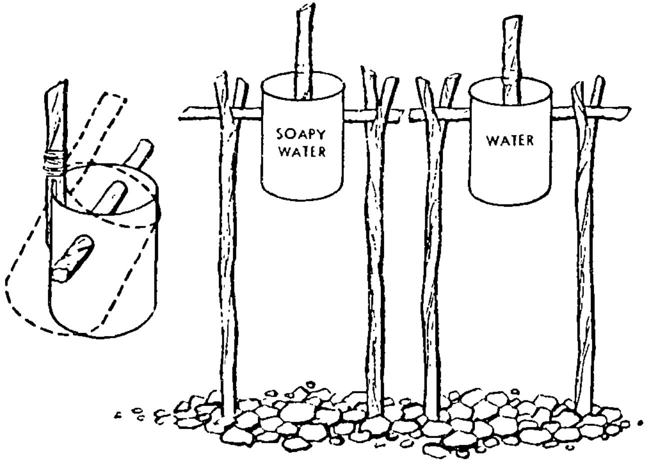


Figure 178. Handwashing device, using number 10 can.

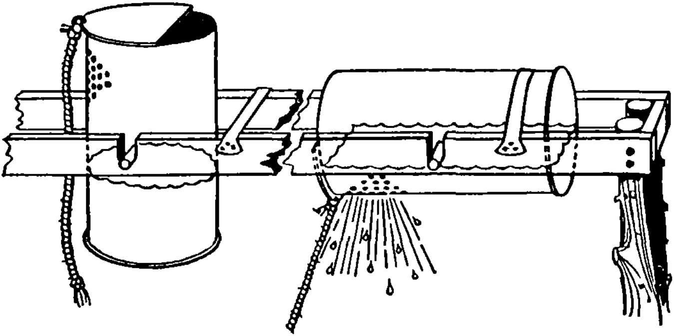


Figure 179. Shower unit, using metal drum.

153. WASTE DISPOSAL

a. *Latrines.*

(1) Size should be adequate to take care of at least 8 percent of the unit at once. Sixteen feet af straddle trench in faur-foat sections, or two deep pit latrines with four-hole latrine boxes, is adequate for a 100-man unit. Five "pipe urinals" are adequate for a 100-man unit.

(2) Locate at least 100 yards from kitchen, outside camp, and convenient ta tents.

(3) See figures 180, 181, and 182.

(4) When filled to within 1 foot of ground level, or when abandoned, latrines should be sprayed with insecticide, filled in, and mounded with a 2-foot overburden of compacted earth.

b. *Garbage Pits.*

(1) Size should be at least 4 feet square and 4 feet deep.

(2) Locate as far from kitchen as possible, outside camp area if practical.

(3) When filled to within 1 foot of ground level, or when abandoned, fill pit in and mound aver with a 2-foot overburden af compacted earth.

(4) Liquid kitchen wastes shauld never be dumped inta garbage pits as this precludes effective burning aut and shartens utilizatian for the pit.

c. *Soakage pits.* Liquid kitchen wastes shauld be dispased of in soakage pits. These shauld be lacated in the kitchen area. The saakage pit may be canstructed the same as the urinal (fig. 182) except that a grease trap must be provided (see fig. 183). In canstructing the pit, amit pipes and have drainage fram grease pipe drain inta pit.

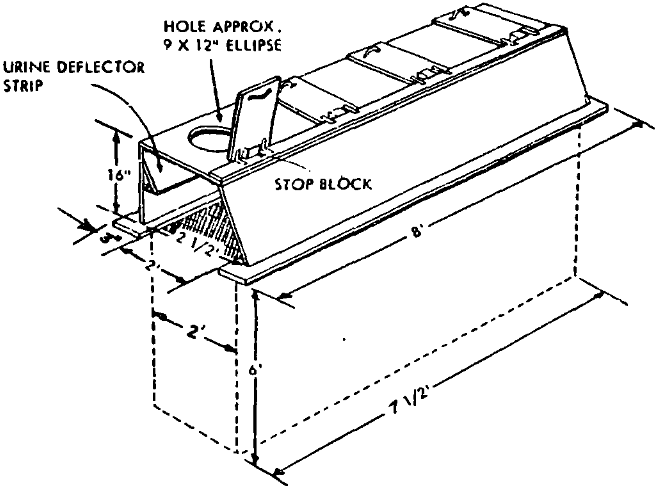


Figure 180. Bax latrine foı 50 men.

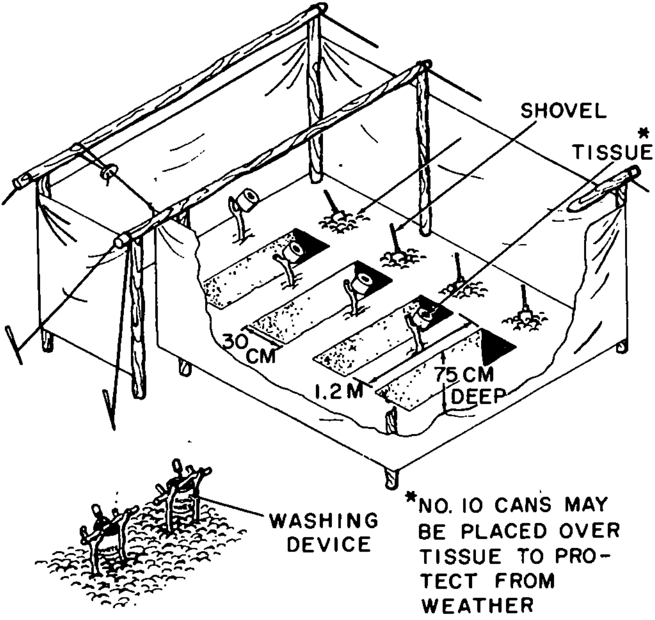


Figure 181. Straddle trench latrine for 100 men, with handwashing device.

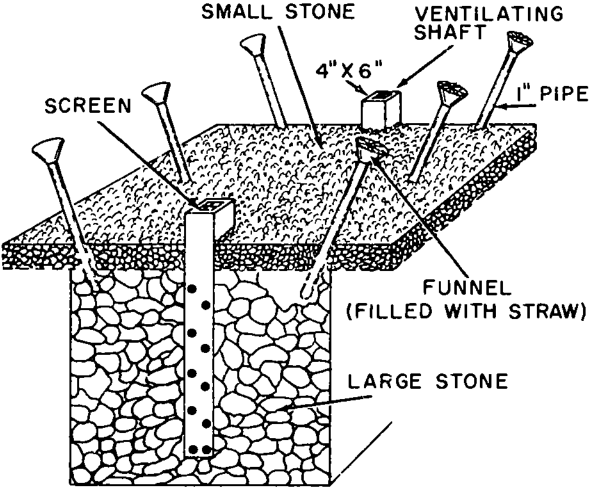


Figure 182. Pipe urinal arrangement.

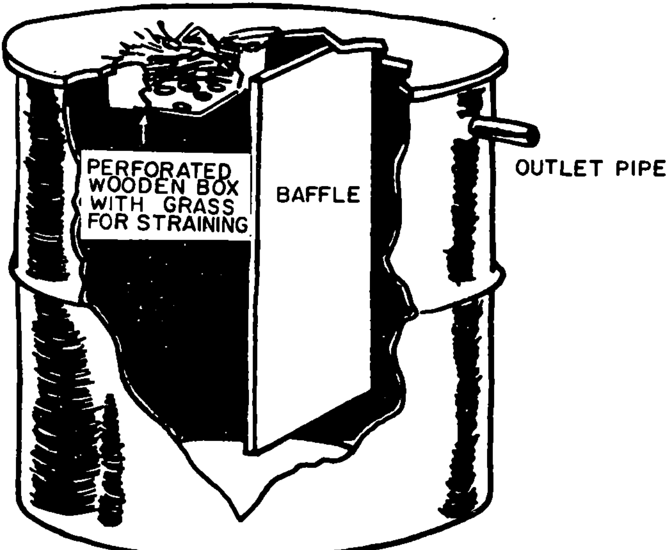


Figure 183. Baffle grease trap (barrel type).

CHAPTER 15

CHEMICAL, BIOLOGICAL, AND RADIOLOGICAL DATA

154. PROTECTION

Individual protection against a toxic agent is obtained through use of the protective mask, protective clothing, and other protective items. A chemical or biological agent attack may be detected through use of chemical agent detector kits, biological sampling kits, or by symptoms which may appear following chemical or biological agent employment. For individual CBR protective measures, see FM 21-41; for unit protection, see FM 21-40.

155 REPORTING

Procedures for reporting chemical or biological attacks are normally prescribed in the unit SOP. Detailed information is given in FM 21-40.

156. DECONTAMINATION

Detailed information pertaining to chemical and biological decontamination is given in TM 3-220.

157. REPORTING NUCLEAR ATTACK

Procedures for reporting nuclear attacks are normally prescribed in the unit SOP. Detailed information is given in FM 3-12 and FM 21-40.

158. RADIOLOGICAL DECONTAMINATION

Detailed information pertaining to radiological decontamination is given in TM 3-220.

159. PROTECTION

For information on individual protection, see FM 21-41. For information on protective shelters, see FM 21-40 and TM 5-311.

785-094 O-66—21

CHAPTER 16
COMMUNICATIONS

160. MORSE CODE

See figure 184.

A	. -	J	. - - -	S	. . .	2	. . - - -
B	- . . .	K	- . -	T	-	3	. . . - -
C	- . - .	L	. - . .	U	. . -	4	. . . . -
D	- . .	M	- -	V	. . . -	5	. . . . .
E	.	N	- .	W	. - -	6	- . . . .
F	. . - .	O	- - -	X	- . . -	7	- - . . .
G	- - .	P	. - - .	Y	- . - -	8	- - - . .
H	. . . .	Q	- - . -	Z	- - . .	9	- - - - .
I	. .	R	. - .	1	. - - - -	0	- - - - -

Figure 184. Morse Code.

161. PHONETIC ALPHABET

See Figure 185.

162. PANEL CODE

See figure 186.

Letter	Pro-word	Pronunciation	Letter	Pro-word	Pronunciation
A	ALFA	AL FAH	N	NOVEMBER	NO VEM BER
B	BRAVO	BRAH VOH	O	OSCAR	OSS CAH
C	CHARLIE	CHAR LEE	P	PAPA	PAH PAH
D	DELTA	DELL TAH	Q	QUEBEC	KEH BECK
E	ECHO	ECK OH	R	ROMEO	ROW ME OH
F	FOXTROT	FOKS TROT	S	SIERRA	SEE AIR RAH
G	GOLF	GOLF	T	TANGO	TANG GO
H	HOTEL	HO TELL	U	UNIFORM	YOU NEE FORM
I	INDIA	IN DEE AH	V	VICTOR	VIK TAH
J	JULIETT	JEW LEE ETT	W	WHISKEY	WISS KEY
K	KILO	KEY LOH	X	XRAY	ECKS RAY
L	LIMA	LEE MAH	Y	YANKEE	YANK KEY
M	MIKE	MIKE	Z	ZULU	ZOO LOO

PHONETIC NUMBERS

1	WUN	4	FO-WER	7	SEVEN	Ø	ZERO
2	TOO	5	FI-YIV	8	ATE		
3	THUH-REE	6	SIX	9	NINER		

Figure 185. Phonetic alphabet.

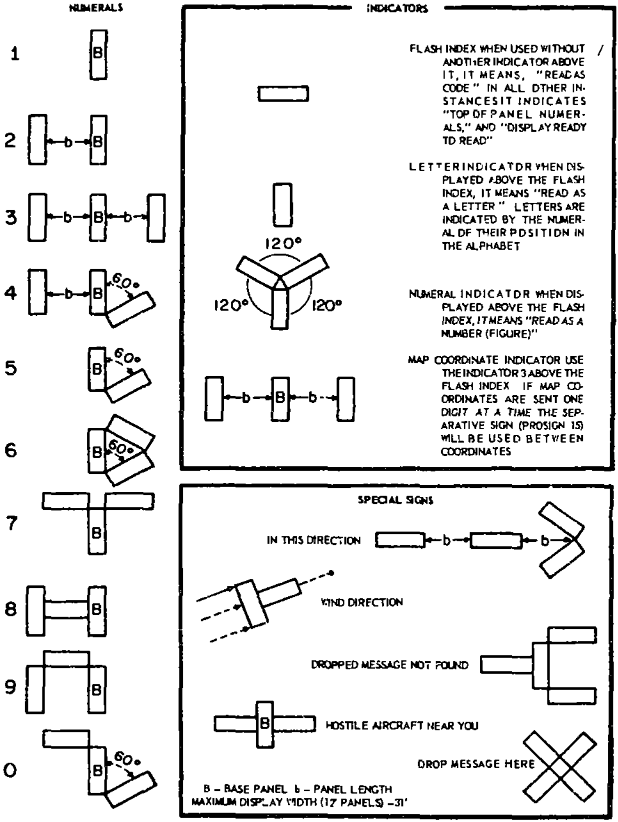
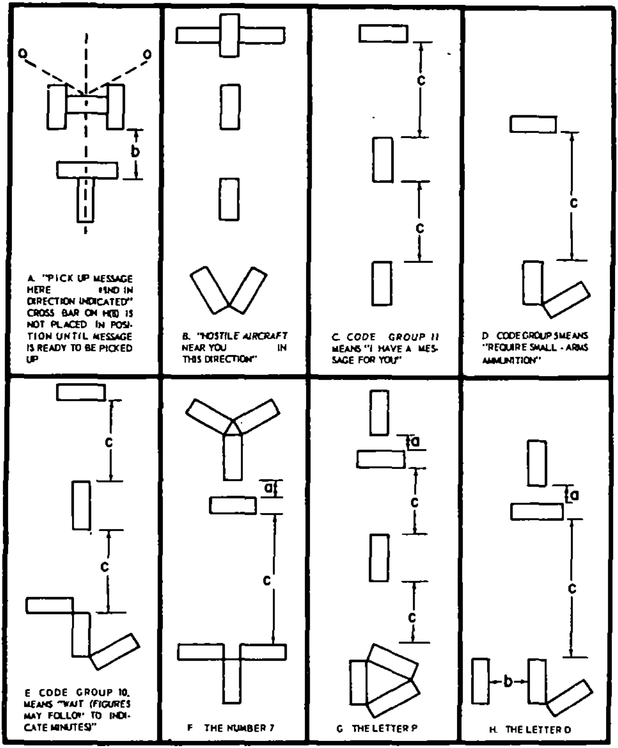


Figure 186. Panel code and messages.



NORMAL SPACINGS:

a–½ PANEL LENGTH b–1 PANEL LENGTH c–1 TO 3 PANEL LENGTHS

Figure 186—Continued

163. GROUND AND AIR EMERGENCY CODE

See figure 187.

Require doctor, serious injuries	I
Require medical supplies	II
Unable to proceed	X
Require food and water	F
Require firearms and ammunition	V
Require map and compass	□
Require signal lamp with battery and radio	¦
Indicate direction to proceed	K
Am proceeding in this direction	↑
Will attempt takeoff	I>
Aircraft seriously damaged	L⌉
Probably safe to land here	Δ
Require fuel and oil	L
All well	LL
No	N
Yes	Y
Not understood	JL
Require engineer (mechanic)	W

NOTE: Elements should be spaced 10 feet apart, whenever possible.

Figure 187. Ground—air emergency code.

164. ANTENNAS

a. *Antenna Length Chart.*
(Lengths are in feet.)

Frequency mega-cycle	Full wave length	Frequency mega-cycle	Full wave length
1	936	31	30.2
2	468	32	29.2
3	312	33	28.4
4	234	34	27.6
5	187.2	35	26.8
6	156	36	26
7	133.6	37	25.2
8	117	38	24.6
9	104	39	24
10	93.6	40	23.4
11	85	41	22.8
12	78	42	22.2
13	72	43	21.8
14	66.8	44	21.2
15	62.4	45	20.8
16	58.4	46	20.4
17	55	47	19.8
18	52	48	19.4
19	49.2	49	19
20	46.8	50	18.8
21	44.6	51	18.4
22	42.6	52	18
23	40.6	53	17.6
24	39	54	17.4
25	37.4	55	17
26	36	56	16.8
27	34.6	57	16.4
28	33.4	58	16.2
29	32.2	59	15.8
30	31.2	60	15.6

FOR ½ WAVE ANTENNA, DIVIDE BY 2.

FOR ¼ WAVE ANTENNA, DIVIDE BY 4.

FOR CENTER FED ANTENNA (S), ½ OF DESIRED ANTENNA LENGTH TO EACH SIDE OF INSULATOR.

ANTENNA LENGTH FORMULAS:

f = frequency in megacycles
answer is antenna length in feet

$$\frac{1}{4}\text{ wave} = \frac{234}{f} \qquad \frac{1}{2}\text{ wave} = \frac{468}{f} \qquad \text{full wave} = \frac{936}{f}$$

b. *Improvised Antennas.* See figures 188 through 193.

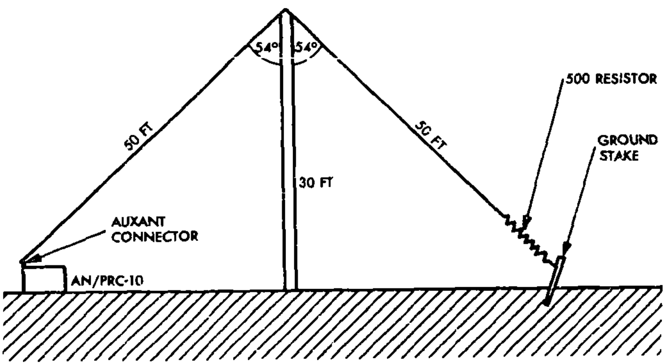


Figure 188. Half rhombic antenna.

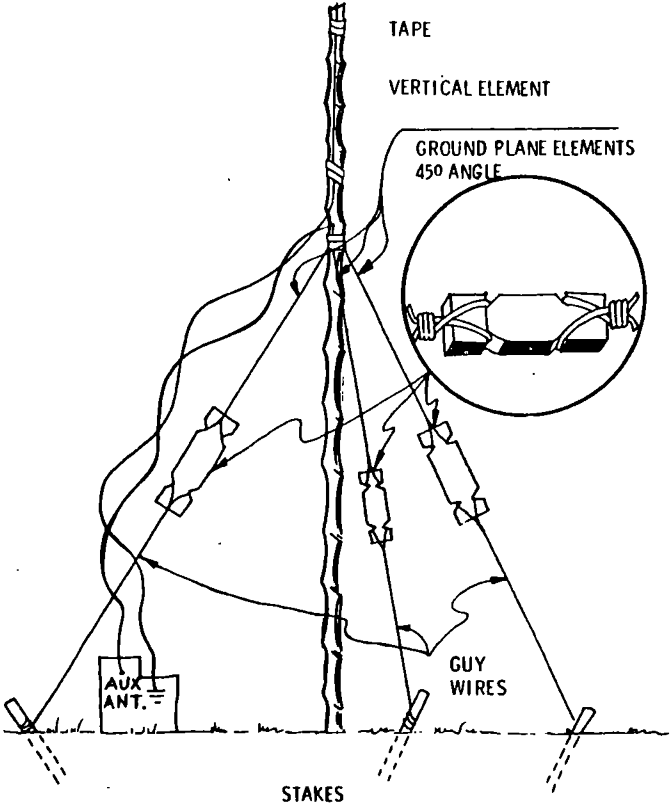


Figure 189. Jungle expedient antenna.

165. RADIO LOCATION

a. Locate radio as high as possible.

b. Location should be away any metal obstructions.

c. Avoid placing in a depression or valley, whenever possible.

d. Avoid locating a radio near electrical power line.

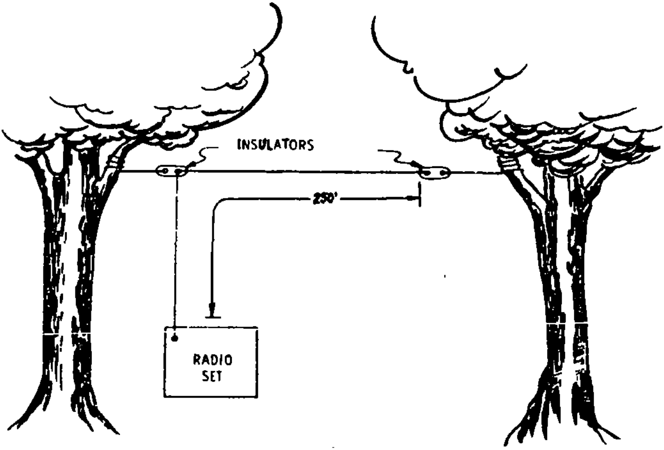


Figure 190. Inverted "L" antenna.

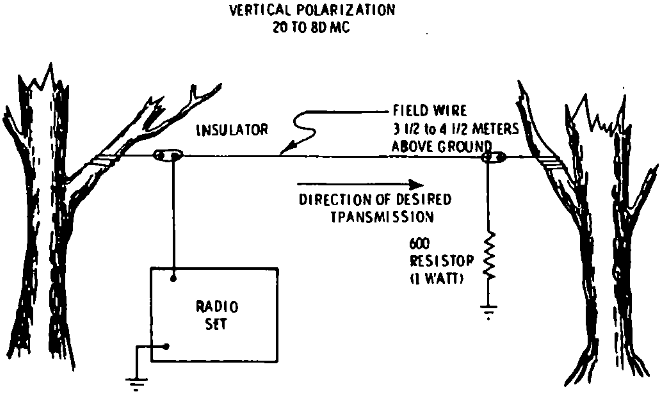


Figure 191. Long wire antenna.

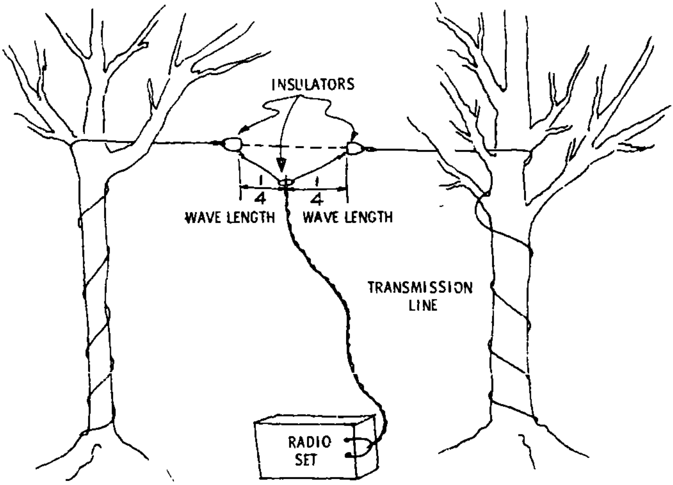


Figure 192. Impravised center fed half-wave antenna.

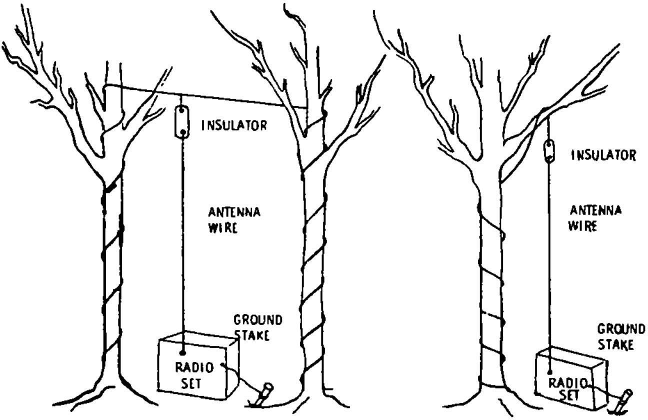


Figure 193. Expedient suspended vertical antennas.

CHAPTER 17

ENGINEERING DATA

166. MANPOWER

As a guide to the manpower available for work use the following: Combat Eng. Bn. (Divisional); 10 men/squad, 30 men/platoon, 80 men/company, 650 men/battalion. Use 10 man-hours per man per day. Increase time 50% per night work.

167. WATER

a. *Water Disinfection.*

(1) *Calcium hypochlorite.* Add calcium hypochlorite to produce residual chlorine of 1 part per million (ppm) after 10-minute contact time, and wait additional 20 minutes before drinking. For a 36-gallon lyster bag, 1 calcium hypochlorite capsule is usually enough. For individual use, prepare a disinfecting solution by placing 1 calcium hypochlorite capsule in a canteen of water. Add 1 canteen-capful of disinfecting solution to each canteen of water, shake, and allow to set for 30 minutes before using.

(2) *Iodine tablets.* Use 1 tablet per canteen of water for clear water and 2 tablets per canteen of water for cloudy water. Allow the water to stand for 5 minutes, shake vigorously, and allow to stand another 10 minutes before drinking. Allow cold water to stand 20 minutes before drinking.

(3) *Boiling.* Bring the water to a rolling boil for 15 minutes.

(4) *Destruction of amoebic dysentery cysts.* When cysts are suspected, pretreat all water by coagulation and sedimentation followed by sand filtration at reduced rates or by diatomite filtration. Water treated in this way is safe to drink if it has a residual chlorine content of 1 ppm after a 10-minute contact time. In emergencies, disinfect water in individual canteens by following the directions on the bottle of individual water purification tablets, unless an increase is directed by the medical officer. Small units may boil their own drinking water; this is a sure method. If the lyster bag is used, the following steps must be taken:

(a) Break 1 ampule and pour into filled bag; stir with clean paddle.

(b) Disinfect faucets by flushing ½ cup of water through each faucet.

(c) After 10 minutes, residual should exceed 1 ppm. Then add another ampule. Keep bag covered.

(d) Water is potable 30 minutes after adding last ampule.

b. Flow of Water Through Pipes. See tables 98 and 99.

c. Daily Water Requirements. See table 100.

168. ELECTRICAL WIRING

a. The procedures pointed out in this section are to be used only for an estimation of required wire sizes or when no other method is known.

b. To determine the wire size required for a given load:

(1) Convert load into amperes required by using

$$\text{Amperes} = \frac{\text{Total watts to be serviced}}{\text{voltage}}$$

or

$$\text{Amperes} = \frac{\text{Voltage}}{\text{resistance (ohms)}}$$

or

$$\text{Amperes} = \frac{.7457 \times \text{Horsepower}}{\text{voltage}}$$

(2) Enter tables 101 or 102 with amperes to be serviced and length of wire required; determine wire size needed.

(3) This procedure is to be used when power is to be furnished to a specific load such as one motor or a group of lights. For the procedure on wiring a facility or wiring a generator see TM 5–766 Electric Power Generation In the Field.

Table 98. *Flow of Water (Gallons Per Minute) Through Smooth-Bore Hose**

Hose (internal diameter inches)	Water pressure, pounds per square inch									
	20	30	40	50	60	70	80	90	100	125
1.00	23	28	33	37	40	43	46	49	52	58
1.25	40	50	57	64	70	76	81	86	90	101
1.50	64	78	90	101	111	120	128	135	143	159
2.00	130	159	184	206	227	242	262	275	292	326
2.50	226	278	322	358	394	425	455	482	509	566
3.00	356	437	504	570	620	665	715	755	800	890
4.00	745	910	1,055	1,180	1,292	1,395	1,492	1,582	1,670	1,850

*Data shown are based on 100-foot length of hose, laid in a straight line with open discharge end. For each set of couplings, deduct 5 percent.

Table 99. Maximum Quantities of Water in Gallons Per Minute Which Can Be Pumped Through 100 Feet of Wrought-Iron Pipe at Various Pressures

Pressure	Pipe diameter (inches)								
	½	¾	1	1¼	1½	2	2½	3	4
17 psi.......	3.2	9.1	18.7	33.5	51.6	106	200	290	589
30 psi.	5.0	14.0	28.0	52.0	78.0	160	308	436	885
40 psi........	6.0	16.0	33.0	60.0	90.0	184	350	504	1,023
50 psi.	6.5	17.5	37.0	70.0	101.0	206	390	564	1,143
60 psi........	7.0	19.5	40.0	76.0	110.0	226	430	617	1,252
75 psi...	7.5	22.0	45.0	85.0	123.0	253	480	690	1,400
100 psi.......	9.0	25.0	52.0	99.0	142.0	292	558	797	1,607

Table 100. Per Capita Water Consumption in a Theater of Operations

For Posts, Camps, Stations (Permanent or Temporary)		
Situation	**gal/man/day**	**Remarks**
Troops in combat	½	Absolute minimum, drinking only, not over 3 days
	1	A small additional allowance for cooking.
March or bivouac	2	Minimum for drinking, cooking, washing mess utensils, hands, and face.
	5	Allows in addition some bathing and laundry.
Temporary camp	5	Minimum; see preceding.
	15	Includes bathing and waterborne sewage on an economy basis.
Semipermanent camp	30-60	
Cantonment (theater)	60-100	
Hospital	10	Per bed. Minimum.
	50	Per bed. Allows for waterborne sewage.
Potable Water for Army in the Field		
Use	**Amount**	**Remarks**
Personal use	5 gal/man/day	Includes; drinking, cooking, personal hygiene. May be reduced in emergencies for not more than 3 days.
Hospital use		Same as for post above.
Non-Potable Water for Army in the Field		
Laundry	18 gal/man/week	
Showers	10 gal/man/week	
Vehicle radiators	1 gal/vehicle/day	Additional required for decontamination of vehicles and equipment during CBR warfare.

Table 101. Wire Sizes for 120-Volt Single-Phase Circuit

Load (amperes)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG) — Distance one way from supply to load (feet) 50	75	100	125	150	175	200	250	300	350	400	450	500
15	14	10	14	12	10	8	8	6	6	6	4	4	4	2	2
20	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25	12	8	10	8	8	6	6	4	4	4	2	2	2	1	1
30	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
35	12	6	8	6	6	4	4	4	2	2	1	1	0	0	2/0
40	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
45	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
50	10	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
55	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
60	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
65	8	4	6	4	4	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
70	8	4	6	4	2	2	1	1	0	2/0	2/0	3/0	4/0	4/0	
75	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
80	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
85	6	4	4	4	2	1	1	0	2/0	3/0	3/0	4/0			
90	6	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0			
95	6	2	4	2	2	1	0	2/0	2/0	3/0	4/0				
100	4	2	4	2	2	1	0	2/0	2/0	3/0	4/0				

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Table 102. Wire Sizes for 220-Volt 3-Phase Circuits

Load (amperes)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG) — Distance one way from supply to load (feet)												
			100	150	200	250	300	350	400	500	600	700	800	900	1,000
15	14	12	14	12	10	8	8	8	6	6	6	4	4	4	2
20	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25	12	8	10	8	8	6	6	6	4	4	2	2	2	2	1
30	12	8	10	8	6	6	6	4	4	2	2	2	1	1	0
35	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
40	10	6	8	6	6	4	4	4	2	2	1	1	0	0	2/0
45	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
50	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
55	8	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
60	8	6	6	6	4	2	2	2	1	0	0	2/0	3/0	3/0	4/0
65	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
70	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
75	6	4	6	4	2	2	2	1	0	2/0	2/0	3/0	4/0	4/0	..
80	6	4	6	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0	.
85	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0	.	.
90	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0	.	
95	6	4	6	4	2	1	1	0	2/0	3/0	3/0	4/0	..	.	..
100	4	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0	.		.
125	4	2	4	2	1	0	2/0	2/0	3/0	4/0	..	..	..	..	..
150	2	2	2	2	0	2/0	2/0	3/0	4/0	..	.		.		.
175	2	1	2	1	0	2/0	3/0	4/0	4/0	.	.	.	..	..	..
200	1	0	1	0	2/0	3/0	4/0	4/0		.	..	.	..	..	..
225	0	0	0	0	2/0	3/0	4/0	.	..	.	..	.	.	.	..
250	2/0	2/0	2/0	2/0	3/0	4/0	..		..	.		.	.	.	..
275	3/0	3/0	3/0	3/0	3/0	4/0	..		.		.	.	..		..
300	3/0	3/0	3/0	3/0	4/0		..	.	..	.	..	.			
325	4/0	4/0	4/0	4/0	..	.	..	.	.	..	..	..	.	..	

169. STRENGTH OF MATERIALS

a. *Bending Moments.*

$$M = fS$$

where f = allowable fiber stress in pounds per square inch
S = section modulus (*b* below)
M = bending moment (in inch—pounds)

b. *Section Modulus.*

(1) Rectangular sections:

$$S = \frac{bd^2}{6}$$

where b = width of section in inches
d = depth of section in inches

(2) Circular sections:

$$S = \frac{d^3}{10}$$

where d = diameter of circle in inches

(3) Steel beams:

$$S = d_1 \left(Af + \frac{Aw}{6}\right)$$

where d_1 = depth of beam
Af = area of flange = $(t_1)(b)$
Aw = cross-sectional area of web = $(t_2)(d_1)$

See figure 95 for dimensioning.

c. *Working Stresses for Average Timber (Douglas Fir or Southern Pine).*

(1) Bending: 2,400.
(2) Shear Parallel to the Grain: 150
(3) Bearing Perpendicular to the Grain: 500
(4) Modulus of Elasticity: 1,600,000.
(5) Compression Numbers.

(a) Short column, for L/d ratios not greater than 11: (L and d are expressed in inches)

$$f = 1{,}300$$

(b) Intermediate columns, where L/d ratios are greater than 11 but less than $K = 0.64\sqrt{E/c}$, in which E is the modulus of elasticity and C is the allowable compression stress parallel to the grain:

$$f = c\left[1 - \frac{L}{3Kd}\right]$$

(c) Long columns, for L/d ratios greater than K:

$$f = \frac{.3E}{(L/d)^2}$$

NOTE For working stress of all types of timber, see FM 5–35.

d. *Working Stresses for Steel* (in pounds per sq in.)

(1) Axial Tension, Net Section: 27,000.

(2) Tension on Extreme Fiber: 27,000.

(3) Beams or Stringers in Bending: 27,000.

$$= \frac{Ld}{b+f} \leq 400$$

(4) Bolts at Root of Thread: 20,000.

(5) Axial Compression.

(a) Stiffeners of plate girders: 27,000.

(b) Members with riveted ends, for L/r ratios not greater than 140:

$$f = 21,300 - \tfrac{3}{8}\,(L/r)^2$$

where r = smallest cross-section dimension

(c) Members with pinned ends, for L/r ratios not greater than 140:

$$f = 21,300 - \tfrac{1}{2}\,(L/r)^2$$

(d) Splice material, gross section: 27,000

(6) Shear: (in pounds per sq. in.)

(a) Girder webs, gross section: 16,500.

(b) Power-driven rivets and pins: 20,000.

(c) Turned bolts: 16,500.

(d) High tensile strength steel bolts: 20,000.

(e) Unfinished bolts: 12,000.

(7) Bearing: (in pounds per sq in.)

(a) On rivets, single shear: 32,000.

(b) On rivets, double shear: 40,000.

(c) On unfinished bolts: single shear: 20,000.

(d) On unfinished bolts: double shear: 25,000.

(e) On milled stiffeners and other steel parts in contact: 30,000.

(f) Expansion rollers and rockers, pounds per linear inch:

1. For diameters up to 25 inches:

$$\frac{S - 13,000}{20,000}\, 900d$$

2. For diameters from 25 to 125 inches:

$$\frac{S - 13,000}{20,000}\, 4500d$$

in which d is the diameter af the raller or racker in inches, ond S is the tensile yield stress of the raller or base, whichever is smoller.

e. *Beom Maments and Sheor far Various Laadings.*

(1) *Symbols.*

A— orea of section
b— width af section
c— distonce fram neutral axis ta extreme fiber
d— depth af sectian
F— laod in pounds
f— ollowable stress in psi
I— moment af inertia af sectian to extreme fiber
L— span length
l— length in inches
M— bending mament
R— reaction farce

S—section madulus $= \frac{I}{C} = \frac{M}{f}$

V—total sheor
v—unit sheor
w—lood per unit of length

(2) *Maximum bending maments ond shear.*

Mament and sheor are shown in toble 103.

170. TIMBER

a. *Dimensians ond Praperties.* Toble 104 gives the dimensions and properties of timber.

b. *Structural Timber Data.* These dato are shown in toble 105.

c. *Baord Feet Log Scale.* See toble 106.

d. *Board Feet Lumber Scale.* See table 107.

171. NAILS AND FASTENERS

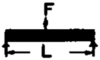
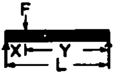
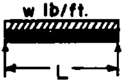
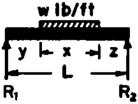
a. *Nails and Spikes.* The safe lateral laod for ane noil ar spike driven inta the side groin af seasaned lumber so that at leost twa-thirds af the length af the nail is in the wood member halding the paint (reduce lood 60 percent far noils in end grain ond 25 percent for unseasaned wood) is os fallaws:

$900 \times D^{3/2}$ far white pine and eostern hemlack
$1200 \times D^{3/2}$ for Dauglos fir ond sauthern yellaw pine
$1700 \times D^{3/2}$ for aok, osh, and hord mople

Where D=diometer af noils, in inches. See tobles 108 ond 109.

b. *Waod screws.* The safe loterol laad in pounds, for one wood screw driven inta the side groin of seosoned lumber to a penetrotian of ot least

Table 103. *Maximum Bending Moments and Shear*

Condition	Diagram	M max	V max
Supported both ends, load concentrated at center Simply supported		$\frac{FL}{4}$ (at center)	$\frac{F}{2}$ (at ends)
Concentrated load, distance X from one Simply supported		$\frac{FXY}{L}$	$\frac{FY}{L}$ (Provided X is less than Y)
Uniformly distributed load Simply supported		$\frac{wL^2}{8}$ (at center)	$\frac{wL}{2}$ (at ends)
Load evenly distributed over a distance X Simply supported		$R_1 \; Y\frac{R_2}{2w}$	$\frac{wX}{2L}\; 2Z+X$
Cantilever, concentrated load at free end		(at connection) FL	(equal throughout) F

seven times its diameter into the member receiving the point (reduce load 25 percent for end grain and 25 percent for unseasoned wood) is as follows:

$2100 \times D^2$ for white pine and eastern hemlock
$2700 \times D^2$ for Douglas fir and southern yellow pine
$4000 \times D^2$ for oak, ash, and hard maple

See table 110.

c. *Lag Screws.* The safe lateral load in pounds, for one lag screw driven into the side grain of seasoned number to a penetration of nine times the diameter into the member receiving the point and holding a

Table 104. Dimensions and Properties (Dressed Timber)

Nominal size	American standard	Area of section	I $\frac{bh^3}{12}$	S $\frac{bh^2}{6}$
In.	In.	In.^{2}	In.^{4}	In.^{3}
1 x 3	25/32 x 2 5/8	2.05	1.18	0.90
1 x 4	25 32 x 3 5/8	2 83	3.10	1.71
1 x 6	25/32 x 5 5/8	4.39	11.59	4 12
1 x 8	25/32 x 7 1/2	5.86	27.47	7 32
1 x 10	25/32 x 9 1/2	7.42	55.82	11.75
1 x 12	25/32 x 11 1/2	8.98	99.02	17.22
2 x 4	1 5/8 x 3 5/8	5.89	6.45	3 56
2 x 6	1 5/8 x 5 5/8	9 14	24.10	8.57
2 x 8	1 5/8 x 7 1/2	12.19	57.13	15.23
2 x 10	1 5/8 x 9 1/2	15.44	116.10	24 44
2 x 12	1 5/8 x 11 1/2	18.69	205.95	35 82
3 x 8	2 5/8 x 7 1/2	19.69	92.29	24 61
3 x 10	2 5/8 x 9 1/2	24.94	187.55	39.48
3 x 12	2 5/8 x 11 1/2	30.19	332.69	57 86
4 x 12	3 5/8 x 11 1/2	41.69	459.43	79 90
4 x 16	3 5/8 x 15 1/2	56.19	1,124.92	145 15
6 x 12	5 1/2 x 11 1/2	63.25	697.07	121.23
6 x 16	5 1/2 x 15 1/2	85.25	1,706.78	220.23
6 x 18	5 1/2 x 17 1/2	96.25	2,456.38	280 73
8 x 16	7 1/2 x 15 1/2	116.25	2,327.42	300 31
8 x 20	7 1/2 x 19 1/2	146.25	4,634.30	475.31
8 x 24	7 1/2 x 23 1/2	176 25	8,111.17	690.31

NOTE:

Lumber quantities are expressed in feet, board measure (fbm or BM). A board foot is the lumber in a rough-sawed board 1 foot long, 1 foot wide, and 1 inch thick. As an example, a 2" x 8" x 12' board has 12 x 2/3 x 2 or 16 fbm.

cleat having a thickness of 3.5 times the screw diameter (reduce load 35 percent for end grain and 25 percent for unseasoned wood) is as follows:

$1500 \times D^2$ for white pine and eastern hemlock
$1700 \times D^2$ for Douglas fir and southern cypress
$1900 \times D^2$ for southern yellow pine and soft maple
$2200 \times D^2$ for oak, ash, and hard maple

Where D=diameter of shank, in inches.

Table 105. Structural Timber Data

Variety and grade of wood		Average unit weight[3], lb per cu ft	Allowable working stresses for military use[1], lb per sq in.				
Species and grade description	Stress grade[2]		Extreme fiber stress in bending[4]	Horizontal shear	Compression perpendicular to grain	Compression parallel to grain[5]	Modulus of elasticity
UNITED STATES SPECIES							
Douglas fir	-	35	-	-	-	-	1,600,000
Dense select structural	1,800f	-	2,700	180	500	1,950	-
Select structural	1,600f	-	2,400	150	450	1,800	-
	1,400f	-	2,100	180	500	1,650	-
Yellow pine (long leaf, or dense short leaf)	-	40	-	-	-	-	1,600,000
Select structural	2,000f	-	3,000	150	500	2,200	-
Prime structural	1,800f	-	2,700	150	500	1,950	-
Merchantable structural; and structural square edge and sound	1,600f	-	2,400	150	500	1,800	-
No. 1 structural	1,400f	-	2,100	150	500	1,500	-
Larch	-	36	-	-	-	-	1,300,000
Select structural	1,800f	-	2,700	200	500	1,950	-
Structural	1,600f	-	2,400	150	470	1,800	-
Common structural	1,200f	-	1,800	135	430	1,650	-
Redwood (structural)	-	30	-	-	-	-	1,200,000
Dense select all heart	1,400f	-	2,100	135	350	1,800	-
Select all heart	1,200f	-	1,800	120	350	1,650	-
Bulkhead and heart	1,000f	-	1,650	120	350	1,500	-
Southern cypress	-	32	-	-	-	-	1,200,000
Select structural	1,400f	-	2,100	180	400	1,800	-

Table 105.—Continued

Variety and grade of wood		Average unit weight[3], lb per cu ft	Allowable working stresses for military use[1], lb per sq in.				
Species and grade description	Stress grade[2]		Extreme fiber stress in bending[4]	Horizontal shear	Compression perpendicular to grain	Compression parallel to grain[5]	Modulus of elasticity
UNITED STATES SPECIES—Continued							
Structural	1,100f	–	1,650	150	400	1,500	–
Eastern hemlock	–	30	–	–	–	–	1,100,000
Select structural	1,100f	–	1,650	105	400	1,050	–
FOREIGN SPECIES							
Group I	–	45	–	–	–	–	1,600,000
Teak, sal, white siris, jarul, oak, ash, Philippine mahogany, lendia	–	–	1,800–2,700	200	360–500	1,680–2,000	–
Group II	–	35	–	–	–	–	1,250,000
Deodar, chir, poon gumhar, Norway (northern) pine	–	–	1,500–2,250	150	300–450	1,340–1,800	–
Group III	–	30	–	–	–	–	1,000,000
White deal, kail	–	–	1,340–2,000	100	260–390	1,110–1,500	–

[1]Reduce all stresses to 70 percent of tabular values for green wood and for design of parts of bridge structure continuously wet. Reduce all stress values to 75 percent of tabular values for design of structures carrying long-continued live load.
[2]Grade designations adopted by United States lumber industry for long-time use.
[3]At about 15 percent moisture content.
[4]Working stress in tensions same as for bending.
[5]Working stresses for compression parallel to grain apply to posts, columns, and struts, the unsupported length of which does not exceed 11 times the least dimension of cross section.

d. Driftpins

(1) *Description.* Driftpins are long, heavy, threadless bolts used to hold heavy pieces of timber together. The term "driftpin" is almost universally used in practice, but for supply purposes the correct designation is "driftbolt." Driftpins have heads and vary in diameter from ½ to 1 inch, and in length from 18 to 26 inches.

(2) *Uses.* To use the driftpins, a hole slightly smaller than the diameter of the pin is made in the timber. The pin is wiped with oil, driven into the hole, and held in place by the compression action of the wood fibers.

Table 106. Log Scale (board measure of volume)

Log diameter (inches)	Length of log in feet						
	8	10	12	14	16	18	20
6	10	10	15	15	20	25	25
7	10	15	25	30	30	35	40
8	15	20	25	35	40	45	50
9	20	30	35	45	50	60	70
10	30	35	45	55	65	75	85
11	35	45	55	70	80	95	105
12	45	55	70	85	95	110	125
13	55	70	85	100	115	135	150
14	65	80	100	115	135	155	175
15	75	95	115	135	160	180	205
16	85	110	130	155	180	205	235
17	95	125	150	180	205	235	265
18	110	140	170	200	230	265	300
19	125	155	190	225	260	300	335
20	135	175	210	250	290	330	370
21	155	195	235	280	320	365	410
22	170	215	260	305	355	405	455
23	185	235	285	335	390	445	495
24	205	255	310	370	425	485	545
25	220	280	340	400	460	525	590
26	240	305	370	435	500	570	640
27	260	330	400	470	540	615	690
28	280	355	430	510	585	665	745

Table 106.—Continued

Log diameter (inches)	Length of log in feet						
	8	10	12	14	16	18	20
29	305	385	465	545	630	715	800
30	325	410	495	585	675	765	860
31	350	440	530	625	720	820	915
32	375	470	570	670	770	875	980
33	400	500	605	715	820	930	1045
34	425	535	645	760	875	990	1110
35	450	565	685	805	925	1050	1175
36	475	600	725	855	980	1115	1245
37	505	635	770	905	1040	1175	1315
38	535	670	810	955	1095	1245	1390
39	565	710	855	1005	1155	1310	1465
40	595	750	900	1060	1220	1380	1540
41	625	785	950	1115	1280	1450	1620
42	655	825	995	1170	1345	1525	1705
43	690	870	1045	1230	1410	1600	1785
44	725	910	1095	1290	1480	1675	1870
45	755	955	1150	1350	1550	1755	1960
46	795	995	1200	1410	1620	1835	2050
47	830	1040	1255	1475	1695	1915	2140
48	865	1090	1310	1540	1770	2000	2235

Table 107. Board Feet

Size of piece (inches)	Length of piece (feet)							
	10	12	14	16	18	20	22	24
2 by 4	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
2 by 6	10	12	14	16	18	20	22	24
2 by 8	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
2 by 10	16⅔	20	23⅓	26⅔	30	33⅓	36⅔	40
2 by 12	20	24	28	32	36	40	44	48
2 by 14	23⅓	28	32⅔	37⅓	42	46⅔	51⅓	56
2 by 16	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64

Table 107.—Continued

Size of piece (inches)	Length of piece (feet)							
	10	12	14	16	18	20	22	24
3 by 6	15	18	21	24	27	30	33	36
3 by 8	20	24	28	32	36	40	44	48
3 by 10	25	30	35	40	45	50	55	60
3 by 12	30	36	42	48	54	60	66	72
3 by 14	35	42	49	56	63	70	77	84
3 by 16	40	48	56	64	72	80	88	96
4 by 4	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
4 by 6	20	24	28	32	36	40	44	48
4 by 8	26⅔	32	37⅓	42⅔	48	53⅓	58⅓	64
4 by 10	33⅓	40	46⅔	53⅓	60	66⅔	73⅓	80
4 by 12	40	48	56	64	72	80	88	96
4 by 14	46⅔	56	65⅓	74⅔	84	93⅓	102⅔	112
4 by 16	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
6 by 6	30	36	42	48	54	60	66	72
6 by 8	40	48	56	64	72	80	88	96
6 by 10	50	60	70	80	90	100	110	120
6 by 12	60	72	84	96	108	120	132	144
6 by 14	70	84	98	112	126	140	154	168
6 by 16	80	96	112	128	144	160	176	192
6 by 18	90	108	126	144	162	180	198	216
6 by 20	100	120	140	160	180	200	220	240
8 by 8	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
8 by 10	66⅔	80	93⅓	106⅔	120	133⅓	146⅔	160
8 by 12	80	96	112	128	144	160	176	192
8 by 14	13⅓	112	130⅔	149⅓	168	186⅔	205⅓	224
10 by 10	83⅓	100	116⅔	133⅓	150	166⅔	183⅓	200
10 by 12	100	120	140	160	180	200	220	240
10 by 14	116⅔	140	163⅓	186⅔	210	233⅓	256⅔	280
10 by 16	133⅓	160	186⅔	213⅓	240	266⅔	293⅓	320
12 by 12	120	144	168	192	216	240	264	288
12 by 14	140	168	196	224	252	280	308	336
12 by 16	160	192	224	256	288	320	352	384
14 by 14	163⅓	196	228⅔	261⅓	294	326⅔	359⅓	392
14 by 16	186⅔	224	261⅓	298⅔	336	373⅓	410⅔	448

Table 108. *Nail and Spike Sizes*

	Size	Length (inches)	Gage	Diameter (D) (inches)	$D^{1/2}$
Nails	3d	1¼"	14	0.0800	0.0226
	4d	1½"	12½	.0985	.0309
	6d	2"	11½	.1130	.0380
	8d	2½"	10¼	.1314	.0476
	10d	3"	9	.1483	.0570
	16d	3½"	8	.1620	.0652
	20d	4"	6	.1920	.0841
	30d	4½"	5	.2070	.0942
	40d	5"	4	.2253	.1066
	60d	6"	2	.2625	.1347
Spikes	7"	7"	5/16"	5/16"	0.1750
	8"	8"	3/8"	3/8"	.2295
	9"	9"	3/8"	3/8"	.2295
	10"	10"	3/8"	3/8"	.2295
	12"	12"	3/8"	3/8"	.2295

Formula to find approximate number of nails required.

No. lbs (12d to 60d, framing) $= d/6 \times bf/100$

No. lbs (2d to 12d, sheathing) $= d/4 \times bf/100$

where d = size of desired nail in pennies

bf = total board feet to be nailed

172. PAINT

a. *Paint Materials.* For details on which type of paint should be used for a specific job, see the paint manual published by National Bureau of Standards, or TM 5–618.

b. *Exterior Wood Surfaces (New Work).*

(1) For the priming coat, the paint comes in cream or grey. Normally, it requires no thinner, but in cold weather thinner may be necessary; in this case, use ½ pint of turpentine added to 1 gallon of paint.

(2) Apply unthinned paint at a spreading ratio of about 450 square feet per gallon if it is to be followed by one coat of finish paint. For three-coat work, thin the priming paint as instructed in (1) above, then apply at 600 square feet per gallon.

Table 109. Wire-Nail Sizes, Wire Gages, and Number Per Pound

Size	Length, in	Common		Siding		Finishing		Flooring		Fence	
		Gage	No./lb	Gage	No./lb	Gage	No./lb	Gage	No./lb	Gage	No./lb
2d . .	1	15	876	15½	1,010	16½	1,351	. . .	. . .	. . . .	. . . .
3d . .	1¼	14	568	14½	635	15½	807	. . .	. . .	. . . .	. . . .
4d . .	1½	12½	316	14	473	15	584	. . .	. . .	. . . .	. . . .
5d . .	1¾	12½	271	14	406	15	500	. . .	. . .	10	142
6d . .	2	11½	181	12½	236	13	309	11	157	10	124
7d . .	2¼	11½	161	12½	210	13	238	11	139	9	92
8d . .	2½	10¼	106	11½	145	12½	189	10	99	9	82
9d . .	2¾	10¼	96	11½	132	12½	172	10	90	8	62
10d . .	3	9	69	10½	94	11½	121	9	69	7	50
12d . .	3¼	9	63	. . .	. . .	11½	113	8	54	6	40
16d . .	3½	8	49	. . .	. . .	11	90	7	43	5	30
20d . .	4	6	31	. . .	. . .	10	61	6	31	. . . .	. . . .
30d . .	4½	5	24	. . .	. . .	. . .	. . .	. . .	. . .	. . . .	. . . .
40d . .	5	4	18	. . .	. . .	. . .	. . .	. . .	. . .	. . . .	. . . .
50d . .	5½	3	15	. . .	. . .	. . .	. . .	. . .	. . .	. . . .	. . . .
60d . .	6	2	11	. . .	. . .	. . .	. . .	. . .	. . .	. . . .	. . . .

Note 1. To avoid splitting, nail diameters should not exceed one-seventh of the thickness of lumber to be nailed.

2. Gages are U. S. Steel Wire Gage. Fractional gages are:

Gage	10¼	10½	11½	12½	14½	15½
Diameter, in . .	0.1314	0.1278	0.1130	0.0985	0.0760	0.0673

Table 110. Wood Screw Diameters

Size	Diameter-D Inches	D^2 Inches^2
½ inch—No. 4	0.1105	0.0122
¾ inch—No. 8	.1631	.0266
1 inch—No. 10	.1894	.0359
1½ inch—No. 12	.2158	.0466
2 inch—No. 14	.2421	.0586
2½ inch—No. 16	.2684	.0720
3 inch—No. 18	.2947	.0868

(3) For the finish coat where a three-coat job is required, apply the paint at the ratio of 600 to 700 square feet per gallon. In good weather, a 48-hour drying period between coats is sufficient. For two-coat work, a spreading ratio of about 550 square feet per gallon is required.

c. *Exterior Metal Surfaces.*

(1) For finishing coats, use oil paint or enamel similar to that used for wood. For new steel bridges, apply two finish coats.

(2) Before painting metal, clean off all grease, rust, loose mill scale, dirt, and other foreign matter.

(3) The priming coat should contain a corrosion-inhibitor paint. Allow 2 days to dry.

d. *Interior Wood Surfaces.* Apply only one primer coat and one finish coat. Two finish coats may be applied if primer and first finish coats have been thinly applied. Allow 48 hours between coats.

e. *Field-Expedient Paints.* See table 111.

173. ROOFING

a. *Introduction.* Roofing repairs should be made in clear, mild weather, with the outside temperature not below 50°F. Repair minor damages by applying asphalt plastic flashing cement. Layer breaks are repaired by opening the horizontal seam below the break and inserting a strip of roofing.

Table 111. Expedient Paints

Paint	Materials	Mixing	Color	Finish
No. 1	Local earth, GI soap, water, soot, paraffin	Mix soot with paraffin; add to solution of 8 gal water and ½ lbs soap. Stir in earth	Dark gray	Flat, lusterless
No. 2	Oil, ground clay, water, gasoline, earth	Mix 2 gal water with 1 gal oil and ½ to ¼ gal clay; add earth. Thin with gasoline or water	Depends on earth colors available	Glassy on metal; otherwise dull
No. 3	Oil, clay, GI soap, water, earth	Mix 1½ bars GI soap with 3 gal water; add 1 gal oil; stir in 1 gal clay. Add earth for color	Depends on earth colors	Glassy on metal; dull on other

NOTE Canned milk or powdered eggs can be used to increase binding properties of either issue or field-expedient paints.

b. Materials Required. Depending on the method used to repair a roof, the quantities and kinds of materials vary.

(1) When 4-inch strips of fabric and asphalt roof coating are used, the quantity of coating for 100 square feet of roofing is 4/5 gallon; 39 linear feet of strips are needed.

(2) When 6-inch strips of roofing, asphalt plastic cement, and asphalt emulsion (clay type) are used, the following quantities per 100 square feet of roofing are used:

Asphalt plastic cement—6 pounds

Roofing strips—39 linear feet

Asphalt emulsion—1 gallon

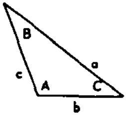
c. Other Roofing. For roofing and repair when asphalt shingles, metal roofing, wood shingles, slats, or tile are used, see TM 5–617.

174. TRIGONOMETRIC FUNCTIONS

a. Solutions of Triangles. See table 112.

b. Natural Trigonometric Functions. See table 113.

Table 112. Trigonometric Solutions of Triangles



$a^2 = b^2 + c^2 - 2\,bc\cos A$

$b^2 = a^2 + c^2 - 2\,ac\cos B$

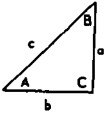
$c^2 = a^2 + b^2 - 2\,ab\cos C$

$s = \frac{a+b+c}{2}$

$\sin A = a/c$

$\cos A = b/c$

$\tan A = a/c$



$a^2 = c^2 - b^2$

$b^2 = c^2 - a^2$

$c^2 = a^2 + b^2$

RIGHT TRIANGLE

Given	TO FIND						
	A	B	C	a	b	c	Area
a,b	$\tan A = \frac{a}{b}$	$\tan B = \frac{b}{a}$	90°			$\sqrt{a^2+b^2}$	$\frac{ab}{2}$
a,c	$\sin A = \frac{a}{c}$	$\cos B = \frac{a}{c}$	90°		$\sqrt{c^2-a^2}$		$\frac{a}{2}\sqrt{c^2-a^2}$
A,a		90°−A	90°		a cot A	$\frac{a}{\sin A}$	$\frac{a^2\cot A}{2}$
A,b		90°−A	90°	b tan A		$\frac{b}{\cos A}$	$\frac{b^2\tan A}{2}$
A,c		90°−A	90°	c sin A	c cos A		$\frac{c^2\sin 2A}{4}$

OBLIQUE TRIANGLE

Given	TO FIND						
	A	B	C	a	b	c	Area
a,b,c	$\cos\frac{A}{2} = \sqrt{\frac{s(s-a)}{bc}}$	$\cos\frac{B}{2} = \sqrt{\frac{s(s-b)}{ac}}$	$\cos\frac{C}{2} = \sqrt{\frac{s(s-c)}{ab}}$				$\sqrt{s(s-a)(s-b)(s-c)}$
a,A,B			180° − (A + B)		$\frac{a\sin B}{\sin A}$	$\frac{a\sin C}{\sin A}$	$\frac{a^2\sin B\sin C}{2\sin A}$
a,b,A		$\sin B = \frac{b\sin A}{a}$				$\frac{b\sin C}{\sin B}$	
a,b,C	$\tan A = \frac{a\sin C}{b - c\cos C}$					$\sqrt{a^2+b^2-2ab\cos C}$	$\frac{ab\sin C}{2}$

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Table 113. Natural Trigonometric Functions

Angle	Sin	Cosec	Tan	Cotan	Sec	Cos	
0°	.000		000		1.000	1.000	90°
1°	017	57.30	017	57.29	1.000	1.000	89°
2°	035	28.65	.035	28.64	1.001	999	88°
3°	052	19.11	052	19.08	1 001	.999	87°
4°	.070	14.34	.070	14.30	1 002	998	86°
5°	.087	11 47	087	11 43	1.004	.996	85°
6°	.105	9 567	.105	9.514	1.006	995	84°
7°	122	8 206	123	8.144	1.008	.993	83°
8°	.139	7 185	.141	7.115	1.010	990	82°
9°	.156	6.392	.158	6.314	1.012	988	81°
10°	.174	5.759	.176	5.671	1.015	.985	80°
11°	.191	5 241	.194	5.145	1.019	.982	79°
12°	208	4.810	.213	4.705	1.022	.978	78°
13°	.225	4.445	.231	4 331	1.026	.974	77°
14°	.242	4.134	.249	4.011	1.031	970	76°
15°	.259	3.864	.268	3.732	1 035	.966	75°
16°	.276	3.628	287	3.487	1.040	.961	74°
17°	292	3.420	306	3.271	1.046	.956	73°
18°	.309	3 236	.325	3.078	1.051	.951	72°
19°	.326	3.072	.344	2.904	1 058	.946	71°
20°	.342	2.924	.364	2.747	1.064	.940	70°
21°	.358	2.790	.384	2.605	1.071	.934	69°
22°	.375	2 669	.404	2.475	1.079	.927	68°
23°	.391	2.559	.424	2.356	1 086	921	67°
24°	.407	2.459	445	2.246	1.095	.914	66°
25°	.423	2.366	466	2.145	1.103	.906	65°
26°	.438	2.281	.488	2.050	1.113	.899	64°
27°	,454	2.203	510	1.963	1.122	.891	63°
28°	469	2.130	.532	1.881	1.133	.883	62°
29°	.485	2.063	.554	1.804	1.143	875	61°
30°	.500	2 000	.577	1.732	1.155	.866	60°
31°	.515	1.942	.601	1 664	1.167	.857	59°
32°	.530	1 887	.625	1.600	1 179	848	58°
33°	.545	1.836	.649	1.540	1.192	.839	57°
34°	.559	1.788	.675	1 483	1.206	.829	56°
35°	.574	1.743	700	1.428	1.221	.819	55°
36°	.588	1.701	.727	1.376	1 236	809	54°
37°	.602	1.662	754	1.327	1.252	799	53°
38°	616	1.624	.781	1.280	1.269	788	52°
39°	.629	1.589	.810	1.235	1.287	.777	51°
40°	.643	1.556	.839	1.192	1.305	766	50°
41°	656	1.524	.869	1.150	1 325	.755	49°
42°	.669	1.494	.900	1.111	1.346	.743	48°
43°	.682	1.466	.933	1.072	1.367	731	47°
44°	.695	1.440	.966	1 036	1.390	.719	46°
45°	.707	1.414	1 .000	1.000	1.414	707	45°
	Cos	Sec	Cotan	Tan	Cosec	Sin	Angle

175. LENGTHS, AREAS, AND VOLUMES OF GEOMETRIC FIGURES

a. *Legend.*

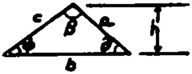
A = area
a = altitude
b = length af base
c = hypatenuse
C = circumference
V = valume
r = radius
D = diameter
$\pi = 3.1416$
L = length af arc
k = length af card

b. *Farmulas.*

(1) Any triangle:

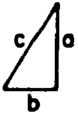
$$A = \tfrac{1}{2}\ bh$$

ar: $$\text{Sin}\ \gamma = \frac{c\ \text{Sin}\ \phi}{a}$$



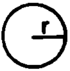
(2) Right triangle:

$$a = \sqrt{c^2 - b^2}$$
$$b = \sqrt{c^2 - a^2}$$
$$c = \sqrt{a^2 - b^2}$$



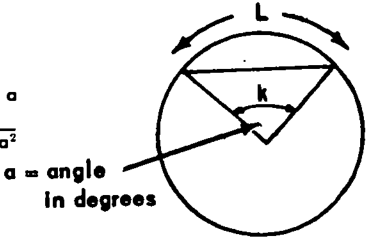
(3) Circle:

$$A = \pi r^2$$
$$A = 0.7854\ D^2$$
$$C = \pi\ D$$



(4) Segment of circle:

$$A = \tfrac{1}{2}[r(1-k) + ak]$$
$$L = \left(\frac{2\pi r}{360}\right) \times a$$
$$k = \sqrt{2ar - a^2}$$



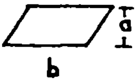
(5) Sector of circle:

$$A = \frac{rl}{2} = \frac{\pi r^2}{360}\ \text{(angle in degrees)}$$

(6) Regular polygons. The area of any regular polygon (all sides equal, all angles equal) is equal to the product of the square of the lengths of one side and the factors shown in table 114. Example: Area of a regular octagon having 6-inch sides is 6 × 6 × 4.828, or 173.81 square inches. See factors in table.

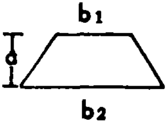
(7) Rectangle and parallelogram:

$A = ab$



(8) Trapezoid:

$A = \frac{1}{2} a(b_1 + b_2)$



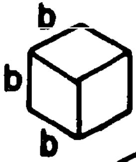
(9) Irregular figures. Measure widths at offsets regularly spaced along any straight line, and apply one of the following:

(a) Trapezoidal rule. A = one half the interval between offsets × (sum of two end widths plus twice the sum of the intermediate widths).

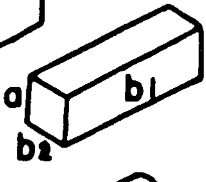
(b) Simpson's rule. (Assumes lateral boundaries are parabolic curves.) A = one third the interval between offsets × [sum of two end widths plus twice the sum of the odd widths, except first and last (3rd, 5th, 7th, etc.) plus 4 times the sum of the even widths (2d, 4th, 6th, etc.)]

NOTE. The above rule required an odd number of widths. If there is an even number, compute separately the area of a trapezoid at one end.

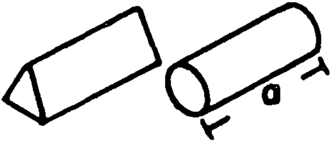
(10) Cube:
$V = b^3$



(11) Rectangular parallelepiped:
$V = a\ b_1\ b_2$



(12) Prism or cylinder:
$V = a \times$ (area of base)



(13) Pyramid ar cane:
V=(1/3) a X (area af base)

(14) Sphere:

$V = (4/3)\,\pi r^3 = \frac{\pi D^3}{6}$

$A = 4\pi r^2$

(15) Prismaidal section:
V = ane-sixth the length X (sum af the end areas plus 4 times the midsectian area)

176. FUNCTIONS OF NUMBERS

See table 115.

177. CHARACTERISTICS OF INFANTRY WEAPONS

See table 116.

178. TROOP MOVEMENT FACTORS

a. *Rates af March.* See table 117.
b. *March Farmulas.* See table 118.

179. CAMOUFLAGE

a. Principles.

(1) *Siting:* Careful selectian of the pasitian far an emplacement af equipment is the mast impartant principle af camauflage. Emplacements and their artificial camauflage materials must be made ta blend with their backgraund.

(2) *Discipline:* Avaid unnecessary mavement af persannel and vehicles and any ather activity that wauld change the ariginal appearance af the area and indicate yaur presence ta enemy abservers.

(3) *Canstructian:* Emplay natural and artificial canstructian and camauflage materials ta canceal the pasitian.

b. *Materials.*

(1) Natural. Natural materials generally pravide the best cancealment and are always available. Natural materials include live vegetatian, cut vegetatian, debris, sail, and sa farth.

Table 114. Polygon Factors

No. of sides	Factor		No. of sides	Factor
3	0.433		8	4.828
4	1.000		9	6.182
5	1.720		10	7.694
6	2.598		11	9.366
7	3.634		12	11.196

(2) *Artificial Material.* Artificial materials include paints, supporting frames, garnishing materials, structural materials, screening materials, adhesives, and texturing materials.

c. *Individual* Camouflage. Make use of terrain and background, adapt clothing to the terrain, and select a route during movement that makes use of the concealment available.

(1) *Helmets.* Break up the shape of helmets by using leaves or twigs secured with a rubber band, making a cover of burlap, distorting with burlap garlands, or painting appropriate colors.

(2) *Skin.* Tone down all visible skin areas with face paint, burnt cork, lampblack, or charcoal.

(3) *Clothing.* Clothing may be toned down to blend with the background by use of camouflage paints, or attaching vegetation to blend in with existing area.

(4) *Equipment.* Remove shine from metal objects with mud or face paint. Any equipment which may make a noise should be muffled by padding.

d. Camouflage of Equipment and Emplacements.

(1) Avoid regular geometric layouts of the position of vehicles, weapons, and supplies. Use natural camouflage material and supplement with artificial materials.

(2) Conceal the tracks made by vehicles so that terrain remains the same.

(3) Eliminate shine on vehicles.

(4) Use shadows and insure that the silhouette of emplacements and equipment is broken, so that the general outline is not detectable.

(5) In urban areas, use shadows cast by buildings.

e. *Garnishing of Camouflage Nets.*

(1) *Garnishing density.* All nets should be garnished to a predetermined degree of density. Drape nets should be garnished 100

Table 115. Functions of Numbers

No.	Square	Cube	Sq. root	Logarithm	No.	Square	Cube	Sq. root	Logarithm
1	1	1	1.0000	0.00000	40	1600	64000	6.3246	1.60206
2	4	8	1.4142	.30103	41	1681	68921	6.4031	1.61278
3	9	27	1.7321	.47712	42	1764	74088	6.4807	1.62325
4	16	64	2.0000	.60206	43	1849	79507	6.5574	1.63347
5	25	125	2.2361	.69897	44	1936	85184	6.6332	1.64345
6	36	216	2.4495	.77815	45	2025	91125	6.7082	1.65321
7	49	343	2.6458	.84510	46	2116	97336	6.7823	1.66276
8	64	512	2.8284	.90309	47	2209	103823	6.8557	1.67210
9	81	729	3.0000	.95424	48	2304	110592	6.9282	1.68124
10	100	1000	3.1623	1.00000	49	2401	117649	7.0000	1.69020
11	121	1331	3.3166	1.04139	50	2500	125000	7.0711	1.69897
12	144	1728	3.4641	1.07918	51	2601	132651	7.1414	1.70757
13	169	2197	3.6056	1.11394	52	2704	140608	7.2111	1.71600
14	196	2744	3.7417	1.14613	53	2809	148877	7.2801	1.72428
15	225	3375	3.8730	1.17609	54	2916	157464	7.3485	1.73239
16	256	4096	4.0000	1.20412	55	3025	166375	7.4162	1.74036
17	289	4913	4.1231	1.23045	56	3136	175616	7.4833	1.74819
18	324	5832	4.2426	1.25527	57	3249	185193	7.5498	1.75587
19	361	6859	4.3589	1.27875	58	3364	195112	7.6158	1.76343
20	400	8000	4.4721	1.30103	59	3481	205379	7.6811	1.77085
21	441	9261	4.5826	1.32222	60	3600	216000	7.7460	1.77815
22	484	10648	4.6904	1.34242	61	3721	226981	7.8102	1.78533
23	529	12167	4.7958	1.36173	62	3844	238328	7.8740	1.79239
24	576	13824	4.8990	1.38021	63	3969	250047	7.9373	1.79934
25	625	15625	5.0000	1.39794	64	4096	262144	8.0000	1.80618
26	676	17576	5.0990	1.41497	65	4225	274625	8.0623	1.81291
27	729	19683	5.1962	1.43136	66	4356	287496	8.1240	1.81954
28	784	21952	5.2915	1.44716	67	4489	300763	8.1854	1.82607
29	841	24389	5.3852	1.46240	68	4624	314432	8.2462	1.83251
30	900	27000	5.4772	1.47712	69	4761	328509	8.3066	1.83885
31	961	29791	5.5678	1.49136	70	4900	343000	8.3666	1.84510
32	1024	32768	5.6569	1.50515	71	5041	357911	8.4261	1.85126
33	1089	35937	5.7446	1.51851	72	5184	373248	8.4853	1.85733
34	1156	39304	5.8310	1.53148	73	5329	389017	8.5440	1.86332
35	1225	42875	5.9161	1.54407	74	5476	405224	8.6023	1.86923
36	1296	46656	6.0000	1.55630	75	5625	421875	8.6603	1.87506
37	1369	50653	6.0828	1.56820	76	5776	438976	8.7178	1.88081
38	1444	54872	6.1644	1.57978	77	5929	456533	8.7750	1.88649
39	1521	59319	6.2450	1.59106	78	6084	474552	8.8318	1.89209

Table 115—Continued

No.	Square	Cube	Sq. root	Logarithm	No.	Square	Cube	Sq. root	Logarithm
79	6241	493039	8.8882	1.89763	90	8100	729000	9.4868	1.95424
80	6400	512000	8.9443	1.90309	91	8281	753571	9.5394	1.95904
81	6561	531441	9.0000	1.90849	92	8464	778688	9.5917	1.96379
82	6724	551368	9.0554	1.91381	93	8649	804357	9.6437	1.96848
83	6889	571787	9.1104	1.91908	94	8836	830584	9.6954	1.97313
84	7056	592704	9.1652	1.92428	95	9025	857375	9.7468	1.97772
85	7225	614125	9.2195	1.92942	96	9216	884736	9.7980	1.98227
86	7396	636056	9.2736	1.93450	97	9409	912673	9.8489	1.98677
87	7569	658503	9.3274	1.93952	98	9604	941192	9.8995	1.99123
88	7744	681472	9.3808	1.94448	99	9801	970299	9.9499	1.99564
89	7921	704969	9.4340	1.94939	100	10000	1000000	10.0000	2.00000

percent in the center portion of the net, thinning out to 65 percent toward the outer edges. This will result in a coverage of about 85 percent of the entire net area. Flat-top nets should be garnished 100 percent in the center portion of the net, thinning out to 25 percent toward the outer edges. This will result in a coverage of about 65 percent of the entire net area. Begin the thin-out at about one-half the radius of the net. This must not be on an abrupt change in percentages, but rather a gradual thinning-out so as to achieve a smooth transition to the desired density at the outer portion of the net.

(2) *Garnishing patterns.* To provide for blending into a variety of seasonal and geographic terrain characteristics, pregarnished twine nets are issued in two blends—the all seasonal and the desert. The color blend of a net is achieved by proportionately varying the garlands of the various colors required for a particular blend, and placing the garlands in the net as an overall mixture of colors. Long, straight runs, large areas, blocks of one color, or regularity of pattern in a net should be avoided. Generally, the garlands are inserted into the net in such a manner that each garland will describe one of the following letters: L, U, S, C, or 1 (fig. 194). This should result in an amolgamation of the letter patterns forming the desired degree of density and color blend.

180. TIME DISTANCE CONVERSION

See table 119.

181. WEIGHTS AND SPECIFIC GRAVITIES

See table 120.

Table 116. Characteristics of Infantry Weapons

Weapons	Unloaded Weight (Approximate lbs)	Type of Feed	Cyclic (C) or Maximum Rate (M) of Fire, Rnds per min	Sustained Rate of Fire, Rnds per min	Maximum Effective Rate of Fire, Rnds per min	Maximum Range (Nearest 25) Meters	Maximum Effective Range (Nearest 25) Meters	Apprx Effective Bursting Area Meters	Remarks
Hand Grenades A26A2	1					40		15	
M34 (WP)	2					35		25	
Pistol Automatic Cal 45 M1911A1	2½	7 Rnd Magazine				1500	50		
Submachinegun Cal 45 M3A1	9	30 Rnd Magazine	450(C)	40-60	40-60	1550	100		Replaced by M-14 Rifle, with Bipod M2
US Carbine Cal .30, M2	5½	30 Rnd Magazine	750-775(C)	40-60	40-60	2025	250		Replaced by M-14 Rifle
US Rifle, Cal 7 62MM, M14	9½	20 Rnd Magazine	700-750(C)	15 (Semi-automatic) 20 (Automatlr)	20-40	3725	450		Full Automatic capability requires the installation of selector Sustained rate based on limited tests Bipod is major item & used in conjunction with rifle when used as an automatic rifle
US Rifle, Cal .30M1	9½	8 Rnd Clip		8-10	16-24	3200	450		Being replaced by the M-14 Rifle
US Rifle, Cal 30M1 with Rifle Grenade Launcher, M7A3, Heat Rifle Grenade, M31 & Sight M15	10½	Manual	4(M)	4	2	275	115		Complete Round Weighs Approx 1½ lbs
US Rifle, Cal 7.62MM with selector and bipod M2	12	20 Rnd magazine	700-750(C)	15 (Semi-automatic) 20 (Automatic)	20-40 (Semi-automatic) 40-60 (Automatic)	37-25	460		Replaces the Browning automatic rifle

Table 116.—Continued

Weapons	Unloaded Weight (Approximate lbs)	Type of Feed	Cyclic (C) or Maximum Rate (M) of Fire, Rnds per min	Sustained Rate of Fire, Rnds per min	Maximum Effective Rate of Fire, Rnds per min	Maximum Range (Nearest 25) Meters	Maximum Effective Range (Nearest 25) Meters	Appx Effective Bursting Area Meters	Remarks
Browning Automatic Rifle Cal 30 M1918A2	19½	20 Rnd magazine	350(C) slow rate 500(C) fast rate	40-60	120-150	3200	460 Pt Tgt 700 Area target		M-14 Rifle with selector and bipod M2
Machinegun Cal 7.62MM M60	Gun 23	belt metallic split link disintegrating	550(C)	100	200 (Rapid)	3725	1100		
Browning Machinegun Cal 30 M1919 A6	33	belt metallic link disintegrating	600-675(C)	100	200 (Rapid)	3200	1100		May be fired from Tripod Mount
US Rifle 7 62MM M14E2	12½	20 Rnd magazine	700-750(C)	15 (Semiautomatic) 20 (Automatic)	20-40 (Semiautomatic) 40-60 (Automatic)	3725	700 (Pt Tgt, semiautomatic only) 700 Area tgt		
US Rifle 5 56MM XM16E1	7	20 Rnd magazine	700-800(C)	20	45-65 (Semiautomatic) 150-200 (Automatic)	2653			
40MM Grenade Launcher M79	6	Breech loaded single shot			5-7	400	150 (Pt tgt) 350 (Area target)		
Machinegun, Cal 50, HB, M2	126	belt metallic link	400-500(C)	40 or less	More than 40 (Rapid)	6800	725 AAA Target 1825 Ground target		

Table 116.—Continued

Weapons	Unloaded Weight (Approximate lbs)	Type of Feed	Cyclic (C) or Maximum Rate (M) of Fire, Rnds per min	Sustained Rate of Fire, Rnds per min	Maximum Effective Rate of Fire, Rnds per min	Maximum Range (Nearest 25) Meters	Maximum Effective Range (Nearest 25) Meters	Appx Effective Bursting Area Meters	Remarks
3.5 in Rocket Launcher M20A1B1	13	Breech Loading by hand		4		825	185 Moving Target 275 Stationary Target	18 x 9	
Portable Flame-thrower M2A1-7	42	Fuel Pro-pelled by gas under pressure	Continuous discharge 8-9 Sec	Continuous discharge 8-9 sec	Continuous discharge 8-9 sec	20-25 Unthickened 40-50 thickened fuel	20-25 Unthickened 40-50 thickened fuel		Operating Capacity 4½ gals of fuel weighing 25 to 29 lbs
81MM Mortar, M29 with Mount M23A3	Barrel 28 Bipod 40 Baseplate 25.5 Sight 4	Muzzle loading by hand	12 for 2 min using HE, M362 with charge 8	3 using HE, M362 with charge 8		4453 (HE, M374)	4453 (HE, 374)	25 x 20(A)	
4.2 in Mortar, M29 M30 with mount, M24A1	640	Muzzle Loading by hand	20(M) for 2 min, 6 for next 20 min	2	1	5500	5500	40 x 15(A)	
106MM Rifle, M40A1 with spotting gun 50 Cal	460 when ground mounted	Breech loading by hand spotting gun 10 Rnd magazine	1 per 6 sec with not more than 5 rounds before letting rifle cool	1		7700(A)	1100	14 radius (HEP-T)	Maximum effective range determined by spotting gun

Table 116.—Continued

Weapons	Unloaded Weight (Approximate lbs)	Type of Feed	Cyclic (C) or Maximum Rate (M) of Fire, Rnds per min	Sustained Rate of Fire, Rnds per min	Maximum Effective Rate of Fire, Rnds per min	Maximum Range (Nearest 25) Meters	Maximum Effective Range (Nearest 25) Meters	Apprx Effective Bursting Area Meters	Remarks
Davy Crockett Light Weapon System M28	116 25 (System complete without projectile)					2000			
Davy Crockett Heavy Weapon System M29	371 (System complete without projectile)					1900 (Zone I Propellant) 4000 (Zone II Propellant)			

Table 117. Rates and Lengths of Marches.[1]

Unit	Average Rates of March (KMPH) [2]				Days March Kilometers
	On Roads		Cross-country		
	Day	Night	Day	Night	
Foot troops	4	3.2	2.4	1.6	20-32
Trucks, general	40	40 (lights) 16 (blackout)	12	8	280
Tracked vehicles	24	24 (lights) 16 (blackout)	16	8	240
Truck-drawn artillery	40	40 (lights) 16 (blackout)	12	8	280
Tractor-drawn artillery	32	32 (lights) 16 (blackout)	16	8	240

[1] This table is for general planning and comparison purposes. All rates given are variable in accordance with the movement conditions as determined by reconnoissance.

[2] These rates include normal periodic rest halts.

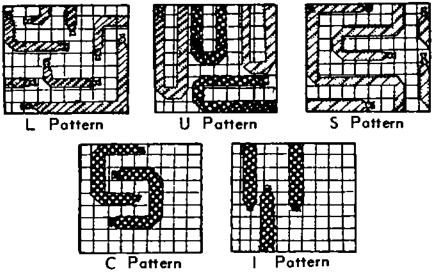


Figure 194. Garnishing.

182. CONVERSION FACTORS

See table 121.

183. WEIGHTS AND CHARACTERISTICS OF SOILS

See table 122.

184. VEHICLE RECOVERY EXPEDIENTS

a. *General.* Normally proper vehicle operator training, operator experience, and common sense can prevent most vehicles from becoming stuck or in a position where they cannot be used. In the tactical situation, vehicle loss cannot always be prevented, due to enemy action or terrain which has to be maneuvered. For a complete coverage of all aspects of vehicle recovery see FM 20–22.

b. Field Expedient Vehicle Recovery.
See figures 195, 196, 197, and 198.

Table 118. March Formulas and Factors

Metric Conversion Factors

Kilometers (Km)—
Miles (mi)
To convert kilometers to miles:
Multiply the number of kilometers by the factor .62
Mi = Nr of Km × .62
To convert miles to kilometers:
Multiply the number of miles by the factor 1.6
Km = Nr of mi × 1.6

Meters (M)—Yards (yds)
To convert meters to yards:
Multiply the number of meters by the factor 1.1
Yds = Nr of M × 1.1
To convert yards to meters:
Multiply the number of yards by the factor .91
M = Nr of yds × .91

For Time Distance (TD):
Divide the distance (kilometers) by the rate of march (kilometers per hour).

$$\text{TD (hours)} — \frac{\text{D (Kilometers)}}{\text{R (Kilometers per hour)}}$$

To convert fractional parts of an hour to minutes, multiply the fractional part by 60

For Time Length (TL) of Foot Column:
Multiply road space (RS) of the column by factor for rate of march.
TL (minutes) = (RS × factor)

Select factor from table below

Rate (kmph)	Factor
4.0	.0150
3.2	.0187
2.4	.0250
1.6	.0375

For Road Space (RS) of Foot Troops:
Multiply number of men by factor for formation and add the total distance of the intervals between units.
RS (meters) = (Nr of men × factor) + distances

Select factor from table below

Formation	2 M Man	5 M Man
Single File	2.4	5.4
Column of Two's	1.2	2.7

Toble 118.—Continued

For Time Length (TL) Vehicles (Open Column):
Multiply number of vehicles by foctor for formotion ond rote of morch ond odd time intervols (TI) between units.
TL (minutes) = (Nr of vehicles × foctor) + TI's

Select foctor from toble below

Rote (kmph)	M/Veh	Foctor
16	100	.3750
24	100	.2500
32	100	.1875
40	100	.1500
48	100	.1250

For Time Length (TL) of Motors (Close Column):
Multiply number of vehicles by .12 ond odd the time intervols (TI) between units.
TL (minutes) = (Nr of vehicles × .12) + TI's

For Completion Time (CT):
Add TL of column, TD from IP to RP, ond ony scheduled holts other thon normol breoks, to the IP time.
CT = IP time + TL + TD + Scheduled Holts

Exomple:

	Hr	Min	
	07	45	IP time (clock time)
	01	12	TL of column (1 hr 12 min)
	05	55	TD (IP to RP, 5 hrs 55 min)
	01	00	Meol holt (one hour)
CT =	14	112 or 1552	

The move will be completed ot 1552 hours.

For Rood Spoce (RS) of vehicles:
Multiply the TL (minutes) by the rote in kilometers per hour ond divide by 60.
RS (kilometers) =

$$\frac{\text{TL (min)} \times \text{R (Kilometers per hour)}}{\text{60 (minutes/hour)}}$$

Table 119. Time Distance Conversion

Miles per hour	Knots	Feet per second	Kilometers per hour	Meters per second
1	0.8684	1.4667	1.609	0.447
2	1.74	2.93	3.22	0.894
3	2.61	4.40	4.83	1.34
4	3.47	5.87	6.44	1.79
5	4.34	7.33	8.05	2.24
6	5.21	8.80	9.66	2.68
7	6.08	10.27	11.27	3.13
8	6.95	11.73	12.87	3.58
9	7.82	13.20	14.48	4.02
10	8.68	14.67	16.09	4.47
11	9.55	16.13	17.70	4.92
12	10.42	17.60	19.31	5.36
13	11.29	19.07	20.92	5.81
14	12.16	20.53	22.53	6.26
15	13.03	22.00	24.14	6.71
16	13.89	23.47	25.75	7.15
17	14.76	24.93	27.36	7.60
18	15.63	26.40	28.97	8.05
19	16.50	27.87	30.58	8.49
20	17.37	29.33	32.19	8.94
21	18.24	30.80	33.80	9.39
22	19.10	32.27	35.41	9.83
23	19.97	33.73	37.02	10.28
24	20.84	35.20	38.62	10.73
25	21.71	36.67	40.23	11.18
26	22.58	38.13	41.84	11.62
27	23.45	39.60	43.45	12.07
28	24.32	41.07	45.06	12.52
29	25.18	42.53	46.67	12.96
30	26.05	44.00	48.28	13.41
31	26.92	45.47	49.89	13.86
32	27.79	46.93	51.50	14.31
33	28.66	48.40	53.11	14.75
34	29.53	49.87	54.72	15.20
35	30.39	51.33	56.33	15.65

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Table 119.—Continued

Miles per hour	Knots	Feet per second	Kilometers per hour	Meters per second
36	31.26	52.80	57.94	16.09
37	32.13	54.27	59.55	16.54
38	33.00	55.73	61.16	16.99
39	33.87	57.20	62.76	17.43
40	34.74	58.67	64.37	17.88
41	35.60	60.13	65.98	18.33
42	36.47	61.60	67.59	18.78
43	37.34	63.07	69.20	19.22
44	38.21	64.53	70.81	19.67
45	39.08	66.00	72.42	20.12
46	39.95	67.47	74.03	20.56
47	40.81	68.93	75.64	21.01
48	41.68	70.40	77.25	21.46
49	42.55	71.87	78.86	21.90
50	43.42	73.33	80.47	22.35
51	44.29	74.80	82.08	22.80
52	45.16	76.27	83.69	23.25
53	46.03	77.73	85.30	23.69
54	46.89	79.20	86.90	24.14
55	47.76	80.67	88.51	24.59
56	48.63	82.13	90.12	25.03
57	49.50	83.60	91.73	25.48
58	50.37	85.07	93.34	25.93
59	51.24	86.53	94.95	26.38
60	52.10	88.00	96.56	26.82
61	52.97	89.47	98.17	27.27
62	53.84	90.93	99.78	27.72
63	54.71	92.40	101.39	28.16
64	55.58	93.87	103.00	28.61
65	56.45	95.33	104.61	29.06
66	57.31	96.80	106.22	29.50
67	58.18	98.27	107.83	29.95
68	59.05	99.73	109.44	30.40
69	59.92	101.20	111.05	30.85
70	60.79	102.67	112.65	31.29

Table 119.—Continued

Miles per hour	Knots	Feet per second	Kilometers per hour	Meters per second
71	61.66	104.13	114.26	31.74
72	62.52	105.60	115.87	32.19
73	63.39	107.07	117.48	32.63
74	64.26	108.53	119.09	33.08
75	65.13	110.00	120.70	33.53
100	86.84	146.67	160.94	44.70

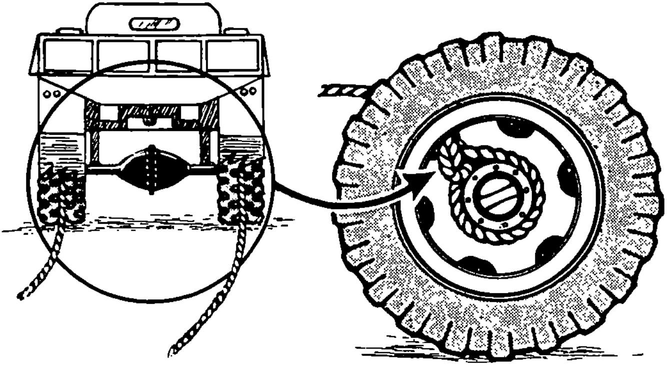

Figure 195. Use of wheels for a winch.

185. FIRE EXTINGUISHERS

a. *Classes of Fires.*

(1) Class A. These are fires in ordinary combustible materials such as bedding, mattresses, dunnage, books, cloth, canvas, wood, and paper.

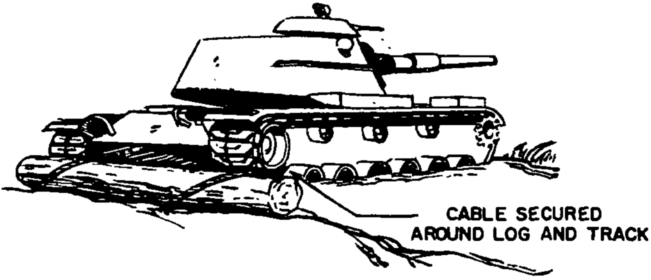

Figure 196. Log used to anchor tracks.

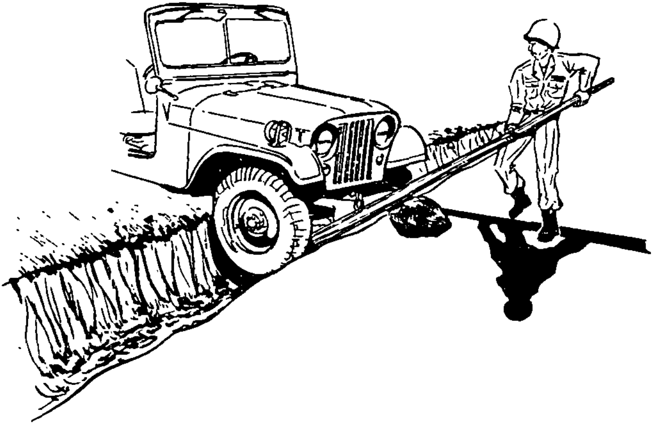

Figure 197. Simple lever.

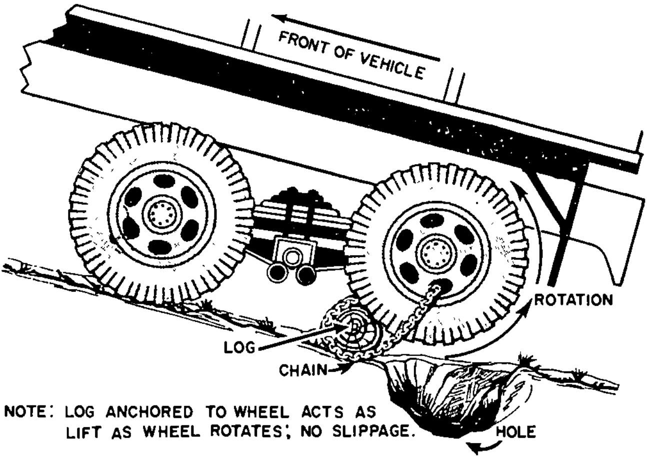

Figure 198. Anchoring a wheel.

(2) Closs B. These are fires which occur in flammable substances such os gasoline, jet fuel, and so forth.

(3) Class C. These ore live electrical fires.

(4) Class D. These are combustible metal (magnesium, etc.) fires.

b. Carbon Dioxide Extinguishers.
See figure 199.

(1) *Agent.* This extinguisher uses CO_2 as an agent. CO_2 converts to a liquid when under pressure, as it is while standing in an extinguisher.

(2) *Inspection.* Monthly inspection requires checking the wire and lead seol which holds the valve locking pin to see that it is not broken and checking for physical damage to the extinguisher. Semionnual inspection requires that the extinguisher be weighed to insure thot the extinguisher hos a full charge. Recharging is necessary if the weight is 10 percent deficient.

Table 120. Weight and Specific Gravities.

Substance	Weight, lbs. per cu. ft.	Specific gravity
Bituminous		
Asphaltum	81	1.1–1.5
Coal, anthracite	97	1.4–1.7
Coal, bituminous	84	1.2–1.5
Coal, coke	75	1.0–1.4
Petroleum, gasoline	42	0.66–0.69
Tar, bituminous	75	1.20
Building materials		
Ashes, cinders	40–45	....
Cement, portland, loose	94	....
Cement, portland, set	183	2.7–3.2
Coal and coke, piled		
Coal, anthracite	47–58	....
Coal, bituminous, lignite	40–54	....
Coal, charcoal	10–14	....
Coal, coke	23–32	....
Earth, etc., excavated		
Chalk	137	1.8–2.6
Clay, damp, plastic	110	....
Clay, dry	63	....
Clay and gravel, dry	100	....
Clay, marl	137	1.8–2.6
Earth, dry, loose	76	....
Earth, dry, packed	96	....
Earth, moist, loose	78	....
Earth, moist, packed	96	....
Earth, mud, flowing	108	....
Earth, mud, packed	115	....
Sand gravel, dry, loose	90–105	....
Sand gravel, dry, packed	100–120	....
Sand gravel, wet	118–120	....
Liquids		
Oils, minerals, lubricants	57	0.90–0.93
Water, 4° C. (max density)	62.428	1.0
Water, ice	56	0.88–0.92
Water, snow, fresh fallen	8	0.125

Table 120.—Continued

Substance	Weight, lbs. per cu. ft.	Specific gravity
Mosanry, oshlar		
Granite, syenite, gneiss	165	2.3–3.0
Limestane, marble	160	2.3–2.8
Sandstane, bluestone	140	2.1–2.4
Masanry, brick		
Pressed brick	140	2.2–2.3
Comman brick	120	1.8–2.0
Saft brick	100	1.5–1.7
Mosonry, concrete		
Cement, stane, sand	144	2.2–2.4
Masanry, dry rubble		
Granite, syenite, gneiss	130	1.9–2.3
Limestane, marble	125	1.9–2.1
Sondstane, bluestane	110	1.8–1.9
Masanry, mortar, rubble		
Granite, syenite, gneiss	155	2.2–2.8
Limestone, marble	150	2.2–2.6
Sandstone, bluestane	130	2.0–2.2
Metals, allays, ares		
Aluminum, cast, hammered	165	2.55–2.75
Copper, cast, ralled	556	8.8–9.0
Iran, cast, pig	450	7.2
Iran, wrought	485	7.6–7.9
Lead	710	11.37
Magnesium olloys	112	1.74–1.83
Manganese	475	7.2–8.0
Steel, ralled	490	7.85
Zinc, cast, ralled	440	6.9–7.2
Minerals		
Asbestas	153	2.1–2.8
Bauxite	159	2.55

Table 120.—Cantinued

Substance	Weight, lbs. per cu. ft.	Specific gravity
Rack		
Limestane, marble	165	2.5–2.8
Sandstane, bluestane	147	2.2–2.5
Riprap, limestane	80–85	....
Riprap, sandstane	90	....
Riprap, shale	105	....
Salids, variaus		
Glass, cammon	156	2.4–2.6
Hay and straw (bales)	20	....
Paper	58	0.70–1.15
Patataes, piled	42	..
Rubber gaods	94	1.0–2.0
Salt, granulated, piled	48	.
Sulfur	125	1.93–2.07
Waal	82	1.32
Stane, quarried, piled		
Basalt, granite, gneiss	96	.
Greenstane, harnblende	107	...
Limestone, marble, quartz	90	....
Sandstone	82	...
Shale	92	...
Excavatians in water		
Clay	80	...
River mud	90	...
Sand or gravel	60	...
Sand ar gravel and clay	65	...
Sail	70	....
Stone riprap	65	.

Table 120.—Continued

Substance	Weight, lbs per cu. ft.	Specific gravity
Timber, U.S. seasoned (Moisture content by weight: seasoned timber, 15% to 20%; green timber, up to 50%)		
Ash, white, red	40	0.62–0.65
Cedar, white, red	22	0.32–0.38
Chestnut	41	0.66
Cypress	30	0.48
Elm, white	45	0.72
Fir, Douglas spruce	32	0.51
Fir, eastern	25	0.40
Hemlock	29	0.42–0.52
Hickory	49	0.74–0.84
Locust	46	0.73
Maple, hard	43	0.68
Maple, white	33	0.53
Oak, chestnut	54	0.86
Oak, live	59	0.95
Oak, red, black	41	0.65
Oak, white	46	0.74
Pine, Oregon	32	0.51
Pine, red	30	0.48
Pine, white	26	0.41
Pine, yellow, longleaf	44	0.70
Pine, yellow, shortleaf	38	0.61
Poplar	30	0.48
Redwood, California	26	0.42
Spruce, white, black	27	0.40–0.46
Walnut, black	38	0.61
Walnut, white	26	0.41

(3) *Operation and use.* Place extinguisher in vertical position, remove horn from bracket holding horn by rubber or wooden handle to prevent frost bite. Remove cocking pin from discharge valve and discharge agent. CO_2 extinguishers should be used on Class B & C fires.

c. *Pump Type Water Extinguishers.*
See figure 200.

(1) *Agent.* Water extinguishers use water as an agent. Care must be taken to prevent this extinguisher from freezing.

(2) *Inspection.* Inspection includes visual and actual operation every month. Semiannual inspection includes visual inspection, actual operation, and lubricating the plunger rod.

(3) *Operation and use.* To operate, point the nozzle toward the fire and pump the water by operating the pump handle. DO NOT USE ON ELECTRICAL OR GASOLINE FIRES.

d. *Soda-Acid Extinguishers.*
See figure 201.

(1) *Agent.* Soda-acid extinguishers use water as the extinguishing agent. When the extinguisher is inverted, the soda and acid mix producing a gas which expels the water.

(2) *Inspection.* Inspection includes visual checking of the extinguisher and removing cap to check for acid, soda, and water. Annual inspection requires discharge, cleaning, and recharging. Care must be taken to prevent this extinguisher from freezing.

(3) *Operation and use.* To operate, grasp the nozzle and invert the container. The chemical reaction and pressure occur almost immediately after inverting the extinguisher. DO NOT USE ON ELECTRICAL OR GASOLINE FIRES.

e. *Foam Extinguishers.*
See figure 202.

(1) *Agent.* The foam type extinguisher is similar in size and shape to the soda-acid type extinguisher, but the operation consists of two agents mixing, producing a gas which expels the foam.

(2) *Inspection.* Inspection visual, removing cap to inspect ingredients.

(3) *Operation and use.* To operate, grasp nozzle and invert container.

f. *Fire Extinguisher Use.*
See table 123.

Table 121. Conversion Factors

Multiply	by	to obtain
Acres	43,560	square feet.
acres	4,047	square meters.
acres	1.562×10^{-3}	square miles.
acres	5645.38	square varas.
acres	4,840	square yards.
acre-feet	43,560	cubic-feet.
ares	0.02471	acres.
ares	100	square meters.
atmospheres	76.0	cms. of mercury.
atmospheres	29.92	inches of mercury.
atmospheres	33.90	feet of water.
atmospheres	10,333	kgs. per square meter.
atmospheres	14.70	pounds per sq. inch.
atmospheres	1.058	tons per sq. foot.
Bars	9.870×10^{-7}	atmospheres.
bars	1	dynes per sq. cm.
bars	0.01020	kgs. per square meter.
bars	2.089×10^{-3}	pounds per sq. foot.
bars	1.450×10^{-5}	pounds per sq. inch.
board-feet	144 sq. in. × 1 in.	cubic inches.
British thermal units	0.2520	kilogram-calories.
British thermal units	777.5	foot-pounds.
British thermal units	3.927×10^{-4}	horse-power-hours.
British thermal units	1.054	joules.
British thermal units	107.5	kilogram-meters.
British thermal units	2.928×10^{-4}	kilowatt-hours.
B.t.u. per min	12.96	foot-pounds per sec.
B.t.u. per min	0.02356	horse-power.
B.t.u. per min	0.01757	kilowatts.
B.t.u. per min	17.57	watts.
B.t.u. per sq. ft. per min	0.1220	watts per square inch.
bushels	1.244	cubic feet.
bushels	2,150	cubic inches.
bushels	0.03524	cubic meters.
bushels	4	pecks.

Table 121.—Continued

Multiply	by	to obtain
bushels	64	pints (dry).
bushels	32	quarts (dry).
Centeres	1	square meters.
centigrams	0101	grams.
centiliters	0.01	liters.
centimeters	0.3937	inches.
centimeters	0.01	meters.
centimeters	393.7	mils.
centimeters	10	millimeters.
centimeters-dynes	1.020×10^{-3}	centimeter-grams.
centimeter-dynes	1.020×10^{-8}	meter-kilograms.
centimeter-dynes	7.376×10^{-8}	pound-feet.
centimeter-groms	980.7	centimeter-dynes.
centimeter-grams	10^{-5}	meter-kilograms.
centimeter-grams	7.233×10^{-5}	pound-feet.
centimeters of mercury	0.01316	atmospheres.
centimeters of mercury	0.4461	feet of water.
centimeters of mercury	136.0	kgs. per square meter.
centimeters of mercury	27.85	pounds per sq. foot.
centimeters of mercury	0.1934	pounds per sq. inch.
centimeters per second	1.969	feet per minute.
centimeters per second	0.03281	feet per second.
centimeters per second	0.036	kilometers per hour.
centimeters per second	0.6	meters per minute.
centimeters per second	0.02237	miles per hour.
centimeters per second	3.728×10^{-4}	miles per minute.
cms. per sec. per sec	0.03281	feet per sec. per sec.
cms. per sec. per sec	0.036	kms. per hour per sec.
cms. per sec. per sec	0.02237	miles per hour per sec.
circular mils	5.067×10^{-6}	square centimeters.
circular mils	7.854×10^{-7}	square inches.
circular mils	0.7854	square mils.
cord-feet	4 ft. × 4 ft. × 1 ft.	cubic feet.
cords	8 ft. × 4 ft. × 4 ft.	cubic feet.
cubic centimeters	3.51×10^{-5}	cubic feet.
cubic centimeters	6.102×10^{-2}	cubic inches.

Table 121.—Continued

Multiply	by	to obtain
cubic centimeters.	10^{-6}	cubic meters.
cubic centimeters................	1.308×10^{-6}	cubic yards.
cubic centimeters................	2.642×10^{-4}	gallons
cubic centimeters..	10^{-3}	liters.
cubic centimeters	2.113×10^{-3}	pints (liq.).
cubic centimeters.	1.057×10^{-3}	quarts (liq.).
cubic feet	2.832×10^{4}	cubic cms.
cubic feet......................	1,728	cubic inches.
cubic feet......................	0.02832	cubic meters.
cubic feet....	0.03704	cubic yards.
cubic feet.	7.481	gallons.
cubic feet....	28.32	liters.
cubic feet........	59.84	pints (liq.).
cubic feet......................	29.92	quarts (liq.).
cubic feet per minute......... ..	472.0	cubic cms. per sec.
cubic feet per minute	0.1247	gallons per sec.
cubic feet per minute...........	0.4720	liters per second.
cubic feet per minute...........	62.4	lbs. of water per min.
cubic inches	16.39	cubic centimeters.
cubic inches...................	5.787×10^{-4}	cubic feet.
cubic inches................. ..	1.639×10^{-5}	cubic meters.
cubic inches..........	2.143×10^{-5}	cubic yards.
cubic inches...................	4.329×10^{-3}	gallons.
cubic inches...................	1.639×10^{-2}	liters.
cubic inches................. .	0.03463	pints (liq.).
cubic inches.........	0.01732	quarts (liq.).
cubic meters....	10^{6}	cubic centimeters.
cubic meters............. . .	35.31	cubic feet.
cubic meters............... ..	61,023	cubic inches.
cubic meters................. .	1.308	cubic yards.
cubic meters....	264.2	gallons.
cubic meters..	10^{3}	liters.
cubic meters..................	2113	pints (liq.).
cubic meters	1057	quarts (liq.).
cubic yards.....................	7.646×10^{5}	cubic centimeters.
cubic yards.....................	27	cubic feet.
cubic yards....	46,656	cubic inches.

Table 121.—Continued

Multiply	by	to obtain
cubic yards	0.7646	cubic meters.
cubic yards	202.0	gallons.
cubic yards	764.6	liters.
cubic yards	1616	pints (liq.).
cubic yards	807.9	quarts (liq.).
cubic yards per minute	0.45	cubic feet per second.
cubic yards per minute	3.367	gallons per second.
cubic yards per minute	12.74	liters per second.
Days	24	hours.
days	1440	minutes.
days	86,400	seconds.
decigrams	0.1	grams.
deciliters	0.1	liters.
decimeters	0.1	meters.
degrees (angle)	60	minutes.
degrees (angle)	0.01745	radians.
degrees (angle)	3600	seconds.
degrees per second	0.01745	radians per second.
degrees per second	0.1667	revolutions per min.
degrees per second	0.002778	revolutions per sec.
dekagrams	10	grams.
dekaliters	10	liters.
dekameters	10	meters.
drams	1.772	grams.
drams	0.0625	ounces.
dynes	1.020×10^{-3}	grams.
dynes	7.233×10^{-5}	poundals.
dynes	2.248×10^{-6}	pounds.
dynes per square cm	1	bars.
Ergs	9.486×10^{-11}	British thermal units.
ergs	1	dyne-centimeters.
ergs	7.376×10^{-8}	foot-pounds.
ergs	1.020×10^{-3}	gram-centimeters.
ergs	10^{-7}	joules.
ergs	2.390×10^{-11}	kilogram-calories.
ergs	1.020×10^{-8}	kilogram-meters.
ergs per second	5.692×10^{-9}	B.t. units per minute.

Table 121.—Continued

Multiply	by	to abtoin
ergs per second	4.426×10^{-6}	foot-pounds per minute.
ergs per second	7.376×10^{-8}	foot-pounds per second.
ergs per second	1.341×10^{-10}	horse-power.
ergs per second	1.434×10^{-9}	kg.-colories per minute.
ergs per second	10^{-10}	kiolwotts.
Fothoms	6	feet.
feet	30.48	centimeters.
feet	12	inches.
feet	0.3048	meters.
feet	.36	voros.
feet	⅓	yords.
feet of woter	0.02950	otmospheres.
feet of woter	0.8826	inches of mercury.
feet of woter	304.8	kgs. per squore meter.
feet of woter	62.43	pounds per sq. ft.
feet of woter	0.4335	pounds per sq. inch.
feet per minute	0.5080	centimeters per sec.
feet per minute	0.01667	feet per second.
feet per minute	0.01829	kilometers per hour.
feet per minute	0.3048	meters per minute.
feet per minute	0.01136	miles per hour.
feet per second	30.48	centimeters per sec.
feet per second	1.097	kilometers per hour.
feet per second	0.5921	knots per hour.
feet per second	18.29	meters per minute.
feet per second	0.6818	miles per hour.
feet per second	0.01136	miles per minute.
feet per 100 feet	1	per cent grode.
feet per sec. per sec.	30.48	cms. per sec. per sec.
feet per sec. per sec.	1.097	kms. per hr. per sec.
feet per sec. per sec.	0.3048	meters per sec. per sec.
feet per sec. per sec.	0.6818	miles per hr. per sec.
foot-pounds	1.286×10^{-3}	British thermol units.
foot-pounds	1.356×10^{7}	ergs.
foot-pounds	5.050×10^{-7}	horse-power-hours.
foot-pounds	1.356	joules.
foot-pounds	3.241×10^{-4}	kilogrom-colories.

Table 121.—Continued

Multiply	by	to obtain
foot-pounds..................	0.1383	kilogrom-meters.
foot-pounds..................	3.766×10^{-7}	kilowatt-hours.
loot-pounds per minute..........	1.286×10^{-3}	B.t. units per minute.
foot-founds per minute..........	0.01667	foot-pounds per sec.
foot-pounds per minute..........	3.030×10^{-5}	horse-power.
foot-pounds per minute..........	3.241×10^{-4}	kg.-colories per min.
foot-pounds per minute..........	2.260×10^{-5}	kilowotts.
foot-pounds per second..........	7.717×10^{-2}	B.t. units per minute.
foot-pounds per second..........	1.818×10^{-3}	horse-power.
foot-pounds per second..........	1.945×10^{-2}	kg.-colories per min.
foot-pounds per second..........	1.356×10^{-3}	kilowotts.
furlongs..................	40	rods.
Gollons..................	3785	cubic centimeters.
gollons..................	0.1337	cubic feet.
gollons..................	231	cubic inches.
gollons..................	3.785×10^{-3}	cubic meters.
gollons..................	4.951×10^{-3}	cubic yords.
gollons..................	3.785	liters.
gollons..................	8	pints (liq.).
gollons..................	4	quorts (liq.).
gollons per minute..........	2.228×10^{-3}	cubic feet per second.
gollons per minute..........	0.06308	liters per second.
gills..................	0.1183	liters.
gills..................	0.25	pints (liq.).
groins (troy)..................	1	groins (av.).
groins (troy)..................	0.06480	groms.
groins (troy)..................	0.04167	pennyweights (troy).
groms..................	980.7	dynes.
groms..................	15.43	groins (troy).
grams..................	10^{-3}	kilogroms.
groms..................	10^{3}	milligroms.
grams..................	0.03527	ounces.
grams..................	0.03215	ounces (troy).
groms..................	0.07093	poundols.
groms..................	2.205×10^{-3}	pounds.
grom-colories..................	3.968×10^{-3}	British thermol units.
grom-centimeters..................	9.302×10^{-3}	British thermol units.

Table 121.—Continued

Multiply	by	to obtain
gram-centimeters	980.7	ergs.
gram-centimeters	7.233×10^{-3}	foot-pounds.
gram-centimeters	9.807×10^{-5}	joules.
gram-centimeters	2.344×10^{-6}	kilogram-calories.
gram-centimeters	10^{-5}	kilogram-meters.
grams per cm	5.600×10^{-3}	pounds per inch.
grams per cu. cm	62.43	pounds per cubic foot.
grams per cu. cm	0.03613	pounds per cubic inch.
grams per cu. cm	3.405×10^{-7}	pounds per mil-foot.
Hectares	2.471	acres.
hectares	1.076×10^{5}	square feet.
hectograms	100	grams.
hectoliters	100	liters.
hectometers	100	meters.
hectowatts	100	watts.
hemispheres (sol. angle)	0.5	sphere.
hemispheres (sol. angle)	4	spherical right angles.
hemispheres (sol. angle)	6.283	steradions.
horse-power	42.44	B.t. units per min.
horse-power	33,000	foot-pounds per min.
horse-power	550	foot-pounds per sec.
horse-power	1.014	horse-power (metric).
horse-power	10.70	kg.-calories per min.
horse-power	0.7457	kilowatts.
horse-power	745.7	watts.
horse-power (boiler)	33,520	B.t.u. per hour.
horse-power (boiler)	9.804	kilowatts.
horse-power-hours	2547	British thermal units.
horse-power-hours	1.98×10^{6}	foot-pounds.
horse-power-hours	2.684×10^{6}	joules.
horse-power-hours	641.7	kilogram-calories.
horse-power-hours	2.737×10^{5}	kilogram-meters.
horse-power-hours	0.7457	kilowatt-hours.
hours	60	minutes.
hours	3600	seconds.
Inches	2.540	centimeters.

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Table 121.—Continued

Multiply	by	to obtain
inches	10^3	mils.
inches	.03	varas.
inches of mercury	0.03342	atmospheres.
inches of mercury	1.133	feet of water.
inches of mercury	345.3	kgs. per square meter.
inches of mercury	70.73	pounds per square ft.
inches of mercury	0.4912	pounds per sq. in.
inches of water	0.002458	atmospheres.
inches of water	0.07355	inches of mercury.
inches of water	25.40	kgs. per square meter.
inches of water	0.5781	ounces per square in.
inches of water	5.204	pounds per square ft.
inches of water	0.03613	pounds per square in.
Joules	9.486×10^{-4}	British thermal units.
joules	10^7	ergs.
joules	0.7376	foot-pounds.
joules	2.390×10^{-4}	kilogram-calories.
joules	0.1020	kilogram-meters.
joules	2.778×10^{-4}	watt-hours.
Kilograms	980,665	dynes.
kilograms	10^3	grams.
kilograms	70.93	poundals.
kilograms	2.2046	pounds.
kilograms	1.102×10^{-3}	tons (short).
kilogram-calories	3.968	British thermal units.
kilogram-calories	3088	foot-pounds.
kilogram-calories	1.588×10^{-3}	horse-power-hours.
kilogram-calories	4183	joules.
kilogram-calories	426.6	kilogram-meters.
kilogram-calories	1.162×10^{-3}	kilowatt-hours.
kg.-calories per min	51.43	foot-pounds per sec.
kg.-calories per min	0.09351	horse-power.
kg.-calories per min	0.06972	kilowatts.
kgs.-cms. squared	2.373×10^{-3}	pounds-feet squared.
kgs.-cms. squared	0.3417	pounds-inches squared.
kilogram-meters	9.302×10^{-3}	British thermal units.

Table 121.—Continued

Multiply	by	to obtain
kilogram-meters	9.807×10^{7}	ergs.
kilogram-meters	7.233	foot-pounds.
kilogram-meters	9.807	joules.
kilogram-meters	2.344×10^{-3}	kilogram-calories.
kilogram-meters	2.724×10^{-6}	kilowatt-hours.
kgs. per cubic meter	10^{-3}	grams per cubic cm.
kgs. per cubic meter	0.06243	pounds per cubic foot.
kgs. per cubic meter	3.613×10^{-5}	pounds per cubic inch.
kgs. per cubic meter	3.405×10^{-10}	pounds per mil. foot.
kgs. per meter	0.6720	pounds per foot.
kgs. per square meter	9.678×10^{-5}	atmospheres.
kgs. per square meter	98.07	bars.
kgs. per square meter	3.281×10^{-3}	feet of water.
kgs. per square meter	2.896×10^{-3}	inches of mercury.
kgs. per square meter	0.2048	pounds per square ft.
kgs. per square meter	1.422×10^{-3}	pounds per square in.
kgs. per sq. millimeter	10^{6}	kgs. per square meter.
kilolines	10^{3}	maxwells.
kiloliters	10^{3}	liters.
kilometers	10^{5}	centimeters.
kilometers	3281	feet.
kilometers	10^{3}	meters.
kilometers	0.6214	miles.
kilometers	1093.6	yards.
kilometers per hour	27.78	centimeters per sec.
kilometers per hour	54.68	feet per minute.
kilometers per hour	0.9113	feet per second.
kilometers per hour	0.5396	knots per hour.
kilometers per hour	16.67	meters per minute.
kilometers per hour	0.6214	miles per hour.
kms. per hour per sec	27.78	cms. per sec. per sec.
kms. per hour per sec	0.9113	ft. per sec. per sec.
kms. per hour per sec	0.2778	meters per sec. per sec.
kms. per hour per sec	0.6214	miles per hr. per sec.
kilometers per min	60	kilometers per hour.
kilowatts	56.92	B.t. units per min.
kilowatts	4.425×10^{4}	foot-pounds per min.

Table 121. —Continued

Multiply	by	to obtain
kilowatts	737.6	foot-pounds per sec.
kilowatts	1.341	horse-power.
kilowatts	14.34	kg.-calories per min.
kilowatts	10^3	watts.
kilowatt-hours	3415	British thermal units.
kilowatt-hours	2.655×10^6	foot-pounds.
kilowatt-hours	1.341	horse-power-hours.
kilowatt-hours	3.6×10^6	joules.
kilowatt-hours	860.5	kilogram-calories.
kilowatt-hours	3.671×10^5	kilogram-meters.
knots	51.48	centimeters per sec.
knots	1.689	feet per second.
knots	1.853	kilometers per hour.
knots	1.152	miles per hour.
Links (engineer's)	12	inches.
links (surveyor's)	7.92	inches.
liters	10^3	cubic centimeters.
liters	0.03531	cubic feet.
liters	61.02	cubic inches.
liters	10^{-3}	cubic meters.
liters	1.308×10^{-3}	cubic yards.
liters	0.2642	gallons.
liters	2.113	pints (liq.)
liters	1.057	quarts (liq.).
liters per minute	5.885×10^{-4}	cubic feet per second.
liters per minute	4.403×10^{-3}	gallons per second.
$\log_{10}N$	2.303	$\log_\varepsilon N$ or $\ln N$.
$\log_\varepsilon N$ or $\ln N$	0.4343	$\log_{10}N$.
lumens per sq. ft	1	foot-candles.
Meters	100	centimeters.
meters	3.2808	feet.
meters	39.37	inches.
meters	10^3	kilometers.
meters	10^3	millimeters.
meters	1.0936	yards.
meter-kilograms	9.807×10^7	centimeter-dynes.

Table 121.—Continued

Multiply	by	to obtain
meter-kilograms	10^5	centimeter-grams.
meter-kilograms	7.233	pound-feet.
meters per minute	1.667	centimeters per sec.
meters per minute	3.281	feet per minute.
meters per minute	0.05468	feet per second.
meters per minute	0.06	kilometers per hour.
meters per minute	0.03728	miles per hour.
meters per second	196.8	feet per minute.
meters per second	3.281	feet per second.
meters per second	3.6	kilometers per hour.
meters per second	0.06	kilometers per min.
meters per second	2.237	miles per hour.
meters per second	0.03728	miles per minute.
meters per sec. per sec.	3.281	feet per sec. per sec.
meters per sec. per sec.	3.6	kms. per hour per sec.
meters per sec. per sec.	2.237	miles per hour per sec.
microns	10^{-6}	meters.
miles	1.609×10^5	centimeters.
miles	5280	feet.
miles	1.6093	kilometers.
miles	1760	yards.
miles	1900.8	varas.
miles per hour	44.70	centimeters per sec.
miles per hour	88	feet per minute.
miles per hour	1.467	feet per second.
miles per hour	1.6093	kilometers per hour.
miles per hour	0.8684	knots per hour.
miles per hour	26.82	meters per minute.
miles per hour per sec	44.70	cms. per sec. per sec.
miles per hour per sec	1.467	feet per sec. per sec.
miles per hour per sec	1.6093	kms. per hour per sec.
miles per hour per sec	0.4470	M. per sec. per sec.
miles per minute	2682	centimeters per sec.
miles per minute	88	feet per second.
miles per minute	1.6093	kilometers per min.
miles per minute	0.8684	knots per minute.
miles per minute	60	miles per hour.

Table 121.—Continued

Multiply	by	to obtain
milliers	10^3	kilograms.
milligrams	10^{-3}	grams.
milliters	10^{-3}	liters.
millimeters	0.1	centimeters.
millimeters	0.03937	inches.
millimeters	39.37	mils.
mils	0.002540	centimeters.
mils	10^{-3}	inches.
miner's inches	1.5	cubic feet per min.
minutes (angle)	2.909×10^{-4}	radians.
minutes (angle)	60	seconds (angle).
months	30.42	days.
months	730	hours.
months	43,800	minutes.
months	2.628×10^6	seconds.
myriagrams	10	kilograms.
myriameters	10	kilometers.
myriawatts	10	kilowatts.
Nautical miles	6080	feet.
nautical miles	1.853	kilometers.
nautical miles	1.152	miles.
nautical miles	2027	yards.
Ounces	8	drams.
ounces	437.5	grains.
ounces	28.35	grams.
ounces	0.0625	pounds.
ounces (fluid)	1.805	cubic inches.
ounces (fluid)	0.02957	liters.
ounces (troy)	480	grains (troy).
ounces (troy)	31.10	grams.
ounces (troy)	20	pennyweights (troy).
ounces (troy)	0.08333	pounds (troy).
ounces per square inch	0.0625	pounds per sq. inch.
Pennyweights (troy)	24	grains (troy).
pennyweights (troy)	1.555	grams.
pennyweights (troy)	0.05	ounces (troy).

Table 121.—Continued

Multiply	by	to obtain
perches (mosonry)	24.75	cubic feet.
pints (dry)	33.60	cubic inches.
pints (liq.)	28.87	cubic inches.
poundols	13,826	dynes.
poundols	14.10	groms.
poundols	0.03108	pounds.
pounds	444,823	dynes.
pounds	7000	groins.
pounds	453.6	groms.
pounds	16	ounces.
pounds	32.17	poundols.
pounds (troy)	0.8229	pounds (ov.).
pound-feet	1.356×10^{7}	centimeter-dynes.
pound-feet	13,825	centimeter-groms.
pound-feet	0.1383	meter-kilogroms.
pound-feet squored	421.3	kgs.-cms. squored.
pounds-feet squored	144	pounds-in. squared.
pounds-inches squored	2.926	kgs.-cms. squared.
pounds-inches squored	6.945×10^{-3}	pounds-feet squared.
pounds of woter	0.01602	cubic feet.
pounds of woter	27.68	cubic inches.
pounds of woter	0.1198	gollons.
pounds of woter per min	2.669×10^{-4}	cubic feet por sec.
pounds per cubic foot	0.01602	grams por cubic cm.
pounds per cubic foot	16.02	kgs. per cubic meter.
pounds per cubic foot	5.787×10^{-4}	pounds per cubic inch.
pounds per cubic foot	5.456×10^{-9}	pounds per mil foot.
pounds per cubic inch	27.68	pounds per cubic cm.
pounds per cubic inch	2.768×10^{4}	kgs. per cubic meter.
pounds per cubic inch	1728	pounds por cubic foot.
pounds per cubic inch	9.425×10^{-6}	pounds per mil foot.
pounds per foot	1.488	kgs. per meter.
pounds per inch	178.6	grams por cm.
pounds per mil foot	2.306×10^{6}	grams per cubic cm.
pounds per squore foot	0.01602	feet of woter.
pounds per squore foot	4.882	kgs. per squore meter.
pounds per squore foot	6.944×10^{-3}	pounds per sq. inch.

Table 121.—Continued

Multiply	by	to obtain
pounds per square inch	0.06804	atmospheres.
pounds per square inch	2.307	feet of water.
pounds per square inch	2.036	inches of mercury.
pounds per square inch	703.1	kgs. per square meter.
pounds per square inch	144	pounds per sq. foot.
Quadrants (angle)	90	degrees.
quadrants (angle)	5400	minutes.
quadrants (angle)	1.571	radians.
quarts (dry)	67.20	cubic inches.
quarts (liq.)	57.75	cubic inches.
quintals	100	pounds.
quires	25	sheets.
Radians	57.30	degrees.
radians	3438	minutes.
radians	0.637	quadrants.
radians per second	57.30	degrees per second.
radians per second	0.1592	revolutions per sec.
radians per second	9.549	revolutions per min.
radians per sec. per sec	573.0	revs. per min. per min.
radians per sec. per sec	9.549	revs. per min. per sec.
radians per sec. per sec	0.1592	revs. per sec. per sec.
reams	500	sheets.
revolutions	360	degrees.
revolutions	4	quadrants.
revolutions	6.283	radians.
revolutions per minute	6	degrees per second.
revolutions per minute	0.1047	radians per second.
revolutions per minute	0.01667	revolutions per sec.
revs. per min. per min	1.745×10^{-3}	rads. per sec. per sec.
revs. per min. per min	0.01667	revs. per min. per sec.
revs. per min. per min	2.778×10^{-4}	revs. per sec. per sec.
revolutions per second	360	degrees per second.
revolutions per second	6.283	radians per second.
revolutions per second	60	revs. per minute.
revs. per sec. per sec	6.283	rads. per sec. per sec.
revs. per sec. per sec	3600	revs. per min. per min.

Table 121.—Continued

Multiply	by	to obtain
revs. per sec. per sec.	60	revs. per min. per sec.
rods	16.5	feet.
Seconds (angle)	4.848×10^{-6}	radians.
spheres (solid angle)	12.57	steradians.
spherical right angles	0.25	hemispheres.
spherical right angles	0.125	spheres.
spherical right angles	1.571	steradians.
square centimeters	1.973×10^{5}	circular mils.
square centimeters	1.076×10^{-3}	square feet.
square centimeters	0.1550	square inches.
square centimeters	10^{-6}	square meters.
square centimeters	100	square millimeters.
square feet	2.296×10^{-5}	acres.
square feet	929.0	square centimeters.
square feet	144	square inches.
square feet	0.09290	square meters.
square feet	3.587×10^{-8}	square miles.
square feet	.1296	square varas.
square feet	1/9	square yards.
sq. feet-feet sqd	2.074×10^{4}	sq. inches-inches sqd.
square inches	1.273×10^{6}	circular mils.
square inches	6.452	square centimeters.
square inches	6.944×10^{-3}	square feet.
square inches	10^{6}	square mils.
square inches	645.2	square millimeters.
sq. inches-inches sqd	41.62	sq. cms.-cms. sqd.
sq. inches-inches sqd	4.823×10^{-5}	sq. feet-feet sqd.
square kilometers	247.1	acres.
square kilometers	10.76×10^{6}	square feet.
square kilometers	10^{6}	square meters.
square kilometers	0.3861	square miles.
square kilometers	1.196×10^{6}	square yards.
square meters	2.471×10^{-4}	acres.
square meters	10.764	square feet.
square meters	3.861×10^{-7}	square miles.
square meters	1.196	square yards.
square miles	640	acres.

Table 121.—Continued

Multiply	by	to obtain
square miles..................	27.88×10^{6}	square feet.
square miles..................	2.590	square kilometers.
square miles..................	3,613,040.45	square varas.
square miles..................	3.098×10^{6}	square yards.
square millimeters..............	1.973×10^{3}	circular mils.
square millimeters..............	0.01	square centimeters.
square millimeters..............	1.550×10^{-3}	square inches.
square mils..................	1.273	circular mils.
square mils..................	6.452×10^{6}	square centimeters.
square mils..................	10^{-6}	square inches.
square varas..................	.0001771	acres.
square varas..................	7.716049	square feet.
square varas..................	.0000002765	square miles.
square varas..................	.857339	square yards.
square yards..................	2.066×10^{-4}	acres.
square yards..................	9	square feet.
square yards..................	0.8361	square meters.
square yards..................	3.228×10^{-7}	square miles.
square yards..................	1.1664	square varas.
steradians..................	0.1592	hemispheres.
steradians..................	0.07958	spheres.
steradians..................	0.6366	spherical right angles.
steres..................	10^{3}	liters.
Temp. (degs. C.)+273.........	1	abs. temp. (degs. C.).
temp. (degs. C.) +17.8.........	1.8	temp. (degs. Fahr.)
temp. (degs. F.) +460.........	1	abs. temp. (degs. F.).
temp. (degs. F.) −32.........	5/9	temp. (degs. Cent.).
tons (long)..................	1016	kilograms.
tons (long)..................	2240	pounds.
tons (metric)..................	10^{3}	kilograms.
tons (metric)..................	2205	pounds.
tons (short)..................	907.2	kilograms.
tons (short)..................	2000	pounds.
tons (short) per sq. ft.........	9765	kgs. per square meter.
tons (short) per sq. ft.........	13.89	pounds per sq. inch.

Toble 121.—Continued

Multiply	by	to obtoin
tons (short) per sq. in..........	1.406×10^{6}	kgs. per square meter.
tons (short) per sq. in..........	2000	pounds per sq. inch.
Voros.........................	2.7777	feet.
voros.........................	33.3333	inches.
varos.........................	.000526	miles.
voros.........................	.9259	yards.
Wotts.........................	0.05692	B.t. units per min.
wotts.........................	10^{7}	ergs per second.
watts.........................	44.26	foot-pounds per min.
wotts.........................	0.7376	foot-pounds per sec.
watts.........................	1.341×10^{-3}	horse-power.
watts.........................	0.01434	kg.-calories per min.
watts.........................	10^{2}	kilowatts.
watt-hours.....................	3.415	British thermol units.
watt-hours.....................	2655	foot-pounds.
wott-hours.....................	1.341×10^{-3}	horse-power-hours.
wott-hours.....................	0.8605	kilogrom-colories.
watt-hours.....................	367.1	kilogrom-meters.
wott-hours.....................	10^{-3}	kilowatt-hours.
webers........................	10^{8}	moxwells.
weeks.........................	168	hours.
weeks.........................	10,080	minutes.
weeks.........................	604,800	seconds.
Yords.........................	91.44	centimeters.
yords.........................	3	feet.
yards.........................	36	inches.
yords.........................	0.9144	meters.
yords.........................	1.08	varos.
yeors (common)................	365	doys.
years (common)................	8760	hours.
yeors (leop)..................	366	days.
yeors (leap)..................	8784	hours.

*Table 122. Approximate Materials Characteristics**

Material	Lbs per cu yd, bank	Percent of swell	Load (or soil) (conversion) factor	Lbs per cu yd, loose
Cinders	1,200	40–50	.72–.65	780–860
Clay, dry	2,700 to	40	.72	1,950 to
Clay, wet	3,500	40	.72	2,500
Coal, anthracite	2,600	35	.74	1,900
Coal, bituminous	2,250	35	.74	1,650
Earth (loam or silt):				
dry	1,700 to	15–35	.87–.74	1,250 to
wet	3,500	25	.80	2,800
Gravel, dry	2,450 to	10–15	.87–.74	1,250 to
Gravel, wet	3,900	10–15	.91–.87	3,550
Gypsum	4,300	30	.77	3,300
Iron ore	4,600	18	.85	3,900
Limestone	4,400	65	.60	2,650
Sand, dry	2,200–3,400	10–15	.91–.87	1,900–3,100
Sand, wet	2,450–3,900	10–15	.91–.87	2,150–3,550
Sandstone	4,000	65	.60	2,400
Shale (soft rock)	4,400	65	.60	2,650
Traprock	5,000	50	.66	3,300

*The weight and load factor of material will vary with such factors as grain size, moisture content, and degree of compaction. If an exact material weight must be determined, then a test must be run on that particular sample.

Table 123. Fire Extinguisher Use

Type	Class A fire	Class B fire	Class C fire	Class D fire
CO_2 Extinguisher	Good	Excellent	Excellent	Good
Water Extinguisher	Excellent	Do not use	Do not use	Do not use
Soda Acid Extinguisher	Excellent	Do not use	Do not use	Do not use
Foam Extinguisher	Good	Excellent	Excellent	Do not use
Commercial Powders and Granular Materials	Do not use	Do not use	Do not use	Good

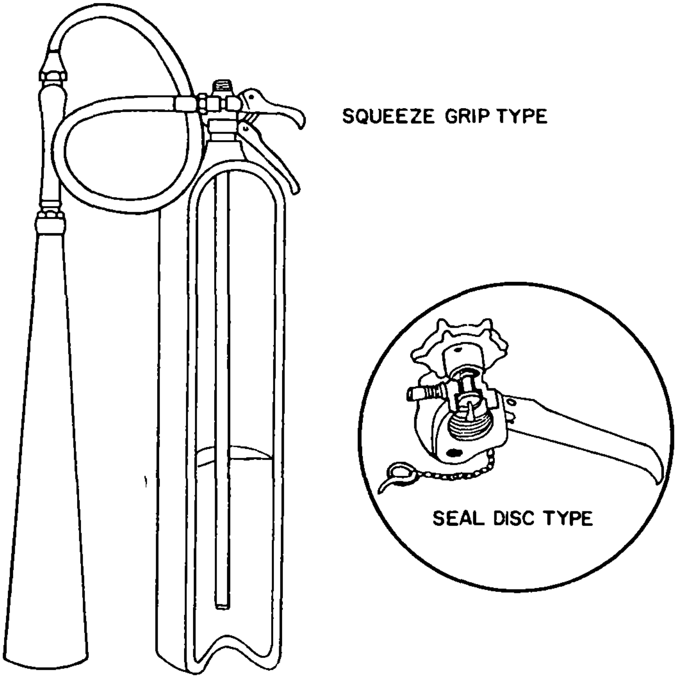


Figure 199. Carbon dioxide extinguisher.

186. MAP DISTANCE CONVERSION

See table 124.

187. CONSTRUCTION DRAWING SYMBOLS

See figure 203.

Table 124. Map Distance Conversion

Map distance	Ground distance	Representative fraction (RF)							
		1/25,000	1/50,000	1/75,000	1/100,000	1/200,000	1/250,000	1/500,000	1/1,000,000
One inch	Inches	25,000	50,000	75,000	100,000	200,000	250,000	500,000	1,000,000
	Feet	2,083	4,167	6,250	8,333	16,667	20,833	41,667	83,333
	Yards	694	1,389	2,083	2,778	5,555	6,944	13,888	27,776
	Meters	635	1,270	1,905	2,540	5,080	6,350	12,700	25,400
	Miles	0.4	0.8	1.2	1.6	3.2	4	8	16
	Kilometers	.64	1.3	1.91	2.54	5.08	6.35	12.7	25.4
One centimeter	Inches	9,843	19,685	29,528	39,370	78,740	98,425	196,850	393,700
	Feet	820	1,640	2,460	3,281	6,562	8,202	16,404	32,808
	Yards	273	547	820	1,094	2,187	2,734	5,468	10,936
	Meters	250	500	750	1,000	2,000	2,500	5,000	10,000
	Miles	0.16	0.3	0.5	0.6	1.2	1.5	3	6
	Kilometers	.25	.50	.75	1.00	2.00	2.50	5.00	10.00

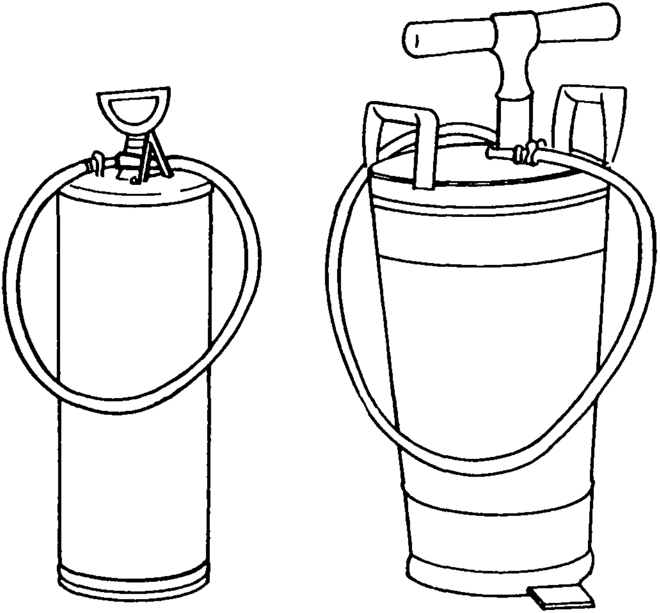


Figure 200. Pump type water extinguisher.

188. CONVERSION-ENGLISH UNITS TO METRIC UNITS

See table 125.

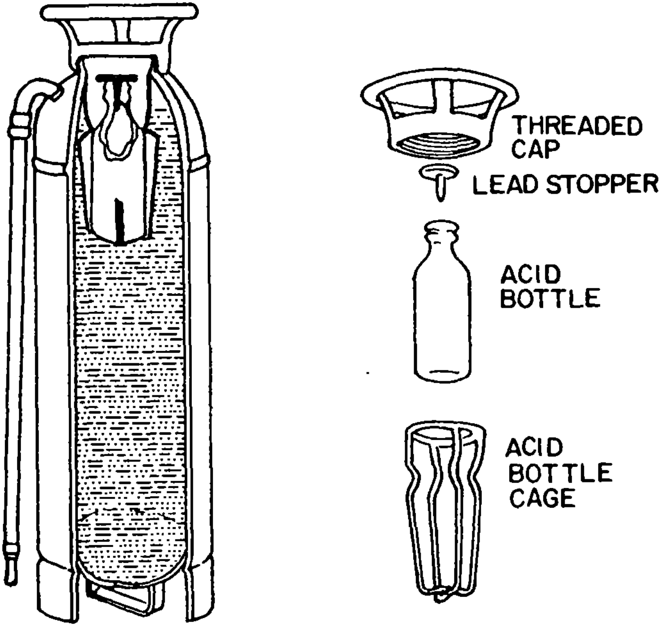


Figure 201. Soda-acid extinguisher.

189. REQUESTING AND ADJUSTING ARTILLERY FIRE

a. For details refer to FM 6–135—Adjustment of Fire by the Combat Soldier.

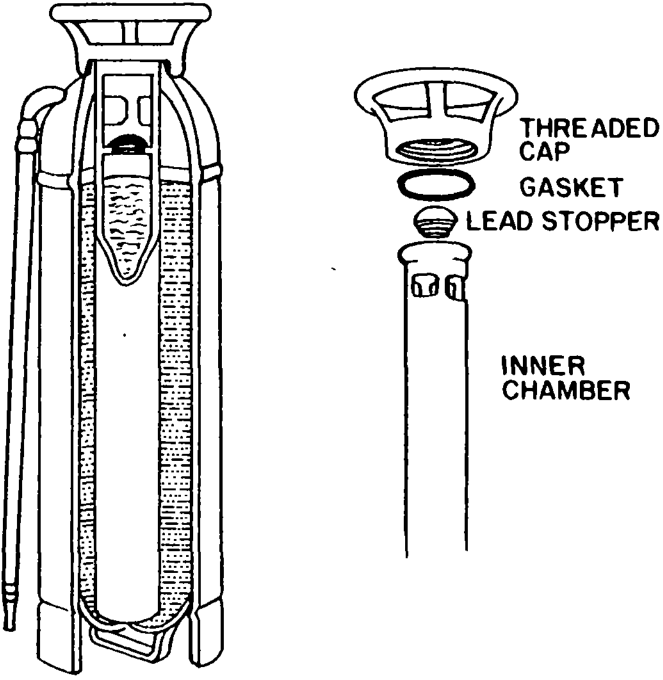


Figure 202. Foam extinguisher.

785-094 O-66—26

Figure 203. Construction drawing symbols.

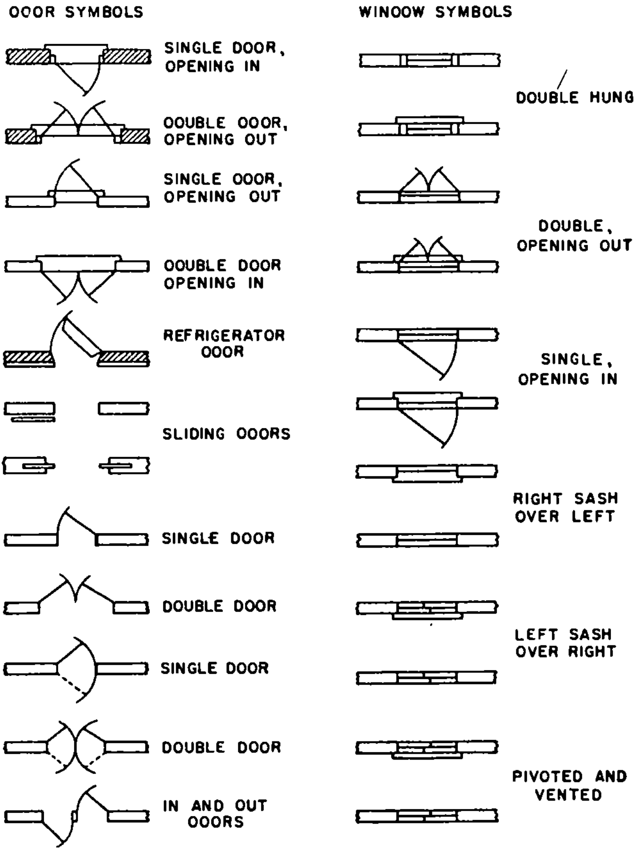


Figure 203—Continued.

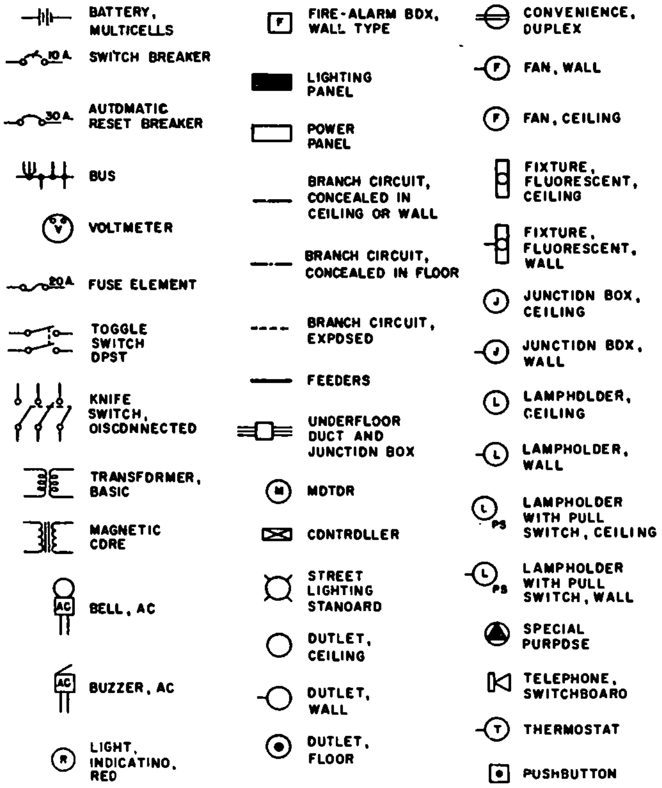


Figure 203—Continued.

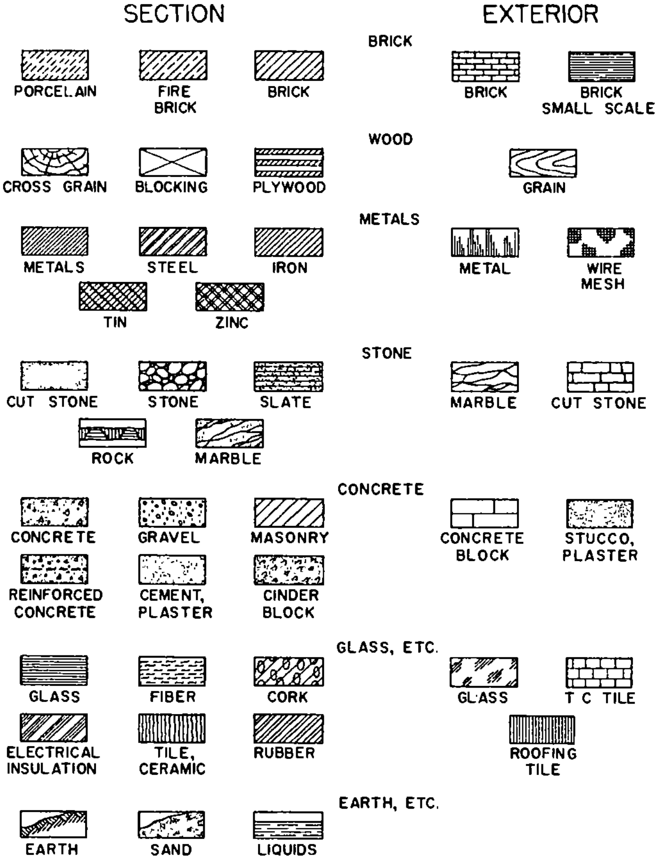


Figure 203—Continued.

b. Initial fire request: (preferably in the order listed below)

Element	*Example*
(1) Identification of observer	(1) This is Red Leg 49
(2) Warning order	(2) Fire mission
(3) Location of target and the azimuth in mils from the observer to the target	(3) Coordinates 384562 Azimuth 4380 (to nearest 10 mils)
(4) Nature of target	(4) Crew-served weapon
(5) Type of adjustment*	(5) Omit if area fire desired
(6) Ammunition *	(6) Omit this and HE will be fired
(7) Fuze action*	(7) Omit this, and fuze point detonating will be fired
(8) Control	(8) Will adjust

*Normally used only by artillery observers.

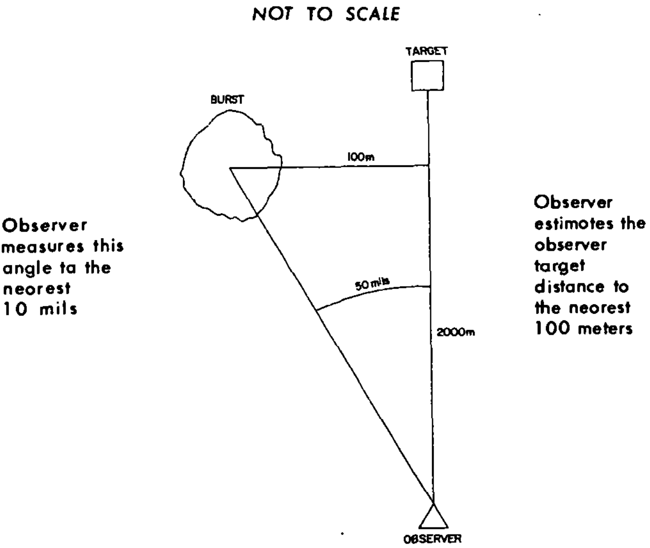
c. Adjustment of rounds:

(1) Correct the bursts laterally to the observer-target line by multiplying the estimated range in thousands of meters, from the observer to the target, times the angle, in mils, formed by the target, observer and bursts. (See diagram below.)

(2) Bracket the target in range along the observer target line and continue to split (or halve) this bracket, always keeping the target within the bracket.

(3) After determining the appropriate corrections, combine them in the same transmission by sending the lateral correction followed by the range correction. In example given below the correction would be Right 100 Add 400 (both in meters).

(4) Correct successive bursts using the same procedures, until a 100 meter range bracket exists. Then add or drop 50 meters and fire for effect.



Laterol Correction

Multiply the range from the observer to the target, in thousands of meters (2), times the ongle in mils (50) formed by the torget, observer ond bursts.

2 x 50 = Right 100 meters

Ronge Correctian

Determine if the bursts are shart or over the target in relotianship ta the observer torget line. Then odd or drap a sufficient number af meters (recammended increments for initial bracket are 400 ar 800 meters), to insure thot the bursts are an the oppasite side af the target. This estoblishes your first brocket which con easily be split (or halved) when carrecting successive bursts.

Add 400

Table 125. Conversion—English-Metric Systems

LENGTH

	km → miles	miles → kilometers	meters → yards	yards → meters	meters → feet	feet → meters	cm → inches	inches → centimeters
1	0.62	1.61	1.09	0.91	3.28	0.30	0.39	2.54
2	1.24	3.22	2.19	1.83	6.56	0.61	0.79	5.08
3	1.86	4.83	3.28	2.74	9.84	0.91	1.18	7.62
4	2.49	6.44	4.37	3.66	13.12	1.22	1.57	10.16
5	3.11	8.05	5.47	4.57	16.40	1.52	1.97	12.70
6	3.73	9.66	6.56	5.49	19.68	1.83	2.36	15.24
7	4.35	11.27	7.66	6.40	22.97	2.13	2.76	17.78
8	4.97	12.87	8.75	7.32	26.25	2.44	3.15	20.32
9	5.59	14.48	9.84	8.23	29.53	2.74	3.54	22.86
10	6.21	16.09	10.94	9.14	32.81	3.05	3.93	25.40
12	7.46	19.31	13.12	10.97	39.37	3.66	4.72	30.48
20	12.43	32.19	21.87	18.29	65.62	6.10	7.87	50.80
24	14.91	38.62	26.25	21.95	78.74	7.32	9.45	60.96
30	18.64	48.28	32.81	27.43	98.42	9.14	11.81	76.20
36	22.37	57.94	39.37	32.92	118.11	10.97	14.17	91.44
40	24.85	64.37	43.74	36.58	131.23	12.19	15.75	101.60
48	29.83	77.25	52.49	43.89	157.48	14.63	18.90	121.92
50	31.07	80.47	54.68	45.72	164.04	15.24	19.68	127.00
60	37.28	96.56	65.62	54.86	196.85	18.29	23.62	152.40
70	43.50	112.65	76.55	64.00	229.66	21.34	27.56	177.80
72	44.74	115.87	78.74	65.84	236.22	21.95	28.35	182.88
80	49.71	128.75	87.49	73.15	262.47	24.38	31.50	203.20
84	52.20	135.18	91.86	76.81	275.59	25.60	33.07	213.36
90	55.92	144.84	98.42	82.30	295.28	27.43	35.43	228.60
96	59.65	154.50	104.99	87.78	314.96	29.26	37.80	243.84
100	62.14	160.94	109.36	91.44	328.08	30.48	39.37	254.00

Example: 2 inches = 5.08 cm

Table 125.—Continued

One unit (below) ↓ Equals →	mm	cm	meters	km
mm (millimeters)	1.	0.1	0.001	0.000,001
cm (centimeters)	10.	1.	0.01	0.000,01
meters	1,000.	100.	1.	0.001
km (kilometers)	1,000,000.	100,000.	1,000.	1.

One unit (below) ↓ Equals →	gm	kg	metric ton
gm (gram)	1.	0.001	0.000,001
kg (kilograms)	1,000.	1.	0.001
metric ton	1,000,000.	1,000.	1.

UNITS OF CENTIMETERS

cm	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.10
Inch	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.31	0.35	0.39

FRACTIONS OF AN INCH

Inch	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
cm	0.16	0.32	0.48	0.64	0.79	0.95	1.11	1.27

Inch	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
cm	1.43	1.59	1.75	1.91	2.06	2.22	2.38	2.54

Table 125.—Continued

WEIGHT[1]

	metric ton[3] → short ton	short ton[2] → metric ton	kg → pounds	pounds → kilograms	grams → ounces	ounces → grams
1	1.10	0.91	2.20	0.45	0.04	28.4
2	2.20	1.81	4.41	0.91	0.07	56.7
3	3.31	2.72	6.61	1.36	0.11	85.0
4	4.41	3.63	8.82	1.81	0.14	113.4
5	5.51	4.54	11.02	2.67	0.18	141.8
6	6.61	5.44	13.23	2.72	0.21	170.1
7	7.72	6.35	15.43	3.18	0.25	198.4
8	8.82	7.26	17.64	3.63	0.28	226.8
9	9.92	8.16	19.84	4.08	0.32	255.2
10	11.02	9.07	22.05	4.54	0.35	283.5
16	17.63	14.51	35.27	7.25	0.56	453.6
20	22.05	18.14	44.09	9.07	0.71	567.0
30	33.07	27.22	66.14	13.61	1.06	850.5
40	44.09	36.29	88.18	18.14	1.41	1134.0
50	55.12	45.36	110.23	22.68	1.76	1417.5
60	66.14	54.43	132.28	27.22	2.12	1701.0
70	77.16	63.50	154.32	31.75	2.47	1984.5
80	88.18	72.57	176.37	36.29	2.82	2268.0
90	99.21	81.65	198.42	40.82	3.17	2551.5
100	110.20	90.72	220.46	45.36	3.53	2835.0

Example: Convert 28 pounds to kg

28 pounds = 20 pounds + 8 pounds

From the tables: 20 pounds = 9.07 kg and 8 pounds = 3.63 kg

Therefore, 28 pounds = 9.07 kg + 3.63 kg = 12.70 kg

[1] The weights used for the English system are avoirdupois (common) weights.

[2] The short ton is 2000. pounds.

[3] The metric ton is 1000. kg.

Table 125—Continued

VOLUME

cu. meters ——————————————————→ cu. ft → cu. yd

cu. yd ——————————→ cu. ft → cu. meters

cu. ft → cu. yd → cu. meters

cu. ft	cu. yd	cu. meters				
		cu. yd	cu. ft	cu. meters		
				cu. meters	cu. ft	cu. yd
1	0.037	0.028	27.0	0.76	35.3	1.31
2	0.074	0.057	54.0	1.53	70.6	2.62
3	0.111	0.085	81.0	2.29	105.9	3.92
4	0.148	0.113	108.0	3.06	141.3	5.23
5	0.185	0.142	135.0	3.82	176.6	6.54
6	0.212	0.170	162.0	4.59	211.9	7.85
7	0.259	0.198	189.0	5.35	247.2	9.16
8	0.296	0.227	216.0	6.12	282.5	10.46
9	0.333	0.255	243.0	6.88	317.8	11.77
10	0.370	0.283	270.0	7.65	353.1	13.07
20	0.741	0.566	540.0	15.29	706.3	26.16
30	1.111	0.850	810.0	22.94	1059.4	39.24
40	1.481	1.133	1080.0	30.58	1412.6	52.32
50	1.852	1.416	1350.0	38.23	1765.7	65.40
60	2.222	1.700	1620.0	45.87	2118.9	78.48
70	2.592	1.982	1890.0	53.52	2472.0	91.56
80	2.962	2.265	2160.0	61.16	2825.2	104.63
90	3.333	2.548	2430.0	68.81	3178.3	117.71
100	3.703	2.832	2700.0	76.46	3531.4	130.79

Example: 3 cu. yd = 81.0 cu ft

Volume: The cubic meter is the only common dimension used for measuring the volume of solids in the metric system.

APPENDIX I
REFERENCES

1. ARMY REGULATIONS (AR)

AR 10–5	Corps of Engineers.
AR 105–30	Joint Use of ICAO Phonetic Alphabet.
AR 105–31	Message Preparation.
AR 320–50	Authorized Abbreviations and Brevity Codes.
AR 385–63	Safety Regulations for Firing Ammunition for Training, Target Practice, and Combat.
AR 525–8	Use of Metric System for Linear Measurement in United States Army Operations.

2. DA PAMPHLETS (DA PAM)

DA PAM 30–107	Coast and Landing Beach Intelligence.
DA Pam 310–1	Military Publications: Index of Administrative Publications.
DA Pam 310–3	Military Publications: Index of Training Publications.
DA Pam 310–4	Index of TM's, TB's, SB's, LO's, and MWO's.
DA Pam 310–5	Military Publications: Index of Graphic Training Aids and Devices.
DA Pam 310–7	Military Publications: Index of TO&E's, TO's, and TA's.

3. SPECIAL REGULATIONS (SR)

SR 385–10–20	Administration of Army Safety Program.
SR 420–510–1	Fire Prevention and Protection.

4. FIELD MANUALS (FM)

FM 3–5	Chemical, Biological, Radiological (CBR) Operations.
FM 3–8	Chemical Corps Reference Handbook.
FM 3–10	Chemical and Biological Weapons Employment.
FM 3–12	Operational Aspects of Radiological Defense.
FM 5–1	Engineer Troop Organizations and Operations.
FM 5–13	The Engineer Soldier's Handbook.
FM 5–15	Field Fortifications.
FM 5–20	Camouflage Basic Principles and Field Camouflage.
FM 5–21	Camouflage of Fixed Installations.
FM 5–22	Camouflage Materials.
FM 5–23	Field Decoy Installations.

FM 5-25	Explosives and Demolitions.
(S) FM 5-26	Employment of Atomic Demolitions Munitions (ADM) (U).
FM 5-30	Engineer Intelligence.
FM 5-31	Use and Installations of Boobytraps.
FM 5-35	Engineer Reference and Logistical Data.
FM 5-36	Route Reconnaissance and Classification.
FM 6-135	Adjustment of Fire by the Combat Soldier.
FM 10-13	Quartermaster Reference.
FM 20-22	Vehicle Recovery Operations.
FM 20-32	Land Mine Warfare.
FM 21-5	Military Training.
FM 21-6	Techniques of Military Instruction.
FM 21-10	Military Sanitation.
FM 21-26	Map Reading.
FM 21-30	Military Symbols.
FM 21-31	Topographic Symbols.
FM 21-40	Small Units Procedures in Chemical, Biological, and Radiological (CBR) Operations.
FM 21-41	Soldier's Handbook for Chemical and Biological Operations and Nuclear Warfare.
FM 21-60	Visual Signals.
FM 21-76	Survival.
FM 24-1	Tactical Communications Doctrine.
FM 24-18	Field Radio Techniques.
FM 30-5	Combat Intelligence.
FM 31-10	Barriers and Denial Operations.
FM 31-60	River Crossing Operations.
FM 31-70	Basic Cold Weather Manual.
FM 31-71	Northern Operation.
FM 55-15	Transportation Reference Data.
FM 101-10	Staff Officers' Field Manual: Organizational, Technical, and Logistical Data, Part I

5. TECHNICAL MANUALS (TM)

TM 3-220	CBR Decontamination.
TM 5-200	Camouflage Nets and Net Sets.
TM 5-210	Military Floating Bridge Equipment.
TM 5-216	Armored Vehicle Launched Bridge.
TM 5-220	Passage of Obstacles Other Than Minefields.

TM 5-232	Elements of Surveying.
TM 5-233	Construction Surveying.
TM 5-258	Pile Construction.
TM 5-270	Cableways, Tramways, and Suspension Bridges.
TM 5-277	Panel Bridge, Bailey Type, M2.
TM 5-279	Suspension Bridges for Mountain Warfare.
TM 5-280	Foreign Mine Warfare Equipment.
TM 5-297	Wells.
TM 5-302	Construction in the Theater of Operations.
TM 5-311	Military Protective Construction.
TM 5-312	Military Fixed Bridges.
TM 5-315	Firefighting.
TM 5-330	Planning, Site Selection, and Design of Roads, Airfields, and Heliports in the Theater of Operations.
TM 5-331	Management; Utilization of Engineer Construction Equipment.
TM 5-332	Pits and Quarries.
TM 5-335	Drainage Structures, Subgrades, and Base Courses.
TM 5-337	Bituminous, Concrete, and Expedient Paving Operations.
TM 5-342	Logging and Sawmill Operation.
TM 5-349	Arctic Construction.
TM 5-461	Engineer Handtools.
TM 5-541	Control of Soils in Military Construction.
TM 5-617	Roofing; Repairs and Utilities.
TM 5-618	Painting; Repairs and Utilities.
TM 5-624	Roads, Runways, and Miscellaneous Pavements; Repairs and Utilities.
TM 5-700	Field Water Supply.
TM 5-725	Rigging.
TM 5-742	Concrete and Masonry.
TM 5-9541	AN/PRS Mine Detecting Set.
TM 9-1375	Demolition Materials.
TM 9-1910	Military Explosives.

APPENDIX II

DIMENSIONS OF VEHICLES

Nomenclature	Class empty	Width inches	Height inches
Towed Artillery			
Howitzer, light, towed: 105-mm, M101 or M101A1........	4	84.5	62.
Howitzer, light, towed: 105-mm, M102....	2	76.0	62.75
Howitzer, medium, towed: 155-mm, M114 and M114A1....	9	96.	71.
Howitzer, medium, towed: 155-mm, auxiliary propelled, M123A1................	9	110.	81.
Howitzer, heavy, towed: 8-inch, M115....	21 *	112.	108.
Tractors, Trucks and Truck Tractors			
Truck, ambulance: ¾-ton, 4 x 4, M43.................	3	73.	92.
Truck, cargo: ¾-ton, 4 x 4, M37 and M3781, w/and w/o winch..	3	73.5	87.
Truck, cargo: 2½-ton, 6 x 6, M135, w/and w/o winch..	6	88.	80.
Truck, cargo: 2½-ton, 6 x 6, M34, w/and w/o winch...	5	88.	109.
Truck, cargo: 2½-ton, 6 x 6, M35, w/and w/o winch...	5	96.	112.
Truck, cargo: 2½-ton, 6 x 6, M36 and M36C, w/and w/o winch..	6	96.	124.5
Truck, cargo: 2½-ton, 6 x 6, M211, w/and w/o winch...	6	96.	112.5
Truck, cargo: 5-ton, 6 x 6, M41, w/ and w/o winch....	9	96.	111.5
Truck, cargo: 5-ton, 6 x 6, M54, w/ and w/o winch....	9	97.	116.
Truck, cargo: 5-ton, 6 x 6, M55, w/ and w/o winch....	10	96.	117.5
Truck, cargo: 10-ton, 6 x 6, M125 w/winch...........	14	114.	129.5
Truck, cargo dump: 2½-ton, 6 x 6, M342, w/ and w/o winch..	7	96.	101.
Truck, dump: 2½-ton, 6 x 6, M59, w/ and w/o winch..	6	....	103.
Truck, dump: 2½-ton, 6 x 6, M215, w/ and w/o winch.	7	96.	108.
Truck, dump: 5-ton, 6 x 6, M51, w/ and w/o winch.....	10	97.	111.
Truck tank: gasoline, 2½-ton, 6 x 6, 1,200-gal, M49 and M49C....................	6	95.5	97.5
Truck, tank: gasoline, 2½-ton, 6 x 6, 1,200-gal, M217 and M217C..............................	7	96.	102.
Truck, tank: water, 2½-ton, 6 x 6, 1,000-gal, M50, w/ and w/o winch........................	7	95.	97.

See footnote end of appendix II.

DIMENSIONS OF VEHICLES—Continued

Nomenclature	Class empty	Width inches	Height inches
Tractors, Trucks and Truck Tractors—Continued			
Truck, tractor: 2½-ton, 6 x 6, M48, w/ and w/o winch.	6	93.5	97.5
Truck, tractor: 2½-ton, 6 x 6, M221, w/ and w/o winch.	5	96	102.
Truck, tractor: 5-ton, 6 x 6, M52, w/ and w/o winch...	11	97.	103.5
Truck, tractor: 10-ton, 6 x 6, M123 and M123C..........	18	114.	113.
Truck, tractor: 12-ton, 6 x 6, M26, M26A1, and M26A2..	28	130.5	123.
Tractor, full tracked, high speed: 18-ton, M4, M4A1, M4A1C, M4A2..................................	13	97.	108.
Tractor, full tracked, high speed: M8A1, and M8A2......	21	130.5	120.
Truck, wrecker: crane, 2½-ton, 6 x 6, M108, w/winch...	9	96.0	99.0
Truck, wrecker: light, 2½-ton, 6 x 6, M60, w/winch.....	11	96.	100.
Truck, wrecker: medium, 5-ton, 6 x 6, M62, w/winch....	16	97.	102.5
Truck, cargo: 1¼-ton, 4 x 4, XM676..................	2	78.	91.
Truck, ambulance: 1¼-ton, 4 x 4, XM679..............	2	78.	94.1
Tanks, Self-Propelled Weapons, and Personnel Carriers			
Gun, anti-aircraft artillery, self-propelled: twin 40-mm, M42 and M42A1..................................	20	127.	112.5
Gun, antitank, self-propelled: 90-mm, M56.............	6	101.5	81.
Gun, field artillery, self-propelled: 155-mm, M53 (T97)...	42	141.	140.
Gun, field artillery, self-propelled: 175-mm, M107, (T235E1)	29	124.	137.
Howitzer, heavy, self-propelled: full tracked, 8-inch, M55 (T108)..	41	141.	146.
Howitzer heavy, self-propelled: 8-inch, M110 (T236E1)...	27	124.	116.
Howitzer, light, self-propelled: full tracked, 105-mm, M37	18	118.	95.
Howitzer, light, self-propelled: full tracked, 105-mm, M52 and M52A1..................................	23	124.	131.
Howitzer, light, self-propelled: 105-mm, T195E1 and M108	20 *	130.	124.5
Howitzer, medium, self-propelled: full tracked, 155-mm, M44 and M44A1..................................	27	128.	127.
Howitzer, medium, self-propelled: 155-mm, T19E1 and M109..	24 *	130.	124.5
Mortar, infantry, self-propelled: full tracked, 107-mm (formerly 4.2-inch), M84........................	19	128.5	109.

See footnote end of appendix II.

DIMENSIONS OF VEHICLES—Continued

Nomenclature	Class empty	Width inches	Height inches
Tanks, Self-Propelled Weapons, and Personnel Carriers—Continued			
Rifle, self-propelled, full-tracked: multiple, 106-mm, M50	8	102.5	84.
Tank, combat, full tracked: 76-mm, M41, M41A1, M41A2, and M41A3	21	126.	121.5
Tank, combat, full tracked: 90-mm gun, M47	45	138.5	116.5
Tank, combat, full tracked: 90-mm gun, M48 and M48C	46	148.	128.
Tank, combat, full tracked: 90-mm gun, M48A1	46	143.	123.5
Tank, combat, full tracked: 105-mm gun, M60 and M60A1	45	143	126.5
Tank, combat, full tracked: 120-mm gun, M103 and M103A1	57	148.	113.5
Tank, combat, full tracked: flamethrower, M67A1	51	143.	123.5
Tank, combat, full tracked: 90-mm gun, M48A2 w/dozer blade	54	....	....
Carrier, personnel, full tracked: armored, M59	18	128.5	104.
Carrier, personnel, full tracked: armored, M75	17	112.	119.
Carrier, personnel, full tracked: armored, M113	9 *	106.	79.5
Carrier, personnel, full tracked: armored M114A1	7	91.75	91.0
Recovery vehicle, full tracked: heavy, M51	54	143.	129.
Recovery vehicle, full tracked: medium, M74	51	122.	133.5
Recovery vehicle, full tracked: light, armored, M578	25	124.	130.5
AVLB Launcher w/bridge folded M-48	60	158.	157
AVLB launcher w/bridge folder M-60	58	158.	159
Trailers			
Dolly, trailer converter: 18-ton, 4-wheel, M199	4	114.75	59.
Semitrailer, low-bed: wrecker, 12-ton, 4-wheel M270 and M270A1	8	....	....
Semitrailer, low-bed: 15-ton, 4-wheel, M172	6	....	....
Semitrailer, tank: gasoline, 12-ton, 4-wheel, 5,000 gal, M131, M131A1, and M131A2	7	....	....
Semitrailer, tank transporter: 45-ton, 8-wheel, M15A1	16	....	....
Semitrailer, van: cargo, 12-ton, 4-wheel, M128A1 and M128A1C, M129A1	6	....	....
Semitrailer, van: cargo, 6-ton, 2-wheel, M119 and M119A1	4	....	....

See footnote end of appendix II.

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DIMENSIONS OF VEHICLES—Continued

Nomenclature	Class empty	Width inches	Height inches
Trailers.—Continued			
Trailer, cargo: ¾-ton, 2-wheel, M101	1	72.	83.
Trailer, cargo: 1½-ton, 2-wheel, M104, M104A1, and M104A2	2	83.	99.1
Trailer, low-bed: guided missile, 7-ton, 4-wheel, XM529..	6	....	....
Pershing			
Carrier, missile equipment, full tracked: XM474E2	5		

* Class for cross country.

APPENDIX III

FOREIGN CONVERSION FACTORS

Denominations	Where used	American equivalents
Almude	Portugal	4.422 gals.
Ardeb	Egypt	5.6188 bu.
Are	Metric	0.02471 acre.
Arr't'l or li'ra	Portugal	1.0119 lbs.
Arroba	Argentine Republic	25.32 lbs.
Arroba	Brazil	32.38 lbs.
Arroba	Cuba	25.36 lbs.
Arroba	Paraguay	25.32 lbs.
Arroba	Venezuela	25.40 lbs.
Arroba (liquid)	Cuba, Spain and Venezuela	4.263 gals.
Arshine	Russia	28 in.
Arshine (sq.)	Russia	5.44 sq. ft.
Artel	Moracco	1.12 lbs.
Baril	Argentine Republic	20.077 gals.
	and Mexico	20.0787 gals.
Barrel	Malta (customs)	11.2 gals.
Berkavets	Russia	361.128 lbs.
Bangkal	Fed. Malay States	832 grains.
Bauw	Sumatra	7,096.5 sq. metrs.
Bu	Japan	0.12 inch.
Bushel	British Empire	1.03205 U.S. bu.
Caffisa	Malta	5.40 gals.
Candy	India (Bombay)	569 lbs.
Candy	India (Madras)	500 lbs.
Cantar	Egypt	99.05 lbs.
Cantar	Moracco	112 lbs.
Cantar	Turkey	124.45 lbs.
Cantara	Malta	175 lbs.
Cast, Metric	Metric	3.086 grains.
Catty	China	1.333⅓ lbs.
Catty	Japan	1.32 lbs.
Catty	Java, Malacca	1.36 lbs.
Catty	Thailand	2⅔ lbs.
Catty (stand)	Thailand	1.32 lbs.
Catty	Sumatra	2.12 lbs.
Centara	Central America	4.2631 gals.
Centner	Brunswick	117.5 lbs.
Centner	Bremen	127.5 lbs.

FOREIGN CONVERSION FACTORS—Continued

Denominations	Where used	American equivalents
Centner............	Denmark, Norway...........	110.23 lbs.
Centner............	Prussia....................	113.44 lbs.
Centner............	Sweden....................	93.7 lbs.
Centner............	Double or metric	220.46 lbs.
Chetvert	Russia.....................	5.957 bu.
Ch'ih..............	China......................	12.60 inches.
Ch'ih (metric).......	China......................	1 meter.
Cho...............	Japan......................	2.451 acres.
Comb..	England....................	4.1282 bu.
Coyan............	Thailand...................	2,645.5 lbs.
Cuadra............	Argentine Republic..........	4.2 acres.
Cuadra............	Paraguay...................	94.70 yds.
Cuadra (sq.)........	Paraguay...................	1.85 acres.
Cuadra............	Uruguay....................	1.82 acres.
Cubic meter........	Metric.....................	35.3 cu. ft.
Cwt. (hund. weight)..	British.....................	112 lbs.
Dessiatine..........	Russia.....................	2.6997 acres.
Fanega (dry)........	Ecuador, Salvador...........	1.5745 bu.
Fanega............	Chile......................	2.75268 bu.
Fanega............	Guatemala, Spain...........	1.53 bu.
Fanega............	Mexico.....................	2.57716 bu.
Fanega (double).....	Uruguay....................	7.776 bu.
Fanega (single).....	Uruguay....................	3.888 bu.
Fanega............	Venezuela..................	3.334 bu.
Fanega (liquid).....	Spain......................	16 gals.
Feddan............	Egypt......................	1.04 acres.
Frail (rais's)........	Spain......................	50 lbs.
Frasco............	Argentine Republic.	2.5098 liq. qts.
Frasco............	Mexico.....................	2.5 liq. qts.
Frasila	Zanzibar...................	35 lbs.
Fuder.............	Luxemburg.................	264.18 gals.
Funt......	Russia.....................	0.9028 lb.
Gallon............	British Empire.............	1.20094 U.S. gal.
Garnice............	Poland	1.0567 gal.
Gram.............	Metric.....................	15.432 grains.
Hectare...........	Metric.....................	2.471 acres.
Hectalitre: Dry......	Metric.....................	2.838 bu.
Hectalitre: Liquid	Metric.....................	26.418 gals.

FOREIGN CONVERSION FACTORS—Continued

Denominations	Where used	American equivalents
Jarib	Persia (New)	2.471 acres.
Joch	Austria (Germany)	1.422 acres.
Joch	Hungary	1.067 acres.
Ken	Japan	5.97 feet.
Kilogram kilo	Metric	2.2046 lbs.
Kilometre	Metric	0.62137 mile.
Klafter	Austria (Germany)	2.074 yds.
Koku	Japan	5.119 bu.
Kwamme	Japan	8.2673 lbs.
Last	Belgium, Netherlands	85.134 bu.
Last	England	82.56 bu.
Last	Germany	2 metric tons. (4.409 + lbs.).
Last	Prussia	112.29 bu.
Last	Scotland, Ireland	82.564 bu.
League (land)	Paraguay	4.633 acres.
Li	China	1,890 ft.
Libra (lb.)	Argentine Republic	1.0128 lbs.
Libra	Central America	1.014 lbs.
Libra	Chile	1.014 lbs.
Libra	Cuba	1.0143 lbs.
Libra	Mexico	1.01467 lbs.
Libra	Peru	1.0143 lbs.
Libra	Uruguay	1.0143 lbs.
Libra	Venezuela	1.0143 lbs.
Litre	Metric	1.0567 liq. qts.
Litre	Metric	0.90810 dry qts.
Livre (lb.)	Greece	1.1 lbs.
Livre	Guiana (Dutch)	1.089 lbs.
Load, timber	England	50 cu. ft.
Lumber (std.)	in Europe	165 cu. ft., or 1,980 ft. b. m.
Manzana	Nicaragua	1.742 acres.
Manzana	Costa Rica, Salvador	1.727 acres.
Marc	Bolivia	0.507 lb.
Maund	India	82 2-7 lbs.
Metre	Metric	39.37 inches.
Mil	Denmark	4.68 miles.
Mil (geographic)	Denmark	4.61 miles.
Milla	Nicaragua	1.1594 miles.

FOREIGN CONVERSION FACTORS—Continued

Denominations	Where used	American equivalents
Milla	Honduras	1.1493 miles.
Mina (old)	Greece	2.202 lbs.
Morgen	Prussia	0.63 acre.
Oke	Egypt	2.8052 lbs.
Oke (Ocque)	Greece	2.82 lbs.
Oke	Turkey	2.828 lbs.
Pic	Egypt	22.83 inches.
Picul	Borneo and Celebes	135.64 lbs.
Picul	China	133⅓ lbs.
Picul	Java	136.16 lbs.
Picul	Philippine Republic	139.44 lbs.
Pie	Argentine Republic	0.94708 foot.
Pie	Spain	0.91416 foot.
Pik	Turkey	27.9 inches.
Pood	Russia	36.113 lbs.
Pund (lb)	Denmark	1.102 lbs.
Quart	British Empire	1.20094 liq. qt.
Quart	British Empire	1.03205 dry qt.
Quarter	Great Britain	8.256 bu.
Quintal	Argentine Republic	101.28 lbs.
Quintal	Brazil	120.54 lbs.
Quintal	Castile, Peru	101.43 lbs.
Quintal	Chile	101.41 lbs.
Quintal	Mexico	101.47 lbs.
Quintal	Metric	220.46 lbs.
Rottle	Israel	6.35 lbs.
Sack (flour)	England	280 lbs.
Sagene	Russia	7 feet.
Salm	Malta	8.2 bu.
Se	Japan	0.02451 acre.
Seer	India	2 2-35 lbs.
Shaku	Japan	11.9303 inches.
Sho	Japan	1.91 liq. quarts.
Skalpund	Sweden	0.937 lbs.
Stone	British	14. lbs.
Sun	Japan	1.193 inches.
Tael Kuping	China	575.64 grs. (troy).
Tan	Japan	0.25 acre.

FOREIGN CONVERSION FACTORS—Continued

Denominations	Where used	American equivalents
Tchetvert	Russia	5.96 bu.
To	Japan	2.05 pecks.
Ton	Space measure	40 cu. ft.
Tonde cereals	Denmark	3.9480 bu.
Tonde Land	Denmark	1.36 acres.
Tonne	France	2204.62 lbs.
Tsubo	Japan	35.58 sq. ft.
Tsun	China	1.26 inches.
Tunna (wheat)	Sweden	4.5 bu.
Tunnland	Sweden	1.22 acres.
Vara	Argentine Republic	34.0944 inches.
Vara	Costa Rica, Salvador	32.913 inches.
Vara	Guatemala	32.909 inches.
Vara	Honduras	32.953 inches.
Vara	Nicaragua	33.057 inches.
Vara	Chile and Peru	32.913 inches.
Vara	Cuba	33.386 inches.
Vara	Mexico	32.992 inches.
Vedra	Russia	2.707 gals.
Verst	Russia	0.663 mile.
Vlaka	Poland	41.50 acres.
Wey	Scotland and Ireland	41.282 bu.

INDEX

By Order of the Secretary of the Army:

HAROLD K. JOHNSON,
General, United States Army,
Chief of Staff.

Official:

J. C. LAMBERT,
Major General, United States Army,
The Adjutant General.

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For explonotion of abbreviotions used, see AR 320–50.

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