Reference

S/S Sep 76

FM 5–34
C 2

Change No. 2

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, D.C., *24 May 71*

ENGINEER FIELD DATA

FM 5–34, 12 December 1969, is changed as follows:

Page 374, Paragraph 12–6a is superseded as follows:

12–6. ATTACHMENTS

a. *Clips.* Clips are used in making eyes in wire rope. The correct method of attaching clips is shown in figure 12–8. The base of each clip should bear against the live, or long rope, end; and the U-bolt should bear against the dead, or short, end. The number and spacing of clips and the proper torque to be applied are shown in table 12–6.1.

By Order of the Secretary of the Army:

W. C. WESTMORELAND,
General, United States Army,
Chief of Staff.

Official:

VERNE L. BOWERS,
Major General, United States Army,
The Adjutant General.

Distribution:

To be distributed in accordance with DA Form 12–11 requirements for Engineer Field Data.

FM 5-34
C 1

CHANGE NO. 1

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., 16 December 1970

ENGINEER FIELD DATA

FM 5-34, 12 December 1969, is changed as follows:

Page 374. Paragraph 12-6a is superseded as follows:

12-6. ATTACHMENTS

a. **Clips**. Clips are used in making eyes in wire rope. The correct method of attaching clips is shown in figure 12-8. The base of each clip should bear against the dead, or short, end. The number and spacing of clips and the proper torque to be applied are shown in table 12-6.1

Page 374.1. Table 12–6.1 is added as follows:

Table 12–6.1. Number, Size, Spacing, and Torque of Clips Necessary to Assemble Wire Rope Eye-Loop Connections with a Probable Efficiency of Not Greater Than 80 Percent.

Wire rope diameter (inch)	(mm)	Nominal size of clips (inch)	Number of clips	Spacing of clips (inches)	(mm)	Torque to be applied to nuts of clips (ft–lb)	(m–kg×0 1382)
$\frac{5}{16}$	(7.95)	$\frac{3}{8}$	3	2	(50)	25	(3.5)
$\frac{3}{8}$	(9.52)	$\frac{3}{8}$	3	$2\frac{1}{4}$	(57)	25	(3.5)
$\frac{7}{16}$	(11.11)	$\frac{1}{2}$	4	$2\frac{3}{4}$	(70)	40	(5.5)
$\frac{1}{2}$	(12.70)	$\frac{1}{2}$	4	3	(76)	40	(5.5)
$\frac{5}{8}$	(15.85)	$\frac{5}{8}$	4	$3\frac{3}{4}$	(95)	65	(9.0)
$\frac{3}{4}$	(19.05)	$\frac{3}{4}$	4	$4\frac{1}{2}$	(114)	100	(14)
$\frac{7}{8}$	(22.22)	1	5	$5\frac{1}{4}$	(133)	165	(23)
1	(25.40)	1	5	6	(152)	165	(23)
$1\frac{1}{4}$	(31.75)	$1\frac{1}{4}$	5	$7\frac{1}{2}$	(190)	250	(35)
$1\frac{3}{8}$	(34.92)	$1\frac{1}{2}$	6	$8\frac{1}{4}$	(210)	375	(52)
$1\frac{1}{2}$	(38.10)	$1\frac{1}{2}$	6	9	(230)	375	(52)
$1\frac{3}{4}$	(44.45)	$1\frac{3}{4}$	6	$10\frac{1}{2}$	(267)	560	(78)

Note: The spacing of clips should be six times the diameter of the wire rope. To assemble end-to-end connection the number of clips indicated above should be increased by two, and the proper torque indicated above should be used on all clips; U-bolts are reversed at the center of connection so that the U-bolts are on the dead (reduced load) end of each wire rope.

By Order of the Secretary of the Army:

W. C. WESTMORELAND,
General, United States Army,
Chief of Staff.

Official.

KENNETH G. WICKHAM,
Major General, United States Army,
The Adjutant General.

Distribution:

To be distributed in accordance with DA Form 12-11 requirements for Engineer Field Data.

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Ch/, 2.

*FM 5–34

FIELD MANUAL
NO. 5–34

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., 12 December 1969

ENGINEER FIELD DATA

*This manual supersedes FM 5–34, 30 December 1965.

CHAPTER 1

INTRODUCTION

Section I. Purpose and Scope

1–1. PURPOSE

The purpose of this manual is to provide pertinent data in a convenient format for officers and noncommissioned officers at the platoon level.

1–2. SCOPE

a. *Contents.* Data has been condensed on a wide variety of subjects pertinent to the duties of engineer unit personnel, particularly officers and noncommissioned officers.

b. *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 will be provided for each comment to insure understanding and proper evaluation. Comments should be prepared using DA Form 2028 (Recommended Changes to Publications) and forwarded direct to the Commandant, U.S. Army Engineer School, Fort Belvoir, Virginia 22060.

Section II. References

1–3. MANUALS

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

1–4. STANDARD AGREEMENTS

Information in this manual reflects the application of Standard NATO Agreements (STANAG) and Standardization of Operations and Logistics (SOLOG) Agreements.

CHAPTER 2

EXPLOSIVES AND DEMOLITIONS

Section I. Introduction

2–1. CHARACTERISTICS OF EXPLOSIVES

See table 2–1 for the principal types of U.S. explosives commonly used for military purposes.

a. *Detonating velocity*. See table 2–1.

b. *Relative effectiveness factor.*

(1) The formulas used in this chapter give the weight of explosive (P) required for a demolition task in pounds of TNT.

(2) 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 2–1, column 4.

(3) *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.

(4) This adjustment is *not* used for rules of thumb.

(5) For further details see FM 5–25.

c. *Rounding-Off Rule.*

(1) When using explosives, 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.

(2) For charges calculated by formula, use the following round-off steps:

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

(*b*) Use the relative effectiveness factor, if required.

(c) Round off answer for one charge to next package size.

(*d*) Multiply answer for one charge by the number of charges to obtain the total explosive required.

Table 2–1. 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 non-electric	1.00	23,000	Good	Dangerous	Excellent	1 lb, 50 or 56 to box
Tetrytol, M1, M2			1.20	23,000	Fair	Dangerous	Excellent	16 2½-lb blocks in wooden box
Composition C3 M3, M5			1.34	25,000	Excellent	Dangerous	Good	16 2½-lb blocks in wooden box
M5A1 Composition C4 M112			1.34	26,000	Excellent	Slight	Excellent	24 2½-lb blocks in wooden box
Ammonium nitrate (cratering charge)	Cratering and ditching	Special blasting cap, electric or nonelectric	0.42	14,800	Excellent	Dangerous	Poor	40-lb charge in metal can
Sheet explosive M186, M118 charge demolition	(See C–4)	(See C–4)	1.14	24,000	Poor	Slight	Excellent	80 ½-lb sheets/box 25-lb roll

Table 2–1. Characteristics of Principal U.S. Explosives—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	
Military dynamite M1	Quarrying stumping-ditching	(See C–4)	0.92	20,000	Good	Dangerous	Good	½-lb 100 to box	
Straight dynamite (Commercial) 40% 50% 60%	Land clearing, cratering, quarrying, and general use in rear areas, such as ditching and stumping	No. 6 commercial cap, electric or nonelectric	0.65 0.79 0.83	15,000 18,000 19,000	Good	Dangerous	Poor Good Excellent	102 103 106	Sticks per 50 lb box
Ammonia dynamite (Commercial) 40% 50% 60%			0.41 0.46 0.53	8,900 11,000 12,700	Excellent	Dangerous	Good Good Good	110 110 110	Sticks per 50 lb box
Gelatin dynamite 40% 50% 60%			0.42 0.47 0.76	8,000 9,000 16,000	Good Good Good	Slight	Good Very Good Very Good	130 120 110	Sticks per 50 lb box
PETN	Detonating cord	Special blasting cap, electric or nonelectric	1.66	20,000 24,000	NA	Slight	Good		
	Blasting cap	NA							

Table 2–1. Characteristics of Principal U.S. Explosives—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
Tetryl	Booster charge	Special blasting cap, electric or nonelectric	1.25	23,400	NA	Dangerous	Excellent	
Composition B	Bangalore torpedo	Special blasting cap, electric or nonelectric	1.35	25,000	Good	Dangerous	Excellent	Bulk
Amatol 80/20	—do—	Special blasting cap, electric or nonelectric	1.17	16,000	Excellent	Dangerous	Poor	Bulk
Black Powder	Time blasting fuze	NA	0.55	1310 Max Depends on Confinement	Fair	Dangerous	Poor	Bulk
Nitrostarch	Substitute for TNT	Special blasting cap, electric or nonelectric	0.80	15,000	Good	Dangerous	Satisfactory	1-lb blocks

2-2. SAFETY

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

b. Always handle explosives carefully.

c. 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.

d. See table 2-2 for minimum safe distances.

e. For further information, see AR 385-63.

f. Do not mix explosives and detonators.

g. Handle misfires with extreme care.

h. Do not take chances.

Table 2-2. 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

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

2-3. FIRING SYSTEMS

Firing systems for explosives are illustrated in figure 2-1. A nonelectric detonating ossembly is shown in figure 2-2.

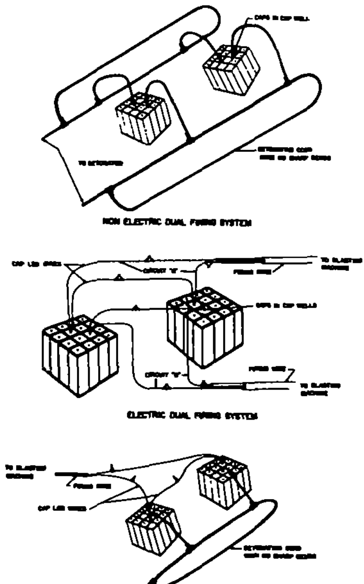


Figure 2-1. Firing systems for explosives.

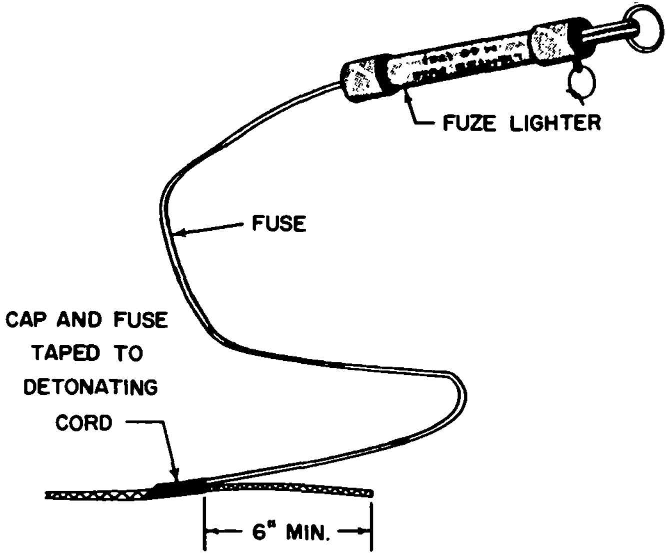


Figure 2–2. Nonelectric detonating assembly.

Section II. Calculation of Charges

2–4. STEEL-CUTTING CHARGES

a. *Formula for structural steel.* Charges to cut I-beams, built-up girders, steel plates, columns, and other structural steel sections are computed by formula as follows:

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

P = pounds of TNT

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

b. Formula for other steels.

(1) The formula below is recommended for the computation of cutting charges for high-carbon or alloy steel, such as that found in machinery.

$P = D^2$
P = pounds of TNT
D = diameter or thickness in inches of section to be cut.

(2) For concrete reinforcing rods, chains, cables and other mild steel items of a diameter of 2 inches or less, use the following rule of thumb:

1 inch or less = 1 lb TNT
Over 1 inch to 2 inches = 2 lb TNT
Over 2 inches = $P = \frac{3}{8} A$

(3) Railroad rails that are 5 inches in height may be cut with 1 pound of TNT. For rails less than 5 inches in height $\frac{1}{2}$ pound is adequate.

c. *Example:*

(1) Calculate the amount of TNT required to cut the steel wide-flange section (fig. 2–3).

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. $\times$ 11in. $= 4\frac{1}{8}$ 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
(P is rounded up to next higher package size.)

(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 2–3? 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 2–1), the amount of C–4 $= \frac{3.42}{1.34} = 2.55$ pounds. Use 3 pounds of C–4.

d. Example. How much TNT is required to cut the steel chain in figure 2–4?

Calculation: $D = \frac{7}{8}$ inch. (Diameter is less than 1 in. therefore use rule of thumb b(2) above.)
P = 1 lb. of TNT

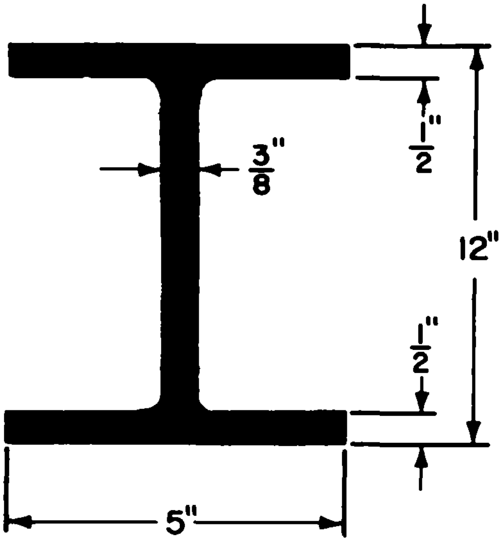


Figure 2–3. Wide flange section.

Use 1 pound of TNT ot A ond 1 paund at B ta destray the chain link.

e. *Table*. See table 2–3 for omount af TNT required to cut different rectangular steel sectians.

f. *Advanced Techniques*. These charges are based on the use of plastic explosive (C4), especially the M112 block which may be ottached directly to the target surface. Sheet explosives (M118 ond M186) may may alsa be used provided thot charges ore ot least ½ inch thick. These chorges may also be prepored in advance far tronsportation to the demolition site. Plostic explasive must be cut to the proper dimensions nat malded.

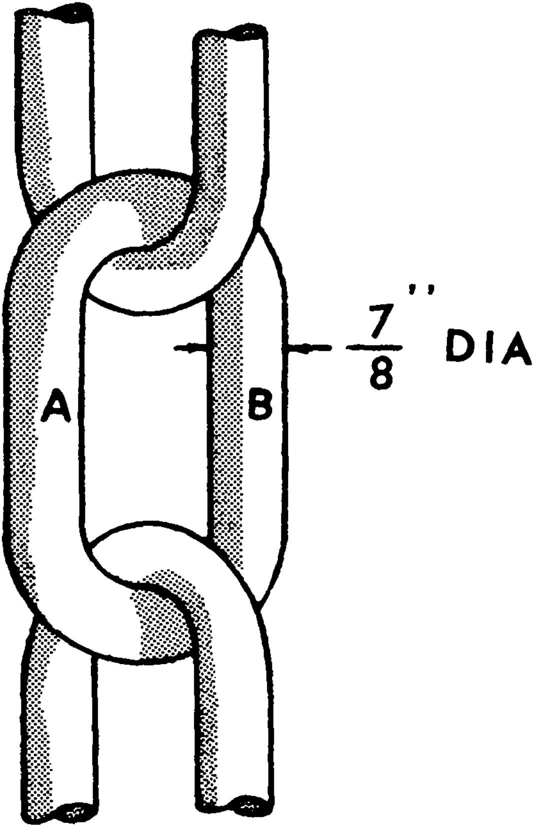


Figure 2–4. Steel chain.

Table 2–3. 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
1/4	.2	.3	.4	.5	.6	.8	1.0	1.2	1.3	1.5	1.7	1.9	2.3
3/8	.3	.5	.6	.7	.9	1.2	1.4	1.7	2.0	2.3	2.6	2.8	3.4
1/2	.4	.6	.8	1.0	1.2	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.5
5/8	.5	.7	1.0	1.2	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.7	5.7
3/4	.6	.9	1.2	1.4	1.7	2.3	2.8	3.4	4.0	4.5	5.1	5.7	6.8
7/8	.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.

(1) *Ribbon charge*. This charge, if properly calculated and placed, cuts steel with considerably less explosive than standard charges. It is effective on noncircular steel targets (figs. 2–5 and 2–6).

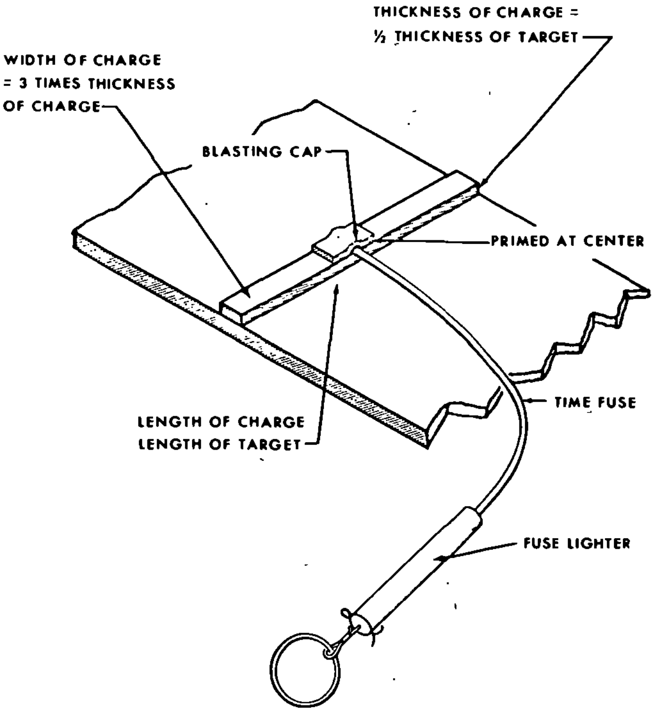


Figure 2–5. Ribbon charge.

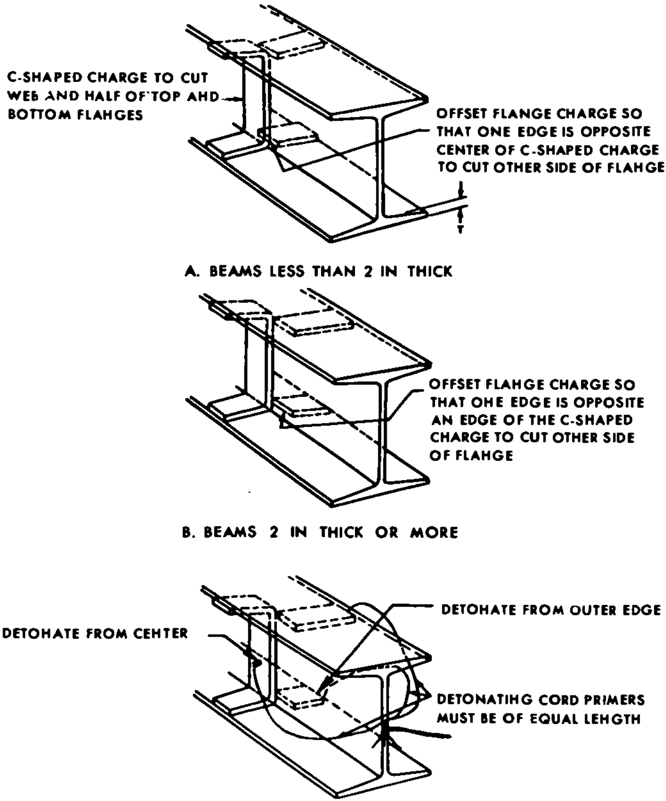


Figure 2—6. Placement of ribbon chorges on structural steel sections.

(2) *Diamand charge.* This is used an high carban steel ar steel allay targets (fig. 2–7). It is shaped like a diamond.

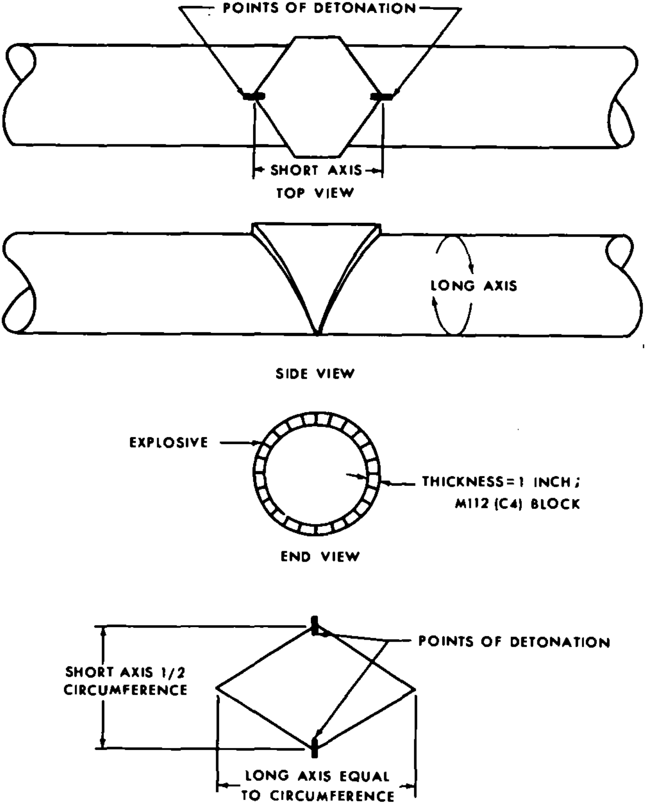


Figure 2–7. Diamand charge.

(3) *Saddle charge.* This charge is used on solid cylindrical mild steel targets up to 8 inches in diameter. Detonation is initiated at the apex of the long axis (fig. 2–8).

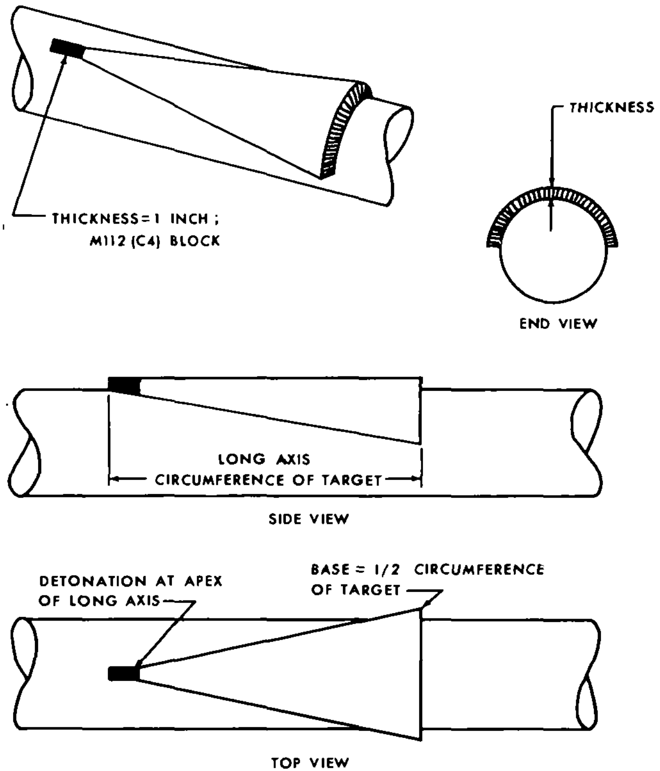


Figure 2–8. Saddle charge.

2–5. TIMBER-CUTTING CHARGES

a. *Test shots.* 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.

b. *Formulas.*

(1) *For untamped external charges.* To cut trees, piles, posts, beams, or other timber, the following formula gives a test shot.

$$P = \frac{D^2}{40} \text{ or } P = 0.025\ D^2$$

when P = pounds of TNT required and

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

$\frac{1}{40} = 0.025 =$ constant.

For other explosives, adjustments for P are made according to paragraph 2–1*b*. See figure 2–9 for placement of charge.

(2) *For tamped internal charges.* The following formula gives a test shot:

$$P = \frac{D^2}{250} \text{ or } P = 0.004\ D^2$$

where P = pounds of explosive (any type)

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

$\frac{1}{250} = 0.004 =$ constant

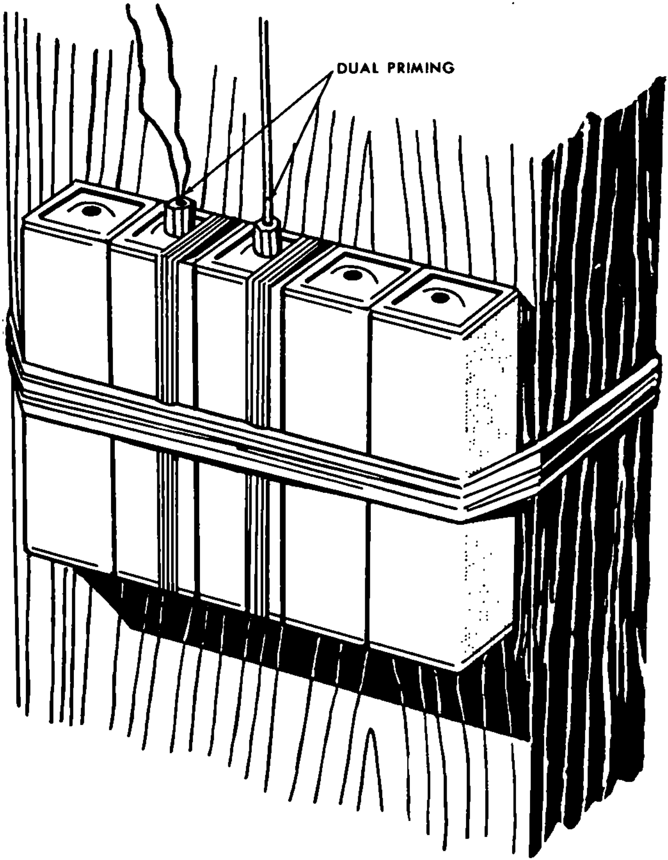


Figure 2–9. Placement of external cutting charge on timber.

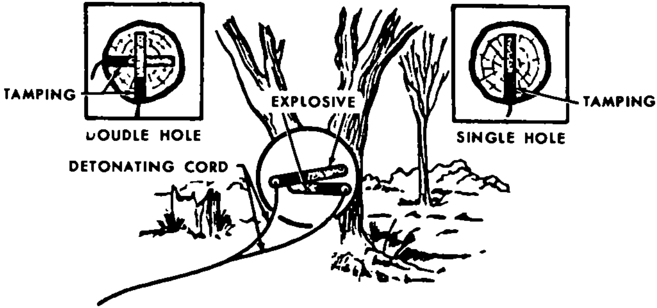


Figure 2–10. Internal timber-cutting charge.

See figure 2–10 for placement of charge.

(3) *For cutting trees to create an abatis.* To cut trees and leave them attached to their stumps, the following formula gives a test shot.

$$P=\frac{D^2}{50} \text{ or } P=0.02\,D^2$$

where P = pounds of TNT needed for external charges

D = diameter of timber in inches and

$\frac{1}{50}=0.02=$ constant.

For other explosives, adjustments are made according to paragraph 2–1*b*.

c. *Calculations by table.* Use table 2–4 as a guide for both internal and external timber cutting test charges.

Table 2–4. 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

2–6. 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 beam

H = height of beam (including thickness of roadway) in feet, and

T = thickness of beam 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 foot in the formula. A minimum of 10 inches of tamping surrounding the charge is required. For other explosives, adjustments are made according to paragraph 2–1*b*

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 2–11? The amount is calculated in figure 2–11.

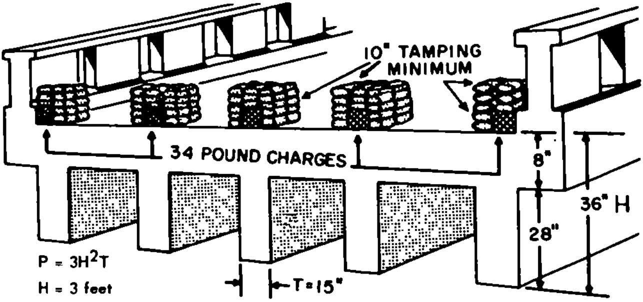


Figure 2–11. Calculation and placement of pressure charges.

e. *Continuous Bridge Spans.* For concrete stringer bridges of continuous spans, charges are calculated by the breaching formula (para 2–8*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.

f. Table. Use table 2–5 for calculation of pressure charges for simple span reinforced concrete T-beams.

2–7. 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. (Blasted road craters will not stop modern tanks indefinitely, because repeated attempts by the tank to traverse the crater will pull loose soil from the slopes of the crater into the bottom reducing both the depth of the crater and angle of the slopes. Road craters are considered effective antitank obstacles if the tank requires three or more passes to traverse the crater, thereby providing sufficient time for antitank weapons to stop the tank. Road craters 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

Table 2–5. 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

crater. Road craters angled at about 45° to the roadway are more effective obstacles than craters blasted perpendicular to the roadway. See also c below.

b. Hasty Road Crater. Hasty road craters blasted with boreholes less than 5 feet deep and loaded with less than 50-lb explosive charges are ineffective against modern tanks. For placement and size of charges see figure 2–12.

c. *Deliberate Road Crater.* See figure 2–13.

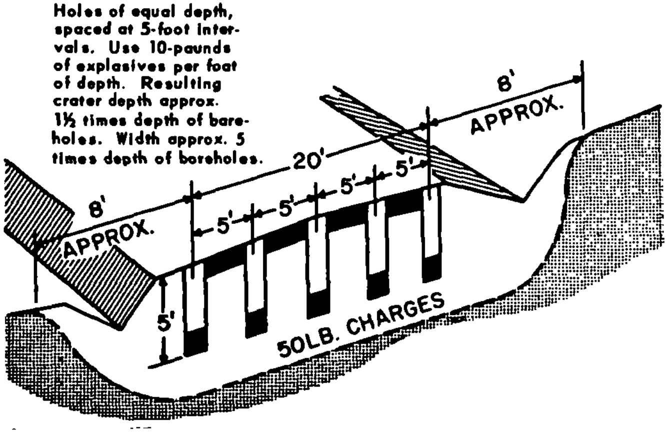


Figure 2–12. Plocement of chorges for hosty road crater.

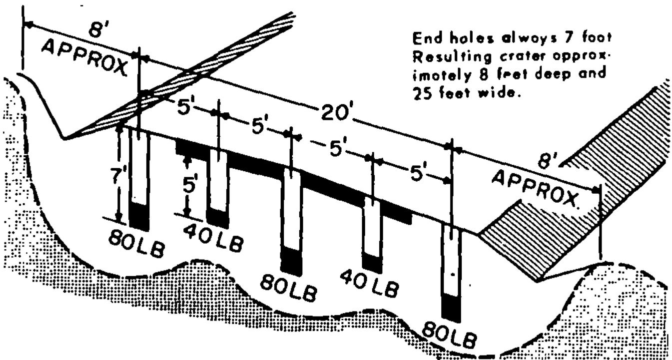


Figure 2–13. Plocement of chorges for deliberate rood crater.

d. Relieved Face Crater. The 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 placement and size of charge, see figure 2–14.

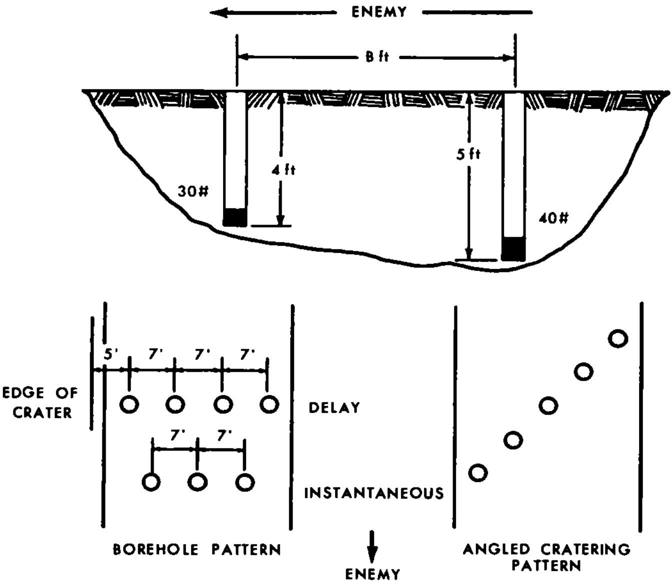


Figure 2–14. Relieved face crater.

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 stap on enemy tank. It may be impraved by placing o log hurdle an the enemy side, by plocing the spails in the friendly side, ond by digging the face in the friendly side verticol.

f. Rules of Thumb.

(1) To insure against misfires, all ommonium nitrote cratering charges must hove an additionol primer, a one-paund chorge placed on top af each can and incorporoted into a dual firing system (figs. 2–1 and 2–2).

(2) Rule of thumb for number of hales required for a hasty ond o deliberate raad croter is:

$$N=\frac{L-16}{5}+1$$

Where L is the tatal length af the blown crater.

(3) Rules of thumb for number af holes in a relieved face crater ore:

Friendly side

$$N=\frac{L-10}{7}+1$$

Where L is the tatal length of the blown crater

Enemy side

N = Number on friendly side minus one.

2–8. BREACHING CHARGES

o. Use. Breoching chorges have their mast importont use in the destruction of bridge piers, bridge abutments, ond field fortifications of a permonent type, or in breaching wolls and blawing holes in concrete slabs ar roadways.

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

P = pounds of TNT required

R = breaching rodius in feet, highest $\frac{1}{2}$ faat increment

K = moteriol foctor (table 2–6) which indicotes strength and hardness af material to be demolished (when it is not known whether or not concrete is reinfarced, it is ossumed ta be reinforced).

C = tomping foctar (fig. 2–15)

Nate. For externol chorges, use at leost 5 pounds for reinfarced cancrete ond at least 3 pounds for dense concrete.

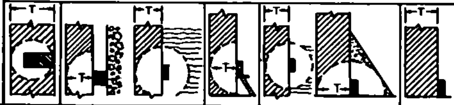
Table 2–6. Values of Material Factor K for Use in Calculating Breaching Charges

Formula $P(TNT) = R^3KC$

VALUES OF *K*

Material	*R*	*K*
Earth	All values	0.07
Poor masonry, shale, hardpan good timber and earth construction	Less than 5 ft	0.32
	5 ft or more	0.29
Good masonry concrete block rock	1 ft or less	0.88
	Over 1 ft to less than 3 ft	0.48
	3 ft to less than 5 ft	0.40
	5 ft to less than 7 ft	0.32
	7 ft or more	0.27
Dense concrete, first class masonry	1 ft or less	1.14
	Over 1 ft to less than 3 ft	0.62
	3 ft to less than 5 ft	0.52
	5 ft to less than 7 ft	0.41
	7 ft or more	0.35
Reinforced concrete (Concrete only, will not cut reinforcing steel)	1 ft or less	1.75
	Over 1 ft to less than 3 ft	0.96
	3 ft to less than 5 ft	0.60
	5 ft to less than 7 ft	0.63
	7 ft or more	0.54

Table 2-7. Breaching Charges, Reinforced Concrete Only

THICKNESS OF CONCRETE	METHODS OF PLACEMENT 					DISTANCE BETWEEN CHARGES	
						INTERNAL	EXTERNAL
FEET	POUNDS OF TNT					FEET	FEET
2	2	8	14	16	28	2	4
2½	2	15	27	30	54	2½	5
3	4	22	39	44	78	3	6
3½	6	35	62	69	124	3½	7
4	8	52	93	103	185	4	8
4½	11	73	132	146	263	4½	9
5	15	79	142	158	284	5	10
5½	20	105	189	210	378	5½	11
6	22	138	245	273	490	6	12
6½	28	173	312	346	623	6½	13
7	35	186	334	371	667	7	14
7½	43	228	410	456	821	7½	15
8	52	277	498	553	996	8	16

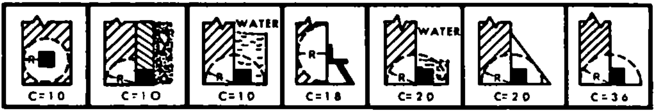
NOTES:

1. FOR BEST RESULTS PLACE CHARGE IN SHAPE OF A FLAT SQUARE.
2. FOR CHARGES LESS THAN 40 LBS USE CHARGE THICKNESS OF 2" (ONE BLOCK THICK); FOR CHARGES 40 LBS TO LESS THAN 300 LBS USE CHARGE THICKNESS OF 4" (ONE HAVERSACK THICK); FOR CHARGES 300 LBS OR MORE USE CHARGE THICKNESS OF 8" (TWO HAVERSACKS THICK).

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 GREATEST AMOUNT OF TNT.

* FOR OTHER TYPES OF CONSTRUCTION, SEE TABLE 2-8



NOTE: FOR WATER, IF THE BREACHING RADIUS IS GREATER THAN THE DEPTH OF WATER USE 2.0 IF EQUAL TO OR LESS USE 1.0

Figure 2–15. Values of Tamping Factor "C".

c. *Tables.* For reinforced concrete breaching, see table 2–7. See table 2–8 for the breaching of masonry items other than reinforced concrete.

*Table 2–8. Breaching Charges for Material Other Than Reinforced Concrete**

Conversion factors for material other than reinforced concrete		
Earth	Ordinary masonry, hardpan 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 2–7, 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 2–7) by the conversion factor from the table above.

*For reinforced concrete table 2–7.

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.

If the number of charges are 0 to less than $1\frac{1}{4}$, use 1 charge; $1\frac{1}{4}$ to less than $2\frac{1}{2}$, use 2 charges; $2\frac{1}{2}$ or more, round off to nearest whole number.

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:

$P = R^3KC, \quad R = 4, \quad K = .80, \quad C = 3.6$
$P = (4)^3 \times (.80) \times (3.6) = 184.3$ pounds, use 185 pounds of TNT.

Number of charges:

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

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

(2) How many pounds of TNT are required to breach a timber and earth wall $6\frac{1}{2}$ feet thick and an explosive charge placed at the base of the wall without tamping? The conversion factor is 0.5 (table 2–8). If this wall were made of reinforced concrete, 623 pounds of TNT would be required to breach it (table 2–7). Multiply 623 pounds of TNT by 0.5 and the result is 312 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 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 2–9 shows the size of boreholes obtained by using the standard shaped charges.

h. Advanced Techniques. Counterforce charge. This technique is very effective against comparatively small cubical concrete and masonry objects and columns 4 feet or less in thickness and width. The amount of explosive is calculated as follows:

$P = 1\frac{1}{2} \times$ thickness of target in feet ($1\frac{1}{2}$ pounds per foot).

Fractional measurements are rounded off to the next higher foot prior to multiplication.

The calculated amount of explosive is divided in half to make two identical charges. The two charges must be placed exactly opposite each other, primed at the exact rear center point, and detonated simultaneously for optimum results (fig. 2–16).

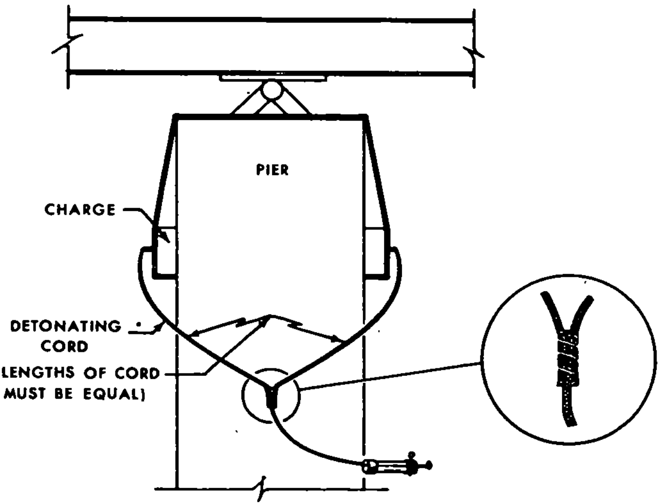


Figure 2–16. Counterforce charge.

Table 2–9. Size of Boreholes Made by Shaped Charges

Material	Information needed	M243 shaped charge	M3 shaped charge
Armor Plate	Penetration	12 in	At least 20 in
	Average Diameter of hole	1½ in	2½ in
Reinforced concrete	Maximum wall thickness that can be perforated	36 in	60 in
	Depth of penetration in thick walls	30 in	60 in
	Average diameter of hole	2¾ in	3½ in
	Minimum diameter of hole	2 in	2 in
10-inch concrete pavement with 21-inch rock base course	Optimum standoff	60 in	42 in
	Minimum depth of penetration	71 in	44 in
	Maximum depth of penetration	109 in	91 in
	Minimum diameter of hole	6¾ in	1¾ in
3-inch concrete pavement with 24-inch rock base course	Optimum standoff	—	42 in
	Minimum depth of penetration	—	38 in
	Maximum depth of penetration	—	90 in
	Minimum diameter of hole	—	3¾ in
Permafrost	Depth of hole with 30 inch standoff	72 in	—
	Depth of hole with 42 inch standoff	60 in	—
	Diameter of hole with 30 inch standoff	6 to 1½ in	—
	Depth of hole with 50 inch standoff	—	72 in
	Diameter of hole with 50 inch standoff	—	8 to 5 in
	Diameter of hole with normal standoff	26–30 to 4 in	26–30 to 7 in
Ice	Depth with 42 inch standoff	7 ft	12 ft
	Diameter with 42 inch standoff	3½ in	6 in

2-9. BRIDGE ABUTMENT DEMOLITION

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

o. *Abutments 5 Feet Thick or Less ond 20 Feet or Less in Height.* See figure 2–17 far details.

b. *Abutments More Than 5 Feet Thick and 20 Feet or Less in Height.* Place breaching charges in contact with the rear face of the abutment (fig. 2–18). Colculate the size and number of charges by the formula in figure 2–18. Charges are ploced ot o depth greater than or equol to *R*. The spacing between charges and number of charges ore determined by the calculations explained in paragraph 2–8.

c. *Abutments Over 20 Feet High.* Place a combinotion of external breaching charges (along bottom of the river face of the abutment) and fill charges (behind the obutment) to destroy obutments more thon 20 feet high. Fire them simultaneously. The fill chorges are either 40 pound charges, a above, or breaching charges, b above, 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

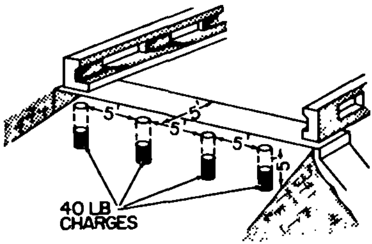


Figure 2–17. Charges placed in the fill behind a reinforced abutment less than 5 feet thick and 20 feet or less in height.

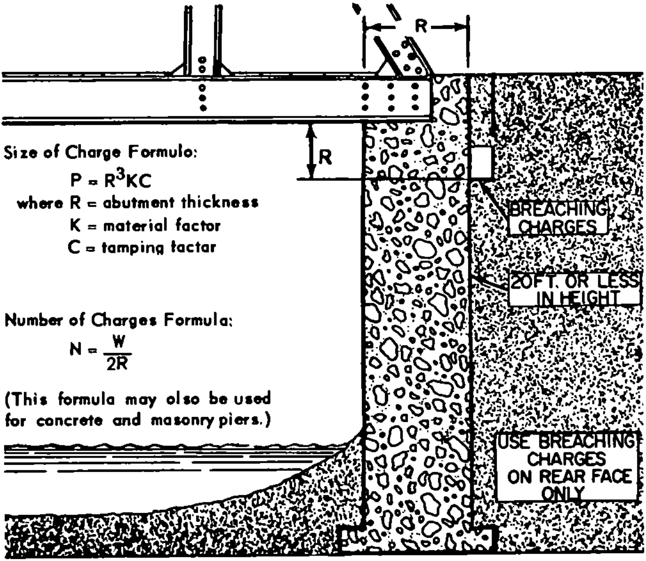


Figure 2–18. Charges in a fill behind a reinforced concrete abutment more than 5 feet thick and 20 feet or less in height.

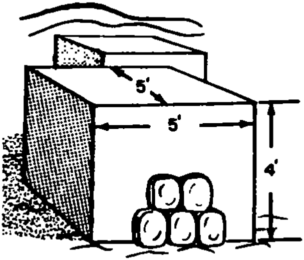
Section III. Destruction of Obstacles

2–10. CONCRETE OBSTACLES

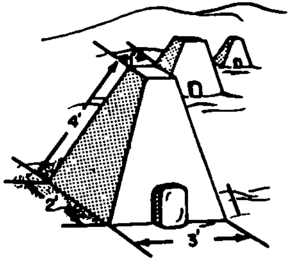
a. *Small Obstacles.* For small obstacles (100 ft^3 or less), such as those found on beaches, use hand-placed charges. As shown in figure 2–19, use 1 pound of military explosive, tetrytol or greater, per cubic foot of reinforced concrete.

b. *Large Obstacles.* For large obstacles (greater than 100 ft^3) use breaching formula (fig. 2–20).

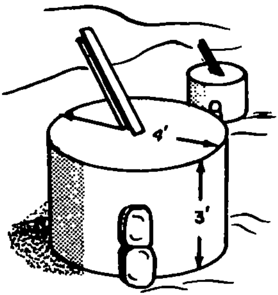
NOTE : SATCHEL CHARGES ARE USED TO DESTROY THESE OBSTACLES. IN COMPUTING THE NUMBER OF SATCHELS REQUIRED, ROUND UP TO THE NEXT FULL 20LB. SATCHEL.



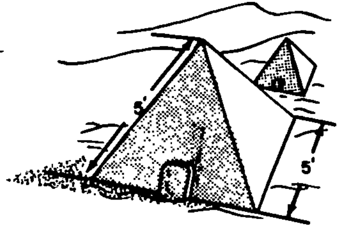
CUBE
CHARGE: 100 LB



SMALL DRAGON'S TOOTH
CHARGE: 20 LB



CYLINDER
CHARGE: 40LB.



TETRAHEDRON
CHARGE: 20 LB.

Figure 2—19. Explosive pocks needed to destroy typicol small concrete obstocles.

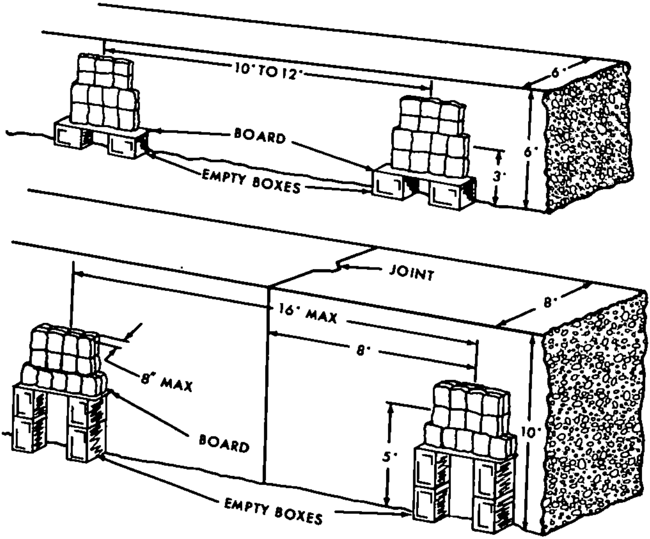


Figure 2–20. Placement of breaching charges on walls.

2–11. STEEL AND LOG OBSTACLES

a. *Placement.* The illustrations in figure 2–21 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.

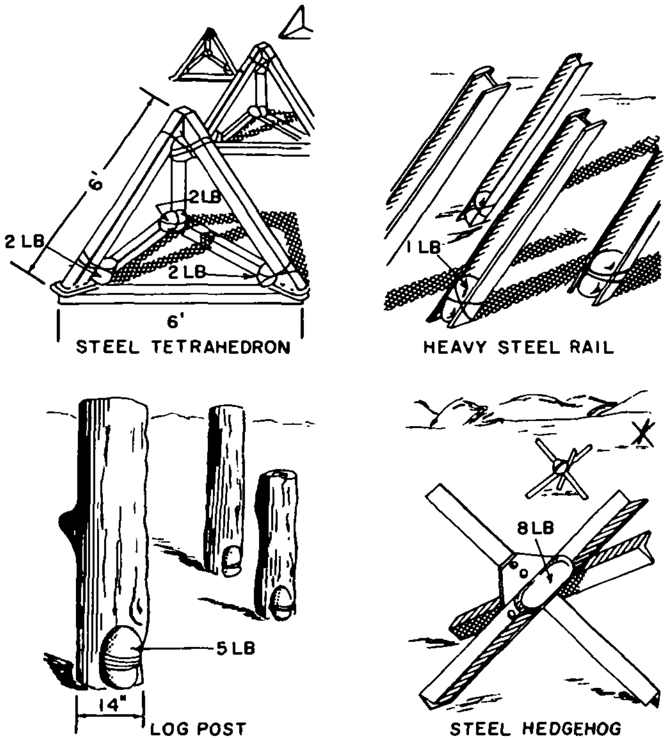


Figure 2–21. Placement of charges for destruction of steel and log obstacles.

2–12. WALLS

o. Cancrete *Walls Not Bockfilled.* Use the breoching formulo an walls. The positions, amounts, ond patterns of charges are shawn in figure 2–20.

b. Bockfilled Wolls.

(1) Concrete. Increase by 20 percent the charges specified for walls nat bockfilled. On some wolls where this may not be enaugh, use o secand shot or cleor with dazers or hond lobor.

(2) Logs. Place o 500-paund charge 10 feet lang an tap of the woll 2 feet from the fan (fig. 2–22).

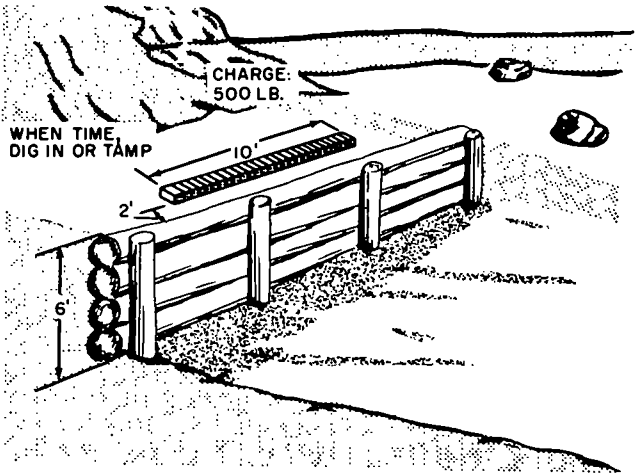


Figure 2–22. Breaching a bockfilled log wall.

Section IV. Construction Projects

2–13. QUARRYING

a. Quarry Development. Whenever possible, military quarries are opened on hillsides and warked parallel to the strike of the rack (fig. 2–23). Overburden is removed ta the right or left of this directian. The quarry may be developed as a single ar multiple bench operation depending an the total product required, expected duration of aperation, and the physical characteristics of the deposit.

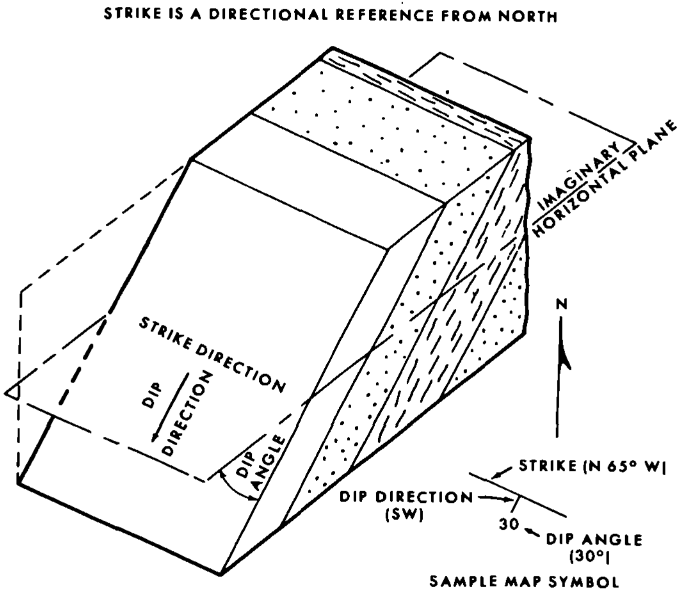


Figure 2–23. Measuring strike and dip.

b. Quarry Objectives. The major objectives of quarry operations are to reduce the product to the proper size for introduction into the rock crusher and to control the rock throw. To accomplish these objectives requires closely controlled blasting and an understanding of rock mechanics.

c. Borehole Orientation.

(1) The borehole pattern is governed by:

(*a*) the energy created by the explosive

(*b*) the resistance to fracture of the rock

(*c*) the diameter of the explosive charge

(2) Design of the borehole pattern involves six critical dimensions (fig. 2–24).

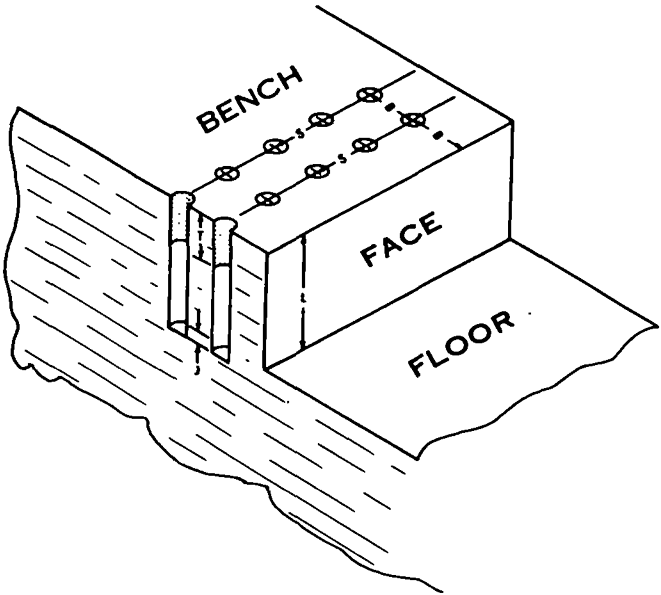


Figure 2–24. Critical quarry dimensions.

Table 2—10. Quarry Indicatars

INDICATORS	CAUSES: INADEQUATE PRIMING	SPACING		SUB. DRILLING		STEMING		LEDGE HEIGHT		BURDEN	
		TOO SMALL	TOO LARGE	TOO SMALL	TOO LARGE	TOO SMALL	TOO LARGE	TOO SMALL	TOO LARGE	TOO SMALL	TOO LARGE
EXCESSIVE FLYROCK		X						X		X	
PREMATURE EJECTION						X					
EXCESS OVERSIZE IN PRODUCT			X								X
EXCESS FINES IN PRODUCT		X						X		X	
OVERSIZE BOULDERS ON TOP OF PRODUCT PILE	X						X		X		
EXCESSIVE BACKBREAK(OVERBREAK)										X	
OVERHANGING LEDGE	X						X		X		
UNEXPLODED EXPLOSIVE TOP OF HOLE	X								X		
FLOOR HUMPS IN FRONT OF HOLES	X			X							
FLOOR HUMPS BETWEEN HOLES			X								
EXCESSIVE CRATERING IN FLOOR					X						

(*a*) Diameter of explosives.......................... D_e in inches
(b) Burden.. B in feet
(c) Ledge Height.................................... *L* in feet
(*d*) Subdrilling...................................... *J* in feet

(e) Stemming.. T in feet
(f) Spacing.. S in feet

d. Quarry Design. Field design of a borehole pattern which will produce acceptable results under normal conditions can be accomplished as follows: (See TM 5–332 for quarry design.)

(1) Determine diameter of explosive (D_e) governed by the size of the drill and explosives available; D_e usually is $2\frac{3}{4}$ inches for a 3-inch borehole.

(2) $B = 3.0\ D_e$ for normal conditions (i.e., dense explosive and average rock).

(3) $L = (1.5 \text{ to } 4.0)B$; L normally is governed by joints, seams, or topography of the site.

(4) $J = 0.3B$ for all vertical boreholes.

(5) $T = 0.5$ to $1.0B$ (Start with $0.75B$ and adjust as results demand).

(6) $S = (1.0 \text{ to } 2.0)B$ (Start with $1.2B$ and adjust as results demand).

e. Characteristics of Breakage. Table 2–10 gives certain cause-effect relationships encountered in blasting. An X in the indicator column signifies a possible cause. Read across the row to determine the possible cause. Correct the borehole pattern accordingly. Often more than one cause will give similar results. Then, further study of local conditions or a trial and error correction for the cause marked will be necessary.

2–14. BLASTING BOULDERS

a. Size of Charge. See table 2–11.

Table 2–11. Charges for Blasting Boulders

Boulder diameter, ft	Lbs of TNT required		
	Blockholing	Snakeholing	Mudcapping
$1\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$	1
2	$\frac{1}{8}$	$\frac{1}{2}$	$1\frac{1}{2}$
3	$\frac{1}{4}$	$\frac{3}{4}$	2
4	$\frac{3}{8}$	2	$3\frac{1}{2}$
5	$\frac{1}{2}$	3	6

b. Methods of Blosting. See figure 2–25 for details.

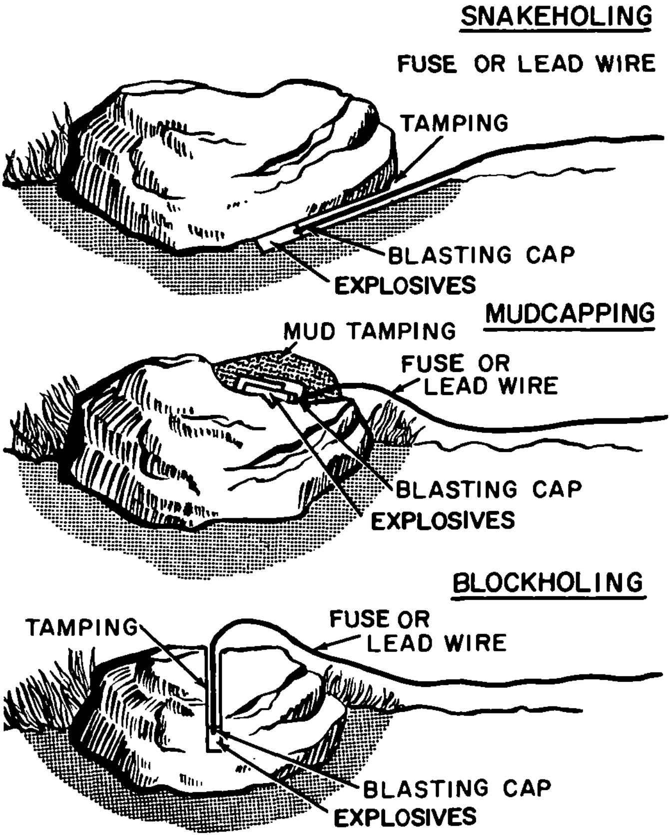


Figure 2–25. Methods of blosting boulders.

2–15. DITCHING

o. *Canditians.* Raugh, 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 sond. Trees, stumps, and lorge boulders are charged seporately, but are fired simultoneously with ditching charges.

b. Test Shots. Before beginning the ditching, run test shots ta determine the proper depth, spocing, and weight of chorges far desired results. Begin with holes 2 feet deep and 18 inches apart for small ditches and increase the charge and depth os required.

c. *Alinement ond Grade.* Mark ditch centerlines by chalk or transit line and holes along it. When survey instruments are used, the grade of the ditch can be accurately controlled by checking the hole depth every 5 or 10 hales ond each change in grode. Drill holes in soft ground with shorp punch ar quicksand punch (fig. 2–26). The depth of the hale normally is a foot above the grodeline of the ditch. Load ond tomp them immediately to prevent cove-ins and insure chorge is at proper depth.

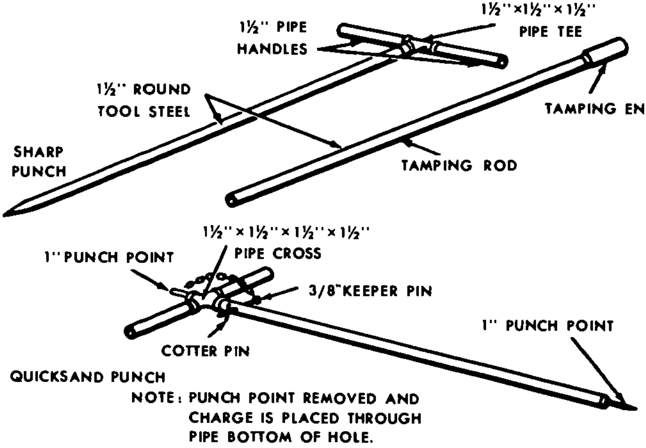


Figure 2–26. Punches used to place charges ot proper depth in soft ground.

d. *Detonotion Methods.*

(1) *Propogotion method.* Prime the hole, or holes, ot one end of the proposed ditch, concussion will set off the succeeding chorges, using stroight dynomite. It works in moist soils, porticulorly in swomps contoining stumps with the ground under severol inches of woter (fig. 2—27). If more thon one line of chorges is used to obtoin o wide ditch, eoch line is primed. Over-chorge the prime hole 1 or 2 pounds.

Note.. The propogotion method con be used only with 50 percent stroight, or greoter, commerciol dynomite.

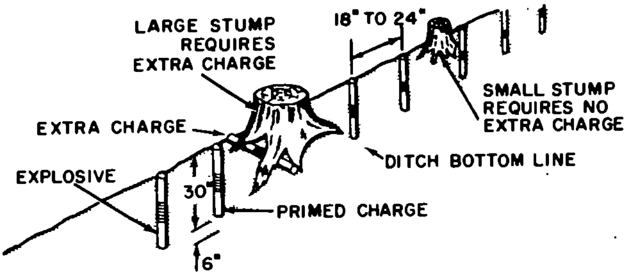


Figure 2—27. Propogotion method of detonotion.

(2) *Electricol method.* Use ony high explosive in this method of ditching, ond in ony soil except sond regordless of moisture. Prime eoch chorge with on electric cop. Blow oll chorges simultoneously.

(3) *Detonoting cord method.* Use ony high explosive with this method. This method is effective in ony soil except sond ond grovel, regordless of the omount of moisture. Eoch chorge is primed with detonoting cord ond connected to o ring moin.

e. *Looding Methods.*

(1) The method of looding for o deep, norrow ditch is pictured in figure 2—28

(2) The relief method of looding for shollow ditches is depicted in figure 2—29. Ditches 1 ond 3 ore blosted first to relieve the chorge in ditch 2.

(3) Figure 2—30 shows the posthole method of looding for shollow ditches in the mud.

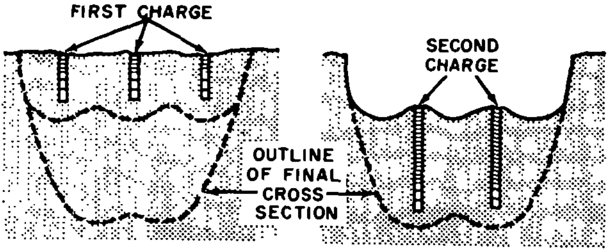


Figure 2–28. Method of loading a deep narrow ditch.

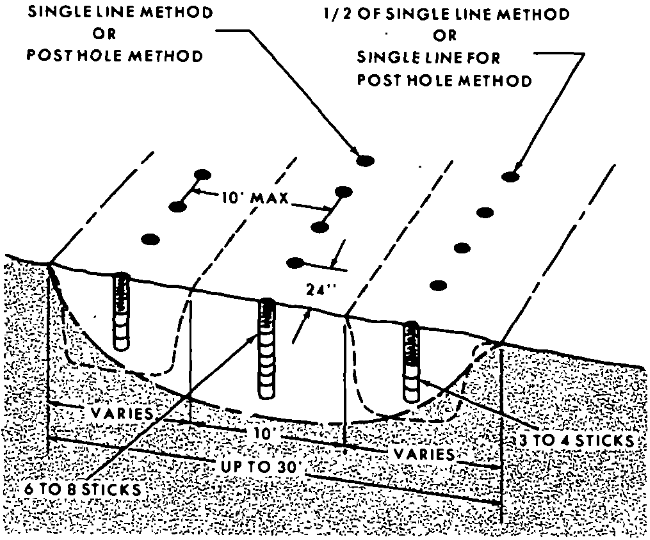


Figure 2–29. Relief method of loading for shallow ditches.

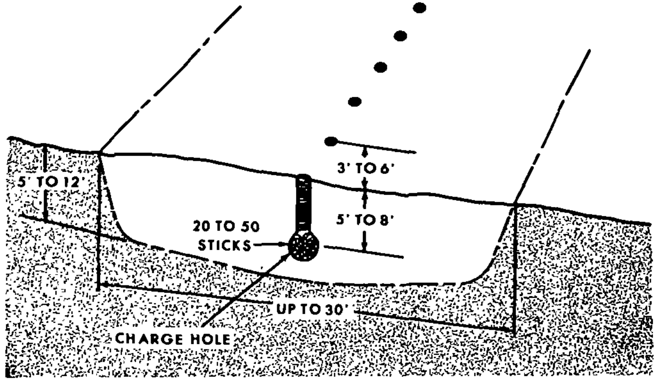


Figure 2—30. Post-hole method of looding for shollow ditches in mud.

(4) The cross section method of looding to cleon ond widen ditches is exploined grophicolly in figure 2—31.

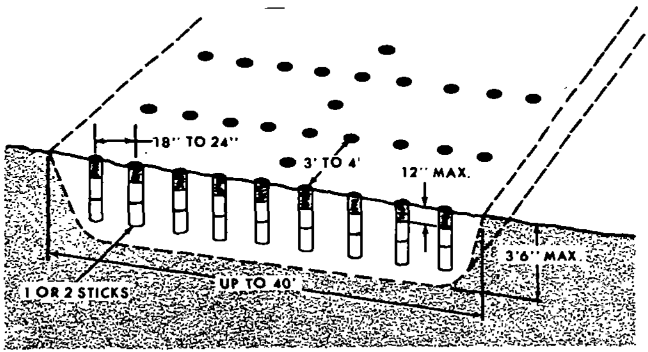
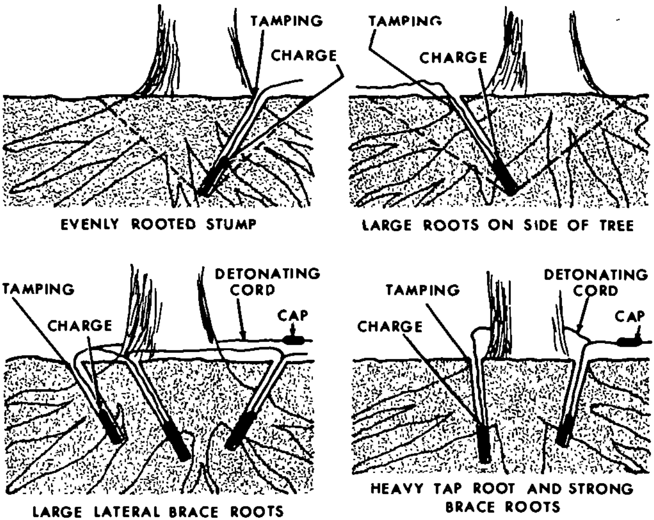


Figure 2—31. Cross section method of looding to cleon ond widen ditches.

2-16. BLASTING TREES AND STUMPS

a. *Size af Charge Required.* The size af the chorge required vories with the size, variety, and age af the tree or stump, and with the soil conditians. The rules af thumb, c below, and figure 2-31, show thot when militory dynamite is being used the size af the chorge varies with the size and oge of the tree. To remave stumps praperly, test shots ore required.

b. *Drilling Holes for Charge.* In drilling holes far the chorge, follow illustrotians in figure 2-32.



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 2-32. Stump blosting methods for vorious raot structures.

c. *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.

CHAPTER 3

LANDMINE WARFARE

Section I. Introduction

3-1. TYPES OF MINEFIELDS

Minefields are classified into five types according to their tactical function. They are protective (hasty and deliberate), defensive, barrier, nuisance, and phony.

3-2. PLANNING AND SITING

a. In planning minefields the commander must consider:

(1) Overall concept of operations.
(2) Probable future missions.
(3) Available resources.
(4) State of training of personnel.

b. The siting of minefields may be influenced by:

(1) Nature of enemy threat (mechanized, infantry, etc.).
(2) Location of other obstacles.
(3) Likely avenues of enemy approach.
(4) Terrain.
(5) Possibility of later expansion of field.
(6) Possibility of channeling the attacking force into mass-fire-covered areas.
(7) Possibility of laying many minefields in large scale patterns so that penetration of the foremost field is contained by subsequent fields.
(8) Enemy capabilities for breaching and harassing or interfering with mine laying.
(9) Availability of mines and restrictions on use of certain type mines.
(10) Experience of troops and materials available for mine laying.

3-3. TYPES OF MINES

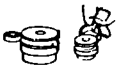
a. *Live Service Mines.* These include antitank mines, antipersonnel mines, and the M24 off-route mine. Live service mines are listed and described in table 3-1.

Table 3–1. Mine Data

M15 HEAVY ANTITANK MINE

	M1TR
Wt	30 lb
Expl	22 lb.
Fuze	M603
Secondary fuze wells	2
Functioning	300 to 400 lb press

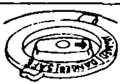
Remove plug and inspect fuze well



Inspect fuze and remove safety

Insert fuze

Replace plug with dial in safe position

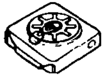


Turn dial to ARMED

To Bury Put mine in hole with pressure plate at or slightly above ground level

To Disarm Reverse arming procedure

M19 PLASTIC HEAVY ANTITANK MINE



Wt	28 lb
Explosive	21 lb
Fuze	M606 integral with pressure plate
Secondary fuze wells	2
Functioning	350 to 500 lb press

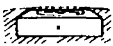
Remove pressure plate fuze

Remove shipping plug, check position of striker (offset) Remove safety fork then turn dial to ARMED position Check position of striker (center) *Turn to SAFE and* replace safety fork

Screw threaded detonator into detonator well

Place mine in hole remove safety fork, and turn dial to ARMED

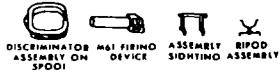
To Bury Put mine in hole with pressure plate at or slightly above ground level



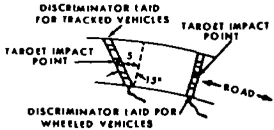
Complete camouflage

To Disarm Reverse arming procedure

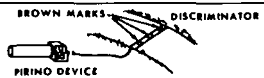
M24 OFF-ROUTE ANTITANK MINE



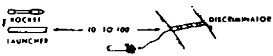
1 Remove above items from accessories pouch Insert batteries (issued separately) in firing device



2 Unreel discriminator starting at far side of road (perpendicular to edge for wheeled vehicles, about 15 from perpendicular for tracked vehicles)



3 Attach discriminator wire to DETECTOR of firing device (toggle switch on SAFE) Stand on two brown marks on discriminator nearest firing device If lamp lights, circuit is good, otherwise, discard system

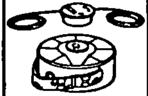


4 Disconnect discriminator wire from firing device Remove launcher from dispenser pouch and place in position Remove packing blocks push rocket forward to safety band, and remove band. Depress ejection pin and push rocket back into launcher until contact ring is exposed at base Grounding clip must be connected Remove tagged shorting clip and push rocket back into launcher Tape plastic covers over ends of launcher

5 Position launcher on bipod assembly or mound of earth Mount sighting assembly and sight along discriminator to target impact point about 39 above road (soldier's belt buckle) To aim move launcher not sight Fill pouches with dirt lay over launcher, recheck sight re connect discriminator wire to firing device (light out) connect rocket cable to firing device and push toggle switch to ARM The system is now armed and will fire when pressure is applied to the discriminator See TM 9 1345 200

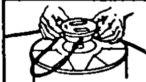
Table 3–1—Continued

M612 FUZE USED WITH M21 ANTITANK MINE

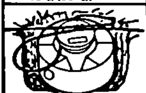


Has two 9 ft pneumatic hoses, safety latch and arming lever

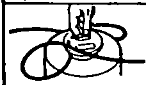
Remove closure plug and insert 120 booster



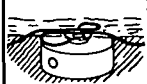
Remove shipping plug from mine. Screw in fuze



Bury mine. Cross and extend hoses



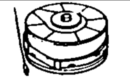
Lift safety latch and turn arming lever to ARMED. Recross hoses



Complete camouflage

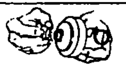
Timer provides a 30 5 minute safe separation period. Both hoses must be depressed for initiation.
To Disarm: Reverse arming procedure

M21 METALLIC (KILLER) ANTITANK MINE



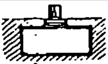
Wt	18 lb
Explosive	10.5 lb
Functioning	290 lb pressure on pressure ring or 20° deflection of tilt rod

Remove closing plug, insert M120 booster in bottom, and replace closing plug



Remove closure assembly from fuze

Remove shipping plug from mine and screw in fuze, then screw in tilt rod extension



Bury mine

Remove safety (pull ring assembly) and complete camouflage

To Bury: Pressure-put mine in hole with fuze cap flush with ground surface.

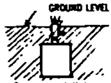
Tilt Rod mines should be seated firmly in snug fitting hole. Effective in tall brush or grass.

To Disarm: Reverse arming procedure

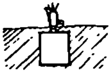
M16 SERIES BOUNDING ANTIPERSONNEL MINES

Wt	8.25 lb
Projectiles	Steel
Fuze	M605 Combination
Functioning	
Pressure	8 to 20 lb
Pull	3 to 10 lb.

Remove shipping plug and screw in fuze



Pressure installation



Trip wire installation

Attach trip wires—first to anchor, then to pull ring

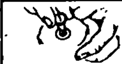
Remove locking safety pin first. The interlocking pin should fall free. Then remove positive safety

Mine bounds into air and explodes at height of 0.6 meters to 1.2 meters. Mine has a 10.6 meter casualty radius.

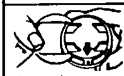
To Disarm: Reverse arming procedure

M14 BLAST ANTIPERSONNEL MINE

Wt	3½ oz.
Explosive	1 oz. TETRYL
Fuze	1 integral with Belleville Spring
Functioning	20 to 35 lb.

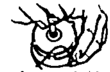


Unscrew shipping plug from bottom of mine. Turn pressure plate to ARMED position with arming tool



Remove safety clip and check for malfunctioning

Replace safety clip



Screw detonator into detonator well

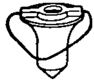
Bury mine and remove safety clip

To Bury: Pressure plate should be slightly above ground level.

To Disarm: Insert safety clip and remove detonator.
Caution: Do not turn pressure plate back to SAFE position as it causes excess wear.

Table 3–1 — Continued

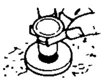
M25 BLAST ANTIPERSONNEL MINE (ELSIE)



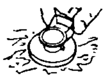
Wt	2¾ oz
Explosive	⅓ oz shaped charge
Fuze	integral with ball release
Functioning	18 to 26 lb press

Push mine into ground Keep dust cap in place If ground *is hard dig hole with bayonet*

Remove dust cap



Insert charge

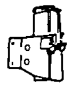


Remove safety clip

To Disarm Replace safety clip and lift charge container from mine

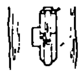
The M25 antipersonnel mine will penetrate a soldier's boot and foot or puncture a 12-ply tire and tube.

M49A1 TRIP FLARE

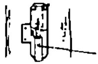


Burning period	55 to 70 sec
Illumination radius	302m (330 yd) (approx)

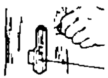
M49A1 initiates by taut or loose trip wire



Attach flare to post tree etc



Attach trip wire to anchor then to trigger Pull trigger to vertical position and secure



To Arm Remove safety clip

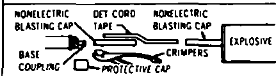
To Disarm Insert safety pin

Check both ends of trip wire and cut near trigger

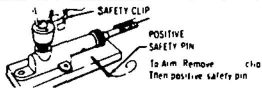
Warning **NEVER LOOK DIRECTLY AT BURNING FLARE**
Note For loose trip wire initiation, attach trip wire to eye of safety pin

M1A1 PRESSURE FIRING DEVICE

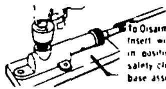
Initiating pressure 10 lb or more



Remove protective cap from base and crimp on nonelectric blasting cap Assemble det cord nonelectric blasting cap and firing device



To Arm Remove clip Then positive safety pin

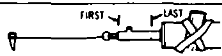


To Disarm Insert wire nail or original pin in positive safety hole Replace safety clip if available Unscrew base assembly from firing device

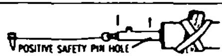
M1 PULL FIRING DEVICE

Initiating Action 3 to 5 lb pull on trip wire

Remove protective cap from standard base and crimp on nonelectric blasting cap Attach firing device assembly to charge Attach anchored trip wire



To Arm Remove locking safety pin first and positive safety pin last

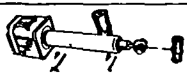


To Disarm Insert nail length of wire or original safety pin in positive safety pin hole first Then insert similar pin in locking safety pin hole Cut trip wire and separate firing device and explosive Unscrew standard base

Table 3-1 — Continued

M3 PULL-RELEASE FIRING DEVICE

Remove protective cap and crimp on a nonelectric blasting cap. Attach firing device assembly to anchored charge (must be firm enough to withstand pull of at least 6-10 lbs. pull on trip wire). Put free end of anchored trip wire in hole in winch with knurled knob. Draw up trip wire until locking safety is pulled into wide part of safety pin hole.

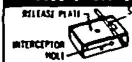


To Arm: With cord, remove small cotter pin from locking safety pin and withdraw locking safety pin. If it does not remove easily, adjust winch winding. With cord, pull out positive safety pin.

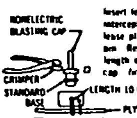
The M3 is too dangerous to disarm. It should be blown in place. If the device must be disarmed proceed as follows.

To Disarm: Insert length of wire, nail or original pin in positive safety pin hole first. Then insert length of wire, nail or original locking pin in locking pin hole. Disassemble trip wire, firing device and explosive.

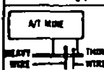
M5 PRESSURE RELEASE FIRING DEVICE



Initiating Action: Lifting ½" or removing restraining weight (5 lb or more).



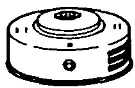
Insert length of 10 gage wire in interceptor hole and holding release plate down remove safety pin. Replace safety pin with length of No. 18 wire. Assemble cap, firing device and mine.



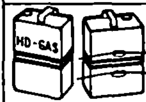
To Arm: Remove thin wire (locking safety) and then heavy wire (positive safety) from interceptor hole. Follow arming procedure carefully.

To Disarm: Insert length of heavy gage wire in interceptor hole. Bend wire to prevent dropping out. Proceed carefully, as the slightest disturbance of restraining weight may detonate mine. Disassemble firing device and mine.

M-23 AND M1, 1-GALLON CHEMICAL LANDMINES



When armed for pressure detonation, emplace in same manner as the M15 antitank mine.



M1 11 lb loaded has an 8 ft length of detonating cord for burster charge. May be armed for electric or trip wire actuation.

Electric Firing

Attach burster charge — 8 ft length of detonating cord — to side of mine.

Bury mine 4 in. and attach detonating cord to controlled firing system.

Non-Electric Firing

Bury mine as above and attach non-electric detonator to burster.

Warning: SOLDIERS PREPARING, LAYING AND REMOVING CHEMICAL LAND MINES MUST WEAR PROTECTIVE MASK AND PROTECTIVE CLOTHING.

M18A1 FRAGMENTATION ANTIPERSONNEL MINE

Wt	3.5 lb
Explosive	1.5 lb C4
Projectiles	700 steel balls

Equipment: One electric cap with 100 ft firing wires per mine. One circuit tester per 6 mines. One electric firing device per mine.

Test Circuit: Mate firing device, circuit tester and blasting cap. Depress handle. Light should show in window. Separate test components.

* Position and aim mine

Remove shipping plug priming adapter, insert blasting cap and screw into either cap well.

Unroll firing wire and connect directly to firing device with safety engaged.

Firing position: A minimum of 16 meters from rear of mine to fox hole. Friendly troops at side and rear should be under cover at a minimum of 100 meters.

To Fire: Disengage safety bail and depress handle.

To Disarm: Reverse arming procedure.

*Open sight mine aim at ground level at 150 ft *b. Training Mines.* These mines are used in training and on maneuvers The two types available are:

(1) *Practice mines.* These mines are blue with white lettering and resemble specific models or a basic type of service mine. Practice mines simulate detonation by o report and a puff of smoke.

(2) *Inert mines.* These are service mines painted either black with white letters or OD with black letters and contain no explosive components. They may be loaded with sand, plaster, concrete, and the like to familiarize troops with the weight and feel of live service mines.

c. *Flares.* Data on flares are found in table 3–1.

d. Antihandling Devices. Descriptions and methods of arming and disarming are found in table 3–1.

Section II. Minefield Installation

3–4. MINEFIELD CHARACTERISTICS

a. *Patterns.* The standard pattern minefield is shown in figures 3–1 and 3–2.

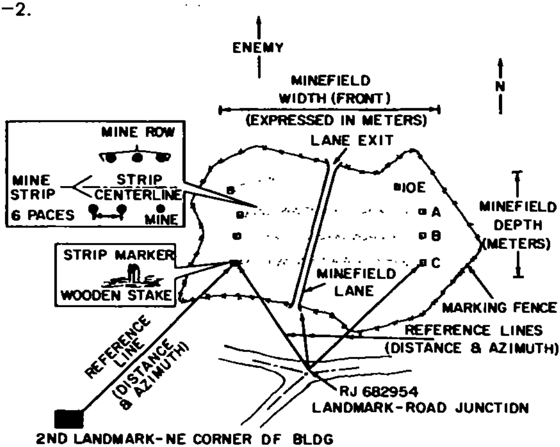


Figure 3–1. Standard pattern minefield fenced, marked, and referenced.

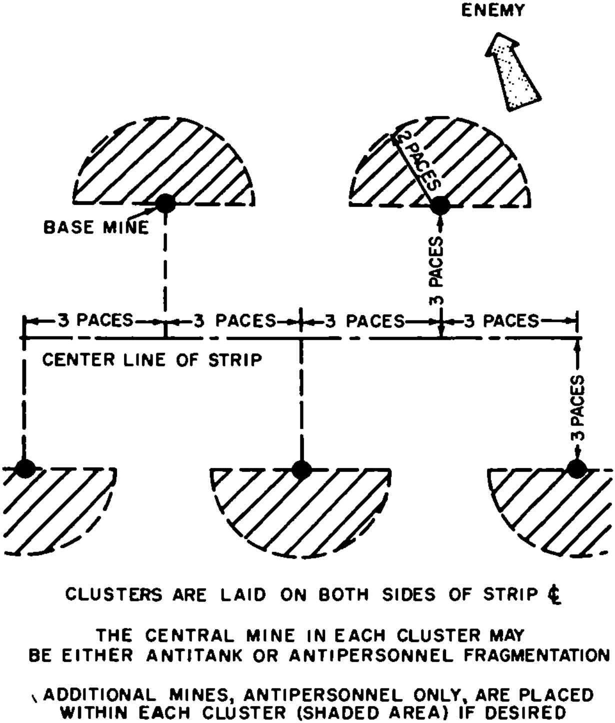


Figure 3–2. Minefield strip.

b. Clusters. The minefield cluster is the bosic unit of the stondord pottern minefield (fig. 3–3). A cluster moy contoin one to five mines. A minefield strip consists of two rows of clusters (figs. 3–2 and 3–4).

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 3–3. Minefield clusters.

c. *Numbering.* The clusters in each strip are numbered from right to left os yau face the enemy beginning with the raw facing the enemy (fig. 3–4). Cluster number 1 is the first cluster ot the right boundory in the raw facing the enemy, or the first cluster ofter a turning point.

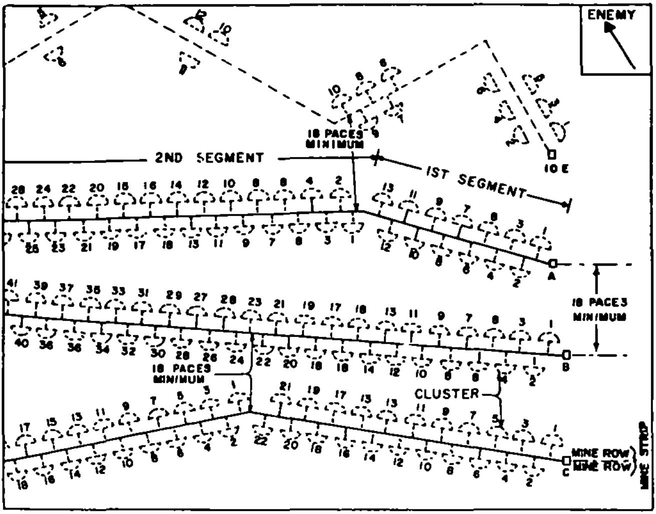


Figure 3–4. Method of numbering clusters in mine strips.

d. Trip Wires. Trip wires, if laid, are attached ta selected antipersannel mines in the row an the enemy side af the strip centerline. There is anly one trip-wire mine ta a cluster, and na claser than one every third cluster (fig. 3–5).

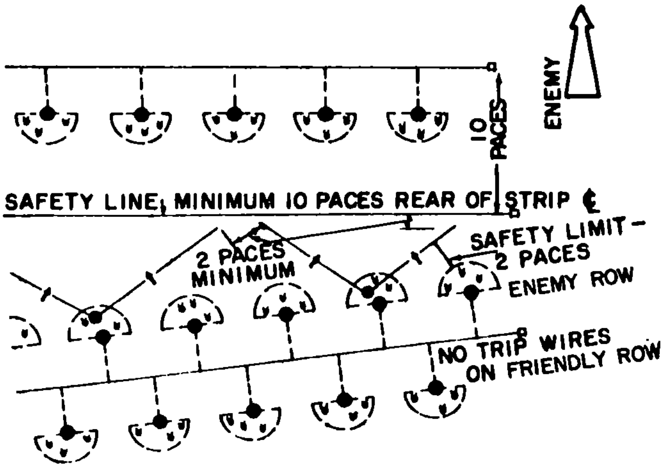
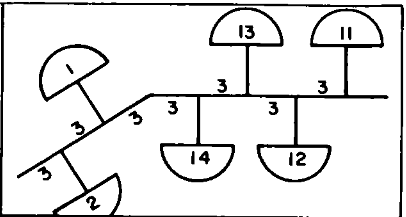


Figure 3–5. Safety line and trip wires an enemy raw.

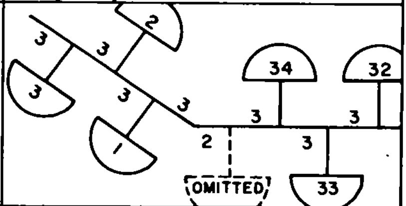
e. *Arrangement.* Mine strips are nat parallel, but their centerlines must be at least 18 paces apart at all paints. A centerline may have as many turning paints as desired (fig. 3–6).

CLUSTER 14 IS LAST CLUSTER IN SEGMENT

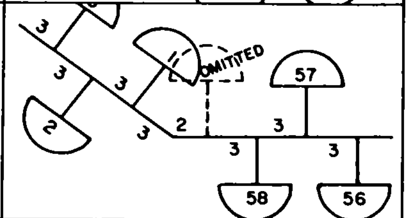
CLUSTER 1 IS FIRST CLUSTER IN NEXT SEGMENT



IF A CLUSTER FALLS LESS THAN 3 PACES FROM A TURNING POINT, IT IS OMITTED. THE FIRST MINE LAID IN A SEGMENT OF ANY STRIP WILL ALWAYS BE 3 PACES FROM THE TURNING POINT AND ON THE OPPOSITE SIDE OF STRIP CENTERLINE FROM PREVIOUS LOCATION.



(SAME AS ABOVE, BUT ON THE OPPOSITE SIDE OF THE STRIP CENTERLINE)



IF NECESSARY TO TURN SHARP ANGLES AND ONE CLUSTER COMES CLOSER THAN 3 PACES TO A STRIP CENTERLINE OR THE BASE MINES IN TWO CLUSTERS ARE LESS THAN 6 PACES APART, ONE OF THE CLUSTERS IS CONSIDERED A GHOST CLUSTER.

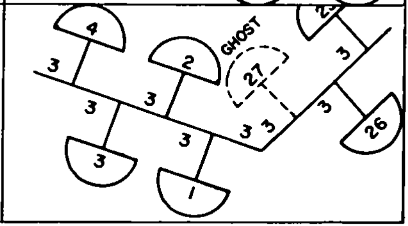


Figure 3–6. Turning points.

3–5. MINE LAYING

a. *Platoon Organizatian.* The plataan organization and duties af platoon members are autlined in table 3–2.

Table 3–2. Organizatian and Duties af Mine Laying Plotoon

Persannel	Officer	NCO	EM	Equipment
Supervisary personnel	1	1	. .	Officer: Map, lensatic campass, notebook, and minefield record farms. NCO: Map, notebook, and lensatic compass.
Siting party	. . .	1	3	Stakes ar 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, glaves, sledges, pickets.
Recarding party	. .	1	2	Sketching equipment, lensatic compass, minefield record farms, map, and metric tape.
1st laying party	.	1	6 to 8	Natebook for squad leader, picks, shovels, and sandbags.
2d laying party	. .	1	6 to 8	—do—
3d laying party	. . .	1	6 to 8	—da—
Tatal	1	7	25 ta 31	

b. *Limitatians.* The pracedure described here may vary according to the men and materials available, the terrain, and the proximity of the enemy.

c. *Laying Out the Field and Placing Mines.* When the OIC arrives in the area with his siting and marking parties, he proceeds ta lay the minefield as illustrated in figures 3–7 through 3–12.

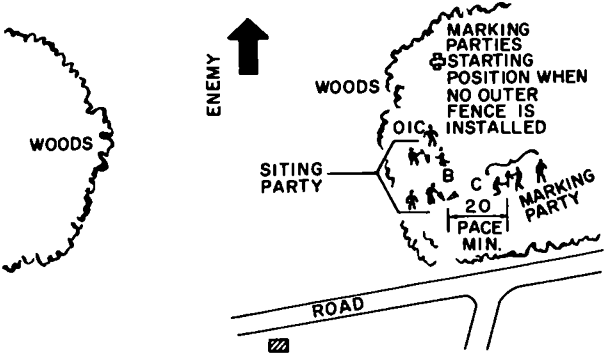


Figure 3—7. Initial steps in laying a minefield.

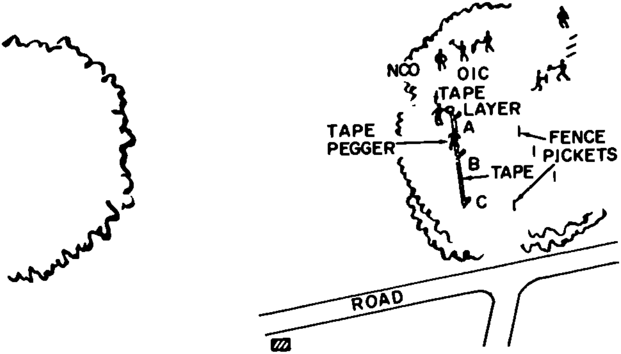


Figure 3—8. Establishing the right boundary stake locations.

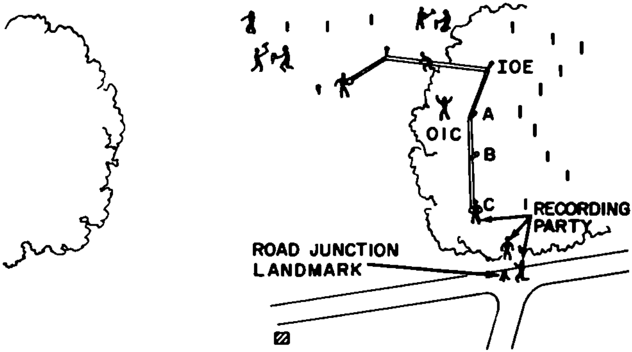


Figure 3–9. Laying out the IOE.

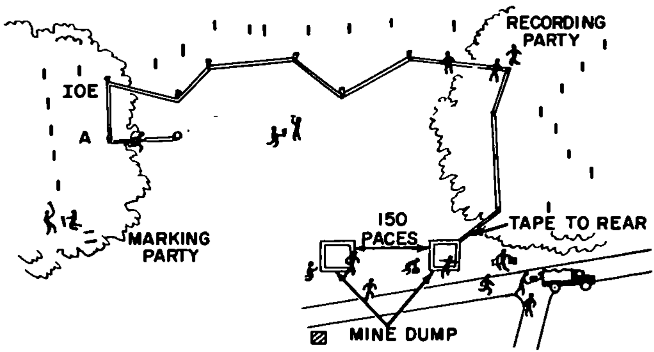


Figure 3–10. Laying out strip A and establishing mine dumps.

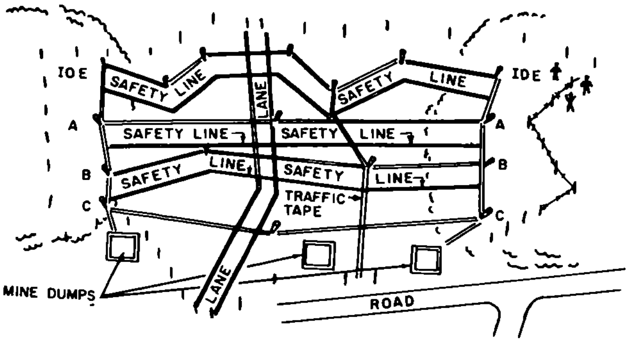


Figure 3—11. Minefield completely taped.

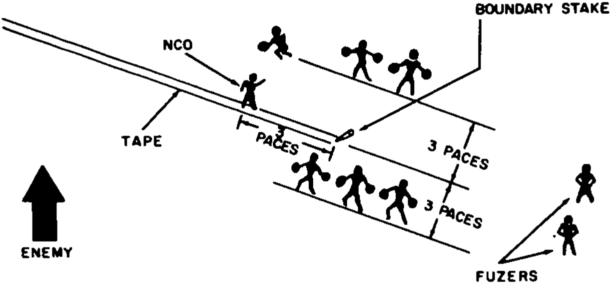


Figure 3—12. Laying mines in a regular strip.

d. Minefield Morking.

(1) Rear orea minefields are completely fenced with two strands of barbed wire at the time of laying (fig. 3—13). As shown in figure 3—1, the fence daes not follow the exact baundary af the field, but rather is placed in a zig-zag pottern. The marking fence will be placed na claser than 20 paces to the nearest mine. Standard markers (fig. 3—14) are hung an the upper strand with the word MINES, BOOBYTRAPS, etc., facing away from the field. If a minefield has been contaminated with toxic chemical agents, the standard chemical contamination marker is hung along with the standard mine marker. Lanes are marked as shown in figure 3—15.

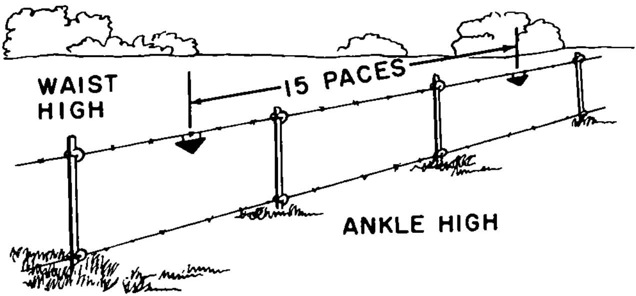


Figure 3—13. Standard minefield marking fence.

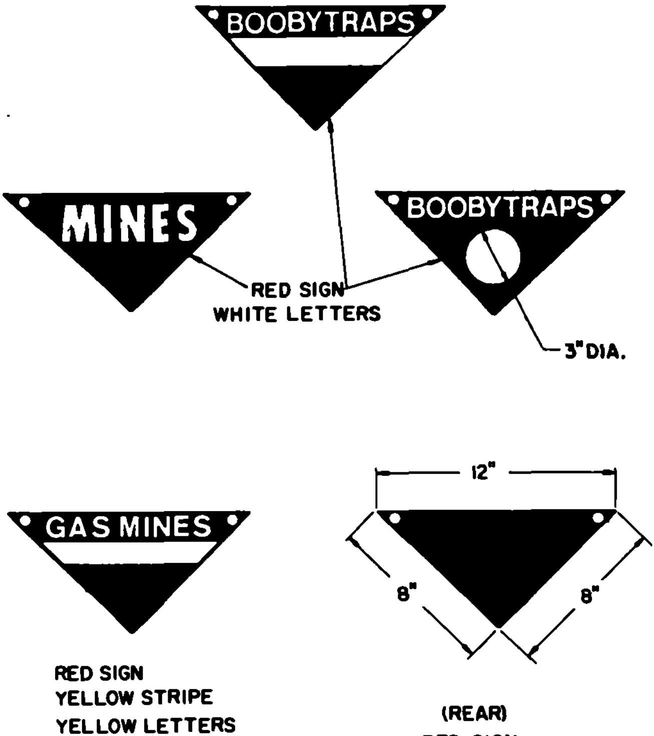


Figure 3–14. Standard marking signs.

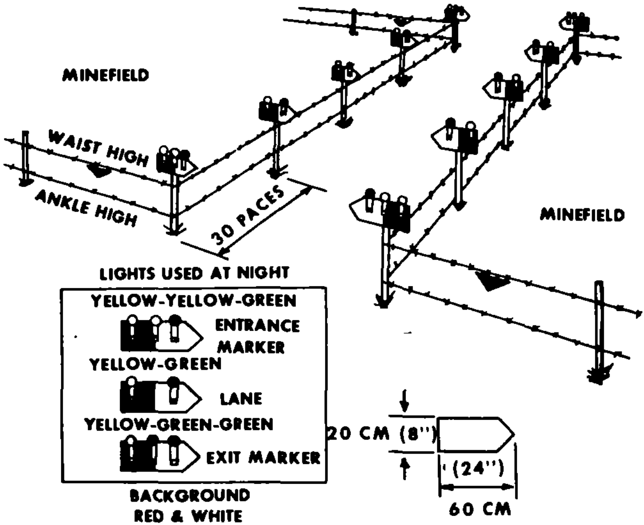


Figure 3—15. Standard rear area lane markings.

(2) Lanes in forward areas are marked inconspicuously by wire, tape, or closely-spaced objects placed on the ground. The entrance is identified by markers such as pickets marked with tape, piles of stores, etc. Lone exits on the enemy side are not marked. Minefield fencing, marking, and comauflage must be carefully maintained.

e. *Lanes and Gaps.*

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

(2) 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 tactical formation. Gaps are seldom less than 100 meters wide.

Table 3–3. Minefield Requirements for 100 Meters of Front

Density			Strips rqr	Mines required			Crated mines		Vehicles required for crated mines		Man-hours	Meters of wire	Number of Pickets
AT	Apers Frag	Apers Blast		AT	Apers Frag	Apers Blast	Weight in tons	Volume in cu ft	5T cargo (Wt governs)	5T dump (Vol governs)			
1	1	1	3	164	164	164	4.98	228.5	1.00	1.68	87	1200	30
1	2	2	3	164	312	312	5.85	260.1	1.17	1.91	120	1200	30
1	4	8	8	164	623	1213	7.82	337.8	1.57	2.47	234	2000	50
2	4	8	9	312	623	1213	11.44	512.7	2.29	3.76	279	2400	60
3	4	8	9	459	623	1213	15.05	686.7	3.01	5.03	323	2400	60

Explanatory Notes:

1. AT, Apers Frag and Apers Blast mines are M15, M16, and M14 respectively.
2. Mines totals include IOE and 10% safety factor.
3. IOE cluster composition used is 1–2–2 (except for the 1–1–1 and 1–2–2 minefields where the IOE cluster composition is 1–1–1).
4. Man-hours are based on laying rate of 4 AT, or 8 AP fragmentation, or 16 AP blast mines per man-hour Includes 20% factor to compensate for minefield siting, marking, and recording.
5. Quantities indicated are for 100 meter of front.
6. The fencing material requirements for minefields other than 100 m frontage can be approximated from this table.

Table 3-4. Land Mine Logistical Data

		Mine packaging data					Capacity of indicated army vehicles (Note figures in parentheses indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space)				
				Crate dimensions (ins)			M-35 2½ ton cargo truck (Cargo space 147 × 88 × 60 ins)				
Mine Model & type	Wt (lbs) per mine	No. of mines, etc., per crate	Wt (lbs) per crate	Lgth	Width	Hgt	No of crates	How carried	No of tiers of crates	Total No mines	Total wt (tons)
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 3–4 — 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 × 87 × 71 ins)					M–47 2½ Ton Dump Truck (Cargo Space 108 × 70 × 15 + ins) (Volume determines capacity)					M–51 5 Ton Dump Truck (Cargo Space: 125 × 82 × 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)
—	flat (on edge)	3 (2)	100 (200)	1 55 (3.1)	—	on end (on 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 3–4.—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 corgo space) — M–35 2½ ton cargo truck (Corgo 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)	flot	2 (34)	224 (444)	2.51 (4 98)
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)
M18Al AP	3 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–68 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 3-4 — 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 × 87 × 71 ins)					M-47 2½ Ton Dump Truck (Cargo Space 108 × 70 × 15 + ins) (Volume determines capacity)					M-51 5 Ton Dump Truck (Cargo Space. 125 × 82 × 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)
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)
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 3–4.—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 × 88 × 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 3–4 — 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 × 87 × 71 ins)					M–47 2½ Ton Dump Truck (Cargo Space: 108 × 70 × 15 + ins) (Volume determines capacity)					M–51 5 Ton Dump Truck (Cargo Space. 125 × 82 × 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 3–4.—Continued

		Mine packaging data					Capacity of indicated army vehicles (Note figures in parentheses indicate maximum load w/in 100% overload capability and/or maximum volume of cargo space)				
Mine Model & type	Wt (lbs.) per mine	No. of mines, etc., per crate	Wt (lbs.) per crate	Crate dimensions (ins)			M–35 2½ ton cargo truck (Cargo space 147 × 88 × 60 ins)				
				Lgth	Width	Hgt	No of crates	How carried	No of tiers of crates	Total No mines	Total wt (tons)
M–48 parachute flare	5	4 w/fuzes & tripwire	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 & tripwire	45	21.25	14 5	11	111 (180)	flat	3+ (5)	1776 (2880)	2.49 (4 04)
		b 25, w/fuzes & tripwire	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 3–4—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 × 87 × 71 ins)					M–47 2½ Ton Dump Truck (Cargo Space 108 × 70 × 15 + ins) (Volume determines capacity)					M–51 5 Ton Dump Truck (Cargo Space 125 × 82 × 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)
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

(3) *Siting and location.* Lanes and gaps ore sited so thot the unit protecting the field and odjacent units moy carry an such activities as potrolling, attocking and counterattacking. The tactical cammander indicates to the cammonder af the loying unit the generol lacation of lones and gaps. Skillful siting is essentiol to cancealment. Locotians of lones and gops are chonged frequently to prevent the enemy from detecting and ambushing friendly farces. Tacticol cammanders ore alwoys consulted regarding changes in lacation.

f. Lagistical Data. Materiol and manpower requirements, ond logistical and planning data are faund in tables 3–3 ond 3–4. Table 3–5 is the Stondard Pattern Minefield Requirements Computotian Form faund an the reverse side af DA Form 1355 (Minefield Record).

Table 3–5. Standard Pattern Minefield Requirements Computation Form

	AT	Apers Frag	Apers Blast
Desired Density..............	a 1	b 4	c 8
IOE Representative Cluster...	a 1	b 2	c 2
Poces of Trace................	267		
1. Paces af trace/9 ar number af IOE clusters..			30
2. Number af IOE clusters (line 1) × IOE representative cluster...	a 30	b 60	c 60
3. Paces af trace × desired density = mines in minefield..............	o267	b 1068	c 2136
4. Add line 2 and line 3 (subtotal af mines)......	a297	b 1128	c 2196

5. 10% of line 4 for mine rejections, strip length variances......... a 30 b 113 c 220

6. Add lines 4 and 5 = total mines needed.................... a 327 b 1241 c 2416

7. Add a + b + c of desired density.. 13

8. $\frac{3}{5}$ × line 7*.. 8

9. 3 × AT density.. 3

10. Number of strips (highest number of 8 and 9)........ 8

11. Desired density × 3..... a 3 b 12 c 24

---

*In minefield calculation, fractions will always be rounded up to the next whole number.

3–6. SPECIAL TECHNIQUES

a. *Protective Minefields*. This type of minefield is employed to assist a unit in its local, close-in protection. They can be employed in both forward and rear areas of the combat zone or in isolated locations such as detached outposts, work parties, or roadblocks. Protective minefields are sited across likely avenues of approach within range of the defender's organic weapons but a sufficient distance away to be outside of enemy hand grenade range of the defender's position. This type of minefield usually is laid on short notice with units using mines from their basic load or from local stocks. The mines must be readily detectable and removable by the installing unit. Examples are metallic antitank and antipersonnel mines, flares, and field expedient flame mines. Directional antipersonnel mines (e.g., M18 type) are particularly well suited for employment. Claymore mines should be physically removed, checked and relocated daily. In addition, precautionary measures should be taken to prevent the enemy from turning the Claymore against the defender during periods of limited visibility.

b. Nuisance Minefields. This type of minefield is employed to delay and disorganize the enemy and to hinder his use of an area or route. All types of antitank and antipersonnel mines are used and, when authorized, chemical mines may be laid. Manually laid antitank mines are equipped with antihandling devices to the maximum extent possible.

Table 3–5 — Continued

	Strip	a	b	c	Total Across
	A	1	1	3	5
	B	0	2	3	5
	C	0	1	3	4
	D	1	1	3	5
CLUSTER	E	0	2	3	5
COMPOSITION	F	1	1	3	5
TABLE	G	0	2	3	5
	H	0	2	3	5
	I				
	J				
	K				
TOTAL DOWN.........		3	12	24	

Mines should be difficult to detect and remove. Boobytraps and dirty trick devices may also be employed. Nonexplosive devices such as punji pits and whips may be improvised and employed alone or in conjunction with mines and boobytraps.

c. *Stream Mining.*

(1) *Water over knee-depth (deeper than 0.6 meter).* The placement of mines from upstream to downstream is accomplished by teams of two or three men. One man selects the emplacement position while the second brings the mine from the shore to the position. The mine is placed unarmed on the water bottom. Green saplings or other nonbuoyant material may be used as outriggers to prevent the mine from being moved by the current. One man stays with the planted mine while the other selects and measures to the next position. A rope knotted in 1-meter increments is used to measure the distance. A compass azimuth and the distance from the second position to the first mine is reported to the recording party on shore. The man remaining at the first position arms the first mine, staying on the downstream side of the mine. He then moves downstream and away from the mine (for recording see para 3—8). The teams are coordinated so that all parties remain downstream from mines that have been armed. Figure 3—16 shows by numbers, the sequence in which mines should be laid and armed in the stream. As the mines are laid, the mine laying teams will report to the recording party the position of each mine. The underwater strips are referenced to a permanent type stake or object downstream so that they may be removed, if necessary, in reverse order of being laid.

(2) *Water under knee-depth (less than 0.6 meter).* The simplest, most reliable minefield to record and remove is the row minefield where cluster spacings are uniform. Rows are parallel to one another; and the ends of mined rows extend or slant upstream. A rope, knotted in even cluster spacings, is stretched and held in place as each row is laid. As each subsequent row is to be laid, the reference rope is oriented by compass or measured from the ends of the prior strip. Figure 3—17 shows the reference rope in place for strip C. As in the prior method, mines upstream are planted first.

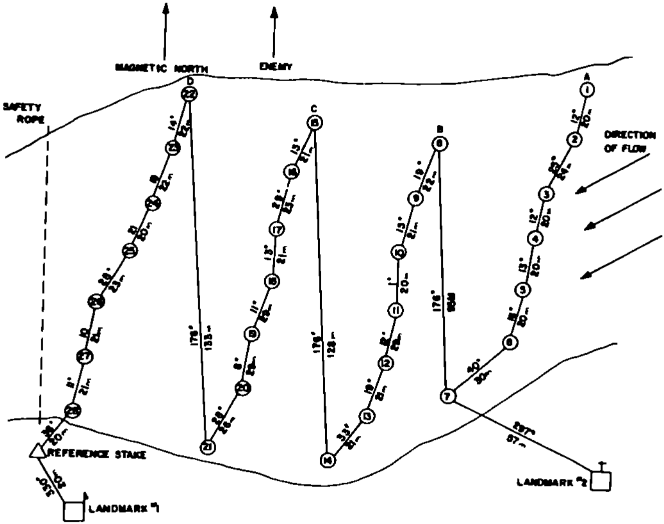


Figure 3–16. Mining of a ford site, water over knee-depth.

Section III. Reporting and Recording

3–7. MINEFIELD REPORTS

A minefield report is any official message or communication, normally verbal, concerning either friendly or enemy mining or demining activities. All reports on friendly minefields are classified SECRET and should be transmitted by a means consistent with this classification.

a. *Mandatory Minefield Reports.*

(1) *Report of intention to lay.* This report is made by any secure means of communication to the next higher commander by any commander having the authority to install a minefield. The required information and desired format usually is described in the unit SOP.

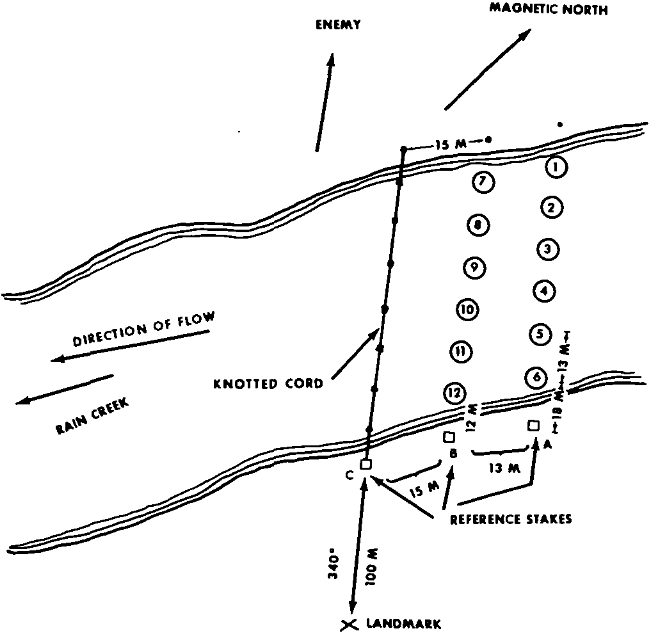


Figure 3—17. Mining o fard site, woter under knee-depth.

(2) *Report af initiotian af laying.* When the commander af the loying unit begins laying the minefield, he infarms the next higher commander by secure means. This report is forwarded ta the commonder autharizing the field.

(3) *Report of completian of laying.* When the minefield has been installed, the commander af the mineloying unit reports this fact ta his next higher cammonder. This report is forworded to army level in all cases except far protective minefields. A repart of completion af o pra-

tective minefield is usually forwarded no higher than division level. The report of completion must be followed by a completed standard minefield record, DA Form 1355 (para 3–8).

b. Optional Reports.

(1) *Progress reports.* This report is a matter of command standing operating procedure (SOP).

(2) *Report of transfer.* This is a written report which transfers the responsibility for a minefield from one commander to another. It must be signed by both the relieved and relieving commanders and is forwarded to the next higher commander having authority over both the relieved and relieving unit commanders.

(3) *Report of change.* Whenever friendly mines are removed, a report is made immediately to the next higher commander and forwarded through channels to the headquarters which maintains the written mine record. Whenever any alterations or changes are made to an existing minefield, a completely new record must be prepared on DA Form 1355 with the latest date time group and marked REVISED. The original minefield number remains unchanged.

c. *Enemy Minefield Report.* Any knowledge or suspicion of the existence of any enemy minefield must be reported to the next higher command immediately. This report, should be arranged to facilitate electrical transmission.

3–8. MINEFIELD RECORDS

a. *DA Form 1355.* This form is used to record all minefields except the hasty protective minefield (*b* below). DA Form 1355 consists of a single printed sheet. The front consists of an upper half for tabular data and a lower half for a scale sketch of the field. On the reverse side are instructions for completing the DA Form 1355 and a form for computing the number of mines (para 3–5*f*). When completed, the DA Form 1355 is classified SECRET When used for training purposes, the word SPECIMEN must appear in the sketch.

(1) *Standard detailed minefield record.* See figure 3–18.

Figure 3–18. Standard detailed minefield record.

(Located in back of manual)

(2) *Nuisance minefield record.* See figure 3–19.

Figure 3–19. *Record of nuisance minefield.*

(Located in back of manual)

(3) *Ford minelaying record.* See figure 3–20.

Figure 3–20. Record of mines emplaced in a ford deeper than 0.6 meter.

(Located in back of manual)

(4) *Enemy minefield record.* The standard DA Form 1355 is used when preparing a record of an enemy field. The record should include a full description of the markings, a sketch or overlay showing location and other information. The record must be marked at the top with the words ENEMY MINEFIELD.

b. Hasty Protective Minefield Record, DA Form 1355–1. The purpose of the Hasty Protective Minefield Record form is to insure the proper recording of any hasty protective minefields laid by detached or isolated units. The form is issued down to and including platoons. It does not replace the current minefield record, DA Form 1355, but serves as an interim record until the information is transcribed to a DA Form 1355, or until the minefield is removed. The Hasty Protective Minefield Record, DA Form 1355–1, is unclassified as long as the minefield is temporary in nature. If the hasty protective minefield is not recovered the form is reclassified SECRET and is retained as backup for the DA Form 1355. Figure 3–21 shows the reverse side of the Hasty Protective Minefield Record which consists of full instructions to the recorder and an example of a recorded minefield.

Section IV. Mine Removal

3–9. MINEFIELD 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 NCO, four to six trained men, and a security element armed with light automatic weapons and grenade launchers (fig. 3–22).

(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, etc.), 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,

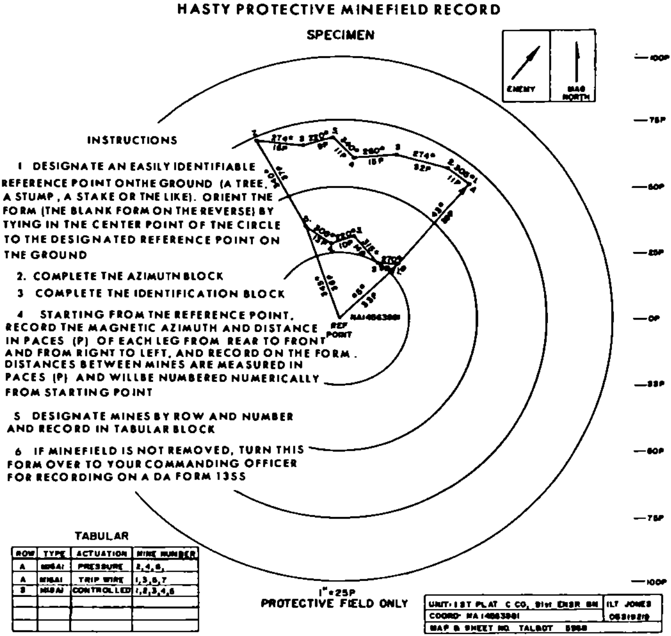


Figure 3–21. Hasty Protective Minefield Record Farm (reverse).

take such equipment os protective clothing, chemical agent detectar set, first aid supplies, and decontaminatian equipment.

(3) Where recannoissance is preliminory to breaching, the patral records informatian by a tope laid an the centerline af the path. Indicate location of tripwires ar types af mines by knots tied on the tape as follows:

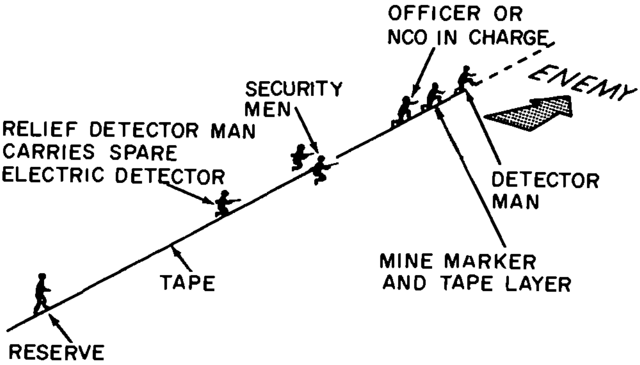


Figure 3–22. Minefield reconnaissance patrol.

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

3–10. MINE DETECTION METHODS

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

b. *Probing.* In this method, the earth is penetrated with a shorp instrument such as a mine probe, a boyonet, or a stiff wire. Probing is the best woy to locate buried nonmetallic mines, porticularly the small antipersonnel type similar to the M14. When probing, the soldier moves on hands and knees with sleeves rolled up to locote tripwires and pressure prongs. In oreas where electrical devices are common only, a nonmetallic probe should be used to avoid actuating the electricol firing device.

c. *Electrical Detection.* When used in conjunction with visuol inspection and probing, mine detectors (metallic and nonmetallic) ore effective aids on 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.

3–11. 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 3–6.

(2) Deliberate breaching requires extensive planning, and is normally done be engineers or other trained personnel, supported by combined arms. Deliberate breaching usually is 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 and most desired 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.

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

d. *Plataon Organization and Equipment for Manual Breaching*. Table 3–7 and figure 3–23 show the organization of this platoon and the operation of a breaching party, respectively.

3–12. METHODS OF CLEARING MINEFIELDS

a. *Introduction*. To clear a minefield is to remove or destroy all mines,

Table 3–6. Minefield Average Breaching/Clearing Time and Material Requirements

Method	Width of cleared lane (in meters)	Man-hours req'd per 100 meters	Remarks
Manual			
Locotion by prabing	1 (faatpath)	16–22	See note.
Removal by rape or explasives	8 aneway (vehicle lane)	38–44	See note.
Lacatian by detectar, assisted by prob-ing	8 aneway (vehicle lane)	27–33	See note.
Remaval by rope ar explasives . .	8	220–247	See note.
Explosive			
Demolitian snakes, M3A1	6	40–100	
Demalitian snake M157 (Diamand Lil)	3.5–4.5	6–8	+6 –8 manhaurs to assemble
Bangalare torpedo.	1 (foatpath)	3.5–4.5	See nate.

NOTE. Bosed upan average conditions of visibility and moderate enemy activity and narmal U.S. countermeosures, i.e. screening of enemy observatian and counter-bottery fires against hostile ortillery or other weapons covering the field.

enemy or friendly, in the field. The methods used in mine clearance are similar ta thase in breaching, but are mare deliberate and carefully applied. Minefield records are used ta the maximum. Brush and other cover in the minefield area may be removed by burning.

b. By Probing. To cleor mines from an enemy field or a friendly field for which records are unavailable, the pracedure described here is ta

Table 3–7. 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	

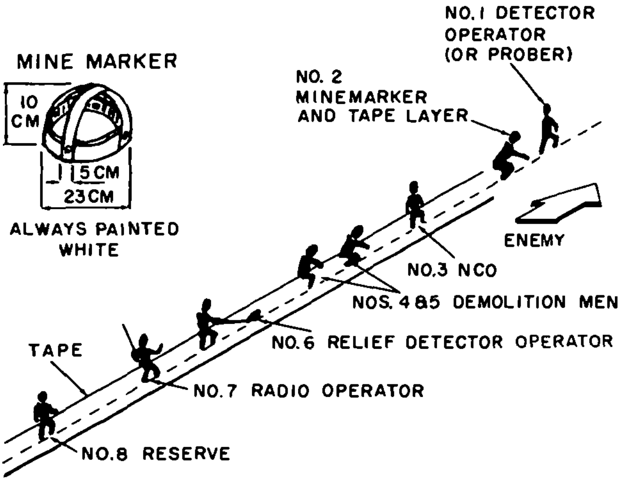


Figure 3–23. Minefield breaching party.

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 3–8. The clearing parties operate as depicted in figure 3–24.

(2) The use of explosive is described in paragraph 3–11.

(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 50 meters long to mine.

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

(*d*) Take cover at least 50 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.

Table 3–8. Plataan 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. *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 increased by one man. The duties and procedures are basically the same as for probing.

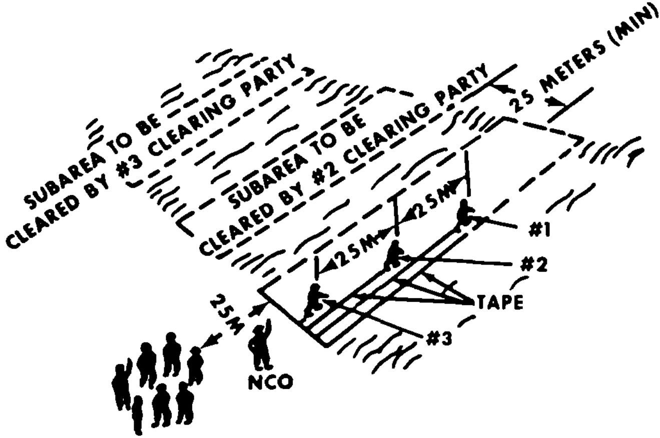


Figure 3–24. Number 1 clearing party.

(2) Figure 3–25 shows the clearing party in action, using electrical detectors.

3–13. ROUTE CLEARING OPERATIONS

a. Organization. Route clearance has some of the characteristics of both minefield breaching and area clearance depending upon the relationship of the route to the enemy and the urgency of the mission. The normal organization for route clearing is shown in figure 3–26. When ambush or command detonated mines are suspected, route clearance should be performed in a manner shown in figure 3–27.

b. Procedure. Normally, route clearance is accomplished in two stages.

(1) The first stage includes removal of sufficient mines and other obstacles to clear a one-way route, reconnaissance for bypasses or alternate routes, prompt report of mined areas which have been breached, cleared or bypassed, and posting of guards or minefield markings to warn succeeding elements.

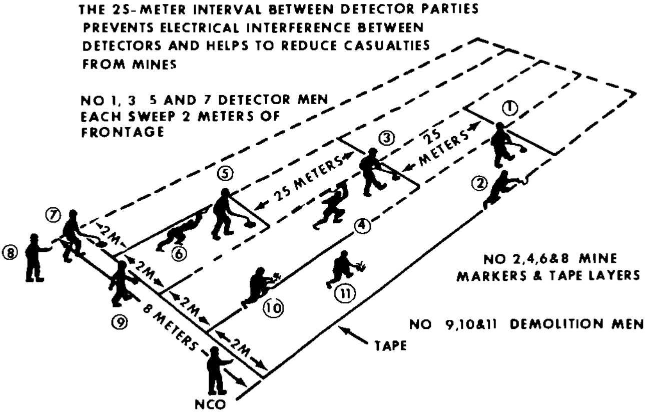


Figure 3—25. Clearing party using electrical detectors.

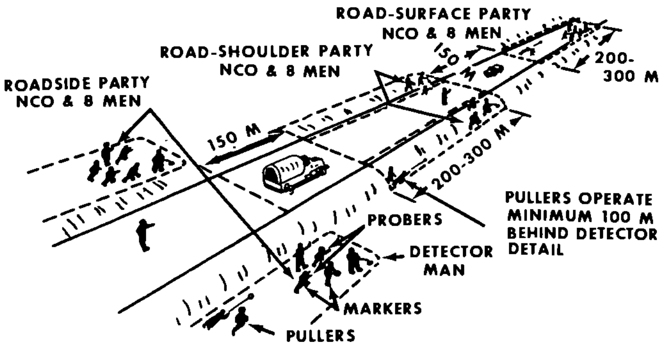


Figure 3—26. Route clearing party.

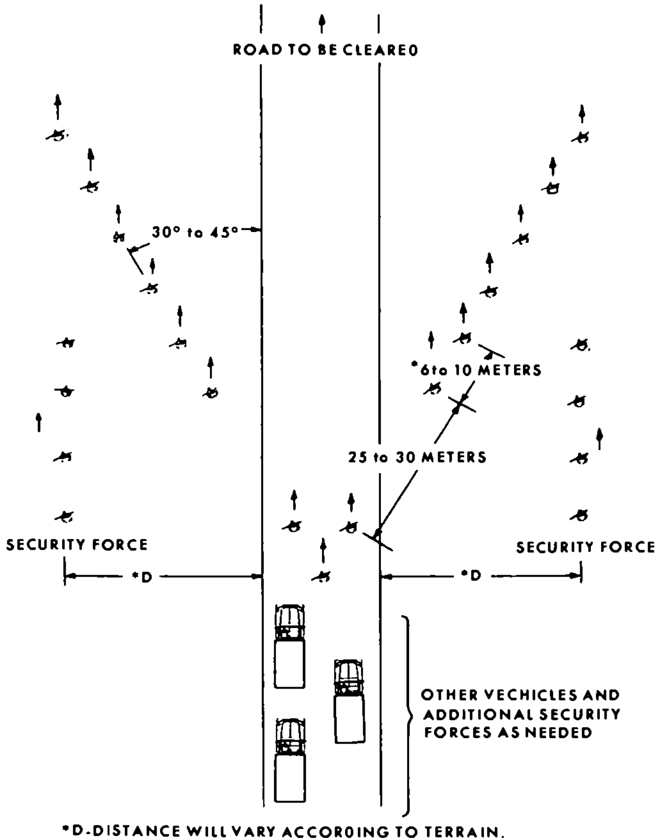


Figure 3–27. Organization of security for route clearing party when ambushes or command detonated mines are suspected.

(2) The second stage includes widening the initially cleared path for double-flow traffic including shoulders, clearing beyond the line of telephone poles or where signal wire has been or will be laid, improving bypasses, filling in craters, moving abandoned vehicles clear of the traveled way, erecting more permanent and elaborate mine-warning and marking signs, complete checking of crossroads and road junctions, and clearing and marking safe turnouts into unit dispersed areas.

3-14. SAFETY PRECAUTIONS

a. Personnel in a minefield will:

(1) Remain dispersed.

(2) Not run.

(3) Move only in cleared areas.

(4) Move to assist injured personnel only when told to do so by unit officers or noncommissioned officer.

b. All areas or facilities are suspect and are carefully investigated.

c. Cleared areas are distinctly marked.

d. All mines are considered to be equipped with antihandling devices until proven otherwise. Never uncover a mine until the ground on top has been thoroughly checked for anti-lift devices.

e. Hand removal of mines is undertaken only when no other means of disposal is feasible.

f. All precautions for handling explosives are observed when handling mines, fuzes, and firing devices.

g. Mines that are removed are completely separated from fuzes and firing devices and separately stored.

h. Rapid means of communication should be maintained to insure maximum control and prompt evacuation of any wounded personnel. Medical aid personnel should be close at hand to accomplish any needed first aid.

3–15. MINE SYMBOLS

See figure 3–28.

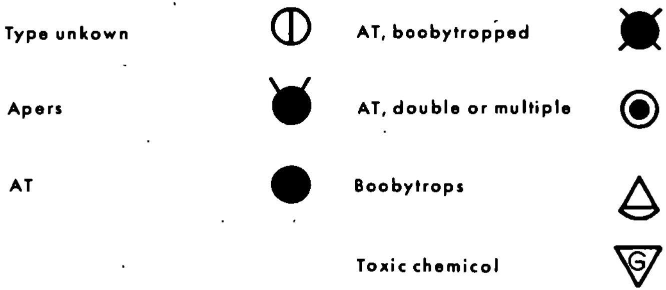


Figure 3–28. Mine symbols.

CHAPTER 4

FIELD FORTIFICATIONS

Section I. General Data

4-1. 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 plans of higher headquarters.

4-2. 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 or 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 be neither 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 then 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 4–1

Table 4–1. 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, brushhooks, machetes, and hatchets	2.5

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

Section II. Types

4–3. EMPLACEMENTS

a. *Requirements.* Emplacements shauld be sa canstructed as ta permit each individuol ar weopans crew ta meet the fallawing requirements:

(1) Permit each individuol ar each weopons crew to accomplish assigned fire missians.

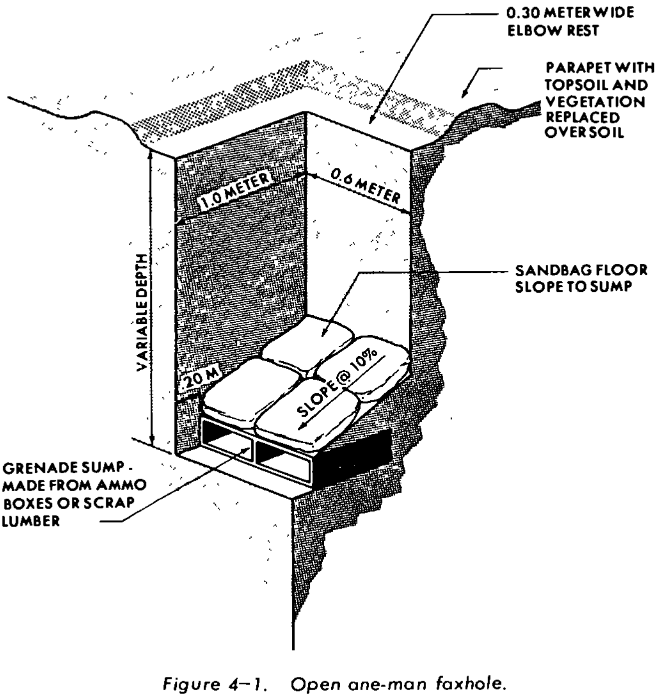


Figure 4–1. Open ane-man faxhole.

(2) Be simple and easily constructed.
(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 4–1 through 4–6 for different types.

c. Labor Requirements for Emplacements. See tables 4–2 and 4–3.

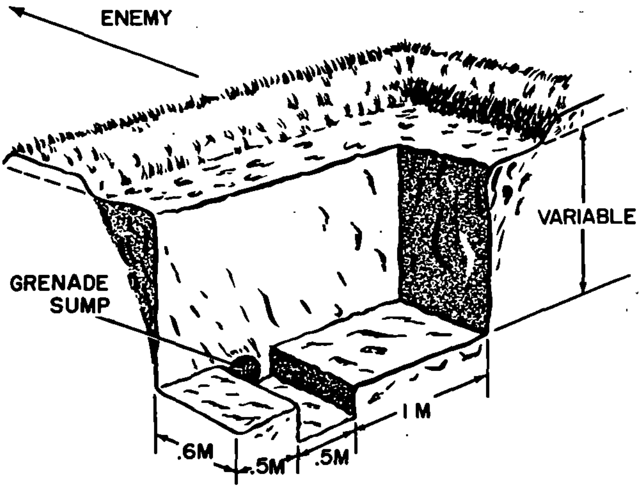


Figure 4–2. Open two-man foxhole.

4–4. REVETMENTS

a. Retaining Wall Type. This type of revetment is used in relatively unstable soils The horizontal layers of the walls are tied together so that the wall acts as a structural unit without any sliding of one part upon another. The revetment (fig. 4–7) may be constructed of sandbags, sod blocks, and various expedients as described below. The methods of building with these construction materials are as follows:

Table 4–2. 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 (kg.)	Volume (cu m)	Weight (kg.)	Volume (cu. m.)	Weight (kg)	Volume (cu m.)	Weight (kg)	Volume (cu. m).
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	86 2	0 10	108 9	0.23
Open one man foxhole with offset	9 0	14 0	10.0	16 0	N/A	22 7	0.02	81 6	0 16	108.9	0.11	190.5	0 37
One man foxhole with half cover	2 5	3.0	4 5	5.5	N/A	4 5	0 01	9 07	0.02	90.7	0 10	117.9	0 23
One man foxhole with half cover and offset	10.0	14 0	12.0	18 0	N/A	27.2	0.02	90.7	0 17	113.4	0 11	199 6	0.40
Open two man foxhole	N/A	N/A	6 0	8.0	3 0	N/A	N/A	N/A	N/A	127 0	0 14	135 2	0 28
Deepened two man foxhole	N/A	N/A	8.0	10.0	5 0	N/A	N/A	N/A	N/A	136 1	0.16	169.6	0.34
Two man foxhole with half cover	4.0	4 0	8 0	10 0	N/A	7 2	0 01	14 5	0.03	127 0	0 14	158 8	0 31
Two man foxhole with half cover and two offsets	20.0	30 0	22.0	35 0	N/A	54 5	0.04	180 4	0.34	172.4	0 17	317.5	0 62
Two man foxhole with half cover and adjoining shelter	11.0	17.0	13 0	22.0	N/A	45 4	0.03	254 0	0.51	208.7	0.20	399.2	0 79
Open fighting trench (25′ length)	N/A	N/A	28.0	32 0	21.0	N/A	N/A	N/A	N/A	222 3	0.23	322.1	0.62
Fighting trench with full cover (25′ length)	27 0	29.0	35 0	40 0	N/A	108 9	0 11	163.3	0 31	331 1	0 34	480 8	0.94

Table 4–3 Time and Material of Crew-Served Infantry and Artillery Weapons Emplacements

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 (kg)	Volume (cu m)	Weight (kg.)	Volume (cu. m.)	Weight (kg)	Volume (cu m)	Weight (kg.)	Volume (cu m)
Open automatic rifle emplacement	N/A	N/A	7 0	8.0	4 0	N/A	N/A	N/A	N/A	77.11	0.085	90 72	0.170
Automatic rifle emplacement with 18" of cover	4 0	5.0	6.0	7.0	N/A	20.81	0.014	31.75	0.057	99 79	0.113	122 5	0 283
Open horseshoe type M60 machinegun emplacement	N/A	N/A	5.0	7.0	2.0	N/A	N/A	N/A	N/A	127 0	0.142	204.1	0 396
Open 2 one-man foxhole type light machinegun emplacement	N/A	N/A	6 0	7 0	4.0	N/A	N/A	N/A	N/A	240 4	0 283	290 3	0.566
Horseshoe type light machinegun emplacement with full cover	9 0	11.0	11 0	14 0	N/A	86 18	0.113	113 4	0 198	326.6	0.368	403.7	0 764
2 one-man foxhole lt. machinegun type emplacement with ½ cover and adjoining shelter	15 0	22 0	19 0	28 0	N/A	113 4	0.071	285 8	0.566	235 9	0 212	385 6	0 850
Circular type 50 cal machinegun emplacement	N/A	N/A	14.5	16 5	10.0	N/A	N/A	N/A	N/A	136 1	0 142	190.5	0 368
Pit type emplacement for recoilless weapons	N/A	N/A	5 0	6.0	3.0	N/A	N/A	N/A	N/A	49.9	0 028	72.58	0 142
81-mm mortar emplacement	N/A	N/A	12.0	N/A	N/A	N/A	N/A	N/A	N/A	95.25	0 085	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	167.8	0.170	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
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

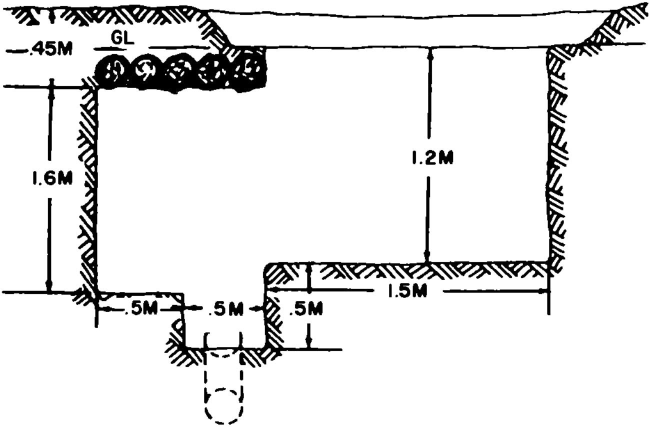


Figure 4–3. Two-man foxhole with half cover.

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

(*a*) Fill to three-fourths of full capacity (13 cm × 25 cm × 51 cm).

(*b*) Place a double row of alternate headers and stretchers as shown in figure 4–7.

(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.

(*h*) Place bags perpendicular to slope.

(*i*) Place all bags on bottom row as headers (fig. 4–7).

(*j*) Alternate intermediate rows as headers and stretchers.

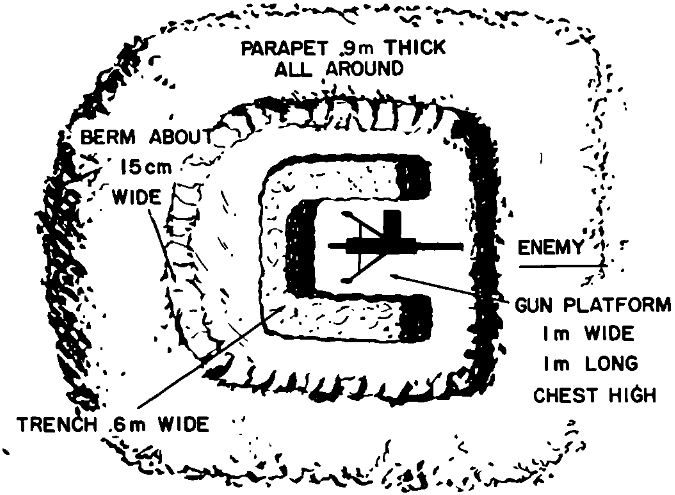


Figure 4—4. Horseshoe type emplacement.

(*k*) Hove top raw consist of headers.

(*l*) Place side seams and choked ends on inside.

(2) Sad blocks of thick sad with good roots provide sotisfactory revetting material. Cut sad blocks into 20- by 45-centimeter sections and lay them flat, using 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.

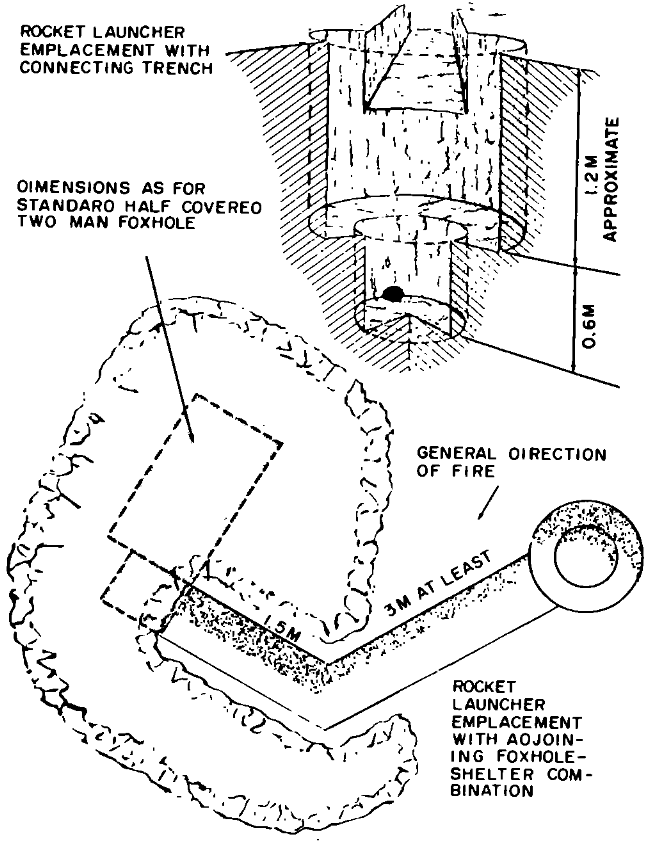


Figure 4–5. Rocket launcher emplacement.

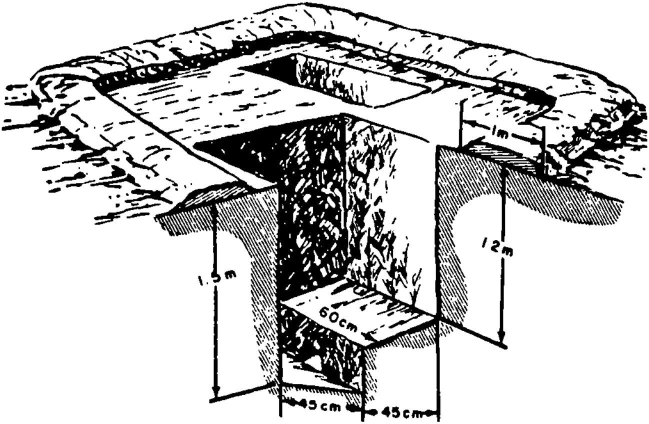


Figure 4–6. Two one-man foxhole type machine gun emplacement.

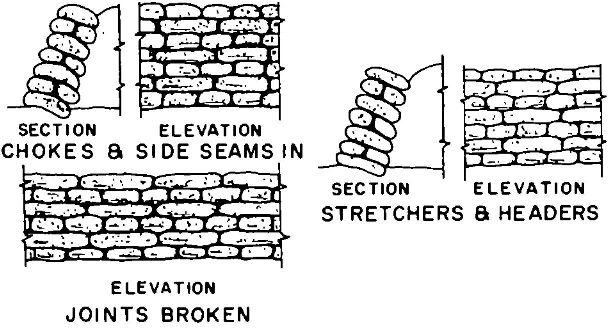


Figure 4–7. Retaining wall type of revetment.

(3) Expedients may be used, such as ice blocks in cold weather. They are stocked the same as sondbags or sod. Woter is run over them to bind by freezing. Another expedient is eorth-filled packing cases or ammunition boxes, which ore ploced in position and nailed to the layer below. The boxes ore then filled with eorth or rock. In wooded areas, small timber may be used as revetting moterial.

b. Facing Type. This type of revetment serves mainly to protect revetted surfaces from weather ond damoge caused by occupation. It consists of facing (revetting) material ond support which holds the material in place. The top of the facing is set below ground level so that the revetting moteriol is not damoged by tanks crossing the emplacement.

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

(2) Methods of support.

(*a*) Timber fromes of dimensioned timber are built to fit the bottom and sides of the position ond hold the facing material aport. This insures that the excavated width remoins stable.

(*b*) Pickets are driven into the ground on the position side of the focing material and held tightly against the focing by brocing the pickets aport or fastening their tops to stakes or holdfasts (fig. 4–8).

(3) Methods of constructing facing type revetments.

(*a*) The size of pickets depends upon the soil type and the kind of focing material, but timber pickets should not be smoller 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 os shown in figure 4–8.

(*b*) A brushwood 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, boord or planks are used.

(*d*) Corrugoted 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 rodiation and to aid camouflage.

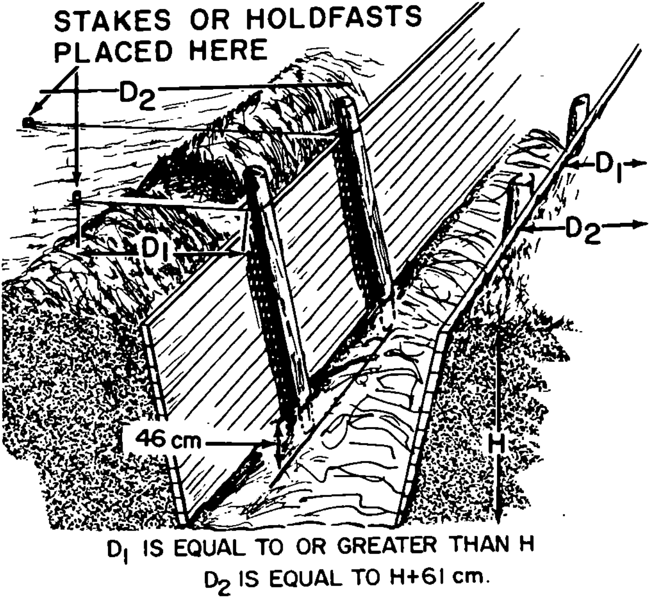


Figure 4–8. Methad of onchoring pickets.

4–5. TRENCHES

Trenches ore excovoted os fighting pasitians ond ta connect individual foxholes, weapons emplocements and shelters in the progressive development of a defensive areo. They provide protection and canceolment for personnel moving between fighting positions ar in ond aut of the areo (figs. 4–9 and 4–10).

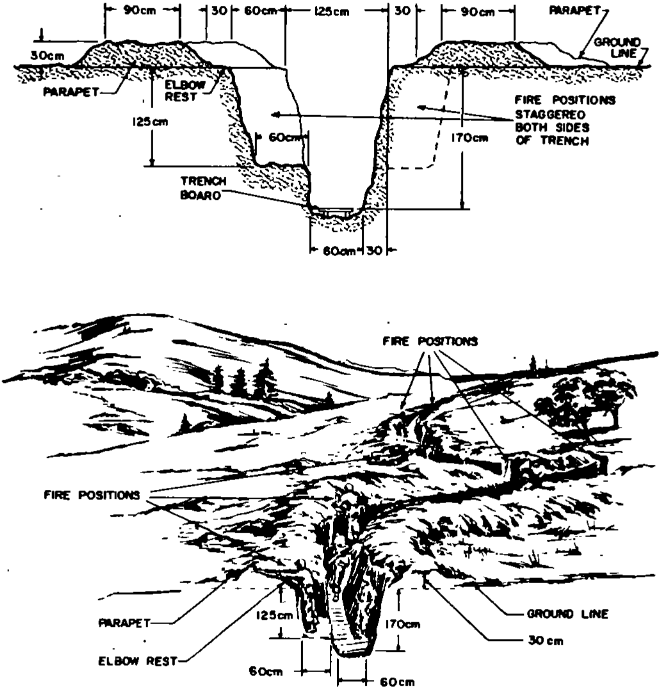
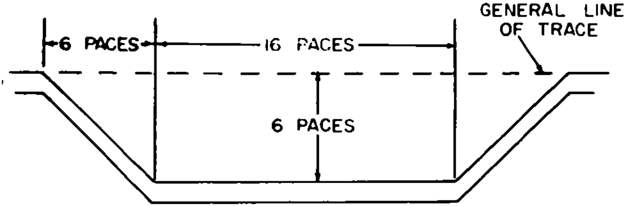


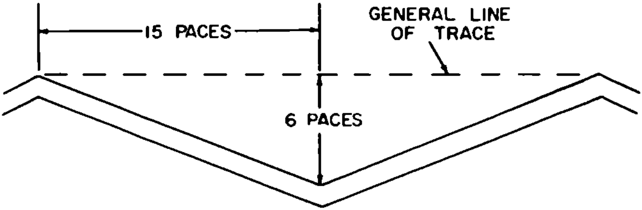
Figure 4–9. Standard trenches.

4–6. BUNKERS

a. Table 4–4 indicates minimum thickness of protective material required under given conditions. TB 5–15–1 has been published to provide detailed information on prefabricated concrete and steel bunkers, shelters and fighting hole covers. A discussion of precast techniques is also included.



① OCTAGONAL TRACE



② ZIGZAG TRACE

Figure 4—10. Standard trench troces.

b. The protective cover ond at least the raof of the supparting structure af on 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 ta absorb or dampen the shack af on exploding shell.

c. Practical fulfillment of this design unity is a sondwich canstructian in which the two outer layers, burster course, and roof structure, possess

Table 4–4. Minimum Thickness of Protective Material Required to Resist Penetration

No Standoff

Material in Inches

Types of ammunition	Soil		Sand		Clay		Soil cement bituminous concrete	Con-crete	Timber	Alumi-num	Steel
	Wet	Dry	Wet	Dry	Wet	Dry					
.30 cal. ball (AP)	36	24	36	24	44	30	18	9	60	2.6	1.3
.50 cal ball (AP)	54	36	45	30	80	54	18	9	120	4.4	2.2
57-mm recoilless rifle	18	12	18	12	36	24	20	10	20	9.0	5.0
82-mm recoilless rifle	40	27	41	27	80	54	42	22	48	21.0	12.5
90-mm recoilless rifle	60	40	63	42	120	80	66	33	75	32.0	19.5
107-mm recoilless rifle	72	48	70	48	144	96	84	42	88	40.0	22.5
60-mm mortar	72	48	45	30	100	64	20	10	20	2.8	1.0
81-mm mortar	90	60	63	42	136	90	26	13	27	3.7	1.3
120-mm mortar	103	70	70	48	180	120	32	16	36	4.7	1.7

¼-Inch Steel or ½-Inch Timber Standoff

.30 cal ball (AP)	18	12	18	12	22	15	9	6	30	1.3	0.6
.50 cal. ball (AP)	27	18	26	15	40	27	9	6	60	2.2	1.1
57-mm recoilless rifle	9	6	9	6	18	12	10	6	10	4.5	2.5
82-mm recoilless rifle	20	13	21	13	40	27	21	11	24	10.5	6.3
90-mm recoilless rifle	30	20	30	21	59	40	33	17	38	16.0	9.8
107-mm recoilless rifle	36	24	35	24	71	48	42	21	44	20.0	11.3
60-mm mortar	36	24	22	15	50	32	10	5	10	1.4	.5
81-mm mortar	45	30	31	21	66	45	13	7	14	1.9	.6
120-mm mortar	52	35	35	24	90	60	16	8	18	2.4	.8

Figure 4—11. 8unker.

o certoin omount of rigidity ond resiliency, ond the middle loyer is a cushion of porous consistency.

d. The most effective test exomple of the design unity for resistonce to direct hits of 155-mm, deloyed fuze shells is shown in figure 4—11.

e. In obtoining protection from direct hits of delayed-fuze shells, it is importont thot the burster course be thick ond rigid enough to effect detonotion before the shell hos possed through it. A 1-foot (30 cm) thickness of 6-inch (15 cm)—to 8-inch (20 cm) stone seems to be optimum for ommunition up through 155 mm.

f. The comoufloge layer of soil over the burster course should be no more thon 2 inches (5 cm) thick.

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

h. Timber field fortificotions with solid wolls ore undoubtedly stronger thon the post, cop, ond stringer type but require considerobly more timber.

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

j. A bunker copoble of withstonding a hit from 81-mm shells is shown in figure 4—12.

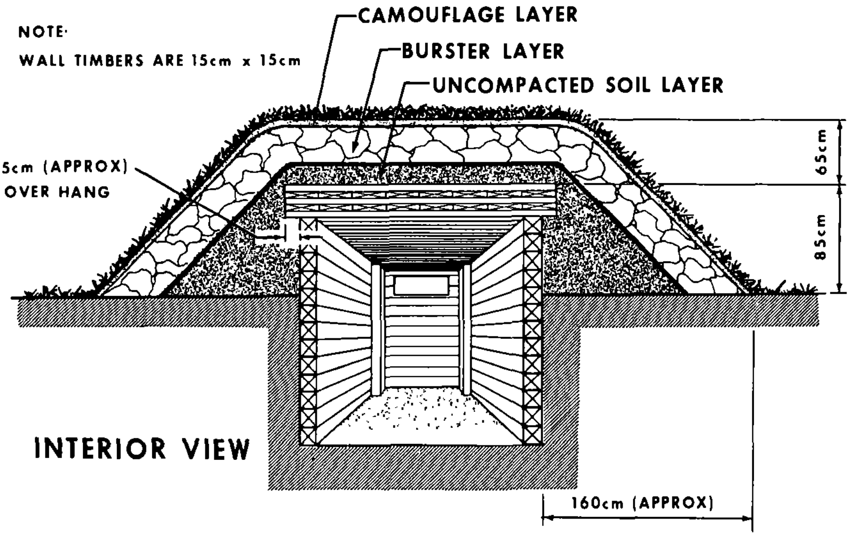
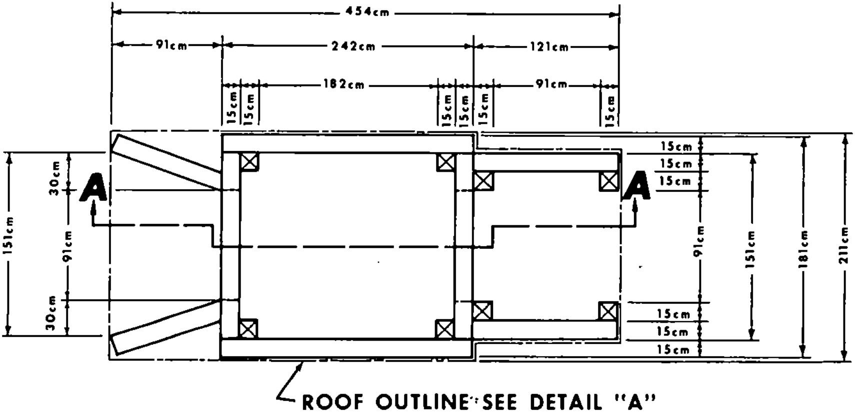


Figure 4–11—Continued.



PLAN VIEW

Figure 4–11 — Continued.

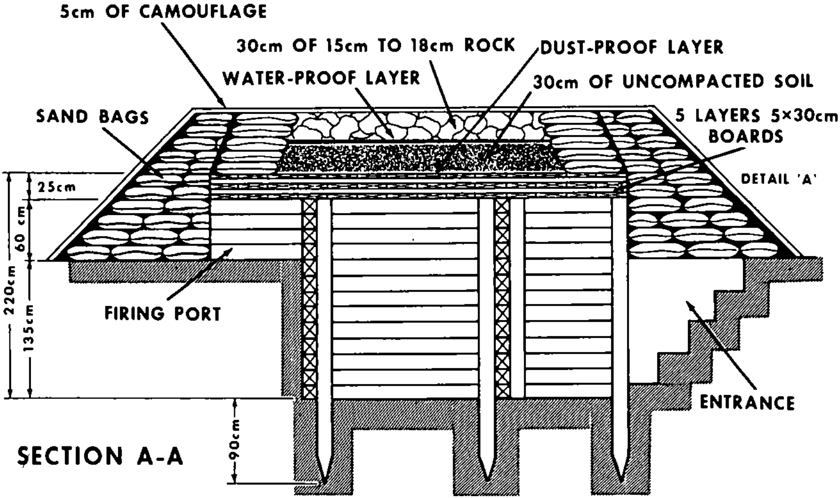


Figure 4–11 — Continued.

ITEM	DESCRIPTION	NO. PCS
ROOF	5cm × 30cm × 2.11m Long — Wood	48pcs
	5cm × 30cm × 4.54m Long — Wood	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 4–11 —Continued.

4–7. SHELTERS

The most effective shelters are deliberate, underground, cut and cover with as deep overhead cover as possible. They should be dispersed and have a maximum capacity of 20 to 25 men. Typical shelters, including a modular (sectional) type are illustrated in figures 4–13, 4–14, and table 4–5. Heavy overhead cover suitable for either shelters or bunkers which will provide protection against 155-mm shells is shown in figure 4–15.

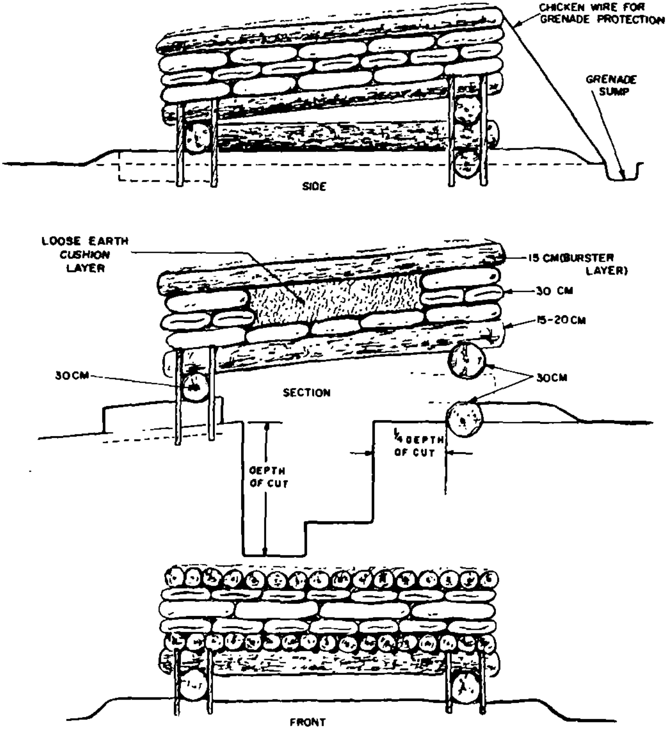
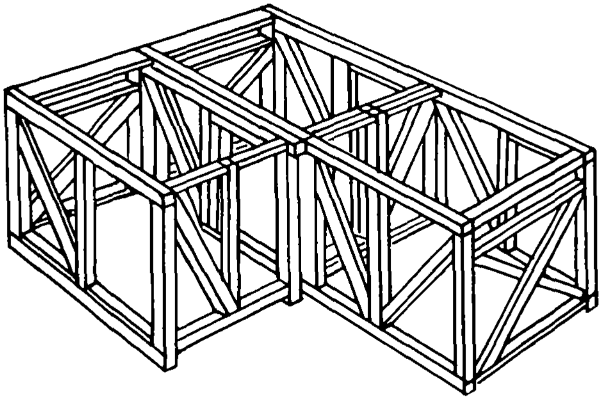
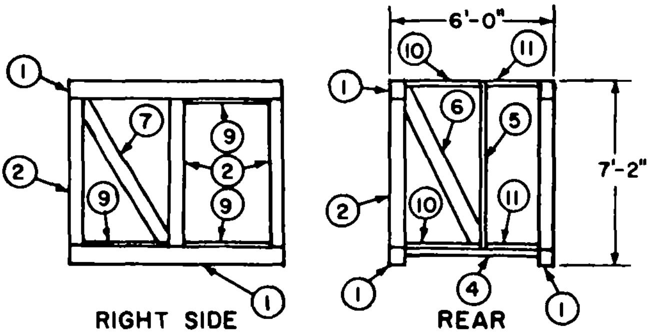


Figure 4-12. Fighting bunker with overheod cover.

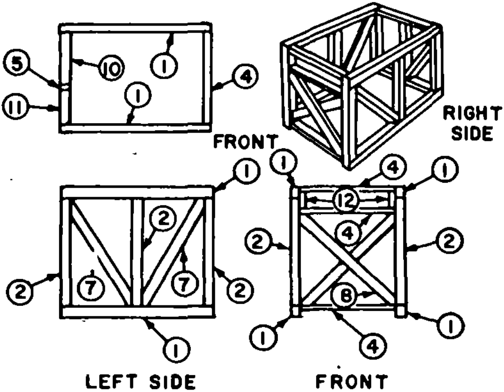


(1) TYPICAL CONNECTION OF THREE SECTIONS

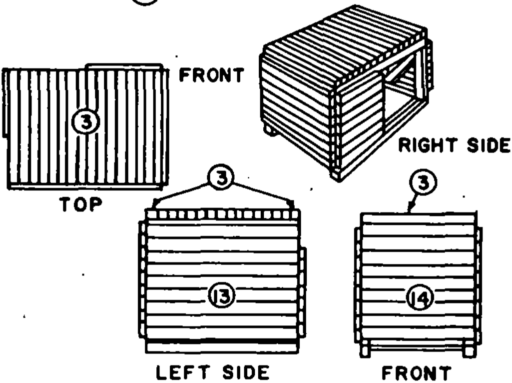


(2) FRAMING DETAILS

Figure 4–13. Sectional Shelter.

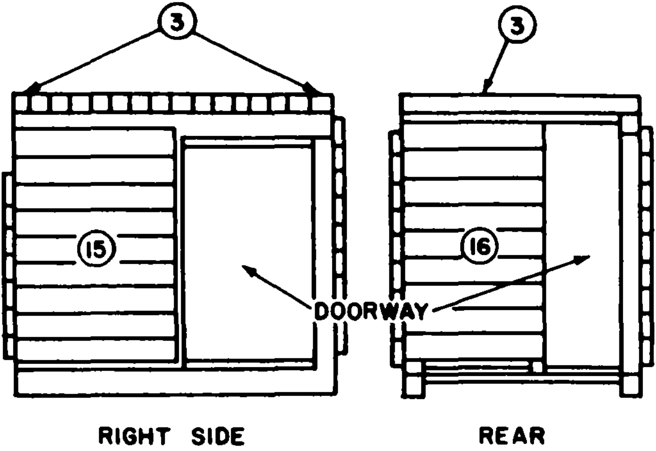


(3) FRAMING DETAILS



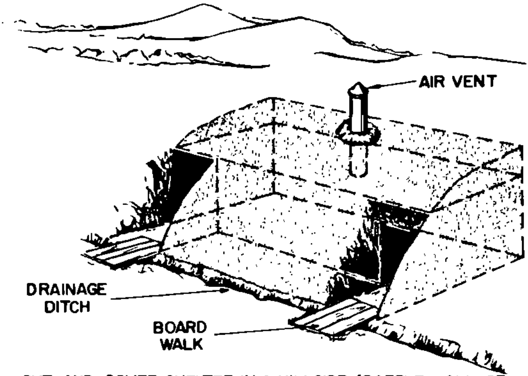
(4) SHEATHING DETAILS

Figure 4-13—Continued.

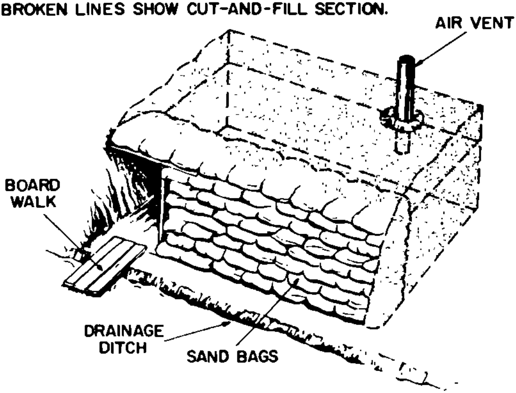


5 SHEATHING DETAILS

Figure 4–13 — Continued.



CUT-AND-COVER SHELTER IN A HILLSIDE (BAFFLE WALL OF ENTRANCE CAMOUFLAGE OMITTED) SHADED AREA AND BROKEN LINES SHOW CUT-AND-FILL SECTION.



CUT-AND-COVER SHELTER IN A CUT BANK SHOWING SAND-BAGGED OUTER WALL. SHADED AREA AND BROKEN LINES SHOW AREA OF CUT-AND-FILL.

Figure 4–14. Cut and cover shelter.

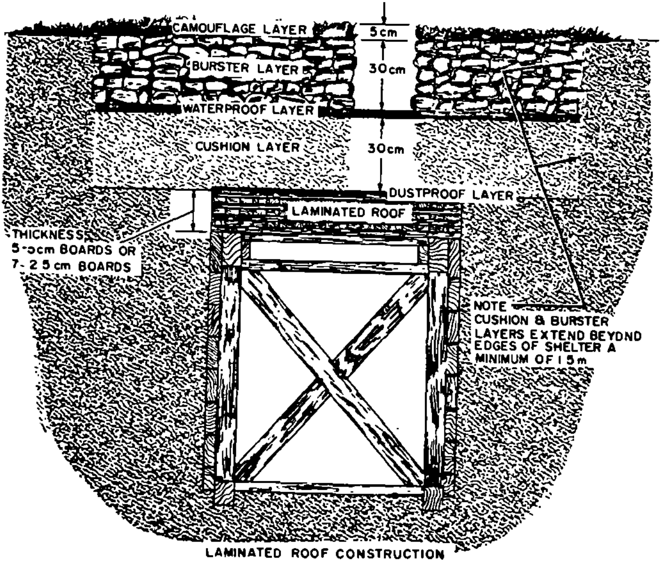


Figure 4–15. Heavy overhead cover.

Table 4–5. Bill of Materials for One 6′ x 8′ Sectional Shelter With Post, Cap and Stringer Construction — Dimensional Lumber

Material List			
No.	Nomenclature	Rough size	Quantities
1	Cap or sill................	6″ x 8″ x 8′0″	4
2	Post.......................	6″ x 6″ x 5′10″	6
3	Stringer**...............	6″ x 6″ x 6′0″	16
4	Spreader................	3″ x 6″ x 5′0″	3
5	Post, door...............	3″ x 6″ x 6′6″	1
6	Brace....................	*3″ x 6″ x 7′0″	1
7	Brace....................	*3″ x 6″ x 6′10″	3
8	Brace....................	*3″ x 6″ x 8′0″	2
9	Spreader................	2″ x 6″ x 3′3″	3
10	Spreader................	2″ x 6″ x 2′9″	2
11	Spreader................	2″ x 6″ x 2′0″	2
12	Scab......................	3″ x 6″ x 2′0″	2
13	Siding....................	3″ x RW x 8′0″	$41\frac{1}{3}$ SF
14	Siding....................	3″ x RW x 6′0″	36 SF
15	Siding....................	3″ x RW x 4′0″	24 SF
16	Siding....................	3″ x RW x 3′6″	21 SF
17	Roll roofing.............	100 Sq ft roll	6
18	Driftpin..................	$\frac{1}{2}$″ x 14″	44
19	Nails......................	60d	32 lb

*Allowance for double cut ends of braces is included in overall length as shown under rough size.

**Laminated wood roof (fig. 4–15) may be substituted if desired.

Section III. Obstacles

4-8. PRINCIPLES OF EMPLOYMENT

To be effective, obstacles should be sited and laid out to meet the following requirements:

a. Under friendly observation, covered by fire, and where practicable, protected by antipersonnel mines, flame mines, trip flares and warning devices.

b. Concealed from enemy observation as far as practicable by incorporating terrain features such as reverse slopes, hedges, woods, paths and fence lines.

c. Erected in irregular and nongeometrical traces.

d. Employed in depth or zones whenever practicable.

e. Coordinated with other elements of the defense.

f. Tie in with other obstacles.

g. Provide lanes and gaps.

h. Afford no advantage to the enemy.

4-9. TYPES

a. *Antipersonnel.* Obstacles in this category include:

(1) Wire obstacles constructed with barbed wire and tape as discussed and illustrated later in this section.

(2) Expedient obstacles constructed from locally available material as illustrated herein.

b. *Antivehicular.* Both deliberate and expedient types of obstacles designed to delay or stop the progress of all types of vehicles are illustrated in this section.

4-10. CLASSIFICATION OF BARBED WIRE

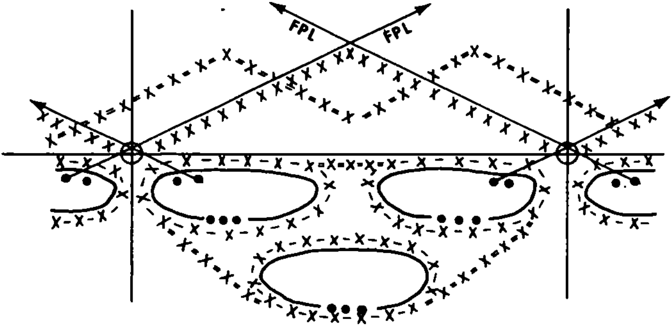
a. *Depth.*

(1) Belt—an entanglement one fence in depth.

(2) Band—two or more belts in depth, with no interval between them. The belts may be fences of the same type, or the band may be composed of two or more fences of different types, in which case it would be called a combination band.

(3) Zone—two or more bands or belts in depth with intervals between them.

b. *Use.* See figure 4-16.



X X X X X X X X X TACTICAL WIRE

X – X – X – X – X PROTECTIVE WIRE

= X = X = X = X SUPPLEMENTARY WIRE

Figure 4–16. Classification of wire by use.

4–11. ESTIMATING BARBED WIRE REQUIREMENTS

a. Conventional Deployment. In estimating borbed wire requirements for conventional deployment as shown in figure 4–16, use the following rules of thumb:

(1) Tactcal wire; front × 1.25 × number of belts

(2) Protective wire; front × 5 × number of belts.

(3) Supplementary wire.

(a) Forward of FEBA; front × 1.25 × number of belts.

(b) Rear of FEBA; front × 2.5 × unit depth × number of belts.

b. Base Camp Defense. In estimating borbed wire requirements for base camp defense as shown in figure 4–17, use the following rules of thumb:

(1) Tacticol wire; sum of the mean perimeter of each toctical wire belt × 1.25.

(2) Protective wire; perimeter of the protective wire × 1.10

(3) Supplementory wire; sum of the mean perimeter or eoch supplementary wire belt × 1.25.

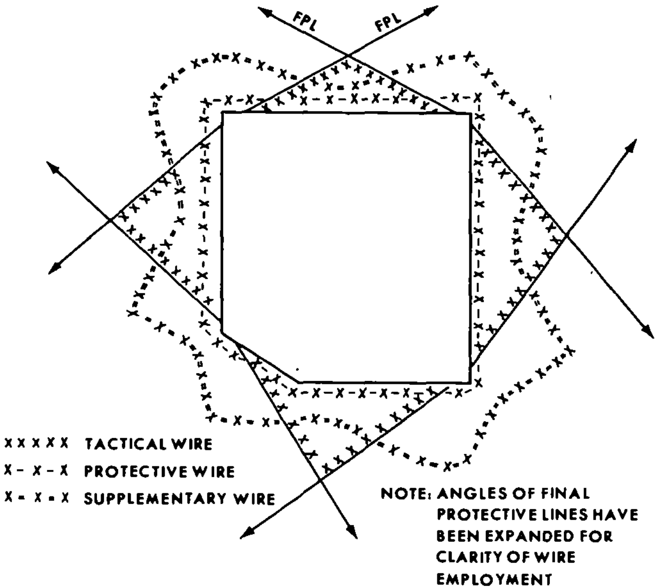


Figure 4—17. Perimeter defense wire.

c. *Supply and Labar.* Far constructian estimates of manhaurs and materials, see tables 4–6 and 4–7.

Table 4–6. Wire and Tape Entanglement Materials

Material	Approx weight, kg	Approx length, m	Na. carried by one man	Apprax weight of man-load kg
8arbed wire reel	41 5	400	½	21
8obbin	3.5–4.0	30	4–6	14.5–24 5
8orbed tape dispenser	0.77	0.45	20	15 5
8arbed tope carrying cose	14.5	300	1	14.5
Stondard borbed tape concertino	14	15 2	1	14
Standard borbed-wire concertina	25.4	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-shoped pickets:				
Extro long	7.25	2.4	3–4	21.8–29.0
Lang	4.5	1.5	4	18.1
Medium	2.7	0.81	6	16.3
Shart	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 4–7. *Material and Labor Requirements for 300-Meter Sections of Various Barbed Wire Entanglements*

Type of entanglement	Pickets: Extra long	Pickets: Long	Pickets: Medium	Pickets: Short	Barbed wire no of 400 m, 41.5 kg reels [1]	No. of concertinos [4]	Staples	Kgs of materials per lin m of entanglement [2]	Manhours to erect 300 m of entanglement [3]
Double-apron, 4- and 2-pace	....	100	....	200	[5] 14–15[19]	....	....	[6] 4.6[3.5]	59
Double-apron, 6- and 3-pace	.. ....	66	... ...	132	[5] 13–15[18]	....	....	[6] 3.6[2.6]	49
High wire (less guy wires)	.... ..	198	. . ... .	... ...	[5] 17–19[24]	....	....	[6] 5.3[4.0]	79
Low wire, 4- and 2-pace	.. ...	..... .	100	200	[5] 11[15]	... . . .	. . . . .	[6] 3.6[2.8]	49
4-strand fence	....	100	....	2	[5] 5–6[7]	. . ... .	....	[6] 2.2[1.8]	20
Double expedient concertino	....	101	....	4	3	100	295	6.9	40
Triple expedient concertino	51	101	....	7	3	148	295	10 4	99
Triple standard concertina	. .	160	. . . .	4	[5] 3[4]	59	317	[6] 7.9[5.4]	30

[1] Lower number of reels applies when screw pickets are used, higher 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] Manhours are based on the use of screw pickets With the exception of the triple-standard concertinas, add 20 percent to the manhours when driven pickets are used With experienced troops, reduce manhours by one-third Increase manhours 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.

[5] Number of 300 m, 14 5 kg barbed tape carrying cases required if barbed tape is used in place of barbed wire.

[6] Kgs of materials required per linear meter of entanglement if barbed tape is used in place of barbed wire and barbed tape concertina is used in place of standard barbed wire concertina

4–12. BARBED WIRE TIES

See figure 4–18.

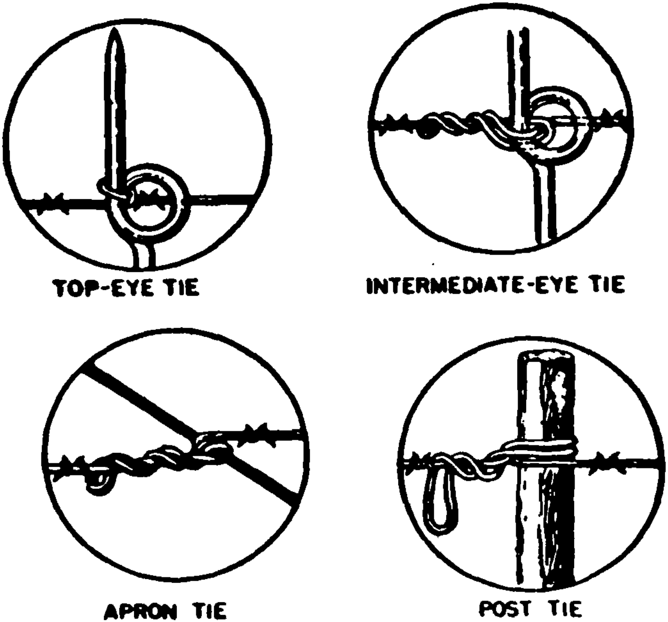


Figure 4–18. Barbed wire ties.

4–13. BARBED STEEL TAPE

Barbed steel tape (fig. 4–19) and barbed tape concertina can be used in the same manner as standard barbed wire and concertina for the

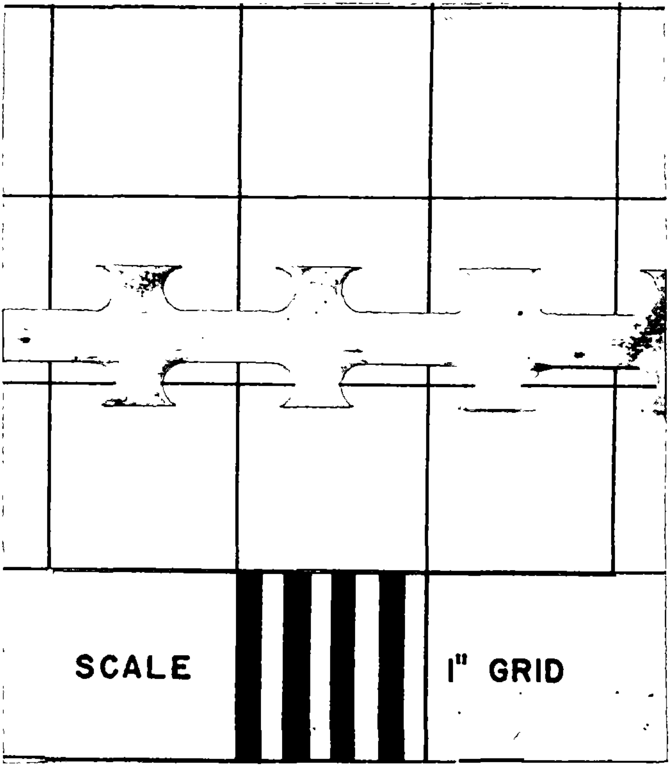


Figure 4–19 Barbed steel tape.

construction of borbed wire entonglements. Stondord ties ore used with borbed steel tope. A speciol dispenser is used to import o twist to the tape when constructing fences. Recovery of the barbed steel tope usuolly is nat procticol.

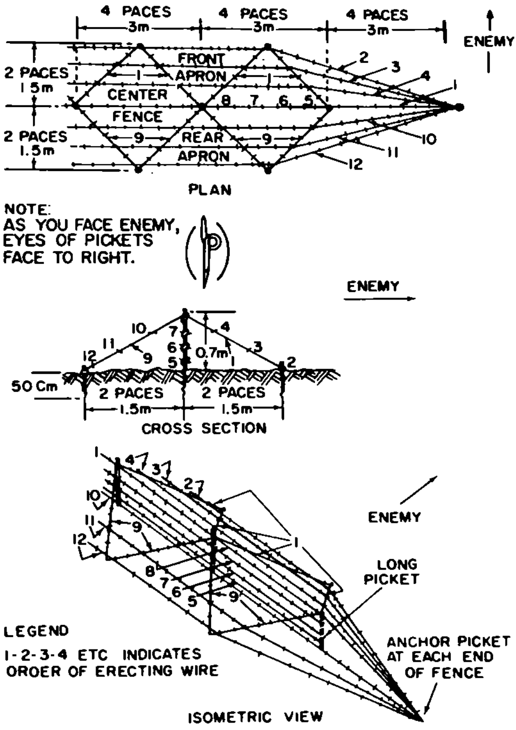


Figure 4—20. Double opron fence.

4–14. 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 4–20.

4–15. 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.

4–16. 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 divided 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.

4–17. 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 of long pickets.

(3) Enemy and friendly rows of pickets are 3 feet (0.9 m) apart.

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

c. See figure 4–21.

d. Concertina fences are constructed of either barbed wire concertina or barbed tape concertina. There is no difference in construction methods.

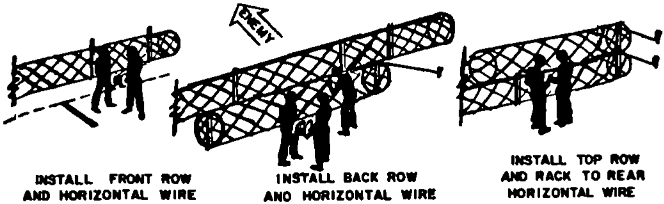


Figure 4–21. Installing concertinas.

4–18. 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.

(c) Remove binding wire and place on handles.

(*d*) Repeat same performance every fourth picket thereafter.

b. Second Operation (*All Personnel*).

(1) Install front row concertina and horizontal wire.

(a) Drop concertinas over pickets.

(*b*) Method of joining (fig. 4–22).

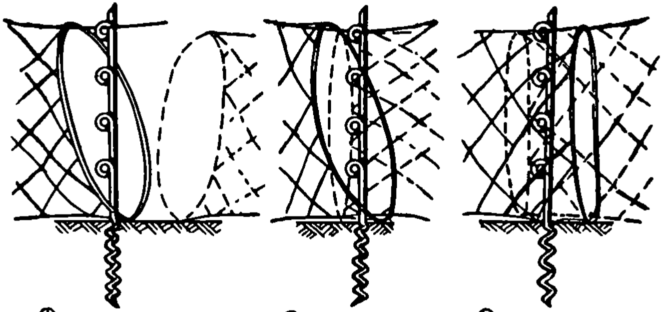


Figure 4–22. Joining concertinas.

1. Bottom of old concertina on joining picket.
2. Bottom and top of new concertina on joining picket.
3. Top of old concertina on joining picket.

(2) Install rear row concertina and horizontal wire.
(3) Install top row concertina and rack to the rear horizontal wire.

4–19. LOW WIRE FENCE

This is like a 4- and 2-pace double apron fence, except that medium pickets instead of long pickets are used in the centerline. The No. 5, 6, and 7 wires are not used, which results in all apron and diagonal wires being much closer to the ground. Being low to the ground, this obstacle is easily hidden in tall grass or shallow water. For best results, it should be used in depth.

4–20. FOUR-STRAND CATTLE FENCE

This is the four-strand center section of a double-apron fence. In farm country, such an obstacle blends in with the landscape. Wooden pickets at 2- to 4-pace intervals are set up. If guy wires are used, they should be added separately when estimating because this material is not included in the amounts listed in table 4–7.

a. Use eight men on short sections of this fence. On 300-meter sections, use up to 17 men.

b. In the first operation the working party is divided into two approximately equal groups. The first group lays out long pickets at 3-meter intervals. It begins and ends the section with an anchor picket, including anchor pickets for guys, if needed. The second group installs the pickets

c. As each man completes the first operation, he moves to the fence. These teams of two or four men are organized to install wires In four-man teams, two men carry the reel, and two make ties and tighten the wire. In two-man teams, the wire is unrolled for 50 to 100 meters, then the men make the ties. The first team installs the bottom wire, and succeeding teams install the next wires in order.

4–21. COMBINATION BANDS

Many types of fence may be combined in bands to form obstacles more difficult to breach than single belts. Other variations may be readily developed.

4–22. PORTABLE BARBED-WIRE OBSTACLES

Standard concertinas are in this category because they are readily moved. Other portable barbed-wire obstacles are listed below.

a. Spirals of loose wire are used to fill open spaces in and between wire entanglements. Prepare them by driving four 1-meter posts into the ground to form a diamond 1 meter by 0.5 meters. Wind 75 meters of wire around them from bottom to top. Remove wire from the frame, tie it at the quarter points, then carry the spirals to site where they are opened and used.

b. The knife rest (fig. 4–23) 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.

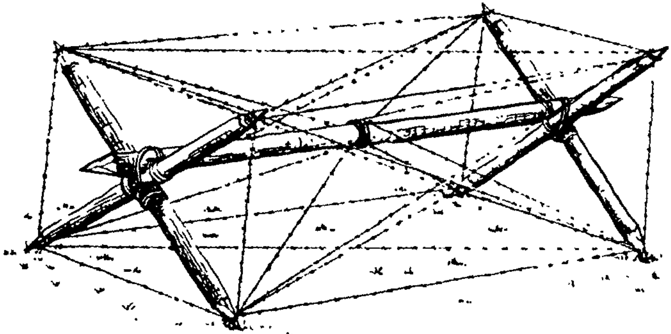


Figure 4–23. Knife rest.

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. 4–24). 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.

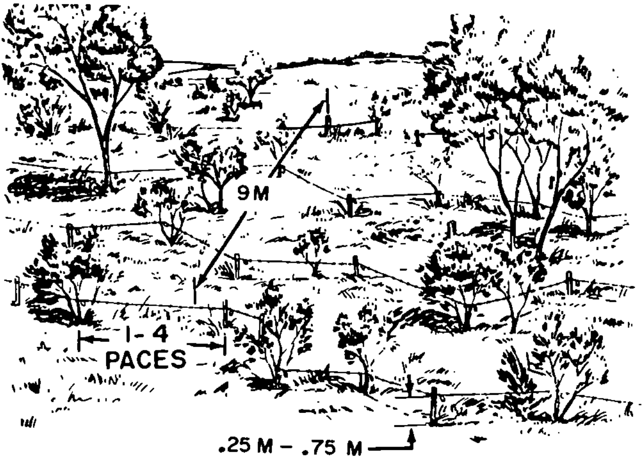


Figure 4–24. Tanglefoot.

e. The trestle apron fence (fig. 4–25) has inclined cross-pieces spaced at 5- to 6-meter intervals to carry wires on the enemy side.

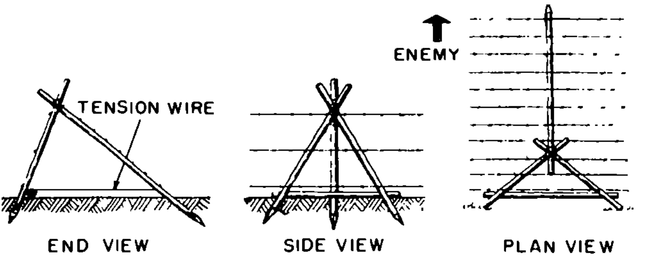


Figure 4–25. Trestle apron fence.

4-23. EXPEDIENT OBSTACLES

See figures 4-26 through 4-33

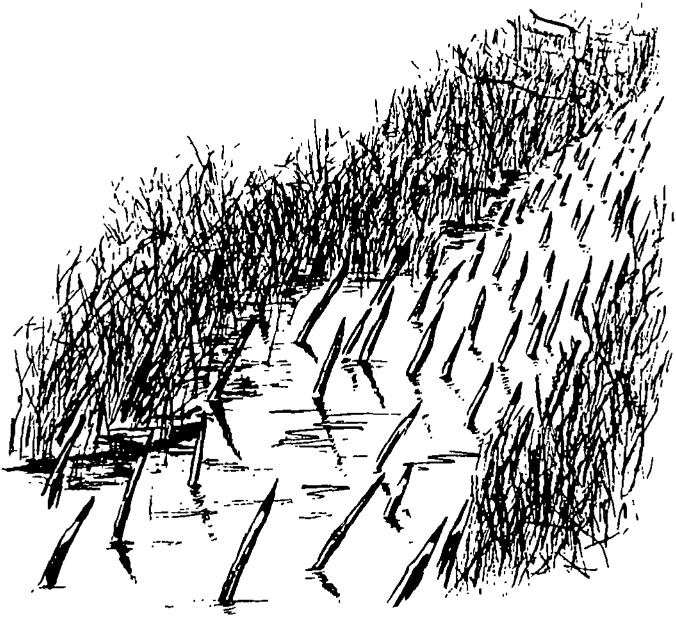


Figure 4-26. Belt of imbedded sharpened stakes.

Figure 4—27. Punji jungle trap.

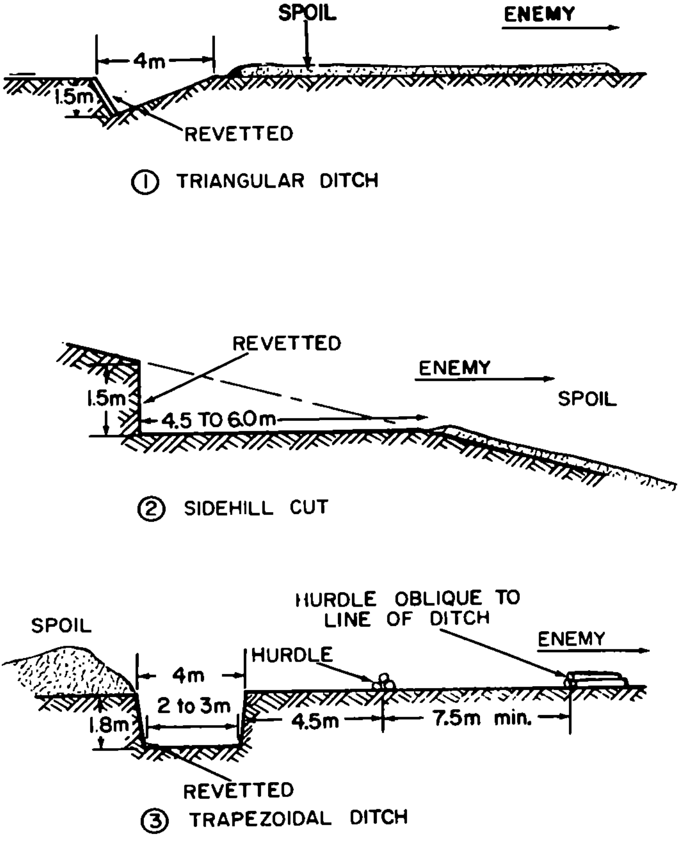


Figure 4–28. Trapezoidal ditch.

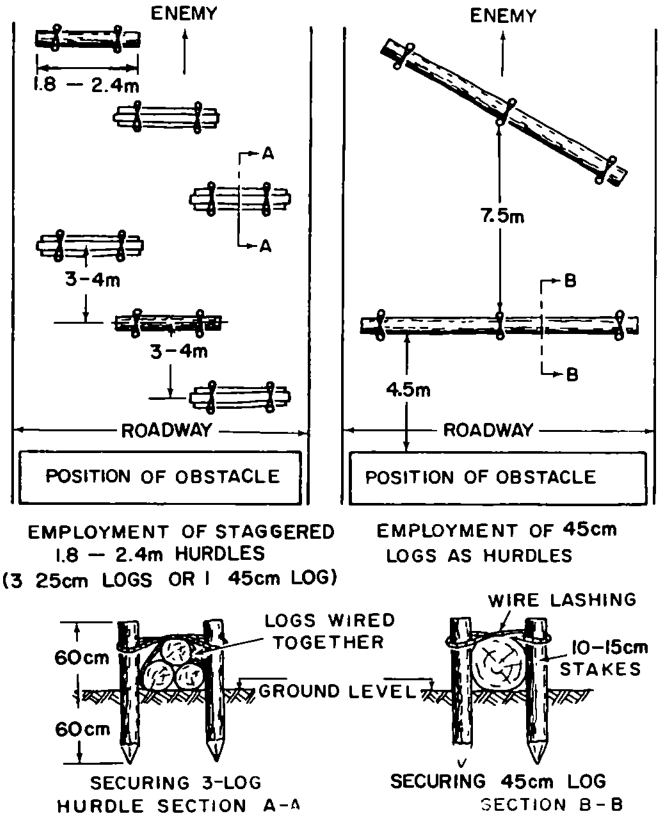
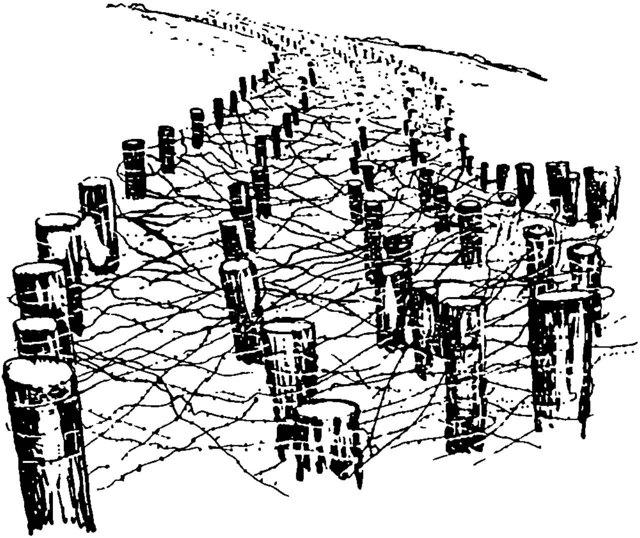


Figure 4–29. Log hurdles.



DIMENSIONS

SPACING: IRREGULAR WIDTH: 3.5 TO 6.5 FEET BETWEEN POSTS

HEIGHT: 2 5 TO 4.0 FEET ABOVE GROUND AND APPROXIMATELY
5 FEET BELOW GROUND.

MINIMUM DENSITY 200 POSTS PER 100 METERS OF FRONT.

DIAMETER OF LOGS 16 INCHES

Figure 4—30. Post obstocles.

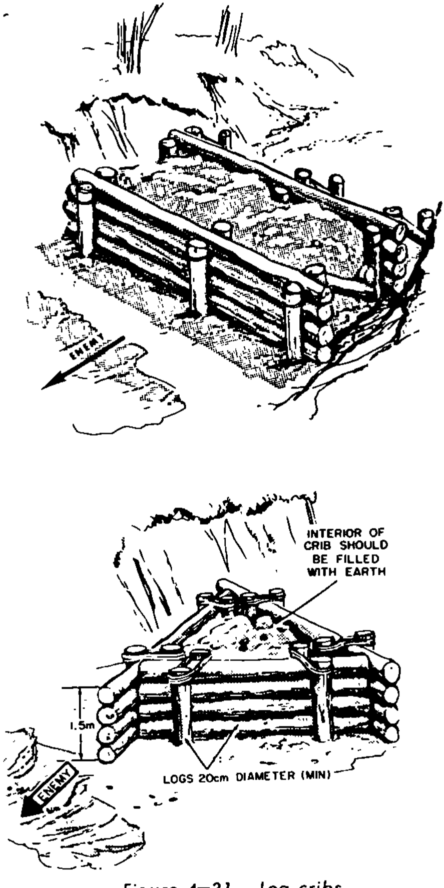
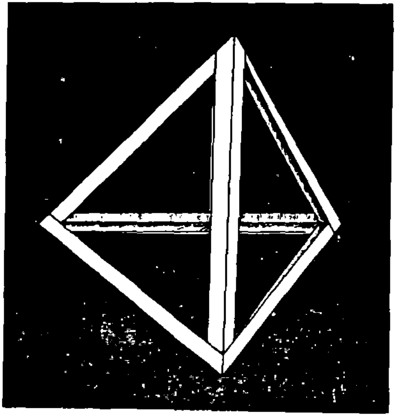


Figure 4—31. Log cribs.

Figure 4—32. Abatis used as roadblock.



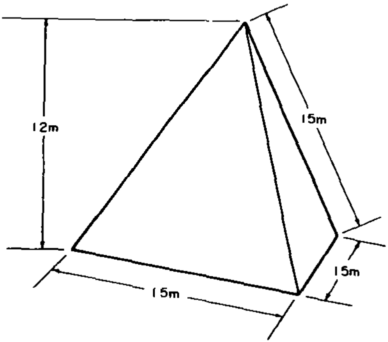


Figure 4–33. Tetrahedrons.

CHAPTER 5

MARKING OF BRIDGES AND VEHICLES

Section I. Bridge and Vehicle Classification System

5–1. PURPOSE OF THE SYSTEM

The standard system of bridge and vehicle classification permits the utilization of bridges at their maximum safe military capacities. It provides a practical means of relating bridge capacity to the overall loading effect of a vehicle on the bridge. The bridge and vehicle classification system will—

a. Assist the commander in route selection for both tactical and logistical movements.

b. Assist the commander in planning bridge reinforcement and new bridge construction.

c. Protect the existing bridge from overload and subsequent damage or failure.

d. Protect the vehicle, payload and driver from bridge failure

e. Prevent costly and time-consuming delays due to bridge failure.

5–2. APPLICATION OF THE SYSTEM

a. The bridge and vehicle classification system has been established through a series of standardization agreements approved for use by member nations of the North Atlantic Treaty Organization (NATO), the Southeast Asia Treaty Organization (SEATO), and the United States, United Kingdom, Canadian, and Australian Armies Nonmaterial Standardization Program. The applicable agreements are: Standard NATO Agreement (STANAG), SEATO Standardization Agreement (SEASTAG), and Standardization of Operations and Logistics (SOLOG)

b. The classification system, as it pertains to traffic controls and the bridge and vehicle marking systems is applicable to all echelons, to include vehicle and equipment operators.

c. The classification system as it pertains to expedient bridge classification and expedient vehicle classification, is applicable to all organizations of the Army that rely on the movement of vehicles and equipment.

d. The clossification system, to include camplete analytical bridge and vehicle classificotion, is applicoble ta all engineer arganizatians down ta battalian level.

5–3. VEHICLE CLASSIFICATION MARKINGS

Vehicles are divided intó two cotegories for classificatian and marking purpases: single and combinotion vehicles.

o. *Single Vehicles.* A single vehicle hos anly ane frame ar chassis, such as a tank or a 2½-tan truck. Single vehicles are assigned a class number rounded up ta the clasest integer. The classificatian number for single vehicles is marked an a circular sign with black numerals on a yellaw bockgraund. This sign is instolled or painted an the front of the vehicle and below the driver's line af vision (fig. 5–1). Signs in front are 9 inches in diameter ond signs on the side are 6 inches in diameter.

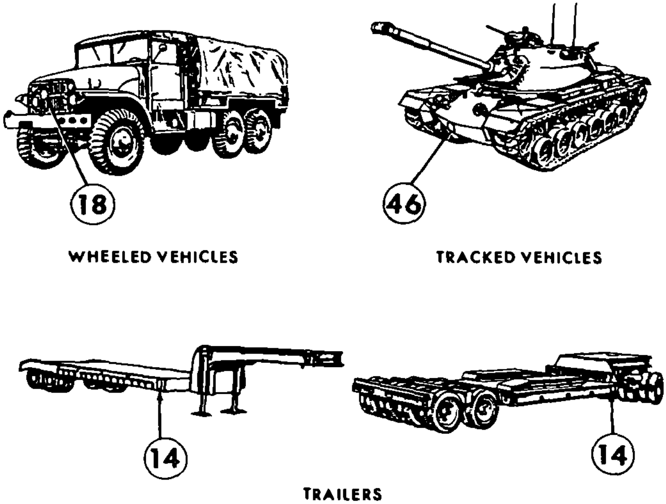


Figure 5–1. Classification morkings af single vehicles.

b. Combination Vehicles. A combinotion vehicle is a vehicle consisting of two or more single vehicles which operate as one unit, such os prime movers pulling semitrailers. If one vehicle is towing another and the distance between them is less thon 30 yards, they must be considered a combination vehicle. The sign on the front of the towing vehicle hos the letter "C" in red above the classification number of the combination. In addition, each component vehicle of the combination carries a sign on the right side which gives the classification number of the component (fig. 5–2).

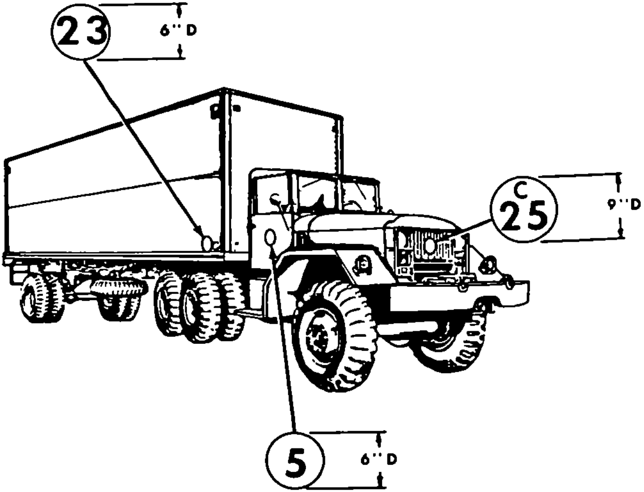


Figure 5–2. Classificatian marking of typical cambination vehicles.

Section II. Vehicle Classification

5–4. PRINCIPLES

o. *Classification Numbers.* Classification numbers represent the loading effect of the vehicle on a bridge. This effect depends on the gross weight of the vehicle, the spacing of axles, the weight distribution to the axles, and the speed at which the vehicle crosses the bridge. The classification number does not represent the actual weight of the vehicle. All standard army vehicles and special equipment that are active in the theater of operations and utilize bridges of military importance are normally given a vehicle class number. Exceptions are trailers with o rated payload of $1\frac{1}{2}$ tons or less, and other types of vehicles with a gross weight of less than 3 tons.

b. Classification of Standard Vehicles. Standord U.S. Military vehicles are classified by the Commanding General, U.S. Army Materiel Command (Mobility Equipment Research and Development Center). FM 5–36 lists classification numbers for most standard U.S. military vehicles. The vehicle classification list is not complete, but future changes to FM 5–36 will include data on new items of equipment as this information becomes available. For any vehicle not listed or for ony nonstandard vehicle, a classification number can be obtoined by submitting lood and dimensional information to U.S. Army Combot Developments Command in accordance with instructions contained in FM 5–36.

c. *Vehicle Data.* The analytical method of vehicle classification is beyond the scope at this manual. It is discussed in TM 5–312. To accurately classify a vehicle by this method, the dimensions of the vehicle and weight distribution data must be obtained. FM 5–36 furnishes a guide to the specific information required. It is important that the weight data is obtained when the vehicle is empty and again when it is loaded with its full rated payload. Weight distribution to each axle should be obtained with scales, unless such information is available in technical publications or from vehicle data plates.

5–5. EXPEDIENT VEHICLE CLASSIFICATION

In an emergency, temporary vehicle classification can be accomplished by using expedient classification methods. The vehicle should be reclassified by the analytical method (para 5–4c) as soon as practicable to obtain a permanent classification number.

a. *Wheeled Vehicles*. Expedient classification for wheeled vehicles may be accomplished as follows:

(1) Compare the wheel and axle loadings and spacings of the unclassified vehicle with those of a classified vehicle of similar design shown in FM 5–36, and assign a temporary class number.

(2) Assign a temporary class number equal to 85 percent of the gross weight of the vehicle in tons as follows:

TEMPORARY CLASS (wheeled vehicles) $= 0.85\ W_T$

where $W_T =$ Gross weight of vehicle in tons.

The gross weight of the vehicle may be estimated from the tire pressure and tire contact area, if no other means are available:

$$W_T = \frac{A_T P_T N_T}{2000}$$

where, $W_T =$ Gross weight of vehicle in tons

$A_T =$ Average tire contact area in square inches (tire in contact with hard surface)

$P_T =$ Tire pressure in psi

$N_T =$ Number of tires

Note. The tire pressure may be assumed to be 75 psi for 2½-ton vehicles or larger if no tire gage is available. For vehicles having unusual load characteristics or odd axle spacings, a more deliberate vehicle classification procedure, as outlines in STANAG 2021 is required.

b. *Tracked Vehicles*. Expedient classification for tracked vehicles may be accomplished as follows:

(1) Compare the ground contact area of the unclassified tracked vehicle with that of a previously classified vehicle to obtain a temporary class number.

(2) Assign a temporary class number equal to the gross weight of the tracked vehicle in tons.

TEMPORARY CLASS (Tracked vehicles) $= W_T$

where, $W_T =$ Gross weight in tons

Tracked vehicles can be assumed to be designed for approximately 2,000 pounds (one ton) per square foot of their bearing area (most heavy vehicles are slightly less than this). Thus, the gross weight of the tracked vehicle (W_T) can be estimated by measuring the total ground contact area of the tracks (square feet) and equating this to the gross weight in tons.

Example: An unclassified tracked vehicle has a ground contact area of 5,500 square inches. Therefore, the area is about 38.2 square feet, and the class of the vehicle is 38.2 or 39, since ground contact area in square feet equals approximate weight of a tracked vehicle in tons, which in turn is approximately equal to class number.

c. *Nonstandard Combinations.* The class number (fig. 5–3) of nonstandard combinations of vehicles may be obtained expeditiously as follows:

Combination class $= 0.9\ (A + B)$ if $A + B \leqslant 60$

Combination class $= A + B$ if $A + B > 60$

$A =$ Class of first vehicle

$B =$ Class of second vehicle

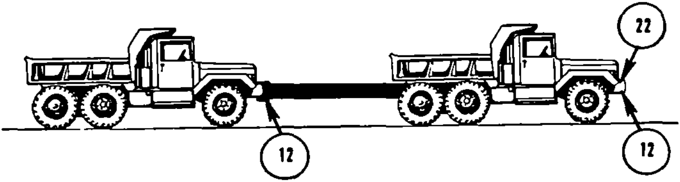


Figure 5–3. Classification marking of nonstandard combination vehicle.

d. *Adjustment for Other Than Rated Load.* An expedient class may be given to overloaded or unloaded vehicles by adding to or subtracting the difference in loading in tons, from the normally assigned vehicle class. The expedient classification number is marked with a standard vehicle class sign to indicate temporary classification as shown in figure 5–4.

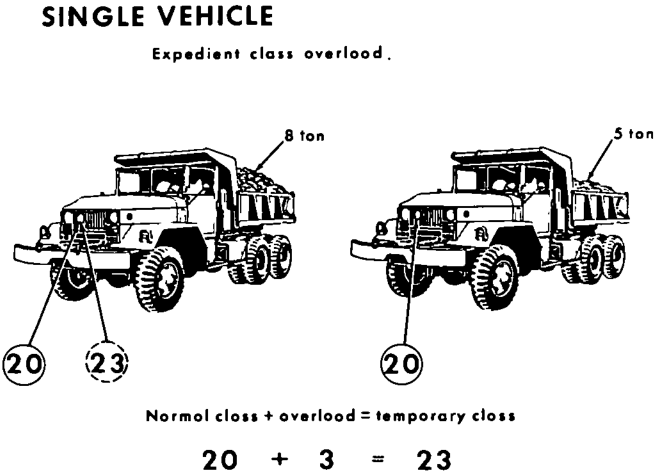


Figure 5–4. Example classification of an overloaded vehicle.

Section III. Bridge Classification and Marking

5-6. CLASSIFICATION NUMBER

The result of bridge classification is the determination of the bridge class number. The bridge class number is the number which represents the safe military load-carrying capacity of the bridge, considering width restrictions and overhead clearance. Bridges may be given a dual classification when the capacity is greater than class 30. This classification consists of both a wheeled vehicle class number and a tracked vehicle class number. General methods for calculating the actual safe military load-carrying capacity of different types of bridges are discussed in TM 5–312. Width restrictions and overhead clearances as they apply to bridge classification are discussed in paragraph 5–7 and TM 5–312.

5-7. WIDTH AND HEIGHT RESTRICTIONS

a. *Minimum Roadway Width.* Roadwoy widths as indicated in toble 5-1 have been prescribed as minimum. If a bridge of a specific classification meets these width requirements, then it can be assumed that all standard militory vehicles bearing the same classification number or lower can cross the bridge without width limitations. No posting is required. If a one-lane bridge meets oll the requirements except minimum width for a certain classification, the classification is not downgraded, but the width is posted as outlined in paragraph 5-8, and appropriate travel restrictions are imposed. A two-lane bridge must meet the minimum lane widths prescribed in table 5-1 If it does not, it must be downgraded to a class within the limits of its actual width. Usually only the two-way class will have to be lowered until the width requirement is met.

b. *Overhead Clearance.* Overhead clearances, as indicated in table 5-2, have been prescribed as minimum. When the overhead clearance is less than the minimum prescribed, the clearance should be indicated by the use of o telltale (fig. 5-5).

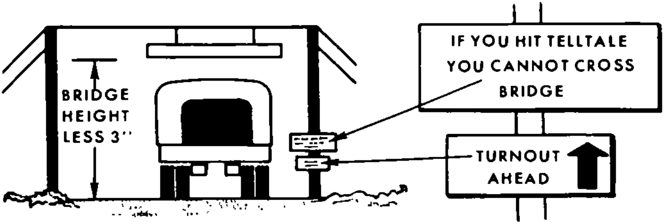


Figure 5-5. Typical telltale indicating overhead clearance of o bridge.

c. *Special Handling.* Turnouts for parking and unloading vehicles are provided near the bridge. Vehicles requiring special handling, such as those making a one-way crossing of a two-lane bridge, will be directed to the turnout. The marking arrangement is shown in figure 5-11.

Table 5–1. Minimum Lane Widths for Bridges

Bridge class	Minimum width between curbs	
	One lane	Two lane
4–12	9′–0″	18′–0″
13–30	11′–0″	18′–0″
31–60	13′–2″	24′–0″
61–100	14′–9″	27′–0″

Table 5–2. Minimum Overhead Clearances for Bridges

Bridge class	Minimum overhead clearance
4–70	14′–0″
71–over	15′–6″

5–8. BRIDGE CLASSIFICATION SIGNS

Standardization agreements establish the following system of posting bridge classifications. In addition, special arrangements may be made by theater commanders to indicate vehicles of exceptional width or to indicate low overhead obstructions. There are two general types of standard military bridge signs. These are *circular* and *rectangular* in shape.

a. *Circular Signs.* Both military and civil bridges in the theater of operations which have been classified are marked with circular signs indicating the military load classification. These signs have a yellow background with black inscriptions. The inscription is as large as the diameter of the sign allows. Circular signs are of two types: *normal* circular signs and *special* circular signs.

(1) *Normal circular signs.*

(a) Signs for one-lane bridges are a minimum of 16 inches in diameter (fig. 5–6).

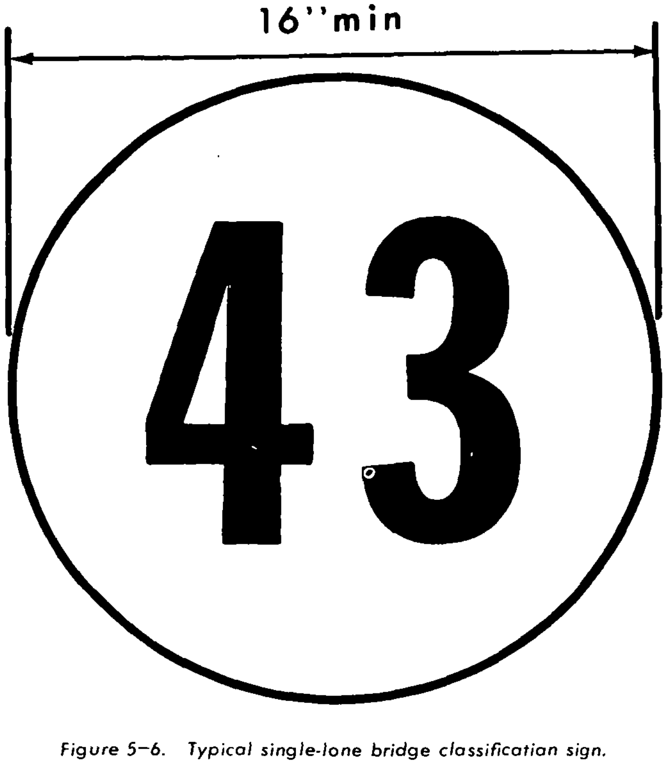


Figure 5–6. Typical single-lane bridge classification sign.

(b) Signs far two-lane bridges are a minimum of 20 inches in diameter and are divided inta right and left sections by a vertical line. The classification for two-way traffic is shawn in the left half with two parallel vertical arrows beneath the number, and the classificatian far single flaw traffic is shown in the right half of the signs with one vertical arrow beneath the number (fig. 5–7).

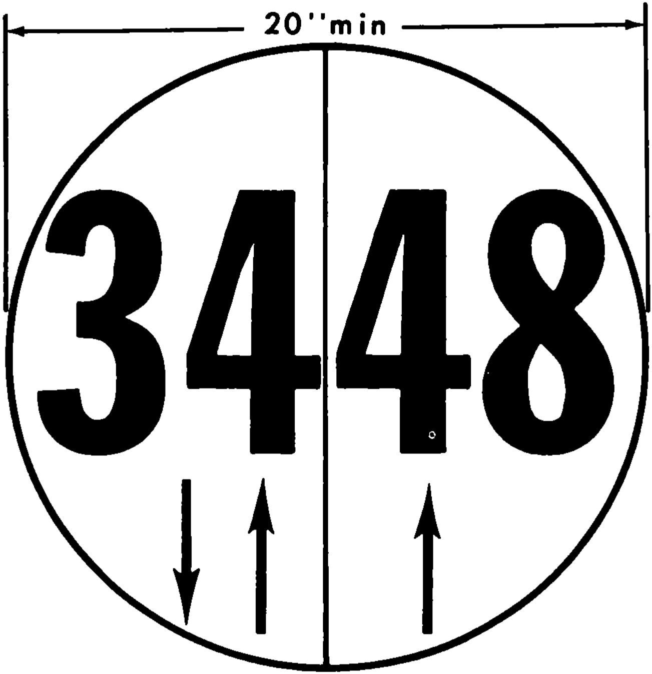


Figure 5–7. Typical twa-lane bridge classificotian sign.

(2) *Specıal circular signs.*

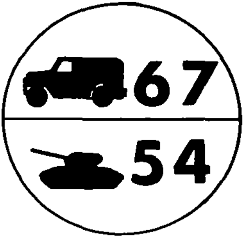
(a) If a bridge has separate classifications for wheeled and tracked vehicles, as a result of dual classificotian, a special circulor sign which indıcates bath classificatians is used (fig. 5—8). The sign is o minimum of 20 inches in diameter and is divided inta two sectians by a harizantol line. On the tap half, the wheeled classificatian is shown olong with a symbol representing a wheeled vehicle. On the battom half, the tracked classificatian is shawn alang with a symbal representing a tracked vehicle.

(*b*) Where similor canditians pertain to a two-lane bridge, the narmol and the speciol signs for wheeled and tracked traffic may be cambined (fig. 5—8).

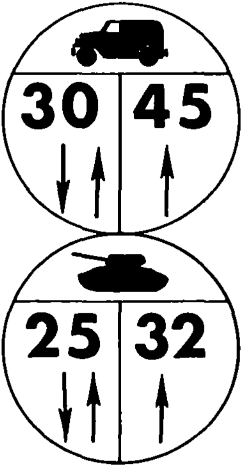
(c) Bridges which have been classified by the expedient methads discussed in chapter 5 are morked with standard cırcular signs.

b. Rectongular Signs. Additional instructians and technicol infarmation are inscribed an rectangular signs. Rectangular signs are a minımum af 16 inches in height ar width and have a yellaw backgraund upon whıch the appropriate letters, figures, ar symbals are inscribed in black. The inscription is as large as the sign permits. Separate rectangular signs are used if necessary ta shaw width limitatians, height limıtatians (fig. 5—9, or technıcol infarmation. Width and height signs ore not required an bridges where existing civilian signs are already in place and are sufficiently clear. In thase cauntries which canfarm to the Geneva Canvention of 1949, internotianal height and width signs may be used in lieu af rectongular military signs.

c. *Multilane* 8rıdges. Bridges af three ar mare lanes are special cases which require individual cansideratian in posting. Ta determine the number of lanes, minimum widths far the respective laad classıficatıon (table 5—1) are used. Often, heavier loads can be corried an a restricted lane(s) than on other lanes. For example: a brıdge lane may be damaged, thereby reducing capacity; or, canversely, lanes may be structurally designed to accammadate significantly heavier laods (fig. 5—10). Under such circumstances, standard bridge classıficatian signs are posted for each lone, and the restricted lanes are marked by barricades, painted lines, or studs.

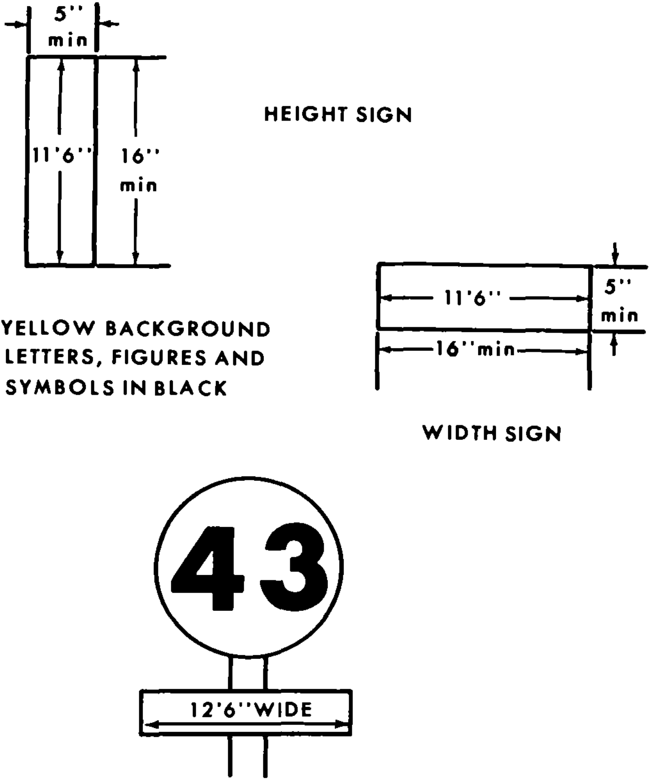


SINGLE LANE



DUAL LANE

Figure 5–8. Typical dual classification bridge signs.



WIDTH LIMITATION POSTED ON A SINGLE LANE BRIDGE

Figure 5–9. Width and height signs.

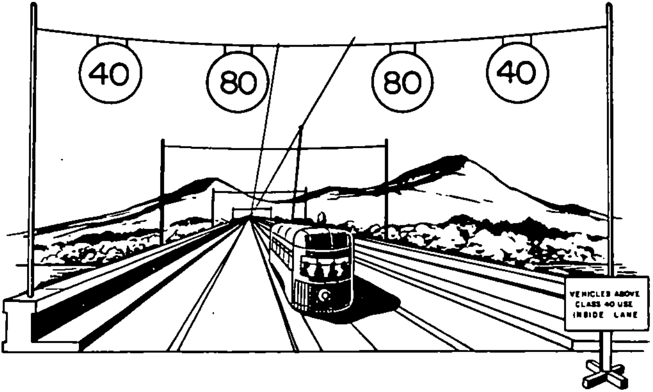


Figure 5–10. Typical multilane bridge applications of bridge classification signs and regulatory signs.

d. Positioning of Bridge Signs. Bridge signs are positioned so as to help maintain an uninterrupted flow of traffic across the bridge (fig. 5–11). The locations of circular and rectangular signs, special military load classification numbers, and appropriate warning signs are as follows:

(1) Circular bridge classification signs are placed at both ends of the bridge in such a position as to be clearly visible to all oncoming traffic.

(2) Rectangular signs other than those indicating height restrictions are placed immediately below the bridge classification (circular) signs.

(3) Signs which indicate height restrictions are placed centrally on the overhead obstruction.

(4) Special classification numbers are never posted on standard bridge marking signs.

(5) Appropriate advance warning signs are placed on the approaches to bridges as required.

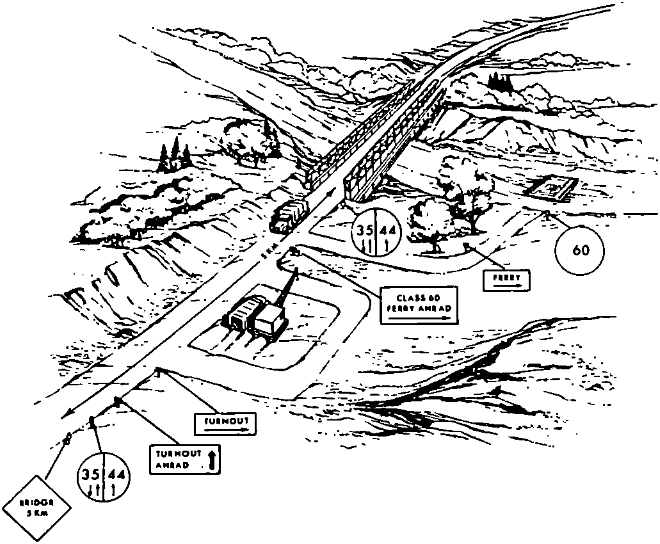


Figure 5–11. Standard bridge signs and typical supplementary signs.

Section IV. Traffic Controls

5–9. NORMAL CROSSINGS

Normal crossings may be made whenever the vehicle class number is equal to or less than the bridge class number. Normal convoy discipline must be imposed on the vehicles making a normal crossing, that is, a minimum spacing of 100 feet and a maximum speed of 25 miles per hour. There are two types of normal crossings, normal one-way and normal two-way.

a. *Normal One-Way.* This type of crossing is possible when the vehicle class number is less than the number posted on a single-lane bridge. If a one-woy crossing is made on a two-lane bridge, the vehicle shauld be driven dawn the middle of the roodwoy.

b. Normal Two-Way. This type of crassing is possible when the vehicle closs number is less than the two-woy class number of a multilane bridge. Two-way traffic may be maintoined with this type of crossing.

5–10. SPECIAL CROSSINGS

Under exceptional operating canditians in the field, the theoter commander may autharize vehicles to crass bridges when the bridges class number is less thon the vehicle class number. These crossings are known os speciol crossings, and a special closs number moy be obtained which represents the load-carrying capocity of o bridge under prescribed crossing conditions (table 5–3). Special closs numbers are never posted on stondard bridge signs. Special crossings, when autharized, are limited to twa types: cautian and risk.

a. Caution Crassings. On nanstandard fixed bridges, a cautian class number moy be obtained by multiplying the narmol ane-woy closs number by 1.25. Far standard prefabricated fixed ond flooting bridges, the caution class number is abtained fram published dato. Caution crossings require that vehicles remain on the bridge centerline, maintoin a 50-yard clear spocing, do nat exceed a speed of 8 mph, and do not stap, accelerate, opply brakes, or shift gears on the bridge.

b. Risk Crossings. Risk crossings may be mode only an stondard prefabricated fixed of floating bridges. The risk class number is obtained from published data pertaining ta the bridge. Risk crassings moy be mode only in emergencies when excessive lasses would atherwise result. Risk crassings require that vehicles remoin an the bridge centerline, da nat exceed speed of 3 mph, maintoin a spacing such that only one vehicle is on the bridge at a time, and do not stop, accelerate, opply brokes, or shift geors on the bridge. Tanks must steer using clutches only. An engineer afficer must inspect the bridge for signs of failure after each risk crossing, ond damoged ports must be replaced ar repaired before troffic can be resumed.

Table 5–3. Types of Crossings

Crossing	Class	Spacing	Speed	Location	Other restrictions
Normal	As posted	100 feet	25 mph	In lane	None
Caution	Standard Bridges. As published Nonstandard Bridges: 1.25 × normal 1-way class	150 feet	8 mph	Bridge centerline	No stopping, acceleration, braking.
Risk	Standard Bridges: As published Nonstandard Bridges: No crossing	1 vehicle on bridge at a time	3 mph	Bridge centerline	No stopping, acceleration, braking Inspection by Engineer Off. after each vehicle.

CHAPTER 6

FLOATING EQUIPAGE

Section I. Anchorage Systems

6–1. TYPES

a. *Basic Considerations.* Anchorage must be provided on float bridges to secure the bridge and keep it alined. The selection of an anchorage system is influenced by the width of the river, its current, stage variation, debris flow, the river bed, embankments and resources available. The anchorage system is designed to withstand the worst conditions anticipated. The basic anchorage systems used are: shore guys, kedge anchors, a combination of shore guys and kedge anchors, and overhead cable-bridle line systems. The strongest standard method of anchoring a floating bridge is the overhead cable-bridle line system supplemented by shore guys. The approach guys are used on each end of the bridge. They are attached at a 45° angle on each side of the bridge to prevent longitudinal and lateral movement. Approach guys are used on all standard bridges regardless of the type of anchorage system employed. Although combinations of the basic anchorage systems may be used during assembly and for reinforcement, the load cannot be properly divided between two systems; one system must supplement the other.

b. *Shore Guys.* Shore guys are used as primary anchorage when the maximum current does not exceed 3 feet per second (fps). They are used downstream when tidal conditions or severe eddies of 3 fps or less exist. See figure 6–1 for a typical shore guy anchorage system.

c. *Kedge Anchors.* Kedge anchors for heavy floating bridges may be used as primary anchorage in low debris currents up to 3 fps. They are useful only in river beds composed of sand, silt or loose rock or other material into which the fluke can take hold. To be effective the horizontal distance from the ponton or float to the anchors must be at least 10 times the depth of water and a 20 to 1 ratio is preferred. Kedge anchors are attached to every ponton upstream and every second ponton downstream. They may be used as primary anchorage in reversal currents up to and including 3 fps When employed in reversal current, they should be attached to every ponton upstream and downstream.

d. *Combination of Shore Guys and Kedge Anchors.* A combination of kedge anchors and shore guys may be used in stream velocities of

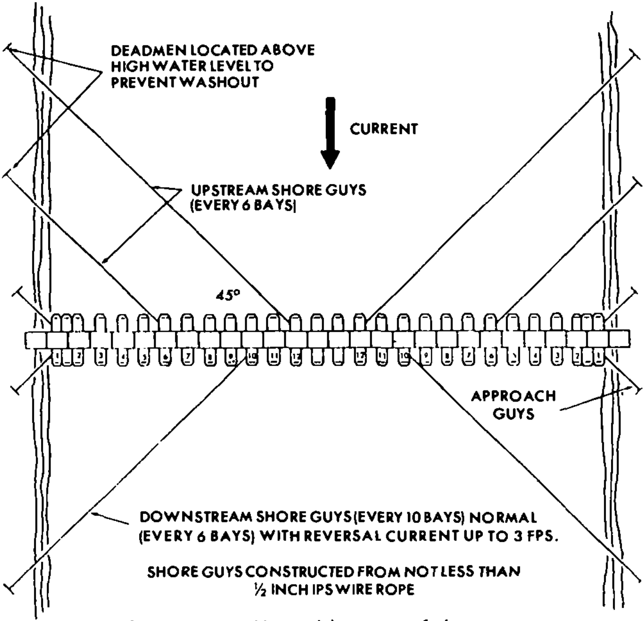


Figure 6–1. Normal location of shore guys.

5 fps or less. In addition to the approach guys, shore guys should be attached to every sixth bay on the upstream side and every tenth bay on the downstream side of the bridge. Kedge anchors should be attached to every ponton on the upstream side and to every second ponton on the downstream side of the bridge.

e. *Overhead Cable-Bridle Line System.* The overhead cable-bridle line system should be used when the stream velocity is 5 fps but not over 5 fps. Overhead cable systems consist of one or more tower-supported cables spanning the river parallel to the bridge on the upstream side. They are also used downstream of the bridge in tidal streams of severe current. Bridle lines are used to make the bridge secure to the cable.

6-2. ANCHORAGE DESIGN STEPS

a. *Symbols far Ancharage Design Farmulas.* See figure 6-2.

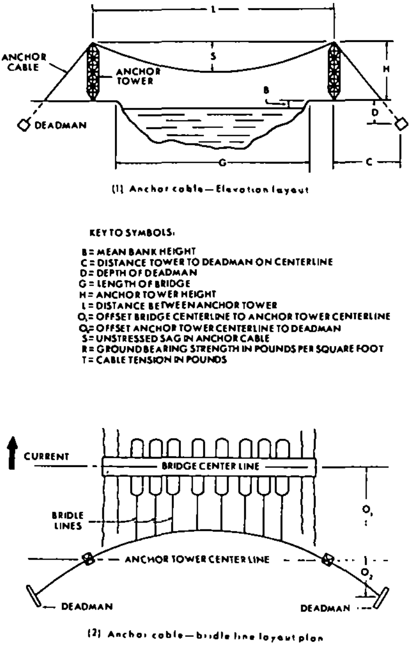


Figure 6-2. Anchar cable-bridle line ancharage systems.

b. *Cables.*

(1) Determine size and number of ancharage cables that are needed (table 6–1).

(a) Round up to next higher value for bridge span (G) shown in table 6–1.

(b) Select cable size for minimum number of cables.

Table 6–1. 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	3/8	3/8	3/8	1/2	3/8	3/8	1/2	1/2	3/8
		R	1/2	3/8	3/8	1/2	3/8	3/8	5/8	1/2	3/8	5/8	1/2	1/2
	M4T6 & CL 60	N	1/2	3/8	3/8	5/8	1/2	1/2	3/4	5/8	1/2	7/8	3/4	5/8
		R	5/8	1/2	3/8	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	3/8	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	3/8	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	3/8
		R	3/4	1/2	1/2	3/4	3/8	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	3/8	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	3/8	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 3/8	1 1/8	7/8		1 1/2	1 1/8
		R	1 1/8	7/8	3/4	1 3/8	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	3/8	1 1/8	7/8	3/4
		R	7/8	3/4	3/8	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

(2) Determine cable sag in feet. (Rule of thumb, $S = 0.02L$). The cable should be adjusted to give the initial unladen sag (fig. 6–3). If the cable sag causes the cable to enter the stream, a floating support may be used at the midspan (fig. 6–4).

c. *Towers.*

(1) Determine distance between towers. Place towers approximately the same distance from each bank. (Rule of thumb, $L = (1.1 \times \text{gap}) + 100$ feet).

(2) Determine required height of tower (H) (Rule of thumb, $H = 3\text{ft} + S - B$). This rule of thumb gives the minimum permissible value of H. Actual value of H will be the next height of tower above

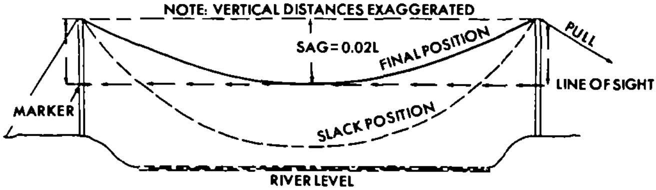


Figure 6–3. Cable sag.

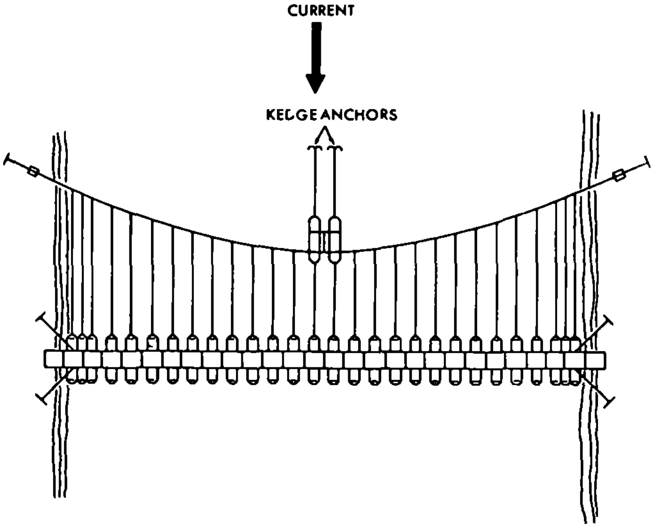


Figure 6–4. Float supported cable.

the required tower height. The possible tower heights are given in table 6–2. Use actual tower height selected for subsequent steps.

(3) Determine distance from bridge centerline to anchor tower centerline (0_1). (Rule of thumb, if mean bank height (8) is less than 15 ft, $0_1 = H + 50$ ft or if B is greater than 15 ft, $0_1 = H + 8 + 35$ ft).

d. Deadmen.

(1) Depth of deadman (D). (Rule of thumb, D = 7 ft or D is one foot less than the depth of ground water—minimum depth = 3 feet. Select the smaller of the two values.

Table 6–2. Possible Anchor Tower Heights

Number of Tower Sections	Height of Tower
Cap, base, and pivot unit	3 ft 8¼ in
1	14 ft 6¼ in
2	25 ft 4¼ in
3	36 ft 2¼ in
4	47 ft ¼ in
5	57 ft 10¼ in
6	68 ft 8¼ in

(2) Determine tower to deadman distance on centerline (C) and deadman offset distance from tower centerline 0_2. The process of selecting deadman positions is in fact a series of approximations leading to a correct position. Whatever position is selected, *it is essential that the correct 0_2 distance is used for the tower to deadman distance* (C) *selected.*

(*a*) From site conditions select approximate position for deadman.

(*b*) Aim to let $C = 4(H + D)$. Minimum permissible value for C is $H + D$.

(c) Read required value of 0_2 for C selected from table 6–3.

(3) To determine deadman size choose available lumber and check length (l), thickness (t), depth (d) or diameter (d_1) of deadman timber (fig. 6–5). Determine l, t, d, or d_1 from figure 6–6. Enter Nomograph "A" (fig. 6–6) at column A with D and slope ratio ($1/h$). Plot cable diameter and type on column B. Connect these points and extend to graph.

Table 6–3. Values of O_2 Per Hundred Feet of C

Current velocities		Offset upstream (O_2) in feet per hundred feet of C
Normal assembly	Reinforced assembly	
3 fps	—	9
5 fps	3 fps	11
7 fps	5 fps	14
9 fps	7 fps	17
11 fps	9 fps	19
—	11 fps	23

Go horizontally to desired depth and read down for length and thickness and up for log diameter. For further details see log deadmen in TM 5–210.

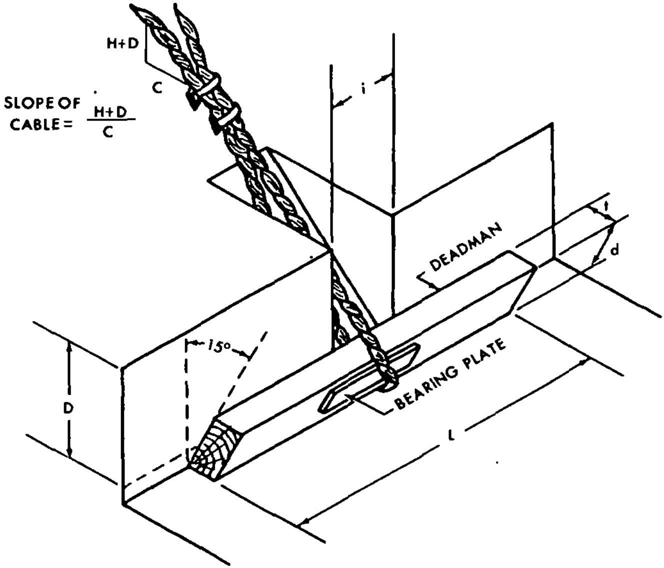
e. *Design Bearing Plate* (fig. 6–7).

(1) To design a flat bearing plate, enter Nomograph "B" (fig. 6–8) at type and size of cable on left and go horizontally across graph to intersect the line indicating the size of timber deadman being used which also shows the required width of the plate. Drop vertically to determine the length of the plate and go to the top of the graph to read the required thickness of the plate.

(2) To design a formed bearing plate, enter Nomograph "C" (fig. 6–9) on left as for a flat bearing plate and proceed as described in (1) above.

f. *Use of More Than One Overhead Cable* (table 6–1). A downstream anchor cable may be needed if a tidal action exists in a river. The calculations for a double or triple overhead cable system are the same as for a single cable system. A double overhead system is illustrated graphically in figure 6–10.

g. *Work Crew*. The organization of an anchorage work crew is illustrated in table 6–4.

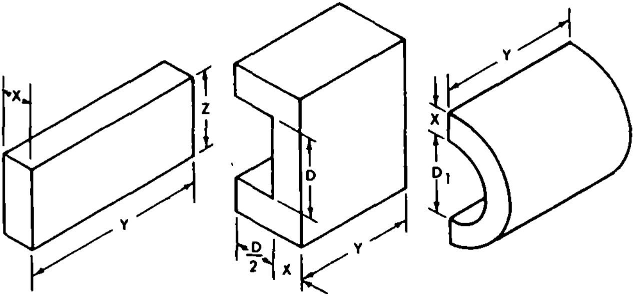


KEY:
D = mean depth of deadman
L = length of deadman
d = depth of deadman (timber); d_1 = diameter of log deadman
t = thickness of deadman
i = width of cable slot (normally 1' —0")
C = distance of deadman behind tower
H = actual tower height

Figure 6–5. Deadman dimensions.

Figure 6–6. Nomograph "A"

(Lacated in back of manual)



(1) FLAT BEARING PLATE (2) FORMED BEARING PLATE

KEY: X = Bearing plate thickness
Z = Height af flat bearing plate
Y = Length of bearing plate
D_1 = Diameter af raund deadman
D = Depth of dressed deadman

(a) Far flat bearing plate, see Namagroph B.
(b) For farmed bearing plate, see Namagroph C.

Figure 6–7. Bearing plote dimensions.

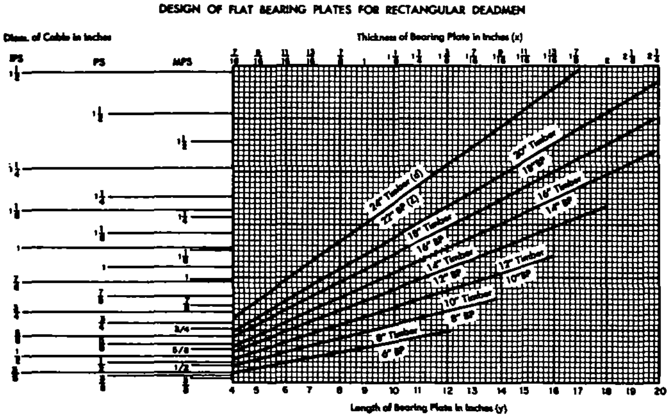


Figure 6–8. Nomograph "B".

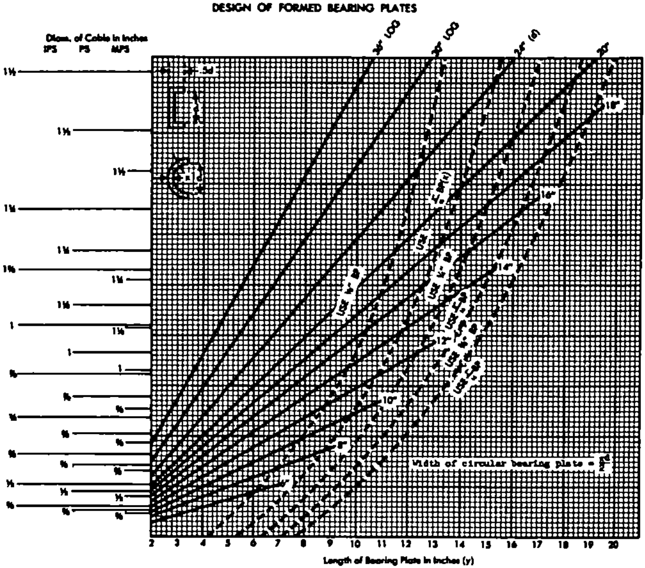


Figure 6–9. Namograph "C".

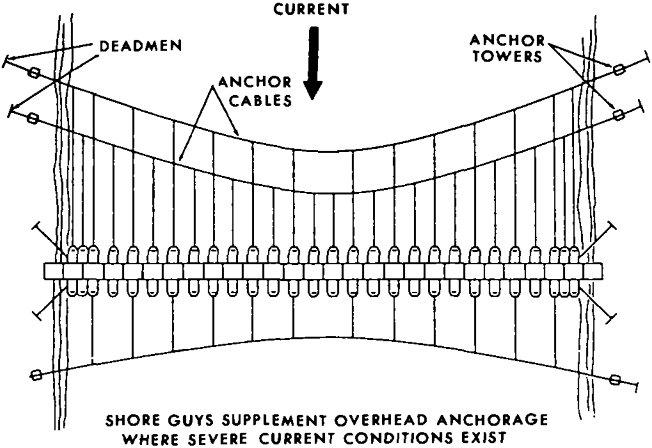


Figure 6–10. Float bridge with multiple overhead cable system.

Table 6–4. *Organizatian af Ancharage Wark Crew far Bridge 300 Feet Lang ar Langer*

	Task	Man-haurs needed	Passible wark (men)	Tatal time (hrs)	Remarks
FAR SHORE	Preparing deadman.........	12	4	3	7′ hale in saft laamy sail.
	Erecting cable tawer.........	12	12	1	Crew task.
	Adjusting cable ta tawer and deadman.	1	2	30 min	
	Installing share guys.........	2	2	1	
NEAR SHORE	Transpart cable ta far share	3	3	1	
	Preparing deadman.......	12	4	3	7′ hale in saft laamy sail.
	Erect cable tower...........	12	12	1	Crew task.
	Attach bridle lines ta cable...	10 min per line	2	5 min per line	

Section II. Light River Crossing Equipment

6–3. RECONNAISSANCE AND ASSAULT BOATS

a. Plastic assault boat—repair at depot level.

b. Pneumatic assault boat—10 individual air compartments; $\frac{1}{2}$ may be punctured and full capacity retained. Repair at unit level.

6–4. ALUMINUM FLOATING FOOTBRIDGE

a. One set allocated to Corps/Army Float Bridge Company.

b. One set = $472\frac{1}{2}$ feet of bridge, or 100 feet of light vehicular bridge, or 3 expedient rafts. Bridge or raft capacity: $\frac{1}{4}$-ton vehicle with trailer.

c. One bay = 11 feet 3 inches effective length; consists of one ponton, one treadway, four handrail posts.

d. Capacity and data—see tables 6–6 and 6–7.

6–5. LIGHT TACTICAL RAFT/BRIDGE (LTR)

a. Allocation.

(1) Div Engr Bn—2 sets

(2) Corps/Army Float Bridge Companies—6 sets

b. Raft. One set is sufficient for one 4-ponton normal or reinforced raft or 44 feet of light vehicular bridge.

c. Component Parts per Set. Eight half pontons, eight deck tread panels, eight long filler panels, six short filler panels, eight long curbs, twelve short curbs, two male ramps, two female ramps, four fluke anchors, necessary erection equipment, ferry conversion kit. See SM 5–4–5420–S05.

d. Transportation. Normally two $2\frac{1}{2}$-ton cargo trucks are required for the super-structure, and one $2\frac{1}{2}$-ton pole type trailer is required for pontons. Five-ton dump trucks, or military bridge trucks may be used as expedient transportation.

e. Construction Time for Light Tactical Raft (table 6–8).

f. LTR Personnel Requirements. Personnel required to construct and operate the LTR are shown in tables 6–9 through 6–11. Raft capacities are shown in table 6–12.

Table 6–5. Recannaissance and Assault Baat Data

Item	Use	Description	Capacity	Remarks
Three-man recannaissance baat	Recan-naissance	Canvas w/5 campartments, issued with towline and 3 paddles; total weight 30 lbs.	3 men in current speeds up ta 4 fps.	Baat is breath-inflated ar hand pumped; easily carried by ane man when deflated and packed in case
Plastic assault	Assault crossing	Plastic, hand paddled, weight 300 paunds, length 16′5″, width 5′4″	12 infantrymen w/full equipment ar equivalent in current speeds up ta 4 fps.	Narmal crew, three engineers; maximum capacity w/na current is 3300 paunds; can be propelled by one 25-hp autbaard matar at speed af 12 fps w/a a laad reduction.
Assault Boat pneumatic	Assoult crossing.	Neoprene coated nylan, pneumatic; weight 250 lbs; length 17 feet, wieth 5′8″	12 fully equipped infantrymen, and a crew of three engineer saldiers	18 in Div. Engr Bn con be paddled or powered by a 25-hp matar at 12 fps in current at 6 4 fps. 70 at Corps/Army Flaat Bridge Ca.

Table 6–6. Aluminum Footbridge Capacity

Aluminum floating footbridge	Condition	Current and capacity	
		0 to 8 fps	9 to 11 fps
	Daylight, doubletime	75 men/min	60 men/min
	Moonlight, quicktime	40 men/min	32 men/min
	Blackout, quicktime	25 men/min	20 men/min

g. *Light Tactical Bridge.*

(1) Erection rate: 3½ feet per minute.

(2) Each bay provides 11 feet of effective bridge length.

(3) Assembly of light tactical bridge by successive pontons (table 6–13).

(4) Light tactical bridge capacities (table 6–14).

(5) *Bridge assembly.*

(*a*) Successive rafts (normally used on streams over 300′).

(*b*) Successive bays (normally used on streams under 300′).

(c) Site layout (fig. 6–11).

Table 6–7. *Aluminum Footbridge Data*

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

Table 6–8. Assembly of Light Tactical Raft

Type of assembly	NCO	EM	Time required, minutes
4-ponton, 3-bay	3	23	20 to 30
5-ponton, 5-bay	3	23	20 to 30
6-ponton, 4-bay	3	23	30 to 45

Table 6–9. Crew Requirements

Crew	NCO	EM
Carrying	1	10
Ponton connecting	1	6
Ponton delivery		2
Deck panel unloading	1	5

Table 6–10. Construction Duties

Step	Crew
(1) Pontons carried to water	Carrying.
(2) Guylines attached	Ponton Delivery.
(3) Half pontons connected	Ponton Connecting.
(4) Deck panels positioned over pontons	Ponton Connecting.
(5) Articulating assembly connected	Ponton Connecting.
(6) Ramps connected	Ponton Connecting.

Table 6–11. Operoting Duties — LTR

Crew	No. of men	Duties
Raft............	8	4 men operate outboord motors; 4 men place and remove chocks from wheels of vehicles.
Near shore....	1	1 man guides vehicles anto rafts 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.

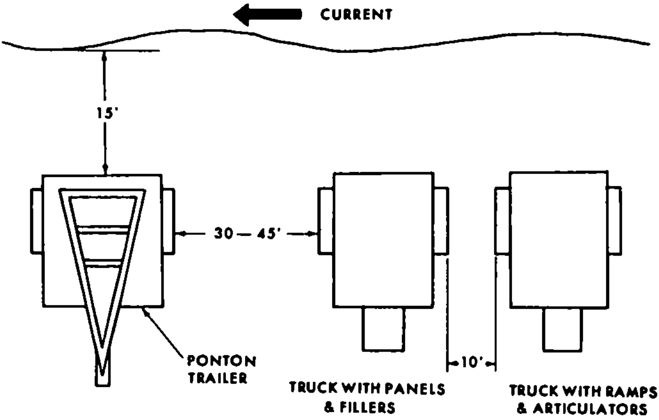


Figure 6–11. LTR site layout.

Table 6–12. *(LTR)* Capacities

Type of raft	Number of pontons of floats	Overall length of raft	Stream velocities in feet per second for specified crossing									
			Normal crossing					Risk crossing				
			5	7	8	9	11	5	7	8	9	11
Light tactical raft with articulators	4 Pontons 3 Bays	58′	12	12	12	8	0	14	14	14	12	4
	5 Pontons 5 Bays	80′	9	9	9	8	3	11	11	11	11	6
	6 Pontons 4 Bays	69′	13	13	13	13	6	15	15	15	15	10

Note When operating without articulators, the raft classification is raised by 4

Table 6–13. Organization for Assembly of LTR by Successive Pontons

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

Table 6–14. Classes of Floating Bridge Construction From LTR Set

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

Toble 6–15. Construction ond Transpartation Dota af M4

Bridge set	Standard B stack basis of issue	Suggested working porty		
	Class IV	Detoil	NCO	EM
Flootıng bridge:	Vehicles requıred far	Near-share abutment.......	1	8
6–8 ft 4 in	transpartatıan of bridge set:	Pontan outfitting (2 crews).	4	36
		Ponton delivery (2 crews).	2	10
Fixed bridges:		Anchorage..................	2	12
2–23 ft	2½-ton cargo truck.	Bolk carrying................	2	88
2–30 ft	2½-ton corgo truck.	Bolk loying..................	1	8
2–38 ft	2½-ton truck, bolster.	For-shore obutment.........	1	16
2–45 ft	2½-tan balster trailer.	Pin checking................	1	3
	2½-ton pole type trailer.			
Rofts:	5-tan dump truck.	Total..................	14	181
4–4 ponton	Transported by arganic vehicles of the using unit.			
4–6 ponton				
4–7 ponton				

Section III. Heavy Floating Bridge Equipment

6–6. M4 FLOATING BRIDGE EQUIPMENT

a. *Description.* The M4 bridge bay consists of two M4 aluminum half pontons jained stern-ta-stern with o flush deck af hollow aluminum balk. The deck balk pottern is so designed that a "cantinuous beam" action results which distributes the load over more than ane ponton. Far design specifics an the deck pattern, see paragraph 6–8. With 18 balk across the deck, the roadway width is 166 inches. The effective length af one bay is 15 feet.

b. *Category.* The M4 bridge is currently stocked as a standard B item and is nat issued to United States units as arganic equipment. It nay be requisitioned against existing needs by length of bridging needed rather than by sets.

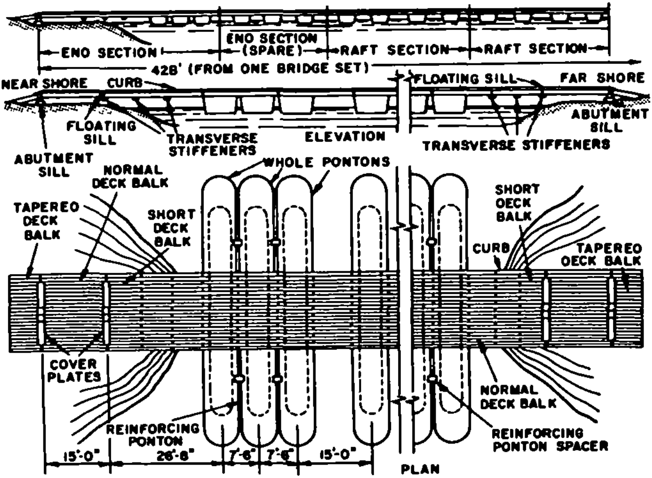


Figure 6–12. Floating bridge, M4.

Table 6–16 Classified [1] of Floating Bridges

Type of bridge	Type of crossing	Normal						Reinforced [2]					
		Stream velocities in feet per second for specified assembly											
		3	5	7	8	9	11	3	5	7	8	9	11
M4 [3]	NORMAL	60	60	45/50	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 [4]	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 [4]	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

[1] Based on abutment deck level within 10" of floating bridge deck level except for hinged or other special end spans. Where limitations are exceeded, capacities must be reduced.
[2] Reinforced by placing 3 floating supports under 2 bays of decking (50% reinforced).
[3] Capacities based on roadway width of 18 balk and deck width of 22 balk. Reinforced assembly requires a 38'4" superimposed end span.
[4] Reinforced bridge capacities up to 9 fps are controlled by end span limitations.

c. *Assembly and Capacity.* Layout, construction, and transportation data are shown in figure 6–12 and table 6–15. Capacities may be found in table 6–16. For more specific information of the M4 floating bridge, refer to TM 5–210.

d. *M4 Raft.*

(1) The M4 raft can be assembled from the components of the M4 floating bridge set. The basic 4-ponton raft can be converted to a reinforced raft with greater load capacity by adding reinforcing pontons. The other recommended types of rafts assembled are the six-ponton and seven-ponton reinforced rafts. The rafts are shown in figure 6–13.

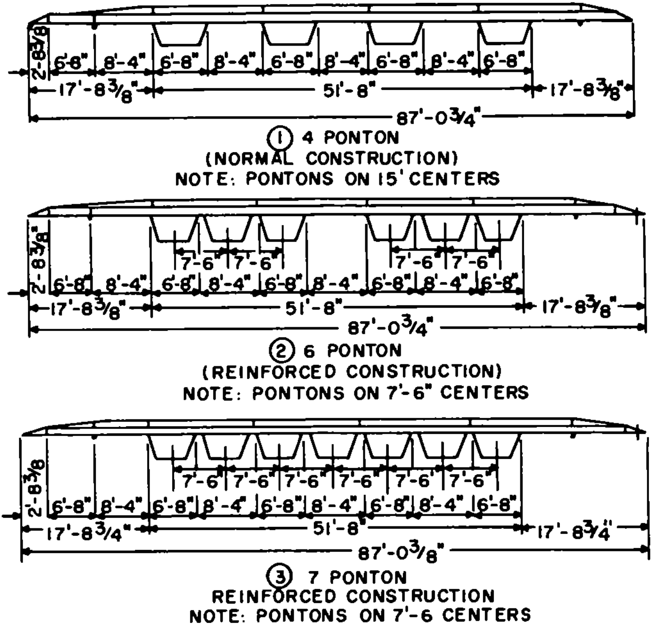


Figure 6–13. M4 raft.

(2) The omaunt of time and the number of trained men required for assembly of M4 rofts are given in table 6–17. Raft classifications are given in toble 6–18. Mare specific informatian concerning M4 rafts can be faund in TM 5–210.

Table 6–17. 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.

6–7. CLASS 60 FLOATING BRIDGE EQUIPMENT

a. *Bridge Bay.* The Class 60 bridge bay consists of two deck-tread panels, two curbs, one filler panel, one 24-ton pneumatic float with saddle panels and saddle beams with an effective bridging length of 15 feet. The floating support for one bay consists of two penumatic 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, 30 inches of water for floats and 40 inches of water for power boats.

b. *Assembly.* A bridge is normally assembled with 15-foot deck tread panels and filler panels centered on floats with a reinforced end section on each end. The reinforced and section consists of two bays of superstructure centered on three floating supports. Construction and transportation and allocation data are listed in table 6–19.

Table 6–18 Classes[1] of Rafts

Type of raft	Number of pontons or floats	Overall length of raft	Stream velocities in feet per second for specified crossing									
			Normal crossing					Risk crossing				
			5	7	8	9	11	5	7	8	9	11
Light Tactical Raft with Articulators	4 Pontons 3 Bays	58	12	12	12	8	0	14	14	14	12	4
	5 Pontons 5 Bays	80	9	9	9	8	3	11	11	11	11	6
	6 Pontons 4 Bays	69	13	13	13	13	6	15	15	15	15	10
M4[2]	4 Normal	87'1"	50/55	50/55	50/55	50/55	40/45	55/60	55/60	55/60	55/60	45/50
	6 Partially Reinforced	87'1"	70/75	70/75	65/70	65/70	50/55	75/80	75/80	75/80	75/80	55/60
	7 Fully Reinforced	87'1"	85/90	85/90	80/85	80/85	55/60	90/95	90/95	90/95	90/95	65/70
Class 60	4 Normal	92'5"	40/45	40/45	35/40	35/40	25/30	50/55	50/55	45/50	45/50	35/40
	5 Normal	107'5"	50/55	50/55	45/50	40/45	30/35	60/65	60/65	55/60	50/55	40/45
	5 Partially Reinforced	92'5"	55/60	50/55	50/55	45/50	35/40	60/70	60/65	60/65	55/60	45/50
	5 With 1 short deck bay reinf	83'1"	60/65	55/60	55/60	50/55	45/50	65/75	65/70	65/70	60/65	55/60
	6 Fully Reinforced	92'5"	65/75	65/75	60/70	60/65	50/55	80/90	80/90	75/85	70/80	60/70
M4T6[2]	4 Normal	87'	50/55	45/50	40/45	35/40	30/35	60/65	55/60	50/55	45/50	35/40
	4 Reinforced	86'	50/55	50/55	45/50	40/45	35/40	60/65	60/65	55/60	50/55	45/50
	5 Normal	101'	55/60	50/55	45/50	40/45	35/40	65/70	60/65	55/60	50/55	45/50
	5 Reinforced	88'9"	60/60	60/60	55/60	45/50	45/50	70/75	70/75	65/70	65/70	55/60

[1] Based on loading rafts with center of gravity of loads 6 inches downstream from centerline of raft and on properly inflated floats
[2] Capacities based on roadway width of 18 balk, deck width of 22 balk and on 18 or 19 ft end span

Bridge capacities are found in table 6–16. Articulation of 33 inches above and below the bridge harizontol is obtained by the use af connectar beoms an the femole end and short deck tread sections and cannectar beams an the male end. The bridge narmally is constructed with the mole end towards the far share.

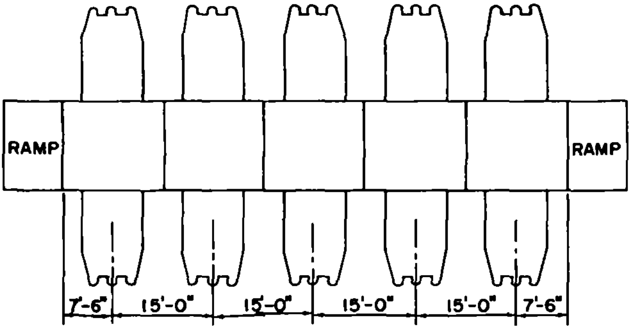
c. *Class 60 Rafts.* The number af rafts which con be assembled fram the set is limited ta ane becouse the raft requires the use af two ramp bays in the set. Raft lengths and classes are found in table 6–18. Figure 6–14 shaws the floot and panel assembly far the five floot narmal and six flaat reinforced rafts. Mare specific informatian and different raft configuratians are faund in TM 5–210.

Table 6–19. Canstructian and Transpartatian Data of Closs 60 Bridges

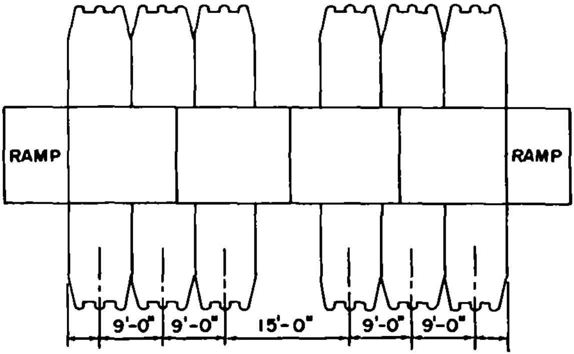
Bridge set	Basis af issue*	Suggested warking party		
		Detail	NCO	EM
Floating bridge 135 ft	Class IV	Supervisory	2	....
		Crane crew	1	1
		Saddle assembly—2 crews	2	20
Fixed bridges:	Vehicles required far transportation af bridge set			
1, 30 ft		Flaat inflation..... .	. . .	9
1, 45 ft		Deck panel.	1	6
1, 60 ft		Flaat handling	.	8
1, 75 ft	9 ea 5-ton 6 × 6 military bridging trucks carry one complete bay each	Single bay, cannecting. . . .	1	6
1 multispan from 85 ta 92 ft		Baat crew	. .	4
		Bridge assembly	1	8
		Ancharage.......	1	10
	3 ea carry accessaries	Trestle.	1	8
Rafts 1 ea, 4, 5, or 6 flaat.	Allacation same as M4T6	Tatal	10	80

*May be partial issue af M4T6 bridge sets

d. Fixed Spans from Closs 60 Campanents. Components af the Class 60 superstructure con be used ta assemble fixed spans. Because of its weight, it is not commonly used in this farm. Two trestle sets ore furnished with eoch Class 60 bridge set. These must be used as sets af two ond crass braced ta each ather ta attain the proper classification. Toble 6–20 and figure 6–15 list the classifications for variaus spans for Closs 60 equipment. Figure 6–16 illustrates the utilizatian af trestles. Table 6–23 lists appraximate heavy bridge erectian times.

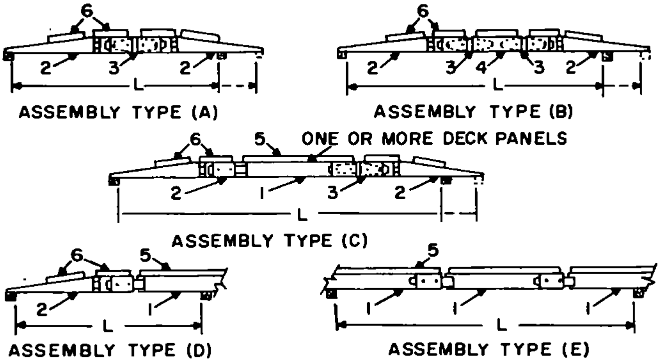


NORMAL 5-FLOAT RAFT



REINFORCED 6-FLOAT RAFT WITH FOUR NORMAL DECK BAYS

Figure 6—14. Class 60 raft.

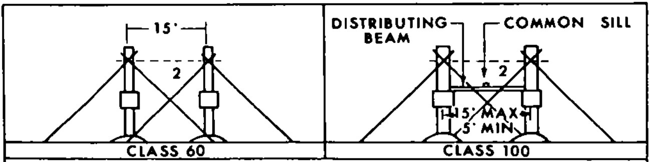


LEGEND

1. NORMAL DECK PANEL
2. RAMP
3. CONNECTOR BEAM
4. SHORT DECK SECTION
5. NORMAL CURB
6. SHORT CURB

L INDICATES CLEAR SPAN LENGTH

Figure 6–15. Class 60 fixed spans.



1. Based on use of 50 ton trestles for the M4 and M4T6 and 60 ton trestles for the class 60.
2. This horizonal brace is required when one of the exterior diagonal braces is omitted.

Figure 6–16. Trestle Assembly and Capacity

Toble 6–20. Classes af Fixed-Span Assemblies

Clear span (feet)	Type af assembly	Classes		
		Narmal	Cautian	Risk
24	ABCDE................	(120*)100	(120*)100*	(120*)100*
26	A8CD.................	(120*)95	(120*)100	(120*)100*
	E........................	(120*)100	(120*)100	(120*)100*
28	ABCD.................	(115)80	(120*)87	(120*).00
	E........................	(120)85	(120*)92	(120*)100*
30	ABCD.................	(105)65	(110)65	(120*)90
	E........................	(110)70	(120)80	(120*)95
32	8CDE..................	(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 far most critical position af abutments

3 For symmetrical erection of type B, with respect to abutments, the stated capacities may be increased 10 tons

4 Number af normal deck panels utilized depends on span length desired.

6–8. M4T6 FLOATING BRIDGE EQUIPMENT

a. *8ridge Bay*. The M4T6 bay cansists af 22 narmal balk (stoggered), 4 curb adapters and ane 24-ton pneumatic flaot with saddle adapters and balk cannecting stiffeners. This is the same floot that is used with the Closs 60 bridge equipment. One bay hos an effective length af 15 feet. The M4T6 bridge con be totally erected by hand and requires on air campressor for assembly. The deck forms o continuous beam action over the pantons with o roadway width af 166 inches.

b. Assembly. A bridge normally is ossembled with the flaats 15 feet an centers and the deck built with o standord balk pattern. The standard balk pattern is shown in figure 6–17. The bridge hos reinforced end sections consisting of one boy of deck supported by two flooting supports os seen in figure 6–18.

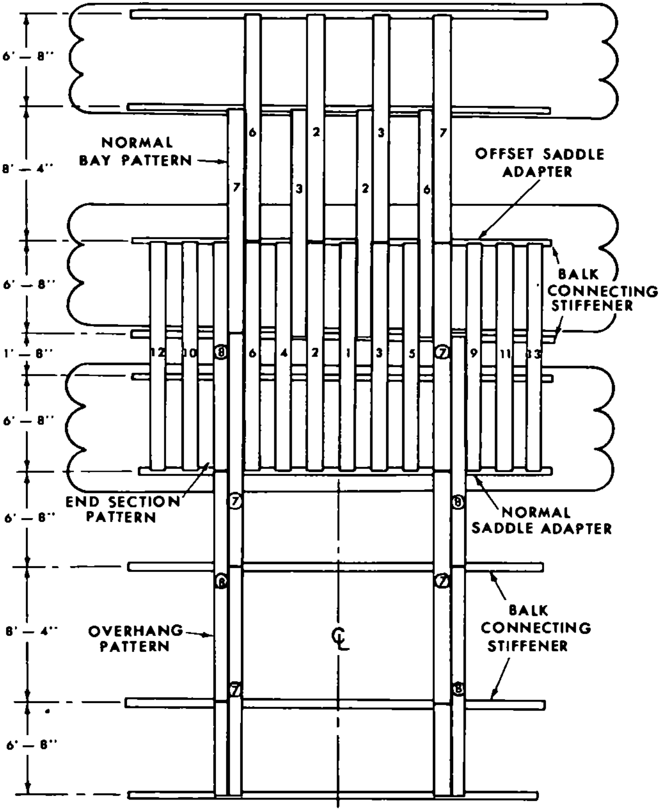


Figure 6–17. Bolk pottern, M4T6 flooting bridge.

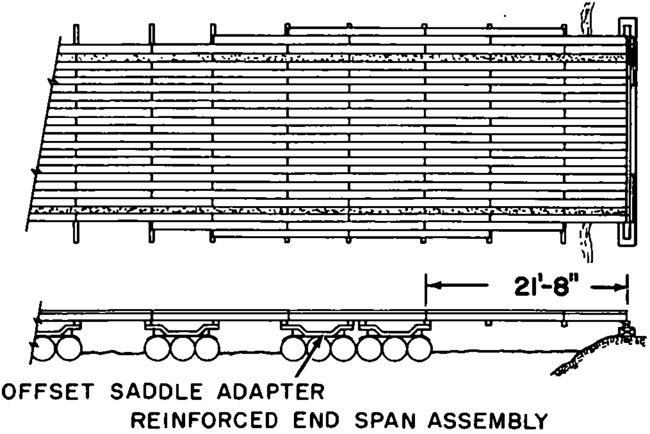


Figure 6–18. Bridge, flaating, aluminum deck-balk superstructure (M4T6).

c. *Capacity and Assembly.* Canstruction and transpartation dato are listed in table 6–21. Bridge capacities are faund in table 6–18. Table 6–22 lists appraximate assembly times far heavy bridges. Additional infarmatian pertaining ta this bridge including expedient cannections with ather floating bridges in contained in TM 5–210.

d. *M4T6 Rafts.* The limiting factors in raft construction are number of flaats and amaunt of normal balk. Fram ane set a five-flaat reinfarced raft and a faur-float reinfarced raft can be constructed. When langer or heavier loads than normal divisian laads must cross the river, a six-flaat reinfarced raft may be canstructed. Rafts may have either a 15 faot, 16 faot 7 inches, 21 foot 8 inches, or 23 foot 4 inches overhang for raft approaches. The four-float reinforced raft and five-float reinforced raft are shawn in figures 6–19 and 6–20. The balk pattern is shawn in figure 6–17. Far ather rafts, see TM 5–210. Raft classifications are listed in table 6–18.

Table 6–21. Construction and Transportation Data of M4T6

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

*May be partial issue of Class 60 steel treadway bridge transportation same as Class 60 bridge set See table 6–19

Table 6–22. Approximate Erection Times for Heavy Bridge (excluding anchorage system)

Length (Normal)	Recommended constr unit	FLT BRG PLT REQ FOR SUP	Number of assy sites(s)	Time hours
150	1 company	2 bridge plts	2	4
200	1 company	2 bridge plts	2	5
250	1 company	3 bridge plts	2	6
300	2 companies	3 bridge plts	3	4
350	2 companies	4 bridge plts	3	5
400	2 companies	5 bridge plts	4	$5\frac{1}{2}$
500	2 companies	5 bridge plts	5	6
600	1 engr bn	5 bridge plts	6	4
700	1 engr bn	6 bridge plts	6	5–7
800	1 engr bn	6 bridge plts	6	6–8
1000	1 engr bn	8 bridge plts	6	7–10
1200	1 engr bn	10 bridge plts	6	8–12

1. Assembly site layout ideal 100 ft × 100 ft Erection time is for trained troops
2 Each assembly site crew consisting of 53 EM, exclusive and site crews

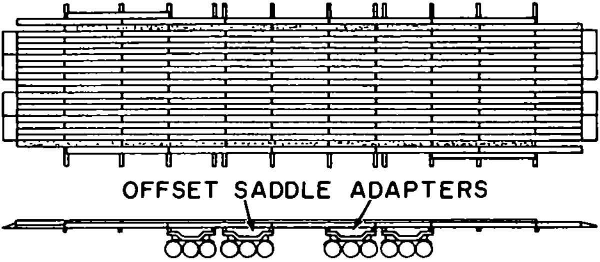


Figure 6–19. M4T6 reinforced raft.

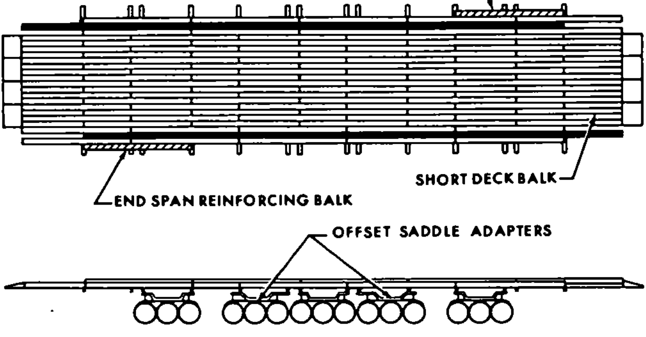


Figure 6–20. Five-float reinforced raft.

e. *M4T6 Fixed Spans.* Components of the superstructure of the M4T6 bridge can be used in an unsupported or supported fixed span. Common lengths of M4T6 fixed spans are 23 feet 4 inches, 30 feet, 38 feet 4 inches and 45 feet. The most common is the 38-foot 4 inch span. The 45 foot fixed span is shown in figure 6–21. Other fixed spans are constructed by shortening the standard bolk pattern of the 45-foot fixed span. The load classes of fixed spans are shown in table 6–23. Two trestle sets are issued with the bridge set The use of trestles is illustrated in figure 6–16.

6–9. RAFT OPERATION

a. *Power.* 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 of 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 normally are powered by four outboard motors. Three of the motors are used to operate the raft and the fourth is kept in reserve. When stream velocities are such as to preclude pushing the raft straight across the stream with available power boats, the unloading point must be downstream from the loading point. Use steel pickets in hard soil and wood pickets in softer soild to form holdfasts to secure rafts for loading and unloading.

b. *Personnel.* Standard rafts require approximately one squad for operation in addition to power boat operators.

Section IV. Amphibious River Crossing Equipment

6–10. FRENCH EQUIPMENT

a. *Description.* This amphibious river crossing equipment consists of two major items: the amphibious bridge vehicle, Class 60 (ABV–60); the amphibious ramp vehicle, Class 60 (ARV–60). The basic unit of each amphibious vehicle is a welded steel plate watertight hull mounted in a four-wheel drive chassis. To insure stability and buoyancy during navigation, each vehicle is equipped with two pneumatic floats about 36 feet in length and $4\frac{1}{2}$ feet in diameter attached to the sides. A compressor is kept in operation during water travel to maintain a constant pressure on the floats. 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 The effective length of the ramp of the ARV–60 is 26 feet 3 inches. It is 13 feet 2 inches wide.

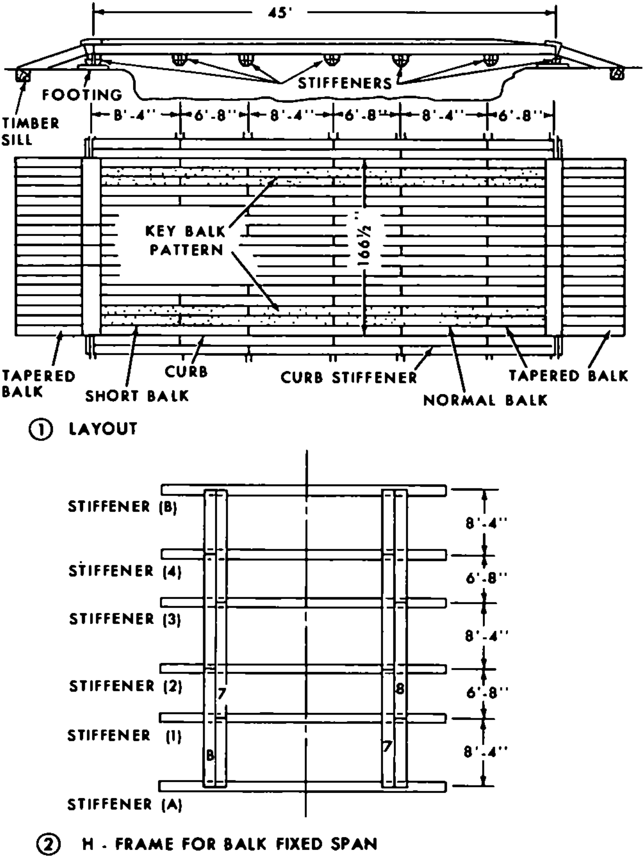


Figure 6–21. Layout of deck-balk fixed bridge.

Table 6–23. Classes of Aluminum Deck Balk Fixed Spans

Type of crossing	Capacity for specified span length (ft) and ratio of deck/roadway widths														
	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	120*/100	85/[illegible]5	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*/100*	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*/100	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)
*Limited by Roadway Width
22/18 Roadway Width (Number of Balk)

b. Capacity. The French ARCE is classified as a Class 60 bridge in currents up to 9 feet per second.

c. Operation. A four-man crew, considting of a driver, pilot, and two crewmen, is required to operate the vehicle on land, in the water, and during bridge construction. The ABV–60 enters the water, ready for incorporation into a bridge or raft, as a 26 foot 3 inch floating section. All movement of the decking during construction is hydraulically controlled. As successive units enter the water, they are joined until the required length of bridge has been built. The end ramp is transported by the ARV–60. The carrier unit positions the ramp for connection to the bridge 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.

d. Rafting. The construction procedure for 2, 3, 4, and 5 unit rafts is similar to that used for the bridge. The time required varies from 15 minutes (2 unit) to 25 minutes (5 unit). In such case, about 10 minutes is required for connection of the ramps. See table 6–24 for raft construction and classification.

Table 6–24. ARCE Raft Capacities

Raft construction	Current 0–4.9	Velocity 5.0–6.6	FPS 6.7–8.2
2 Unit	55	49.5	4.4
3 Unit	88	80.3	71.5
4 Unit	121	110	99

6–11. MOBILE ASSAULT BRIDGE/EQUIPMENT (MAB)

a *Description.* This amphibious river crossing equipment consists of a basic hull of aluminum slate with either an intermediate superstructure or an articulating ramp end section mounted on top of it. The hull alone provides all the buoyancy for the vehicle and the bridge load. The four wheels which propel the MAB unit on land retract in the water and the wheel wells can be air pressurized for added buoyancy. Similar to the ARCE, the MAB has a superstructure which is rotated 90° to form one bay of bridge decking. The effective length of the ramp is 36 feet and the interior bay is 26 feet.

b. Capacity. The MAB is classified as a Class 60 bridge.

c. *Operation.* A three-man crew operates the bridge unit on land and in the woter, ratating the superstructure and maneuvering to connect the unit ta anather interior bay or ramp unit. The romp daes not disconnect fram the ramp vehicle os with the ARCE.

d. Allocation. The MAB is allocated ta the Divisional Engineer Battalion. One MAB campany cansists af 16 interiar bays and 8 end bays. The effective length of ane bridge is 488 feet.

e. *Rafting.* The canstruction pracedure far MAB rofts is similar to that used far bridging. A faur unit raft cansisting af twa end bays and two interior boys capable af carrying a Class 60 load at 8 mph, can be assembled by its crew of three men per unit in about 8 minutes. Table 6–25 shaws clossification af MAB rofts. Table 6–26 cantains specifications far MAB equipment.

Table 6–25. MAB Raft Capacities

Raft construction	Classification in current up to 8 fps
2 end bays	25
3 bays	40
4 boys	60
5 bays	75
6 bays	90

Table 6–26. Mobile Assault Bridge Vehicles

Specification	U.S.	French
Vehicle length	42′3″	39′11″
Vehicle width — lond travel	12′	10′6″
intermediate		13′
water trovel	12′	19′8″
Vehicle height — interior boy	10′6″	12′10″
end bay	11′9″	12′10″
Droft — unloaded		
Wheel wells at atmospheric pressure	2′7″	
Wheel wells pressurized	2′0″	2′0″
Weight ton — interior bay	23.25	29.70
end bay	25.80	30.20
Turning radius	40′	57′5″
Vehicle speed — land travel	42 mph	45 mph
Fuel tank capacity — U.S. gallons	100	132
Engine horsepower	335	222
Superstructure dimensions		
Length — interior bay	26′	26′3″
end bay	36′	26′3″
Width	13′6″	13′2″
Ramp articulation		
Above horizontal	Any angle	5′6″
Below horizontal	6′3″	5′6″

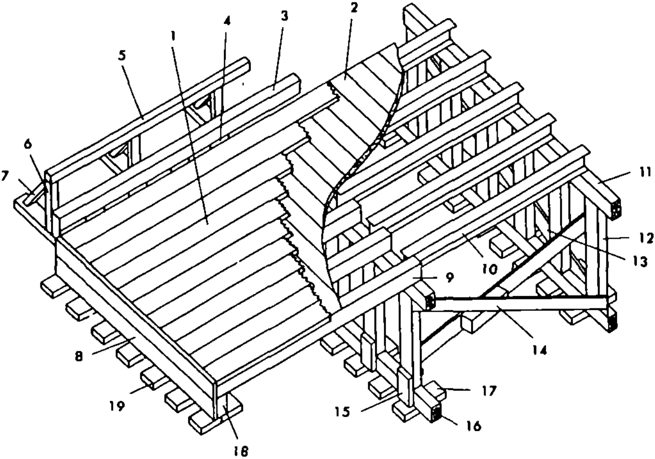
CHAPTER 7

FIXED BRIDGES

Section I. Highway Bridge Classification

7–1. NOMENCLATURE

a. *Superstructure.* A timber trestle bridge (fig. 7–1) is one of the simplest types of bridges built in a theater of operations. Steel or timber stringers rest on near- and far-shore abutments and intermediate supports. 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.



(NUMBERS REFER TO TABLE 7-1)

Figure 7–1. Timber trestle bridge.

Table 7–1. 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 para 7–5a.
10	Steel stringers	See para 7–5c.
11	Cap	See para 7–6f.
12	Posts	See para 7–6i.
13	Traverse 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 para 7–6a.
18	Abutment sill	Same size as cap (11).
19	Abutment footings	Same size as footings (17).

b. Substructure. Intermediate supports for the superstructure may be timber bents (fig. 7–2), timber piers (fig. 7–3), pile bents (fig. 7–4), or a combination of these supports. Deep water, swift current, or adverse footing conditions require the use of piles.

7–2. HIGHWAY STRINGER BRIDGE CLASSIFICATION

a. Procedure. Bridge classification as discussed herein is based on the class of the superstructure only, since this is considered to be the controlling feature in bridge classification. The theoretical substructure design for the given superstructure can be determined using the bridge design card (para 7–6) and then comparing the result with the substructure in place as a basis of determining whether or not the bridge classification should be lowered. The condition of both superstructure and substructure components should be examined closely for damage or deterioration and the probable effect on the bridge capacity.

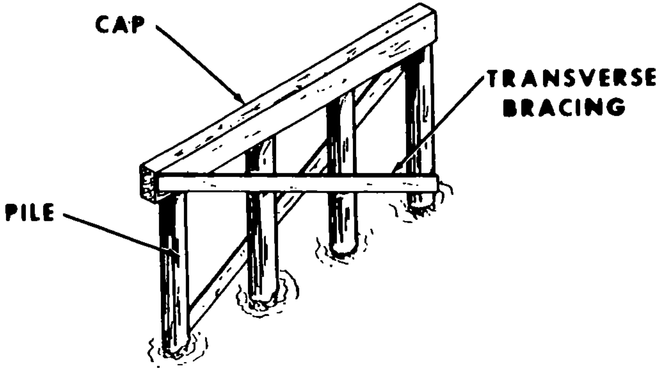


Figure 7—2. Timber trestle bent.

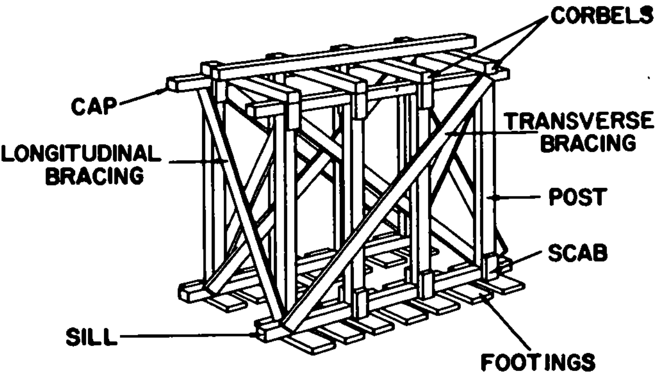


Figure 7—3. Timber trestle pier.

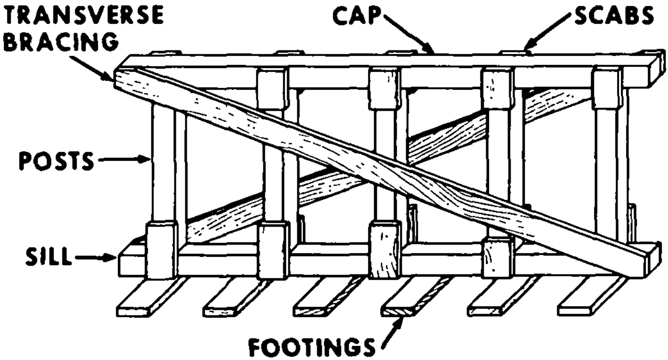


Figure 7–4. Pile bent.

b. Timber Stringers. Classify the weakest spon to obtoin the classification of the bridge. If the weakest spon is unknown, use the following procedure for each span.

(1) Meosure width and depth of stringers (measure diameter of stringer if circular), span length, and width of roodwoy. Caunt total number of stringers in the spon. If overhead obstruction exists determine the amount of averhead clearonce to the roodway.

(2) Obtain maximum allowable bending mament per stringer (m) from toble 7–2. Use the formula in figure 7–5 to abtain (m) for a concrete T-beam bridge.

(3) Reod dead load per foat of bridge (W_{DL}) from figure 7–6, then divide by the total number af stringers to obtoin w_{DL}.

(4) Knowing w_{DL} ond the span length determine the moment per stringer (m_{DL}) due to the dead laad, fram figure 7–7.

(5) Calculote the allawable live moment per stringer (m_{LL}) due ta live load: $m_{LL} = m - m_{DL}$.

Note. Check moximum spon length (L_m) af stringer. If L_m obtained from table 7–2 is greater thon span length (L) proceed ta step 6. If the moximum span length (L_m) of the stringer is less thon the spon length (L) reduce m_{LL} by the ratio L_m/L and proceed to step 6.

Table 7–2. Properties of Timber Stringers

Actual size (b × d) (in)	(a) Moment capacity m (kip·ft)	(b) Shear capacity v (kips)	(c) Maximum span Length (L_m) (ft)	Actual size (b × d) (in)	(a) Moment capacity m (kip·ft)	(b) Shear capacity v (kips)	(c) Maximum span Length (L_m) (ft)
4 × 8	8.53	3.2	9 5	12 × 20	160 0	24.0	23.8
*4 × 10	13.33	4.0	11.9	12 × 22	193.6	26 4	26.2
*4 × 12	19.20	4 8	14.3	12 × 24	230	28.8	28.6
6 × 8	12.80	4.8	9.5	14 × 14	91.5	19.6	16.7
6 × 10	20.0	6 0	11.9	14 × 16	119.5	22.4	19.1
6 × 12	28.8	7.2	14 3	14 × 18	151.2	25.2	21.5
*6 × 14	39.2	8.4	16.7	14 × 20	186.7	28.0	23 8
*6 × 16	51.2	9.6	19.1	14 × 22	226	30.8	26.2
*6 × 18	64.8	10.8	21.5	14 × 24	269	33.6	28 6
8 × 8	17.07	6.4	9.5	16 × 16	136.5	25 6	19 1
8 × 10	26.7	8 0	11.9	16 × 18	172.8	28.8	21.5
8 × 12	38.4	9 6	14.3	16 × 20	213	32.0	23.8
8 × 14	52.3	11.2	16.7	16 × 22	258	35 2	26 2
8 × 16	68.3	12 8	19.1	16 × 24	307	38.4	28.6
*8 × 18	86.4	14.4	21.5	18 × 18	194.4	32.4	21.5
*8 × 20	106.7	16.4	23.8	18 × 20	240	36.0	23.8
*8 × 22	129.1	17 6	26 2	18 × 22	290	39.6	26 2
*8 × 24	153.6	19 2	28 6	18 × 24	346	43.2	28 6
10 × 10	33.3	10.0	11.9	8φ	10.05	5.7	9.5
10 × 12	48.0	12.0	14 3	9φ	14.31	7 2	10.7
10 × 14	65 3	14.0	16.7	10φ	19.63	8 8	11.9
10 × 16	85.3	16.0	19.1	11φ	26.1	10.6	13.1
10 × 18	108.0	18 0	21.5	12φ	33.9	12 7	14 3
10 × 20	133.3	20 0	23.8	13φ	43 1	15.0	15.5
*10 × 22	161.3	22.0	26.2	14φ	53.9	17.4	16.7
*10 × 24	192.0	24.0	28.6	16φ	80.4	22 6	19.1
12 × 12	57 6	14.4	14.3	18φ	114.5	28.6	21.5
12 × 24	78.4	16 8	16.7	20φ	157 1	35.4	23.8
12 × 16	102.4	19.2	19.1	22φ	209	42.7	26.2
12 × 18	129.6	21 6	21.5	24φ	271	50.8	28.6

Key to symbols:

φ Diameter

* Lateral bracing required at mid-point and ends of span.

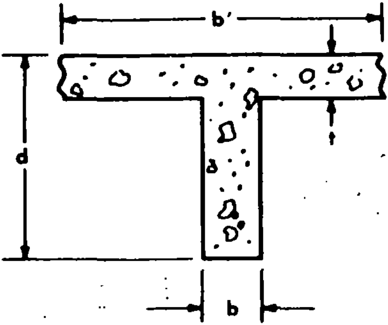
(a) For rectangular stringer not listed, $m = \frac{bd^2}{30}$

For a round stringer not listed, $m = 02d^2$

(b) For rectangular stringer not listed, $v = \frac{bd}{10}$

For a round stringer not listed, $v = .09d^2$

(c) For stringer not listed, $L_m = 1.19d$



$m = 0.585\ b'td$

b' in inches
t in inches
d in feet
m in kip ft

Figure 7–5. Concrete T-beam section.

(6) Compute stringer spacing (S_S).

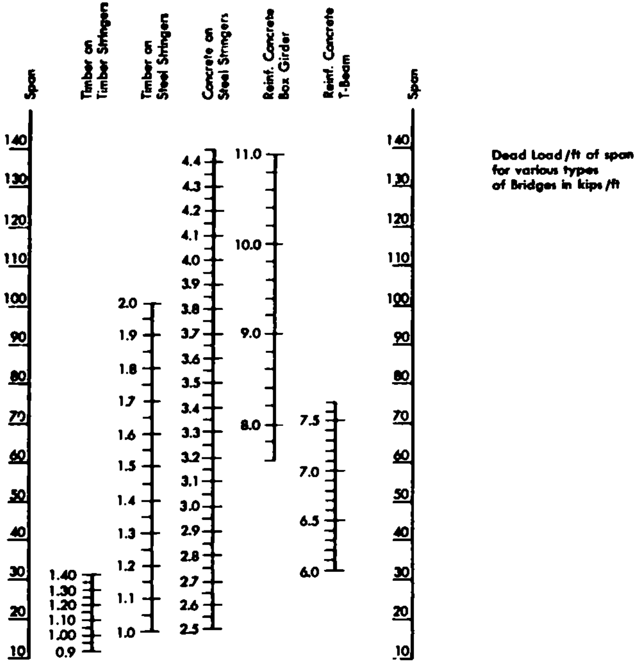
$$S_S = \frac{W_R}{N_S - 1}$$

Read the effective number of stringers (N_1) for one-way traffic from figure 7–8. Compute effective number of stringers for two-way traffic (N_2).

$$N_2 = \frac{3}{8} N_s$$

where N_s equals the total number of stringers in the span. Compare N_1 and N_2. If N_2 is greater than N_1 the one- and two-way class will be the same and the value of N_1 is used to determine the class. If N_2 is less than N_1, N_2 will be used to determine the two-way class and N_1 will be used to determine the one-way class.

(7) Determine the live load moment per lane (M_{LL}) by entering figure 7–9 with the value of m_{LL} obtained from step 5 and either N_1 or N_2 as obtained in step 6.



Notes: 1. Span is center to center of supports in feet.
2. All dead load weights are in kips/ft of bridge.
3. Weights are for a 24′ roadway. If roadway width is different multiply by, $\frac{x}{24}$, where x is actual roadway width.

Figure 7–6. Dead load nomograph.

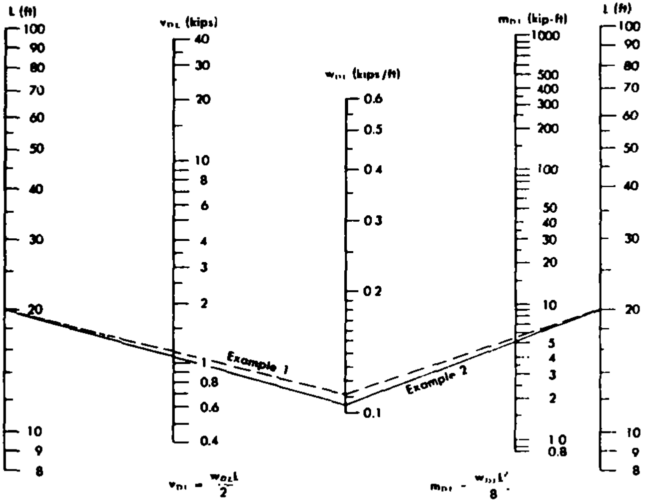


Figure 7–7. Dead load moment and shear.

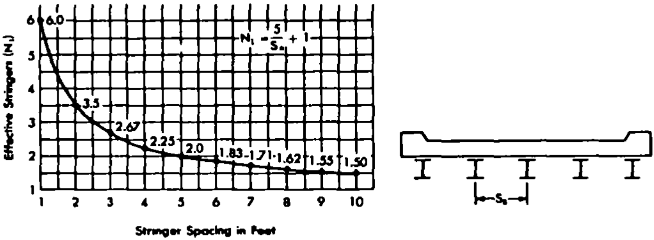


Figure 7–8. Stringer spacing graph.

(8) Determine the classification of the bridge based on bending moment by entering figure 7–10 (moment graph) with M_{LL} as obtained from step 7 and the span length as measured.

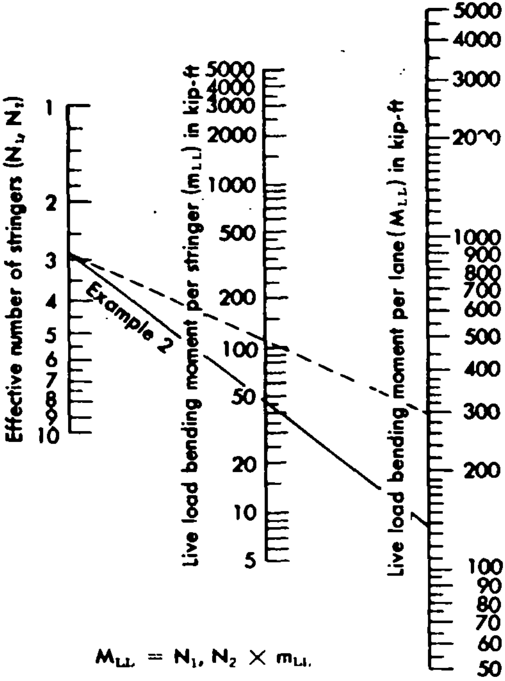


Figure 7–9. Live load moment/lane (M_{LL})

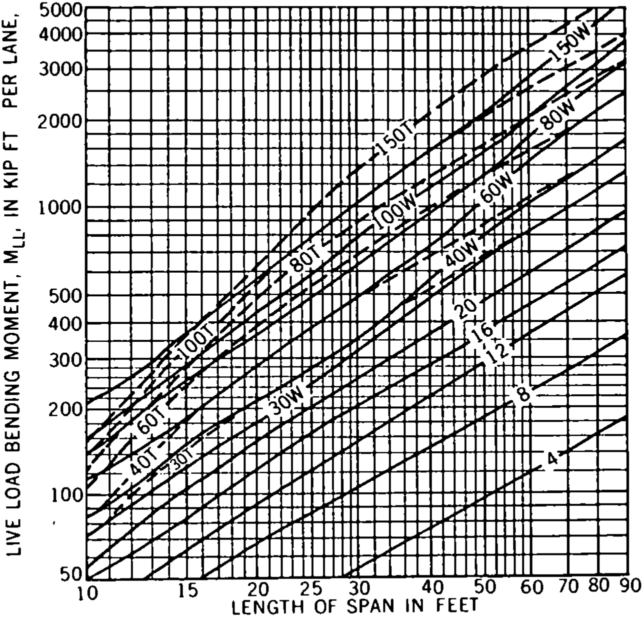


Figure 7–10. Moment graph.

(9) Obtain maximum allowable shear per stringer (v) from table 7–2. (See figure 7–5 for concrete T-beam section.)

(10) Knowing w_{DL} from step 3 and the span length, determine dead load shear per stringer (v_{DL}) from figure 7–7.

(11) Knowing the maximum allowable shear per stringer (v) from step 9 and the dead load shear per stringer (v_{DL}) from step 10, calculate the allowable live load shear per stringer (v_{LL}) from: $v_{LL} = v - v_{DL}$.

(12) Determine the live load shear per lane (V_{LL}) by entering figure 7–11 with v_{LL} and either N_1 or N_2 as determined in step 6.

(13) Determine the bridge classification based on shear by entering the shear graph (fig. 7–12) with the value for v_{LL} obtained in step 12 and the measured span length.

(14) Compare the classifications obtained in step 8 for bending moment and in step 13 for shear. The lower of the two classifications obtained will govern.

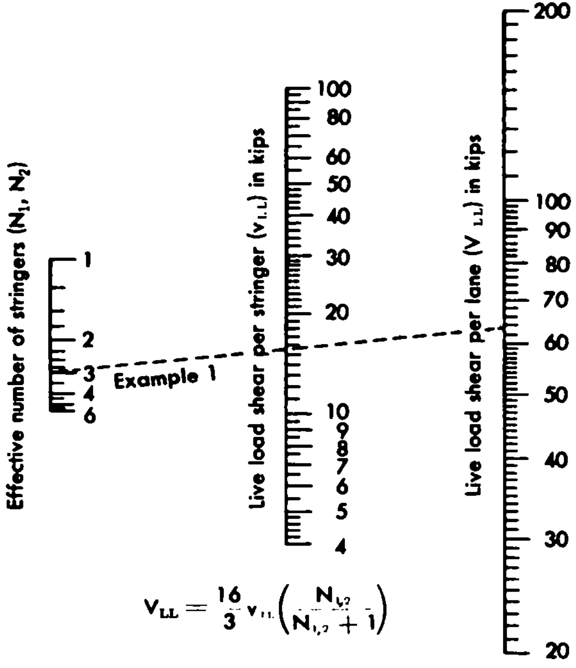


Figure 7–11. Live load shear per lane (V_{LL}).

(15) Check the width and clearance restrictians (tables 5–1 and 5–2) and downgrade the two-way class or post a width restriction sign far one-way class.

(16) Check decking chart (fig. 7–13) based on deck thickness ond stringer spacing. Dawngrade the classificatian if the deck thickness cantrals.

(17) Check lateral bracing. Lateral braces are required as indicated in table 7–2. If necessory add brocing as required before posting bridge clossification.

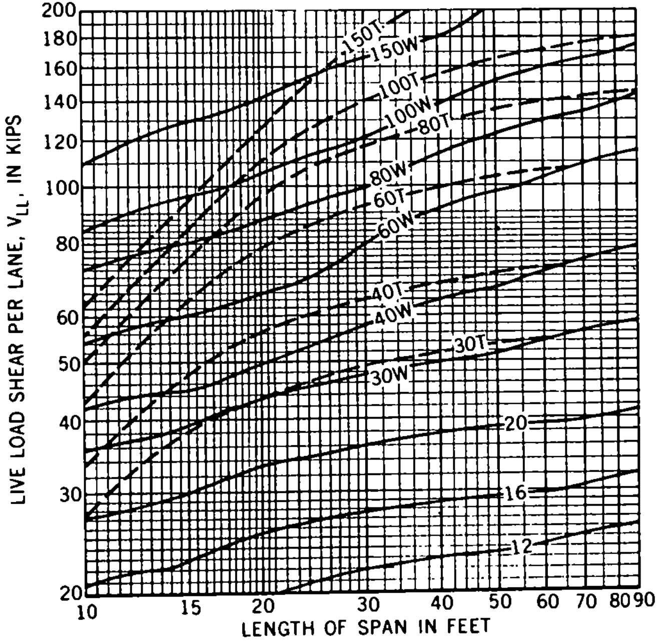


Figure 7–12. Shear graph.

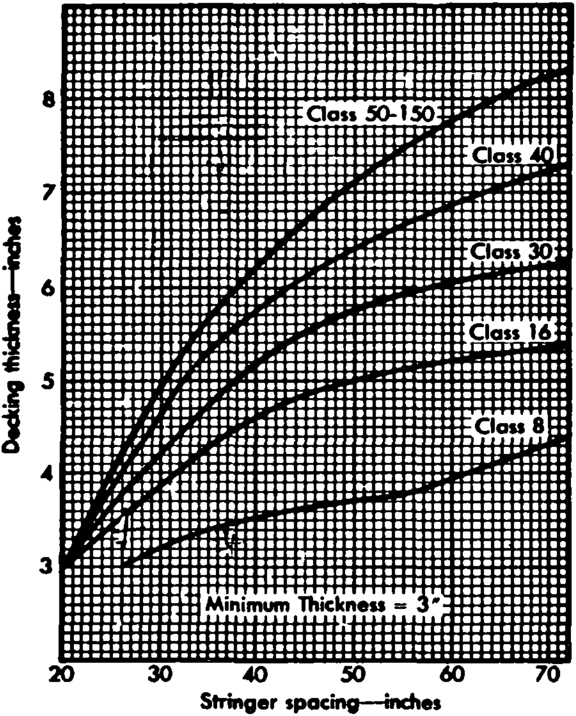


Figure 7–13. Decking chart.

c. *Example (1), Clossificotian of Timber Stringer Bridge.* Classify o two-lane timber stringer bridge hoving na overhead obstructions; spon 20 feet, 10 stringers, each 10" × 18" actual dimensions; raadway width (W_R) 24 feet; timber decking 5 inches thick; no laterol braces.

(1) Make fiield measurements to.determine obave infarmation.

(2) m = 108.0 kip-ft.

(3) $w_{DL} = \frac{1.12 \text{ kips}}{10} = 0.112$ kips per foot of span.

(4) $m_{DL} = 6.0$ kip-ft.

(5) $m_{LL} = 108.0 - 6.0 = 102$ kip-ft.

L_M for $10 \times 18 = 21.5$ ft > 20 ft $\therefore$ OK.

(6) Stringer spacing $(S_S) = \frac{W_R}{N_S - 1} = \frac{24}{10 - 1} = 2.67$ ft.

$N_1 = 2.9$; $N_2 = \frac{3}{8}(10) = 3.75$

N_2 is greater than N_1, therefore one- and two-way class will be the same. Use N_1 to determine both one- and two-way class.

(7) $M_{LL} = 290$ kip-feet.

(8) Class based on moment from figure 7–10 is:
Wheel — 60
Track — 40

(9) v = 18 kips (from table 7–2).

(10) $v_{DL} = 1.1$ kips (from fig. 7–7).

(11) $v_{LL} = 18.0 - 1.1 = 16.9$ kips.

(12) $v_{LL} = 63$ kips from figure 7–11.

(13) Class based on shear from figure 7–12 is:
Wheel — 60
Track — 48

(14) Comparing classifications obtained from moment and shear (steps 8 and 13) one- and two-way classification is:
Wheel — 60
Track — 40

(15) There are no width or height (clearance) restrictions.

(16) Deck thickness is 5 inches with stringer spacing of 32 inches yields class 40 from figure 7–13, so deck thickness controls and classification is:
Wheel — 40
Track — 40

(17) No lateral bracing is required.

d. Steel Stringers. Classify the weakest span to obtain the classification of the bridge. If the weakest span is unknown use the following procedure for each span.

(1) Measure stringer dimensions to obtain information required by table 7–3, and measure span length and width of roadway. Count total number of stringers in one span. If overhead obstruction is present, measure the overhead clearance.

(2) Same as step b(2) for timber bridges except use table 7–3.

Table 7–3. Properties of Steel Stringers

Nominal size	Actual depth (d) (in)	Actual width (b) (in)	Flange thick-ness (t_f) (in)	Web thick-ness (t_w) (in)	Moment capacity m (kip-ft)	Shear capacity v (kips)	Max span length (L_m) (ft)	Max bracing spacing (S_b) (ft)
518U278	51 1/4	14	1 5/8	3/4	3067	594	133	15
*39WF211	39 1/4	11 3/4	1 7/16	3/4	1770	450	100	15
*37WF206	37 1/4	11 3/4	1 7/16	3/4	1656	425	95	15
36WF300	36 3/4	16 5/8	1 11/16	15/16	2486	520	94	25.5
36WF194	36 1/2	12 1/8	1 1/4	13/16	1492	431	93	14
36WF182	36 3/8	12 1/8	1 3/16	3/4	1397	406	93	13
36WF170	36 1/8	12	1 1/8	1 7/16	1302	381	92	12
36WF160	36	12	1	11/16	1217	365	92	11.5
36WF230	35 7/8	16 1/2	1 1/4	3/4	1879	421	91	19.5
36WF150	35 7/8	12	15/16	5/8	1131	350	91	10.5
*36WF201	35 5/8	11 3/4	1 7/16	3/4	1545	402	90	16
33WF196	33 3/8	11 3/4	1 7/16	3/4	1433	377	85	17
33WF220	33 1/4	15 3/4	1 1/4	13/16	1661	392	85	20
33WF141	33 1/4	11 1/2	15/16	5/8	1005	313	85	11
33WF130	33 1/8	11 1/2	7/8	9/16	911	300	85	10
33WF200	33	15 3/4	1 1/8	3/4	1506	362	84	18.5
*31WF180	31 1/2	11 3/4	1 5/16	11/16	1327	327	80	16.5
30WF124	30 1/8	10 1/2	15/16	5/8	797	273	77	11
30WF116	30	10 1/2	7/8	9/16	738	263	76	10
30WF108	29 7/8	10 1/2	3/4	9/16	672	255	76	9
*30WF175	29 1/2	11 3/4	1 5/16	11/16	1156	304	75	17.5
*27WF171	27 1/2	11 3/4	1 5/16	11/16	1059	282	70	18.5
27WF102	27 1/8	10	13/16	1/2	599	217	69	10
27WF94	26 7/8	10	3/4	1/2	546	205	68	9
*26WF157	25 1/2	11 3/4	1 1/4	5/8	915	237	65	19
24WF94	24 1/4	9	7/8	1/2	497	191	62	11
24WF84	24 1/8	9	3/4	1/2	442	174	61	9.5
24WF100	24	12	3/4	1/2	560	173	61	13
24I120	24	8	1 1/8	1 5/16	564	286	61	12.5
24I106	24	7 7/8	1 1/8	5/8	527	224	61	12
24I80	24	7	7/8	1/2	391	183	61	8.5
24WF76	23 7/8	9	11/16	7/16	394	163	61	8.5
*24WF153	23 5/8	11 3/4	1 1/4	5/8	828	217	60	20.5
*24I134	23 3/8	8 1/2	1 1/4	13/16	634	283	60	15
*22I75	22	7	13/16	1/2	308	168	56	8.5

Table 7—3. Properties of Steel Stringers—Continued

Nominal size	Actual depth (d) (in)	Actual width (b) (in)	Flange thick-ness (t_f) (in)	Web thick-ness (t_w) (in)	Moment capacity m (kip-ft)	Shear capacity v (kips)	Max span length (L_m) (ft)	Max bracing spacing (S_b) (ft)
*21WF139	21 5/8	11 3/4	1 3/16	5/8	699	198	55	24 5
*21I112	21 5/8	7 7/8	1 3/16	3/4	495	238	55	14.5
21WF73	21 1/4	8 1/4	3/4	1/2	338	148	54	9 5
21WF68	21 1/8	8 1/4	11/16	7/16	315	140	54	9
21WF62	21	8 1/4	5/8	3/8	284	130	53	8
20I85	20	7 1/8	13/16	11/16	337	195	51	11
*20I65	20	6 1/2	13/16	7/16	245	132	51	9
*20WF134	19 7/8	11 3/4	1 3/16	5/8	621	177	50	23.5
18WF60	18 1/4	7 1/2	11/16	7/16	243	115	46	9.5
*18I86	18 1/4	7	1	11/16	326	184	46	13
18WF55	18 1/8	7 1/2	5/8	3/8	220	108	46	8 5
*18I80	18	8	13/16	1/2	292	133	46	14
18WF50	18	7 1/2	9/16	3/8	200	99	46	8
18I55	18	6	11/16	1/2	199	126	46	7.5
*18WF122	17 3/4	11 3/4	1 1/16	9/16	648	145	45	23 5
*18I62	17 3/4	6 7/8	3/4	5/8	238	100	45	9 5
*18I77	17 3/4	6 3/8	13/16	5/8	281	163	45	11 5
16WF112	16 3/4	11 3/4	1	9/16	450	136	42	23.5
*16I70	16 3/4	6 1/2	13/16	5/8	238	146	42	12
16WF50	16 1/4	7 1/8	5/8	3/8	181	94	41	9
16WF45	16 1/8	7	9/16	3/8	163	85	41	8
16WF64	16	8 1/2	11/16	7/16	234	106	40	12 5
16WF40	16	7	1/2	5/16	145	75	40	7 5
*16I50	16	6	11/16	7/16	155	105	40	8 5
16WF36	15 7/8	7	7/16	5/16	127	74	40	6 5
*16WF110	15 3/4	11 3/4	1	9/16	345	127	40	25
*16I62	15 3/4	6 1/8	7/8	9/16	200	129	40	11.5
*16I45	15 3/4	5 5/8	5/8	7/16	150	104	40	7 5
*15WF103	15	11 3/4	13/16	9/16	369	121	38	24.5
15I56	15	5 7/8	13/16	1/2	173	110	38	10 5
15I43	15	5 1/2	5/8	7/16	132	93	38	7.5
*14WF101	14 1/4	11 3/4	13/16	9/16	344	114	36	26
*14I40	14 1/4	5 3/8	3/8	3/8	119	83	36	8
14I51	14 1/8	5 5/8	3/4	1/2	150	104	36	10
14I70	14	8	13/16	7/16	204	87	35	18

Table 7–3. Properties of Steel Stringers — Continued

Nominal size	Actual depth (d) (in)	Actual width (b) (in)	Flange thick-ness (t_f) (in)	Web thick-ness (t_w) (in)	Moment capacity m (kip-ft)	Shear capacity v (kips)	Max span length (L_m) (ft)	Max bracing spacing (S_b) (ft)
*14I57	14	6	7/8	1/2	153	101	35	12.5
*14I40	14	5 1/2	5/8	3/8	121	78	35	8
14WF34	14	6 3/4	7/16	5/16	109	61	35	7.5
14WF30	13 7/8	6 3/4	3/8	1/4	94	58	35	6
*14WF92	13 3/8	11 3/4	7/8	1/2	297	96	34	25 5
*14I46	13 7/8	5 3/8	11/16	1/2	126	99	34	9
*13I35	13	5	5/8	3/8	85	72	33	8
*13I41	12 5/8	5 1/8	11/16	9/16	108	104	32	9 5
12WF36	12 1/4	6 5/8	9/16	5/16	103	56	31	9 5
*12I65	12	8	15/16	7/16	182	73	30	21
12WF27	12	6 1/2	3/8	1/4	76	44	30	7
12I50	12	5 1/2	11/16	11/16	113	120	30	10
12I32	12	5	9/16	3/8	81	62	30	7 5
*12I34	11 1/4	4 3/4	5/8	7/16	81	72	28	8.5
*11WF76	11	11	13/16	1/2	202	77	28	27
*10I29	10 5/8	4 3/4	9/16	5/16	67	48	27	8 5
10WF25	10 1/8	5 3/4	7/16	1/4	59	38	25	8
*10I40	10	6	11/16	3/8	92	53	25	14
10I35	10	5	1/2	5/8	65	88	25	8
10I25	10	4 5/8	1/2	5/16	55	46	25	7 5
10WF21	9 7/8	5 3/4	3/16	1/4	48	36	25	6 5
*10WF59	9 1/4	9 1/2	11/16	7/16	132	56	23	23
*9I25	9 1/2	4 1/2	1/2	5/16	51	43	24	8
*9I50	9	7	13/16	3/8	103	45	23	21
*8I35	8	6	5/8	5/16	65	34	20	15 5
*8I28	8	5	9/16	5/16	49	35	20	11 5
8WF31	8	8	7/16	5/16	61	33	20	14 5
*8WF44	7 7/8	7 7/8	5/8	3/8	81	40	20	21
*7WF35	7 1/8	7 1/8	9/16	3/8	58	37	18	18 5
*6WF31	6 1/4	6 1/4	9/16	3/8	45	31	16	18 5

*These naminal sizes have na U S equivalent
For stringers nat listed:

$$m = 2.25d_t(bt_f + d_t t_w/6)$$

$$v = 16.5(d_t \times t_w)$$

(3) Same as step *b*(3) for timber bridges.

(4) Same as step *b*(4) for timber bridges.

(5) Calculate the total live load moment per stringer (m_{LL}) knowing m from step (2) and m_{DL} from step (4).

$$m_{LL} = \frac{m - m_{DL}}{1.15}$$

Note. Check L_M as in step (5) for timber stringers.

(6) Same as step *b*(6) for timber bridges.

(7) Same as step *b*(7) for timber bridges.

(8) Same as step *b*(8) for timber bridges.

(9) Same as step *b*(9) for timber bridges except use table 7–3.

(10) Same as step *b* (10) for timber bridges.

(11) Same as step *b* (11) for timber bridges.

(12) Determine live load shear per lane, (V_{LL}): $V_{LL} = \frac{2v_{LL}}{1.15}$

(13) Same as *b* (13) for timber bridges.

(14) Same as *b* (14) for timber bridges.

(15) Same as *b* (15) for timber bridges.

(16) Same as *b* (16) for timber bridges.

(17) Same as *b* (17) for timber bridges except use $N_b = \frac{L}{S_b} + 1$ to calculate number of lateral braces. S_b is the maximum bracing spacing for a given steel stringer and is found in table 7–3.

e. *Example (2), Classification of Steel Stringer Bridge.* Classify a bridge with 10–10WF25 stringers, 5-inch timber deck, span length 20 feet, $W_R = 24$ feet. There are no overhead obstructions and no lateral braces.

(1) The given data shown is usually obtained by field measurements.

(2) m = 59 kip-ft for 10WF25 beam from table 7–3.

(3) w_{DL} = 1.05 kips, figure 7–6 for a 20-foot span

$$w_{DL} = \frac{W_{DL}}{N_S} = \frac{1.05}{10} = 0.105 \text{ kips/ft.}$$

(4) $m_{DL} = 5.3$ kip-ft from figure 7–7.

(5) $m_{LL} = \frac{m - m_{DL}}{1.15} = \frac{59 - 5.3}{1.15} = 46.7$ kip-ft.

$L_M = 25$ (fram table 7–3) $> 20 \therefore$ OK

(6) $S_S = \frac{W_R}{N_S - 1} = \frac{24}{10 - 1} = 2.67$ ft.

$N_1 = 2.9$ feet fram figure 7–8.

$N_2 = \frac{3}{8} N_S = \frac{3}{8} \times 10 = 3.75$

Since N_2 is larger than N_1 one- and two-way class will be the same. Use N_1 ta abtain bath one- ond twa-woy closs.

(7) $M_{LL} = 140$ kip-ft.

(8) Class based on mament from figure 7–10 is:

Class 18 far bath wheel and track vehicles.

(9) $v = 38$ kips fram table 7–3 far 10WF25 beam.

(10) $v_{DL} = 1.1$ kips.

(11) $v_{LL} = v - v_{DL} = 38 - 1.1 = 36.9$ kips.

(12) $V_{LL} = \frac{2v_{LL}}{1.15} = \frac{(2)(36.9)}{1.15} = 64.2$ kips.

(13) Class based on shear fram figure 7–12 is: Wheel—60 Track—46.

(14) Class 18 abtained fram bending moment (step (8)) will gavern.

(15) No width ar clearance restrictions.

(16) Deck thickness af 5 inches with stringer spacing af 32 inches yields class 40 from figure 7–13.

(17) Class af bridge must be bosed an class af the weokest spon. Therefore, the mament class af the steel stringer span gaverns and the bridge classificatian is: 18.

(18) Number af braces, $N_b = \frac{L}{S_b} + 1 = \frac{20}{8} + 1 = 3.5$

$\therefore$ 4 braces must be added.

7–3. REINFORCED CONCRETE BRIDGES

Due to wide variatians in design criteria, it is nat possible ta calculate the exact capacity of a reinfarced cancrete bridge based anly an the measurable external dimensians. Therefore, when infarmatian is ovailable pertoining ta the design laading ar civil laad rating for the bridge (fram o locol agency ar from intelligence reparts), the class will be obtained by correlotian if chorts ore avoilable relating civilian design laad ta the military class far variaus span lengths. Such charts are available in TM 5–312 far many United States and foreign civilion design loads, or they may be developed within certain army areas. When the necessary information is not available for classification by correlation, the expedient methods shown below may be used.

a. *Slab Bridges.* Measure the span length from center-to-center of supports in feet, the roadway width (W_R) in feet, the slab width (W_S) in feet, and the depth (D) of the concrete slab (fig. 7–14) in inches exclusive of any wearing surface or fill. Enter figure 7–15 with the span length, drawing a vertical line until it intersects the curve representing the depth (D) of the slab, estimating when necessary where this point should be. From this intersection draw a horizontal line to read the value of m_{LL} on the left hand axis. Depending on one- or two-way classification, use one or both of the following formulas to determine the effective roadway width:

$$\text{One-way, } W_1 = \frac{L}{\frac{3}{4} + \frac{L}{W_S}} \qquad \text{Two-way, } W_2 = \frac{L}{\frac{1}{4} + \frac{2L}{W_S}}$$

Find M for one-way or two-way traffic using W_1 or W_2 respectively:

$$M_{1,2} = W_{1,2} m_{LL}$$

Enter figure 7–10 with this value of $M_{1,2}$ and the span length to obtain the class of the bridge. Check width and height restrictions for the class bridge obtained.

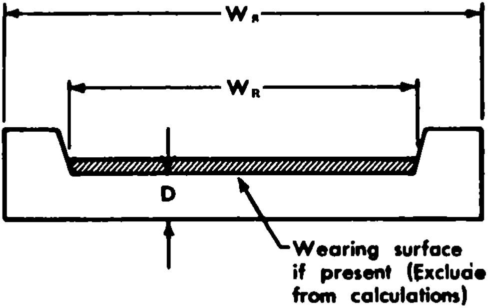


Figure 7–14. Concrete slab bridge.

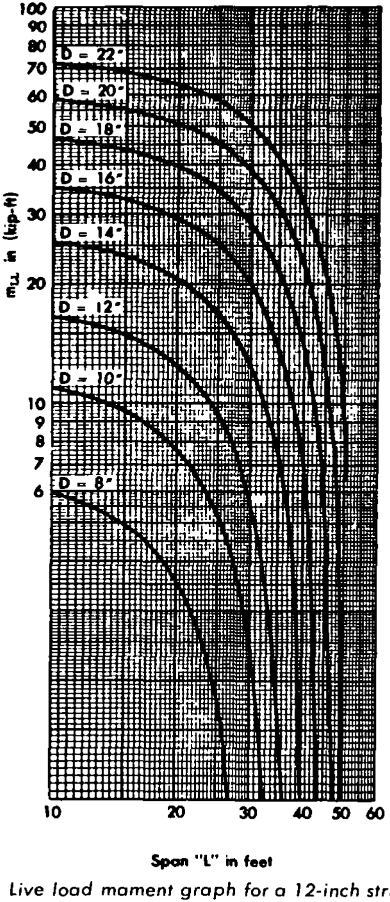


Figure 7—15. Live load moment graph for a 12-inch strip of reinforced concrete.

b. *Example* (3), *Classification of a Slab Bridge.* Classify a two-lane concrete slab bridge; span length = 20 feet; $D = 14$ inches; roadway width (W_R) = 28 feet, slab width (W_S) = 3 feet. To find the bridge class, enter figure 7—15 with the span length on the harizontol scole and move vertically until it intersects curve for $D = 14$ inches and read across to 20 kip-ft on the verticol scale.

(1) One-way closs: $W_2 = \dfrac{L}{\dfrac{3}{4} + \dfrac{L}{W_S}} = \dfrac{20}{\dfrac{3}{4} + \dfrac{20}{31}} = 14.3$

(2) Two-woy closs: $W_2 = \dfrac{L}{\dfrac{1}{4} + \dfrac{2L}{W_S}} = \dfrac{20}{\dfrac{1}{4} + \dfrac{40}{31}} = 13.0$

(3) $M_1 = 20\ (14.3) = 286$ kip-ft yields class 60 wheel, 40 track from moment graph (fig. 7—10).

(4) $M_2 = 20\ (13.0) = 260$ kip-ft yields class 52 wheel, 34 track.

(5) Bridge class is:

	One-way	Two-woy
a. wheel	60	52
b. track	40	34

c. *T-Beam Bridges.* Make the necessory measurements os shown in figure 7—16, ond find L, the span length from center-to-center of supports. All dimensians are in inches except L and W, which are in feet. Calculote "M" by the formula:

$$M = N\ [(158 + D(1.07T + 0.34L + 0\ 027S + 0.77b - 24.1)] + 0.08L^2$$

Enter the graph, figure 7—10 with this value of "M" and the span length to obtain the class of the bridge.

d. *Exomple* (4), *Classificatian af o T-Beam Bridge.* Classify o twa-lone cancrete T-8eom bridge; 32′ spon length; 7 T-Beams, $S = 48''$, $D = 30''$, $b = 12''$, $T = 6''$; 24′ roadway (see fig. 7—16). To find bridge closs: Raodwoy width limits twa-way closses 4 ta 60. Number of stringers per lane = 3.5.

$$M = 3.5[158 + 30(1.07(6) + 0.34(32) + 0.027(48) + 0.77(12) - 24.1] + 0.08(32)^2$$

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

$$M = 3.5[158 + 30(3.74)] + 82 = 3.5(158 + 112\ 2) + 82 = 1028$$

With this value of "*M*" and the span length, obtain the class from the moment graph (fig. 7–10).

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.

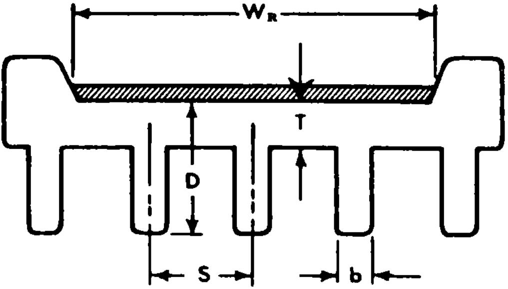


Figure 7–16. Concrete *T-beam bridge.*

7–4. MASONRY ARCH BRIDGE

To obtain the bridge classification for a masonry arch bridge, a provisional class number based on the crown thickness and span length is determined, this provisional class number is then adjusted by applying factors based on the materials and the condition of the bridge.

a. *Provisional Class Number.* Mark span length (*S* in fig. 7–17) on column A of figure 7–18. Mark total crown thickness ($t + D$ in fig. 7–17) on column B of figure 7–18. Draw a straight line through the points marked in steps 1 and 2 and where this line intersects column C, read the provisional class number.

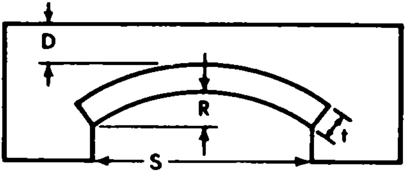


Figure 7–17. Masonry arch bridge.

b. Profile Factor. Divide span length (*S* in fig. 7–17) by the rise (*R* in fig. 7–17) and mark the result at the bottom of figure 7–19. If the result is 4 or less, profile factor is 1. Otherwise, draw a vertical line from the mark made in step 4 and mark the point where it intersects the curved line. Draw a horizontal line from the mark made in step 5 to the left edge of figure 7–19 and read the profile factor at this point.

c. *Other Factors* (table 7–4). Select the material, joint, deformation, crack, abutment size, and abutment fault factors from the table. Use only those factors which apply.

d. Actual Class Number. Multiply the provisional class number by each of the various factors found above. The result is the bridge classification number.

e. *Example (5), Classification of a Masonry Arch Bridge.* Classify a masonry arch bridge; span (*S*) 40 feet; rise (*R*) 8 feet, arch ring thickness (*t*) 18 inches; depth of fill at crown (*D*) 12 inches; roadway width 15 feet; 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.

(1) *Find bridge class.* Solution: Roadway width limits bridge to one lane. Total crown thickness ($t + D$, see fig. 7–17) = 18 in + 12 in = 2.5 ft. Using figure 7–18 line up straight edge at span of 40 feet (col. A) and total crown thickness of 2.5 feet (col. B). At the intersection of straight edge and column C, read provisional class number, 34.

(2) *Determine the profile factor.* Span/rise ratio $= S/R = 40/8 = 5$. Enter the bottom of figure 7–19 with the span/rise ratio and draw a vertical line. At the intesection of this vertical line and the curved line on the chart, pivot (going horizontally) to the left edge of the chart. Read the profile factor as 0.86.

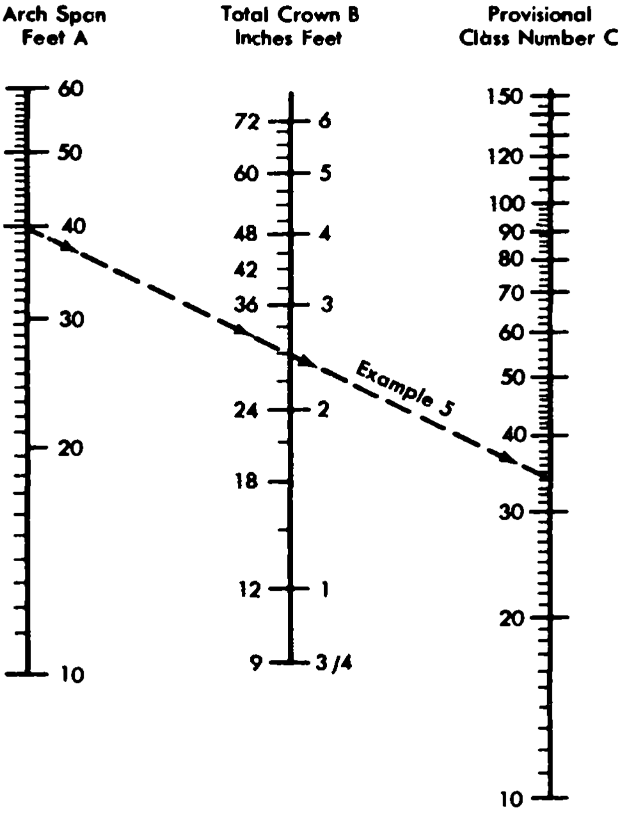


Figure 7–18. Chart for determining provisional road class of arch bridges.

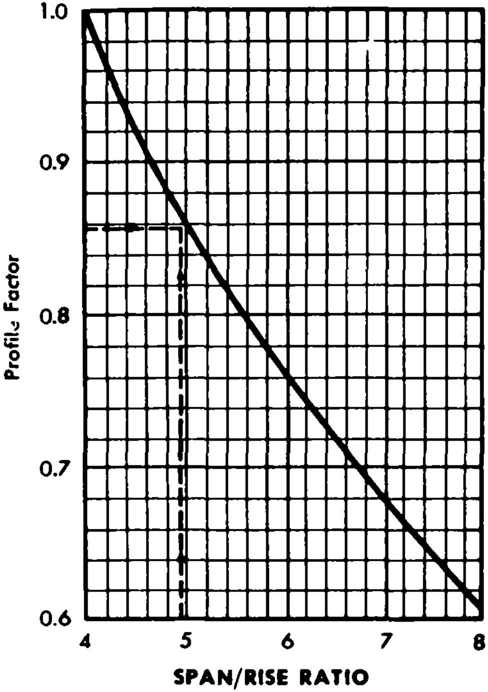


Figure 7–19. Profile factors for orch bridges.

(3) *Joint factor.* Material factor for limestone in gaod conditian is 1.0. Joint factar is between 0.80 ond 0.70, soy 0.75. Crack factor far one crock ot the edge af the ring is 0.90. Abutment foctor far one unsatisfactory abutment is 0.95.

(4) *Determine class number.* Determine actual closs number by multiplying pravisianal closs number by foctars found above. Actual Class Number = 34 × 0.86 × 1.0 × 0.75 × 0.90 × 0.95 = Class 19.

Table 7–4. Arch Factors

MATERIAL FACTOR	
1. Granite, whitstone and built-in-course masonry	1 5
2. Concrete or blue engineering bricks	1.2
3. Good limestone mosonry and building bricks	1.0
4. Poor masonry ar brickwaod (of any kind)	0.7 to 0.5
JOINT FACTORS	
1. Thin joints, 1/10" or less in width	1.25
2. Narmal joints, with width up to 1/4"	1.00
3. Ditto, but with mortar unpainted	0.90
4. Joint aver 1/4" wide, irregular good mortor	0.80
5. Ditto, but with mortar containing voids deeper than one-tenth of the ring thickness	0.70
6. Joints 1/2" or more wide, poor mortar	0.50
DEFORMATION FACTORS	
1. The rise over the offected portion is always positive.	—Apply span-rise ratio of affected portion to the whole arch.
2. Flat section of profile.	—Maximum: 12
3. A portion of the ring is sagging.	—Maximum class: 5; if fill at crown exceeds 18"
CRACK FACTORS	
1. Small tronsverse crocks within 2 ft. of the edge	1.0
2. Large tronsverse cracks within 2 ft. of the edge	1.0
3. Longitudinal cracks in center third of bridge	0.9 to 0 7
One smoll crack	1.0
One lorge crack or several narrow cracks	0.5
4. Small lateral and diagonal cracks	1.0
5. Large lateral and diogonal crocks—Maximum Class: 12; or the figure derived by using the other factors.	
6. Cracks between the arch ring and parapet wall due to laterol spread of the fill	0.9
7. Cracks between the ring and spandrel, due to a dropped ring—Reclossify from the nomograph, on the assumption that the crown thickness is that of the ring alone.	

Table 7–4.—Continued

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 one abutment and one pier	0.90
6. Arch supported on two piers	0.80

ABUTMENT FAULT FACTORS	
1. Inward movement of one abutment	0.75 to 0.50
2. Outward spread of abutments	1.00 to 0.50
3. Vertical settlement of one abutment	0.90 to 0.50

Section II, Highway Bridge Design

7–5. SUPERSTRUCTURE

Bridge design as discussed herein is limited to rapid field design of temporary or semi-permanent type highway bridges. For more detailed design procedures including the design of railroad bridges see TM 5–312.

NOTATIONS

A = Area (in^2)
A_p = Bearing area of post or pile (in^2)
B = Width of stringer (in)
b_c = Width of corbel
b_{cap} = Width of cap
B_{H} = Width of bearing plate (in)
d = Total depth of stringer (in)
d_c = Depth of corbel
d_{cap} = Depth of cap (in)
D_p = Diameter of pile (in)
H = Height of timber bent post
H_p = Distance from stream bed to top of pile
H_m = Max height of post
kip = 1000 lbs
L = Span length (ft)

L_c = Effective corbel length (ft)
L_e = Effective span length (ft)
L_{ftg} = Length of footing (in)
L_m = Max span length (ft)
L_{PL} = Length of bearing plate (in)
M_{DL} = Dead load bending moment for entire bridge (kip ft)
M_{LL} = Live load bending moment per lane (kip ft)
m = Total bending moment per stringer (kip ft)
m_{DL} = Dead load bending moment per stringer (kip ft)
m_{LL} = Live load bending moment per stringer (kip ft)
N_c = Number of corbels
N_L = Number of lones
N_p = Number of posts or piles
N_S = Number of stringers
N_1 = Effective number of stringers
P_T = Total design load on substructure (kips)
S_b = Maximum spacing of brocing (ft)
S_S = Center to center spocing of stringers (ft)
t_{PL} = Thickness of bearing plate (in)
V_{DL} = Dead lood shear for entire span (kips)
V_{LL} = Live load shear per lane (kips)
v = Total shear per stringer (kips)
v_{DL} = Dead load shear per stringer (kips)
v_{LL} = Live load shear per stringer (kips)
W_R = Width of roadway from inside curb to inside curb (ft)

a. *Timber Stringers.*

(1) Determine the number of required stringers, N_S.

$$N_S = \frac{W_R}{6} + 1 \text{ (minimum number of stringers 4).}$$

Round N_S down to the nearest stringer if the decimol is .09 or less, otherwise round up. Do not round off where asterisk oppears. Determine the center to center spacing (S_S).

$$^{*}S_S = \frac{W_R}{N - 1}$$

(2) Determine the effective number of stringers, N_1.

$$*N_1 = \frac{5}{S_S} + 1$$

(3) Determine M_{LL} from figure 7–10. Determine m_{LL} from figure 7–20.

(4) Determine M_{DL} from figure 7–21. Calculate m_{DL}.

$$m_{DL} = \frac{M_{DL}}{N_S}.$$

(5) Colculate m. $m = m_{LL} + m_{DL}$. Choose o stringer from table 7–2 which hos on m value equal to or greater than m just calculoted. $\left(\text{For a stringer not listed in table 7–2, } m = \frac{bd^2}{30}.\right)$

(6) Determine V_{LL} from figure 7–12. Determine v_{LL} from figure 7–22.

$$\left(\frac{3V_{LL}}{16}\right)\left(\frac{N_l + 1}{N_l}\right)$$

(7) Determine V_{DL} from figure 7–21. Calculote $v_{DL} \cdot v_{DL} = \frac{V_{DL}}{N_S}$.

(8) Colculate v. $v = v_{LL} + v_{DL}$ Check to see if v of stringer selected in step (5) is equal to or greater thon v just calculated. If not, increose the size of the stringer until this requirement is satisfied keeping in mind the m requirement. (For a stringer not listed in table 7–2 $v = \frac{bd}{10}$.)

(9) Determine L_m of stringer selected. Verticol deflection will not be a problem if the span is less thon the value of L_m in table 7–2. If verticol deflection is criticol, increase the size of the stringer until the L_m requirement is sotisfied, keeping in mind the requirements for m and v. (For a stringer not listed in toble 7–2 $L_m = 1.19d$.)

(10) For lateral bracing see table 7–2.

(11) Determine the minimum decking thickness required from figure 7–13. Use at least 2″ of material for treod.

b. Exomple (1)—Design of Timber Stringer Bridges. Design the superstructure of o class 30, 20-foot span, two-lone bridge, $W_R = 24$ feet with timber deck ond timber stringers.

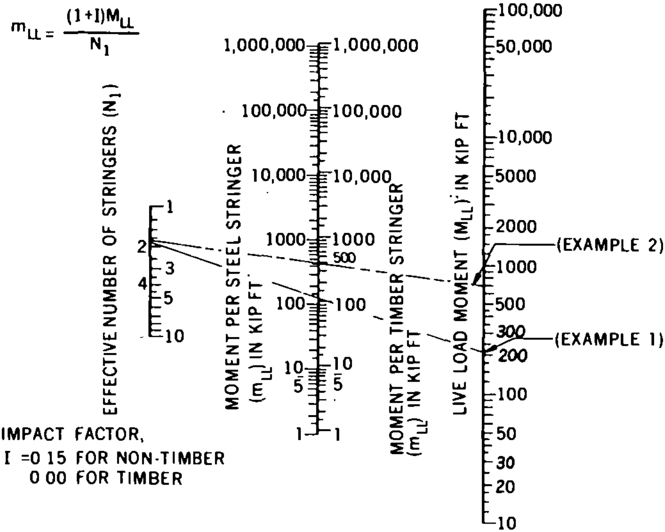


Figure 7—20. Moment nomograph.

(1) $N_S = \frac{W_R}{6} + 1 = \frac{24}{6} + 1 = 5$

$S_S = \frac{W_R}{N_s - 1} = \frac{24}{5-1} = 6$ ft

(2) $N_1 = \frac{5}{S_S} + 1 = \frac{5}{6} + 1 = 1.83$

(3) $M_{LL} = 210$ kip ft

$m_{LL} = 115$ kip ft

(4) $M_{DL} = 56$ kip ft

$m_{DL} = \frac{M_{DL}}{N_S} = \frac{56}{5} = 11.2$ kip ft

(M_{DL} is in kip-feet, V_{DL} is in kips)

L (feet)	M_{DL}	V_{DL}	M_{DL}	V_{DL}	M_{DL}	V_{DL}	M_{DL}	V_{DL}	L (feet)
70					649.25	37.10	1133.13	64.75	70
65					538.68	33.15	937.42	57.69	65
60					441.00	29.40	765.00	51.00	60
55					355.44	25.85	614.45	44.69	55
50					281.25	22.50	484.38	38.75	50
45					217.69	19.35	373.36	33.19	45
40					164.00	16.40	280.00	28.00	40
38					145.12	15.28	247.85	26.03	38
36					127.66	14.18	217.08	24.12	36
34					111.55	13.12	189.30	22.27	34
32					96 77	12.10	163.84	20.48	32
30	91.13	12.15	160 88	21.45	83.25	11.10	140.63	18.75	30
28	76.24	10.89	134.06	19.15	70.95	10.14	119.56	17.08	28
26	63.04	9.70	110.36	16.98	59.83	9.20	100.56	15.47	26
24	51.41	8.57	89.57	14.93	49.82	8.30	83.52	13.92	24
22	41.26	7.50	71.51	13.00	40.90	7.44	68.37	12.43	22
20	32.50	6.50	56.00	11.20	33.00	6.60	55.00	11.00	20
18	25.03	5.56	42.85	9.52	26.10	5.80	43.34	9.63	18
16	18.75	4.89	31.87	7.97	20.10	5.02	33.28	8.32	16
14	13.57	3.88	22.88	6.54	14.99	4.28	24.75	7.07	14
12	9.40	3.13	15.70	5.23	10.73	3.58	17.64	5.88	12
10	6.13	2.45	10.13	4.05	7.25	2.90	11.88	4.75	10
9	4.80	2.13	7.89	3.51					9
8	3.66	1.83	5.98	2.99					8
Span in feet	Timber Stringer - Timber Deck One Lane		Timber Stringer - Timber Deck Two Lane		Steel Stringer - Timber Deck One Lane		Steel Stringer - Timber Deck Two Lane		Span in feet

Figure 7—21. Dead load moment and shear for various types of bridges.

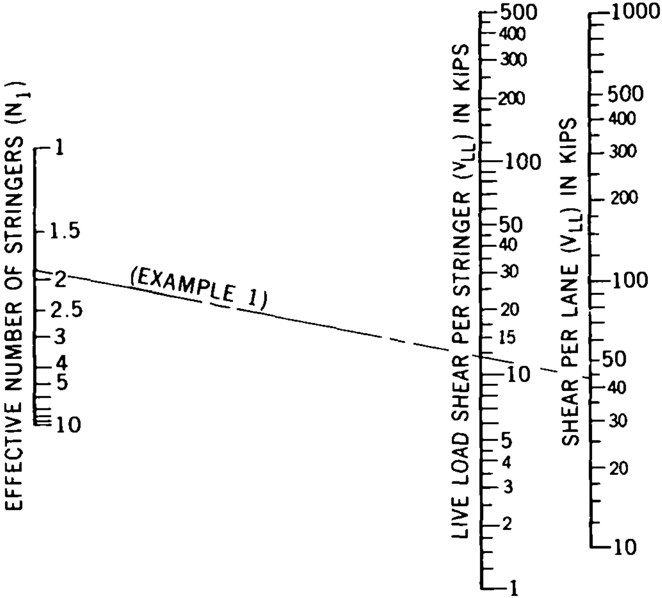


Figure 7–22. Sheor nomogroph.

(5) $m = m_{LL} + m_{DL} = 115 + 11.2 = 126.2$ kip ft
Use 12″ × 18″ stringer ($m = 129.6$ kip ft)

(6) $V_{LL} = 43$ kips
$v_{LL} = 12.4$ kips

(7) $V_{DL} = 11.2$ kips

$$v_{DL} = \frac{V_{DL}}{N_S} = \frac{11.2}{5} = 2.25 \text{ kips}$$

(8) $v = v_{LL} + v_{DL} = 12.4 + 2.25 = 14.65$ kips
v for o 12″ × 18″ stringer = 21.6 kips > 14 65 kips ∴ OK

(9) $L_m = 21.5$ ft > 20 ft ∴ OK

(10) No loterol broces required.

(11) Minimum deck thickness = 6+", say 7"; use 2" material for tread.

c. *Steel Stringers.*

(1) through (4). Same as a above (timber stringers).

(5) Same as a(5) above except use table 7–3. (For a stringer not listed in table 7–3, $m = d_1 \left(bt_f + \frac{d_1 t_w}{6} \right)$ (2.25).)

(6) Determine V_{LL} from figure 7–12. Determine $v_{LL} \cdot v_{LL} = \frac{1.15 V_{LL}}{2}$.

(7) Same as a(7) above.

(8) Same as a(8) above except use table 7–3 (For a stringer not listed in table 7–3, $v = 16.5\,(d_1 \times t_w)$.)

(9) Same as a(9) above except use table 7–3. (For a stringer not listed in table 7–3, $L_m = 2.56d$.)

(10) The number of lateral braces (N_b) between adjacent stringers is computed by $N_b = \frac{L}{s_b} + 1$. Space braces evenly along span length always placing a brace at each end. S_b is found in table 7–3. $\left(\text{For a stringer not listed in table 7–3, } S_b = \frac{33bt_f}{d} \right)$.

(11) Bearing plate design will be made for all steel stringers.

$$L_{ff.} - \min L_{ff.} = 6"; \max L_{ff.} = b_{cap}$$

$$B_{ff.} - B_{ff.} = \frac{2v}{L_{ff.}}; \min B_{ff.} = b \text{ of stringer}$$

$$t_{ff.} - t_{ff.} = \frac{B_{ff} - 2.5}{8} \text{ (Round up to nearest } \tfrac{1}{8}")$$

(12) Same as a(11) above.

d. *Example* (2) *Design of Steel Stringer Bridge.* Design the superstructure for a class 60, 30-foot span, two-lane bridge, $W_R = 24$ feet with steel stringers and timber deck.

(1) $$N_S = \frac{W_R}{6} + 1 = \frac{24}{6} + 1 = 5$$

$$^{*}S_S = \frac{W_R}{N_S - 1} = \frac{24}{5 - 1} = 6 \text{ ft}$$

(Do not round off where asterisks appear.)

(2) $^*N_1 = \frac{5}{S_S} + 1 = \frac{5}{6} + 1 = 1.83$

(3) $M_{LL} = 675$ kip ft
$m_{LL} = 450$ kip ft

(4) $M_{DL} = 140.63$ kip ft
$$m_{DL} = \frac{M_{DL}}{N_S} = \frac{140.63}{5} = 28.13 \text{ kip ft}$$

(5) $$m = m_{LL} + m_{DL} = 450 + 28.13 = 478.13 \text{ kip ft}$$

Use a 24WF94 stringer ($m = 497$ kip ft).

(6) $V_{LL} = 92$ kips
$$v_{LL} = \frac{1.15\,V_{LL}}{2} = \frac{1.15(92)}{2} = 53.0 \text{ kips}$$

(7) $V_{DL} = 18.75$ kips
$$v_{DL} = \frac{V_{DL}}{N_S} = \frac{18.75}{5} = 3.75 \text{ kips}$$

(8) $$v = v_{LL} + v_{DL} = 53.0 + 3.75 = 56.75 \text{ kips}$$

v for a 24WF94 stringer $= 191$ kips > 56.75 $\therefore$ OK

(9) $L_m = 62$ ft > 30 ft $\therefore$ OK

(10) $N_b = \frac{L}{S_b} + 1 = \frac{30}{11} + 1 = 2.73 + 1 = 3.73$, say 4

Use 4 braces, 1 at each end and two spaced evenly between.

(11) $L_{\text{P}} = 6''$

$$B_{\text{P}} = \frac{2v}{L_{\text{P}}} \quad \frac{2 \times 56.75}{6} = 18.9 > 9'' \text{ (b of 24WF94)} \therefore \text{OK}$$

$$t_{\text{P}} = \frac{B_{\text{P}} - 2.5}{8}$$

$$t_{tr} = \frac{18.9 - 2.5}{8}$$

$$t_{tr} = 2.05$$

(12) Minimum deck thickness = 8+, say 9″. Use 2″ material far tread.

7-6. SUBSTRUCTURE

a. *Single Trestle Bent.*

(1) Use harizantal braces at midpoint when past height exceeds that listed in table 7–5.

Table 7–5. Past Criteria

Size of post ar pile Rect (in)	Capacity per past (Kips)	Max height af past (ft)
6 × 6	18	15
6 × 8	24	15
8 × 8	32	20
8 × 10	40	20
10 × 10	50	25
10 × 12	60	25
12 × 12	72	30
RND (IN)		
8ø	25	18
9ø	32	20
10ø	40	22
11ø	47	25
12ø	56	27
13ø	66	29
14ø	76	31

(2) For a bent under adjacent spans, add L_1 to L_2 to find effective span length, L_e (fig. 7–23). Using L_e determine the live load shear (V_{LL}). Determine the dead load shear (V_{DL}) as the sum of the dead load shear for spans L_1 and L_2. $P_T = V_{LL}(N_L) + V_{DL}$.

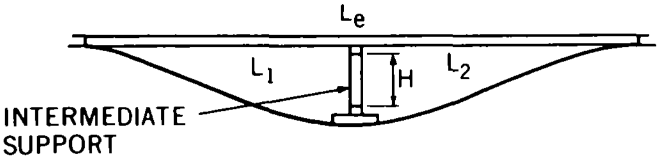


Figure 7–23. Adjacent spans.

(3) Determine the capacity per post from table 7–5. (For posts not listed, capacity per post $= \frac{A_p}{2}$ in kips.)

(4) Determine the number of posts required, N_p. $N_p = \frac{P_T}{\text{capacity per post}}$

(5) Determine length of footing, L_{ftg}. $L_{ftg} = k + b_{sill}$. L_{ftg} may be rounded down but never up. Obtain k from figure 7–24.

(6) Determine capacity per footing.
*capacity per footing = (Area per footing) (SBC)
(Do not round off where asterisk appears.)
Area/ftg (actual area in contact with ground $= L \times W$ (sq ft))
SBC = soil bearing capacity (kips/sq ft) see table 7–6 for SBC.

(7) Determine the number of footings (N_{ftg}).

$$N_{ftg} = \frac{P_T}{\text{capacity per ftg}}$$

N_{ftg} must be equal to or greater than N_P.

$$^*Sp\ ftg = \frac{W_R \times 12}{N_{ftg} - 1}$$

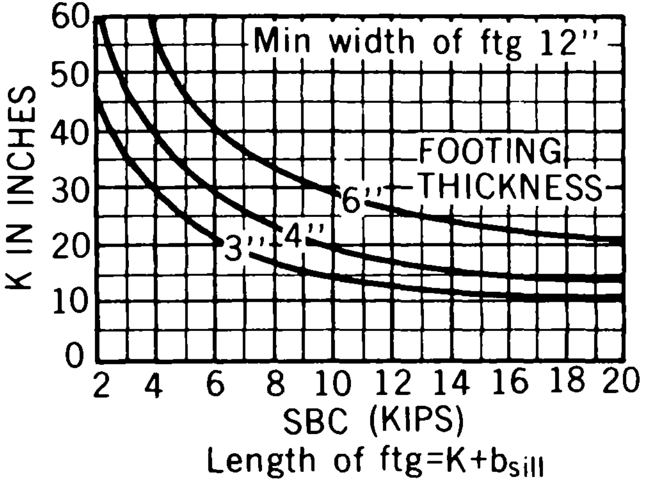


Figure 7–24. Footing chart.

b. Example (1). Substructure Design With a Single Trestle Bent. Design the substructure for a class 50 bridge, $W_R = 24$ feet, $L_1 = 20$ feet, $L_2 = 30$ feet, 6" × 8" posts, 6" × 10" cap and sill, 3" × 12" × RL footings, $H = 6$ feet, compact sand clay, 6" timber deck, 7 steel stringers, $N_L = 2$ lanes.

(1) $H_m = 15' > 6'$, ∴ no horizontal braces required

(2) $L_e = L_1 + L_2 = 20 + 30 = 50'$

$V_{LL} = 86$ kips

$V_{DL} = V_{DL1} + V_{DL2} = 18.75 + 11.00 = 29.75$ kips

$P_T = V_{LL}(N_L) + V_{DL} = 86(2) + 29.75 = 201.75$ kips

(3) Capacity per post = 24 kips

(4) $N_P = \frac{P_T}{\text{capacity per post}} = \frac{201.75}{24} = 8.36$, say 9

Toble 7—6. Soil Beoring Copocity

Soil description	Beoring volues in kips per squore foot
Hordpon overloying rock	24
Very compoct sondy grovel	20
Loose grovel ond sondy grovel, compoct sond ond grovelly sond; very compoct sond-in-orgonic silt soils	12
Hord dry consolidoted cloy	10
Loose coorse to medium sond, medium compact fine sond	8
Compoct sond cloy	6
Loose fine sond, medium compoct sond-inorgonic silt soils	4
Firm of stiff cloy	3
Loose soturoted sond-cloy soils, medium soft cloy	2

(5) $L_{ftg} = k + b_{sill} = 21 + 6 = 27''$

(6) Copocity per ftg = (oreo per ftg) (SBC)

$$\text{oreo per ftg} = \text{L} \times \text{W (sq ft per ftg)} = \frac{12 \times 27}{144} = 2.25 \text{ sq ft per ftg}$$

$$\text{SBC} = 6 \text{ kips per sq ft}$$

$$\text{cop per ftg} = (2.25)\ (6) = 13.5 \text{ kips}$$

(7) $$N_{ftg} = \frac{P_T}{\text{cop/ftg}} = \frac{201.75}{13.5} = 14.4\text{, soy } 15$$

$$\text{Sp ftg} = \frac{W_R \times 12}{N_{ftg} - 1}\ \frac{24 \times 12}{14 - 1} = 22.1''\ \text{C–C.}$$

c. *Two Trestle Bents.* (Timber trestle pier.) A timber trestle pier is designed exoctly the some os o trestle bent except thot eoch bent is designed for one-holf the totol lood. A timber trestle pier will be used for the following conditions:

(1) Loads are too great to be carried by a single bent.

(2) Span lengths are greater than 25 feet, making bracing cumbersome. Cap and corbel system design is described in *f* below.

d. Pile Bent or Pier.

(1) Use lateral braces down to flood level in all cases. For piers longitudinal bracing must also be used. The distance (H_P) from the streambed to the top of the pile may not exceed H_m values given in table 7–5.

(2), (3) Same as *a* above.

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

	Drophammer	Single-Acting Pneumatic or Steam Hammer	Double-Acting Pneumatic or Steam Hammer
Timber	$P=\frac{2W_d h}{(S+1)}$	$P=\frac{2W_r H}{(S+0.1)}$	$P=\frac{2E}{(S+0.1)}$
Steel	$P=\frac{3W_d h}{(S+1)}$	$P=\frac{3W_r H}{(S+0.1)}$	$P=\frac{3E}{(S+0.1)}$

where:

P = estimated safe capacity of pile (Kips)
W_d = weight of drop hammer (Kips)
W_r = weight of ram of steam or pneumatic hammer (Kips)
h = average height of fall of drop hammer for last 6 blows (ft)
H = stroke of ram (ft)
S = average pile penetration in *inches* per *blow* for last 6 blows of a drop hammer or last 20 blows of steam or pneumatic hammer
E = work energy in ft/kip of hammer

(5) Determine the number of piles (N_{Pr}) required.

$$*N_{Pr}=\frac{P_T}{\text{allowable capacity/pile}}$$

Allowable capacity/pile is the smaller of the values found in steps 3 and 4.

(6) Calculate $\frac{*S_P}{D_P}\quad\frac{W_R\times 12}{(N_{Pr}-1)D_P}$ $\left(\frac{S_P}{D_P}\text{ must equal or exceed 3}\right)$

(Nate subparagraph *i* belaw.)

(7) Using the pile chart (fig. 7–25a) determine N_P for a single pile bent (minimum $N_P = 4$).

(8) Check the c–c spacing between piles.

*max $Sp = 5d_{cap}$. (If cap is nat knawn it must be designed, (see *f* below).)

$$*\text{min } Sp = 3D_P$$

$$*\text{actual } Sp = \frac{W_R \times 12}{N_P - 1}$$

If spacing requirements are nat met using a single bent, a pier is required. Use (b) figure 7–25 to determine the actual number af piles required per bent far the pier. See f belaw far carbel and camman cap design.

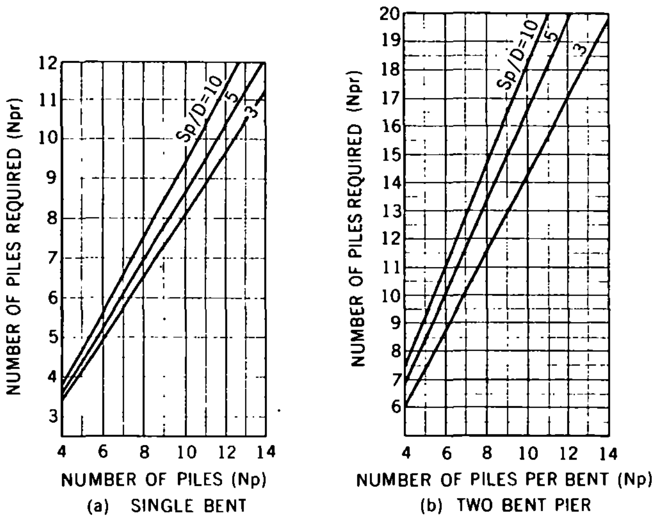


Figure 7–25. Pile charts.

e. *Example* (2). *Substructure Design With a Pile Bent.* Design a substructure for class 60 bridge, $L_1 = 20$ feet, $L_2 = 30$ feet, $H = 15$ feet, 12-inch x 12-inch cap, $D_P = 10$ inches, $H = 10$ feet, $W_d = 2$ kips, penetration for last 6 blows = 6 inches, $W_R = 24$ feet, 7 steel stringers, 6-inch timber deck, $N_L = 2$ lanes.

(1) $Hp = 15' < 22'$; $\therefore$ OK, No midpoint bracing required

(2) $V_{DL} = V_{DL1} + V_{DL2} = 18.75 + 11\ 00 = 29.75$ kips
$L_e = L_1 + L_2 = 20 + 30 = 50'$
$V_{LL} = 103$ kips
$P_T = V_{LL}(N) + V_{DL} = 103(2) + 29.75 = 235.75$ kips

(3) Capacity per pile = 40 kips

(4) $P = \dfrac{2W_d h}{S+1} = \dfrac{(2)(2)(10)}{\frac{6}{6}+1} = 20$ kips

$\therefore$ Allowable capacity per pile = 20 kips (lower of steps 3 and 4)

(5) $N_{pr} = \dfrac{P_T}{\text{allowable capacity per pile}} = \dfrac{235.75}{20} = 11.79$

(6) $\dfrac{S_p}{D_p} = \dfrac{W_R \times 12}{(N_{pr} - 1)D_p} = \dfrac{24 \times 12}{10.79(10)} = 2.67$

(7) Spacing requires $\dfrac{S_p}{D_p} > 3.0$ to enter figure 7–25.

(8) As spacing requirements are not met try a pier.

$$\frac{S_p}{D_p} = \frac{W_R \times 12}{(N_{pr} - 1)D_p} = \frac{24 \times 12}{\left(\frac{11.79}{2} - 1\right)10} = 5.9$$

N_p/bent = 7 +, say 8/bent for a two bent pier.

$$\text{Actual spacing} = \frac{W_R \times 12}{(N_p/\text{bent} - 1)} = \frac{24 \times 12}{8-1} = 41''$$

Max sp = $5(d_{cap}) = 5(12) = 60''$

Min sp = $3(D_p) = 3(10) = 30''$ $\therefore$OK

(9) See *f* below for cap and corbel design.

f. Cap and Corbel Design.

(1) Determine the effective corbel length, L_c.

(a) $L_c >$ c − c spacing

(b) $L_c > (1/6)\ (H_p)$

(c) ∴ Select convenient length greoter than (o) and (b) above.

(2) Moment design.

(a) Determine M_c. $M_c = \frac{P_T L_c}{4}$

(b) Determine m_c ($m_c = m$) from table 7−2 or 7−3.

(c) Determine N_c. $N_c = \frac{M_c}{m_c}$.

(3) Shear design.

(a) Determine V_c. $V_c = \frac{P_T}{2}$.

(b) Determine v_c. $v_c = (v_c = v)$ from table 7−2 or 7−3.

(c) Determine N_c. $N_c = \frac{V_c}{v_c}$.

Note: The higher of steps (2) and (3) above determines N_c. Minimum N_c = lesser number of piles or stringers.

(4) Determine corbel spacing, Sp.

$$*Sp = \frac{W_R \times 12}{N_c - 1}.$$

(5) Common cap design.

(a) Determine d_{cap}. $d_{cap} = \frac{Sp}{5}$

(b) Determine b_{cap}. $b_{cap} = \frac{2P_T}{N_c b_c}$

g. Example (3). Corbel and Common Cap Design. Design a 12-inch × 12-inch corbel and common cap using the information given in example (2) (e above).

(1)

(a) $L_c > 41'' = 3.42'$ (See example 2, e above)

(b) $L_c > 1/6\ (H_p) = (1/6)(15) = 2.5'$

(c) Select L_c a convenient length, say $L_c = 4.0'$ ($> 3.42'$, $> 2.5'$)

(2)

(a) $M_c = \frac{P_T L_c}{4} = \frac{(235.75)(4.0)}{4} = 235.8$ kip ft

(b) $m_c = 57.6$ kip ft

(c) $N_c = \frac{M_c}{m_c} = \frac{235.8}{57.6} = 4.1$, say 5 corbels

(3)

(a) $V_c = \frac{P_T}{2} = \frac{235.8}{2} = 117.9$ kips

(b) $v_c = 14.4$ kips

(c) $N_c = \frac{V_c}{v_c} = \frac{117.9}{14.4} = 8.2$, say 9 corbels

∴ use 9 ea 12″ × 12″ corbels

(4) $Sp = \frac{W_R \times 12}{N_c - 1} = \frac{14 \times 12}{9 - 1} = 21''$

(5)

(a) min $d_{cap} = \frac{Sp}{5} = \frac{21}{5} = 4.2''$

(b) min $b_{cap} = \frac{2P_T}{N_c b_c} = \frac{(2)235.75}{(7)(12)} = 5.2''$

Absolute min = 6″ × 8″ ∴ 12″ × 12″ OK for common cap.

h. Abutments. Figures 7–26 through 7–28 show sketches of abutment types that are normally used for temporary or semipermanent bridges. A guide to the selection of abutments is given in table 7–7.

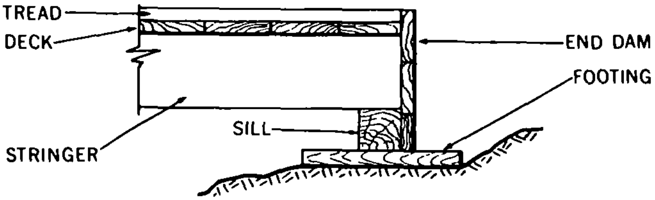


Figure 7–26. Timber sill abutment.

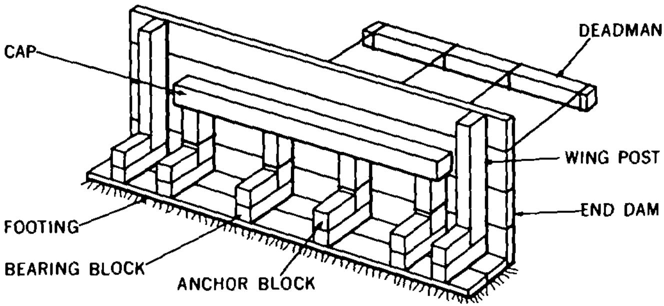


Figure 7–27. Timber bent abutment.

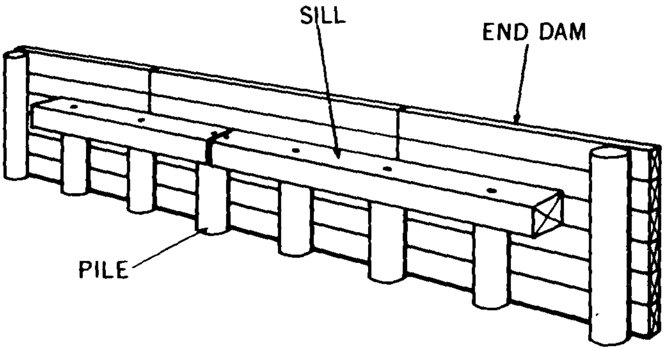


Figure 7–28. Timber pile abutment.

Table 7–7. Abutment Selection Guide

Type	Span	Height	Remarks
Timber sill	To 25′	To 3′	Highway bridges only. Designed for vertical loads only and steel or timber stringers. Use par C for design.
Timber bent	To 30′	To 6′	Highway bridges only. Designed for vertical loads. Deadman used for horizontal stability. Used with steel or timber stringers Use Par C for design. See TM 5–312 for deadman design.
Timber or steel pile	Any length	To 10′	Designed for vertical and longitudinal loads and steel or timber stringers. Use par E for design.

i. *General Notes*. The following guidelines are generally applicable in the design of substructures as discussed in this paragraph and illustrated in the above examples.

(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.

(2) *Caps and sills*. With round timber, diameter at least 2 inches greater than that of post. Hew timber to fit at top and joints. With rectangular timber, at least same size timber as posts with larger dimensions vertical; 6″ × 8″ is absolute 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. Minimum size bracing is 2″ × 10″.

(4) *Round off rule*. The round off rule, noted in step 1, o above, is used for the entire rapid field design except where noted with an asterisk, *.

(5) To obtain the most economical bridge design for a given size stringer, use the procedures outlined in a or b above and repeat the procedure increasing or decreasing N_s by 1 until the most economical design is obtained, or increase N_s by:

$$N_s \frac{m \text{ required}}{m \text{ available}}$$

(6) For pier design use N_{PR} per row $\left(\frac{N_{PR}}{2}\right)$ to calculate $\frac{S_P}{D_P}$.

Section III. Panel Bridge, Bailey Type, M2

7-7. INTRODUCTION

a. The panel bridge, Bailey type, M2 (fig. 7—29) 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 eight 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 capability of the above vehicles to carry 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. For more detailed information see TM 5—277.

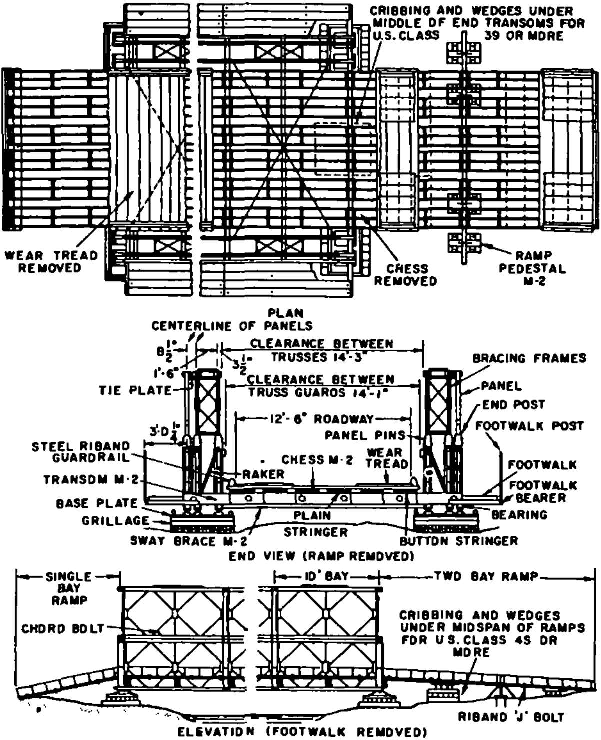


Figure 7–29. Steel panel fixed bridge, Bailey type, M2.

7–8. CONSTRUCTION DATA

a. Organization of assembly crews is given in table 7–8.

Table 7–8. Organization of Assembly Crews

	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 7–9. Types of Grillage Needed[1]

Construction	Safe soil pressure (tons per sq ft)	30′	40′	50′	60′	70′	80′	90′	100′	110′	120′	130′	140′	150′	160′	170′	180′	190′	200′	210′
SS	0.5	5,7,8	5,6,7,8	5,6,7,8	4	4	4	4	4											
	1.0	4	3	3	1	1	1	1	1											
	2.0	1	(2)	(2)	(2)	(2)	1	1	1											
	2.5	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)											
	3.5	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)											
OS	0.5			7	7	7,8	5,7,8	5,7,8	5,7,8	5,7,8	5,7,8	5,7,8	5,7,8							
	1.0			5,7,8	6,7,8	4	4	4	4	4	4	4	4							
	2.0			4	3	1	1	1	1	1	1	1	1							
	2.5			1	1	1	1	1	1	1	1	1	1							
	3.5			1	(2)	(2)	(2)	(2)	(2)	1	1	1	1							
TS	0.5						7	7	7,8	5,7,8	5,7,8	5,7,8	7	7,8	5,7,8					
	1.0						5,7,8	6,7,8	4	4	4	4	4	4	4					
	2.0						4	3	1	1	1	1	2	1	1					
	2.5						3	1	1	1	1	1	1	1	1					
	3.5						1	1	1	1	1	1	1	1	1					
OO	0.5								7	7	7	7	7	7	7	7	7			
	1.0								7,8	6,7,8	6,7,8	4	4,5,7,8	4,7,8	4,5,7,8	4,7,8	4,5,7,8			
	2.0								4	4	3	2	2	4,5,7,8	2	4,5,7,8	2			
	2.5								3	1	1	1	1	2	1	2	1			
	3.5								1	1	1	1	1	1	1	1	1			
TO	0.5									7	7	7	7	7	7	7	7	7		
	1.0									7,8	7,8	7,8	7,8	7,8	7,8	7,8	7,8	7,8		
	2.0									4,7,8	4,5,7,8	4,5,7	4,7,8	4,7,8	4,7,8	4,7,8	4,7,8	4,7,8		
	2.5									4,5,7,8	3	2	2	2	2	2	2	2		
	3.5									1	1	1	2	2	2	2	2	2		

Table 7–9. Types of Grillage Needed[1] — Continued

Construction	Safe soil pressure (tons per sq. ft.)	30′	40′	50′	60′	70′	80′	90′	100′	110′	120′	130′	140′	150′	160′	170′	180′	190′	200′	210′
OT	0.5											7		7	7	7	7	7	7	7
	1.0											7,8	7,8	7,8	7,8	7,8	7,8	7,8	7,8	7,8
	2.0											7,8	4,7,8	4,7,8	7,8	7,8	7,8	4,7,8	4,7,8	4,7,8
	2.5											5,7,8	4,5,7,8	4,5,7,8	7,8	7,8	7,8	4,5,7,8	4,5,7,8	4,5,7,8
	3.5											2	2	2	2	2	2	2	2	2
TT	0.5															7	7	7	7	7
	1.0															7,8	7,8	7,8	7,8	7,8
	2.0															7,8	7,8	7,8	7,8	4,7,8
	2.5															7,8	7,8	5,7,8	5,7,8	4,5,7,8
	3.5															5,7,8	5,7,8	2	2	2

[1] See figures 7–30 and 7–31

b. Grillage requirements are shown in table 7–9 and figures 7–30 through 7–31. Grillage shown in figure 7–30 is built from the panel bridge set.

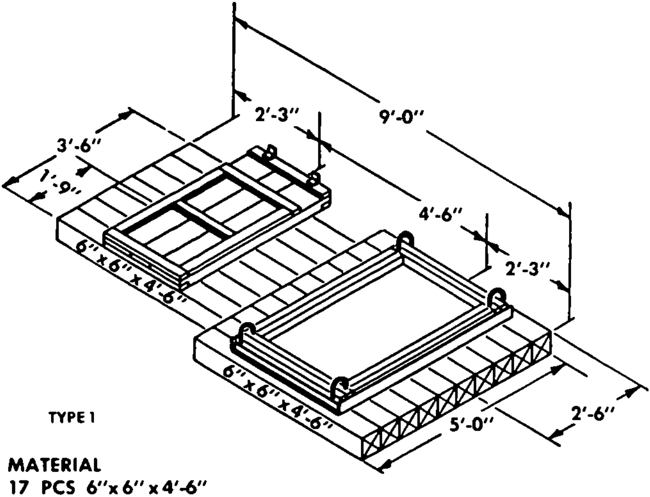
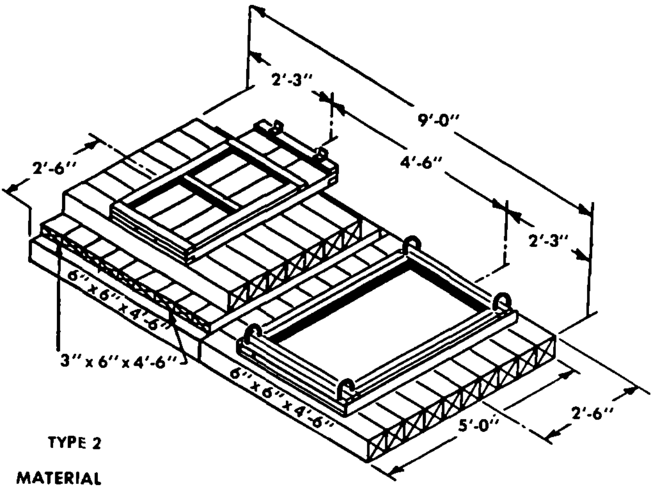


Figure 7–30. Grillage built from panel bridge set.



TYPE 2

MATERIAL
27 PCS 6" x 6" x 4'-6"
9 PCS 3" x 6" x 4'-6"

Figure 7–30—Continued.

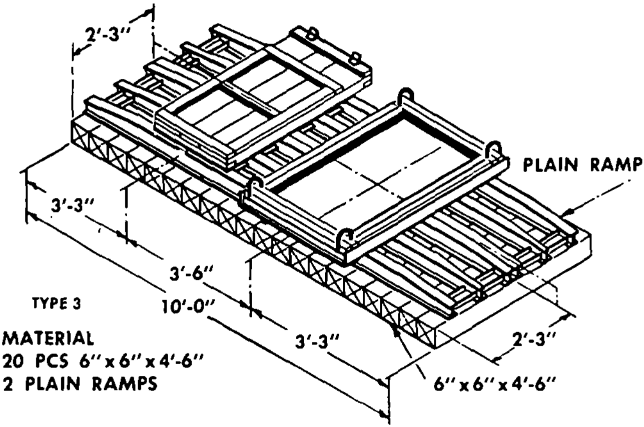


Figure 7—30—Continued.

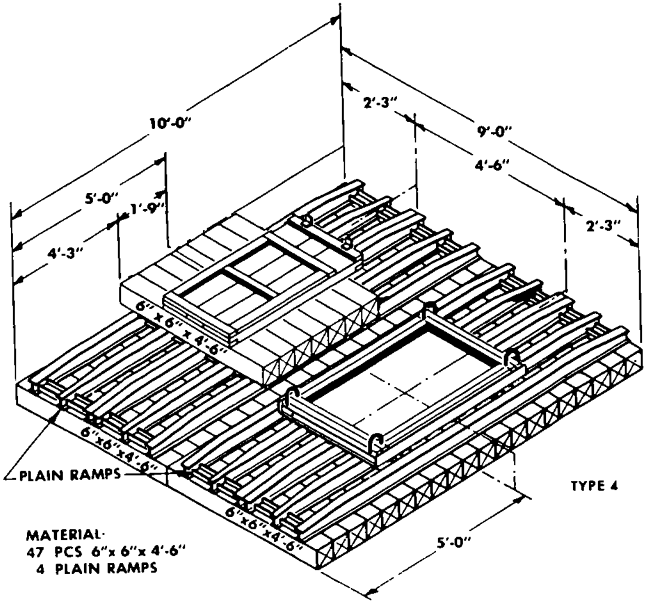


Figure 7–30—Continued.

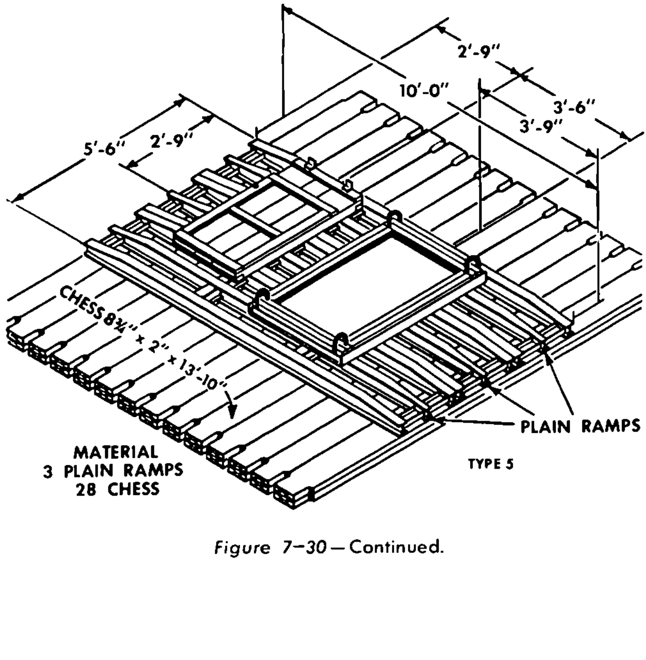


Figure 7–30—Continued.

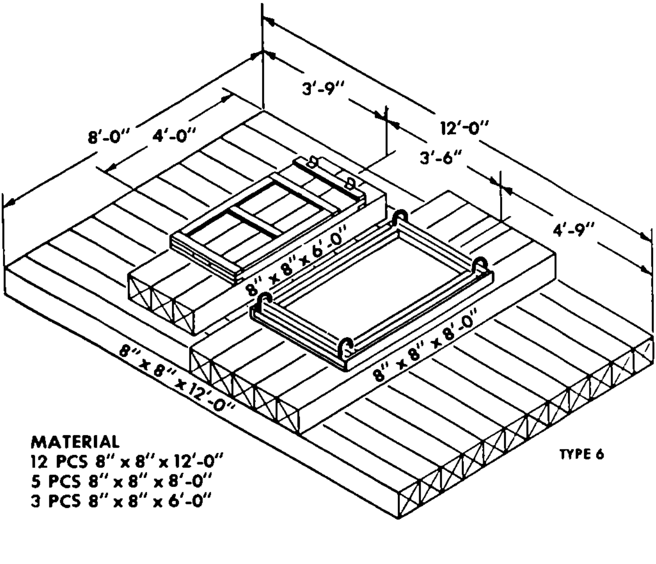


Figure 7–31. Grillage not supplied in panel bridge set.

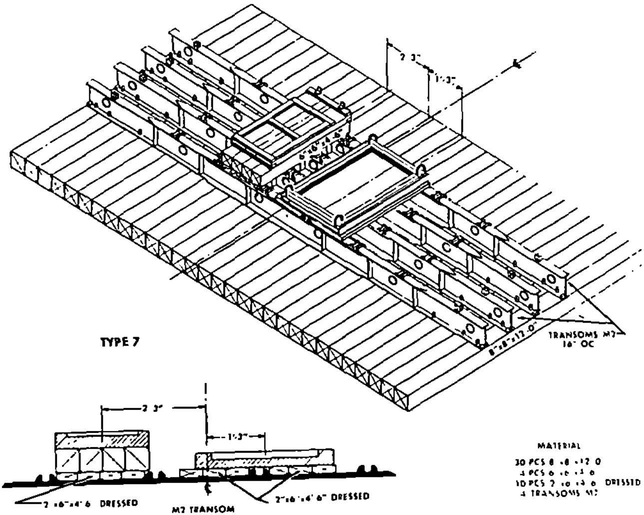


Figure 7–31 — Continued.

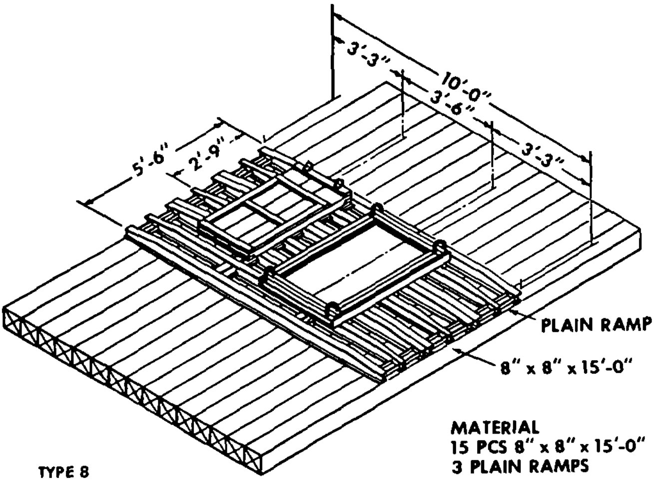


Figure 7-31 — Continued.

c. Figures 7–32 through 7–43 show bridge layout equipment and a typical bridge site layout for training purposes.

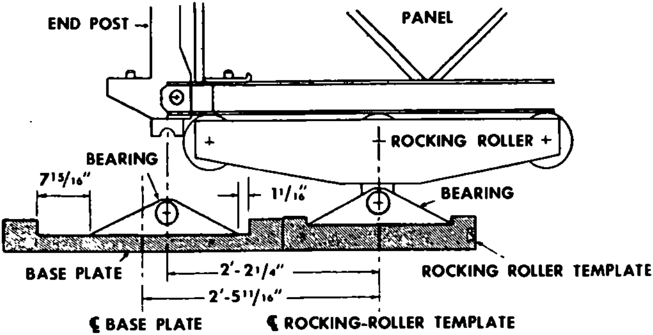


Figure 7–32. Rocking rollers and base plate at the end of the bridge.

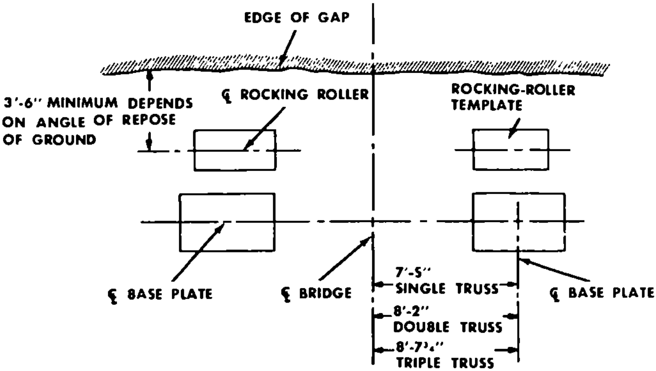


Figure 7–33. Lateral spacing of base plates.

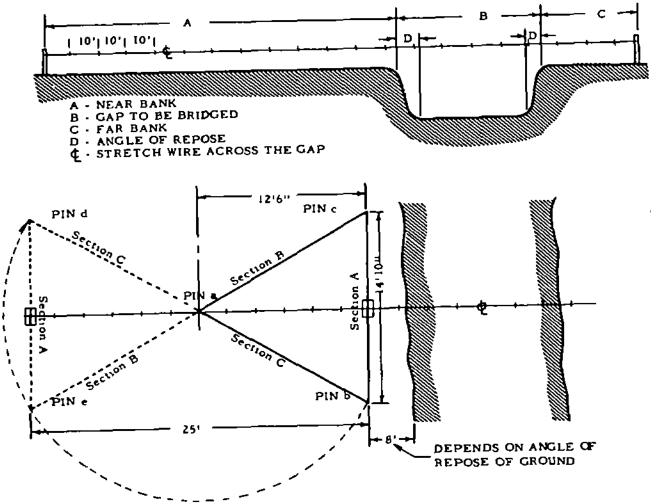


Figure 7–34. *Site layout template.*

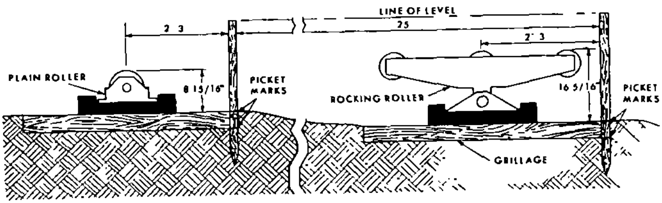


Figure 7–35. *Leveling for placement of grillage bearing templates, and rollers.*

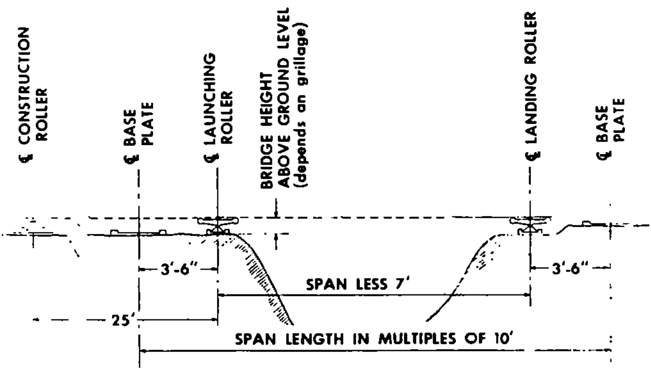


Figure 7—36. Sketch af proposed loyout of o panel bridge.

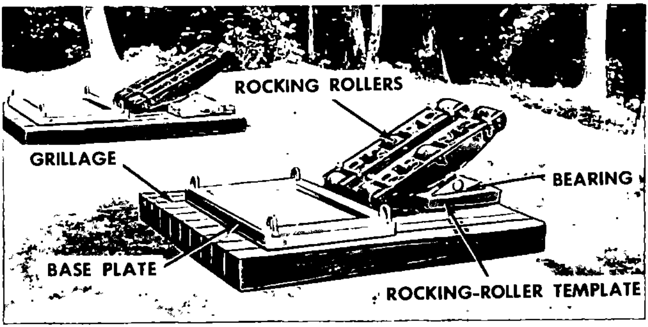


Figure 7—37. Base plote ond racking rollers in position on grilloge before launching bridge.

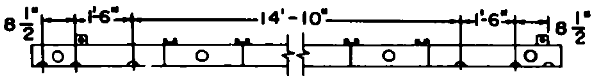


Figure 7–38. Transam used as template.

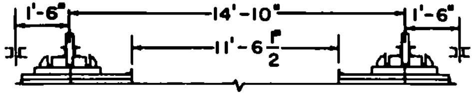


Figure 7–39. Plain roller, SS, DS bridges.

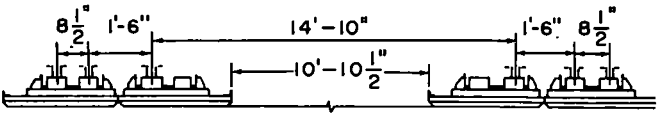


Figure 7–40. Plain roller, TS, DD, TD, DT, TT bridges.

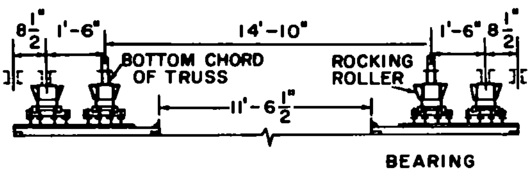


Figure 7–41. Layout of rocking roller template.

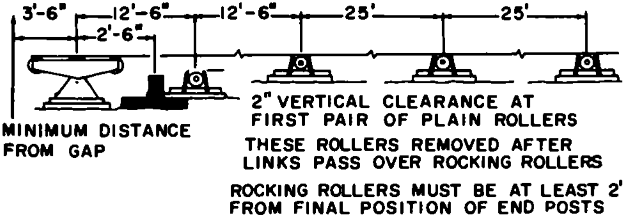


Figure 7–42. Vertical clearance necessary for removing first pair of near shore plain rollers after links pass rocking rollers.

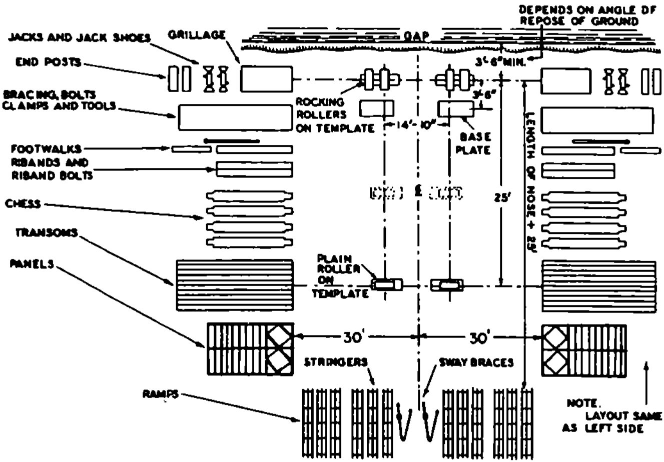


Figure 7–43. Layout of equipment at bridge site for training purposes.

d. Other pertinent data pertaining to transportation, launching and construction of the bridge is contained in tables 7–10 through 7–15.

Table 7–10. Bridge Lounching Construction

Bridges Type	Span ft.	No. of bays in nose SS	DS	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

Bridges Type	Span ft.	No. of bays in nose SS	DS	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 7–11. Bridge Spans Lounched Incomplete

Typo	Span, ft.	No. of bays, docking & 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 initiol con-struction *
TT	160	3	14
	170	6	14
	180	6	14
	190	All	15
	200	All	14
	210	All	13

* First throo bridgo bays ore constructod DT with only ono tronsom por bay. Lost bridgo bay is constructed DT becouso of stoggored construction necessary when adding subsequent boys.

Table 7–12. Number of Jacks Needed at Each End of 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 7–13. Number of Rocking Rollers Needed for Bridge

Type	Span, ft.	Near bank	Far bank
SS	30 - 100	2	*
DS	50 - 80	2	*
	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 7–14. Weight per Bay of 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.

Table 7–15. Critical Dimensions of 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"

7–9. CLASSIFICATION

Table 7–16 provides classification data for the panel bridge.

Table 7–16. Dual Classification by Type of Construction and Type of Crossing

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	38/35	75/70	83/86	88/84															
60	20	30/29	33/32	65/65	77/73	85/79															
70	20	24	30/30	60/60	60/69	78/75															
80	16	20	24	50/55	60/60	66/64	85/80	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	64/68	80/80	88/90	98/60									
110				20	30/32	34/36	35/40	47/49	52/54	65/70	72/76	80/83	90/90*	100*/90*	100*/90*						
120				18	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	53/58	55/60	65/72	74/80	70/80	80/90*	90/90*			
140				8	14	17	18	24	29/31	30/35	39/42	44/48	45/55	57/62	64/70	70/70	80/90*	88/90*			
150							12	18	22	24	32/35	38/40	35/45	47/51	54/58	60/60	77/85	85/90*			
160							8	15	17	18	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	38/40	45/50	57/64	64/74	70/70	80/90*	90/90*
180										8	15	18	16	24	29/32	35/45	48/53	55/60	55/60	68/75	77/87
190													12	18	22	30/35	39/43	46/51	45/55	58/68	68/77
200																20	32/38	38/43	35/40	48/52	55/62
210																16	25	31/35	24	38/43	46/51

Notes. 1. N = Normal, C = Caution, R = Risk.

*2. Limited by Roadway Width

3 Upper figure represents wheel load class.
Lower figure represents tracked load class *Example:* 46/51

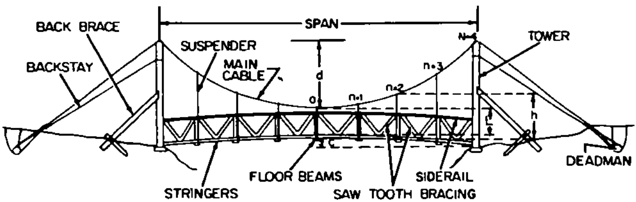
4 Bridges which have a normal rating over class 70 must be constructed with double transoms.

5. Single classification is designated below class 30.

Section IV. Miscellaneous Bridging

7–10. LIGHT SUSPENSION BRIDGE DESIGN

The suspension bridge (fig. 7–44) is used for long spans high above abstacles. The flaar system is suspended fram cables, which are supported on towers and anchored to abutments.



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 7–44. Light suspensian bridge.

a. Design Data. See table 7–17 and figure 7–43.

Table 7–17. Light-Suspension Bridge Design Data

Item	Data		
Panel length	10 to 15 ft.		
Camber	Approximately 2 ft.		
Stringer design	See paragraph 7–5a		
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 12–2 for cable strength.		
Length of suspenders	$h = L + \left(\frac{n}{N}\right)^2 (C + d)$ See figure 7–44 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. Example-Main Cable Design. Determine tension in main cables for a 200-foot-span suspension bridge with a suspended weight of 10 tons. Assume a 10-percent sag ratio and a 4-ton line load.

	Pounds
Suspended weight	20,000
Line load	8,000
Impact	8,000
Total	36,000

Maximum total tension in main cables for a 10-percent sag ratio = 36,000 × 1.35 = 48,600 pounds. If two main cables are used, each must have a tensile strength of 24,300 pounds.

7–11. THREE-ROPE BRIDGE

The three-rope bridge is used to carry personnel with full field pack, maximum of 7 men at 5-pace interval. Maximum length is 150 feet. Construction procedures follow:

a. Construct stringers or support for tread rope and hand ropes on near and far shore.

b. Lay out tread rope and hand ropes parallel and one pace apart on near shore. Minimum diameters = 1″ for tread ropes and $\frac{3}{4}$″ 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 ($\frac{1}{2}$ 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.

7–12. 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 7–11) 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.

7-13. EXPEDIENT LOG BRIDGES

Figure 7-45 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.

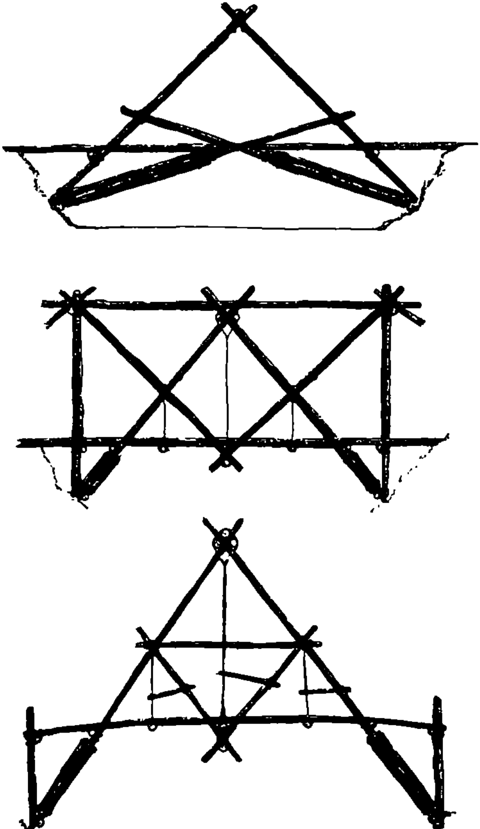


Figure 7–45. Expedient wooden bridges.

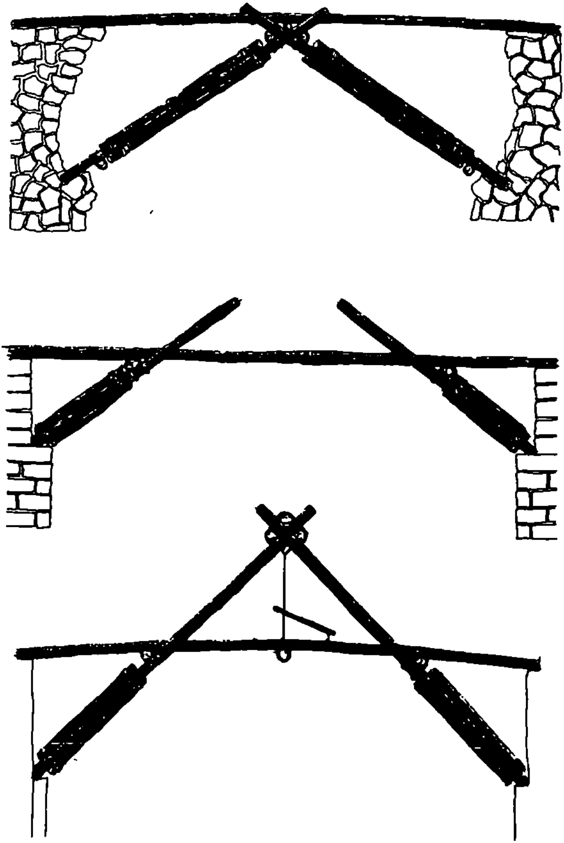


Figure 7–45—Continued.

CHAPTER 8

CONCRETE CONSTRUCTION

8–1. EXCAVATION

Initial excavation should be done with any available equipment, however, final excavation should be done by hand, to the prescribed depths. If too much material is excavated, place the concrete to the depth actually excavated. Do not refill excavations to the specified depth before placing the concrete because it is too difficult to compact the fill surface properly. When making time estimates for excavations, refer to chapter 13 for equipment production rates and table 8–1 for hand excavation production rate.

Table 8–1. Earth excavation by hand

Type of material	Cubic yards 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

8-2. FORMING

a. Elements of wooden forms for a concrete wall or slab are shown in figure 8-1.

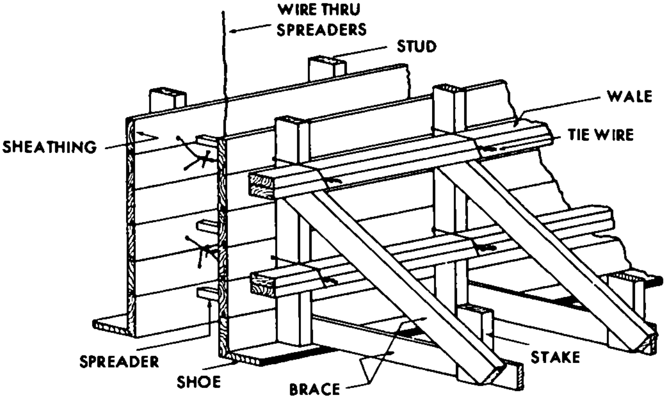


Figure 8-1. Form for a concrete wall.

(1) *Sheathing.* Sheathing forms the surfaces of the concrete. It should be as smooth as possible, especially if the finished surfaces are to be exposed. Since the concrete is in a plastic state when placed in the form, the sheathing should be watertight. Tongue and groove sheathing gives a smooth watertight surface. Plywood or masonite can also be used.

(2) *Studs.* The weight of the plastic concrete will cause the sheathing bulge if it is not reinforced. Studs are run vertically to add rigidity to the wall form. Studs are generally made from 2 x 4 or 3 x 6 material.

(3) *Wales (Walers).* Studs also require reinforcing when they extend over 4 or 5 feet. This reinforcing is supplied by double wales. Double 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. Joints normally should be staggered to minimize weaknesses in form construction. Wales usually are the same material as the studs.

(4) *Braces.* There are many types of braces which can be used to give the forms stability. The most common type is a diagonal member and horizontal member nailed to a stake and to a stud or wale. The diagonal member should make a 30° angle with the horizontal member. Additional bracing may be added to the form by placing vertical members behind the wales (strongbacks) or by placing vertical members in the corner formed by intersecting wales. Braces are not part of the form design and are not considered as providing any additional strength.

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

(6) *Spreaders.* In order to maintain proper distance between forms, small pieces of wood are cut to the same length as the thickness of the wall and are placed between the forms. These are called spreaders. The spreaders must be removed before the concrete hardens. A wire should be securely attached to the spreaders so that they can be pulled out after the concrete has exerted enough pressure to the walls to allow them to be easily removed.

(7) *Tie wires.* Tie wire is a tensile unit designed to hold the concrete forms secure against the lateral pressure of unhardened concrete. A double strand of tie wire is always used.

b. Elements of wooden forms for concrete columns are shown in figure 8–2.

(1) *Sheathing.* In column forms, sheathing runs vertically to save on the number of sawcuts required. The corner joints should be firmly nailed to insure watertightness.

(2) *Batten.* Batten are narrow strips of boards (cleats) that are placed directly over the sawcuts to fasten the several pieces of vertical sheathing together.

(3) *Yokes.* The horizontal dimensions on a column are small enough so that bracing is not required in the vertical plane. A rectangular horizontal brace known as a yoke is used. The yoke wraps around the column and keeps the concrete from distorting the form. The yoke can be locked by the sheathing, scab, or bolt type yoke lock.

c. Elements of steel paving forms are shown in figure 8–3.

(1) The steel forms are made in 10-foot lengths and vary in height from 8 to 12 inches.

(2) Anchoring pins of proper length (18-inch pin for 8-inch form to 30-inch pin for 12-inch form) are inserted in the three holes and are held in place by the locking wedges.

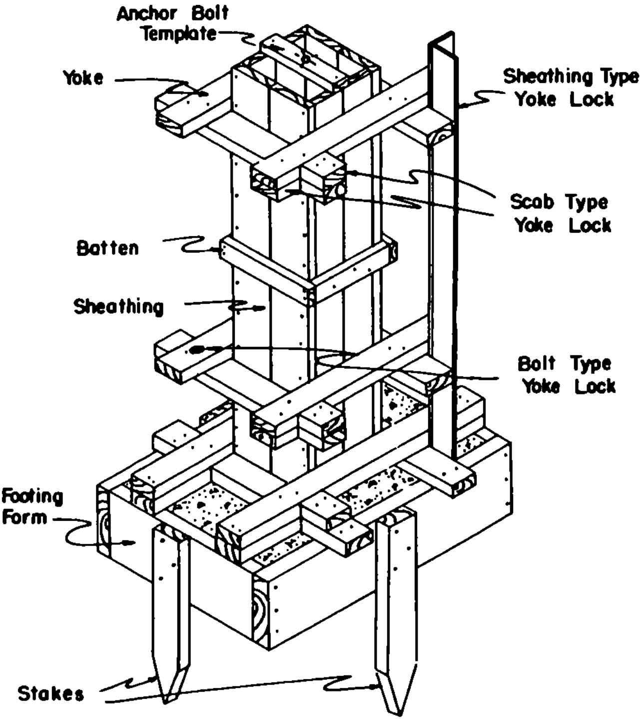


Figure 8–2. Form for a concrete column.

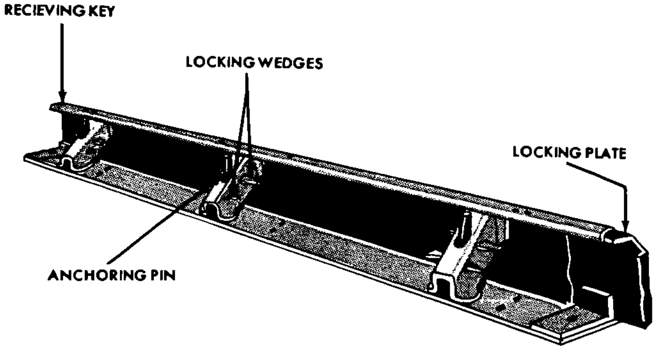


Figure 8–3. Steel paving form.

(3) Steel forms have sliding lock plates at one end to fit under the flanges of adjacent forms to insure positive alinement at the joints. They should slide easily into locking position.

d. The rate of construction for wooden forms is 10 square feet per hour. Steel paving forms can be set by 4-man teams at the rate of approximately 50 linear feet per hour.

8–3. FORM DESIGN

a. Wooden forms for a concrete wall should be designed by the following steps:

(1) Determine the materials available for sheathing, studs, wales, braces, shoe plates and tie wires.

(2) Determine the mixer output by dividing the mixer yield by the batch time. Batch time includes loading all ingredients, mixing, and unloading. If more than one mixer will be used, multiply mixer output by the number of mixers.

$$\text{Mixer output (cu ft/hr)} = \frac{\text{Mixer yield (cu ft)}}{\text{Batch time (min)}} \times \frac{60 \text{ min}}{\text{hr}}$$

(3) Determine the area that is enclosed by the forms.

$$\text{Plan area (sq ft)} = L \times W$$

(4) Detemine the rate of placing the concrete in the form by dividing the mixer output by the plan area.

$$\text{Rate of placing (ft/hr)} = \frac{\text{Mixer output (cu ft/hr)}}{\text{Plan area (sq ft)}}$$

(5) Make a reasonable estimate of the placing temperature of the concrete.

(6) Determine the maximum concrete pressure by entering the bottom of figure 8–4 with the rate of placing. Draw a line vertically up until it intersects the correct concrete temperature curve. Read horizontally across from the point of intersection to the left side of the graph and determine the maximum concrete pressure.

(7) Determine the maximum stud spacing by entering the bottom of figure 8–5 with the maximum concrete pressure. Draw a line vertically up until it intersects the correct sheathing curve. Read horizontally across from the point of intersection to the left side of the graph. If the stud spacing is not an even number of inches, round the value of the stud spacing down to the next lower even number of inches. For example, a stud spacing of 17.5 inches would be rounded down to 16 inches.

(8) Determine uniform load on a stud by multiplying the maximum concrete pressure by the stud spacing.

Uniform load on stud (lb/lineal ft)

$$= \text{Maximum concrete pressure (lb/sq ft)} \times \text{stud spacing (ft)}$$

(9) Determine the maximum wale spacing by entering the bottom of figure 8–6 with the uniform load on a stud. Draw a line vertically up until it intersects the correct stud size curve. Read horizontally across from the point of intersection to the left side of the graph. If the wale spacing is not an even number of inches, round the value of the wale spacing down to the next lower even number of inches. Double wales (two similar members) are used in every case as shown in figure 8–6.

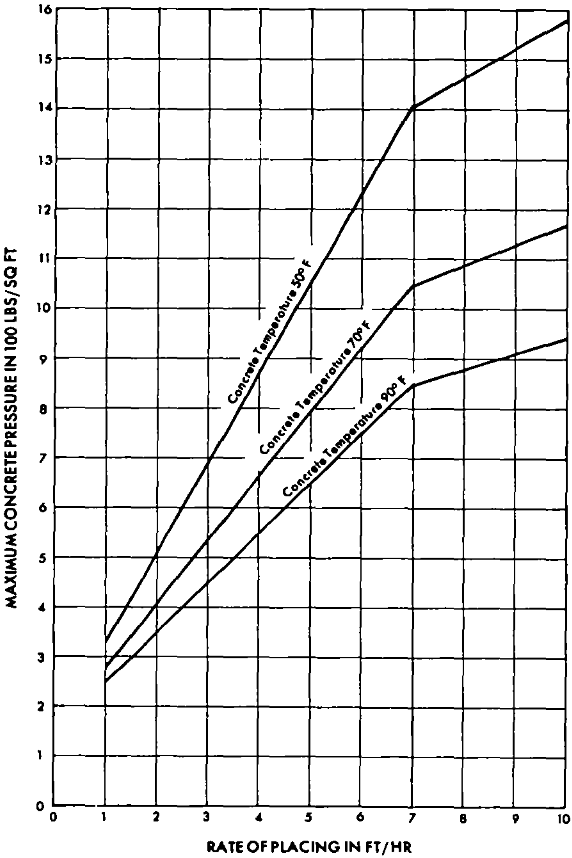
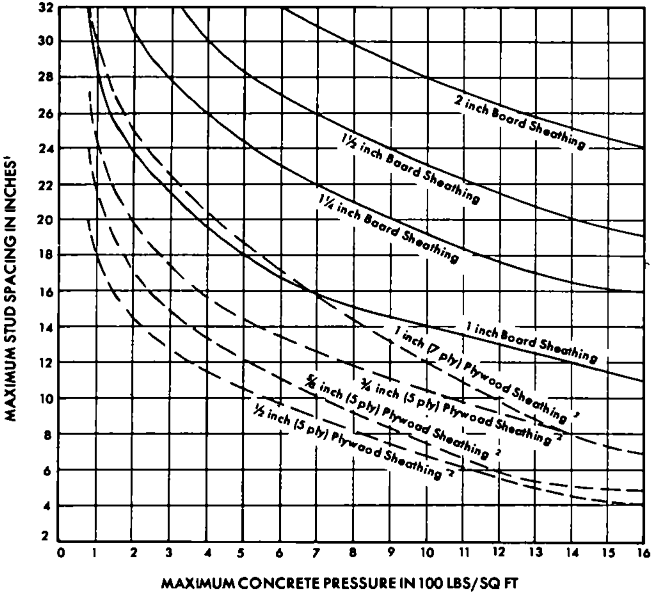


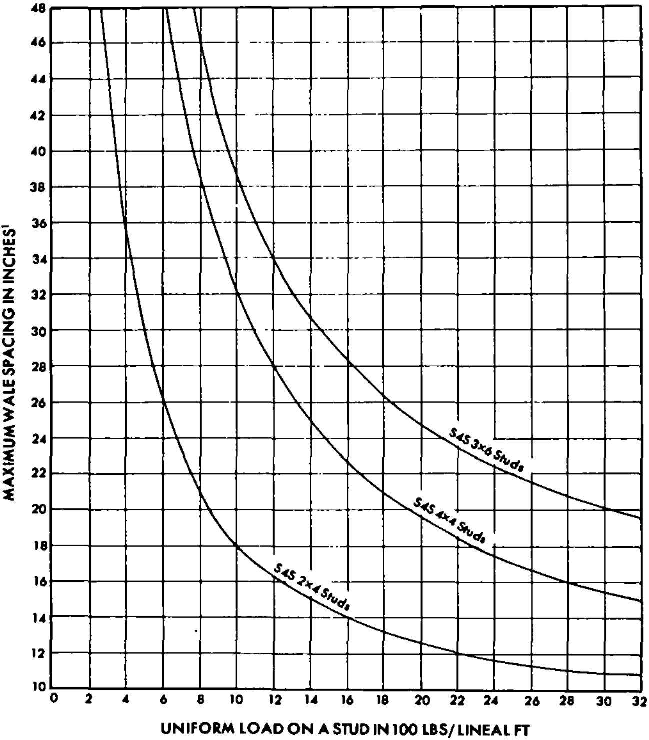
Figure 8–4. Maximum concrete pressure graph.



[1] MAXIMUM ALLOWABLE STUD SPACING = 32 INCHES

[2] SANDED FACE GRAIN PARALLEL TO SPAN

Figure 8–5. Maximum stud spacing graph.



¹ MAXIMUM ALLOWABLE WALE SPACING = 48 INCHES

Figure 8–6. Maximum wale spacing graph.

(10) Determine the uniform load on a wale by multiplying the maximum concrete pressure by the wale spacing.

Uniform load on wale (lb/lineal ft)

$$= \text{Maximum concrete pressure (lb/sq ft)} \times \text{wale spacing (ft)}$$

(11) Determine the tie wire spacing, based on the wale size, by entering the bottom of figure 8–7 with the uniform load on a wale. Draw a line vertically up until it intersects the correct double wale size curve. Read horizontally across from the point of intersection to the left side of the graph. If the tie spacing is not an even number of inches, round the value of the tie spacing down to the next lower even number of inches.

(12) Determine the tie wire spacing based on the tie wire strength by dividing the tie wire strength by the uniform load on a wale. If the tie wire spacing is not an even number of inches, round the computed value of the tie spacing down to the next lower even number of inches. If possible, use a tie wire size that will provide a tie spacing equal to or greater than the stud spacing. Always use a double strand of wire. If the strength of the available tie wire is unknown, the minimum breaking load for a double strand of wire (found in the Army supply system) is given in table 8–2.

$$\text{Tie wire spacing (in)} = \frac{\text{Tie wire strength (lbs)} \times \text{(12 in/ft)}}{\text{Uniform load on wale (lb/ft)}}$$

(13) Determine the maximum tie spacing by selecting the smaller of the tie spacings based on the wale size and on the tie wire strength.

(14) Compare the maximum tie spacing with the maximum stud spacing. If the maximum tie spacing is less than the maximum stud spacing, reduce maximum stud spacing to equal to the maximum tie spacing and tie at the intersections of the studs and wales. If the maximum tie spacing is greater than the maximum stud spacing, tie at the intersections of the studs and wales.

(15) Determine the number of studs for one side of a form by dividing the form length by the stud spacing. Add one (1) to this number and round up to the next integer. During form construction, place studs at the spacing determined above. The spacing between the last two studs may be less than the maximum allowable spacing

$$\text{No. of studs} = \frac{\text{Length of form (ft)} \times 12 \text{ (in/ft)}}{\text{Stud spacing (in)}} + 1$$

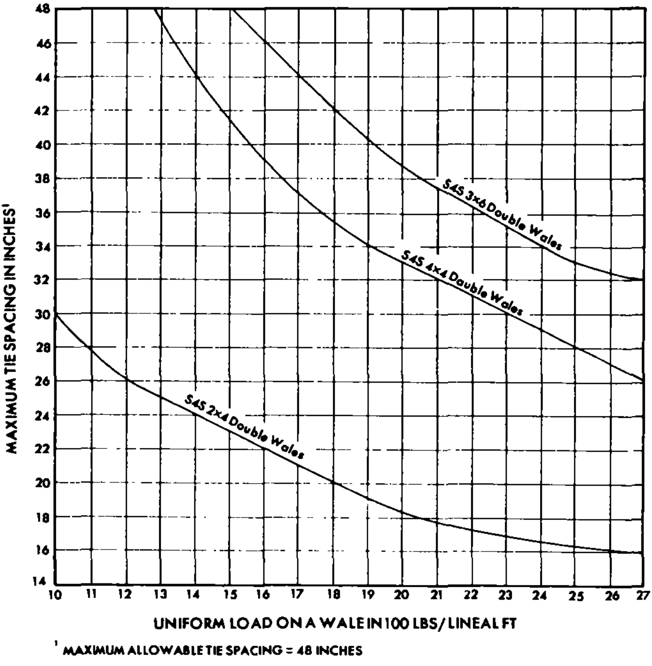


Figure 8–7. Moximum tie wire spocing.

(16) Determine the number of wales for one side of the form by dividing the form height by the wale spacing and round up to the next integer. Ploce first wale one-holf up from the bottom and the remainder at the maximum wole spacing.

Table 8–2. Breaking Load of Wire

STEEL WIRE

Size of wire gage No	Minimum breaking load double strand pounds
8	1700
9	1420
10	1170
11	930

BARBED WIRE

Size of each wire gage No.	Minimum breaking load pounds
12½	950
13[1]	660
13½	950
14	650
15½	850

[1] Single strand barbed wire

(17) Determine the time required to place the concrete by dividing the height of the form by the rate of placing.

b. Example Form Design Problem: Design the forms for a concrete wall 40 feet long, 2 feet thick, and 10 feet high. A 16S Mixer is available and the crew can produce a batch (16 cu ft) of concrete every 5 minutes. The concrete temperature is estimated to be 70° F. Material available for use in constructing forms, includes 2 × 4's and one-inch board sheathing.

Solution Steps:

(1) Material available: 2 × 4's, one inch sheathing and No. 9 wire.

(2) $\text{Mixer output} = \frac{16 \text{ cu ft}}{5 \text{ min}} \times \frac{60 \text{ min}}{\text{hr}} = 192 \text{ cu ft/hr}$

(3) Plan area of forms = 40 ft × 2 ft = 80 sq ft

(4) Rate of placing $= \frac{192 \text{ cu ft/hr}}{80 \text{ sq ft}} = 2.4$ ft/hr

(5) Temperature of concrete: 70°F

(6) Maximum concrete pressure (fig. 8–4) = 460 lb/sq ft

(7) Maximum stud spacing (fig. 8–5) = $18^{\times}$ use 18 inches

(8) Uniform load on studs $= 460 \text{ lb/sq ft} \times \frac{18 \text{ in}}{12 \text{ in/ft}} = 690$ lb/ft

(9) Maximum wale spacing (fig. 8–6) = 23^{+} use 22 inches

(10) Uniform load on wales $= 460 \text{ lb/sq ft} \times \frac{22 \text{ in}}{12 \text{ in/ft}} = 843$ lb/ft

(11) Tie wire spacing based on wale size (fig. 8–7) = > 30″

(12) Tie wire spacing based on wire strength

$$= \frac{1420 \text{ lb} \times 12 \text{ in/ft}}{843 \text{ lb/ft}} = 20^{+} \text{ use 20 inches}$$

(13) Maximum tie spacing = 20 inches

(14) Maximum tie spacing is greater than moximum stud spacing, therefare, reduce the tie spacing to 18 inches and tie at the intersection of each stud and double wale.

(15) Number of studs per side $= \left(40 \text{ ft} \times \frac{12 \text{ in/ft}}{18 \text{ in}}\right) + 1$

$$= 26.7 + 1, \text{ use 28 studs}$$

(16) Number of double wales per side $= 10 \text{ ft} \times \frac{12 \text{ in/ft}}{22 \text{ in}}$

$$= 5^{+} \text{ use 6 double wales}$$

(17) Time required to place concrete $= \frac{10 \text{ ft}}{2.4 \text{ ft/hr}} = 4.17$ hrs.

c. Wooden forms for a concrete column should be designed by the following steps:

(1) Determine the materials available for sheathing, yokes, and battens. Standard materials for column forms are 2 × 4's and 1-inch sheathing.

(2) Determine the height of the column.

(3) Determine the largest cross-sectional dimension of column.

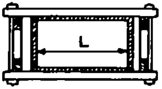
(4) Determine the yoke spacings by entering table 8–3 and reading down the first column until the correct height of column is reached. Then reod horizontally across the page to the column heoded by the

Table 8–3. Column Yoke Spacing
(based on use of 2 × 4's and 1-inch sheathing)

LARGEST DIMENSION OF COLUMN IN INCHES–'L'

Column height: 1' 2' 3' 4' 5' 6' 7' 8' 9' 10' 11' 12' 13' 14' 15' 16' 17' 18' 19' 20'

	16"	18"	20"	24"	28"	30"	32"	36"
Yoke 1	31"	29"	27"	23"	21"	20"	19"	17"
Yoke 2	31"	28"	26"	23"	21"	20"	19"	17"
Yoke 3	30"	28"	26"	23"	20"	19"	18"	17"
Yoke 4	29"	26"	24"	22"	18"	18"	17"	15"
Yoke 5	21"	20"	19"	16"	15"	18"	13"	12"
Yoke 6	20"	18"	16"	14"	13"	12"	12"	11"
Yoke 7	18"	16"	15"	13"	12"	12"	10"	10"
Yoke 8	15"	15"	14"	12"	10"	10"	10"	8"
Yoke 9	14"	13"	12"	11"	9"	9"	8"	8"
Yoke 10	13"	12"	11"	10"	9"	8"	8"	7"
Yoke 11	13"	12"	11"	9"	9"	8"	8"	7"
Yoke 12	12"	11"	10"	9"	8"	8"	7"	7"
Yoke 13		11"	10"	9"	8"	7"	7"	6"
Yoke 14			10"	8"	8"	7"	7"	6"
Yoke 15			9"	8"	7"	7"	6"	6"
Yoke 16				8"	6"	7"	6"	6"
Yoke 17						6"		



largest cross-sectional dimension. The center-to-center spacing of the second yoke above the base yoke will be equal to the value in the lowest interval that is partly contained in the column height line. All subsequent yoke spacings may be obtained by reading up this column to the top. This procedure gives maximum yoke spacings. Yokes may be placed closer together, if desired.

d. *Example Problem:* Determine the yoke spacings for a 9-foot column whose largest cross-sectional dimension is 36 inches. 2 × 4's and 1-inch sheathing are available.

Solution Steps:

(1) Material available—2 × 4's and 1-inch sheathing

(2) Height of column is 9 feet

(3) Largest cross-sectional dimension of the column is 36 inches.

(4) Maximum yoke spacing for column (table 8–3) starting from the bottom of form are 8", 8", 10", 11", 12", 13", 17, 17" and 10". The space between the top two yokes has been reduced because of the limits of the column height.

8–4. IMPORTANT CONSIDERATIONS IN MIXING GOOD CONCRETE

a. *Sand and Aggregate.* Assuming that the proper cement is available, the first item of importance for a concrete job is the availability of suitable sand and coarse aggregate. Use sound, clean sand and coarse aggregate. The sand should be free of clay and silt and the aggregate should be hard and strong. The amount of sand and coarse aggregate required for each batch should be carefully measured by weight or volume.

b. Water. The major factor that affects the strength of a concrete mix is the water-cement ratio. The type, gradation, cleanliness, and shape of the aggregate particles definitely affect the strength, but not to the extent that the water-cement ratio does. Water for mixing concrete should be free of foreign matter such as silt, organic materials, alkali, and sulphates. The amount of water required should be carefully measured.

8–5. TYPES OF CEMENT

a. *Normal Portland Cement (Type I).* Normal portland cement is used for all general types of construction. It is used in pavement and sidewalk construction, reinforced concrete buildings and bridges, railways, structures, tanks, and reservoirs, sewers, culverts, waterpipes, masonry units and soil cement mixtures.

b. Modified Portland Cement (Type II). Modified portland cement has a lower heat of hydration than Type I, generates heat at a slower rate and has improved resistance to sulfate attack. It is intended for use in structures of considerable size where cement of moderate heat of hydration will tend to minimize temperature rise, as in large piers, heavy abutments, heavy retaining walls and when the concrete is placed in warm weather.

c. *High-Early Portland Cement (Type III).* High-early portland cement is used where high strengths are desired at very early periods. It is used where it is desired to remove forms as soon as possible, to put the concrete in service as quickly as possible and in cold weather construction to reduce the period of protection against low temperatures.

d. Low-Heat Portland Cement (Type IV). Low-heat portland cement is to be used when the amount and rate of heat generated must be kept to a minimum. It is intended for use only in large masses of concrete such as large dams where temperature rise resulting from the heat generated during hardening is a critical factor.

e. *Sulfate-Resistant Portland Cement (Type V).* Sulfate-resistant portland cement is intended for use only in structures exposed to severe sulfate attack.

f. Air-Entrained Portland Cement (Type IA, IIA or IIIA). Air-entrained portland cement is a special cement that can be used with good results to resist severe frost action, to resist the effect of applications of salt to pavements for snow and ice removal, and to reduce the amount of water loss.

8–6. ESTIMATING QUANTITY OF STORED AGGREGATE

a. Aggregate is often stored in cone-shaped or tent-shaped piles. A good formula to estimate the volume of aggregate in a cone-shaped pile is: volume = 0.2618 × height × diameter squared. The volume of a tent-shaped pile is: volume = 0.2618 × height × diameter squared + .5 × height × diameter × length of the linear section. The weight of the stored aggregate is determined by multiplying the volume by the unit weight of aggregate. A good estimate of the unit weight of aggregate is 100 lbs/cu ft.

b. Figure 8–8 provides a graphical method of determining the weight of aggregate in a pile. The capacity of the pile has been related to the width of the base of the pile. The base width can be obtained by measuring the pile with a tape or, approximately, by pacing.

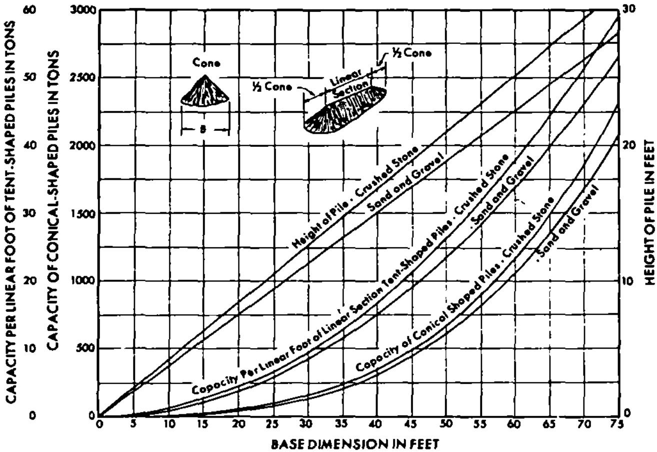


Figure 8–8. Storage capacity curves.

(1) The capacity of a conical-shaped pile is determined from the bottom pair of curves. Enter the bottom of the graph with the base dimension and draw a line vertically up until it intersects the correct moterial curve. Read horizontally across from the point of intersection to the capacity in the vertical column on the inside left. For example, o conical-shoped stockpile of crushed stone 60 feet wide at the base hos a capacity of 1200 tons.

(2) Determining the capacity of o tent-shaped pile requires two steps. Note that the two ends of a tent-shaped pile are equivolent to one conical pile ond their capacity can be determined in the manner described above. The capacity per linear foot of the middle section is determined from the middle pair of curves. Enter the bottom of the groph with the bose dimension and drow a line vertically up until it intersects the correct material curve. Read horizontolly across from the point of intersection to the capacity per linear foot in the vertical column on the outside left. Multiplying the capacity per linear foot times the length of the middle section in feet gives the copacity of the middle section. Adding the middle section capacity to the copacity of the ends gives

the totol capacity. For exomple, the middle section of o tent-shoped stockpile of gravel 40 feet wide hos o copacity of 15 tons per linear foot. If the middle section were 50 feet long, the capacity of the middle section would be 50 ft × 15 tons/ft = 750 tons. The copacity of the two end sections is 300 tons, therefore the totol copocity is 750 tons + 300 tons = 1050 tons of gravel.

(3) The top pair of curves con be used to determine the height of the pile. Enter the bottom of the curve with the bose dimension ond drow a line vertically up until it intersects the correct moterial curve. Reod horizontally across to the right from the point of intersection to the height of the pile.

8–7. CONCRETE MIX DESIGN (TRIAL BATCH METHOD)

o. 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 ovoilable, the procedures given in this manual will be satisfoctory. For lorge projects, a mixer should be used for mixing trial batches. For small projects, mixing by hand will suffice. The method given here is for trial mixing done by hond.

b. Construct a measuring box which has the inside dimensions of 6 inches × 6 inches × 6 inches. This will give a container that will hold 0.125 ($\frac{1}{8}$) cubic foot of materiol.

c. The amount of water that is to be added to the cement to produce the required strength concrete must be determined. It con be expressed in terms of gallons per sock of cement, or in terms of weight of water per sock of cement. Table 8–4 gives the quantities of water for concrete of given strengths for Type I non-air-entrained ond oir-entroined cement. A 15 percent sofety foctor should be added to the desired strength when selecting the amount of water. Where strength and economy are important, tests for strength should be made with materials to be used on the job.

d. The slump required for the type of construction can be obtained by referring to toble 8–5. Be sure to pick one particular slump instead of a range.

e. Using the measuring box, measure out one box of cement, two boxes of sond, ond three boxes of gravel. (Aggregote should have no surface moisture.) Place on a surfoce which will not absorb moisture. Mix the cement, sand and gravel until evenly mixed. Ploce the mixture in a mound and form o depression in the middle.

Table 8—4. Relations Between Mixing Water and Compressive Strength of Concrete

Normal Portland Cement (Type I)—Non-Air-Entrained

Water-gal per sack of cement	Probable Average Strength*, psi	
	7-day strength	28-day strength
4	4,300	6,200
5	3,400	5,200
6	2,700	4,300
7	2,100	3,500
8	1,500	2,900

Normal Portland Cement (Type IA)—Air-Entrained

Water-gal per sack of cement	Probable Average Strength*, psi	
	7-day strength	28-day strength
5.5	2,200	3,700
6.0	1,800	3,300
6.5	1,500	2,900
7.0	1,200	2,500

*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 3,220 psi should be selected.

*Table 8–5. Recommended Slumps for Various Types of Construction**

Type of construction	Slump (inches)	
	Maximum	*Minimum*
Reinforced foundation walls and footings	4	2
Unreinforced footings, caissons, and substructure walls	3	1
Reinforced slabs, beams, and walls	5	2
Building columns	5	3
Pavements	2	1
Heavy mass construction	2	1
Bridge decks	3	2
Sidewalk, driveway, and slabs on ground	4	2

*When high-frequency vibrators are not used, the values may be increased by about 50 percent, but in no case should the slump exceed 6 inches.

f. Measure out ⅛ 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 the cement-water paste.

g. Test the slump of the mixture and compare it against what is required. The procedure for determining the slump of concrete is as follows:

(1) Obtain or construct slump cone as shown in figure 8–9.

(2) 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.

(3) Completely fill the cone in three layers, each layer consisting of approximately ⅓ of the volume of the cone. As each layer is placed, it must be rodded 25 times with a ⅝-inch, bullet-pointed, tamping rod. 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.

(4) When the cone is full, strike off any excess concrete.

(5) Carefully remove the cone and place next to the concrete. Measure the slump of the concrete as shown in figure 8–9. To be an acceptable mixture, the measured slump should be within ½-inch of the recommended slump.

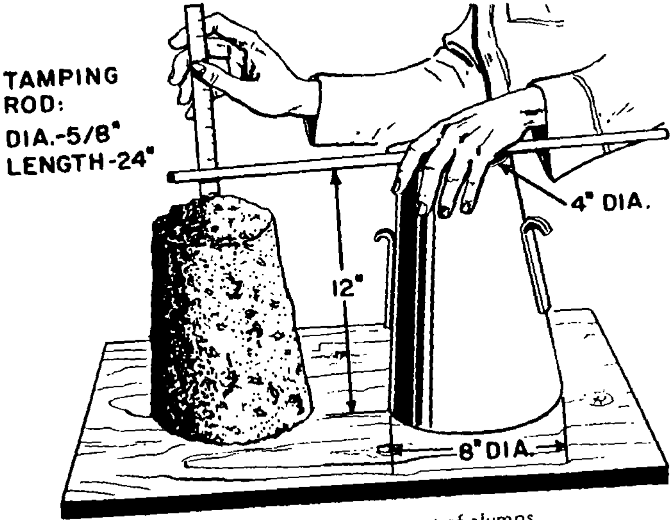


Figure 8–9. Measurement of slumps.

h. If slump is more than required, repeat the trial mix using more sand-gravel. If slump is less than what is desired, repeat the trial mix using less sand-gravel. Caution: Never increase water content to increase the 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 sack of cement and the determined amount of water.

j. Example problem: Place non air-entrained concrete which will have a 7-day strength of 3,500 psi for a footing.

Solution:

1. Add 15 percent to the strength for a safety factor
   3,500 × 1.15 = 4,025
2. Amount of water (table 8–4): 4 gallons
3. Required slump (table 8–5): 3 inches

4. 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
   Water $= 4$ gal

8-8. ESTIMATING AMOUNT OF MATERIALS REQUIRED

a. After the mix proportions have been determined, the amount of each material for the job must be determined.

(1) Determine the volume of concrete needed in cubic feet.

(2) Multiply volume of concrete needed by $\frac{3}{2}$ This gives the total amount of dry loose material needed.

(3) Determine the volumetric proportion of cement, sand and gravel. This can be done by the trial batch method or if necessary by assuming a 1–2–3 mix.

(4) Determine the total volume of each material needed by summing the desired proportion of each decided on in (3) above (i.e., 1–2–3 = 6)

(5) Determine the amount of cement, sand and gravel needed by multiplying the volume of dry material needed ((2) above) by the proportional amount of the total mix (cement $= \frac{1}{6} \times$ total volume).

(6) Add loss factor due to handling by using rule of thumb: 10% loss for job up to 200 cubic yards of concrete needed and .5% loss for jobs 200 cubic yards and over. Round off to nearest whole number. (Note: 1 sack (bag) cement = 1 cu ft)

(7) Determine amount of water by using rule of thumb: 8 gal of water per sack of cement. This allows extra water for waste, cleanup and curing.

b. *Example Problem:* 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.

(1) Volume: 10 ft $\times$ 3 ft $\times$ 1 ft $= 30$ cu ft

(2) Dry loose materials required: 30 cu ft $\times \frac{3}{2} = 45$ cu ft

(3) Mix proportion: 1–2–3 = 6

(4) Amount of each material required
   Cement $= 45$ cu ft $\times \frac{1}{6} = 7.5$ cu ft $= 7.5$ bags
   Sand $= 45$ cu ft $\times \frac{2}{6} = 15$ cu ft
   Gravel $= 45$ cu ft $\times \frac{3}{6} = 22.5$ cu ft

(5) Amount of concrete is less than 200 cubic yards, therefore apply 10% loss factor:
Cement = 1.10 × 7.5 bags = 8.25 say 9 bags
Sand = 1.10 × 15 cu ft = 16.5 say 17 cu ft
Gravel = 1.10 × 22.5 cu ft = 24.75 say 25 cu ft

(6) Amount of water: $8 \frac{\text{gal}}{\text{bag}} \times 9$ bags = 72 gal

8–9. BATCHING

a. Once a design mix has been determined the project site must be laid out and organized to facilitate quality control of the batch (charge) which will go into the mixer. A recommended layout is to place the cement, sand, gravel and water as close to the skip (load bucket) of the mixer as possible.

b. When the batch is being placed in the skip, the 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 inside dimensions of 1 foot × 1 foot × 1 foot and measuring all sand and gravel 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 in 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.

c. The actual mixing time will depend on the method of discharge and size of batch. If discharge is directly into the form, the mixing time should be at least one minute for any mix. For a batch exceeding one cubic yard the mixing time is increased 15 seconds for each additional ½ cubic yard or part thereof. If the concrete is discharged into small containers, the mixing time will be longer due to the additional time required to empty the mixer drum.

8–10. CONCRETE PLACING

a. All forms should be oiled before concrete is placed. This is to aid in removing forms after the concrete has hardened.

b. Concrete should not be allowed to free fall into forms at heights greater than 3 to 5 feet unless suitable drop chutes, baffles or vertical pipes are provided.

c. 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 the differential concentration of the components of mixed concrete, resulting in nonuniform proportions in the mass.

8–11. CURING AND PROTECTING CONCRETE

a. The loss of moisture must be prevented during hydration. Keep the exposed surface moist by spraying or ponding water, or by covering the concrete with earth, sand, or burlap maintained in a moist condition.

b. Spray-on curing compounds are available. Spray on the compound in one coat. Do not use the compounds if the air temperature is above 100° F and the air is dry.

c. Do not let fresh concrete drop below 40° F in temperature.

8–12. MIXER CLEANING

Cleaning of the mixer should be performed after every use. To clean a mixer, all cement paste should be washed off the outside of the mixer. The inside of the drum should be cleaned. This can be done by placing water and small stones in the drum and allowing the mixer to rotate to clean and flush out all concrete from the drum. After cleaning, a light coat of oil on the outside of the mixer will prevent concrete from sticking to the mixer during the next operation.

CHAPTER 9

MILITARY ROAD CONSTRUCTION

9–1. MINIMUM DESIGN REQUIREMENTS

Table 9–1 gives a summary of military road specifications.

Table 9–1. 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 — 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%
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 (40m) for each 4% algebraic difference in grades
Sight distance:	
Nonpassing..............	Absolute minimum — 200 ft (60 m)
Passing....................	Absolute minimum — 350 ft (110m)

Toble 9-1.—Continued

Choracteristic	Specification
Laad copacity:	
Raad praper	Sustain 18,000 lb Single axle, dual wheel equivalent laad
Bridges	Accammodate using troffic
Slapes:	
Shaulders	$\frac{3}{4}$ in per ft ta $1\frac{1}{2}$ in per ft
Crawn (gravel and dirt).	$\frac{1}{2}$ to $\frac{3}{4}$ in per ft
Crown (poved)	$\frac{1}{4}$ ta $\frac{1}{2}$ in per ft
Superelevatian	$\frac{1}{4}$ ta $1\frac{1}{4}$ in per ft
Cut	Variable
Fill	Variable
Drainage	Adequate crown or superelevatian with adequate ditches and culverts in goad candition. Toke full advantage af natural droinage. Try to lacate raod at least 5 ft above the graund-water table
Miscellaneaus:	
Overhead clearance	Min—14 ft (4.3 m)
Traffic volume	2,000 vehicles per day
Turnouts (single lane)	Min—every $\frac{1}{4}$ mile

9-2. CROSS-SECTIONS

Figures 9-1 through 9-5 give typical military road specifications.

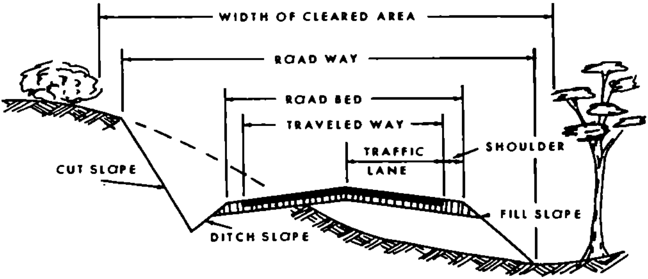


Figure 9-1. Typical cross-sections illustrating road nomenclature.

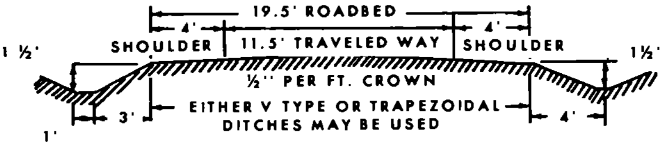


Figure 9-2. One way earth road.

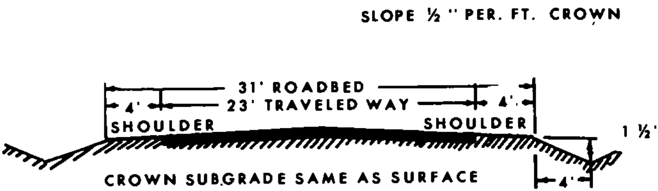


Figure 9-3. Two-woy road using single course construction.

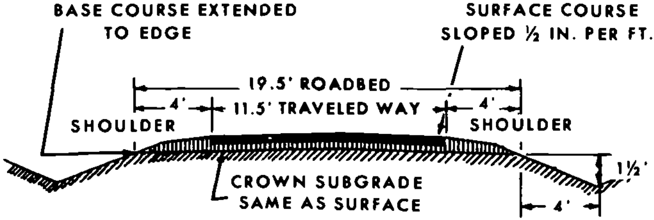


Figure 9–4. One-way road using double course construction.

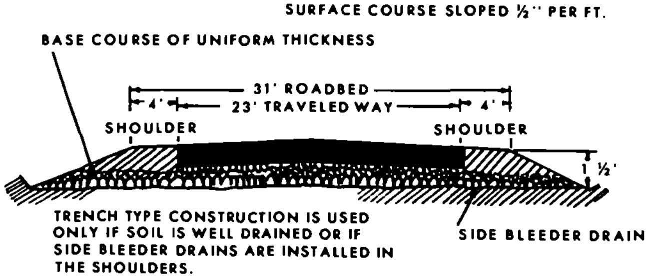


Figure 9–5. Two-way road using double course construction.

9–3. CONSTRUCTION STAKES
(fig. 9–6)

a. *Centerline Stakes.*

(1) *General.* Centerline or alinement stakes are placed on the centerline of a road or airfield to indicate its alinement, location, and direction. These stakes are the first stakes to be placed and are usually placed at 100-foot intervals. On rough ground or on sharp horizontal and vertical curves, the stakes are placed closer together.

(2) *Placement and marking.*

(a) *Placement.* Stakes are placed with the broad portion of the stake perpendicular to the centerline. The side of the stake which faces the starting point (station 0+00) is called the front of the stake.

(b) *Marking.* The front of the stake is marked with a ℄ which means centerline, and the station number or the distance from the starting point. As an example 78+00 means 7800 feet from the starting point. On the reverse side, or back side of the stake, is placed the amount of cut or fill, in feet, required at this station.

b. Shoulder Stakes.

(1) *General.* Shoulder stakes are set on the inside edge of the shoulder and are used as guides for the operator to determine the width of the road.

(2) *Placement and marking.*

(a) *Placement.* These stakes are set at right angles to the centerline opposite each centerline stake.

(b) *Marking.* Markings can be the same as those for rough grade stakes or the stake can be simply a plain, unmarked piece of wood that marks the inside edge of the shoulder.

c. Slope Stakes.

(1) *General.* Slope stakes define the limits of grading work. Usually the area to be cleared extends 6 feet beyond the slope stakes.

(2) *Placing and marking.*

(a) *Placing.* Slope stakes are set on lines perpendicular to the centerline (one on 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-foot intervals on tangents and at 50-foot intervals on horizontal or vertical curves.

(b) *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.

d. Offset Stakes.

(1) *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.

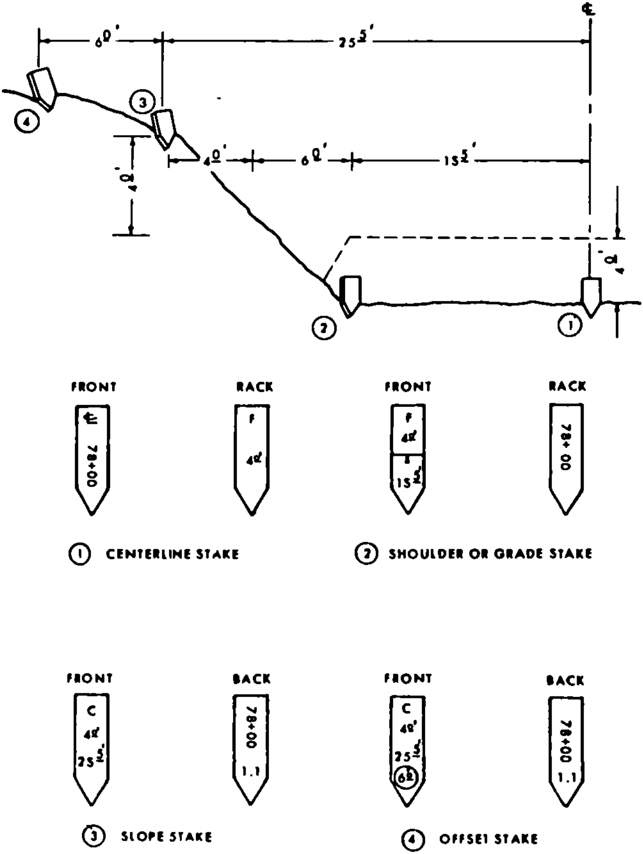


Figure 9–6. Construction stake marking.

(2) *Marking*. The affset stake will cantain all the informatian found an the original slape stake plus the horizantal distance fram the ariginol slope stake ta the affset stake. This distonce is marked an the front of the stake and is circled ta indicate that it is an affset distance.

e. *Grade Stakes.*

(1) *Rough grade stokes.*

(a) *General.* Raugh grade stakes are ploced on centerlines, shoulder lines, ar slape lines after grading has begun. These stakes are placed to shaw the operatar the amount of cut or fill remaining and are nat cansidered a permanent reference.

(b) *Placement and marking.* The raugh grade stake is placed at either a paint of cut ar a paint af fill ta shaw haw much eorth is left befare final grade is abtained. The frant of the stake (the side af the stake facing the centerline) is marked with the letter F ar C indicating fill or cut, a reference line with a "craw's faat" and the distance fram the stake ta the centerline. To eliminate canfusian, the surveyar wha put in the grade stakes shauld explain haw he used the reference line faund an the stake. Same surveyors use this line as final grode and athers use this line os o reference line (to measure the amaunt of fill or cut fram the back af the stake cantaining the stotian number).

(2) *Final grade stakes.*

(a) *Generol.* Narmally these are 2 × 2-inch waoden stakes driven inta the graund until the tap af the stake is at a level ta represent final elevation.

(b) *Plocement and marking.* These stakes are placed wherever it is felt a reference ta final grade should be made such as an centerline statians. There are no markings an these stakes ather thon the blue ar red tops. The setting af the stake could represent the exact finish grade ar a certain standord distonce abave exact grade.

9–4. SOILS

a. *Procedure far Field Identificatian Tests* (fig. 9–7).

(1) *Separate gravel.*

(a) Remove fram sample all particles larger thon $\frac{1}{8}$" diameter.

(b) Estimate percent gravel.

(2) *Sedimentatian test.*

(a) Place sample (less gravel) in conteen cup ond fill with water.

(b) Shake mixture rigarausly.

(c) Allaw mixture ta stand far 30 secands ta settle out.

(*d*) Pour off water after 30 seconds of settlement and save.
(e) Repeat (*b*) through (*d*) obove until water poured off is clear.
(*f*) Evaporate water from (*d*) above.
(g) Estimate percent fines.

(3) *Comparison of gravel ond sand.*
(a) Gravels have been removed in test (1), ((*b*) above).
(*b*) Fines hove been removed in test (2), ((e) above).
(c) Dry soil remaining in cup.
(*d*) Soil remaining in cup will be sand.
(e) Compare dry sond in cup with gravel from test (1), ((*b*) above).

(4) *Dry strength.**
(*a*) Form moist pat 2″ in diameter by ½″ thick.
(*b*) Allow to dry with low heat.
(c) Place dry pat between thumb and index finger only and attempt to break.
(*d*) Breakage easy—silt.
Breakage difficult—CL.
Breakage impossible—CH.

(5) *Powder test.**
(a) Rub portion of broken pat with thumb and attempt to flake particles off.
(*b*) Pat powders—silt (M).
Pat does not powder—clay (C).

(6) *Thread test.**
(a) Form ball of moist soil (marble size).
(*b*) Attempt to roll ball into ⅛″ diameter thread (wooden match size).
(c) Threod eosily obtained—clay (C).
Threod cannot be obtained—silt (M).

(7) *Ribbon test.**
(a) Farm cylinder of soil approximately cigar shape in size.
(*b*) Flatten cylinder over index finger with thumb; attempting to form ribbon 8″–9″ long, ⅛″ to ¼″ thick, ond 1″ wide.
(c) 8″ to 9″ ribbon obtained—CH.
Less than 8″ ribbon—CL.

(8) *Wet shaking test.**
(a) Place pat of moist (not sticky) soil in palm of hand (vol about ½ cu in.).
(*b*) Shoke hand vigorously and strike against other hand.

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*Tests indicated by an asterisk (*) are conducted on material smaller than 1/32″ diameter

(c) Observe ropidity af water rising ta the surface.

(*d*) If fast, sample is silty (M).

If na reaction, sample is clayey (C).

(9) *Grit, ar bite test.**

(a) Place pinch of sample between teeth ond bite.

(*b*) If sample feels gritty, sample is silt (M)

(c) If sample feels floury, sample is clay (C)

(10) *Feel test.**

(*a*) Rub partion of dry sail aver a sensitive portion af skin, such as inside of wrist.

(*b*) If feel is harsh and irritating, sample is silt (M).

(c) If feel is smaoth and flaury, sample is clay (C).

(11) *Shine test.**

(*a*) Draw smaath surface, such as knife blade ar thumb nail, aver pat af slightly maist sail.

(*b*) If surface becames shiny and lighter in texture, sample is a high campressible clay (CH).

(c) If surface remains dull, sample is a low campressible clay (CL).

(12) *Odar* test.*

(*a*) Heat sample with match ar apen flame.

(*b*) If adar becames musty ar foul smelling, there is a strang indicatian that arganic material is present.

(13) Cast test.

(*a*) Campress a handful af maist sail inta a ball.

(*b*) Crumbles with hondling—GW, SW, GP ar SP.

(c) Withstands careful handling—SM ar SC.

(*d*) Handled freely—ML or MH.

(*e*) Withstands raugh handling—CL or CH.

(14) *Slaking test.*

(*a*) Place sail ar rack in sun to dry.

(*b*) Saak in water far 24 haurs.

(c) Repeot (a) and (*b*) abave several times.

(*d*) If soil ar rack disintegrates, it is paar material.

b. Charocteristics af Sails Pertinent ta Raads. Table 9–2 gives characteristics of soils pertinent ta raads and airfields.

---

*Tests indicoted by an asterisk (*) are canducted an material smaller thon $\frac{1}{32}''$ diameter.

c. *Field Density Determination.* The sand displacement method is so named because a calibrated sand is used to determine the volume of the hole from which a sample has been taken. The test consists essentially of digging out a sample of the material to be tested, determining the volume of the hole from which the sample was removed, and determining the dry weight of the sample. There are three requirements that must be met:

(1) The volume of the sample must be 0.05 cu. ft. or larger.

(2) When the sand-displacement method is used, a double cone cylinder must be used that permits calibrating the sand for each sampling operation.

(3) The sand moisture content must be constant while performing the test. (See TM 5–330 for complete testing procedure.)

Notes.

1. Column 1, division of GM and SM groups into subdivisions of *d* and u, is on the basis of Atterberg limits; suffix d is used when the liquid limit is 25 or less and the plasticity index is 5 or less; the suffix u will be used otherwise.

2 Column 3 is not for basecourse directly under bituminous pavements.

3. Column 5 has several types of equipment listed.

a. *Processed base material and other angular material.* Steel-wheeled and rubber-tired rollers are recommended for hard, angular materials with limited fines or screening. Rubber-tired equipment is recommended for softer materials subject to degradation.

b. *Finishing.* Rubber tired equipment is recommended for rolling during final shaping operations for most soils and precessed materials.

9–5. DRAINAGE

a. *Runoff.* The rational method of estimating runoff combines engineer judgment with calculations based on analysis, measurement, or estimation. It is expressed by: $Q = CIA$

where Q = runoff from a given area in cubic feet per second

C = a coefficient that represents the ratio of runoff to rainfall

I = intensity of rainfall in inches per hour for the estimated time of concentration

A = drainage areas in acres.

Table 9–2. Characteristics of soils

Letter Symbal		Name	Volue as a Subgrade Beneath Landing Mat ar as an Unsurfoced Area		Freedam af Dry Surface Fram Dust	
			Wet	Dry	Firm Surfoce	Laose Surface
(1)		(2)	(3)	(4)	(5)	(6)
GW		Well-graded gravels or gravel-sand mixtures, little or no fines.	Excellent	Excellent	Excellent to gaad	Excellent ta gaad
GP		Paarly graded gravels or gravel-sond mixtures, little or na fines.	Very gaad	Excellent	Excellent ta good	Excellent to good
GM	d	Silty gravels, gravel-sand-silt mixtures.	Excellent	Very gaad	Gaad	Gaad ta Fair
	u		Excellent	Good	Good	Gaad to Fair
GC		Clayey gravels, gravel-sand, clay mixtures.	Excellent	Good	Gaad	Gaad to Foir

Pertinent to Roods ond Airfields

Compressibility ond Expansion (7)	Droinoge Chorocteristics (8)	Campoction Equipment (9)	Dry Unit Weight #/cu ft (10)	Airfield Index (11)
Almast nane	Excellent	Crawler-type tractor, rubber-tired raller, steel-wheeled raller	125–140	15+
Almast none	Excellent	Crawler-type tractor, rubber-tired raller, steel-wheeled raller	110–140	15+
Very slight	Fair ta poor	Rubber-tired raller, sheepsfaot raller, clase cantrol of moisture	125–145	15+
Slight	Poor to practi-cally im-perviaus	Rubber-tired raller, sheepsfaat raller.	115–135	15+
Slight	Paar ta practi-cally im-perviaus	Rubber-tired raller, sheepsfaat raller	130–145	15+

Table 9–2. *Characteristics of soils*

Letter Symbol (1)		Name (2)	Value as a Subgrade Beneath Landing Mat or as an Unsurfaced Area		Freedom of Dry Surface From Dust	
			Wet (3)	Dry (4)	Firm Surface (5)	Loose Surface (6)
SW		Well-graded sands or gravelly sands, little or no fines.	Very good	Very good	Good	Good to Fair
SP		Poorly graded sands or gravelly sands, little or no fines.	Good	Very good	Good	Fair
SM	d	Silty sands, sand-silt mixtures	Very good	Good	Fair	Fair to Poor
	u		Very good	Fair	Fair	Fair to Poor
SC		Clayey sands, sand-clay mixtures	Very good	Fair	Fair	Fair to Poor
ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	Good	Very Poor	Fair to Poor	Poor

Pertinent to Roads and Airfields—Continued

Compressibility and Expansion (7)	Drainage Characteristics (8)	Compaction Equipment (9)	Dry Unit Weight #/cu ft (10)	Airfield Index (11)
Almost none	Excellent	Crawler-type tractor, rubber-tired roller	110–130	15+
Almost none	Excellent	Crawler-type tractor, rubber-tired roller.	105–135	10–15
Very slight	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture.	120–135	13–15
Slight to medium	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller.	100–130	10–15
Slight to medium	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller.	100–135	7–15
Slight to medium	Fair to poor	Rubber-tired roller, sheepsfoot roller, close control of moisture	90–130	13 or less

Table 9–2. Characteristics of soils

Letter Symbol	Name	Value as a Subgrade Beneath Landing Mat or as an Unsurfaced Area		Freedom of Dry Surface From Dust	
		Wet	Dry	Firm Surface	Loose Surface
(1)	(2)	(3)	(4)	(5)	(6)
CL	Inorganic clays of low to medium plasticity, gravelly clays; sandy, silty, and lean clays.	Good	Poor	Fair to Poor	Poor
OL	Organic silts and organic silt-clays of low plasticity	Good	Very Poor	Fair to Poor	Poor
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Good	Very Poor	Good to Fair	Poor
CH	Inorganic clays of high plasticity, fat clays.	Good	Poor	Good to Fair	Poor
OH	Organic clays of medium to high plasticity, organic silts.	Good	Very Poor	Good to Fair	Poor
Pt	Peat and other highly organic soils.	Very Poor	Extremely Poor	Good	Poor

Pertinent to Roads and Airfields—Continued

Compressibility and Expansion (7)	Drainage Characteristics (8)	Compaction Equipment (9)	Dry Unit Weight #/cu ft (10)	Airfield Index (11
Medium	Practically impervious	Rubber-tired roller, sheepsfoot roller.	90–130	13 or less
Medium to high	Poor	Rubber-tired roller, sheepsfoot roller.	90–105	7 or less
High	Fair to Poor	Sheepsfoot roller, rubber-tired roller.	80–105	10 or less
High	Practically impervious	Sheepsfoot roller, rubber-tired roller	90–115	13 or less
High	Practically impervious	Sheepsfoot roller, rubber-tired roller.	80–110	7 or less
Very high	Fair to poor	Compaction not practical	....	....

The value of C is derived from a study of the soil, the slope and conditions of the surface. The more commonly used values are shown in table 9–3. The value for *I* is derived from a study of available rainfall data. When past rainfall data is not available refer to TM 5–330 for charts pertinent to the area in question.

Table 9–3. Surface Runoff Factors

Types of surface	Factor
Asphalt pavements	0.80 to 0.95
Concrete pavements	0.70 to 0.90
Gravel or macadam pavements	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 areas depending on surface slope and soil cover.	0.01 to 0.20

*For slopes from 1 to 2 percent

Note. The figures given are for comparatively level ground For slopes greater than 1 in 50 (2%) the factor should be increased by 0 2 for every 2 percent of slopes up to a maximum 1.0

b. Open Ditch Design.

(1) Determine the rate of runoff (Q) in CFS from the area contributing to the ditch.

(2) Determine the slope (S) in feet per foot of the ditch from the grading plan of the area.

(3) Using table 9–4, select a retardance coefficient (n) and a maximum permissible velocity (V max) in fps for the soil conditions in which the ditch is to be constructed.

(4) Determine the type of ditch to be used (i.e., non-symmetrical triangular, symmetrical triangular, or trapezoidal).

(5) Using the slope (S), the retardance coefficient (n), and velocity (V max) determine the actual hydraulic radius using the nomagraph figure 9–8.

Table 9–4. Manning's "n" and Maximum Permissible Velacity af Flaw in Open Channels

Ditch Lining	*Manning's "n"*	*V fps*
a. Rack		
(1) Smaath and Unifarm	0.035–0.040	20
(2) Jagged & Irregular	0.040–0.045	15–18
b. Sails		

Ditch Lining		*Manning's "n"*	*V fps Max*
GW		0.022–0.024	6–7
GP		0.023–0.026	7–8
GM	d	0.023–0.025	3–5
	u	0.022–0.024	2–4
GC		0.024–0.026	5–7
SW		0.020–0.024	1–2
SP		0.022–0.024	1–2
SM	d	0.020–0.023	2–3
	u	0.021–0.023	2–3
SC		0.023–0.025	3–4
CL		0.022–0.024	2–3
ML		0.023–0.025	3–4
OL		0.022–0.024	2–3
CH		0.022–0.023	2–3
MH		0.023–0.024	3–5
OH		0.022–0.024	2–3
PT		0.022–0.025	2–3

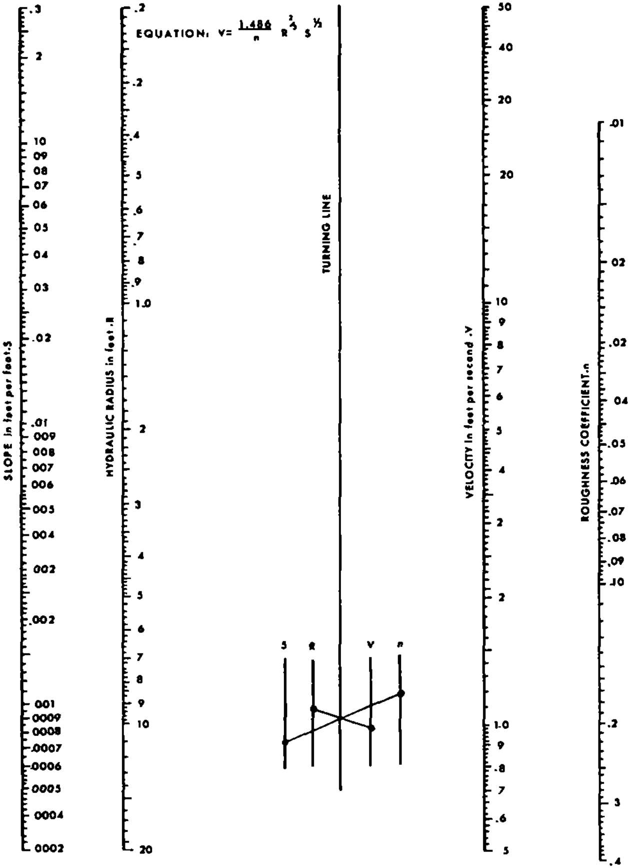


Figure 9—8. Nomograph for solutian of Manning equatian.

(6) Calculate using *R* and the type of ditch selected, the depth *d* and area *A*. Note figure 9–9.

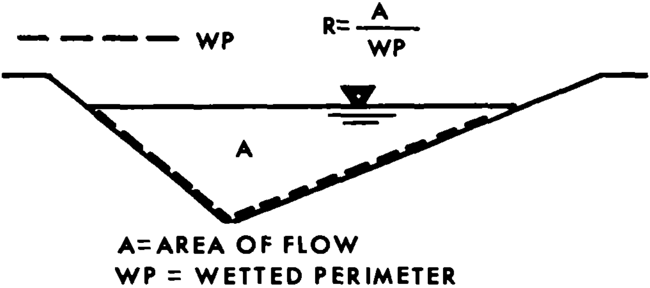


Figure 9–9. Typical ditch.

(7) Calculate $Q = AV$ where *A* is the area as determined in (6) above and *V* is the velocity of flow as determined in (3) above.

(a) If Q calculated is not greater or less than 5 percent of the runoff Q, then the ditch can be used.

(b) If Q calculated is greater than 5 percent of the runoff Q, use the same ditch but with steeper side slopes and repeat (6) and (7) above. If velocity chosen was maximum for the soil use lower velocity and repeat (5), (6), and (7) above.

(c) If Q calculated is less than 5 percent of the runoff Q and the velocity used was maximum for the ditch material, change the cross section of the ditch by making side slopes flatter or by increasing bottom width if trapezoidal.

(8) As an additional safety factor add 0.5 ft to the depth.

c. 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 9–10 shows the method of computing checkdam spacing.

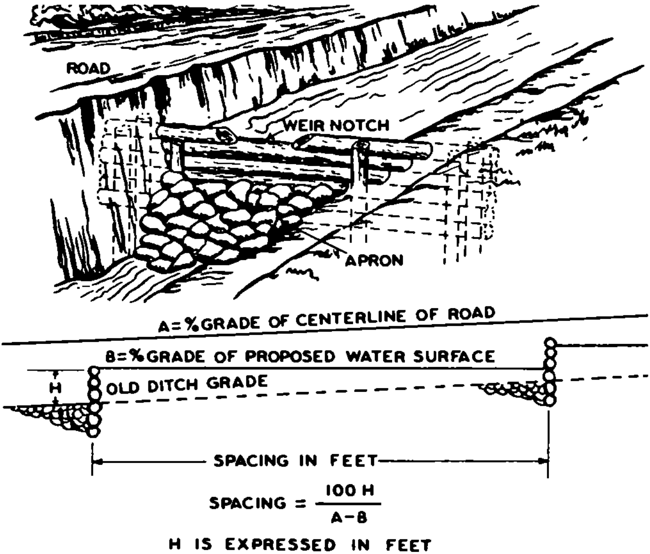


Figure 9—10. Methods of computing checkdam spacing.

d. Culverts.

(1) *General.* 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.

(2) *Cross-sectional area.*

(a) 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

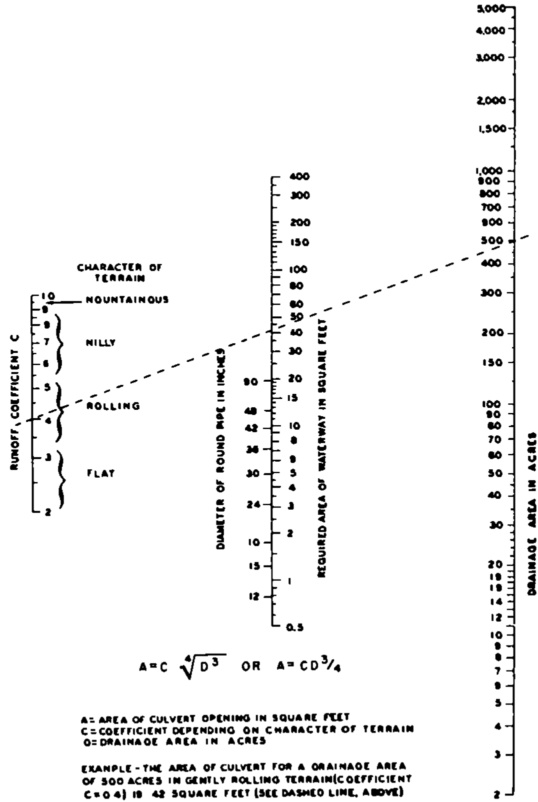


Figure 9—11. Nomograph for solution of Talbot's formula.

D = drainage area in acres

C = coefficient of retardation based upon slope and soil charteristics, (see table 9–3).

An alignment chart for solutions to Talbot's formula is given in figure 9–11.

(*b*) Hasty culvert area calculation. See figure 9–12.

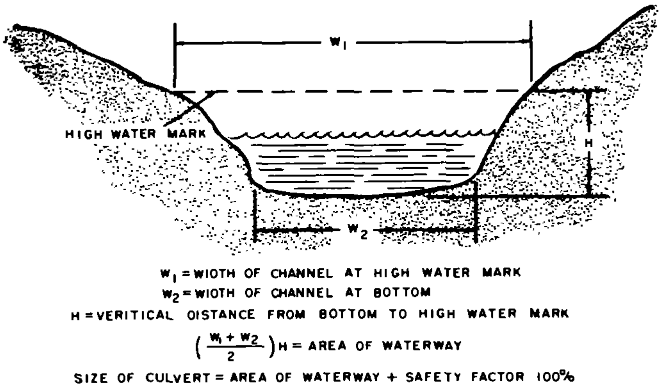


Figure 9–12. Hasty culvert calculation.

(3) *Alignment.* Culverts are placed in natural drainage channels, unless such installation would require an unusually long culvert, or produce a sharp bend in the channel on the upstream side. Where old drainage channels are not encountered, culverts should be installed at right angles to the centerline. Ditch relief culverts should be installed at an angle of 60° to the centerline. See figure 9–13.

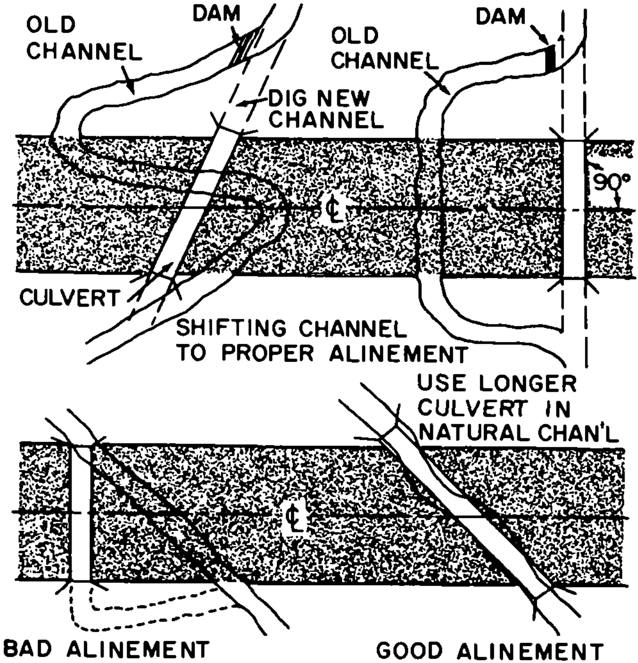


Figure 9—13. Alignment of culverts.

(4) *Length.* Usuolly culverts should be long enough to extend through fills to the point where the fill slope meets the ground. To minimize scour ot the downstreom end, culverts should be 1 to 2 feet longer thon required, with the odded length on the discharge end (fig. 9—14).

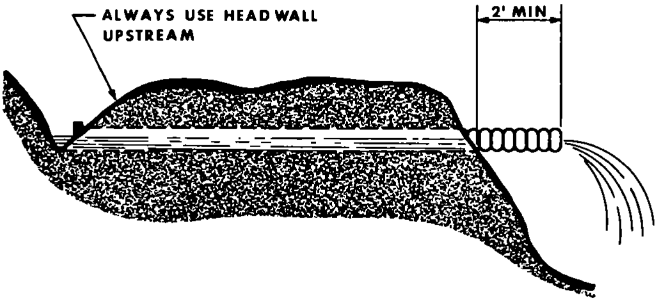


Figure 9–14. Culvert extended beyond fill to prevent erosion.

(5) *Elevation*. The bottom of the culvert at the inlet is placed on or below, but not above streambed elevation. At the outlet end, the bottom of the culvert normally should be at the elevation of the surface of the stream since it may fill with sediment if placed below the surface.

(6) *Slope*. Culverts normally are constructed at the grade of the natural and artificial drainage channels which discharge into them. It is desirable to use grades of 2 to 4 percent; 0.5 percent as an absolute minimum.

(7) *Bedding*. The foundation is always shaped to fit at least one-tenth of the outside diameter of the pipe. Cradles or footers may also be used if the soil will not provide proper support (fig. 9–15).

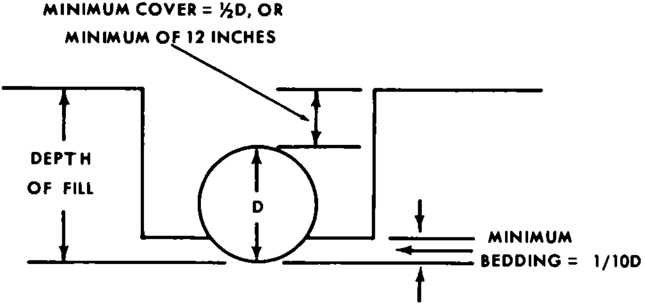
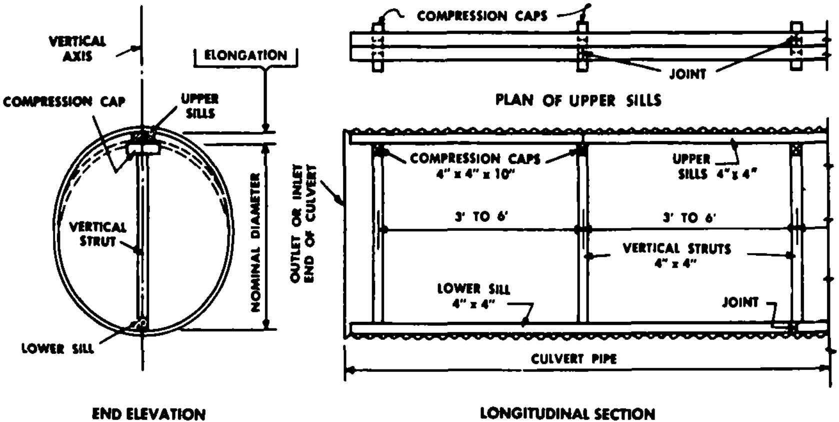


Figure 9–15. Culvert bedding, cover.

(8) *Strutting.* Figure 9–16 shows the strutting diagram for elongating the vertical dimensions of the larger sizes of corrugated pipe culvert prior to backfilling.



NOTE CULVERTS 60" TO 72" IN DIAMETER SHALL BE ELONGATED 2" ALONG THE VERTICAL AXIS DIMENSION. CULVERTS 84" IN DIAMETER SHALL BE ELONGATED 2½".

Figure 9–16. Strutting diagram showing end and longitudinal views—carrugated culvert pipe.

(9) *Strength.* Culverts must be strong enough to carry the weight of the fill above it plus the weight of the live load that passes over the road. See table 9–5 for recommended gages for nestable corrugated pipe.

Table 9–5. Recommended gages for Nestable Corrugated Pipe

Diam. in inches	Cross-sectional area (sq ft)	Fills up to 8 ft.	Fills up to 16 ft.	20-ft. fill	25-ft. fill	30-ft. fill	35-ft. fill	40-ft. fill
8	.35	16	16	16	16	16	16	16
10	.55	16	16	16	16	16	16	16
12	.79	16	16	16	16	16	16	16
15	1.23	16	16	16	16	16	16	16
18	1.77	16	16	16	16	16	16	16
21	2.41	16	16	16	16	16	16	16
24	3.14	16	16	16	16	14	14	14
30	4.91	14	14	14	14	14	12	12
36	7.07	14	14	14	12	12	12	10
42	9.62	14	14	12	12	10	10	8
48	12.57	12	12	12	10	8	8	8
54	15.90	12	12	10	8	8	8	8
60	19.64	12	10	8	8	8	8	8
66	23.76	10	10	8	8	8	8	
72	28.27	10	10	8	8	8		
78	33.18	8	8	8	8	Must be designed for these fill heights and others above 40 ft.		
84	38.49	8	8	8	8			

Note. Culverts below heavy line should be strutted during installation. See figure 9–16.

(10) Cover. The minimum cover for road culverts is one-half the pipe *diameter*, or 12 *inches*, whichever is greater.

(11) *Head walls, wing walls*. They are constructed to prevent or control erosion, guide water into the culvert, reduce seepage, and hold the culvert in place. Headwalls usually can be omitted on the outlet end. They should not protrude above shoulder grade and should extend 2 feet outside the shoulder. If headwalls and wing walls are not used, the culvert will have to be extended to at least 2 feet beyond the toe of the fill. See figures 9–17 through 9–19.

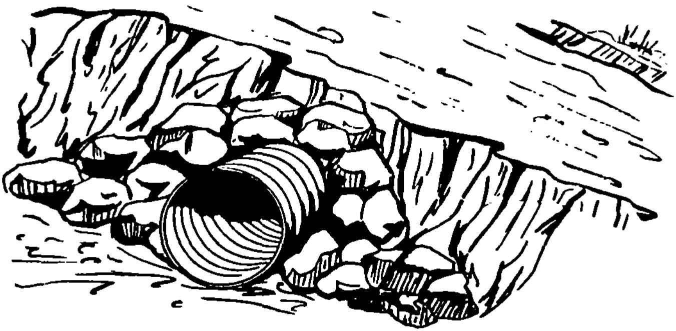


Figure 9–17. Rubble headwall.

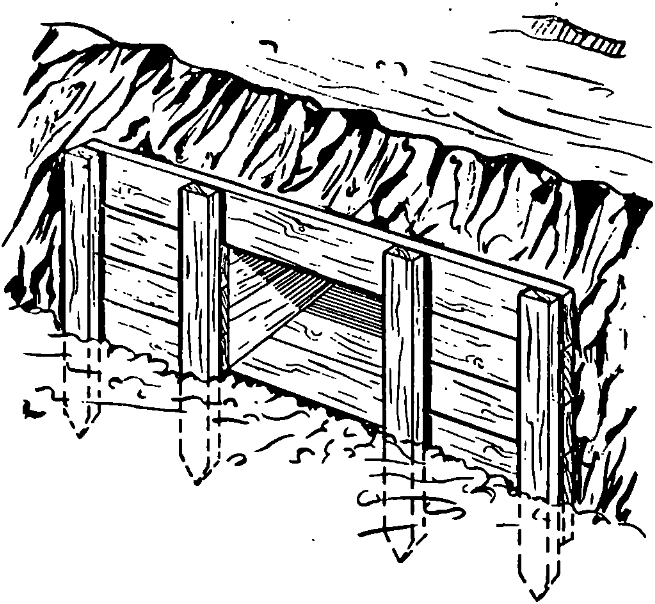


Figure 9—18. Plank headwall.

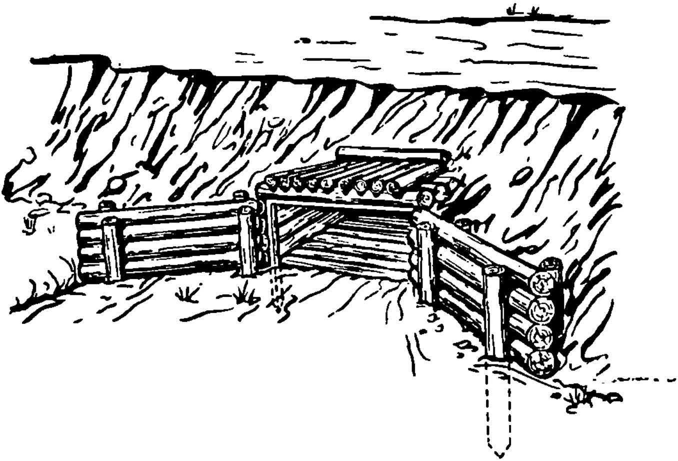


Figure 9—19. Lag headwall.

(11) *Spocing.* Culverts shauld be lacated wherever natural drainage channels are large enaugh ta require cross-drainage. On 8-percent grades, ditch-relief culverts shauld be ploced about 300 feet apart; an 5 percent grades, 500 feet opart (fig. 9—20). The bedding and spacing of pipes in multiple-pipe culverts is at least one-half the diameter af the pipe (fig. 9—21).

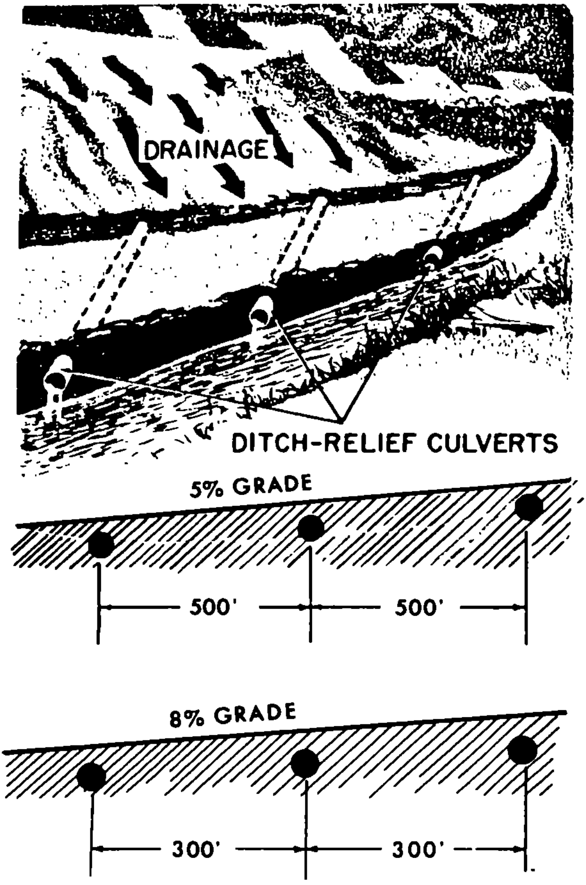


Figure 9—20. Culvert spacing.

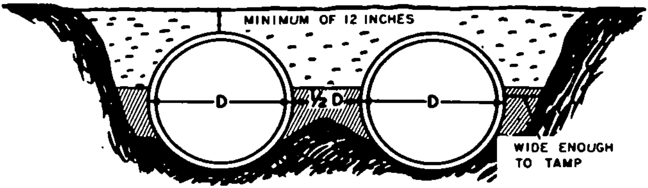


Figure 9–21. Spacing of multiple-pipe culvert.

(12) *Types.* Various types of culverts are shown in figures 9–22 through 9–25.

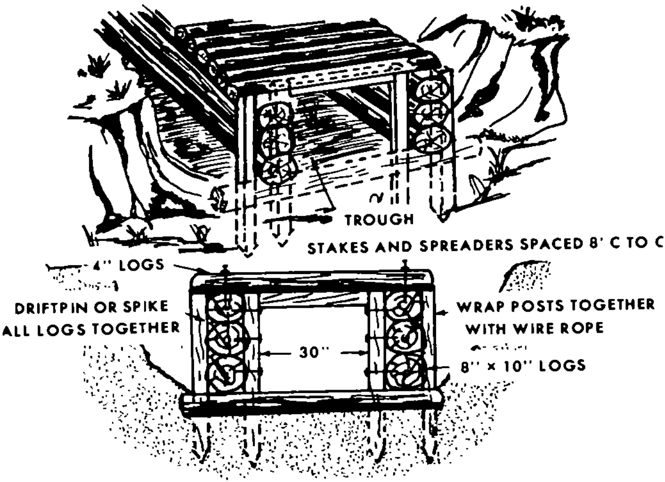


Figure 9–22. Log box culvert, 30-inch.

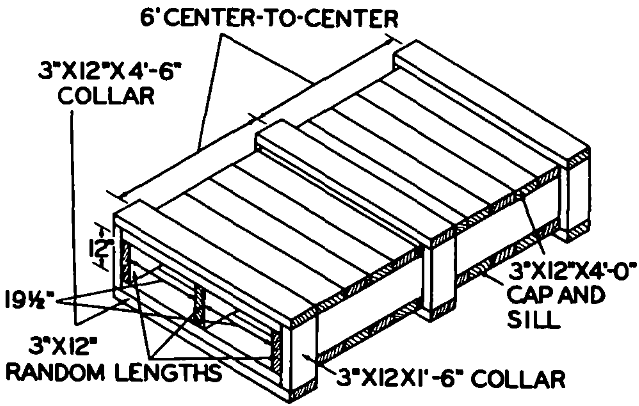


Figure 9–23. Timber box culvert, 19½- by 12-inch.

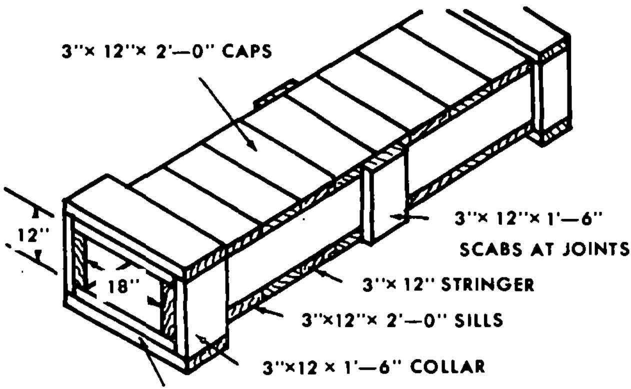


Figure 9–24. Timber box culvert, 18- by 12-inch.

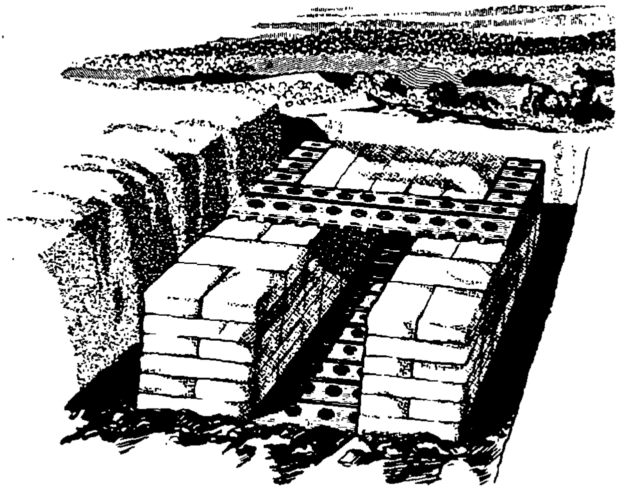
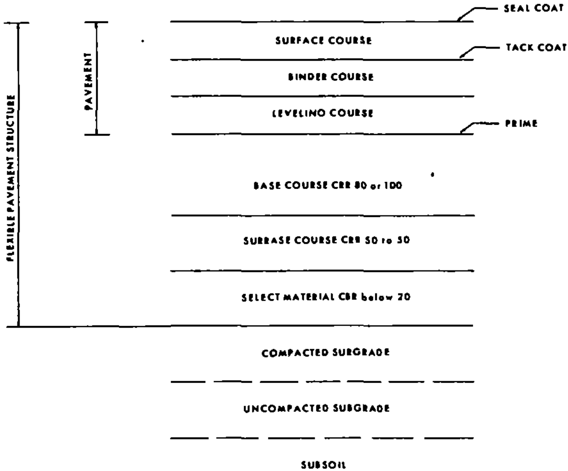


Figure 9–25. *Expedient culvert.*

9–6. FLEXIBLE PAVEMENTS

Figure 9–26 depicts a typical flexible pavement structure. All the layers shown in figure 9–26 are not present in every flexible pavement structure. For complete design criteria for a flexible pavement structure refer to TM 5–330.



Note:

1. The word "structure" is often deleted from the phrase "flexible pavement structure." Also the word "course" is often deleted from "binder course," "base course," and "subbase course."
2. All layers and coats are not present in every flexible pavement structure.
3. Demarcation between subgrade and subsoil is indefinite.

Figure 9–26. Typical flexible pavement.

9-7. TYPES OF SURFACES

a. *Roads of Processed Materials.* Processed materials are prepared by crushing and screening rock, gravel, and slag. They should meet the grading requirements set forth in table 9–6.

Table 9–6. Suggested Grading Requirements for Fine-graded Type Surface Caurse of Processed Materials

Sieve designatian	Percent passing, by weight
$\frac{3}{4}$ in	100
Na. 4	70–100
Na. 10	35–80
Na. 40	25–50
Na. 200	8–25

b. Gravel Raods. Gravel roads are camposed of a compacted loyer af well graded gravelly sail. See table 9–7 far gradatian requirements for gravel raads. River gravels narmally require the additian of binder soil. The capability of gravel roads to carry heavy, sustained traffic depends on the strength and hordness af gravel, the cahesiveness af cloy binder, the thickness af the layer, and the stability of the subgrode. These surfaces make an excellent base for later pavements.

Toble 9–7. Suggested Groding Requirements for Gravel and Composite Type Surface Courses of Pracessed Moterials

Sieve designatian	Percent passing, by weight
1 in	100
$\frac{3}{4}$ in	85–100
$\frac{3}{8}$ in	65–100
Na. 4	55–85
No. 10	40–70
No. 40	25–45
Na. 200	0–10

c. *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.

d. *Soil-Stabilized Surfaces.*

(1) *Compaction.* Compaction equipment for the different types of soils are given in table 9–2.

(2) *Chemical stabilization.* Table 9–8 gives a summary of soil stabilizers for strength improvement.

e. *Portable Road Surfaces.* During operations in the field, it is often necessary to make temporary use of metal mesh, metal landing mats, wood mats, or various types of treadways. These materials are rapidly transported and assembled over mud, swamps, beaches, or other unstable soils. TM 5–337 gives the details of constructing portable surfaces.

9–8. BITUMINOUS MATERIAL

a. *Field Identification of Bituminous Material.* Refer to figure 9–27 and figure 9–28 for field identification of unknown bituminous material.

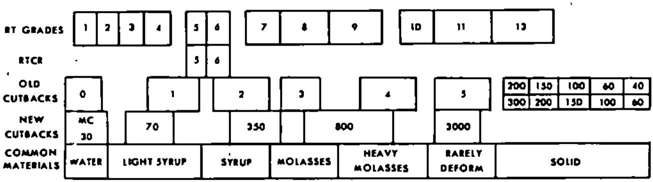


Figure 9–27. *Viscosity* comparisons.

Table 9–8. Summary of Soil Stabilizers for Strength Improvement

(1) Material	(2) Form of material	(3) Applicable soil range	(4) Estimated range of quantity requirements (%)†	(5) Minimum curing time requirements
Portland cement	Powder	Gravels........ ...	3–4	24 hours.
		Sands.............	3–5	
		Silts, clayey silts..	4–6	
		Clays.....	6–8	
Lime·				
1. Hydrated	Powder	Clayey gravels	2–4	7 days
		Silty clays........ .	5–10	
		Clays.	3–8	
2. Quickline	Powder	Clayey gravels	2–3	4 hours.
		Silty clays	3–8	
		Clays.........	3–6	
Bituminous material.				
1. Asphaltic cutbacks				
a. RC–70 to RC–800	Liquid.....	Sands.....	††5–7	1–3 days.
		Silty sands.... .	6–10	
		Clayey sands.....	6–10	
b. MC–70 to MC–800	Liquid... .	Sands.......	5–7	1–3 days
		Silty sands.... .	6–10	
		Clayey sands. ...	6–10	
2. Asphaltic emulsions	Liquid.....	Sands....	5–7	1–3 days.
		Silty sands........	6–10	
		Clayey sands... .	6–10	

†Based on dry density of existing soil.
‡All quantities listed for asphalts are actual bitumen requirements, exclusive of volatiles

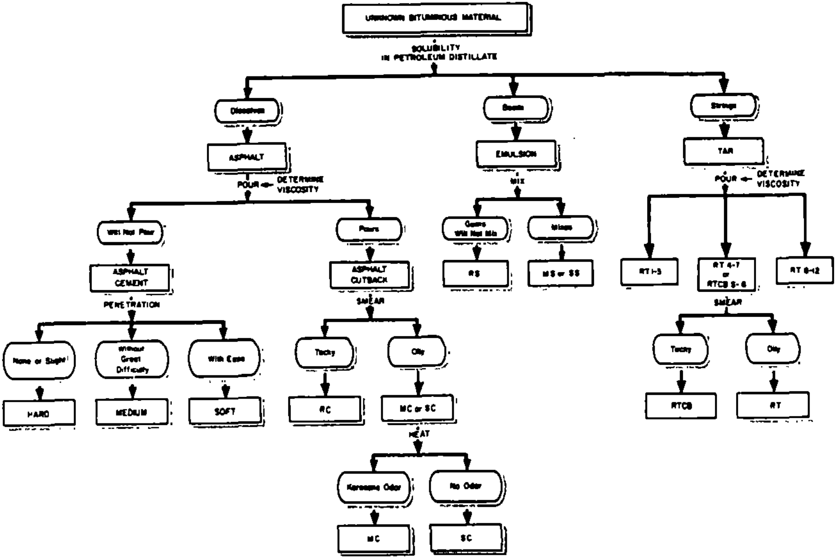


Figure 9–28. Field identificotion of unknown bituminous moteriols.

b. *Thinning an Asphalt Cutback.* Refer to table 9–9 for composition of asphalt cutback.

Table 9–9. Asphalt Cutback Composition (in percent of total volume)

TYPE	COMPONENTS / SOLVENT	GRADES 30	70	250	800	3000
RAPID CURING RC	ASPHALT CEMENT		65	75	83	87
	GASOLINE OR NAPTHA		35	25	17	13
MEDIUM CURING MC	ASPHALT CEMENT	54	64	74	82	86
	KEROSENE	46	36	26	18	14
SLOW CURING SC	ASPHALT CEMENT		50	60	70	80
	FUEL OIL		50	40	30	20

CHAPTER 10

ARMY AIRFIELDS AND HELIPORTS

10–1. CLASSIFICATION

a. *General.* The oirfield ond heliport classification system consists of combining the controlling aircroft clossification with the appropriote military area.

b. *Militory Areas.*

(1) *Battle* orea. Sector of the bottle normally under military control of a brigade.

(2) *Foward* area. Sector of the theater of operations immediately behind the battle area and normally under military control of o brigade or division.

(3) *Support* area. Sector of the theater of operations behind the forward area, normally within the ormy corps service areas or areas under military control of the fighter air security command.

(4) *Rear* orea. Sector of the theoter of operations behind the support area, normolly within the army service areo or the zone of communications.

c. *Controlling Aircroft.*

(1) Liaison (0–1).
(2) Surveillance (0V–1).
(3) Light lift (C–7A).
(4) Medium lift (C–130).
(5) Tactical (F–46 and F–105).
(6) Heovy lift (C–124, C–133, C–135, and C–141).

d. *Controlling Rotary Wing Aircraft.*

(1) Observation (light) helicopter (OH–6A).
(2) Utility helicopter (UD–1D).
(3) Cargo (medium transport) helicopter (CH–47).
(4) Cargo (heavy lift) helicopter (CH–54).

10–2. LAYOUT AND NOMENCLATURE

The general layout and nomenclature of army airfield ond heliports is illustrated in figures 10–1, 10–2, and 10–3.

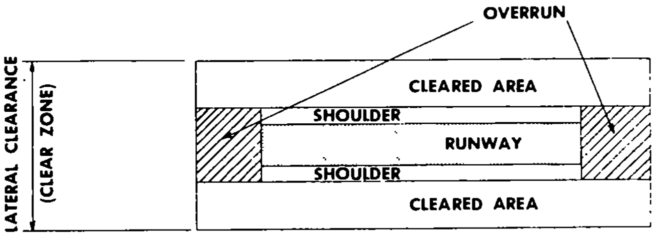


Figure 10–1. Flightstrip nomenclature.

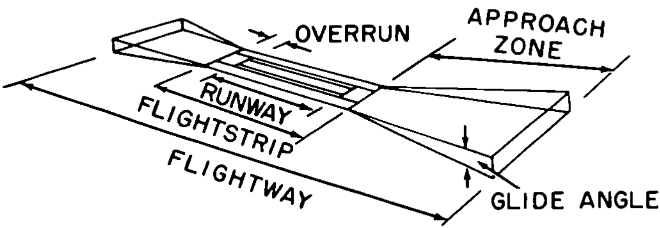


Figure 10–2. Flightway nomenclature.

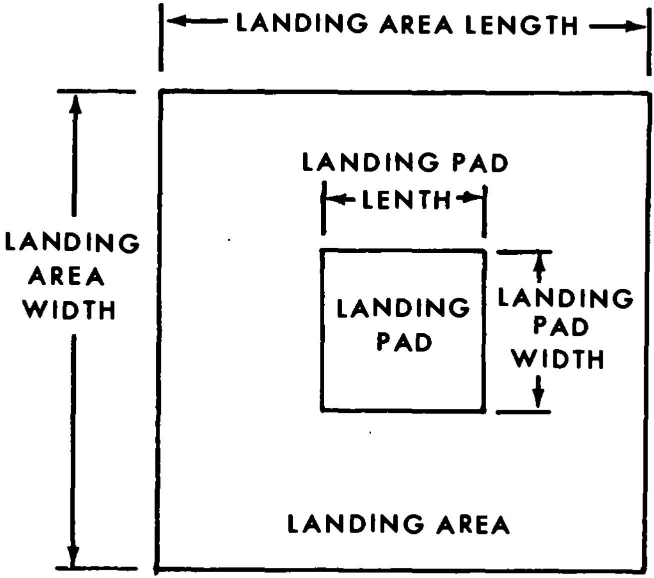


Figure 10–3. Landing area of helipad.

10–3. ARMY AIRFIELD DESIGN

a. *Runway Length.* Use the following steps to determine runway length.

(1) Takeoff ground run (TGR) for individual aircraft is shown in table 10–1.

(2) Increase the takeoff ground run (TGR) by 10 percent for each 1,000 feet increase in altitude above 1,000 feet.

(3) Increase the corrected runway length obtained from the previous computation by 7 percent for each 10° F increase in temperature

Table 10–1. Aircraft Characteristics Used in Design of T/O Airfields

Airfield type	Anticipated service life	Possible using aircraft U.S. type	Ground run at sea level and 59°, ft[b]	Minimum runway length ft.	Minimum runway width ft.
Battle area:	3 days				
Light lift		C–7A[a]	625	1,000	50
Medium lift		C–130[a]	1,600	2,000	60
		C–123	1,600		
Forward area:	2 weeks				
Liaison		O–1[a]	390	750	50
Surveillance		OV–1[a]	2,000	2,500	60
Light lift		C–7A[a]	625	1,200	60
Medium lift		C–130[a]	2,000	2,500	60
		C–7A	625		

[a] Particular aircraft that is critical in load and/or ground run from which area requirements, geometrics, and expedient surfacing requirements were developed

[b] Ground run lengths indicated are for classification and can undergo changes depending on operating weight of aircraft, pressure altitude corrections, temperature corrections and local conditions

above 59° F, if takeoff ground run is greater than 5,000 feet. Increase by 4 percent per 10° above 59° if takeoff ground run is less than 5,000 feet.

Note. The temperature to be considered is the mean temperature for the warmest period during which operations will be conducted from the airfield.

(4) Multiply the corrected runway length from the previous computations by 1.5 for rear area airfields and 1.25 for support, forward and battle area airfields.

(5) Increase the corrected runway length obtained from the previous computation by 8 percent for each 1 percent of effective gradient over 2 percent. Using the above runway length, the effective gradient can be determined from the profile of the airfield

(6) The final runway length will be the takeoff ground run corrected (if required) for conditions of altitude, temperature, safety factor, and effective gradient, and raised to the next larger 100 feet.

Table 10–2. Basic Airfield Expedient Surfacing Requirements

Airfield Type.	Runway, Taxiway, and Apron Surfacing Requirements for Airfield Index of							Overrun Area and Shoulder Surfacing Requirements for Airfield Index of						
	Minimum Airfield Index	5–6	6–8	8–10	10–12	12–15	15 or Greater	Minimum Airfield Index	5–6	6–8	8–10	10–12	12–15	15 or Greater
Battle area														
Light lift	4	U	U	U	U	U	U	2	U	U	U	U	U	U
Medium lift	4	L	U	U	U	U	U	4	U	U	U	U	U	U
Forward area														
Liaison	3	U	U	U	U	U	U	2	U	U	U	U	U	U
Surveillance	3	L	L	U	U	U	U	4	U	U	U	U	U	U
Light lift	5	U	U	U	U	U	U	3	U	U	U	U	U	U
Medium	S	L	L	U	U	U	U	4	U	U	U	U	U	U
Support area														
Liaison	3	U	U	U	U	U	U	2	U	U	U	U	U	U
Surveillance	3	L	L	U	U	U	U	5	U	U	U	U	U	U
Light lift	5	U	U	U	U	U	U	3	U	U	U	U	U	U
Medium lift	4	M	M	L	U	U	U	3	L	U	U	U	U	U
Heavy lift	6	I	M	M	L	L	U	3	L	L	L	U	U	U
Tactical	...	M	M	M	L	L	L	...	L	L	L	L	U	U
Rear area:														
Army	5	L	L	L	U	U	U	S	U	U	U	U	U	U
Medium lift	6	I	M	M	L	L	U	4	L	L	U	U	U	U
Heavy lift	8	I	I	M	M	L	L	3	M	L	L	L	U	U
Tactical	7	I	M	M	M	L	L	4	L	L	L	L	U	U

Note. U= unsurfaced soil with or without membrane, M=medium duty mat, and I=subgrade airfield index must be increased to that required for heavy duty mat. L=light duty mat.

(7) Compare calculated length obtained from the previous computation with the minimum length required as shown in column 5 of table 10–1. Use the greater value.

b. Runway Width. See table 10–1 for minimum runway width.

c. Basic Surfacing Requirements. Subgrade strength requirements for both unsurfaced areas and those to be surfaced with landing mat at battle, forward, support, and rear areas are shown for traffic areas (runway, taxiway, and apron) and nontraffic areas (overrun and shoulder) in table 10–2. The following types of landing mat and membrane have been field tested under field conditions and classified as follows based on test results·

(1) Light duty landing mat—M8A1

(2) Medium duty landing mat—MX18B, MX19, AM2

(3) Membrane—T17

10–4. HELIPAD DESIGN

a. Minimum Geometric Requirements. See table 10–3 for minimum geometric requirements.

Table 10–3. Minimum Geometric Requirements (Helipad)

Description	Forward area			
	OH–6A	UH–1D	CH–47	CH–54
Length, ft (landing pad)	12	20	50	50
Width, ft (landing pad)	12	20	25	50
Landing pad grade in one direction, %	3	3	3	3
Grade of clear area maximum %	10	10	10	10
Length, ft (landing area)	72	100	150	150
Width, ft (landing area)	72	100	125	150

b. Design Strength. See table 10–4 for helipad and heliport surfacing requirements. Note table 9–2 for airfield indexes of soils.

Table 10–4. Helipad and Heliport Surfacing Requirements

Airfield Index

Helipad ar heliport type	1 2	2 3	3 4	4 5	5 6	6 8	8 10	10 12	12 15	≥ 15
Forward Area Helipad:										
OH–6A	L	U	U	U	U	U	U	U	U	U
UH–1D	L	L	U	U	U	U	U	U	U	U
CH–47	I	M	M	L	L	L	L	U	U	U
CH–54	I	M	M	M	L	L	L	L	U	U
Farward Area Heliport:										
UH–1D	L	L	U	U	U	U	U	U	U	U
CH–47	I	M	M	L	L	L	L	U	U	U
Support Area Helipod:										
OH–6A	L	U	U	U	U	U	U	U	U	U
UH–1D	L	L	U	U	U	U	U	U	U	U
CH–47	I	I	M	M	L	L	L	U	U	U
CH–54	I	I	I	M	M	L	L	L	L	U
Support Areo Heliport:										
UH–1D Co	L	L	U	U	U	U	U	U	U	U
CH–47 Ca	I	I	M	M	L	L	L	U	U	U
CH–54 Ca	I	I	M	M	M	M	L	L	L	U
Mixed Bn	I	I	M	M	L	L	L	U	U	U
Rear Area Helipad:										
OH–6A	L	L	U	U	U	U	U	U	U	U
UH–1D	L	L	L	U	U	U	U	U	U	U
CH–47	I	I	M	M	L	L	L	L	U	U
CH–54	I	I	I	M	M	M	L	L	L	U
Rear Area Heliport:										
UH–1D Co	L	L	L	U	U	U	U	U	U	U
CH–47 Ca	I	I	M	M	L	L	L	L	U	U
CH–54 Co	I	I	I	M	M	M	L	L	L	U
Mixed Bn	I	I	M	M	L	L	L	L	U	U
Raods:										
Farward	M	L	L	L	U	U	U	U	U	U
Support	M	L	L	L	L	U	U	U	U	U
Reor	M	M	L	L	L	U	U	U	U	U

Nates.

I—Subgrade index must be increased to that required far medium duty mat

U—Unsurfaced sail with ar withaut membrane

L—Light duty mat

M—Medium duty mat

10–5. SOIL STABILIZATION AND DUST CONTROL

a. *Strength Improvement.* See table 9–8.

b. *Dust Control and/or Soil Waterproofing.* Sprinkling with water, lime solutions, and oils provides temporary relief from dust. Longer relief is achieved by use of asphaltic materials such as Peneprime (AP5B), or special compounds such as DCA–70. Any asphaltic material must be allowed to cure before being exposed to traffic. Asphaltic cutback materials also serve to waterproof soils. (See table 10–5.)

Table 10–5. Dust Control Requirements for Heliports

Area	Dimension of area requiring dust control (ft)				
	OH–6A Cayuse	UH–1D Iroquois	AH–1G Huey Cobra	CH–47A Chinook	CH–54A Skycrane
Taxi-hover Lane and Parking Pads	75	75	80	150	150
Takeoff and Landing Areas	80	132	150	295	216

Note: Measurements are taken from the center of rotation of the controlling aircraft and are approximately equal to the radius of the area affected by the rotor downwash.

10–6. MARKING EXPEDIENT RUNWAY

The determination of an airfield marking system in a theater of operations is a prerogative of the theater commander. See figure 10–4 for marking configuration considered applicable to theater of operation use.

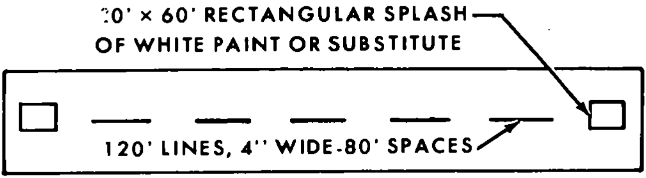


Figure 10–4. Marking expedient runway.

10–7. FORTIFICATIONS FOR PARKED ARMY AIRCRAFT

a. *Dispersal and Spacing.*

(1) *Spacing.* Fortification spacing should provide individual aircraft with protective structures which do not hinder ready access to the aircraft for efficient servicing, maintenance, and tactical operations.

(2) *Dispersal.* Dispersal should separate aircraft sufficiently to minimize the danger of interacting ammunition and fuel explosions. The method used must avoid any consistent pattern that will facilitate adjustment of high angle fire on the aircraft.

b. *Minimum Requirements.* See table 10–4 for minimum thickness of protective material required to resist penetration.

CHAPTER 11

MAP READING

11-1. DEFINITION OF A MAP

A map is a graphic representation of a portion of the earth's surface drawn to scale on a plane.

11-2. TYPES OF MAPS

The following are the different types of maps used.

a. *Planimetric Map*. A map which presents only the horizontal positions for the detail plotted. It is distinguished from a topographic map by the omission of relief in a measurable form.

b. *Topographic Map*. A map which portrays relief in a measurable form, as well as the horizontal positions of the details plotted. The vertical positions, or relief, normally are represented by contour lines. On maps showing relief, the elevations usually are referred to as mean sea level datum plane.

c. *Plastic Relief Map*. A topographic map pre-printed on plastic materials and formed by heat and vacuum over a reproductive mold, thus giving the same information as contained in a topographic map in a three dimensional form so that the user can readily see variation in elevation.

d. Photomap. A reproduction of an aerial photograph or a mosaic made from a series of aerial photographs upon which grid lines, marginal data, place names, spot elevations, boundaries, and scale have been added. Photomaps usually are not contoured. They usually are used to supplement other maps of an area, or serve as a map substitute.

e. *Joint Operations Graphics* (JOG's). A series of 1 : 250,000 military maps which are printed in a ground (G) and an air (A) version. JOG's are designed to provide common base graphics for use in combined operations by ground and air force elements. The topographic information is identical on both versions of the same map sheet; however, the (G) series indicates elevations in meters while the (A) series elevations are depicted in feet. Both series emphasize the air landing facilities but the (A) series has additional symbols to identify aids and obstructions to air navigation.

f. *Pictomap*. A photomap-type product which stresses the use of photolithographic operations rather than the conventional techniques used for preparation of standard maps. Heights of map features are accentuated pictorially, while terrain and vegetation are shown in near natural colors. Important cultural features are overprinted in red. Names, contours, and railroads are shown in black and water features in blue. Pictomaps are usually published at 1 : 25,000 scale and larger.

g. *Military City Map.* A topographic map which has a scale of 1 : 12,500 or larger. It shows detailed road networks of urban areas, principal buildings, and other prominent features that are of military importance. Thoroughfares or main highways leading through urban areas are indicated.

11–3. MAP SCALES

Map scales are categorized as follows:

a. *Small Scale Maps.* Maps at scales of 1 : 600,000 and smaller are used for general planning and for strategical studies at high command echelons. The standard small scale map is considered to be at the scale 1 : 1,000,000.

b. *Medium Scale Maps.* Maps at scales larger than 1 : 600,000, but smaller than 1 : 75,000 are used for planning operations including road movements and concentration of troops and supply elements. The standard medium scale map is 1 : 250,000.

c. *Large Scale Maps.* Maps at scale of 1 : 75,000 and larger are used to meet the tactical, technical, and administrative needs of field units. The standard large scale map is the 1 : 50,000 map. City maps are considered to be a large scale map product.

11–4. MAP COLORS

Maps, especially topographic type products, are depicted in five basic colors:

a. *Black.* Cultural (man-made) features, marginal data and primary grid.

b. *Brown.* Terrain features and contour lines depicting elevations.

c. Green. Depicts vegetation features such as wooded areas, orchards, etc.

d. *Blue.* Represents water features such as lakes, streams, rivers, etc.

e. *Red.* Main roads, built-up areas are indicated in this color.

11–5. MAP MARGINAL DATA

The location of marginal data is indicated below for maps printed prior to 1968. AMS Style Sheet 25–50–100, September 1968 contains new criteria for the location of marginal data as shown below in parenthesis.

a. *Sheet Name*. The sheet nome is found in two places, the center af the upper margin ond on the right side af the lower margin. Generally the map is named after its outstanding cultural ar geagraphic feoture.

b. *Sheet Number*. The sheet number is found in the upper right (and lawer left) margin(s) and is used as a reference number to identify a map sheet. It is also used as part of the Stock Number Identification which is used in requisitioning maps (x below).

c. *Series Name* and *Scale*. The map series name is faund in the upper left margin. A map series usually comprises a graup af similar maps at the same scale and an the some sheet lines ar format design cavering a particular geagraphic area. (The editian number is faund in the upper right and lawer left margin.) The scale note is a representotive fractian which gives the ratia af a map distance to the corresponding distonce an the earth's surface.

d. *Series Number*. The series number appears in the upper right margin and the lower left margin. It is a camprehensive reference system campased usually af four elements and is expressed either as a four digit number ar as a letter followed by a three ar four digit numeral. Compasitian of the series number is explained in detail in FM 21–26.

e. *Edition Number*. The edition number is found in the upper left and lower left margins. It represents the number of times the map has had major revisions and the agency responsible far its praduction.

f. *Bar Scales*. The bar scales are locoted in the center of the lawer margin. They are distance rulers used for the determination af graund distance. Maps have three or more bar scales, each depicting a different unit af measure.

g. *Credit Nate*. The credit note is lacated in the lawer left margin. (The credit lines are lacated in the center af the lawer margin.) It lists the praducer, dates, and general methods used in the preparation of the map and any revisians thereta. This information is impartant ta the map user in evaluating the reliability of the map.

h. *Adjaining Sheets Diagram*. Maps at all standard scales contain a diagram which illustrates the adjaining sheets to the north, south, east, west, and dioganally from the sheet being used. Sheet numbers are indicated an the adjoining sheets diagram far the purpose af requisitianing. Far smaller scale maps this diagram is alsa known as the "locatian diagram" ar "Index to Adjoining Sheets". (This diagram appears in the lawer right margin.)

i. Index to Boundaries. The projection is identified on the map by o note in the lower or right margin (center of the lower margin). This diagram, which is a miniature of the map, shows the boundaries which occur within the map areo, such as county and stote boundories.

j. Projection Note. The projection is identified on the map by o note in the lower margin. Refer to TM 5–241–1 for the development characteristics of the conformal type projection systems.

k. Grid Note. The grid note is located in the center of the lower margin. It gives information pertaining to the grid system used, the interval of grid lines, and the number.

l. Grid Reference Box. The grid reference box contains instructions for composing a grid reference of a specific point and provides o step by step exomple referred to a sample point on the mop. This box usuolly is located in the lower center margin.

m. *Vertical Datum Note.* This note is located in the center of the lower margin. It designates the bosis for all vertical control stations, contours and elevations appearing on the map.

n. *Horizontal Dotum Note.* This note is located in the center of the lower morgin. It indicates the bosis for oll horizontal control appearing on the map. The network of horizontal station controls the horizontol position of oll mopped features.

o. *Legend.* The legend is located in the lower left margin. It illustrotes and identifies the topographic symbols used on the mop. To preclude any change of error in the identificotion of symbols, the legend must always be referred to when o map is used.

p. Declination Diagram. The declination diagram is locoted in the lower margin and indicates the ongular relationship of true north, grid north, and mognetic north os pertoins to the map area.

q. User's Note. A user's note is located in the center of the lower morgin. It requests cooperotion from map users in notifying the map moking agency listed in the note of any errors found on the map sheet so these errors con be corrected the next time the map is revised or printed.

r. Unit Imprint. The unit imprint note is located in the lower right (center lower) margin and indicates the key number, the mop printing agency, and printing date.

s. Contour *Interval.* The contour interval appears in the center of the lower margin. It stotes the vertical distance between odjacent contour lines on the mop.

t. *Glossary.* A glossary is on explanation of technicol terms or a tronslation of terms on maps of foreign areas where the native languoge is other than English.

u. *Classification*. Certain maps require a note indicating the security classification of the map. These labels are located in the upper and lower margins of a map usually in red.

v. *Protractor Scale*. This scale may appear in the upper margin of some maps. It is used for plotting a magnetic north line on a map.

w. *Coverage Diagram*. On maps at scale of 1 : 100,000 and larger the coverage diagram may be used. It normally is in the lower or right margin and indicates the methods and source data used in making the map such as aerial photography dates and reliability of map sources.

x. *Stack Number Identification*. All maps published by or for the Corps of Engineers which are in the Army map supply system contain stock number identifications, which are used in requisitioning maps. The identification consists of the words STOCK NO. followed by a unique designation which is composed of the series number and sheet number of the individual map. The designation is limited to 15 units (letters and numbers).

y. *Elevation* Guide. (The elevation guide is located in the lower right margin. This diagram, which is a minature of the map shows the highest points on the maps. Elevation is shown with different shades of gray.)

11–6. DECLINATION DIAGRAM

There are three basic base lines used to express direction as a unit of angular measure when using a map. These base lines are known as true north, magnetic north, and grid north. The most commonly used are magnetic and grid north. The magnetic north is used when working with a compass and the grid north when working with a military map.

a. *True North*. True north is defined as an imaginary line from any position on the earth's surface to the north pole. All lines of longitude are true north lines. The true north line on the Declination Diagram is represented by a star.

b. *Magnetic North*. The magnetic north declination is established by the compass and changes slightly on an annual basis. Magnetic north is symbolized by a half arrowhead.

c. *Grid North*. This base line is established by the grid lines on the map. Grid north may be symbolized by the letters GN or the letter Y (fig. 11–1).

Note. For detailed explanation on declination diagram base line convergence refer to FM 21–26.

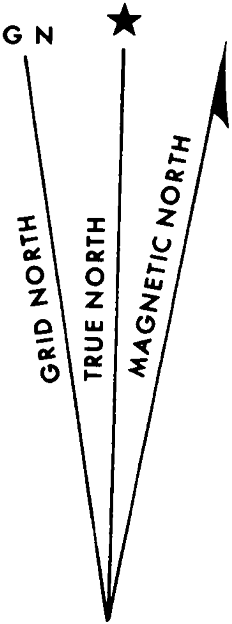


Figure 11–1. Declination diagram base lines.

11–7. SCALE AND DISTANCE (REPRESENTATIVE FRACTION)

a. The scale of a map expresses the ratio of horizontal distance on the map to the corresponding horizontal distance on the ground using *the same unit of measurement for both.* The representative fraction (RF) is *always* written with the *map distance* as 1. An RF of $\frac{1}{50,000}$ or 1/50,000 or 1 : 50,000 means that one (1) unit of *measurement* on the map equals a corresponding number of like units of measurements (50,000) on the ground.

b. The ground distance between two points on a map is determined by measuring the distance between the points and multiplying the map measurement by the denominator of the RF.

Example: a. Map distance between two points = 5 units.
b. The RF of the map is 1 : 50,000, therefore,
c. 5 × 50,000 = 250,000 units of ground distance.

c. Further data on finding unknown RF's, ground or map distances is explained in FM 21–26 and table 11–1.

11–8. CONTOURS

A contour line is a line representing an imaginary line on the ground along which all points are of the same elevation.

a. Contour lines evenly spaced and wide apart indicate a uniform gentle slope.

b. Contour lines evenly spaced and close together indicate a uniform steep slope. The closer the contour lines to each other the steeper the slope.

c. Contour lines closely spaced at the top and widely spread at the bottom indicate a concave slope.

d. Contour lines widely spaced at the top and closely spaced at the bottom indicate a convex slope.

11–9. SLOPE

The rate of rise and fall of a ground form is known as its slope. Slope may be expressed in several ways but all depend upon a comparison of vertical distance (VD) to horizontal distance (HD). VD is the difference between the highest and lowest elevations of a slope and is determined from the contour lines. HD is the horizontal ground distance between the highest and lowest elevations of the slope and is measured using the bar scale of the map. The VD and HD must be expressed in the same unit of measurement.

a. A common expression of slope is as a percent (%) which indicates the number of vertical units of elevation to every hundred units of horizontal distance. Whenever a gradient or percent is used, a plus or minus sign must be given to indicate whether the slope is rising or falling.

b. Slope may also be expressed in degrees, a unit of angular measure. Determine the value of $\frac{VD}{HD}$ in decimal form. This will be the tangent of

Table 11–1. 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

the slape angle. The slape ongle can then be faund in a table of trigano-metric tangent functians. The appraximote slope angle moy be calculated by multiplying the grodient by 57.3. This methad is reasonably accurate for slope angles under 20°.

11–10. TOPOGRAPHIC SYMBOLS

Topagraphic symbals used an an individual map are faund and explained in the LEGEND which is placed an every map. Far detail listing of topo-graphic symbols used an large, medium, and small scole maps refer ta FM 21–31.

CHAPTER 12
RIGGING

For a complete discussion of rigging see TM 5–725.

12–1. KNOTS

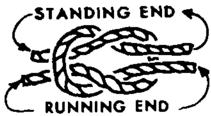
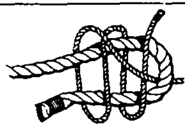
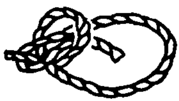
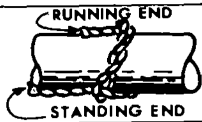
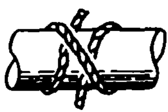
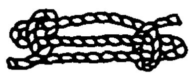
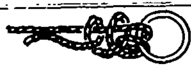
Name	Illustration	Use
Square		Join two ropes of same size. (Will not slip, but will draw tight under strain.) To end block lashing.
Double sheet bend		Join wet ropes, of unequal size, or rope to an eye. (Will not slip or draw tight under strain.)
Bowline		Form a loop. (Will not slip under strain and 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 andmay 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 12–1. Knots.

12–2. FIBER ROPES, WIRE ROPES, CHAINS, AND HOOKS

a. *Data.* See tables 12–1, 12–2, and 12–3 for data on manila and sisal rope, wire rope, and chains.

Table 12–1. Properties of Manila and Sisal Rope

Nominal diameter, in.	Circum-ference, in.	Lbs. per ft.	No. 1 manila: Breaking strength, tons	No. 1 manila: Safe working capacity tons (F.S. = 4)	Sisal: Breaking strength, tons	Sisal: Safe load, tons (F.S. = 4)
1/4	3/4	0.20	0.30	0.07	0.24	0.06
3/8	1 1/8	.040	0.67	0.16	0.54	0.13
1/2	1 1/2	.075	1.32	0.33	1.06	0.26
5/8	2	.133	2.20	0.60	1.76	0.44
3/4	2 1/4	.167	2.70	0.67	2.16	0.54
7/8	2 3/4	.186	3.85	0.96	3.08	0.77
1	3	.270	4.50	1.12	3.60	0.90
1 1/8	3 1/2	.360	6.00	1.50	4.80	1.20
1 1/4	3 3/4	.418	6.75	1.69	5.40	1.35
1 1/2	4 1/2	.600	9.25	2.31	7.40	1.85
1 3/4	5 1/2	.895	13.25	3.31	10.60	2.65
2	6	1.08	15.50	3.87	12.40	3.10
2 1/2	7 1/2	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 12–2. 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
1/4	0.10	1.4	2.6	2.39	2.74	....
3/8	0.23	2.1	4.0	5.31	6.10	7.55
1/2	0.40	3.6	6.8	9.35	10.7	13.3
5/8	0.63	5.5	10.4	14.5	16.7	20.6
3/4	0.90	7.9	14.8	20.7	23.8	29.4
7/8	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
1 1/8	2.03	17.2	32.7	45.7	52.6	65.0
1 1/4	2.50	21.0	40.6	56.2	64.6	79.9
1 1/2	3.60	29.7	56.6	80.0	92.0	114.0
1 3/4	....	....	....	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 1 1/4 inch, 6 x 7, Improved Plow Steel wire rope
Breaking strength of 6 x 19, 1 1/4 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

*Table 12–3. 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

b. Properties of Hooks.

(1) Slip hook.

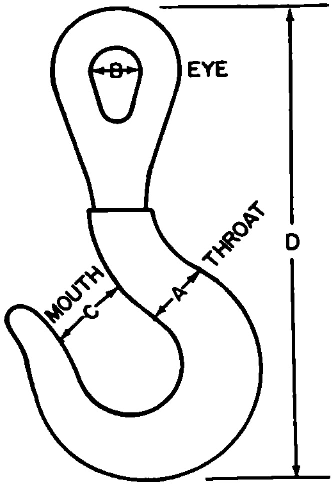


Figure 12–2. Slip hook.

(2) Safe loads for hooks are given in table 12–4.

Table 12–4. 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.
$\frac{11}{16}$	$\frac{7}{8}$	$1\frac{1}{16}$	$4\frac{15}{16}$	1,200
$\frac{3}{4}$	1	$1\frac{1}{8}$	$5\frac{13}{32}$	1,400
$\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$6\frac{1}{4}$	2,400
1	$1\frac{1}{4}$	$1\frac{3}{8}$	$6\frac{7}{8}$	3,400
$1\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$7\frac{5}{8}$	4,200
$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{11}{16}$	$8\frac{19}{32}$	5,000
$1\frac{3}{8}$	$1\frac{5}{8}$	$1\frac{7}{8}$	$9\frac{1}{2}$	6,000
$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{16}$	$10\frac{11}{32}$	8,000
$1\frac{5}{8}$	2	$2\frac{1}{4}$	$11\frac{27}{32}$	9,400
$1\frac{7}{8}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$13\frac{9}{32}$	11,000
$2\frac{1}{4}$	$2\frac{3}{4}$	3	$14\frac{13}{16}$	13,600
$2\frac{5}{8}$	$3\frac{1}{8}$	$3\frac{3}{8}$	$16\frac{1}{2}$	17,000
3	$3\frac{1}{2}$	4	$19\frac{3}{4}$	24,000

*For reference to A, B, C, or D, see figure 12–2.
Note Formula for safe work load for hooks: $T\ (tons) = D^2(in^2)$ ·

12–3. MECHANICAL ADVANTAGES OF VARIOUS BLOCK ARRANGEMENTS

a. *Blocks and Tackle.* Figure 12–3 shows examples of typical tackle systems. In a simple tackle with 2 lines leaving the load (1, fig. 12–3), the mechanical advantage is 2. In a simple tackle with three lines leaving the load (2, fig. 12–3), the mechanical advantage is 3. In a simple tackle, using 2 double blocks (3, fig. 12–3), with 5 lines leaving the load (3, fig. 12–3), the mechanical advantage is 5. In a compound system with 5 lines leaving the load (4, fig. 12–3), and the fall line of this tackle attached to a traveling block with 2 lines supporting it, the mechanicol odvantage is 2 times 5, or 10. A more complicoted compound system (5, fig. 12–3) is made up of twa simple systems, each af which has 4 lines supparting the load. The traveling block af the first simple system is fastened ta the fall line of the second simple system, and the mechanical advantage of this campaund system is 4 times 4, ar 16.

b. Chain Haists. With a chain hoist, a load can remoin statianary withaut requiring attention, and the hoist can be aperated by ane man to raise loads af severol tons.

c. Determining Actual Pull.

FL = friction loss, the amount of farce lost ta friction in the system.

AP = actual pull, the amount of farce required on the fall line to lift the laad.

Ff = friction foctor, varies with canditions of the blocks.

$1/10$, excellent condition (new)

$1/8$, gaod condition

$1/5$, fair condition

N_S = number of sheaves, tatal number af sheaves in the system including change af directian blacks.

MA = theoretical mechanical advantage

W_L = weight of the laad

Example: Assume $W_L = 2500$ lbs

$N_S = 6$

$MA = 6:1$

$Ff = 1/5$

Then $FL = W_L + N_S + Ff$

$= 2500 \text{ lbs } (6)\ (\tfrac{1}{5})$

$= 3000$ lbs

And $AP = W_L + FL$

$$= \frac{2500 + 3000}{6}$$

$= 916.67$ lbs

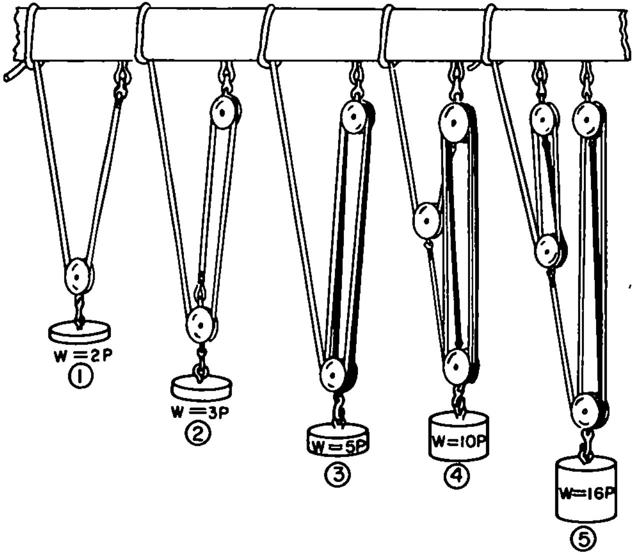


Figure 12–3. Mechanicol advantage af various tackle riggings.

12–4. PICKET HOLDFAST

a. *Holding Power.* Sound pickets 5 feet long driven 3 feet into the earth, spaced 3 to 6 feet apart, and inclined away from the laad at an angle af 15° should stond the pull indicoted in table 12–5.

Table 12–5. Holdfast Capacities

Type of holdfast	Undis-turbed eorth	Wet clay and gravel	Wet river clay and sond
Single picket	700	630	350
1–1 Picket holdfast	1400	1260	700
1–1–1 Picket holdfast	1800	1620	900
2–1 Picket holdfast	2000	1800	1000
3–2–1 Picket haldfast	4000	3600	2000

b. *Picket Haldfast, 1–1–1 Cambination.*

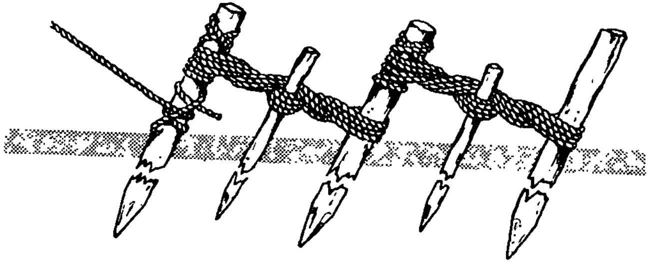


Figure 12–4. Picket holdfast 1–1–1 cambinotian.

c. *Picket Holdfost, 3–2–1 Combinatian.*

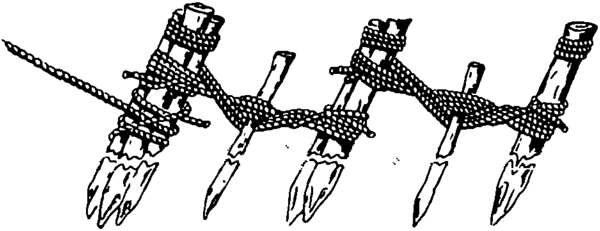


Figure 12–5. Picket holdfast, 3–2–1 combination.

12–5. DEADMEN

a. *Log Deadman* (fig. 12–6).

b. *Steel Beam Deadman* (fig. 12–7).

c. *Holding Power of Deadmen in Ordinary Earth.*

(1) Log Deadman

Symbols for figure 12–6 and the formulas below are:

T = tension (breaking strength of rope)
MD = mean depth (you select)
SR = slope ratio ($\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, 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 12–5)
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)
D = timber diameter (you select)
L = timber length (see formula in (2) below)

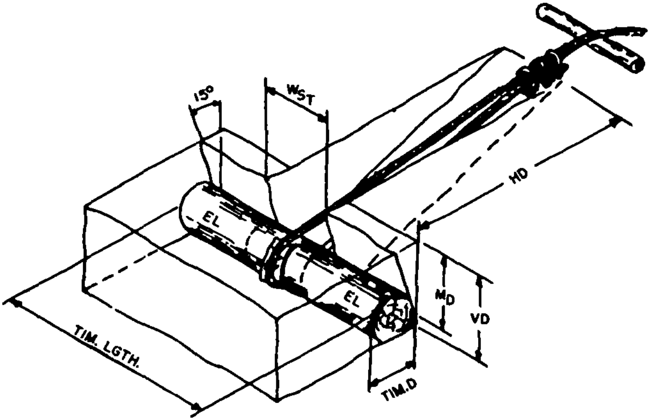


Figure 12–6. Log deadman.

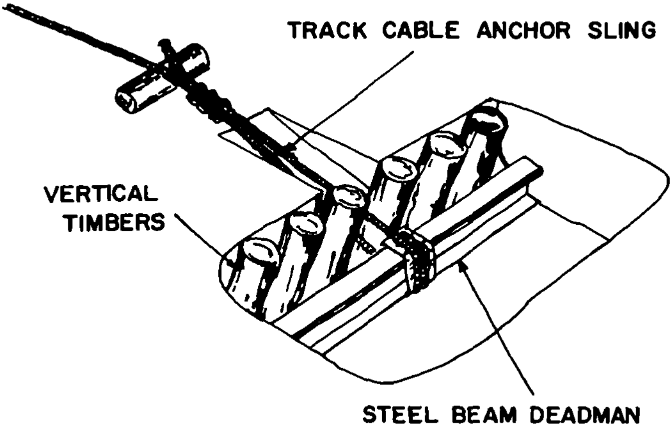


Figure 12–7. Steel beam deadman.

Toble 12–6. Halding Power of Deodmen in Ordinory Eorth

Mean depth af ancharage, ft	Safe resistance far inclination of pull (vertical or horizontal) af prajected area of deadman, lbs per sq ft.				
	Verticol	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

(2) *Farmulas.*

(a) $8Ar = \frac{T}{HP}$ (in lbs)

(b) $EL = \frac{8Ar}{D}$

(c) $L = EL + WST$

(d) $VD = MD + \left(\frac{D}{2}\right)$

(e) $HD = \frac{VD}{SR}$

(3) *Prablems.*

Given: $T = 1$ in. wire rope I.P.S. (improved plow steel)

Given	Find:
$MD = 7$ ft.	8Ar
$SR = \frac{1}{4}$	EL
$HP = 8{,}400$ lb. (table 12–5)	L
$WST = 1\frac{1}{2}$ ft.	VD
$D = 2$ ft.	HD

Solution:

$$BAr = \frac{84{,}000}{8{,}400} = 10 \text{ sq. ft.}$$

$$EL = \frac{10}{2} = 5 \text{ ft.}$$

$$L = 5 \text{ ft.} + 1\tfrac{1}{2} \text{ ft.} = 6\tfrac{1}{2} \text{ ft.}$$

$$VD = 7 \text{ ft.} + \frac{2 \text{ ft.}}{2} = 8 \text{ ft.}$$

$$HD = \frac{8}{\frac{1}{4}} = 32 \text{ ft.}$$

12–6. ATTACHMENTS

o. *Clips.* Clips* ore used in moking eyes in wire rape. The correct methad of attaching clips is shown in figure 12–8. The base of each clip shauld bear against the line, ar lang rape, end, and the U-bolt shauld bear against the dead, or shart, end. Space the clips six rape diameters apart; the number of clips equols three times the rope diameter (in inches) plus ane. If this calculatian results in o froction, use the next larger whole number. Never use less than three clips per cannectian. For example, an a $\frac{3}{4}$-inch rope:

No. af clips $= 3D + 1$ (minimum of 3 clips)
$= (3 \times \frac{3}{4}) + 1$
$= 3\frac{1}{4}$, or 4

Spocing of clips $= 6D = 6 \times \frac{3}{4} = 4\frac{1}{2}$ in.

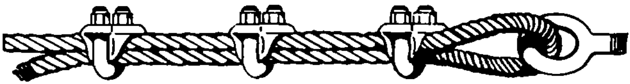


Figure 12–8. Wire rope clips.

b. Clamps. Figure 12–9 shows how to apply o wire rope clamp. Slip the two end collars of the clamp on the rope, facing eoch 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.

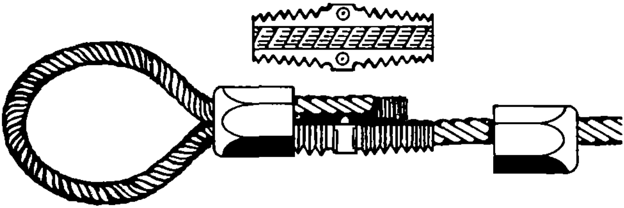


Figure 12–9. Wire rope clamp.

c. *Wedge Socket.* This fitting is shown in figure 12–10. It is used when the fitting must be changed at frequent intervals. This socket has two ports, 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 o loop of wire rope through the tapered opening from the bottom of the socket up. Ploce the wedge through the loop and pull the ends of the wire rope back through the topered 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.

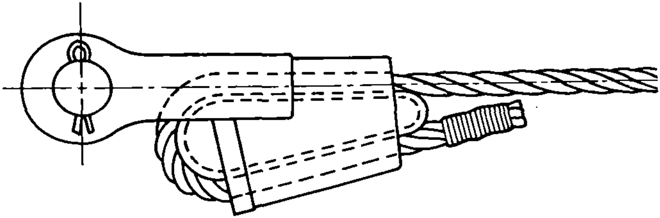


Figure 12–10. Wedge socket and fitting.

12–7. SAFE CAPACITY OF SPRUCE TIMBER AS A GIN POLE

See table 12–7 for these capacities. Weight of timber is 40 pounds per cubic foot.

Table 12–7. 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.

12–8. SLINGS

o. *Single Slings*. See figure 12–11 for components of a single sling.

(1) A basket hitch hos o single sling passed under the laod and both ends hooked aver the haisting hook (A, fig. 12–12).

(2) Single slings with twa haaks ore sametimes used for lifting stone (B, fig. 12–12).

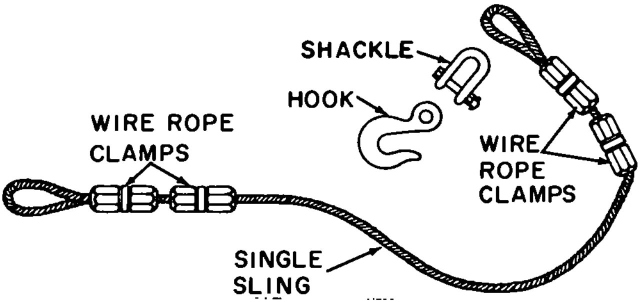


Figure 12–11. Single sling components.

(3) The dauble anchor hitch is used sometimes for hoisting cylindrical abjects (C, fig. 12–12).

b. *Endless Slings*.

(1) The anchor, ar chaker, hitch is a common methad af using an endless sling by casting the sling under the laad and inserting one laap thraugh the ather and aver the hoisting hook (D, fig. 12–12).

(2) For a basket hitch, the endless sling is passed oraund the object and both remaining loops are slipped on the hook (E, fig. 12–12).

(3) The taggle hitch is o madificatian af the basket hitch and is used only for special applicatian (F, fig. 12–12).

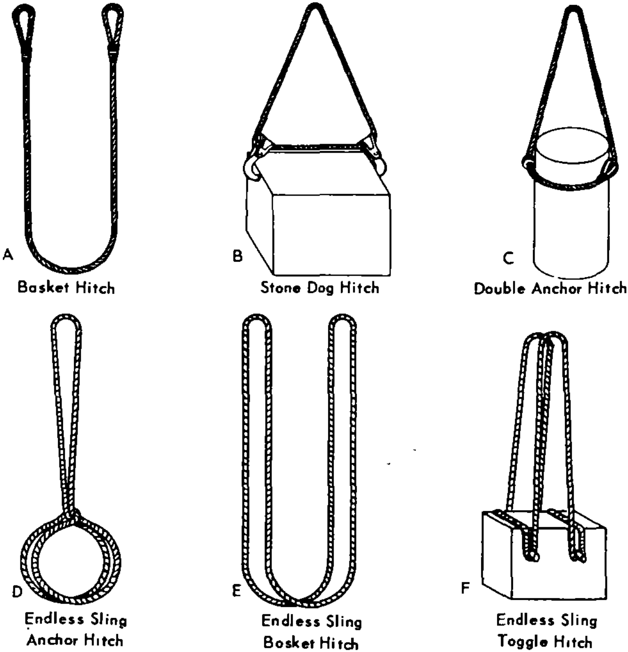


Figure 12–12. Hitches.

12–9. SLING LOAD FORMULA

a. *Stress.* The stress of tension in each leg of a sling depends on the number of legs, the angle of the sling leg, and the total load.

b. *Formula.*

$$T=\frac{W}{N}\times\frac{L}{V}$$

where T = tension, in pounds
N = number of legs
W = weight, in pounds
V = vertical distance, in feet
L = length of leg, in feet

c. *Problem.* Is it safe to use a $\frac{3}{4}$-inch diameter manila 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 (fig. 12–13)?

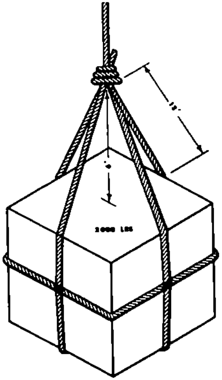


Figure 12–13. Sling stresses.

$$T = \frac{W}{N} \times \frac{L}{V}$$

$$T = \frac{2{,}000}{4} \times \frac{12}{6} = 1{,}000 \text{ pounds}$$

The tension on each leg will be 1,000 pounds. The safe working capacity of $\frac{3}{4}$-inch diameter manila rope from table 12–1 is 0.67 tons or 1340 pounds. Since the safe working capacity is greater than the tension, the rope is safe to use.

12–10. HELICOPTER SLING DESIGN

a. *Strength of Sling.*

(1) For a single leg sling the minimum safe load capacity of the sling should be twice the weight of the load.

(2) For a multiple leg sling each leg should have as a minimum safe load capacity the weight of the load.

b. *Helicopter Sling Length.*

(1) For a short haul the length of each sling leg should be the same as the greatest dimension of the load. (*L* max)

(2) For a long haul: the length of the rear sling legs should be the same as the greatest dimension of the load (*L* max); the length of the front sling legs should be .82 times the greatest dimension of the load (.82 *L* max).

c. *Stabilization of Loads.* Helicopter sling loads are stabilized by one or more of the following methods:

(1) Reduce the airspeed of the helicopter.

(2) Increase the weight of the load.

(3) Reduce the drag surface by adjusting the relationship between the center of gravity and the center of air pressure of the suspended load so as to assure that the narrowest load surface points in the direction of flight. This effect is obtained by either adding surface to the rear of the load or adding weight to the front. The general rule is that the load will be stable at normal helicopter speed when the center of gravity of the load is located at the front of the surface area.

d. *Safety.*

(1) Place padding on sling where rubbing may occur.

(2) To prevent in-flight "flapping" of prefabricated nylon, nylon slings, twist each sling leg one turn for every three (3) feet of length.

(3) It may be desirable to use clevises to attach sling legs to the load.

12–11. GROUND CREW

a. *Positioning.* See figure 12–14.

b. *Hand Signals.* See figure 12–15.

c. *Safety.* Police area thoroughly.

(1) Ground personnel should wear:

(a) Steel helmet.

(b) Protective mask, or dust goggles with respirator.

(c) Earplugs.

(2) Helicopters acquire a large charge of static electricity during flight. A static discharge probe, which is not issued, is used to neutralize the charge. The probe consists of an insulated contact rod joined to a 15'–25' length of metallic tape or wire, which in turn is attached to a ground rod. The ground rod is driven into the earth and the contact rod is held by a ground crewman and touched to the helicopter hook

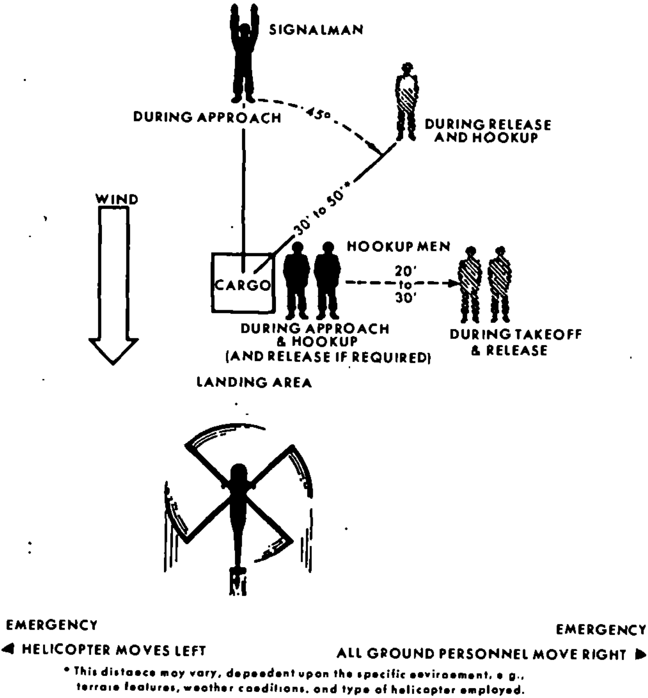


Figure 12–14. Position diagram for hook-up/release of helicopters sling loads.

Figure 12–15. Hand signals.

12–12. SHEARS

o. *Moteriols*. Sheors ore used to erect heovy mochinery ond bulky objects. Figure 12–16 shows the proper construction of sheors Sheors must be guyed to hold their position. They ore designed to work inclined from the verticol. Moximum sheor leg length is 60 times the leost diometer of the leg. This rotio must be reduced for extremely heovy loods.

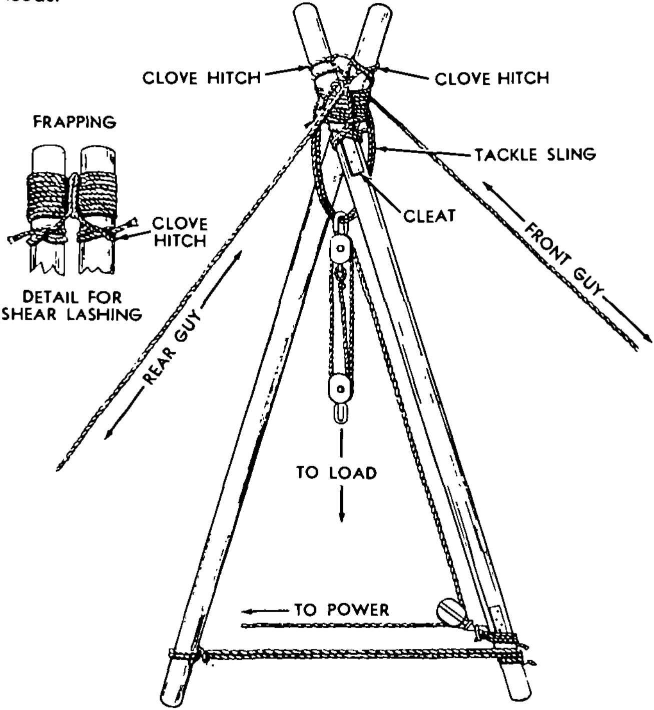


Figure 12–16. Loshing for sheors.

b. Erection. Holes should be dug and the shear legs placed in them. This will prevent spreading of legs. On hard surfaces, the legs should be level and lashed together to prevent spreading.

12–13. GIN POLE

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 (fig. 12–17)

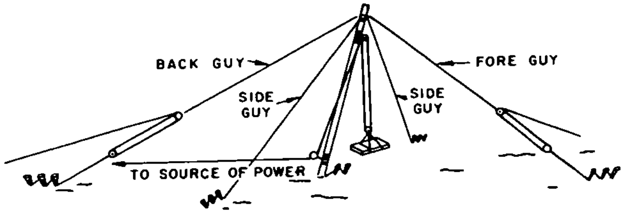


Figure 12–17. Gin pole ready for operation.

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 12–17 shows the gin pole in position for operation, while the necessary rigging is illustrated in figure 12–18. The maximum allowable length is 60 times the minimum diameter. Guys are 3 to 4 times the pole length.

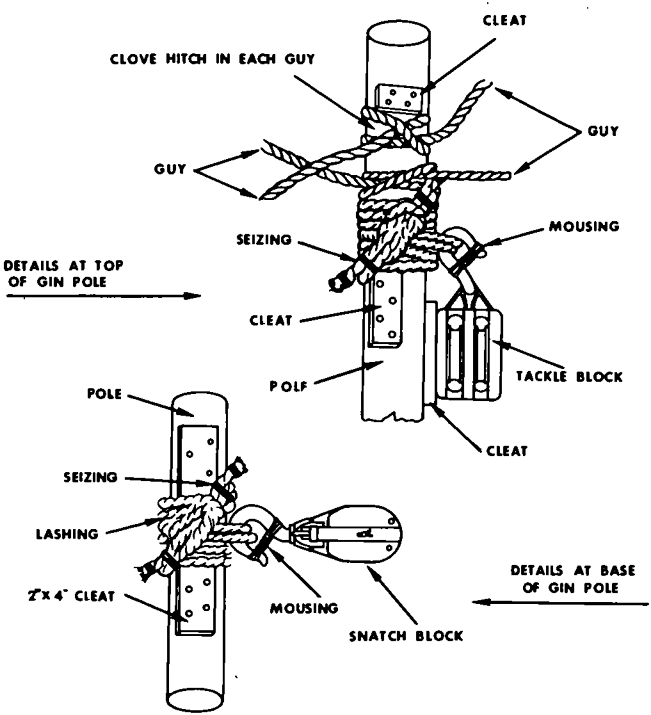


Figure 12–18. Lashing for a gin pole.

12–14. 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 ond flotcors, and for use on docks or piers. Figure 12–19 shows the boom derrick in position for operotion.

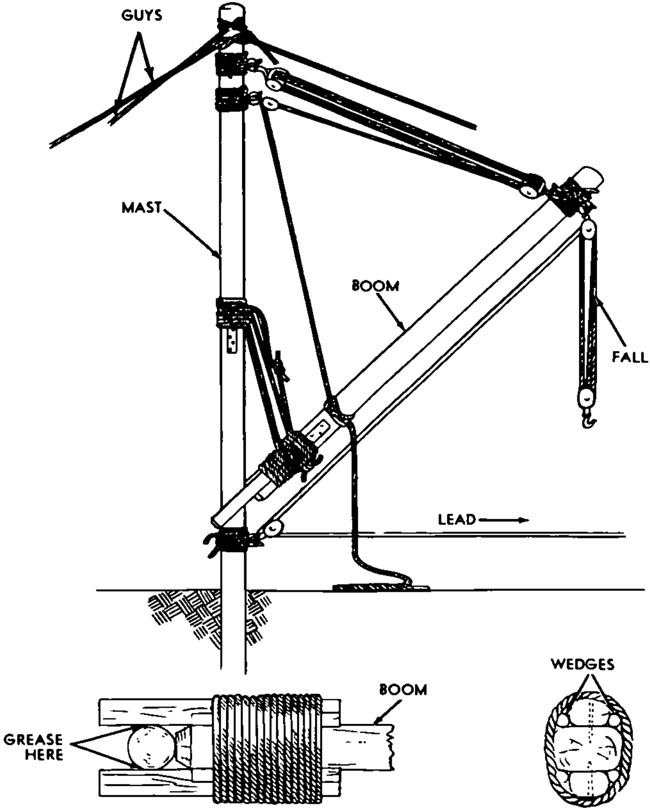


Figure 12–19. Boom derrick.

12–15. GUY LINE TENSION FOR SHEARS AND GIN POLES

a. *Tensions.* 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 following formula.

$$T = \frac{(W_L + \frac{1}{2} W_S)\, D}{Y}.$$

Where:

T = tension in guyline
W_L = weight of load
W_S = weight of spar
D = drift distance
Y = perpendicular distance

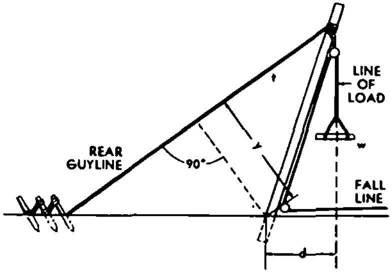


Figure 12–20. Computing tension in single guylines.

b. *Example Problem.*

Given:
Load = 2,500 lbs
Weight of spar = 800 lbs.
Drift distance = 10 feet
Y-distance = 20 feet

Solution:

$$T = \frac{(2{,}500 + \frac{1}{2}[800])\ 10}{20}$$

$$T = 1{,}450 \text{ lbs.}$$

12–16. HIGHLINE

The highline is a trolley line passing through a snatch block at each suppart (fig. 12—20). It is the type most commanly erected at the plotaan level.

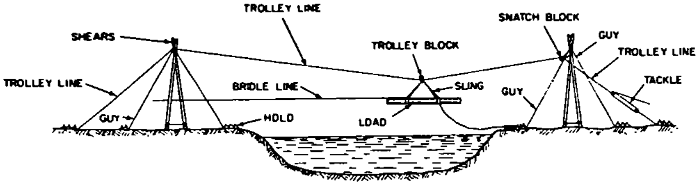


Figure 12—21. Highline.

o. *Sag.* The sag in the track cable when loaded shauld be not less than 5 percent of the span.

b. Farmulo for Safelaad Highline.

$$SL = \frac{BS\ (\text{lbs})}{5 \times SF} - \frac{DL\ (\text{lbs})}{2}$$

Where: SL = safeload
$8S$ = breoking strength af line
DL = dead laad
SF = safety factor

Prablem: Span is 400 feet
Track line is ¾-inch diameter manila rape
Haul line is ½-inch diameter monila rope
Sofety foctor is 4.0
Track cable sog is 5 percent

Solutian. $8S$ (breaking strength) far ¾-inch diameter-manila rope = 5,400 pounds.
W (¾-inch rope) = 66.8 pounds/400 feet (table 12—1)
W (½-inch rape) = 60 paunds/800 feet (table 12—1)

Therefore: $$SL = \frac{5{,}400}{5 \times 4.0} - \frac{66.8}{2}$$
$$SL = 270 - 33.4$$
$$SL = 236.6 \text{ pounds}$$

Far the poyload, use the formula:
$PL = SL - (1/2W$ qf haul rape $+ W$ af troveler $+ W$ of carrier)

For this prablem, this would mean:
$PL = 236.6 -$ (30 plus the weight af the traveler and carrier)

Note. Far infarmatian on suspension bridges see chapter 7.

CHAPTER 13

UTILIZATION OF HEAVY EQUIPMENT

13-1. CRAWLER AND RUBBER TIRED TRACTORS

a. The economical hauling distance for a dozer ranges from 25 to 300 feet.

b. Dozer output chart. See table 13-1.

c. The recommended uses of tractors to increase production are:

(1) *Slot dozing*. This is a method of digging and pushing material in the same path to reduce blade spillage. As the dozer cuts into the earth, windrows are built up acting as retaining walls to keep the material in front of the blade. Production may increase up to 30 percent.

(2) *Blade to blade dozing*. Using this method requires close coordination by the operators. The machines have to travel at the same speed and keep the blades together. Blade to blade dozing can produce 1 to 1.5 cubic yards more per pass in a range of 50-300 feet.

(3) *Downhill dozing*. The dozer should be operated downhill when possible. It will receive the benefit of gravity and be able to push a larger load.

Table 13-1. Data on Tractors

Model	Capacity in LCY*	Speeds in MPH		Fuel consumed per hr
		Low	High	
D8-9A	7.8	1.5	5.2	11
TD24	7.8	1.7	8.2	11
HD16	5.0	3.5	7.4	9
D7E	5.0	2.3	6.2	9
TD20	3.5	1.6	7.3	9
TD18	3.5	1.7	5.7	9
HD6M	2.6	1.5	6.5	7
D6S	2.8	2.0	7.0	7
830M	5.0	5 7	30	12
290M	5.0	5.1	32	12
MRS100	2.6	2.2	30	8

*Loose cubic yards

(4) *Back ripper attachments.* Standard military blades are 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 to loosen hard material, making it easier to obtain a full load on the forward portion of the cycle.

13-2. EARTH MOVING PRODUCTION FOR TRACTORS

a. Production for Tractors.

$$\text{Variable Time (Forward)} = \frac{\text{Distance in Ft}}{\text{MPH} \times 88}$$

$$\text{Variable Time (Return)} = \frac{\text{Distance in Ft}}{\text{MPH} \times 88}$$

$$\text{Hourly Production} = \frac{\text{EFF Hr} \times \text{Load Factor} \times \text{Blade Capacity}}{\text{Cycle Time}}$$

b. Production for Tractors with Treedozer Blades. Before committing a tractor equipped with the treedozer clearing blade, the soil condition in the proposed area of operation should be investigated to determine if it will support the equipment. The treedozer clearing blade can be used to make cuts through any kind of forest, except heavy swampland. Trees can be sheared at ground level, swept by the same machines into piles or windrows, and burned there. One tractor equipped with a treedozer clearing blade can clear approximately one to two acres per hour, depending on the density and size of the trees in the area. When the tractor can move forward almost continuously, shearing to ground level everything in its path, fast production can be obtained by laying out long areas, 200 to 400 feet wide, that can be cut from the outside toward the center in a counterclockwise direction. The cut material then slides off the trailing (right) end of the treedozer clearing blade and leaves the uncut area free of fallen debris. Occasionally the cut material will not shed, but will accumulate instead. When this occurs, the operator should make an immediate sharp turn to the right, followed by a sharp left turn, to resume the original line of travel. This causes the accumulated material to fall off without stopping the tractor. The windrows are placed lengthwise on the borders of the areas, and piling is done by sweeping with the treedozer clearing blade, a blade width at a time, working from the center of each area, at a right angle to the border, from left to right.

13–3. SCRAPERS

a. Crawler tractor-scraper combination can be efficiently operated from 300 to 1200 feet.

b. Rubber-tired tractor-scraper combinations can be efficiently operated from 1200 feet to infinity.

c. Methods of increasing scraper production are:

(1) *Downhill loading.*

(2) *Straddle loading.*

(a) Make two cuts, one on each side of a lane which is slightly smaller than the width of the scraper.

(*b*) On the third cut, strip the lane left by cuts one and two.

d. Push *Loading.*

(1) *Back track loading.* With this method, a tractor is used to push the loading tractor-scraper. It is good where the pushing tractor has to back only a short distance to get into position to push the next tractor-scraper.

(2) *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.

(3) *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

(4) *Traveling.* All loaded units should leave the cut area as fast as possible.

e. *Haul Road Maintenance.* All haul roads should be maintained with a grader to lower rolling resistance and increase the haul speed of earth-movers.

f. Rippers or Rooters. For ease in scraper loading rip soil prior to loading scrapers if required.

g. *Capacities of Scrapers.* See table 13–2.

13–4. 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, accelerat-

Table 13–2. Scraper Capacity

Make and model	Weight lbs	Capacity struck cu yds	Capacity heaped cu yds
Murray	11,700	7.5	9
LeTaurneau	30,500	18.9	24.1
Euclid	33,500	18	23
Curtiss-Wright	38,900	18.25	23.6

ing, decelerating and dumping. This time can be estimated in the field ar if na data is available table 13–3 may be used as a guide.

(2) *Variable time.* Variable time is determined by the farmula:

$$\text{Variable time (min)} = \frac{\text{haul distance (feet)}}{\text{speed (mph)} \times 88}$$

Speed is determined by haul raad canditians. This includes grade resistance, ralling resistance, and tractian. Far detailed calculatians see TM 5–331A. Assume high speed far haul raads with hard surface and slight grades, middle speed far average raad surface and medium grades, and lawest speed far paar raad surface and steep grades.

Table 13–3. Basic Fixed Time Canstants (Use as Guide Only)

Wheel scraper (with pusher):	Fixed time
	Minutes
4th gear haul	2.2
3rd gear haul	2.0
2nd gear haul	1.9
Track tractar with scraper:	
Self-laaded	2.5
Push-laaded	2.0

b. Determine Laad Capacity. See table 13–2.
c. Determine Efficiency Factar. See table 13–4.

Table 13–4. Efficiency Foctar Chort

	Type tractar	Warking hours	Efficiency foctor
Doy operation	Trock-type Wheel-type	50 min/hr 45 min/hr	0.83 0.75
Night aperatian	Trock-type Wheel-type	45 min/hr 40 min/hr	0.75 0.67

d. Estimate Praductian. Production (P) is estimoted by the farmula:

$$P = E \times \frac{L \times H}{C}$$

P = Praductian in bonk cu yd/unit/hr
E = Efficiency foctor
L = Laad factar
H = Heaped capocity (laose cu yds)
C = Cycle time (fixed ond variable)

e. *Estimote Job Durotian.* This is determined by the farmula:

$$\text{Jab duratian (hours)} = \frac{\text{Laad foctor} \times \text{Soil to be maved (yds)}}{\text{Loose cubic yords per haur}}$$

See table 13–5 far laod factors.

f. Example: How long will it take ta move 500 cubic yords af clay (in ploce), 5000 feet ane woy with on 830M rubber-tired troctar pulling a Curtiss-Wright scroper? The haul raod is paar, work during daylight, 45-minute warking hour.

(1) *Cycle time.* Fram table 13–3 fixed time = 1.9 min

$$\text{Variable time (min)} = \frac{5000 \text{ feet}}{5.7 \text{ mph} \times 88 \text{ feet per secand}} = 10 \text{ min}$$

Speed fram table 13–1
Cycle time = 1.9 min + 10 min = 11.9 min

(2) *Laod capocity.* Fram table 13–2 assume heaped capacity = 23.6 cu yds.

(3) *Efficiency factar.* From table 13–4 efficiency factar = 0.75.

Table 13–5. Load Factors (Estimated)

Sail type	Soil candition initially	In place	Laose	Compocted
Sand	In place		1.11	0.95
	Laose	.90		.86
	Compocted	1.05	1.17	
Loam	In ploce		1.25	0.90
	Loose	.80		.72
	Campacted	1.11	1.39	
Clay	In place		1.43	0.90
	Loose	.70		.63
	Campacted	1.11	1.59	
Rock (blasted)	In place		1.50	1.30
	Loose	.67		.87
	Compacted	.77	1.15	
Hard coral (dead) camporable to limestone	In place		1.50	1.30
	Loose	.67		.87
	Compacted	.77	1.16	

(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 yords of material per haur.

(5) *Time required to finish job.* From table 13–5, 1 cubic yard of in place clay equals 1.43 cubic yards of loose material.

$$\text{Job duration} = \frac{1.43 \times 500 \text{ cu yds}}{89 \text{ cubic yards per hour}}$$
$$= 8.05 \text{ hours or about 8 hours.}$$

13–5. EQUIPMENT UTILIZATION CHART

See table 13–6.

Table 13–6. Equipment Utilization

	clearing		stripping	finishing		compaction	sloping		haul or doze			spread		cut or ditch	
	very high no trees	heavy		fine	rough		hold	finish	short	medium	long	light	heavy	shallow	deep
motorized scraper	not applicable	not applicable	excellent	excellent	excellent	excellent	fair	fair	excellent	excellent	excellent	excellent	excellent	excellent	excellent
rubber-tired dozer	fair	not applicable	fair	not applicable	fair	excellent	fair	not applicable	excellent	excellent	fair	excellent	excellent	excellent	excellent
track-type tractor	excellent	excellent	excellent	fair	excellent	excellent	excellent	fair	excellent	not applicable	not applicable	excellent	excellent	excellent	excellent
tractor scraper	not applicable	not applicable	excellent	excellent	excellent	excellent	fair	fair	excellent	excellent	not applicable	excellent	excellent	excellent	excellent

Legend: excellent (hatched) fair (black) not applicable (white)

13–6. 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 13–7.

Table 13–7. 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

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-inch 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 13–8.

e. *Efficiency Factor for Graders.* For general grader production estimation, assume a 60-percent efficiency factor.

13–7. 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) Compaction is obtained with loads of not more than 7 tons.

(2) Compaction lifts should not exceed 6 inches.

Table 13–8. Production Capacities of the Grader

Operation	Rate per hour	Unit	Conditions
Ditching	250 150 85	cu yd cu yd cu yd	"V" ditching, easy digging "V" ditching, medium digging "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	200 450	cu yd cu yd	Spread material Shaping surface
Surface treatment	150	sq yd	Mixing in place 2-in bituminous material

(3) The 13-wheel roller is best in granular type soils.

(4) 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 unit pressure of tires and wheel load.

d. Steel Wheel Roller, 3-Wheel, 10-Ton.

(1) The 3-wheel, 10-Ton roller will compact up to a 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 base course material.

e. *9–14 Ton Roller.* The 9–14 ton roller is used only as a finish roller on materials such as asphalt.

13–8. EARTH LIFTING EQUIPMENT

a. *Shovel-Dipper Capacity in Cubic Yards.* See table 13–9.

Table 13–9. 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

b. *Short Boom Dragline Performance.* See table 13–10.

c. *Scoop Loader Production.* See table 13–11.

Table 13–10. 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 13–11. 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

13–9. PRODUCTIVE CAPACITY OF ENGINEER EQUIPMENT

When time does not permit calculation of production of engineer equipment table 13–12 may be used.

Table 13–12. Productive Capacity of Equipment

Equipment	Rate units per hour	Unit	Conditions
ORAINAGE OITCHES			
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	[1] MH/100 ft	V-ditches, 3 ft wide, 1 foot deep, easy digging
	9	MH/100 ft	V-ditches, 3 ft wide, 1 foot deep, medium hard digging
Oitching 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
Oitching machine, mobile	0–28	ft per min	Same as above, except 24 in wide
CLEARING ANO GRUBBING			
Hand tools	1½	MH/tree	3 man blasting team, good conditions
	125	MH/acre	Light clearing
	350	MH/acre	Medium clearing
	25	MH/100 lin yd	Light clearing, 30 ft wide
	70	MH/100 lin yd	Medium clearing, 30 ft wide
Crawler 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

[1] Manhours

Table 13–12—Continued

Equipment	Rate units per hour	Unit	Conditions
GRADING			
Crawler 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
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 13–12—Continued

Equipment	Rate units per hour	Unit	Conditions
SUBGRADE PREPARATION			
Grade, 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	2550	sq yd	0.1 gal per sq yd, 24-ft spray
Distributor, truck mounted	1250 (See TM 5–3895–201–10)	sq yd	0.2 gal per sq yd, 24-ft spray
Spreader, aggregate, tractor 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 13–12—Continued

Equipment	Rate units per hour	Unit	Conditions
			AGGREGATE PRODUCTION
Crusher, two-unit, 35 ton per hr	15	ton	1-in aggregate, screened [2]
	20	ton	1½-in aggregate, screened [2]
	45	ton	2½-in aggregate, screened [2]
Crusher, 75 tph	60	ton	1½-in aggregate, screened [2]
Crusher, 225 tph	110	ton	½-in aggregate, screened, washed [2]
	220	ton	1½-in aggregate, screened, washed [2]
Crusher 15 tph, Airborne	15	ton	1-in aggregate, crushed [2]
	25	ton	1½-in aggregate, crushed [2]
	38	ton	2-in aggregate, crushed [2]
Compressor, 210 cfm	210	cfm	At sea level
(Reciprocating)	194	cfm	5000 ft above sea level
Compressor, 250 cfm	250	cfm	At sea level
(Rotary)	250	cfm	5000 ft above sea level
Compressor, 600 cfm	600	cfm	At sea level
(Rotary)	600	cfm	5000 ft above sea level
Compressor, 210 cfm	210	cfm	At sea level
(Rotary)	210	cfm	5000 ft above sea level
Drill, rock, 35-lb class	20	lin ft	1¾-in hole, max depth 8 ft.[2] Requires 40 to 60 cfm of air
Drill, rock, 45-lb class	30	lin ft	1¾-in hole, max depth 12 ft.[2] Requires 70 to 90 cfm of air
Scoop leader, wheel 2 cu yd	200	cu yd	Truck loading [2]

[2] Production may vary + or − 25 percent depending upon the toughness of the rock

CHAPTER 14

FIELD SANITATION

14–1. SANITATION FACILITIES

For details on field sanitotion see FM 21–10

14–2. WASHING FACILITIES

a. Hand-washing devices should be set up near latrines and kitchens. See figure 14–1.

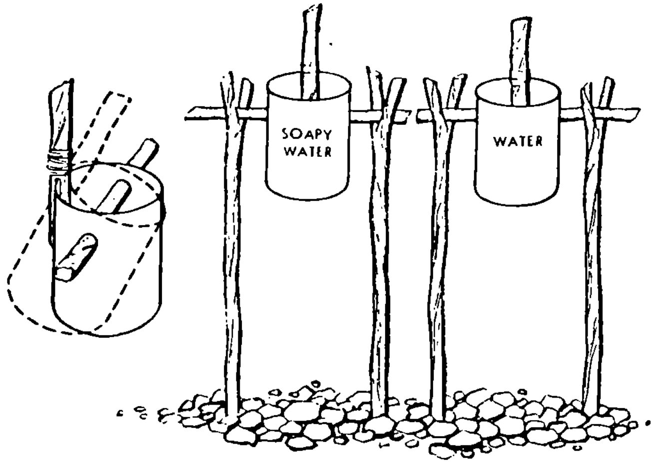


Figure 14–1. Hand-washing device, using number 10 can.

b. Showers should be set up whenever possible for personal hygiene and morale. See figure 14–2.

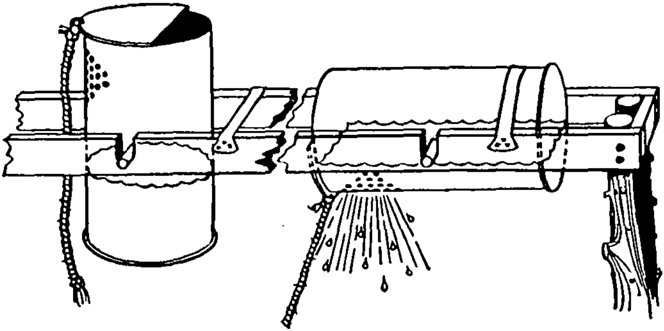


Figure 14–2. Shower unit, using metal drums.

14–3. WASTE DISPOSAL

a. *Latrines.*

(1) Size should be adequate to take care of at least 8 percent of the unit at once. Sixteen feet of straddle trench in four-foot sections, or two deep pit latrines with four-hole latrine boxes, is adequate for a 100-man unit.

(2) Locate at least 100 meters from kitchen, outside the cantonment area but inside the perimeter, and convenient to tents.

(3) See figures 14–3, 14–4, and 14–5.

(4) When filled to within 30-cm of ground level, or when abandoned, straddle trench latrines should be sprayed with insecticide, filled in, and mounded with a 60-cm overburden of compacted earth.

(5) Lime should be added to pit latrines daily. In closing a deep pit latrine, the level of excrement should not be closer than one meter from ground elevation.

(6) Pipe urinals should be maintained by periodically adding disinfectant to the urinal pipes and washing into the pit. Disinfectant should also be spread on the gravel around the pit area.

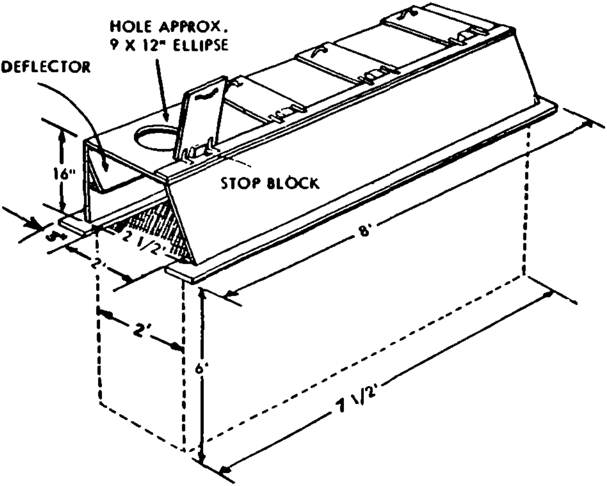


Figure 14–3. Box latrine for 50 men.

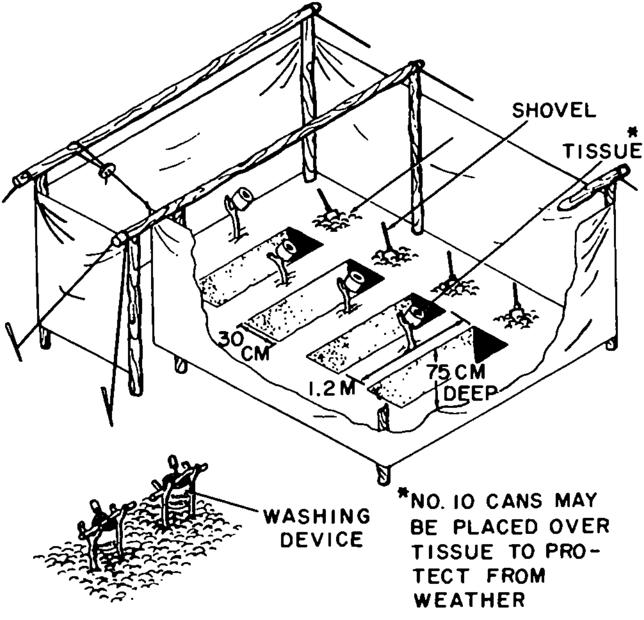


Figure 14–4. Straddle trench latrine for 100 men, with hand-washing device.

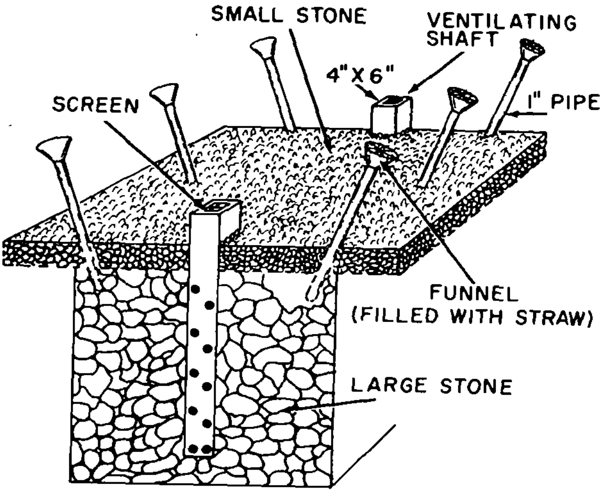


Figure 14–5. Pipe urinal arrangement.

(7) When high water tables preclude the use of pit latrines, burn-out latrines may be used. Half of a 55-gallon drum or barrel is installed under each hole in the latrine box (fig. 14–6). The drum is removed daily, fuel oil is added and the contents are burned to a dry ash. An inch of diesel fuel is added for insect control before replacing the drum in the latrine box.

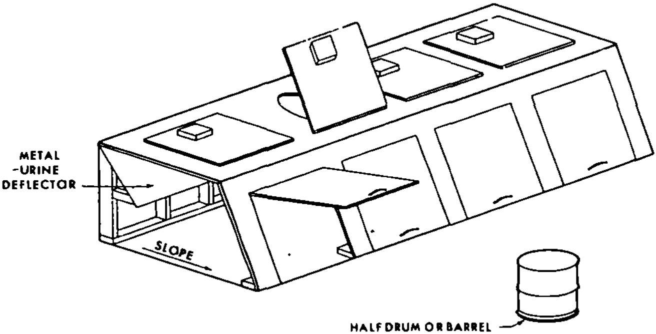


Figure 14–6. Burn-out latrine.

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 30-cm of ground level, or when abandoned, fill pit in and mound over with 60-cm overburden of compacted earth.

(4) Liquid kitchen wastes should never be dumped into garbage pits as this precludes effective burning out and shortens utilization for the pit.

c. *Soakage Pits*. Liquid kitchen wastes should be disposed of in soakage pits These should be located in the kitchen area. The soakage pit may be constructed the same as the urinal (fig. 14–5) except that a grease trap must be provided (fig. 14–7) and drainage provided to prevent surface runoff from filling up the pit. In constructing the pit, omit pipes and have drainage from grease pipe drain into pit.

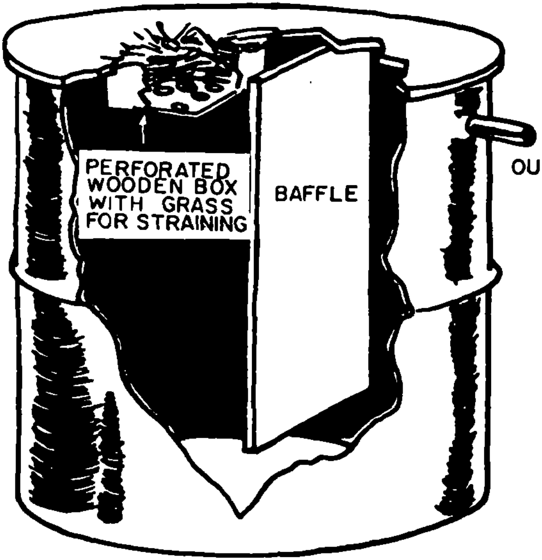


Figure 14–7. Baffle grease trap (barrel type).

CHAPTER 15

RECONNAISSANCE

15–1. ROUTE RECONNAISSANCE

o. *Definition.* Route recannoissance is gaverned by the same fundamentals that apply to oll recannaissance. Usually it is made an the ground, but it should be supplemented by air reconnaissance when procticoble. Route recannoissonce provides infarmatian ta aid in route selectian for the movement of troops, equipment, and supplies. Infarmation saught in this type of recannaissance includes:

(1) Nature of terrain.

(2) Existing raads and their characteristics, including load-bearing capabilities. See TM 5–330 for more detoiled information.

(3) Obstructions.

(4) Bridges and ather stream crassing means.

(5) Tunnels.

b. *Mission.* Raute recannaissance must consider the mission of the parent unit. Reconnaissance foctors include the weight, width, and height of the vehicles thot will be used; the classification of these vehicles; the appraximate number af each class ta be moved per hour; and the appraximote length of time the raute will be used.

c. *Report.* A recannaissance report shauld be accurate, cancise, and clear. The preferred methad of preparation is in simplified map farm or overlay (fig. 15–1), using symbols (toble 15–1) ta shaw the limiting features. A route recannaissance report is occompanied by an engineer recannaissance repart farm, a raad recannaissance repart and bridge, tunnel, ferry, and fard reconnaissonce reports as needed. Military sketches af limiting features, local mops, and phatagraphs of significant factors (terrain, raads, tunnels, bridges, ferries, fards, and so forth) support the route repart.

Table 15–1. Overlay Symbols

SYMBOLS FOR USE IN THE RECONNAISSANCE REPORT

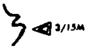
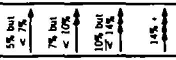
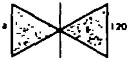
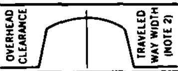
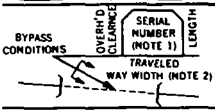
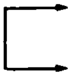
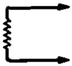
SYMBOL	DESCRIPTION & CRITERIA
	**SHARP CURVE:** (OB) Any radius less than or equal to 30 meters; however, any curve grester than 30 meters, but less than 45 meters is reportable.
	SERIES OF SHARP CURVES: The figure to the left indicstes the number of curves; thst to the right, the minimum rsdius of curvature in meters.
	**STEEP GRADES** (OB) Any grade 7% or higher *Actual % of grade will be shown Arrows* always point uphill and length of arrow represents length of grade if map scale permits
	**CONSTRUCTION** (OB) Any reduction in the traveled way below the standards of TABLE 15-2. The figure to the left indicstes the width of the constriction; that to the right, the total constricted length, both in meters.
	**UNDERPASSES** Show shape of structure (OB) when overhead clearance is less than 4.30M) or when the traveled way is below the standards of TABLE 15-3 See FIG 15-13, NOTE 4
	**TUNNEL.** (Includes manmade snowsheds) Show shape of structure (OB) when overhead clearance is less than 4.30M) or when the traveled way is below the standards of TABLE 15-3 See FIG 15-13, NOTE 4
	BYPASSES Are local alternate routes which enable traffic to avoid an obstruction Bypasses are classified as EASY DIFFICULT or IMPOSSIBLE Each type bypass is represented symbolically on the line extending from the symbol to the map location and defined as follows
	BYPASS EASY: The obstscle can be crossed within the immediste vicinity by a US 2.5 ton truck (or NATO equivalent) without work to improve the bypass.
	BYPASS DIFFICULT: The obstacle can be crossed within the immediate vicinity, but some work will be necessary to prepare the bypass.

Table 15-1—Continued

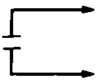
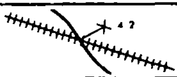
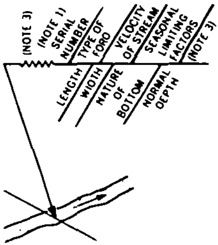
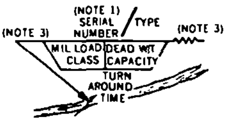
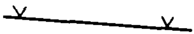
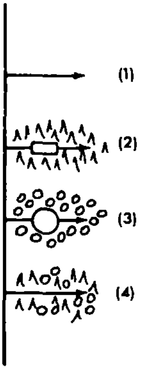
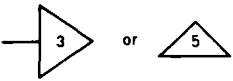
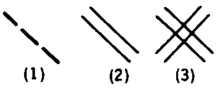
SYMBOL	DESCRIPTION & CRITERIA
	**BYPASS IMPOSSIBLE** The obstacle can only be crossed by one of the following methods: (1) Repair of item; i.e., bridge (2) New construction (3) Detour using an alternate route which crosses the obstacle some distance away.
	**RAILROAD (RR) LEVEL GRADE CROSSING** Passing trains will interrupt traffic flow The figure indicates overhead clearance.
	**FORD** All fords are considered as obstructions (OB) to traffic. Trafficability conditions shown in TABLE 15-5 **Type of Ford** V-Vehicular P-Pedestrian **Seasonal Limiting Factors** X—No seasonal limitation except for limited duration sudden flooding Y—Significant seasonal limitations **Approach Conditions** -^v^v- Difficult —— Easy **Nature of bottom:** M—Mud C—Clay S—Sand G—Gravel R—Rock P—Artificial Paving
	**FERRY.** All ferries are considered as obstructions (OB) to traffic **Approach Conditions** -^v^v- Difficult —— Easy **Type of Ferry** V-Vehicular Ferry P-Pedestrian Ferry
	**LIMITS OF SECTOR** Limits of reconnoitered sector or of route having the same road classification formula

Table 15–1—Continued

SYMBOL	DESCRIPTION & CRITERIA
(495)	**ROUTE DESIGNATION** Civil or Military Route Designation Written in parentheses along route
	**OFF-ROUTE MOVEMENT (TURN OFF'S) & CONCEALMENT (arrows point to left or right of road where turn off exists)**· (1) Possible turn off. (2) Tracked vehicle turn off with coniferous concealment. (3) Wheeled vehicle turn off with deciduous concealment. (4) Possible turn off in mixed concealment.
	**CRITICAL POINTS**· are used as numbered keys to describe in detail on attached reconnaissance forms or documents, those features that cannot be adequately covered by other reconnaissance symbols on the overlay
	**OBSTACLES (road blocks, craters, blown bridges, landslides, etc.):** 1 Proposed obstacle 2 Prepared but passable obstacle 3 Completed obstacle
?	**UNKNOWN OR DOUBTFUL INFORMATION**: Used in all symbols where information is not known or doubtful

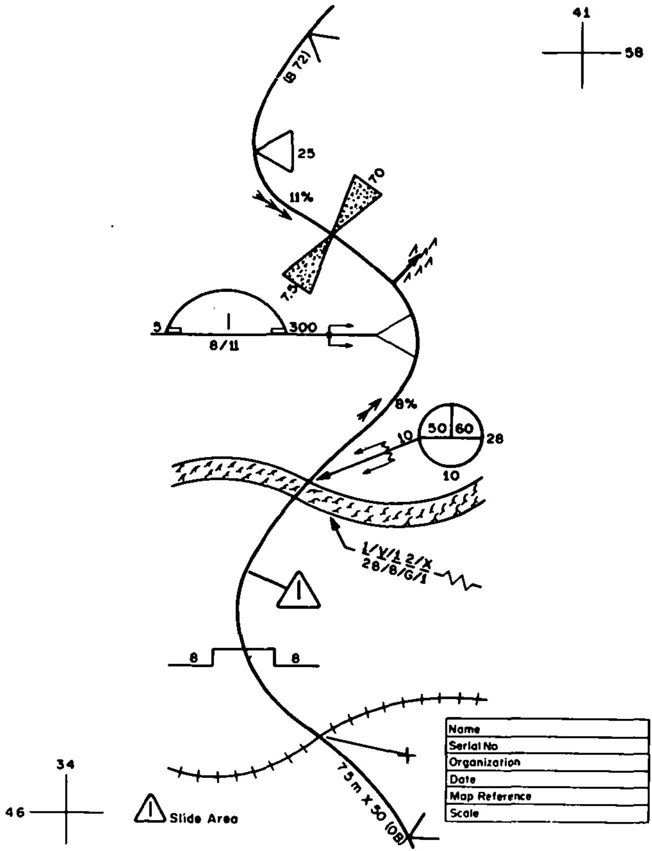


Figure 15–1. Example of a route reconnaissance overlay.

d. *Overlay.* Impartant features to be included an an averlay are shown belaw. The first five items are required:

(1) Twa grid references.

(2) Magnetic north arrow.

(3) Raute drawn ta scale.

(4) Title black.

(5) Raute classification farmula.

(6) Length (in kilameters) between well morked points.

(7) Curves having radii af less than 45 meters ar 150 feet.

(8) Steep grades, with their maximum gradients in percent, and length af any grade af 5 percent ar greater

(9) Road width of constrictians (bridges, tunnels ond sa forth), with the widths and lengths af the traveled ways in meters.

(10) Underpass limitatians, with their limiting heights and widths in meters.

(11) Bridge bypasses, classified as eosy, difficult, or impassible (para. 15–1c).

(12) Civil ar military raod numbers, or other designatians.

(13) Feasibility af driving aff raads, including shaulders.

(14) Lacotians of fards, ferries, ond tunnels including limiting infarmation.

(15) When causeways, snawsheds, and galleries constitute an obstructian ta traffic they shauld be included in the raute recannaissance report. Limit the dato to clearances and laad-carrying capacity. If possible, support the infarmation with photographs or sketches af each structure. Alsa, include enough descriptive informatian ta permit on evaluation concerning the strengthening ar remaval of these structures.

e. *Route Classificatian Farmula.* It is a standardized sequence af traveled woy width, raute type, lowest military laad classificatian, abstructians if present, and speciol conditians if present. The route classification formulo is required for the map averlay (fig. 15–1).

(1) *Width.* Narrawest width af the raute expressed in meters ar feets.

(2) *Route type.* Determined by worst section of the route.

(a) (X) All-weather. Any raod which, with reosanable maintenonce, is passable thraughaut the yeor to a valume of traffic never oppreciably less than its maximum capocity. This type af raad has a waterproof surface and is only slightly affected by rain, frast, thaw, or heat. At na time is it clased ta traffic due to weather effects other thon snaw blackoge. The following are exomples af this categary: cancrete; bituminous; brick or stane.

(b) (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 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 metaled surface.

(c) (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.

(3) *Military route classification.* Normally it is the lowest bridge load classification number of the route. If no bridges occur, the worst section of the route governs.

(4) *Obstructions (OB).* Any factors which restrict the type, amount, or speed of traffic flow, e.g., overhead clearances, traveled way widths, steep gradients, sharp curves, ferries, and fords may cause obstructions, denoted by (OB) in the route classification formula. Consult tables 15–1 and 15–2 for limiting values.

(5) *Special conditions.* Snow blockage (T) and flooding (W) are used when the condition is regular, recurrent, and serious.

Examples:

6.7 m Y 30. Route is 6.7 meters wide, limited all-weather route with a load carrying capacity of class 30 with no obstructions.

21 ft 10(OB)(W). Route is 21 feet wide, fair weather route with load carrying capacity of class 10. Obstructions do exist, and route is subject to flooding.

15–2. ROAD RECONNAISSANCE

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 purpose is to find out the quantity and kind of loads that a road can accommodate in its present condition. It may also include estimates of the effort necessary to improve and/or maintain a road subjected to specific traffic for a definite period of time. An example of a road reconnaissance report (DA Form 1248) is shown in figures 15–2 and 15–3.

Table 15–2. Critical Dimensions for Route Classification

– MINIMUM OVERHEAD CLEARANCES FOR BRIDGES

Bridge classification	Minimum overhead clearance
Up to 70	4.30 meters (14 ft-0 in)
Above 70	4.70 meters (15 ft-6 in)

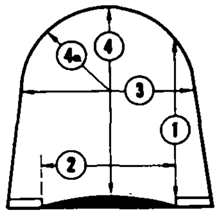
– MINIMUM ROUTE WIDTHS FOR BRIDGES

Bridge classification	Minimum width between curbs	
	One lane (meters)	Two lane (meters)
4-12	2.75 (9'-0")	5.50 (18'-0")
13-30	3.35 (11'-0")	5.50 (18'-0")
31-60	4 00 (13'-2")	7.30 (24'-0")
61-100	4.50 (14'-9")	8 20 (27'-0")

– ROUTE WIDTHS

Traffic flow possibilities	Widths for wheeled vehicles	Widths for tracked vehicles
Single flow	5 50 meters to 7 meters (18 ft to 23 ft)	6 meters to 8 meters (19½ ft to 26 ft)
Double flow	Over 7 meters (23 ft)	Over 8 meters (26 ft)

Measuring width of roadway and horizontal and vertical clearances for tunnels underpasses, and through truss bridges



1 Minimum overhead clearance measured vertically from edge of traveled way
2 Effective width of the traveled way, curb-to-curb
3 Horizontal clearance, is the minimum width measured at least four feet above the traveled way
4 Maximum overhead clearance, is the minimum distance between the top of the traveled way and the lower edge of the overhead, or any obstruction below the overhead, such as trolley wires or electric light wires
4a Rise of arch (radius of curved portion)

ROAD RECONNAISSANCE REPORT (FM 5-36)

DATE: 25 JUN 68

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: VIRGINIA, ALLANDALE — b. SCALE: 1:25,000 — c. SHEET NUMBER OF MAPS: US SHEET 5561 I S.W. AMS V834

2. DATE/TIME GROUP (Of signature): 1Ø123ØZ JUN68

SECTION I - GENERAL ROAD INFORMATION

3. ROAD GRID REFERENCE — FROM: 1Ø5155 — TO: 119169

4. ROAD MARKING (Civilian or Military number of road): FAIRFAX Co. #644

5. LENGTH OF ROAD (Miles or kilometers, specify): 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 68

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. ALIGNMENT (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):
- [ ] (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

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 66 1248

For use of this form, see FM 5-36, the proponent agency is the United States Army Combat Developments Command

Figure 15–2. Road reconnaissance report (front).

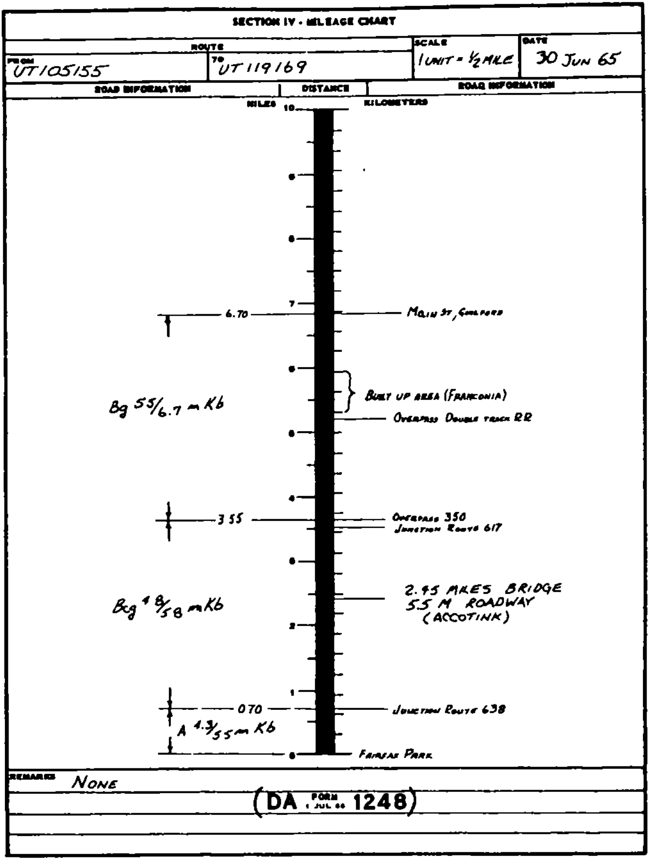


Figure 15–3. Road reconnoissance report (bock).

a. Information required—

(1) Local name of road and/or designation.

(2) Location of road by map grid reference.

(3) Obstructions, which include, among other items, underpasses, fords, large tree limbs, craters, projecting buildings, areas subject to inundation, and so forth.

(4) Bridge locations. (Bridge reconnaissance is outlined in para 15–13.)

(5) Tunnel locations, together with their lengths, widths, and heights. (Tunnel reconnaissance is described in para 15–5 and table 15–1.)

(6) Snowshed locations and estimated coverage.

(7) Gallery locations, together with their lengths, widths, and heights.

(8) Other requirements are listed in paragraph 15–1c.

b. *Road Classification Formula.* The road classification formula is expressed in a standardized sequence of a prefix, limiting characteristics at present, width of the traveled way/combined width of the traveled way and the shoulders, road surface material, length if desired, obstructions if present, and special conditions if present.

(1) *Prefix.* The formula is prefixed by the letter "A" if there are no limiting characteristics. The letter "B" is the prefix if there are any limiting characteristics.

(2) *Limiting characteristics.*	*Symbol*
Curves (radius less than 30m)............................	c
Gradients (7% or more)..................................	g
Drainage (inadequate)...................................	d
Foundation (unstable)...................................	f
Surface Condition (rough)..............................	s
Camber or superelevation (excessive)...................	j

An unknown or undetermined characteristic is represented by a question mark following the symbol of the feature to which it refers, e.g., (d?).

(3) *Width.* Width of the traveled way is expressed in meters followed by a slash and the combined width of the traveled way and the shoulders, e.g., 14/16.

(4) *Road surfoce material.* Road surfoce moterial is expressed by a letter symbol as follows:

Symbol	*Material*
k	Concrete
kb	Bituminous or asphaltic concrete (bituminous plant mix).
nb	Bituminous surface treatment on natural earth, stabilized soil, sand-clay or other select material.
b	Used when type of bituminous construction cannot be determined.
pb	Bituminous surface on paving brick or stone
rb	Bitumen-penetrated macadam water-bound macadam with superficial aspholt ar tar caver.
p	Paving brick or stone
r	Waterbound macadam, crushed rock, or coral
l	Gravel or lightly metaled surface
n	Natural earth, stabilized soil, sand-clay, shell cinders, disintegrated granite, or other select material.
v	Various other types not mentioned above (indicate length when this symbol is used).

(5) *Length.* Length af road in km may or may nat be shown. If shown place in porentheses, e.g., (7.2 km).

(6) *Obstructions.* Expressed as (OB) when existing on road, e.g., overhead clearances less than 4.30 m, reduction in the traveled way widths below the standards of (table 15–2), gradients of 7 percent or greater, and curves with a radii less than 30 m (100 ft).

(7) *Special conditions.* Snow blockage (T) and flooding (W) are used when the condition is regular, recurrent, and serious.

Exomples:

A 5.4/6.2 k: Road has no limiting characteristics with 5.4 m traveled way, combined width of 6.2 m traveled way and shoulder, and o concrete surface.

Bcgs 14/16 (2.4 km)(OB): Road has limiting characteristics of sharp curves, steep grades, and a rough surface condition; 4.3 m of clear traveled way, 4.9 m combined with shoulders; a graveled or lightly metoled surface, 2.4 km length; obstructions ore present-

Bcgd (f?)s 3.2/4.B nb (4.3 km) (OB)(T): Road has limiting charocteristics of shorp curves, steep grades, bad drainage, unknown foundation condition, and rough surface; 3.2 m wide traveled way, 4.8 m wide with shoulder; a bituminous surface treatment; 4.3 km long, and it contains obstructions. The road is subject to snow blockage.

c. *Measuring Radii of Curves.*

(1) A method of determining the radius of a curve is based on the formula —

$$R=\frac{c^2}{8m}+\frac{m}{2}\ \text{(fig. 15–4)}$$

Where:

c = length of cord

m = perpendicular distance from center of cord to centerline (℄) of road

R = radius of circle

By fixing m at any convenient distance, such as 2 meters, the formula becomes —

$$R=\frac{c^2}{16}+1$$

Note: Convert R, c, and m to like units, either feet or meters, before making computations.

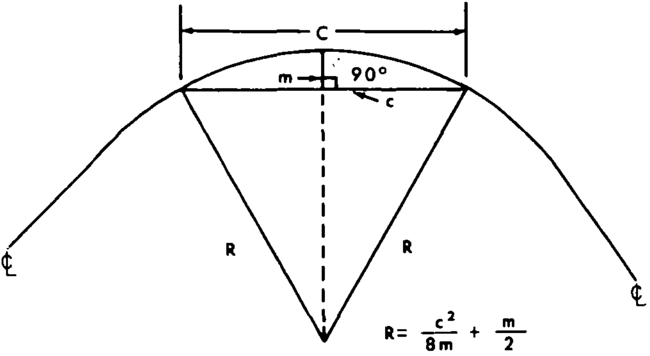
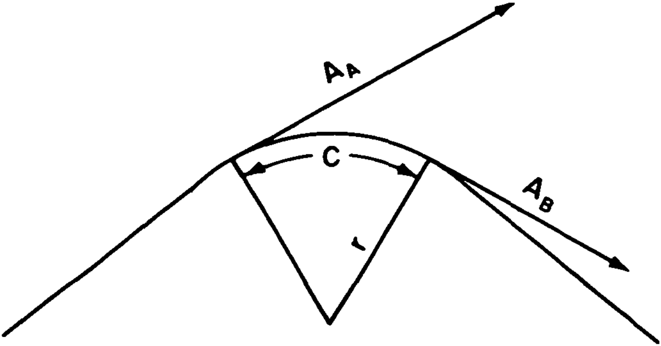


Figure 15–4. Measuring the radius of a curve.

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 perpendicularly to *m*, making sure that c is centered on *m*. If *c* is measured at 16 meters, $R = 17$ meters.

(2) Figure 15–5 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.



A_A = AZIMUTH A

A_B = AZIMUTH B

C = DISTANCE ALONG ℄ OF ROAD

r = RADIUS OF CURVE

Figure 15–5. Alternate method for measuring a curve.

(a) If A_B is larger than A_A:

$$\gamma = \frac{57c}{A_B - A_A} \text{ (γ is in the units of c)}$$

(b) If A_A is larger than A_B:

$$\gamma = \frac{57c}{360 + A_B - A_A} \text{ (γ is in the units of c)}$$

(3) Methad a above is mare accurate than methad b. Bath have their advantqges.

d. Determining raad gradient—

$$\frac{\text{Vertical distance}}{\text{Harizantal distance}} \times 100 = \% \text{ af slape}$$

(or a clinameter may be used).

15-3. FIXED BRIDGE RECONNAISSANCE

The limiting features of bridges are af basic importance to the selection of a raute far normal traap movements. See tables 15-3 and 15-4.

a. Bridge reconnaissance has two methads.

(1) Hasty reconnaissance determines immediate trafficability.

(2) Deliberate recannaissance is dane when there is enaugh time and qualified personnel ta make a tharaugh analysis and classification af the bridge, including necessary repairs or demalitian pracedures.

b. Bridge symbals include the lacatian of the bridge, the arbitrarily assigned bridge number, the military lacal classification number, the overall length of the bridge, the roadway width, the vertical clearance, the bridge bypasses, harizontal clearance, under-bridge clearance, number af spans, type af span canstruction, type of span canstruction material, and length and condition of spans (fig. 15-6). Infarmation should be obtained to camplete the Bridge Reconnaissance Repart Form (DA Form 1249), figures 15-7 and 15-8. Cansult chapter 7 ta determine military bridge classification.

Table 15–3. General Dimension Data Required for Each of The Seven Basic Types of Bridges

Numbar on figure	Oimansion data	Basic type of bridge						
		Simple stringer	Slab	T-beam	Truss	Girder	Arch	Suspension
1	Overall length	X	X	X	X	X	X	X
2	Number of spans	X	X	X	X	X	X	X
2	Length of spans	X	X	X	X	X	X	X
2a	Panal length	---	---	---	X	---	---	X
3	Height above streambed	X	X	X	X	X	X	X
3a	Height above estimated normal water level	X	X	X	X	X	X	X
4	Travalad way width	X	X	X	X	X	X	X
5	Overhead clearance	∞	∞	∞	X	∞	∞	X
6	Horizontal clearance	X	X	X	X	X	X	X

Note The letter "X" indicates the dimension is required

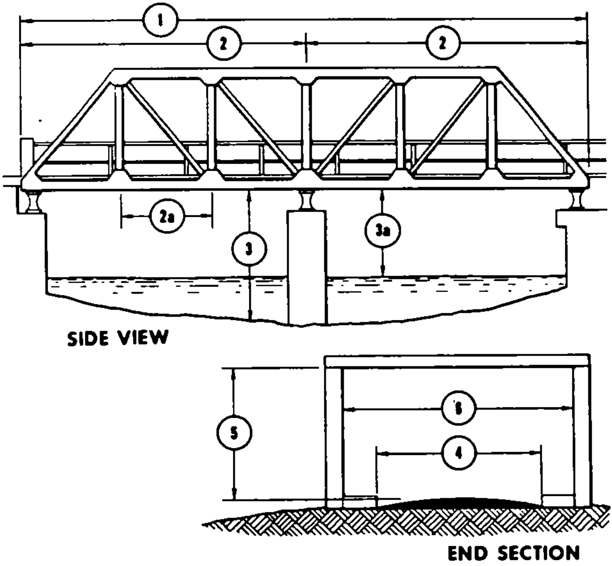


Table 15–4. Capacity Dimension Data Required for Each of The Seven Basic Types of Bridges

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								
	Rec-tang.	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 sizes 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.

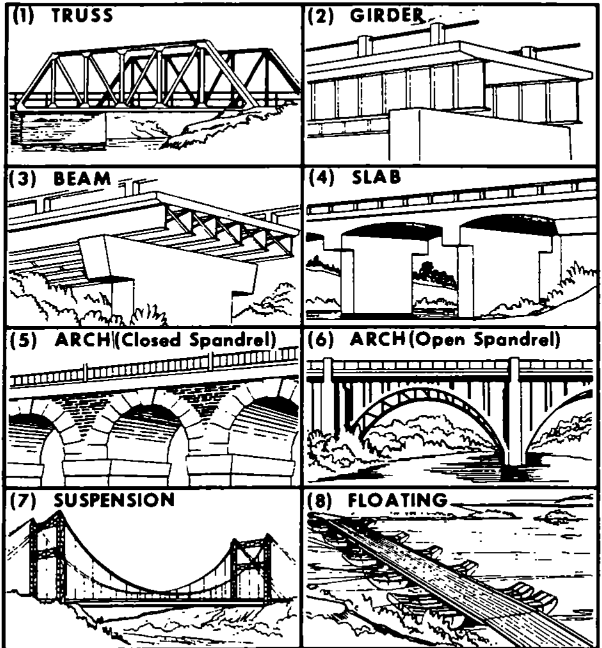
1 Capacity is computed by the use of formulas and data in bridge manuals.

2 Diameter.

3 Width of flange.

Symbolized on Bridge Reconnaissance Report (DA Form 1249) by Number (Type of Construction) and Letter (Material of Construction)

Example: 3 ak = Beam type bridge constructed of reinforced concrete



(9) Use 9 for all other type span construction (i e , swing, lift, cantilever, bascule) specify on reconnaissance report by name

Material Used in Span Construction

Steel or other metal	a
Concrete	k
Reinforced Concrete	ak
Pre-stressed Concrete	kk
Stone or Brick	p
Wood	n

(1) Spans which are not useable because of damage are symbolized by "x" placed after the dimension of span length

(2) Spans which are over water are indicated by placing the symbol "W" also after the dimension of the span length

Figure 15–6. Common types of span construction.

BRIDGE RECONNAISSANCE REPORT

DATE	SIGNATURE
10 JUN 65	W D Atkinson 2/LT CE

TO:	FROM: (Name, grade, and unit of officer or NCO making reconnaissance)
21ST ENGR BN, ATT S2	W D ATKINSON 2/LT CE CoA, 21ST ENGR BN

MAPS (Country, scale and sheet number or name)	DATE-TIME GROUP (Of signature)
VIRGINIA ALLANDALE 1:25000 SHEET 55W	1Ø153ØZ

ESSENTIAL BRIDGE INFORMATION								ADDITIONAL BRIDGE INFORMATION (Add columns as needed) (Military load class, overall length, roadway width, vertical clearance, bridge by-pass)					
		CLEARANCE		SPANS									
SERIAL NO 1	LOCATION 2	HORIZONTAL 3	UNDER-BRIDGE 4	NUMBER 5	TYPE OF CONSTRUC-TION 6	TYPE OF CONSTRUC-TION MATERIAL 7	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	5.5M	2 M	1	3	k	47 M	30	42 M	3.5 M	∞	EASY	NONE
2	LA118759	9.5M	6.5M	1	4	K	4 M	40 50	24M	7.5M	4 M	DIFFICULT	NONE
				1	1	a	16 M						
				1	4	K	4 M						
3	LA16565Ø	14.2M	2.3M	5	3	aK	25 M	80 60	12.5M	12 M	∞	IMPOSSIBLE	NONE
4	LA156645	10.5M	8.5M	3	6	K	10 M	80 100 60 60	180M	10 M	10.5M	IMPOSSIBLE	NONE
				2	2	a	20 M						
				3	6	K	10 M						

DA FORM 1 JUN 64 1249

Figure 15–7. Bridge reconnoissonce report form (front).

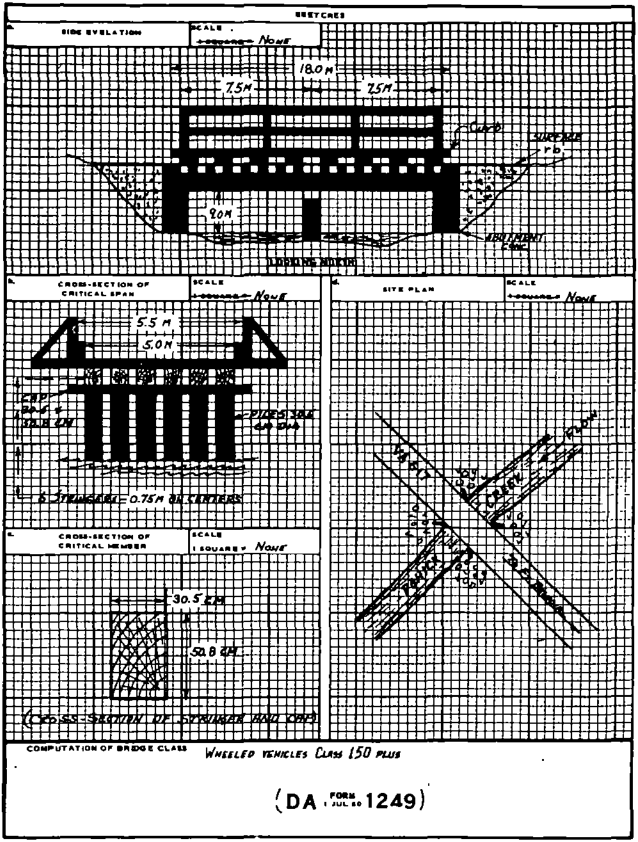


Figure 15–8. Bridge recannaissance report form (back).

c. Bridge bypasses ore local detours, which are clossified os easy, difficult, or impossible. Table 15–1 shows the symbols and requirements for each classification.

15–4. FLOAT BRIDGE RECONNAISSANCE

a. Two types of river crossings—hasty ond deliberote.

(1) Hasty reconnaissonce determines immediate crossing.

(2) Deliberate reconnaissance is performed when there is enough time and qualified personnel are ovoiloble to moke o thorough analysis considering the engineer plan and the eight common factors. These considerations are only *guidelines* and discretion must be used.

b. Engineer plan at compony level must know:

(1) Tactical requirement.

(a) What must cross.

(b) Where it must cross.

(c) When it must cross.

(2) Resources ovailable.

(a) Bridging

(b) Equipment, i.e., dozer.

(c) Men.

(3) Riverline data — Reconnaissance (see c below).

(4) Time — must know the starting time of the operation.

c. Eight common factors for reconnaissance.

(1) Rood nets.

(a) At least same closs as largest vehicle crossing.

(b) Well drained.

(2) Approaches.

(a) Straight for 150′.

(b) 10 percent maximum grade

(c) Two lane.

(d) All weather, well drained.

(3) Abutments on banks.

(a) Same closs os bridge.

(b) Protect from scouring.

(c) Use local moteriol where possible.

(d) 30″ to 40″ high to adjust for closs 60 ramps

(4) Width.

(a) Direct measurement.

(b) Stadii and transit.

(c) Triangulotion — see number 1, figure 15–10.

(d) Scoling from map or oerial photo.

(5) Depth.

(a) Sounding.

(b) Expedient methods.

(6) Current (tide variation)—see number 2, figure 15–10.

(7) Assembly sites—desire 100′ × 100′ for each 100′ of bridge.

(8) Obstructions.

(a) Protect from debris using any expedient methods.

(b) Protect from floating mines using anti-mine boom.

(c) On a reconnaissance local populus may be helpful but keep in mind the enemy could be present.

(d) Other references—TM 5–210.

15–5. TUNNEL RECONNAISSANCE

Because tunnels are sometimes used for storage, maintenance, assembly, or other purpose, their limitations must be known. The required information (DA Form 1250) is pointed out in FM 5–36.

15–6. FORD RECONNAISSANCE

a. *Classification of Fords.* Fords are classified according to their crossing potential for foot, wheeled, or tracked movement.

(1) Their trafficability is indicated for vehicles and foot troops in table 15–5.

(2) 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.

(3) The composition of the stream bottom determines its passability. It is important, therefore, to indicate it.

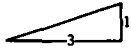
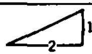
(4) The stream bottom at a ford may be paved, in some cases, to improve its load-bearing capacity and to reduce the stream's depth. The paved area may be of concrete, gravel, layers of sandbags, steel mats, or wooden planks.

(5) Seasonal floods, excessively dry periods, freezing, and other extreme conditions of weather affect the fordability of a stream.

(6) Swiftness of the current and presence of debris affect passability of a ford. Current is recorded as swift (over 1.5 meters per second), moderate (1 to 1.5 meters per second), or slow (less than 1 meter per second).

(7) Dimensional data of a ford are pointed out in figure 15–9.

Toble 15–5. Trafficability of Fords

Type ot traftic	Shallow tordable depth (meters)	Minimum width (meters)	Maximum desirable slope for approaches[1]	Symbol
Foot	1 (39")	t (39") (single tile) 2 (70") (column of 2's)	1:1	
Trucks and truck-drewn artillery	0.75 (30")	3.6 (12')	3 1	
Light tank	1 (39")	4.2 (14')	2:1	
Medium tanks[2]	t.05 (42")	4.2 (14')	2.1	

[1] Based on hard, dry surtace

[2] Depths up to 4.3 meters cen be negotiated with deep weter tording kit

b. *Stream Width.*

(1) With a compass, determine the azimuth from a point an the near share clase to the water's edge ta o point near the woter's edge an the far share af the streom directly oppasite. Then anather point, either upstream or downstream from the previausly morked points, is estoblished an the neor shore, from which the azimuth ta the point on the far shore is 45° at variance with the previausly marked azimuth. The distance between the twa paints on the near share is equal to the distance across the streom (fig. 15–10).

(2) Stretch a string acrass the stream, then measure the distance on the string. A meosuring tape may be used if one lang enough is available.

c. *Stream Velocity.* Stream velocity is calculated by measuring o distance olang the riverbank, then determining the time it takes o light object ta flaat this meosured distonce (fig. 15–10). Velocity is computed as follows:

$$\frac{\text{Measured distance (m or ft)}}{\text{Time (sec)}} = \text{velocity in meters of feet per secand}$$

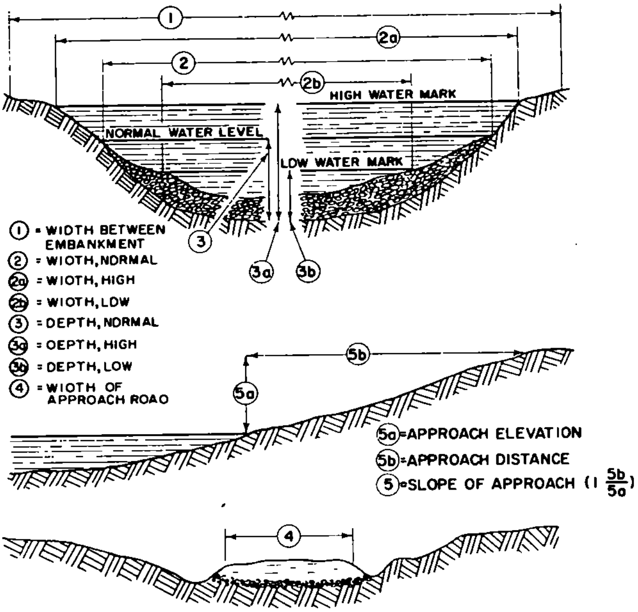


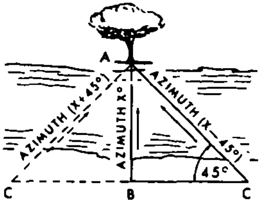
Figure 15–9. Standard dimensianal data far fards.

d. Fard Recannaissance Repart. This repart is made an DA Form 1251, (Fard Recannaissance Repart). If required, worksheets may be used for rapid field wark; details are later transferred ta DA Farm 1251.

15–7. FERRY RECONNAISSANCE

Ferries differ widely in appearance, capacity, propulsion, constructian, etc. Far infarmation on ferry recannaissance, see FM 5–36.

1. MEASURING STREAM WIDTH, USING A COMPASS.



1. SELECT PROMINENT OBJECT A (i.e., tree) ON FAR BANK.
2. STAND AT POINT B, OPPOSITE A, AND READ AZIMUTH X°
3. MOVE UP OR DOWN STREAM TO A POINT C SO THAT AZIMUTH TO A EQUALS X+45° OR X—45°.
4. DISTANCE BC THEN EQUALS GAP AB.

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

$$V(FPS) = \frac{AB\ (FEET)}{TIME\ TO\ FLOAT\ A'B'\ (SEC)}$$

Figure 15–10. Methods of measuring stream width and velocity.

15–8. WATER RECONNAISSANCE

a. *Location of Water Source.* This always involves field reconnaissance, with a brief study of a map.

b. *Source.* When troops are in combat and moving rapidly, there is usually no time to search for the best water, and consequently, units must take whatever is available and purify it with materials on hand. Quantities of water required per man per day are given in table 17–2. The principal sources are—

(1) Surface water (streams, lakes, and ponds).
(2) Springs.
(3) Wells.
(4) Sea water.
(5) Rain.

(6) Snow and ice.

c. *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 out-flow. The amount of water that passes a point in one minute is determined as follows:

$$Q = A \times V \times 6.4$$

Where: Q = Flow in gallons per minute
A = Cross-section area of stream in square feet
V = Flow in ft/min.
6.4 = (7.5 gal of water per cu ft) × (correction factor of 0.85)

d. *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.

e. *Tests.* Tests are performed by personnel operating water supply and by medical service personnel.

f. *Accessibility.* There should be a road system connecting a water supply with the users.

g. *Proposed Development.* Compute the time, labor, and material necessary to improve the site.

h. *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.

i. *Standard Symbols.* The above data should be reported on pertinent maps with the conventional military symbols and signs described in FM 21–30.

15–9. ENGINEER RECONNAISSANCE

An engineer reconnaissance is often performed in conjunction with a route reconnaissance or other reconnaissance. Its primary mission is to locate materials to maintain, improve or support engineer activities. The results of an engineer reconnaissance are usually reported on an overlay similar to the route reconnaissance overlay (fig. 15–1). An Engineer Reconnaissance Report, DA Form 1711–R (figs. 15–11 and 15–12) is prepared with the map overlay to provide a uniform method of reporting reconnaissance of engineer interest.

a. *Front Side.* Shows sketch, key number, time, and location of item reported.

b. *Reverse Side*. Gives work estimate of 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. 15–11). Only those columns which are applicable need be completed. Additional sketches may be drawn if needed to better explain the type work required.

c. *Engineer Reconnaissance Report*. Items which should be recorded on the Engineer Reconnaissance Report (DA Form 1711–R).

(1) *Where it is*. Give grid coordinates of the location.

(2) *What it is*. Give a clear, complete and concise description of the item reported.. (Use sketch, standard symbols, and abbreviations where applicable.)

Report:

(a) *Obstacles*. To movement, natural and artificial, include demolitions, mines, boobytraps.

(b) *Engineer materials*. Particularly road material, bridge timber lumber, steel, fill, gravel, explosives.

(c) *Engineer equipment*. Rock crushers, saw mills, garages, machine shops, abandoned enemy equipment, etc.

(d) *Bivouac areas*. Access roads, soil, drainage, size, cover, concealment, fields of fire.

(e) *Utilities*. Water, sewage, electricity, natural gas, pipe lines.

(f) *Water points*. Recommended locations.

(g) *Map errors*

(h) *Work estimates* for construction, repair, or removal of any item encountered on a reconnaissance.

(3) *Time observed*.

15–10. RECONNAISSANCE OVERLAY SYMBOLS

a. For frequently used symbols on overlays refer to table 15–1.

b. *Bridge Symbols*. See figure 15–13 for correct bridge reconnaissance symbols. Consult table 15–2 and chapter 7 for bridge classification procedures.

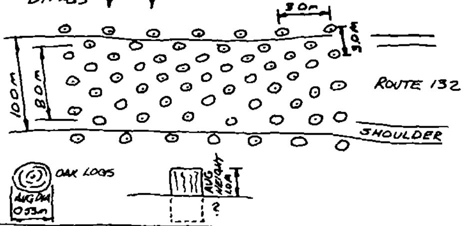
c. *Engineer Resource Symbols*. Use the symbols shown in figure 15–14 to depict engineer resources on the engineer reconnaissance overlay. Possible resources, such as water points, are denoted by dashed line symbols.

d. *Airfield Symbols*. Abbreviations, symbols, and notations as used for route reconnaissance are useful in airfield reconnaissance (FM 21–30).

e. *Minefield Symbols*. The symbols used in the sketches and reports of minefields are as given in chapter 3.

ENGINEER RECONNAISSANCE REPORT		PAGE 1 OF 1 PAGES
TO: CO, 21ST ENGR BN, ATT: S2	FROM: Co A, 21ST ENGR BN	
FILE NO. / REPORT NO. 1	PARTY LEADER (NAME, GRADE, ORGANIZATION) W.C. STEVENS, M/SGT, E8 Co A, 21ST ENG BN	PLACE - HOUR - DATE UT586708 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	UT058684 - LOG POST OBSTACLE BLOCKING ROUTE 132 (59) LOGS @ 1.5 M C-C ON ALL SIDES. OBSTACLE NOT DEFENDED. BOOBY TRAP CHECK REVEALED NO BOOBY TRAPS. BYPASS
2		0940	No	UT509974 - ABANDONED ENEMY EQPT. QUANTITY & TYPE: (2) "ZIPLO" MODEL 200 CRAWLER CRANES (OPERATIONAL) CHECKED FOR BOOBY TRAPS - NONE
3		1000	No	UT761432 - 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
WD ATKINSON, 2/LT, C.E. CoA, 21ST ENGR BN	William D Atkinson 2/LT C.E

DA Form 1711-R, 1 Jun 61

Figure 15–11. Engineer reconnaissance report (front).

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 $D = (0.53)(39.37)$ $= 20.8$ INCHES $P = \frac{D^2}{40} = \frac{(20.8)^2}{40}$ $= 10.8$ LBS 11#/LOG = 649#	REMOVE LOG POST FROM ROUTE 132 BY DEMO	1 590	2	DEMO SET #1	1	2	TNT	lbs	649
				D-8 DOZER	1	2	D-CORD	FT	1100
							NON ELECT CAP	EA	2
							TIME FUSE	FT	3
							M-2 FUSE LIGHTER	EA	2
RECONNAISSANCE REPORT ON OTHER SIDE									

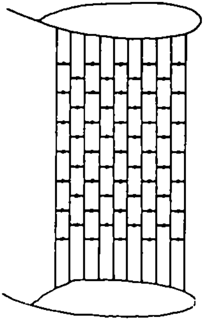
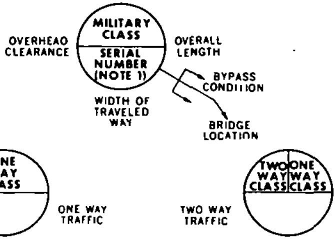


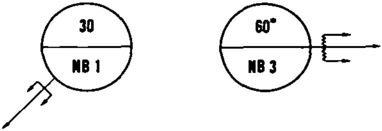
Figure 15–12. Engineer work estimate (back of engineer reconnaissance report).

FULL BRIDGE SYMBOLS (NOTE 4)



ABBREVIATED BRIDGE SYMBOLS

(When used overlay must be accompanied with DA Form 1249 or detailed report.)



Only the single flow traffic is represented in abbreviated bridge symbols. For bridges with separate tracked and wheeled vehicle classification, only the lower classification is shown. If a bridge has more than one classification, then the classification number shown is asterisked ( ) and full classification is shown in the accompanying report.

NOTE 1 Serial Numbers	A SERIAL NUMBER IS ASSIGNED TO EACH BRIDGE, TUNNEL, FORD AND FERRY. SERIAL NUMBERS MUST NOT BE DUPLICATED ON ANY ONE MAP SHEET, OVERLAY OR DOCUMENT.
NOTE 2 Traveled Way Width	**IF SIDEWALKS EXIST AND WILL PERMIT THE PASSAGE OF WIDER VEHICLES, SYMBOLIZE THE SIDEWALKS AND RECORD THE WIDTH AS THE TRAVELED WAY/TOTAL WIDTH I.E. (5.0/5.9M)**
NOTE 3 Bank Orientation	THE LEFT AND RIGHT BANK OF A STREAM ARE DETERMINED BY LOOKING IN THE DIRECTION OF THE CURRENT **DOWNSTREAM**. SPECIAL ATTENTION MUST BE PAID WHEN RECORDING APPROACH CONDITIONS ON THE SYMBOL FOR PROPER ORIENTATION OF DESIGNATING THE LEFT AND RIGHT BANK.
NOTE 4 Critical Dimensions	ANY OVERHEAD CLEARANCE OF A BRIDGE LESS THAN THE STANDARDS OF TABLE 15-2 IS UNDERLINED. ANY WIDTH OF A **ONE LANE** BRIDGE WHICH IS LESS THAN THE STANDARDS OF TABLE 15-2 IS UNDERLINED. THE **TWO WAY** CLASS OF ANY **TWO LANE** BRIDGE IS DOWNGRADED IF THE WIDTH OF THE BRIDGE IS LESS THAN THE STANDARDS OF TABLE 15-2. THE WIDTH OF THE TRAVELED WAY OF TUNNELS OR UNDERPASSES WHICH IS LESS THAN THAT OF THE OUTSIDE ROUTE IS UNDERLINED.

Figure 15—13. Bridge reconnaissance symbols.

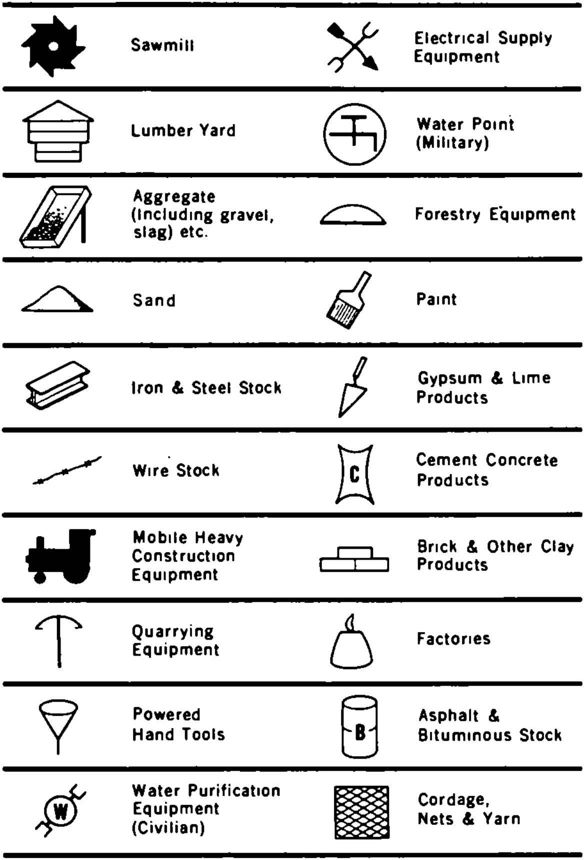


Figure 15–14. Engineer resource symbols.

15–11. UNIT DESIGNATIONS

For a complete coverage of military symbols see FM 21–30.

a. *Branch and Duty Symbols.* At times, two or more branch and duty symbols may be combined. For example, armored infantry would combine the symbols for armor and infantry.

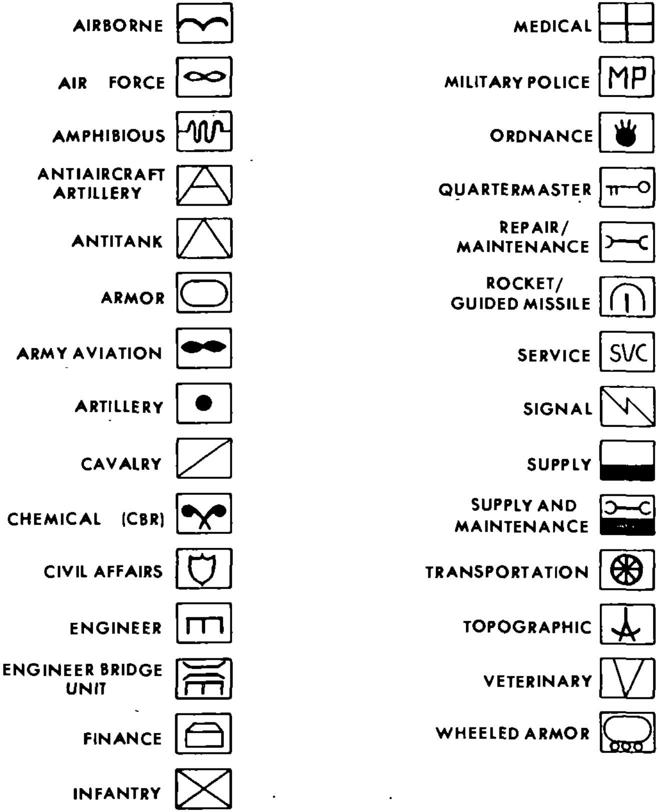


Figure 15–15. Branch and duty symbols.

b. Size and Type of Activity Symbols.

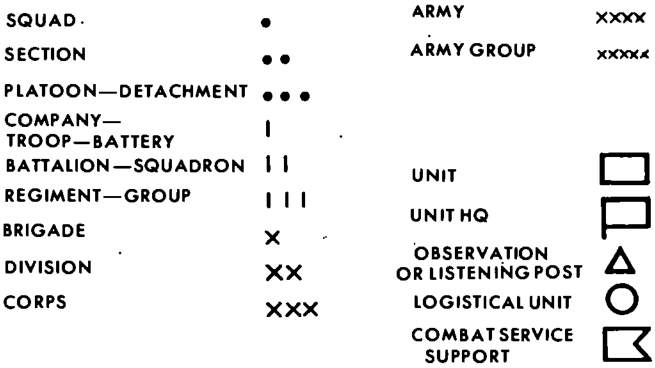


Figure 15–16. Size and type of activity symbols.

c. Unit Designation and Basic Symbol. The arrangement of various combinations of symbols to depict specific units is shown in figure 15–17. Examples of unit designations and basic symbols for engineer units and weapons are found in figures 15–18 and 15–19.

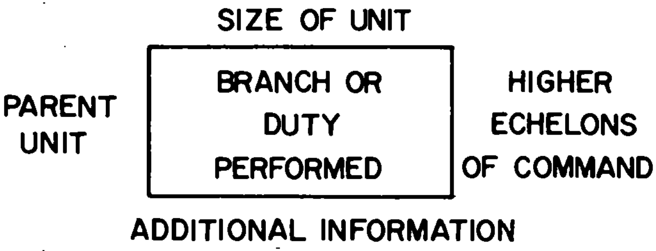
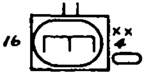
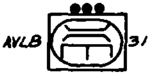


Figure 15–17. Unit designation and basic symbols.

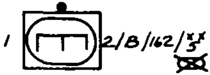
BRIDGE CO., 50TH ENGR. BN.



16TH ARMORED ENGR. BN. 4TH ARMORED DIV.

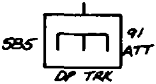


AVLB PLATOON, BRIDGE CO., 31ST ARMORED ENGR. BN.

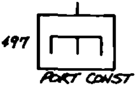


1ST SQ'D., 2D PLATOON, CO. B., 162D ENGR. BN., 5TH INFANTRY DIV (MECHANIZED)

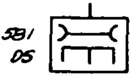
ATOMIC DEMO. MUNITIONS PLATOON, 69TH ENGR. BN.



585TH DUMP TRUCK CO., ATTACHED TO 91ST ENGR. BN.



497TH ENGR. PORT CONST. CO.



581ST ENGR. MAINT CO. (DIRECT SUPPORT)

Figure 15–18. Examples of specific engineer unit symbols.

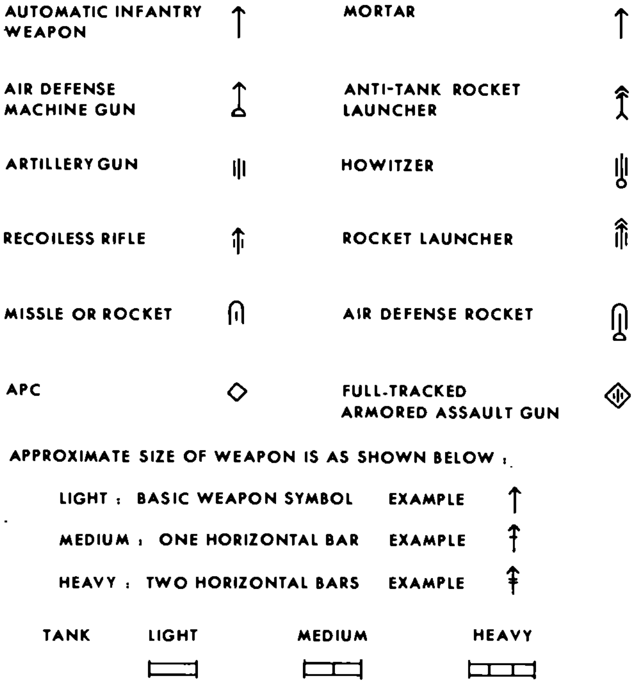


Figure 15–19. Weapons symbols.

d. *Unknown Symbols*. When the correct symbol is not known, a symbol may be made up, provided it is explained in a legend added to the map or overlay being drawn.

CHAPTER 16

COMMUNICATIONS

16–1. MORSE CODE

See figure 16–1.

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 16–1. Morse code.

16–2. PHONETIC ALPHABET

See figure 16–2.

16–3. GROUND AND AIR EMERGENCY CODE

See figure 16–3.

Letter	Pro-word	Pronunciation
A	ALFA	AL PAH
B	BRAVO	BRAH VOH
C	CHARLIE	CHAR LEE
D	DELTA	DELL TAH
E	ECHO	ECK OH
F	FOXTROT	FOKS TROT
G	GOLF	GOLF
H	HOTEL	HO TELL
I	INDIA	IN DEE AH
J	JULIETT	JEW LEE ETT
K	KILO	KEY LOH
L	LIMA	LEE MAH
M	MIKE	MIKE
N	NOVEMBER	NO VEM BER
O	OSCAR	OSS CAH
P	PAPA	PAH PAH
Q	QUEBEC	KEH BECK
R	ROMEO	ROW ME OH
S	SIERRA	SEE AIR RAH
T	TANGO	TANG GO
U	UNIFORM	YOU NEE FORM
V	VICTOR	VIK TAH
W	WHISKEY	WISS KEY
X	XRAY	ECKS RAY
Y	YANKEE	YANK KEY
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 16–2. Phonetic alphabet.

Require doctor, serious injuries	I
Require medical supplies	II
Unable to proceed	X
Require food and water	F
Require firearms and ammunition	≚
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	L7
Probably safe to land here	△
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 16–3. Ground-air emergency code.

16–4. ANTENNAS

a. *Antenna Length Chart.* Lengths are in feet.
b. *1/2 Wave Antenna.* Divide by 2.
c. *1/4 Wave Antenna.* Divide by 4.

Table 16–1. Antenna Length Chart

Frequency megacycle	Full wave length	Frequency megacycle	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

d. Center Fed Antenna(s). ½ of desired antenna length to each side of insulatar.

e. *Antenna Length Formulas.*

f = frequency in megacycles

answer is ontenna length in feet

$\frac{1}{4} = \frac{234}{f}$ $\frac{1}{2}$ wave $= \frac{468}{f}$ full wave $= \frac{936}{f}$

f. Impravised Antennas. See figure 16–4 thraugh 16–9.

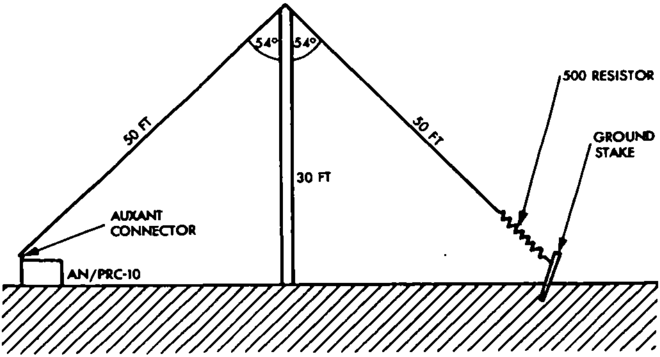


Figure 16–4. Half rhambic antenna.

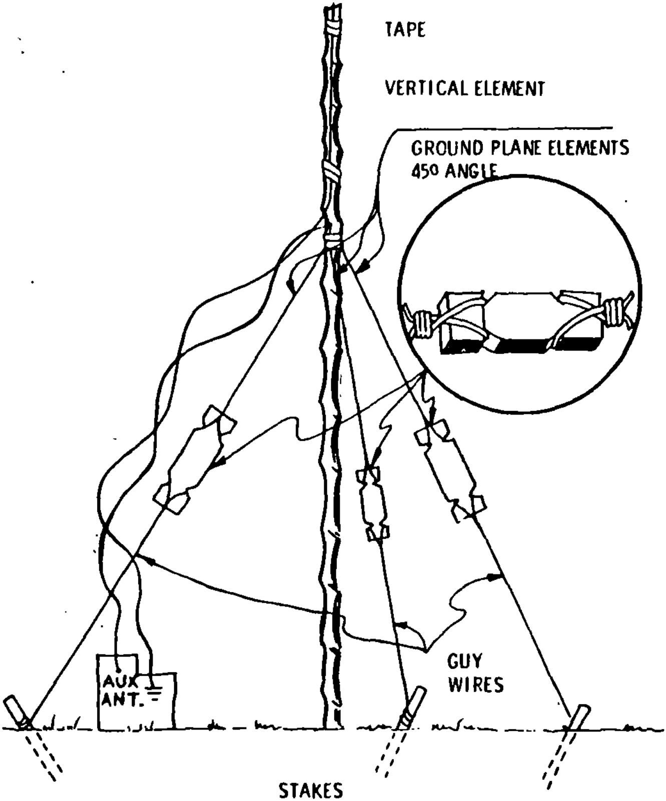


Figure 16–5. Jungle expedient antenna.

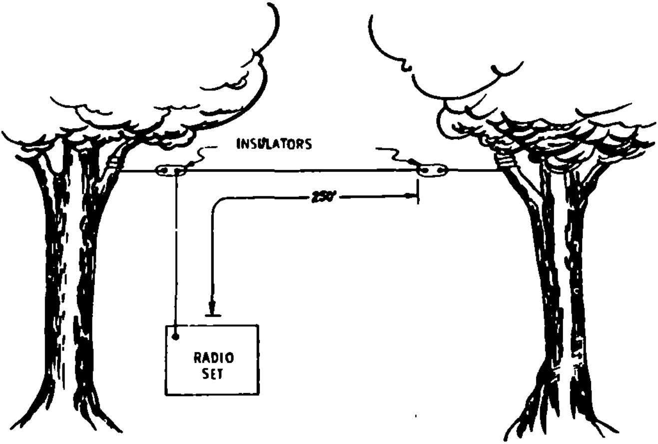


Figure 16–6. Inverted "L" antenna.

VERTICAL POLARIZATION
20 TO 80 MC

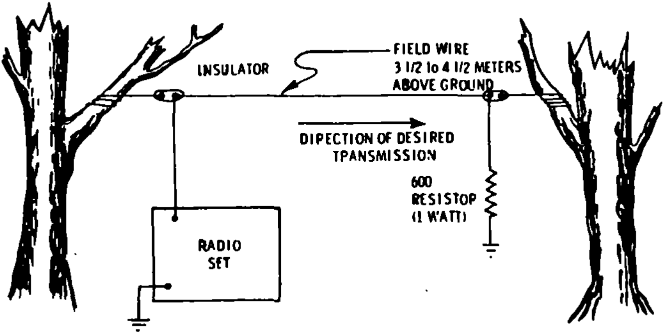


Figure 16–7. Long wire antenna.

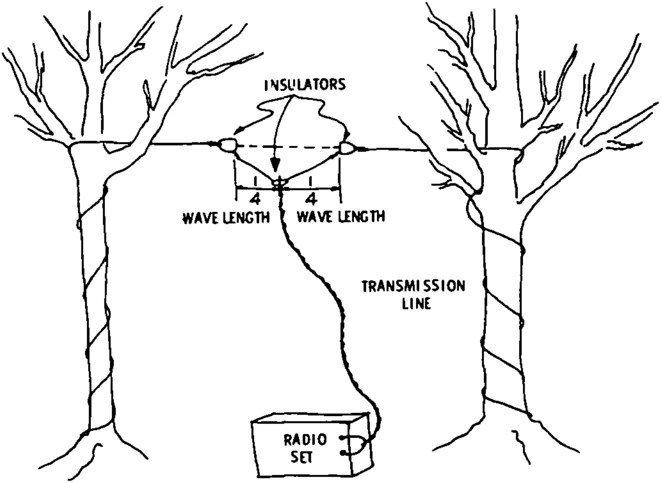


Figure 16—8. Improvised center fed half-wave antenna.

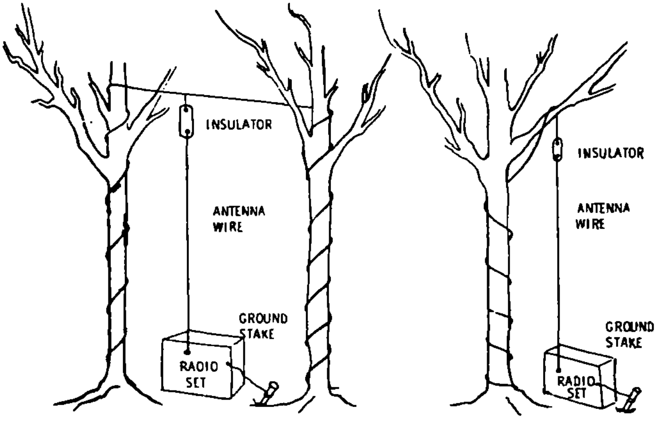


Figure 16–9. Expedient suspended vertical antennas.

16–5. RADIO LOCATION

a. Lacate rodia as high os possible.
b. Locatian shauld be away fram ony metal abstructions.
c. Avoid placing in a depressian or valley, whenever passible.
d. Avoid locating a rodio near electricol power line.

CHAPTER 17

MISCELLANEOUS FIELD DATA

17-1. WEIGHTS AND SPECIFIC GRAVITIES

Table 17—1 gives weights and specific gravities of materials commonly used in an engineer unit.

17-2. WATER; DISINFECTION AND QUANTITY REQUIREMENTS

a. *Water Disinfection.*

(1) *Calcium hypochlorite.* Add calcium hypochlorite to produce residual chlorine of 5 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 usually is 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 seconds.

(4) *Destruction of amaebic 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:

Table 17–1. Weights and Specific Gravities

Substance	Weight, lbs. per cu. ft.	Specific gravity
Bituminaus		
Asphaltum	81	1.1–1.5
Coal, anthracite	97	1.4–1.7
Caal, bituminaus	84	1.2–1.5
Coal, coke	75	1.0–1.4
Petraleum, gasoline	42	0.66–0.69
Tar, bituminous	75	1.20
Building materials		
Ashes, cinders	40–45	....
Cement, portland, laase	94	...
Cement, portland, set	183	2.7–3.2
Caal and coke, piled		
Coal, anthracite	47–58	....
Caal, bituminaus, lignite	40–54	...
Caal, charcoal	10–14	....
Caal, cake	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, laase	76	...
Earth, dry, packed	96	...
Earth, moist, laase	78	....
Earth, maist, packed	96	...
Earth, mud, flawing	108	....
Earth, mud, packed	115	....
Sand gravel, dry, laase	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, snaw, fresh fallen	8	0.125

Table 17–1. Weights and Specific Gravities—Continued

Substance	Weight, lbs. per cu. ft.	Specific gravity
Masanry, ashlar		
Granite, syenite, gneiss	165	2.3–3.0
Limestane, marble	160	2.3–2.8
Sandstane, bluestane	140	2.1–2.4
Masanry, brick		
Pressed brick	140	2.2–2.3
Camman brick	120	1.8–2.0
Saft brick	100	1.5–1.7
Masanry, cancrete		
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
Sandstane, bluestane	110	1.8–1.9
Masanry, martar, rubble		
Granite, syenite, gneiss	155	2.2–2.8
Limestane, marble	150	2.2–2.6
Sandstane, bluestone	130	2.0–2.2
Metals, allays, ares		
Aluminum, cast, hammered	165	2.55–2.75
Copper, cast, rolled	556	8.8–9.0
Iran, cast, pig	450	7.2
Iran, wraught	485	7.6–7.9
Lead	710	11.37
Magnesium allays	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 17–1. Weights and Specific Gravities—Continued

Substance	Weight, lbs. per cu. ft.	Specific gravity
Rock		
Limestone, marble	165	2.5–2.8
Sandstone, bluestone	147	2.2–2.5
Riprap, limestone	80–85	....
Riprap, sandstone	90	....
Riprap, shale	105	....
Solids, various		
Glass, common	156	2.4–2.6
Hay and straw (bales)	20	....
Paper	58	0.70–1.15
Potatoes, piled	42	....
Rubber goods	94	1.0–2.0
Salt, granulated, piled	48	....
Sulfur	125	1.93–2.07
Wool	82	1.32
Stone, quarried, piled		
Basalt, granite, gneiss	96	....
Greenstone, hornblende	107	....
Limestone, marble, quartz	90	....
Sandstone	82	....
Shale	92	....
Excavations in water		
Clay	80	....
River mud	90	....
Sand or gravel	60	....
Sand or gravel and clay	65	....
Soil	70	....
Stone riprap	65	....

Table 17–1. Weights and Specific Gravities—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

(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. *Daily Water Requirements.* Table 17–2 gives water requirements in gallons per unit consumer per day under various conditions of use.

Table 17–2. Daily Water Requirements

1	2	3		4
Unit consumer	Conditions of use	Gal per unit Consumed per day		Remarks
		Temperate/cold climate	Desert/Jungle	
Man.	In combat			
	Minimum......	1/2–1	2–3 [1]	For eating and drinking only, periods not to exceed 3 days
		2	3–4 [1]	When field rations are used
	Normal	3	6 [2]	Drinking plus small amount for cooking or personal hygiene
	March or bivouac	2	5 [2]	Minimum for all purposes.
	Temporary camp.	5	. . . .	Desirable for all purposes (does not include bathing)
	Temporary camp with bathing facilities	15	. . . .	Includes allowance for waterborne sewage system
	Semipermanent camp	30–60		
	Permanent camp	60–100		

Table 17–2. Daily Water Requirements—Continued

1	2	3		4
Unit consumer	Conditions of use	Gal per unit Consumed per day		Remarks
		Temperate/cold climate	Desert/Jungle	
Vehicle	Level and rolling country	$\frac{1}{8}$–$\frac{1}{2}$	.....	Depending on size of vehicle.
	Mountainous country.	$\frac{1}{4}$–1	.....	Depending on size of vehicle
Hospital	Drinking and cooking	10 per bed	.....	Minimum, does not include bathing or water for flushing
	Water waterborne sewage.	50 per bed	.....	Includes water for medical personnel
Impregnating plant, clothing, M2A1	Maximum impregnating capacity	2,400	.....	Aqueous process Includes 2,000 gals for plant operations and 400 gals for washing and cleaning purposes
QM bakery company (mobile)	Two 10-hour shifts	2,600	.....	Water for making bread and cleaning baking utensils
QM laundry company.	Two 10-hour shifts.	64,000 (4,000 per unit)		

[1] For unacclimatized personnel or for all personnel when dry bulb readings exceed 105 °F, in the jungle.
[2] Maximum consumption factor is dependent upon work performed, solar radiation, and other environmental stresses.

17–3. 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

$$\text{Amperes} = \frac{\text{Voltoge}}{\text{resistance (ohms)}}$$

or

$$\text{Amperes} = \frac{745.7 \times \text{Horsepower}}{\text{voltage}}$$

(2) Enter table 17–3 or 17–4 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. The procedure for wiring a facility or wiring a generator is shown in TM 5–766.

17–4. TIMBER

a. *Board Measure, Size and Weight.*

(1) Lumber quantities are expressed in feet, board measure (ft b.m.) or in board feet (bd.ft.), or in thousand board feet (M bd.ft.). One board foot (or ft. b.m.) is the amount of lumber in a rough-sawed board 1 foot long, 1 foot wide, and 1 inch thick (144 cubic inches) or the equivolent volume in ony other shape. These originals or "nominal" dimensians and volumes determine the number of board feet in a given quantity of dressed lumber, regardless of the fact that the process of surfacing or other machining has reduced the actual dimensions ond volume. Under American standards, for example, a dressed board designated as 1 inch by 12 inches is in foct $^{25}/_{32}$ inch by $11\frac{1}{2}$ inches. This must be token into account in computing the amount of lumber needed for a given job. Thus, one hundred 1-inch by 12-inch dressed boards 16 feet long contain $\frac{100 \times 1 \times 12 \times 16}{12} = 1{,}600$ board feet, but have on actual area of only $\frac{100 \times 11\frac{1}{2} \times 16}{12} = 1{,}533$ square feet; so that if 1,600 square feet of 1-inch by 12-inch material are desired, 1,670 board feet, plus allowance for wastage, must be ordered.

(2) Toble 17–5 gives the number of board feet in one piece of lumber of the sizes given.

(3) Table 17–6 gives nominal size, dressed size, section area ond weight per foot of the most common sizes of southern pine timbers.

Table 17–3. Wire Sizes for 120-Volt Single-Phase Circuits

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	...	...	...	...

Table 17–4. Wire Sizes for 220-Volt Three-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											

Table 17–5. 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
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 17–6. Properties of Southern Pine Beams

1	2	3	4
Nominal Size	Actual* size dressed S 4 S	Area of section bd. A. Sq. Ins.	Weight per foot pounds
2×4	$1\frac{5}{8} \times 3\frac{5}{8}$	5.89	1.63
4×4	$3\frac{5}{8} \times 3\frac{5}{8}$	13.14	3.64
2×6	$1\frac{5}{8} \times 5\frac{5}{8}$	9.14	2.53
3×6	$2\frac{5}{8} \times 5\frac{5}{8}$	14.77	4.10
4×6	$3\frac{5}{8} \times 5\frac{5}{8}$	20.39	5.65
6×6	$5\frac{5}{8} \times 5\frac{5}{8}$	31.64	8.76
2×8	$1\frac{5}{8} \times 7\frac{1}{2}$	12.19	3.38
3×8	$2\frac{5}{8} \times 7\frac{1}{2}$	19.69	5.47
4×8	$3\frac{5}{8} \times 7\frac{1}{2}$	27.19	7.55
6×8	$5\frac{5}{8} \times 7\frac{1}{2}$	42.19	11.72
8×8	$7\frac{1}{2} \times 7\frac{1}{2}$	56.25	15.58
2×10	$1\frac{5}{8} \times 9\frac{1}{2}$	15.44	4.28
3×10	$2\frac{5}{8} \times 9\frac{1}{2}$	24.94	6.93
4×10	$3\frac{5}{8} \times 9\frac{1}{2}$	34.44	9.57
6×10	$5\frac{5}{8} \times 9\frac{1}{2}$	53.44	14.84
8×10	$7\frac{1}{2} \times 9\frac{1}{2}$	71.25	19.74
10×10	$9\frac{1}{2} \times 9\frac{1}{2}$	90.25	25.00
2×12	$1\frac{5}{8} \times 11\frac{1}{2}$	18.69	5.18
3×12	$2\frac{5}{8} \times 11\frac{1}{2}$	30.19	8.39
4×12	$3\frac{5}{8} \times 11\frac{1}{2}$	41.69	11.58
6×12	$5\frac{5}{8} \times 11\frac{1}{2}$	64.69	17.96
8×12	$7\frac{1}{2} \times 11\frac{1}{2}$	86.25	23.89
10×12	$9\frac{1}{2} \times 11\frac{1}{2}$	109.25	30.26
12×12	$11\frac{1}{2} \times 11\frac{1}{2}$	132.25	36.63
2×14	$1\frac{5}{8} \times 13\frac{1}{2}$	21.94	6.09
3×14	$2\frac{5}{8} \times 13\frac{1}{2}$	35.44	9.84
4×14	$3\frac{5}{8} \times 13\frac{1}{2}$	48.94	13.59
6×14	$5\frac{5}{8} \times 13\frac{1}{2}$	75.94	21.09
8×14	$7\frac{1}{2} \times 13\frac{1}{2}$	101.25	28.05
10×14	$9\frac{1}{2} \times 13\frac{1}{2}$	128.25	35.53

Table 17–6. *Properties of Southern Pine Beams—Continued*

1	2	3	4
Nominal Size	Actual* size dressed S 4 S	Area of section bd. A. Sq. Ins.	Weight per foot pounds
12 × 14	11½ × 13½	155.25	43.00
14 × 14	13½ × 13½	182.25	50.48
2 × 16	1⅝ × 15½	25.19	7.00
3 × 16	2⅝ × 15½	40.69	11.30
4 × 16	3⅝ × 15½	56.19	15.61
6 × 16	5⅝ × 15½	87.19	24.22
8 × 16	7½ × 15½	116.25	32.20
10 × 16	9½ × 15½	147.25	40.79
12 × 16	11½ × 15½	178.25	49 37
14 × 16	13½ × 15½	209.25	57.96
16 × 16	15½ × 15½	240.25	66.55
2 × 18	1⅝ × 17½	28.44	7.90
3 × 18	2⅝ × 17½	45.94	12.76
4 × 18	3⅝ × 17½	63.44	17.62
6 × 18	5⅝ × 17½	98.44	27.34
8 × 18	7½ × 17½	131.25	36 36
10 × 18	9½ × 17½	166.25	46.05
12 × 18	11½ × 17½	201.25	55.75

*In some species 5½" is the dressed size for nominal 6" sizes in 6" × 6" and larger.

b. *International Log Rule.* A log rule, or scale, is marked at each inch with the number of board feet which can be sawed from logs if the log is measured inside the bark at the small end. Many such rules have been devised, recognized in the lumber industry, and used in various localities. The international ¼-inch log rule, which is based on ¼-inch saw kerfs, has been adopted by statute in some states and may eventually become the universal standard. In applying the rule, no interpolation is made for diameters between inch marks, but scaling practice in some localities permits using the next higher inch for diameters with a fraction larger than ½ inch; for example, a log 23¾ inches in diameter is scaled as 24 inches. The scale is given in table 17–7.

Table 17–7. Log Scale (Board Measure of Volume)

Diameter (inches)	Length of log in feet (board measure)						
	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
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

Table 17–7. *Log Scale (Board Measure of Volume)*—Continued

Diameter (inches)	Length of log in feet (board measure)						
	8	10	12	14	16	18	20
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

17–5. NAILS AND FASTENERS

a. *Nails and Spikes.* The safe lateral load for one nail or spike driven into the side grain of seasoned lumber so that at least two-thirds of the length of the nail is in the wood member holding the point is as follows (reduce load 60 percent for nails in end grain and 25 percent for unseasoned wood):

$900 \times D^{3/2}$ for white pine and eastern hemlock

$1200 \times D^{3/2}$ for Douglas fir and southern yellow pine

$1700 \times D^{3/2}$ for oak, ash, and hard maple

Where D = diameter of nails, in inches. See tables 17–8 and 17–9.

Table 17–8. Nail and Spike Sizes

	Size	Length (inches)	Gage	Diameter (D) (inches)	$D^{3/2}$
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″	⅜″	⅜″	.2295
	9″	9″	⅜″	⅜″	.2295
	10″	10″	⅜″	⅜″	.2295
	12″	12″	⅜″	⅜″	.2295

Formula to find approximate number of nails required.
No. lbs (12d to 60d, framing) = d/6 × bf/100
No. lbs (2d to 12d, sheathing) = d/4 × bf/100
where d = size of desired nail in pennies
bf = total board feet to be nailed

b. Wood Screws. The safe lateral load in pounds, for one wood screw driven into the side grain of seasoned lumber to a penetration of at least seven times its diameter into the member receiving the point is as follows (reduce load 25 percent for end grain and 25 percent for unseasoned wood):

$2100 \times D^2$ 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 17–10.

Table 17–9. Nail Types and Number Per Pound

Size	Length, in	Common		Finishing		Flooring	
		Gage	No./lb	Gage	No./lb	Gage	No./lb
2d	1	5	876	16½	1,351		
3d	1¼	14	568	15½	807		
4d	1½	12½	316	15	584		
5d	1¾	12½	271	15	500		
6d	2	11½	181	13	309	11	157
7d	2¼	11½	161	13	238	11	139
8d	2½	10¼	106	12½	189	10	99
9d	2¾	10¼	96	12½	172	10	90
10d	3	9	69	11½	121	9	69
12d	3¼	9	63	11½	113	8	54
16d	3½	8	49	11	90	7	43
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

c. *Lag Screws.* The safe lateral load in pounds, for one lag screw driven into the side grain of seasoned lumber to a penetration of nine times the diameter into the member receiving the point and holding a cleat having a thickness of 3.5 times the screw diameter is as follows (reduce load 35 percent for end grain and 25 percent for unseasoned wood):

$1500 \times D^2$ for white pine and eastern hemlock

$1700 \times D^2$ for Douglas fir and southern cypress

Table 17–10. Wood Screw Diameters

Size	Diameter-D Inches	D^2 Inches ^{2}
1/2 inch — No. 4	0.1105	0.0122
3/4 inch — No. 8	.1631	.0266
1 inch — No. 10	.1894	.0359
1 1/2 inch — No. 12	.2158	.0466
2 inch — No. 14	.2421	.0586
2 1/2 inch — No. 16	.2684	.0720
3 inch — No. 18	.2947	.0868

$1900 \times D^2$ for southern yellow pine and soft maple
$2200 \times D^2$ for oak, ash, and hard maple
Where $D =$ diameter of shank, in inches.

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 may or may not 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.

17–6. 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.

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 $\frac{4}{5}$ 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.

17–7. CAMOUFLAGE

a. *Principles.*

(1) *Siting.* Careful selection of the position for an emplacement of equipment is the most important principle of camouflage. Emplacements and their artificial camouflage materials must be made to blend with their background.

(2) *Discipline.* Avoid unnecessary movement of personnel and vehicles and any other activity that would change the original appearance of the area and indicate your presence to enemy observers.

(3) *Construction.* Employ natural and artificial construction and camouflage materials to conceal the position.

b. *Materials.*

(1) *Natural.* Natural materials generally provide the best concealment and are always available. Natural materials include live vegetation, cut vegetation, debris, soil, and so forth.

(2) *Artificial material.* Artificial materials include paints, supporting frames, garnishing materials, structural materials, screening materials, adhesives, and texturing materials. See table 17–11 for expedient paints that can be made from materials readily available. FM 5–35 has more detail on camouflage materials and manhour requirements involved.

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.

Table 17–11. *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.

(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 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. Flattop 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 obrupt 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 o 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 gorlonds 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. 17–1). This should result in an amalgamation of the letter pattern forming the desired degree of density and color blend.

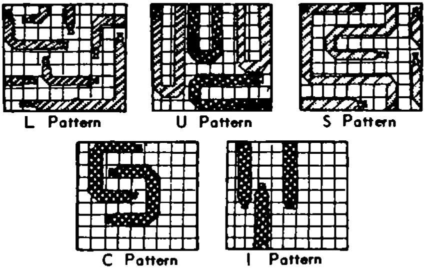


Figure 17–1. Garnishing.

f. Calculation of Net Size.

(1) *Drape net.*

$$\text{Length} = 2H + L + 5'$$
$$\text{Width} = 2H + W + 5'$$

(2) *Flat top net.*

$$\text{Length} = 4(H + 2) + L$$
$$\text{Width} = 4(H + 2) + W$$

Where: L = length of object being camouflaged
W = width of object
H = height of object

17–8. VEHICLE RECOVERY EXPEDIENTS

a. *General.* Normally proper vehicle operator training, operator experience, and comman sense can prevent most vehicles from becoming stuck or in a pasition where they cannot be used. In the toctical situation, vehicle loss cannot olways 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 17–2, 17–3, 17–4, and 17–5.

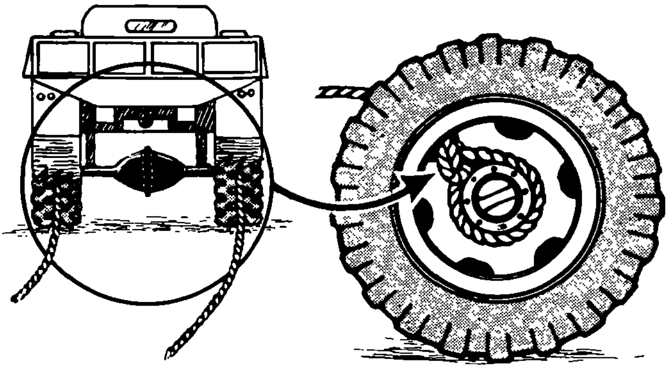


Figure 17–2. Use af wheels for a winch.

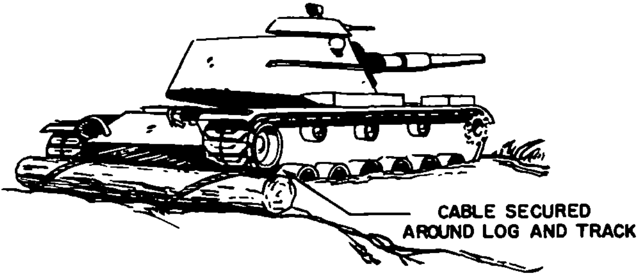


Figure 17–3. Log used to anchor tracks.

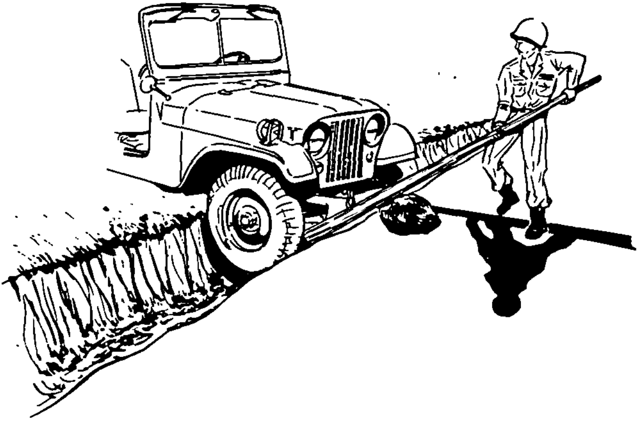


Figure 17–4. Simple lever.

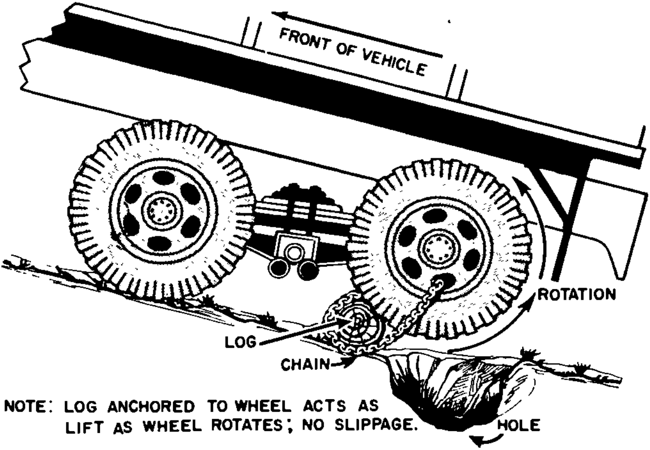


Figure 17–5. Anchoring a wheel.

17–9. 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.

(2) *Class B.* These are fires which occur in flammable substances such as gasoline, jet fuel, and so forth.

(3) *Class C.* These are live electrical fires.

(4) *Class D.* These are combustible metal (magnesium, etc.) fires.

b. *Carbon Dioxide Extinguishers* (fig. 17–6).

(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 seal which holds the valve locking pin to see that it is not broken and checking for physical damage to the extinguisher. Semiannual inspection requires that the extinguisher be weighed to insure that the

extinguisher has a full charge. Recharging is necessary if the weight is 10 percent deficient.

(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.

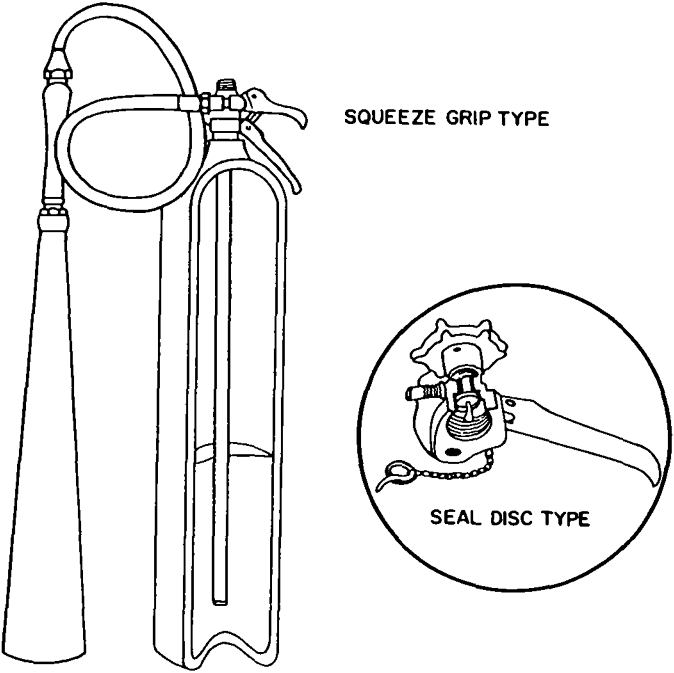


Figure 17–6. Carbon dioxide extinguisher.

c. *Pump Type Water Extinguishers* (fig. 17–7).

(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.

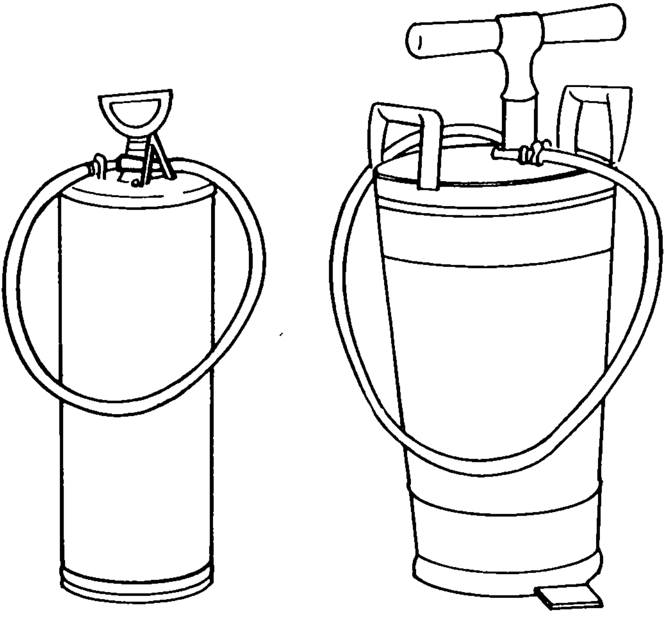


Figure 17–7. Pump type water extinguisher.

d. Sada-Acid Extinguishers (fig. 17–8).

(1) *Agent.* Sada-acid extinguishers use water as the extinguishing agent. When the extinguisher is inverted, the sada and acid mix praducing a gas which expels the water.

(2) *Inspectian.* Inspectian includes visual checking af the extinguisher and remaving cap ta check far acid, sada, and water. Annual inspectian requires discharge, cleaning, and recharging. Care must be taken ta prevent this extinguisher fram freezing.

(3) *Operatian and use.* Ta aperate, grasp the nazzle and invert the cantainer. The chemical reactian and pressure accur almast immediately after inverting the extinguisher. DO NOT USE ON ELECTRICAL OR GASOLINE FIRES.

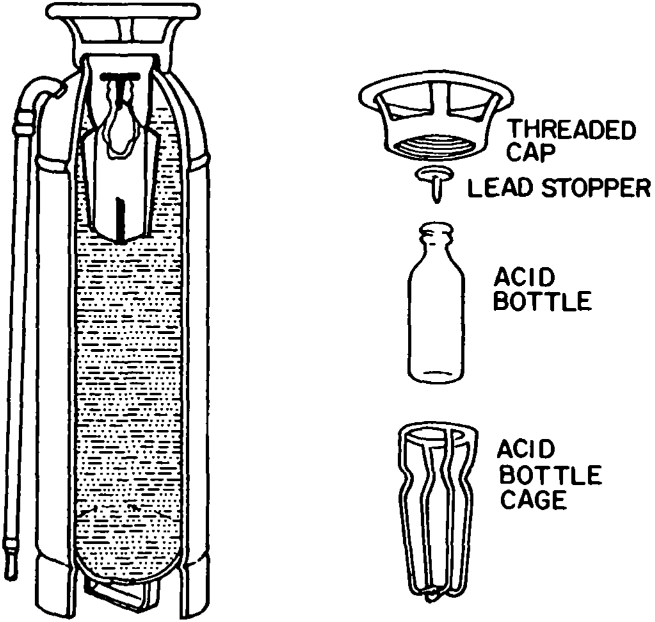


Figure 17–8. Sada-acid extinguisher.

e. *Foam Extinguishers* (fig. 17–9).

(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.

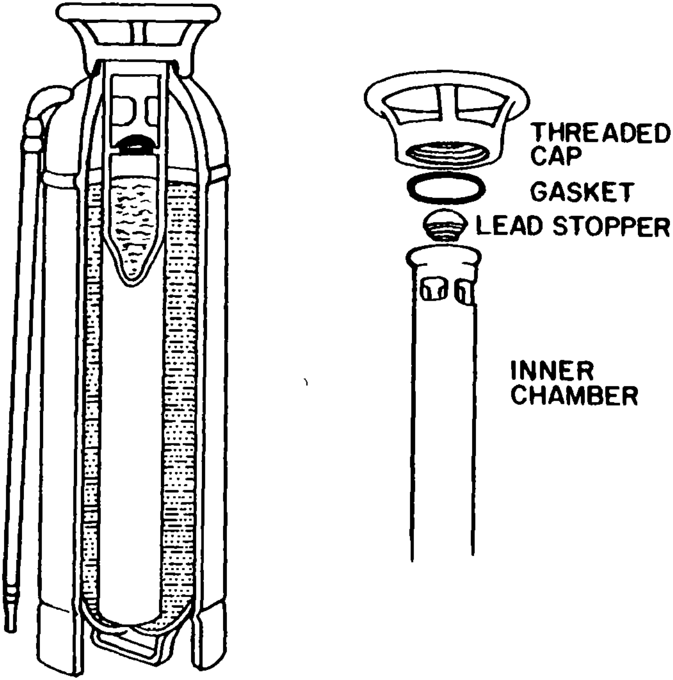


Figure 17–9. Foam extinguisher.

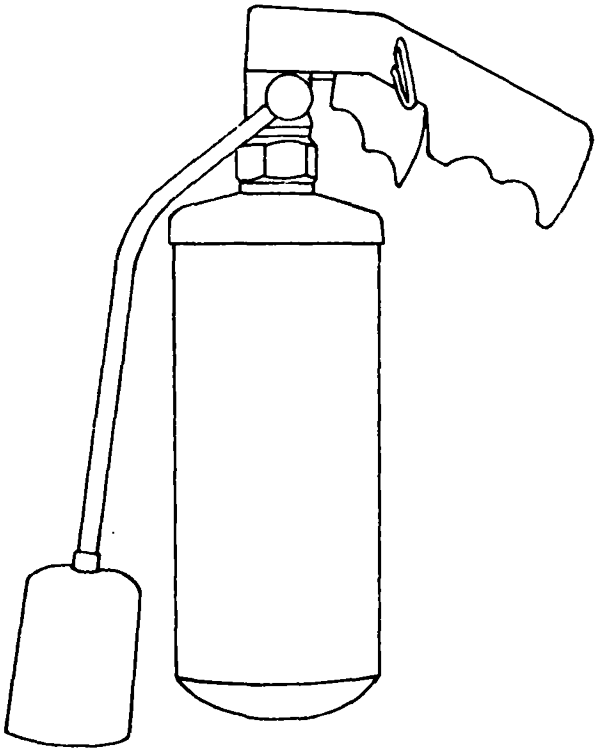


Figure 17–10. CF_3 8r extinguisher.

f. Bromotrifluoromethane (CF_3Br) *Extinguishers* (fig. 17–10).

(1) *Agent.* This extinguisher uses bromotrifluoromethane, commonly known as Freon 1301, a liquefied compressed gas, as the extinguishing agent.

(2) *Inspection.* In addition to visual inspection, this extinguisher must be weighed semiannually on an accurate scale to determine leakage. If weight is 10 percent or more deficient, recharging is necessary.

(3) *Operation and use.* Pull ring pin, point horn to base of fire and depress trigger. Avoid breathing smoke Is especially safe and effective against class B and C fires.

g. *Dry Chemical Extinguishers* (fig. 17–11).

(1) *Agent.* These extinguishers use bicarbonate of soda or potassium bicarbonate as the extinguishing agent.

(2) *Inspection.* Check sealing wire and seal, pressure gage, hose and nozzle. Semiannually, weigh cartridge of nonpressurized extinguishers and replace if 10 percent or more below prescribed weight.

(3) *Operation and use.* Break sealing wire, remove locking pin, depress operating handle and direct agent at base of fire.

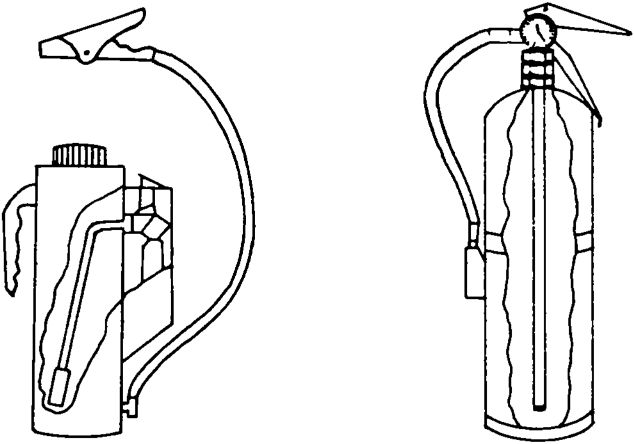


Figure 17–11. Dry chemical extinguisher.

h. Fire Extinguisher Use. See table 17–12.

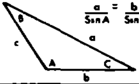
Table 17–12. Fire Extinguisher Use

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
CF_3Br Extinguisher..........	Do not use	Excellent	Excellent	Do not use
Dry Chemical Extinguisher	Only with ABC powders.	Excellent	Excellent	Special powders.

17-10. TRIGONOMETRIC FUNCTIONS

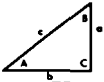
a. Table 17-13 gives the formulas for solving right and oblique triangles.

Table 17-13. Trigonometric Solutions of Triangles



$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$a^2 = b^2 + c^2 - 2bc \cos A$$
$$b^2 = a^2 + c^2 - 2ac \cos B$$
$$c^2 = a^2 + b^2 - 2ab \cos C$$
$$S = \frac{a + b + c}{2}$$



$$a^2 = c^2 - b^2$$
$$c^2 = a^2 + b^2$$
$$b^2 = c^2 - a^2$$

$\sin A = a/c$

$\cos A = b/c$

$\tan A = a/b$

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		$\tan A = \frac{a \sin C}{b - a \cos C}$				$\sqrt{a^2+b^2-2ab \cos C}$	$\frac{ab \sin C}{2}$

b. Table 17–14 gives the natural triganometric functions.

Table 17–14. Natural Triganometric 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

17–11. LENGTHS, AREAS, AND VOLUMES OF GEOMETRIC FIGURES

a. *Legend.*

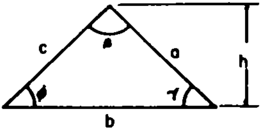
A = area
h = height
b = length of base
c = hypotenuse
C = circumference
V = volume
r = radius
D = diameter
π = 3.1416
L = length of arc
K = length of card

b. *Formulas.*

(1) *Any triangle:*

$$A = 1/2\ bh$$

or: $$\text{Sin}\ \gamma = \frac{c\ \text{Sin}\ \phi}{a}$$

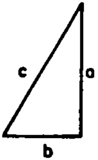


(2) *Right triangle:*

$$a = \sqrt{c^2 - b^2}$$

$$b = \sqrt{c^2 - a^2}$$

$$c = \sqrt{a^2 + b^2}$$

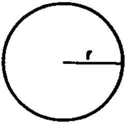


(3) *Circle:*

$$A = \pi r^2$$

$$A = 0.7854\ D^2$$

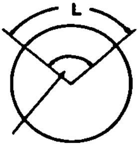
$$C = \pi D$$



(4) *Segment of circle:*

$$A = \frac{\pi r^2}{360} - \frac{r^2 \sin a}{2}$$

$$L = \frac{2\pi r}{360}\ x/a$$



a=angle
in degrees

(5) *Sector of circle:*

$$A=\frac{rl}{2}=\frac{\pi r^2}{360}\text{ (angle in degrees)}$$

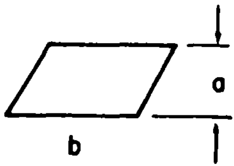
(6) *Regular polygons.* The area of any regular polygon (all sides equal, all angles equal) is equal to the product of the square of the lengths of one side and the factors shown in table 17–15. Example: Area of a regular octagon having 6-inch sides is $6 \times 6 \times 4.828$, or 173.81 square inches. See factors in table.

Table 17–15. 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

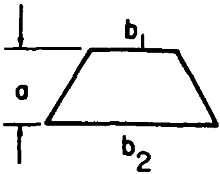
(7) *Rectangle and parallelogram:*

$$A=ab$$



(8) *Trapezoid.*

$$A=1/2a(b_1+b_2)$$



(9) *Irregular figures.* Measure widths at offsets regularly spaced along any straight line, and apply one of the following:

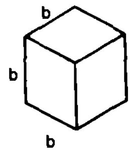
(a) *Trapezoidal rule.* $A =$ one half the interval between offsets $\times$ (sum of two end widths plus twice the sum of the intermediate widths).

(b) *Simpson's rule.* (Assumes lateral boundaries are parabolic curves.) $A =$ one third the interval between offsets $\times$ 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 (2nd, 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.

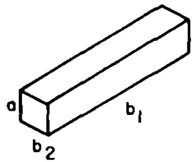
(10) *Cube:*

$$V = b^3$$



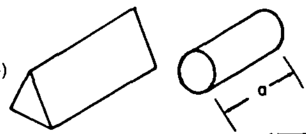
(11) *Rectangular parallelepiped:*

$$V = ab_1b_2$$



(12) *Prism or cylinder:*

$$V = aX \text{ (area of base)}$$



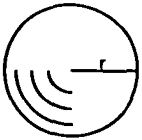
(13) *Pyramid or cone:*

$$V = (1/3)aX \text{ (area of base)}$$

(14) *Sphere:*

$$V = (4/3)\pi r^3 = \frac{\pi D^3}{6}$$

$$A = 4\pi r^2$$



(15) *Prismoidol* section:

V = one-sixth the length X (sum of the end areas plus 4 times the midsection orea)

17–12. FUNCTIONS OF NUMBERS

Table 17–16 gives the most used functions of all whole numbers from 1 to 100.

Table 17–16. Functions of Numbers

No.	Square	Cube	Sq. root	Logorithm
1	1	1	1.0000	0.00000
2	4	8	1.4142	.30103
3	9	27	1.7321	.47712
4	16	64	2.0000	.60206
5	25	125	2.2361	.69897
6	36	216	2.4495	.77815
7	49	343	2.6458	.84510
8	64	512	2.8284	.90309
9	81	729	3.0000	.95424
10	100	1000	3.1623	1.00000
11	121	1331	3.3166	1.04139
12	144	1728	3.4641	1.07918
13	169	2197	3.6056	1.11394
14	196	2744	3.7417	1.14613
15	225	3375	3.8730	1.17609

Table 17–16. Functions of Numbers—Continued

No.	Square	Cube	Sq. root	Logarithm
16	256	4096	4.0000	1.20412
17	289	4913	4.1231	1.23045
18	324	5832	4.2426	1.25527
19	361	6859	4.3589	1.27875
20	400	8000	4.4721	1.30103
21	441	9261	4.5826	1.32222
22	484	10648	4.6904	1.34242
23	529	12167	4.7958	1.36173
24	576	13824	4.8990	1.38021
25	625	15625	5.0000	1.39794
26	676	17576	5.0990	1.41497
27	729	19683	5.1962	1.43136
28	784	21952	5.2915	1.44716
29	841	24389	5.3852	1.46240
30	900	27000	5.4772	1.47712
31	961	29791	5.5678	1.49136
32	1024	32768	5.6569	1.50515
33	1089	35937	5.7446	1.51851
34	1156	39304	5.8310	1.53148
35	1225	42875	5.9161	1.54407
36	1296	46656	6.0000	1.55630
37	1369	50653	6.0828	1.56820
38	1444	54872	6.1644	1.57978
39	1521	59319	6.2450	1.59106
40	1600	64000	6.3246	1.60206
41	1681	68921	6.4031	1.61278
42	1764	74088	6.4807	1.62325
43	1849	79507	6.5574	1.63347
44	1936	85184	6.6332	1.64345
45	2025	91125	6.7082	1.65321

Table 17–16. Functions of Numbers—Continued

No.	Square	Cube	Sq. root	Logarithm
46	2116	97336	6.7823	1.66276
47	2209	103823	6.8557	1.67210
48	2304	110592	6.9282	1.68124
49	2401	117649	7.0000	1.69020
50	2500	125000	7.0711	1.69897
51	2601	132651	7.1414	1.70757
52	2704	140608	7.2111	1.71600
53	2809	148877	7.2801	1.72428
54	2916	157464	7.3485	1.73239
55	3025	166375	7.4162	1.74036
56	3136	175616	7.4833	1.74819
57	3249	185193	7.5498	1 75587
58	3364	195112	7.6158	1.76343
59	3481	205379	7.6811	1.77085
60	3600	216000	7.7460	1.77815
61	3721	226981	7.8102	1 78533
62	3844	238328	7.8740	1.79239
63	3969	250047	7.9373	1 79934
64	4096	262144	8.0000	1.80618
65	4225	274625	8.0623	1.81291
66	4356	287496	8.1240	1.81954
67	4489	300763	8.1854	1.82607
68	4624	314432	8.2462	1 83251
69	4761	328509	8.3066	1.83885
70	4900	343000	8.3666	1.84510
71	5041	357911	8.4261	1.85126
72	5184	373248	8.4853	1.85733
73	5329	389017	8 5440	1.86332
74	5476	405224	8.6023	1.86923
75	5625	421875	8.6603	1.87506

Table 17–16. Functions of Numbers — Continued

No.	Square	Cube	Sq. root	Logarithm
76	5776	438976	8.7178	1.88081
77	5929	456533	8.7750	1.88649
78	6084	474552	8.8318	1.89209
79	6241	493039	8.8882	1.89763
80	6400	512000	8.9443	1.90309
81	6561	531441	9.0000	1.90849
82	6724	551368	9.0554	1.91381
83	6889	571787	9.1104	1.91908
84	7056	592704	9.1652	1.92428
85	7225	614125	9.2195	1.92942
86	7396	636056	9.2736	1.93450
87	7569	658503	9.3274	1.93952
88	7744	681472	9.3808	1.94448
89	7921	704969	9.4340	1.94939
90	8100	729000	9.4868	1.95424
91	8281	753571	9.5394	1.95904
92	8464	778688	9.5917	1.96379
93	8649	804357	9.6437	1.96848
94	8836	830584	9.6954	1.97313
95	9025	857375	9.7468	1.97772
96	9216	884736	9.7980	1.98227
97	9409	912673	9.8489	1.98677
98	9604	941192	9.8995	1.99123
99	9801	970299	9.9499	1.99564
100	10000	1000000	10.0000	2.00000

17–13. TROOP MOVEMENT FACTORS

a. *Rates of March.* See table 17–17.

Table 17–17. 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 far general planning and comparison purposes. All rates given are variable in accordance with the movement conditions as determined by reconnaissance.

[2] These rates include normal periodic rest halts.

b. *March Formulas.* See table 17–18.

Table 17–18. 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).

$$TD\ (\text{hours}) — \frac{D\ (\text{Kilometers})}{R\ (\text{Kilometers per hour})}$$

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

For Time Length (TL) Vehicles (Open Column):
Multiply number of vehicles by factor for formation and rate of march and add time intervals (TI) between units.
TL (minutes) = (Nr of vehicles × factor) + TI's

Select factor from table below

Rate (kmph)	M/Veh	Factor
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 and add the time intervals (TI) between units.
TL (minutes) = (Nr of vehicles × .12) + TI's

For Completion Time (CT):
Add TL of column, TD from IP to RP, and any scheduled halts other than normal breaks, to the IP time.
CT = IP time + TL + TD + Scheduled Halts

Example:

	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	Meal halt (one hour)
CT =	14	112 or 1552	

The move will be completed at 1552 hours.

For Road Space (RS) of vehicles:
Multiply the TL (minutes) by the rate in kilometers per hour and divide by 60.
RS (kilometers) =

$$\frac{\text{TL (min)} \times \text{R (Kilometers per hour)}}{\text{60 (minutes/hour)}}$$

17–14. TIME DISTANCE CONVERSION

See table 17–19.

Table 17–19. 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

Table 17–19—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 17–19 — 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

17–15. CONVERSION FACTORS

See table 17–20.

Table 17–20. Conversion Factors

Multiply	by	to obtain
Acres	43,560	square feet
acres	4,047	square meters
acres	1.562×10^{-3}	square miles.
acres	5645.3B	square varas.
acres	4,840	square yards.
acre-feet	43,560	cubic-feet.
acres	0.02471	acres.
acres	100	square meters.
atmospheres	76.0	cms. of mercury
atmaspheres	29.92	inches af mercury.
atmaspheres	33.90	feet of water.
atmospheres	14.70	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	faot-paunds.
British thermal units	3.927×10^{-4}	harse-power-hours.
British thermal units	1.054	joules.
British thermal units	107.5	kilagram-meters.
British thermal units	$2.92B\times10^{-4}$	kilowatt-hours.
B.t.u. per min	12.96	foat-paunds per sec

Table 17—20. Conversion Factors — Continued

Multiply	by	to obtain
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
bushels	64	pints (dry).
bushels	32	quarts (dry).
Centares	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-grams	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.
cemtimeters 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.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
cord-feet	4 ft. × 4 ft × 1 ft.	cubic feet.
cords	8 ft. × 4 ft. × 4 ft.	cubic feet.
cubic centimeters	3.531×10^{-5}	cubic feet
cubic centimeters	$6\ 102 \times 10^{-2}$	cubic inches.
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
cubci centimeters	2.113×10^{-3}	pints (liq.)
cubic centimeters	1.057×10^{-3}	quarts (liq)
cubic feet	$2\ 832 \times 10^{4}$	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.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
cubic yords..	46,656	cubic inches.
cubic yards..	0 7646	cubic meters
cubic yards......	202 0	gollons.
cubic yords......	764.6	liters.
cubic yords..........	1616	pints (liq.).
cubic yords.........	807.9	quorts (liq.)
cubic yords per minute	0.45	cubic feet per second.
cubic yords per minute	3 367	gallans per secand.
cubic yords per minute	12.74	liters per secand
Doys.	24	haurs.
days....	1440	minutes
days......	86,400	secands
decigroms..	0 1	groms.
deciliters..	0.1	liters.
decimeters.	0 1	meters
degrees (ongle)........	60	minutes
degrees (angle)	0 01745	radions.
degrees (ongle).	3600	seconds.
degrees per secand...	0 01745	rodians per second
degrees per second.....	0.1667	revalutions per min.
degrees per second......	0.002778	revalutions per sec
dekagroms	10	groms.
dekaliters.	10	liters
dekometers.	10	meters.
drams.....	1.772	groms.
droms.........	0.0625	ounces.
dynes................	$1\ 020 \times 10^{-3}$	grams.
dynes...............	$7\ 233 \times 10^{-5}$	poundals.
dynes....	2.248×10^{-6}	paunds.
Ergs................................	9.486×10^{-11}	British thermal units.
Fothams...	6	feet.
feet	30 48	centimeters.
feet	12	inches
feet	0.3048	meters.
feet.................	.36	voros
feet....	$\frac{1}{3}$	yards.
feet af woter	0.4335	pounds per sq. inch.
feet per minute.....	0.5080	centimeters per sec.
feet per minute.....	0.01667	feet per secand.
feet per minute..............	0.01829	kilameters per haur

Table 17–20. Conversion Factors — Continued

Multiply	by	to obtain
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 grade
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 thermal 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}	kilogram-calories.
foot-pounds	0.1383	kilogram-meters.
foot-pounds	3.766×10^{-7}	kilowatt-hours
foot-pounds per minute	1.286×10^{-3}	B t. units per minute.
foot-pounds 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-calories per min.
foot-pounds per minute	2.260×10^{-5}	kilowatts.
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-calories per min
foot-pounds per second	1.356×10^{-3}	kilowatts
furlongs	40	rods.
Gallons	3785	cubic centimeters
gallons	0.1337	cubic feet
gallons	231	cubic inches.
gallons	3.785×10^{-3}	cubic meters
gallons	4.951×10^{-3}	cubic yards
gallons	3.785	liters.
gallons	8	pints (liq.).
gallons	4	quarts (liq.).
gallons per minute	2.228×10^{-3}	cubic feet per second.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
gallons per minute	0.06308	liters per second.
gills	0.1183	liters.
gills	0.25	pints (liq.).
grains (troy)	1	grains (av.).
grains (troy)	0.06480	grams
grains (troy)	0.04167	pennyweights (troy).
grams	980.7	dynes.
grams	15.43	grains (troy).
grams	10^{-3}	kilograms
grams	10^{3}	milligrams.
grams	0.03527	ounces.
grams	0.03215	ounces (troy).
grams	0.07093	poundals.
grams	2.205×10^{-3}	pounds.
gram-calories	3.968×10^{-3}	British thermal units.
gram-centimeters	9.302×10^{-3}	British thermal units.
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^{-8}	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	steradians.
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

Table 17–20. Conversion Factors — Continued

Multiply	by	to obtain
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.
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 square 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.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
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.
kg.-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
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.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
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.
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	$\log_\epsilon N$ or $\ln N$.
$\log_\epsilon N$ or $\ln N$	0.4343	$\log_{10} N$.
lumens per sq. ft.	1	foot-candles.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtoin
Meters	100	centimeters.
meters	3 2808	feet.
meters	39.37	inches.
meters	10^{-3}	kilometers.
meters	10^{3}	millimeters.
meters	1 0936	yords
meter-kilogroms.	9.807×10^{7}	centimeter-dynes
meter-kilogroms	10^{5}	centimeter-groms
meter-kilogroms	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	yords
miles	1900.8	voros.
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.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
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
milliers	10^3	kilograms.
milligrams	10^{-3}	grams
milliliters	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)	$2\ 909 \times 10^{-4}$	radians
minutes (angle)	60	seconds (angle).
months	30.42	days.
months	730	hours.
months	43,800	minutes.
months	$2\ 628 \times 10^6$	seconds
myriograms	10	kilograms.
myriometers	10	kilometers.
myriowatts	10	kilowatts
Nautical miles	6,080	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.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
Pennyweights (troy)	24	grains (troy)
pennyweights (troy)	1.555	grams.
pennyweights (troy)	0.05	ounces (troy).
perches (masonry)	24.75	cubic feet.
pints (dry)	33.60	cubic inches
pints (liq.)	28.87	cubic inches.
poundals	13,826	dynes.
poundals	14 10	grams.
poundals	0.03108	pounds.
pounds	444,823	dynes.
pounds	7000	grains.
pounds	453.6	grams.
pounds	16	ounces.
pounds	32 17	poundals
pounds (troy)	0.8229	pounds (av).
pound-feet	1.356×10^{7}	centimeter-dynes.
pound-feet	13,825	centimeter-grams.
pound-feet	0.1383	meter-kilograms
pound-feet squared	421.3	kgs.-cms. squared.
pounds-feet squared	144	pounds-ins. squared.
pounds-inches squared	2.926	kgs.-cms squared.
pounds-inches squared	6.945×10^{-3}	pounds-feet squared.
pounds of water	0.01602	cubic feet
pounds of water	27.68	cubic inches.
pounds of water	0.1198	gallons
pounds of water per min.	2.669×10^{-4}	cubic feet per sec.
pounds per cubic foot	0.01602	grams per 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	$5\ 456 \times 10^{-9}$	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 per 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 per cm.
pounds per mil foot	2.306×10^{6}	grams per cubic cm.
pounds per square foot	0 01602	feet of water.
pounds per square foot	4.882	kgs. per square meter.
pounds per square foot	6.944×10^{-3}	pounds per sq. inch.
pounds per square inch	0.06804	atmospheres

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
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	$1\ 745 \times 10^{-3}$	rods 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
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.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
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.
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.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
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	$3\ 228 \times 10^{-7}$	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.
tpns (short) per sq. ft	9765	kgs per square meter
tons (short) per sq. ft	13 89	pounds per sq. inch.
tons (short) per sq. in	1.406×10^6	kgs. per square meter.
tons (short) per sq. in	2000	pounds per sq inch.
Varas	2.7777	feet
varas	33 3333	inches
varas	000526	miles.
varas	.9259	yards.

Table 17–20. Conversion Factors—Continued

Multiply	by	to obtain
Watts	0.05692	B.t. units per min.
watts	10^{7}	ergs per second.
watts	44.26	foot-pounds per min
watts	0.7376	foot-pounds per sec.
watts	1.341×10^{-3}	horse-power
watts	0.01434	kg.-calories per min.
watts	10^{-3}	kilowatts.
watt-hours	3.415	British thermal units.
watt-hours	2655	foot-pounds.
watt-hours	1.341×10^{-3}	horse-power-hours.
watt-hours	0.8605	kilogram-calories
watt-hours	367.1	kilogram-meters.
watt-hours	10^{-3}	kilowatt-hours.
webers	10^{8}	maxwells.
weeks	168	hours.
weeks	10,080	minutes.
weeks	604,800	seconds
Yards	91.44	centimeters.
yards	3	feet
yards	36	inches
yards	0.9144	meters
yards	1.08	varas
years (common)	365	days.
years (common)	8760	hours.
years (leap)	366	days
years (leap)	8784	hours.

17–16. CONSTRUCTION DRAWING SYMBOLS

See figure 17–12.

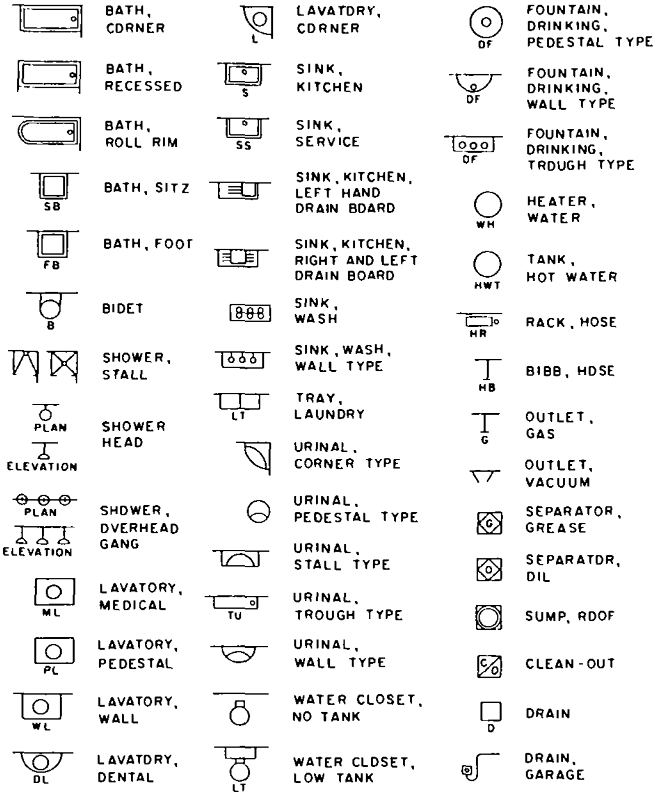


Figure 17–12. Construction drawing symbols.

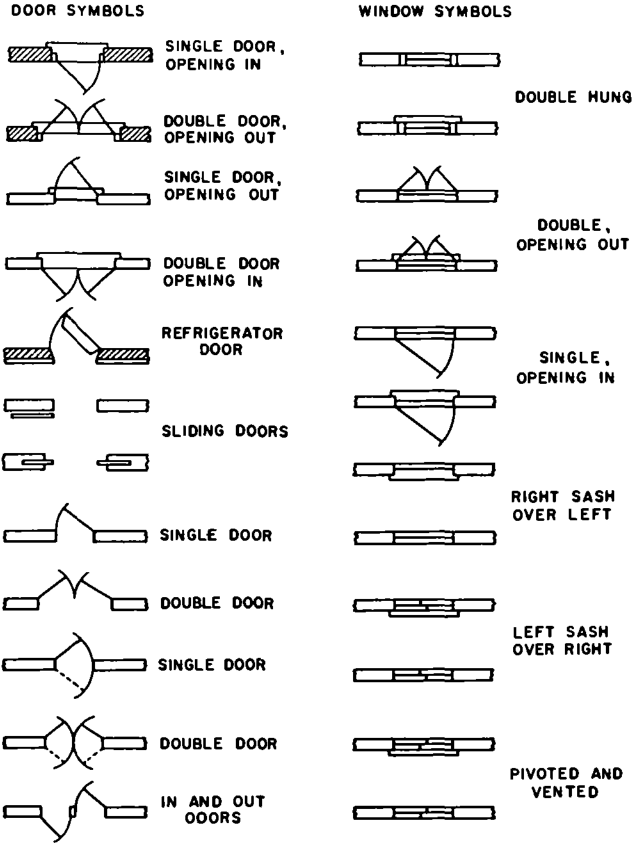


Figure 17–12—Continued.

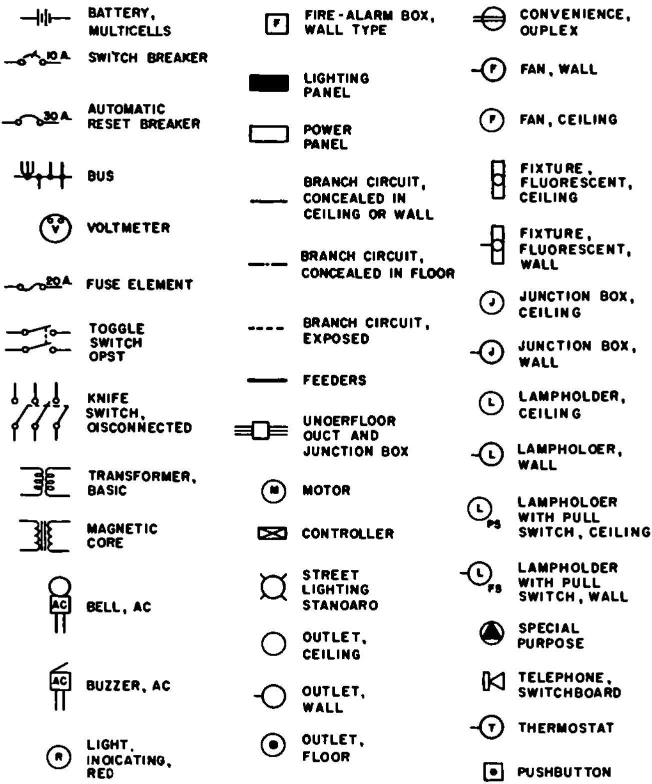


Figure 17–12—Continued.

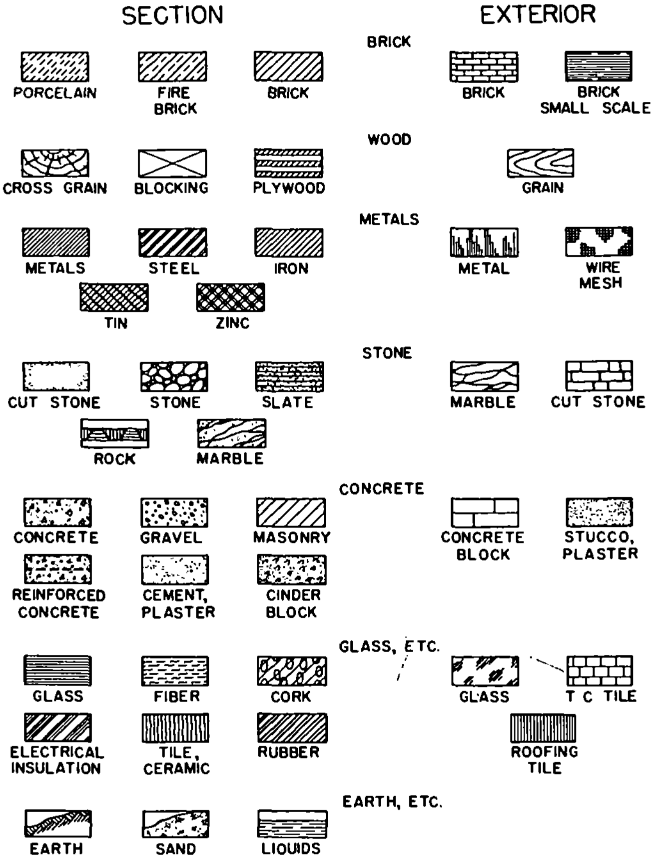


Figure 17–12 — Continued.

Table 17–21. 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

17–17. CONVERSION-ENGLISH UNITS TO METRIC UNITS

See *table* 17–21.

Table 17–21—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 17–21 — 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.

VOLUME

cu. meters →					cu. ft →	cu. yd
cu. yd →			cu. ft →	cu. meters		
cu. ft →	cu. yd →	cu. meters				
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.

17-18. CHARACTERISTICS OF INFANTRY WEAPONS

See table 17-22.

Table 17–22. Characteristics of

Weopan	Unlooded weight (appraximate in pounds)	Type of feed	Methad of operotian	*Cyclic (C) or moximum (M) rate af fire (rds per min)
Hond Grenodes Frogmentation M26A2 Grenade M26A1 WP Grenode M34	 1 1 1½		Electrical impoct fuse 4-5 secand time delay fuse	
Mine Antipersonnel M18A1 Cloymore	3.5		Controlled electric detonation or uncantralled trip wire aperotian	One Shot
Pistol Automotic Cal. 45, M1911A1	2½	7 Rd Magazine	Recail semi- outamotic	35–42 (M)
Submochine Gun, Col. 45, M3A1	9	30 Rd Magozine	Blaw back autamotic	450 (C)

Infantry Weapons

*Sustained rate of fire (rds per min)	*Maximum effective rate of fire (rds per min)	*Maximum range (in meters)	*Maximum effective range (in meters)	Remarks
		40 40 35		The M26A1 and M34 may be fired as rifle grenades with projection M1A2 adapter. The M26A2 will not be used as a rifle grenade with the projection adapter. Approximate effective bursting radii in meters are: M26A1−15, M26A2−15, M34−25
	One Shot Weapon	250	Most effective range is 50 meters	Check FM 23−33 for back-blast effects. When employed in uncontrolled role Claymore must be treated as a mine and its location recorded and reported Directional fragmentation — 60° sector with radius of 50 meters.
		1500	50	
40−60	40−60	1550	100	Used as on-vehicle equipment. Replaced by M14 rifle and M16A1 rifles.

Table 17–22. Characteristics of

Weapon	Unloaded weight (approximate in pounds)	Type of feed	Method of operation	*Cyclic (C) or maximum (M) rate of fire (rds per min)
US Carbine Cal. 30, M2	5½	30 Rd Magazine	Gas operated semi-automatic and automatic	750–775 (C)
US Rifle 7.62mm, M14	9.84	20 Rd magazine	Gas operated semiauto-matic and automatic	700–750 (C)
US Rifle 7.62mm, M14A1	12.12	20 Rd magazine	Same as for M–14 rifle	700–750 (C)
Rifle, 5.56mm, M16A1	6½	20 Rd magazine	Gas operated semiauto-matic and automatic	700–800
US Rifle Cal. 30, M1	9½	8 Rd clip	Gas operated semiautomatic	

Infantry Weapons—Continued

*Sustained rate of fire (rds per min)	*Maximum effective rate of fire (rds per min)	*Maximum range (in meters)	*Maximum effective range (in meters)	Remarks
40–60	40–60	2025	250	Replaced by M14 rifle. May be equipped with sniper-scope infrared set No 1, 20,000 Volts Lts.
40 for first two minutes (semi-automatic)	60 for first minutes (automatic)	3725	460	Full automatic capability requires installation of selector. Sustained rate based on limited tests. Bipod is a major item and used in conjunction with rifle when used as an automatic rifle.
Same as for M–14 rifle	Same as for M–14 rifle	3725	700 (semi-automatic) 460 (automatic)	Essentially same characteristics as M–14. Major difference lies in modified straight line stack with pistol grip.
45–65 (semi-automatic) 150–200 (automatic)	20–40 (semi-automatic) 40–60 (automatic)	2653	460	Installed selector with choice of semiautomatic or automatic fire. Bipod issued with the rifle.
8–10	16–24	3200	460	Replaced by M–14 Rifle.

Table 17–22. Characteristics of

Weapon	Unloaded weight (approximate in pounds)	Type of feed	Method of operation	*Cyclic (C) or maximum (M) rate of fire (rds per min)
US Rifle, Cal. 30M1, with rifle grenade launcher, M7A3, heat riflle grenade M31 amd sight M15	10½	Manual	Manual single shot	4 (M)
US Rifle, 7.62mm, M14 with Rifle Grenade Launcher M76, Heat Rifle Grenade, M31 and Sight M15	10½	Manual	Manual Single Shot	4 (M)
Browning Automatic Rifle Cal. 30 M1918A2	19½	20 Rd Magazine	Gas Operated Automatic	350 (C) Slow Rate 550 (C) Fast Rate 120–150 (M)
Machinegun 7.62mm, M60	23	Belt Metallic Split Link	Gas Operated Automatic	550 (C)

Infantry Weapons—Continued

*Sustained rate of fire (rds per min)	*Maximum effective rate of fire (rds per min)	*Maximum range (in meters)	*Maximum effective range (in meters)	Remarks
4	2	275	115	Complete Round weighs approximately 1½ pounds.
4	2	275	115	Grenade Launcher and M15 sight, weight approximately 1 lb Complete round weighs approximately 1½ lb.
40–60	40–60 (2 or 3 Round Bursts) 120–150 (20 Round Bursts)	2750–3200	460	Replaced by M14A1 or M16A1 rifles.
100	200	3725	1100	Maximum effective range limited by gunner's ability to see and adjust on target.

Table 17–22. Characteristics of

Weapon	Unloaded weight (approximate in pounds)	Type of feed	Method of operation	*Cyclic (C) or maximum (M) rate of fire (rds per min)
Machinegun, Cal. 50 HB, M2	MG —82 Tripod —44 Total —126	Belt Metallic Split Link	Recoil Semi-automatic and Automatic	450–500
66mm Heat Rocket, M72 (Law)	4.7 (Rocket and Launcher Combined)			Single shot throwaway
Portable Flame-Thrower, M2A1–7	42½	Fuel Propelled by Gas Under Pressure	Manual	Continuous discharge 6–9 seconds
Portable Flamethrower, ABC, M9–7	25	Fuel Propelled by Gas under Pressure	Manual	Continuous discharge 5–8 seconds
Self-Propelled Flamethrower M132A–1	Approximate 21700	Fuel Propelled by Gas Pressure	Electrical	Continuous discharge 32 seconds

Infantry Weapons—Continued

*Sustained rote of fire (rds per min)	*Maximum effective rate of fire (rds per min)	*Maximum range . (in meters)	*Maximum effective range (in meters)	Remorks
40	100	6800	725 AA Target, 1825 Graund Target	
		1000	200	Launcher is disposable after firing racket and is baresighted during monufacture. Front sight graduated to 325 meters The M72 is issued as ammunition.
Continuaus discharge 6–9 seconds	Cantinuous discharge 6–9 secands	20–30 Unthick-ened Fuel 40–50 Thick-ened Fuel	55	Cantains 4½–4¾ gallans of fuel weighing 25 ta 29 paunds. To be replaced by M9–7 flame-thrower.
Cantinuaus dis-charge 5–8 seconds	Continuaus dis-charge 5–8 seconds	20–30 Unthick-ened Fuel; 40–50 Thick-ened Fuel		Contains 4 gallons of fuel.
Cantinuaus dis-charge 32 seconds	Cantinuous dis-charge 32 secands	150–170	150–170	Contains 200 gallons af thickened fuel.

Table 17–22. *Characteristics of*

Weapon	Unloaded weight (approximate in pounds)	Type of feed	Method of operation	*Cyclic (C) or maximum (M) rate of fire (rds per min)
Irritant Gas Dispenser, Portable M–3	Approximate 40	Agent Propelled by Gas Pressure	Manual	Continuous discharge 25 seconds
40mm Grenade Launcher M79	6	Percussion Type Single Shot		
81mm Mortar, M29 with Mount, M23A2	Barrel 28 Bipod 40 Sight 4 Baseplate 25.5	Muzzle Loading by Hand	Drop Fire	12 (M) for 2 minutes with any charge
4.2 Mortar, M30 with Mount, M24A1	640	Muzzle Loading by Hand	Drop Fire	18 (M) for 1 minute 5 per minute for next 9 minutes
Shotgun 12 Gage Riot Type	7½	5 Rd. tub. mag.	Manual (pump handle) air cooled	

*Cyclic Rate of Fire (C)...... ...... Rate at which weapon fires automatically.
*Maximum Rate of Fire (M).. . .... Greatest rate at which well-trained gunner can fire
**Sustained Rate of Fire* .... *Rate at which weapon can fire indefinitely without seriously overheating*

Infantry Weapons—Continued

*Sustained rate of fire (rds per min)	*Maximum effective rate of fire (rds per min)	*Maximum range (in meters)	*Maximum effective range (in meters)	Remarks
Continuous discharge 25 seconds	Continuous discharge 25 seconds	Up to several hundred feet	Up to several hundred feet	Contains about 20 pounds of C51
			PT Tgts-150, Area Tgts-35	Minimum safe range: Combat: 31 meters Training: 80 meters. Arming distance: 14–28m. Effective Bursting Radius· 5m
8 indefinitely with any charge	12 (M) for first 2 minutes with Charge Eight	4,512	4,512	Ammunition weighs 7–12 pounds (A) Effective Bursting Area: 25 X 20 meters.
3	20 (M) for first 2 min; 6 for next 20 min; 2 indefinitely	5,650	5,650	Ammunition weighs 26–29 pounds.(A) Effective Bursting Area: 40 X 15 meters.
		Depends on type of shot	Depends on type of shot	

*Maximum Effective Rate . . . Rate at which trained gunner can fire and obtain reasonable number of hits (50%)
*Maximum .... Greatest distance weapon will fire.
*Maximum Effective Rate . . Greatest distance at which gunner may be expected to fire accurately.
Note (A) Depending upon Type of Ammunition Used

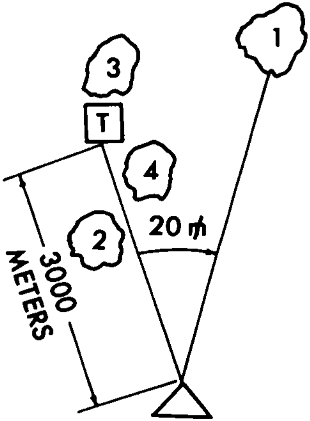
d. After initial fire request to FDC, subsequent corrections are requested as fallaws:

ROUND #1: Left 60, drop 400

ROUND #2: Add 200

ROUND #3. Drop 100

ROUND #4: Add 50, Fire far effect

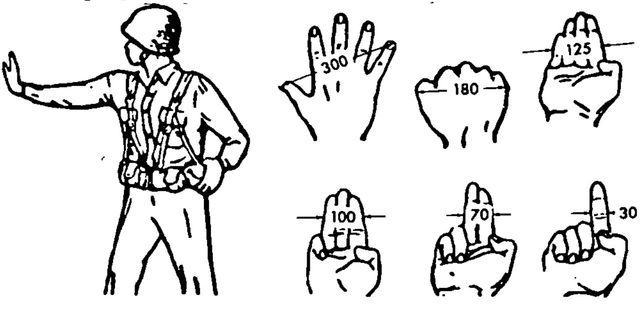


RULES: (1) Keep rounds an abserver-target line.
(2) Bracket target during adjustment.
(3) Split 100 meter bracket befare firing far effect.

e. Angle between target and burst is read in mils, and distance thon determined by multiplying mils by range in thausands.

Example: 20 mils × 3(000) meters = 60 meters.

Fallawing figures indicate hasty methad far estimating angle in mils:



17–19. REQUESTING AND ADJUSTING ARTILLERY FIRE

a. For details refer to FM 6–135.

b. Initial fire request.

Element	*Example*
Identification of observer	"Big Digger 14"
W—Warning order	"Fire mission"
A—Azimuth (From map, or compass)	"Direction 230" (Between 0–6400)
L—Location (Map coordinate or shift from known point)	"Grid NV 645734" or "From target CD 101, right 220, add 400"
N—Nature of target	"15 Man patrol"
U—Unusual factors	(Special fuze, shell, etc)
T—Type control	"Adjust fire, or cannot observe, etc"

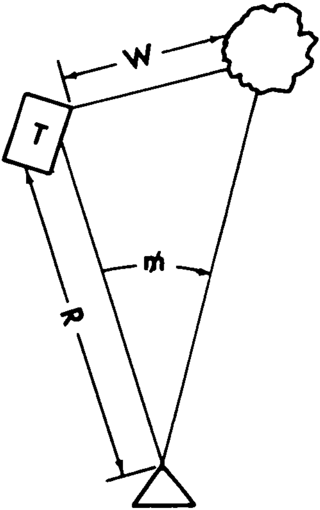
c. WORM formula, for calculating adjustments.

$W = R \times m$

W = Distance in meters from burst to target

R = Range to target in thousands of meters

m = Angular deviation in mils



f. Artillery weapons.

Type	*Range*
105 mm	11,000 meters
155 mm	14,000 meters
8 inch	16,800 meters
175 mm	32,800 meters

g. Artillery ammunition.

HE—high explosive
WP—white phasphorous
SMK—smoke, all colors
HEAT/HEPT—antitank

h. Fuzes.

M557—paint detonatian/delay
M501—mechanical time
M513—radar, airburst

APPENDIX A

REFERENCES

A-1. ARMY REGULATIONS

AR 310-25	Dictionary of United States Army Terms.
AR 310-50	Authorized Abbreviations and Brevity Codes.

A-2. DEPARTMENT OF THE ARMY PAMPHLETS

DA Pam 108-1	Index of Army Motion Pictures and Related Audio-Visual Aids.
DA Pam 310 series	Military Publications Indexes (as applicable).

A-3. FIELD MANUALS

FM 3-8	Chemical Reference Handbook.
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.
FM 5-25	Explosives and Demolitions.
FM 5-30	Engineer Intelligence.
FM 5-31	Boobytraps.
FM 5-35	Engineers' Reference and Logistical Data.
FM 5-36	Route Reconnaissance and Classification.
FM 6-135	Adjustment of Artillery Fire by the Combat Soldier.
FM 10-13	Quartermaster Reference Data.
FM 20-22	Vehicle Recovery Operations.
FM 20-32	Landmine Warfare.
FM 21-5	Military Training Management.
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 21-41	Soldier's Handbook for Defense Against Chemical and Biological Operations and Nuclear Warfare.

FM 21–60	Visual Signals.
FM 21–76	Survival, Evasion and Escape.
FM 24–1	Tactical Communications Doctrine.
FM 24–18	Field Radio Techniques.
FM 30–5	Combat Intelligence.
FM 31–10	Denial Operations and Barriers.
FM 31–60	River-Crossing Operations.
FM 31–70	Basic Cold Weather Manual.
FM 55–15	Transportation Reference Data.
FM 101–10–1	Staff Officers' Field Manual: Organizational, Technical, and Logistical Data, Unclassified Data.

A–4. TECHNICAL MANUALS

TM 3–220	CBR Decontamination.
TM 5–200	Camouflage Materials.
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	Bailey Bridge.
TM 5–280	Foreign Mine Warfare Equipment.
TM 5–297	Well Drilling Operations.
TM 5–302	Construction in the Theater of Operations.
TM 5–311	Military Protective Construction (Nuclear Warfare and Chemical and Biological Operations).
TM 5–312	Military Fixed Bridges.
TM 5–315	Firefighting (Structures, Aircraft, Petroleum, and Nuclear Material) and Rescue Operations in Theaters of Operations.
TM 5–330	Planning and Design of Roads, Airbases, and Heliports in the Theater of Operations.
TM 5–331A	Earthmoving, Compaction, Grading and Ditching Equipment.

TM 5–331B	Lifting, Loading, and Hauling Equipment.
TM 5–331C	Rock Crushers, Air Compressors, and Pneumatic Tools.
TM 5–331D	Asphalt and Concrete Equipment.
TM 5–331E	Engineer Special Purpose and Expedient Equipment.
TM 5–332	Pits and Quarries.
TM 5–333	Construction Management.
TM 5–337	Paving and Surfacing Operations.
TM 5–342	Logging and Sawmill Operations.
TM 5–349	Artic Construction.
TM 5–461	Engineer Handtools.
TM 5–617	Roofing; Repairs and Utilities.
TM 5–618	Paints and Protective Coating.
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 9–1300–214	Military Explosives.
TM 9–1375–200	Demolition Materials.

INDEX

By Order of the Secretary of the Army:

W. C. WESTMORELAND,
General, United States Army,
Chief of Staff.

Officiol:

KENNETH G. WICKHAM,
Major Generol, United States Army,
The Adjutant General.

Distribution:

To be distributed in accordance with DA Form 12–11 requirements for Engineer Field Dato.

U.S. GOVERNMENT PRINTING OFFICE 1969 OL—362—487

⑰ **SECRET** (when completed)

MINEFIELD RECORD

(FM 20-32)

③ Copy No. 1 OF 7

Sheet 1 of 1 Sheets.

⑤ Type: NUISANCE

① Authority for Laying: CG 19 US ARMY

Laying Unit: CO A 92 ENGR BN

Officer in Charge: 1ST LT RUTLEDGE 06092194

② Date & Time — Start: 130645 MARCH 1967

Completion: 131755 MARCH 1967

Recorder: RONALD COMPOZ SGT RA 19 524 643

④ Minefield No. 19XXX-59-E

⑥ Map: Name and Scale: TALBOTSVILLE 1:50,000

Sheet No (or Name): 7739

⑦ LANDMARKS

No.	Co-ordinates	Description
1.		
2.		
3.		
4.		

⑧ INTERMEDIATE MARKERS

No.	Description
1	
2	
3.	
4.	

⑨ Description of Boundary Fence or Marking:

⑩ No. of Strips/Groups — Description of Strip/Group Markers

⑪ LANES

No.	Width	How Marked	Provisions for Closing
1			
2.			
3.			

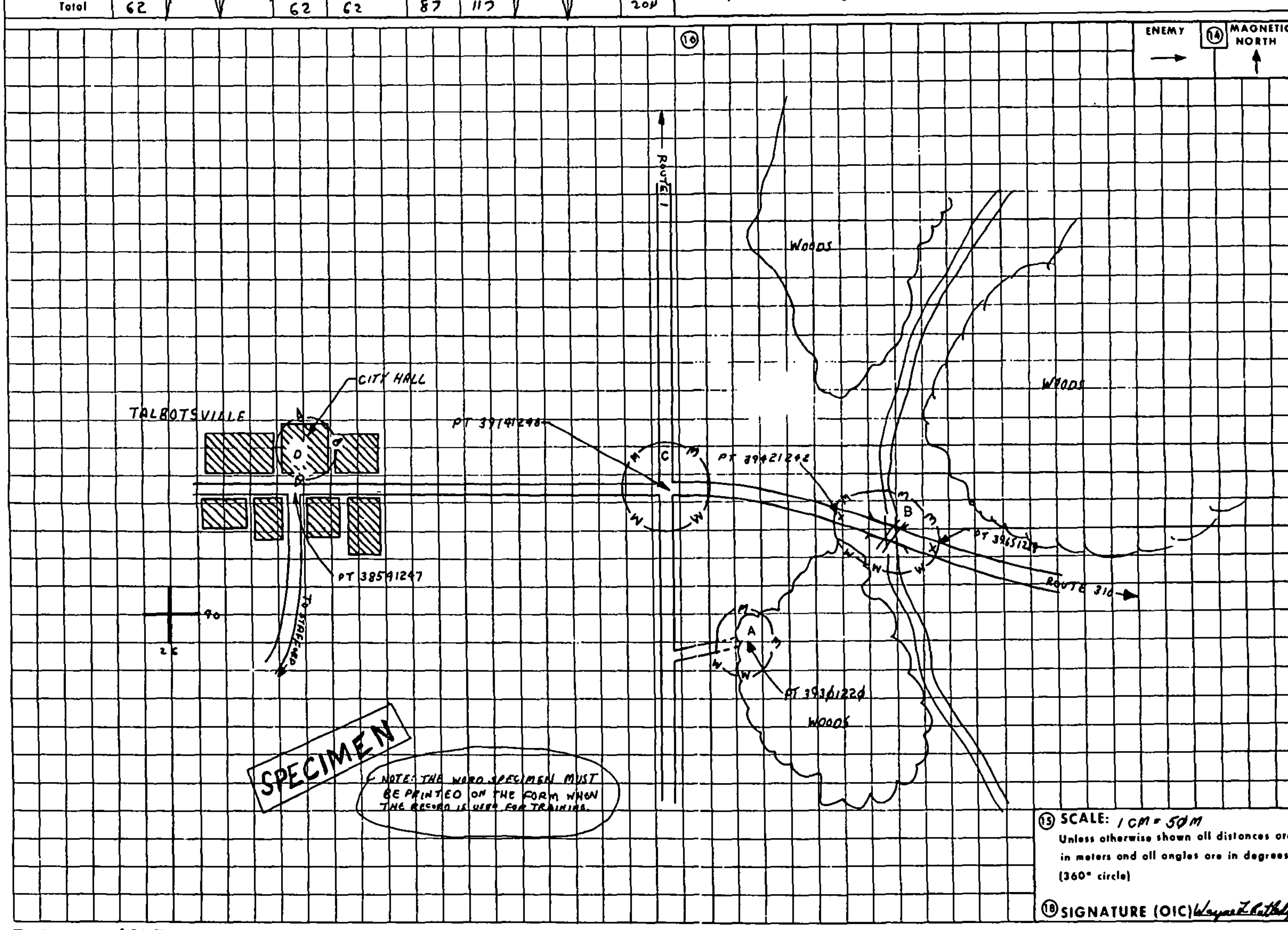
⑫ Method of Laying & Types of Mines Laid: Scattered/Deliberately Laid on Surface/Buried by Hand/ in GROUPS

	ANTI-TANK MINES Type M19 No.	Type No.	Type No.	Total AT Mines No.	Anti Handling Device No.	ANTI-PERSONNEL MINES Type M16 No.	Type M14 No.	Type No	Type No.	Total AP Mines No.
IOE										
A	29			29	29	15	47			62
B	17			17	17	40	52			92
C	21			21	21	32	18			50
D										
E										
F										
Total	62			62	62	87	117			204

⑬ NOTES

MINES EQUIPPED WITH M5 FIRING DEVICES
GROUP A: 15 IN BOTTOM ACTIVATOR WELL.
9 IN SIDE ACTIVATOR WELL.
GROUP B: ALL IN BOTTOM ACTIVATOR WELL.
GROUP C: 12 IN BOTTOM ACTIVATOR WELL
GROUP C HAS 9 M19 MINES WITH M1 FIRING DEVICES INSERTED INTO A 2½ LB BLOCK OF C4 AND ATTACHED TO BOTTOM OF MINE.
GROUP D2 BOOBY TRAPS PLACED. - 1) 2 LB TNT UNDER CENTER OF LOBBY FLOOR ACTIVATED BY MAIN ENTRANCE LIGHT SWITCH OR BY PRESSURE ON M1A1 PRESSURE DEVICE UNDER FLOOR BOARD 2) 2 LB TNT OVER DOOR SILL (MAYOR'S OFFICE) ATTACHED TO M1 PULL DEVICE ACTIVATED BY OPENING DOOR. TEMPORARY MARKERS REMOVED 131755 MARCH 1967.
LOCAL POPULACE INFORMED THAT THEIR AREA WAS MINED BUT WERE NOT INFORMED OF TRUE LOCATION OF MINED AREA.

⑯



⑮ SCALE: 1 CM = 50 M

Unless otherwise shown all distances are in meters and all angles are in degrees (360° circle)

⑱ SIGNATURE (OIC) Wayne T. Rutledge

DA FORM 1355, 1 JUL 67 — REPLACES EDITION OF 1 JUN 66, WHICH IS OBSOLETE.

⑰ **SECRET** (when completed)

Figure 3–19. Record of nuisance minefield.

⑰ **SECRET** (when completed)

MINEFIELD RECORD

(FM 20-32)

③ Copy No 1
Sheet 1 of 1 Sheets.

① Authority for Laying: 8XX (INF) CG	② Date & Time — Start: Ø711ØØ MARCH 1967	④ Minefield No 8XX(INF)-1E	⑤ Type: NUISANCE
Laying Unit: 317th ENGR BN COMBAT	Completion: Ø72ØØØ MARCH 1967	⑥ Map: Name and Scale: TALBOTSVILLE 1:50,000	
Officer in Charge: LT JERRY D. WILLIAMS Ø4062194	Recorder: SGT. M. B. DAVIS RA 18 887 654	Sheet No. (or Name). 721	

⑦ LANDMARKS

No.	Co-ordinates	Description
1.	UT 78267748	BRICK CHURCH BUILDING
2.	UT 78527771	R.J. (RIGHT SIDE)
3.		
4.		

⑧ ~~INTERMEDIATE MARKERS~~ REFERENCE STAKE

No.	Description
1.	U-SHAPE PICKET EX-LONG
2.	
3.	
4.	

⑨ ~~Description of Boundary Fence or Marking~~

⑩ No. of ~~Strips/Groups~~ 4 ROWS. ~~Description of Strip/Group Markers~~

⑪ LANES

No.	Width	How Marked	Provisions for Closing
1			
2.			
3.			

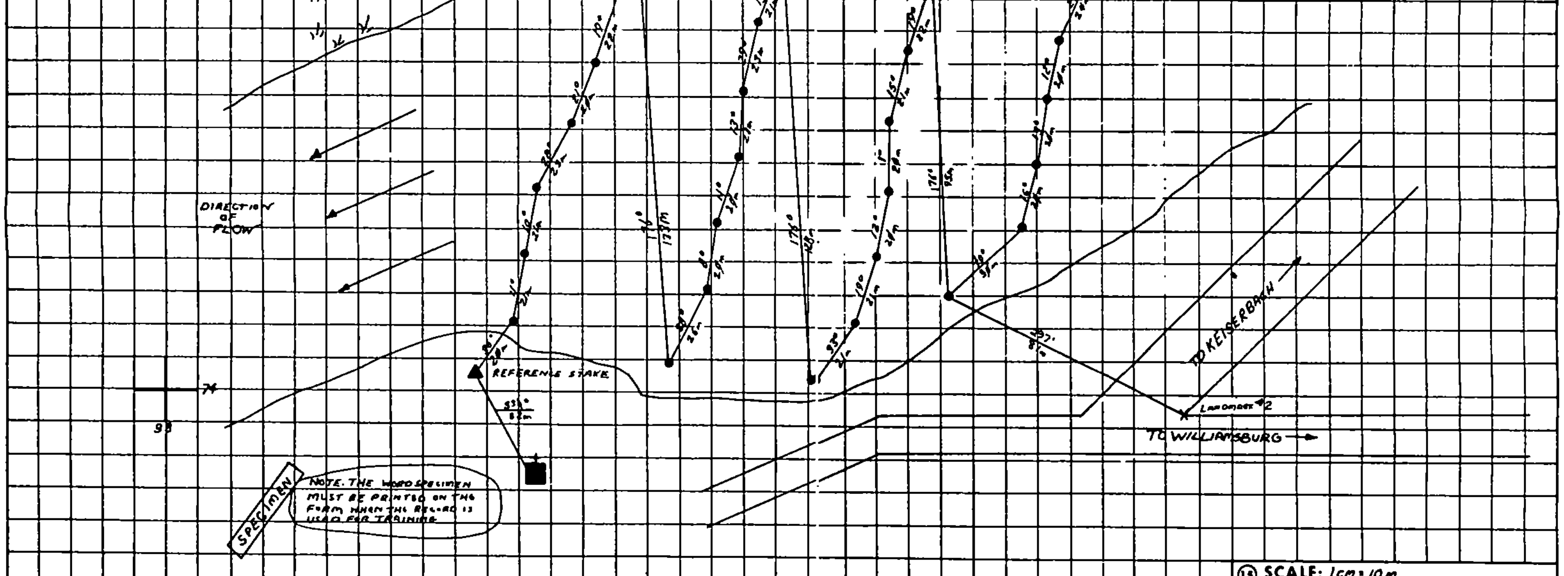
⑫ Method of Laying & Types of Mines Laid: Deliberately laid UNDERWATER by Hand, ROWS

	ANTI-TANK MINES Type M15 No	Type No.	Type No	Total AT Mines No	Anti Handling Device No.	ANTI-PERSONNEL MINES Type No.	Type No.	Type No.	Type No.	Total AP Mines No.
IOE										
A	7			7						
B	7			7						
C	7			7						
D	7			7						
E										
F										
Total	28			28						

⑬ NOTES

① ALL MINES EQUIPPED WITH OUTRIGGERS.
② ALL MINES ARE WATER RESISTANT TREATED.
③ ALL SAFETIES BURIED 1/3 METER SOUTH OF REFERENCE STAKE.
④ AVERAGE DEPTH OF STREAM IS ONE METER.

⑯



⑮ SCALE: 1cm = 10m
Unless otherwise shown all distances are in meters and all angles are in degrees (360° circle)

⑱ SIGNATURE (OIC) Jerry D. Williams 2LT

DA FORM 1 JUL 67 1355 — REPLACES EDITION OF 1 JUN 66, WHICH IS OBSOLETE.

⑰ **SECRET** (when completed)

Figure 3–20. Record of mines emplaced in a ford deeper than 0.6 meter.

⑰ **SECRET** (when completed)

MINEFIELD RECORD

(FM 20-32)

③ Copy No. 1 OF 7 — Sheet 1 of 1 Sheets.

① Authority for Laying: CG 19 U.S. ARMY
Laying Unit: CO A 92 ENGR BN
Officer in Charge 1ST LT RUTLEDGE 06042194

② Date & Time — Start: 130645 MARCH 1967 — Completion: 131755 MARCH 1967
Recorder: RONALD COMPOZ SGT RA19 524 683

④ Minefield No. MXXY-59-E
⑤ Type: NUISANCE
⑥ Map Name and Scale: TALBOTSVILLE 1:50,000
Shoot No. (or Name): 7739

⑦ LANDMARKS

No.	Co-ordinates	Description
1.		
2.		
3.		
4.		

⑧ INTERMEDIATE MARKERS

No	Description
1.	
2.	
3.	
4.	

⑨ Description of Boundary Fence or Marking:

⑩ No. of Strips/Groups — Description of Strip/Group Markers:

⑪ LANES

No.	Width	How Marked	Provisions for Closing
1.			
2.			
3.			

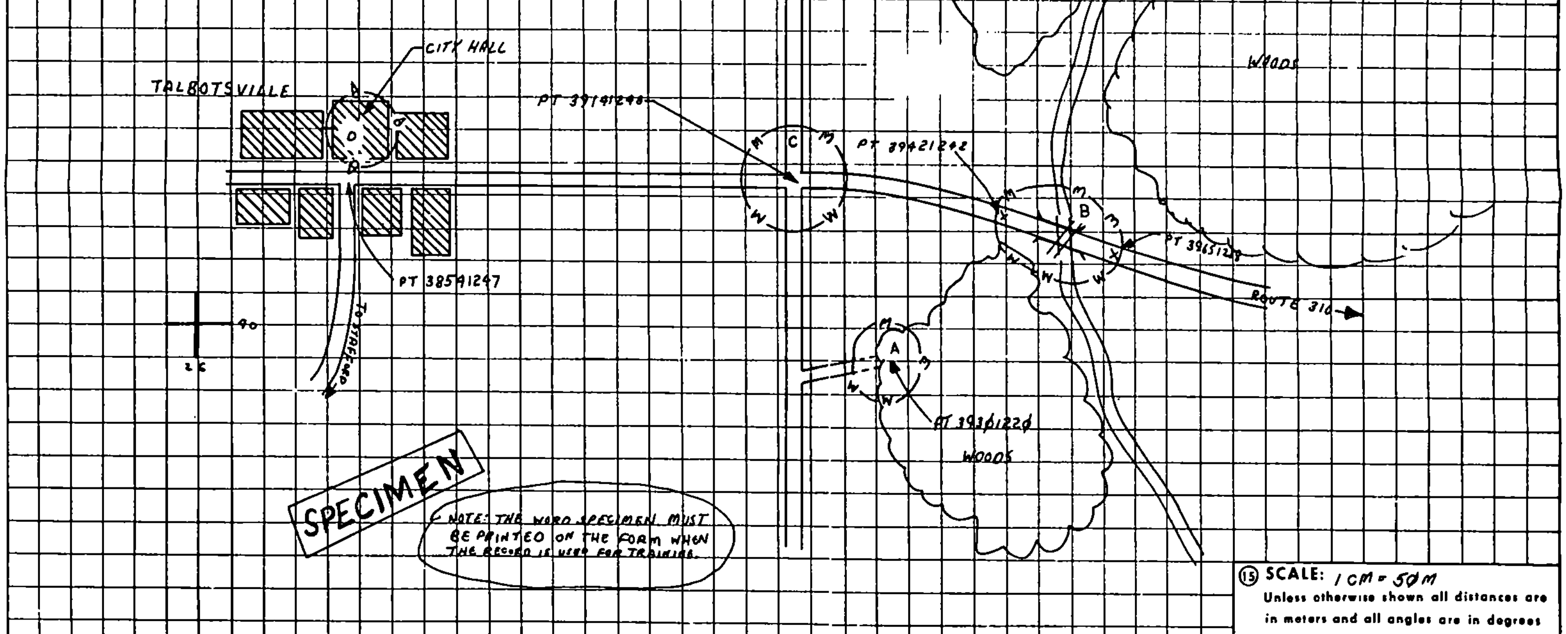
⑫ Method of Laying & Types of Mines Laid: Scattered/Deliberately Laid on Surface/Buried by Hand/in GROUPS

	ANTI-TANK MINES Type M19 No.	Type No.	Type No.	Total AT Mines No	Anti Handling Device No	ANTI-PERSONNEL MINES Type M16 No.	Type M14 No.	Type No.	Type No.	Total AP Mines No
IOE										
A	24			24	24	15	47			62
B	17			17	17	40	52			92
C	21			21	21	32	18			50
D										
E										
F										
Total	62			62	62	87	117			204

⑬ NOTES

MINES EQUIPPED WITH M5 FIRING DEVICES
GROUP A: 15 IN BOTTOM ACTIVATOR WELL.
9 IN SIDE ACTIVATOR WELL.
GROUP B: ALL IN BOTTOM ACTIVATOR WELL.
GROUP C: 12 IN BOTTOM ACTIVATOR WELL
GROUP C HAS 9 M19 MINES WITH M1 FIRING DEVICES INSERTED INTO A 2½ LB. BLOCK OF C4 AND ATTACHED TO BOTTOM OF MINE.
GROUP D 2 BOOBY TRAPS PLACED. - 1) 2 LB TNT UNDER CENTER OF LOBBY FLOOR ACTIVATED BY MAIN ENTRANCE LIGHT SWITCH OR BY PRESSURE ON M1A1 PRESSURE DEVICE UNDER FLOOR BOARD
2) 2 LB TNT OVER DOOR SILL (MAYOR'S OFFICE) ATTACHED TO M1 PULL DEVICE ACTIVATED BY OPENING DOOR. TEMPORARY MARKERS REMOVED 131755 MARCH 1967.
LOCAL POPULACE INFORMED THAT THEIR AREA WAS MINED BUT WERE NOT INFORMED OF TRUE LOCATION OF MINED AREA.

⑯



⑮ SCALE: 1 CM = 50 M
Unless otherwise shown all distances are in meters and all angles are in degrees (360° circle)

⑱ SIGNATURE (OIC) [signature]

DA FORM 1 JUL 67 1355 — REPLACES EDITION OF 1 JUN 66, WHICH IS OBSOLETE.

⑰ **SECRET** (when completed)

Figure 3–19. Record of nuisance minefield.

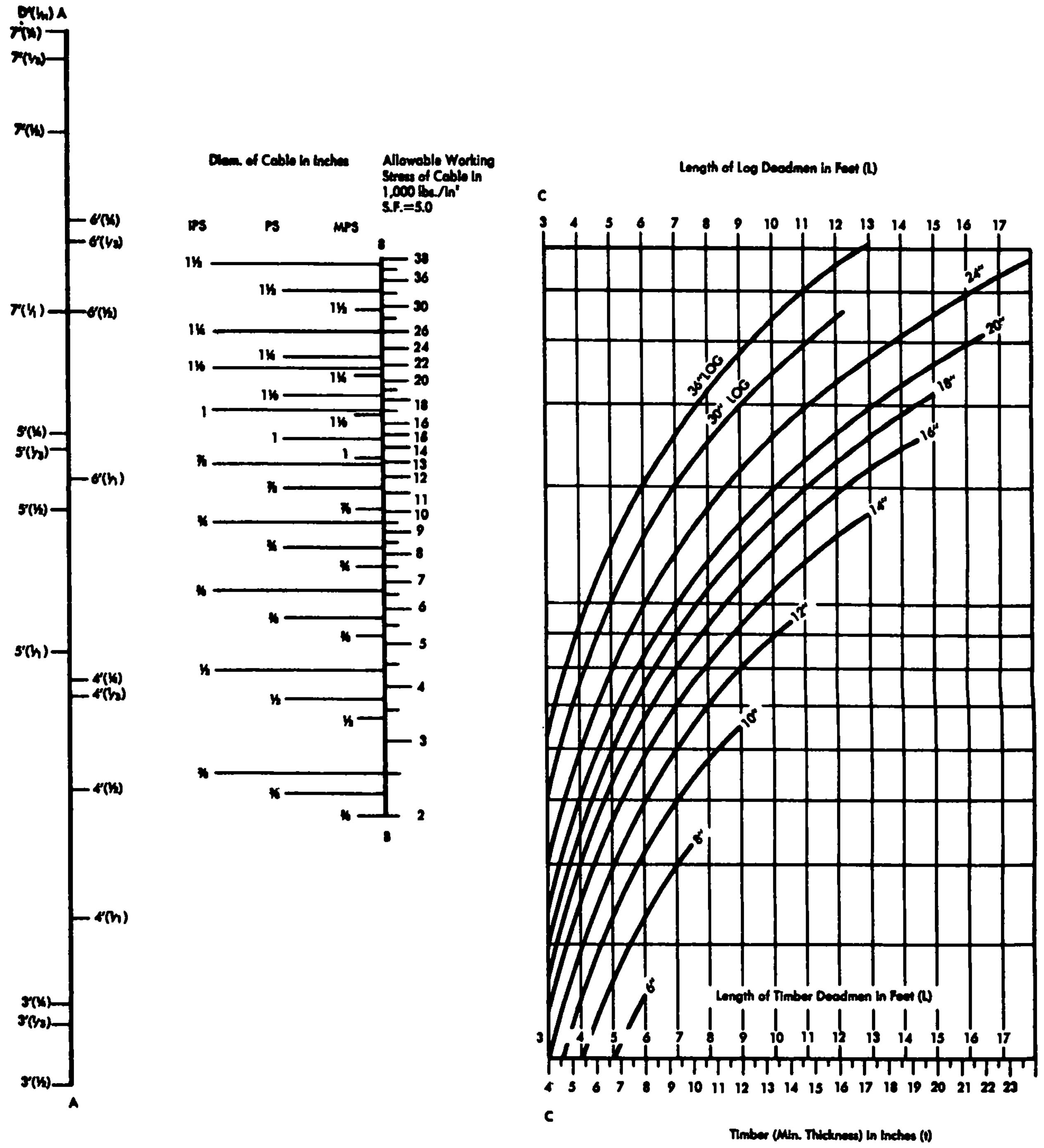


Figure 6–6. Nomograph "A".

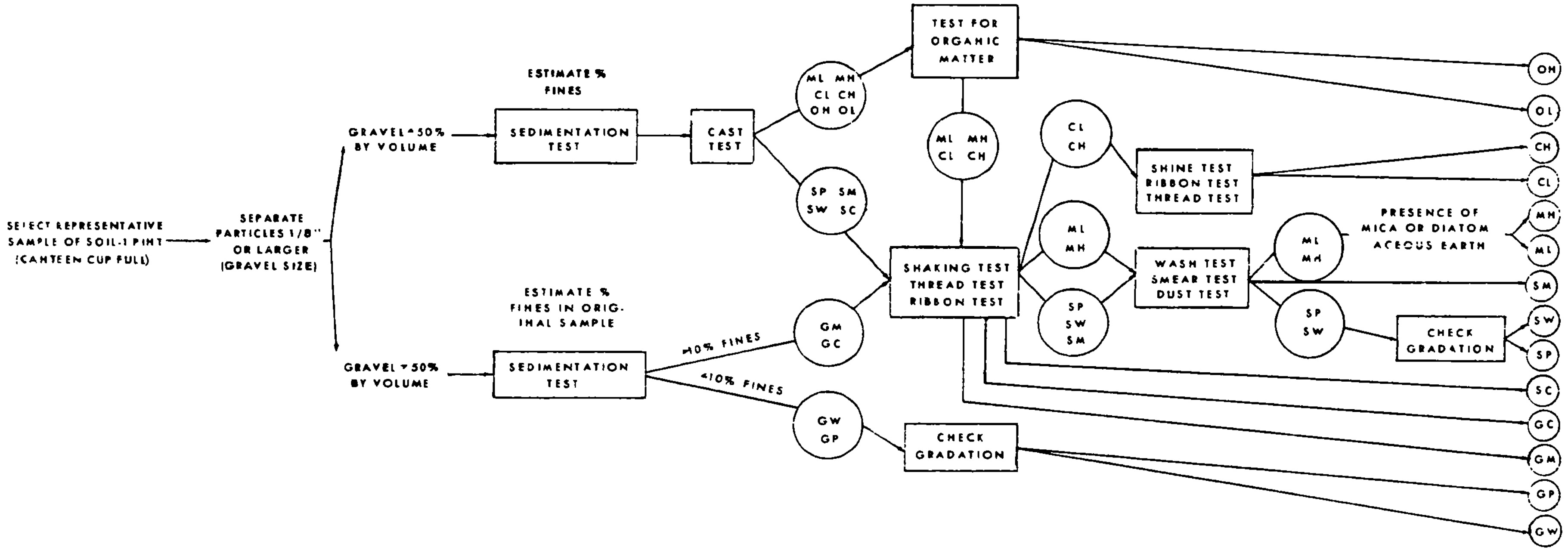


Figure 9–7. Procedure for field identification tests of soils.