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* FM 5–34

FIELD MANUAL
NO. 5–34

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, D.C., 24 September 1976

ENGINEER FIELD DATA

*This manual supersedes FM 5–34, 12 December 1969, with all changes.

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. These subjects apply especially to the duties of engineer unit personnel, particularly officers and noncommissioned officers *in combat Engineer units where mobility is important and the constantly changing missions prevent the use of other references.*

b. Comments. The proponent agency of this publication is the United States Army Engineer School. 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 directly to the Commandant, U.S. Army Engineer School, Fort 8elvoir, Virginia 22060.

Section II. REFERENCES

1–3. MANUALS

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

1–4. STANDARD AGREEMENTS

Information in this manual reflects the application of Standard NATO Agreements (STANAG). Applicable STANAG's can be found in the appendix.

1–5. SYSTEM OF MEASUREMENT AND ABBREVIATIONS

In accordance with AR 310–3, linear distances used in tactical situations are expressed in the metric system throughout the text. Dimensions of a technical nature are expressed in the English system of measurements. Webster's standard abbreviations, such as "km" (kilometers), "m" (meters), "ft" (feet), and "mi" (miles) are used to clearly identify measurement units. A pace or step in marching (referred to as pace in STANAG 2036) is defined as three-quarters (0.75) of a meter (30 inches). Additional conversion factors are included in tables 16–18 and 16–19.

CHAPTER 2

EXPLOSIVES AND DEMOLITIONS

Section I. INTRODUCTION

2–1. CHARACTERISTICS OF EXPLOSIVES

a Demolitions are primarily used for the rapid creation of obstacles, the reduction of enemy obstacles, and construction blasting. The primary advantages are the limited logistical support requirements and the short time and small crews needed for emplacement and detonation.

b See table 2–1 for primary uses of U.S. Military Explosives, and relative effectiveness (RE) factors.

2–2. PROBLEM–SOLVING FORMAT

a Evaluate the mission and determine the results desired.

b. Determine the types and quantity of explosives available.

c. Identify and measure critical dimensions.

d Determine the size of the charge(s). The formulas used in this chapter give the weight of explosive (P) required for a demolition task in pounds of TNT. Where any explosive other than TNT is used, the required pounds of explosive are obtained by dividing P by the relative effectiveness factor (RE) for the explosive used (see table 2–1).

If results require a fraction of a package, round up.

Example:

P(TNT) = 20 lbs (taken from table or chart)

$$P(C-4) = \frac{20 \text{ lbs}}{1.34} = 14.91 \text{ lbs of C-4}$$

Using M–112 blocks (1¼ lbs each)

$$\frac{14.91}{1.25} = 11.9 \text{ blocks, use 12 blocks}$$

e. Determine the total number charges needed.

f. Determine total amount of explosive required. (Size of charge) x (no. of charges needed) + (explosives required for priming) = total explosives required. (Must be computed for each size charge if more than one size charge is used.)

g. Calculate safe distance. See paragraph 2–3 and table 2–2.

Table 2–1 Characteristics of U S Military Explosives

Explosive	Usage	Det. Vel. (fps)	RE Factor	Size, Wgts, & Packaging
TNT	Breaching	23,000	1.00	1 lb 48–56/Box, ½ lb 96–108/Box
Tetrytol	Breaching	23,000	1.20	8–2½ lb/Sack, 2 Sacks/Box
C–4 M5A1 & M112	Cut & Breach	26,000	1 34	M5A1 24–2½ lb Blks/Box M112 30–1¼ lb Blks/Box
Sheet Exp M118 M186	Cutting	24,000	1.14	4–½ lb Sheets/Pack W/20 Packs per Box (1 Sheet = 3" x ¼" x 12") 3–25 lb Rolls/Box (50' long)
Dynamite M1	Qry/Stump/ Ditch	20,000	0.92	100–½ lb Sticks/Box
Det Cord	Priming	20,000–24,000		3–1000' Rolls or 8–500' Rolls/Box
Crater Charge	Craters	8,900	0.42	1–40 lb Cannister/Box
Bangalore M1A2	Wire & Breaching	25,600	1.17	10–5' Sections/Box (176 lb)
Shaped Charges M2A4 M3A1	Cutting Holes	 25,600 25,600	 1.17 1 17	 3–15 lb Shape Charges/Box 1–40 lb Shape Charge/Box

NOTES

1. Dynamite which is to be submerged under water for a period exceedin[g] 24 hours must be waterproofed by sealing in plastic or dipping in pitch.
2. C–4 which is to be used under water must be kept in packages to prevent erosion.
3. Cratering charges will malfunction if the ammonium nitrate is exposed to moisture.

Table 2—2. Minimum Safe Distance for Personnel in the Open

POUNDS OF EXPLOSIVE	SAFE DISTANCE (METERS)	SAFE DISTANCE (FEET)	POUNDS OF EXPLOSIVE	SAFE DISTANCE (METERS)	SAFE DISTANCE (FEET)
1 to 27	300	985	150	532	1745
30	311	1020	175	560	1831
35	327	1072	200	585	1919
40	342	1121	225	609	1997
45	356	1168	250	630	2068
50	369	1210	275	651	2135
60	392	1285	300	670	2198
70	413	1352	325	688	2257
80	431	1413	350	705	2312
90	449	1470	375	722	2365
100	465	1525	400	737	2420
125	500	1640	425	750	2460

Note All safe distances are determined through use of the following formula and are based on normal expected missile hazard rather than blast effect. Metal fragments can exceed the above distances and require maximum cover.

$$\text{Safe Distance (meters)} = 100\sqrt[3]{\text{Pounds of Explosive}}$$

Safe distance using missile—proof shelter = 100 meters

2–3. SAFETY

a. Refer to AR 385–63 for necessary safety precautions pertaining to the use of explosives.

b. Refer to FM 5–25, Explosives and Demolitions, for use of explosives by US Army personnel.

c. Report receipt of damaged or otherwise unsatisfactory explosive material on DD Form 6 in accordance with AR 700–58.

d. Report malfunctions in accordance with AR 75–1.

e. Detonation or burning of ANY explosive releases toxic gases which should not be inhaled. Burning of explosives as a source of heat or for cooking is strictly prohibited since serious illness, injury, or death can be expected.

f. Specific safe practices for handling, transporting, and firing explosives are prescribed in TM 9–1300–206, TM 9–1375–213–12, and FM 5–25.

g. *Misfires.*

(1) Only ONE person should approach a misfired charge, and then only after an appropriate "cook–off" time has lapsed (minimum of 30 minutes for all nonelectrically primed charges and buried charges).

(2) Misfired charges *above ground* should be blown in place with 1 lb of explosive.

(3) Misfired charges which are *buried* should be carefully excavated to no closer than 1 foot from the charge and then blown in place with at least 2 lbs of explosive.

(4) Never abandon misfired explosives.

(5) Never attempt to move or disarm misfires.

h. HANDLE EXPLOSIVES CAREFULLY! DO NOT TAKE CHANCES!

2–4. METHODS OF PRIMING

a *Detonating cord priming* is the use of detonating cord to initiate an explosive charge. When used as a primer, it is not considered as part of the charge it initiates. Detonating cord is initiated as part of either an electric or nonelectric firing system. *It is the most simple, safe, and versatile method of priming. See figure 2–1*

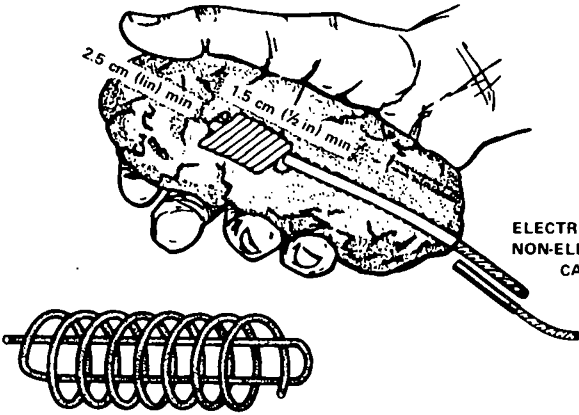


Figure 2–1 Detonating cord priming using plastic explosives.

b. Electric priming is the use of an electric cap to initiate an explosive charge. It has the advantage of command detonation but requires additional equipment.

c. Nonelectric priming is the use of a nonelectric cap to initiate an explosive charge. It cannot be command detonated but requires less equipment than electric priming.

d. All explosive charges should be dual primed to insure detonation. See paragraph 2–5.

2–5. FIRING SYSTEMS

A firing system is a complete means of detonating a charge and includes a primer. A dual-firing system is two completely separate firing systems, each of which can detonate the charges. Possible dual systems are:

a. Dual Electric.
b. Dual Nonelectric
c Combination Dual System (1 Electric, 1 Nonelectric) (fig. 2–2).

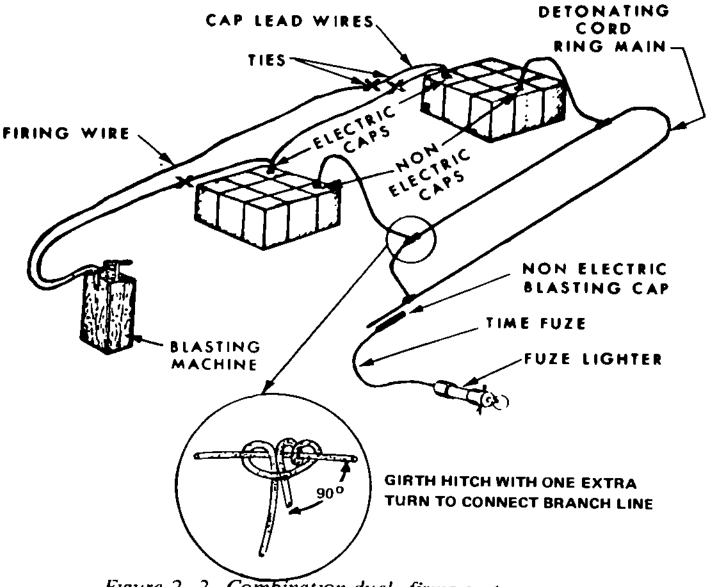


Figure 2–2 Combination duel–firing system.

Note. The hazards of induced current prematurely detonating electric blasting caps may be reduced by following the precautions outlined in FM 5–25.

Section II. DEMOLITION OBSTACLES

2–6. OBSTACLE PLANNING CONSIDERATIONS

a. The combat mission of the unit being supported.

b. Any limitations or instructions issued by higher authority.

c. The current tactical and strategic situation.

(1) The length of time the enemy must be delayed.

(2) The time available to prepare the obstacle.

(3) Direct and indirect supporting fires available.

d. Tie in with other natural or man-made obstacles and plans for effective covering fire.

e. Requirements for lanes and gaps and concealment of mines.

f. The manpower needed to guard and maintain the demolitions while awaiting authority to fire.

g. The materials and equipment available.

h. The possibility that friendly forces will soon reoccupy the area and require the obstacle to be neutralized.

i The immediate and long term effect on the local population.

2–7. BRIDGE DEMOLITION

Generally, bridges are demolished to create obstacles which delay the enemy; however, bridges seldom require complete destruction. The method used for demolition should normally permit the economical reconstruction of the bridge by friendly troops in future operations. Normally, the needed delay can be obtained by blasting a gap that exceeds the capability of the prefabricated high–speed bridging available to the enemy where the construction of an intermediate support will be difficult or impossible. All bridges, because of differences in size, design, and construction materials present individual peculiarities and problems which must be considered, such as

a. How are the spans of the bridge supported and what will be the results of cutting each at various points?

b. Which parts will be easiest to cut with demolitions, what is the extent of desired destruction, and what will be the difficulty of repair?

c. What are the desired points of cut (figs. 2–3 through 2–20)? (Consider the special means of cutting each type of span.)

d Has each member in the plane of cut been identified and measured?

e Is the problem- solving format being followed? See paragraph 2–2.

f. Who has authority to detonate or disarm?

g. Destroyed span should be hardest for enemy to replace.

h. Single abutment destruction should be the friendly side.

i. Piers should be breached at an angle.

j. On very large bridges, consider creating a gap in the approaches instead of the bridge.

2–8. BRIDGE SPAN TYPES

a. Multiple Simple Span (fig. 2–3). Mid–span is most critical point and span ends are normally unsecured. If the gap is shallow, multiple cuts are needed to insure dropping the span completely. If necessary, two or more spans and piers can be cut to obtain the needed gap.

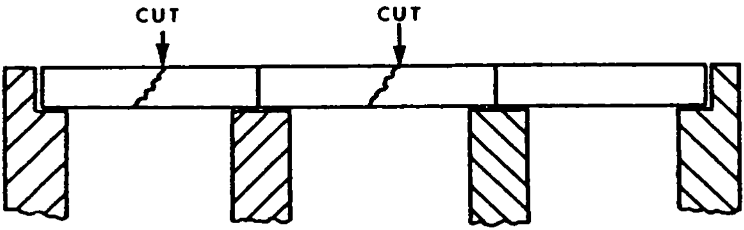


Figure 2–3. Multiple simple spans

b Continuous Span (fig 2–4). Cut at both ends of a span to release a section.

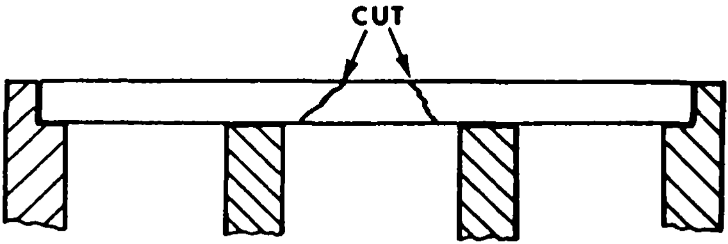


Figure 2–4. Continuous span.

c. Cantilever With Suspended Span (fig. 2–5). Suspended span may be pin connected.

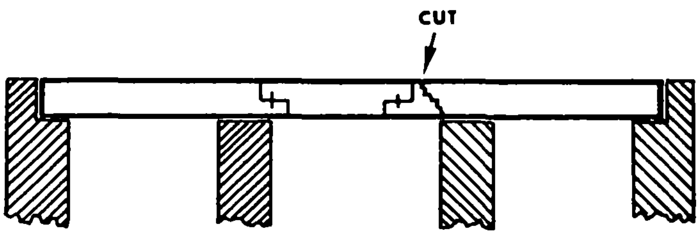


Figure 2–5 Cantilever with suspended span.

2–9. SPAN ANALYSIS

a. Timber Spans. Cut stringers using timber cutting calculations.

b. Steel Stringer Span (fig. 2–6). Cut stringers at different lengths near the plane of cut.

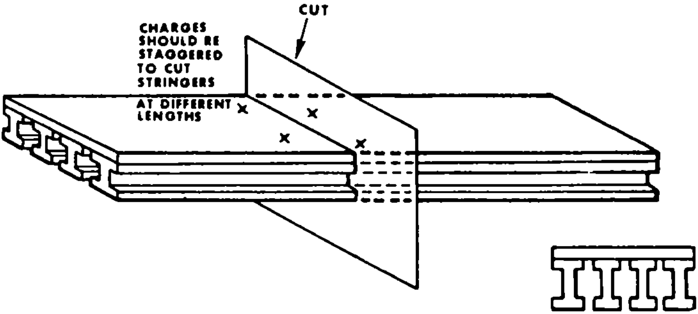


Figure 2–6. Steel stringer span.

c. Through Truss (fig. 2–7).

(1) Method 1 – cut all members where intersected by the plane. Cut in three places if the gap is shallow.

(2) Method 2 – if clearance below the bridge is more than the maximum diagonal truss height (D), four charges, placed on the upstream side at the points marked with an "x," will rotate and totally destroy the span.

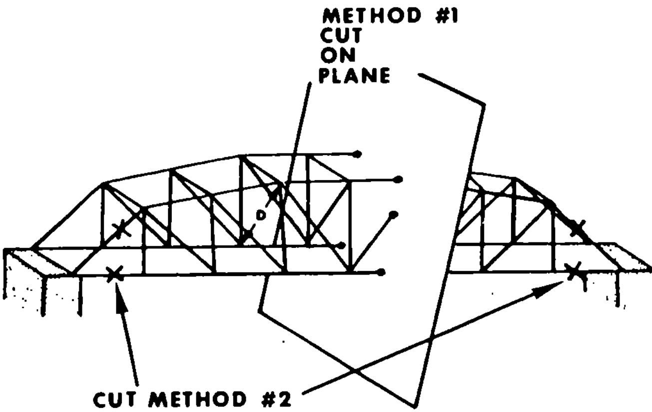


Figure 2–7. Through truss

d. Deck Truss (fig. 2–8). Cut the same as the through truss.

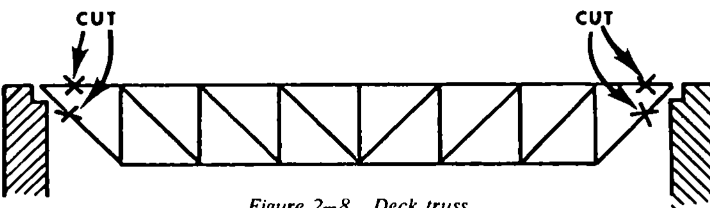


Figure 2–8. Deck truss.

e. Plate Girder (fig. 2–9).

(1) Method 1 – totally cut one girder at A and one at B for total destruction.

(2) Method 2 – cut both girders at either A or B for deep gaps.

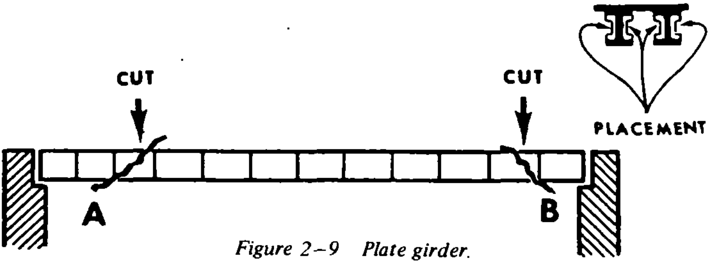


Figure 2–9 Plate girder.

f. Concrete Box Beams (Long Spans) (fig. 2–10). Long prestressed box beams require special charges as the location of the internal openings cannot always be determined prior to demolition. In cases of very massive beams of this type, it may be more efficient to attack the substructure.

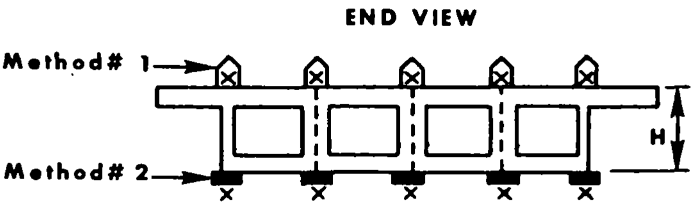


Figure 2–10 Concrete box beam.

(1) Method 1 – if the exact location of the webs can be determined, use shaped charges to cut all webs (fig. 2–10).

(2) Method 2 – external breaching charges can be placed at the joints between the box beams or next to the webs (fig. 2–10).

g. *Filled Arch Bridge.*

(1) Method 1 – cut at point A with charges placed on the arch ring, i.e., dig down to the arch ring or place beneath (fig. 2–11).

(2) Method 2 – place charges on the arch ring at points B.

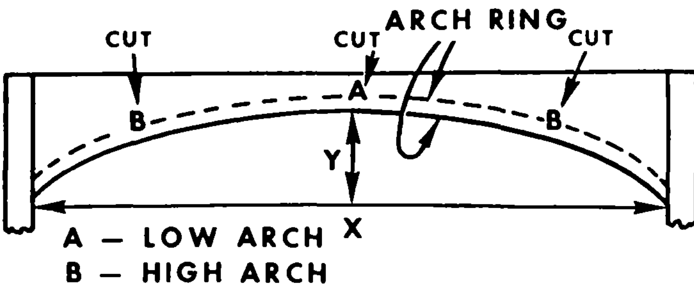


Figure 2–11. Filled arch bridge.

h. *Open Spandrel Arch (fig. 2–12).* Cut at points A, B, and C.

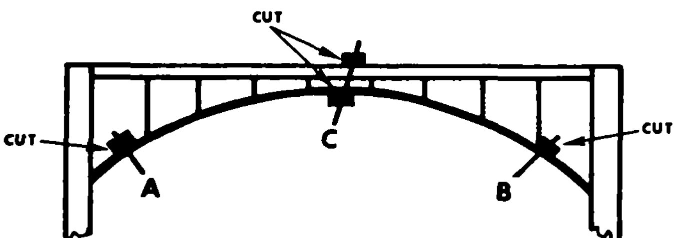


Figure 2–12. Open spandrel arch.

i. Concrete T Beam (fig. 2–13). Breach the top, bottom, or side, or cut beams with 40 pound shaped charge.

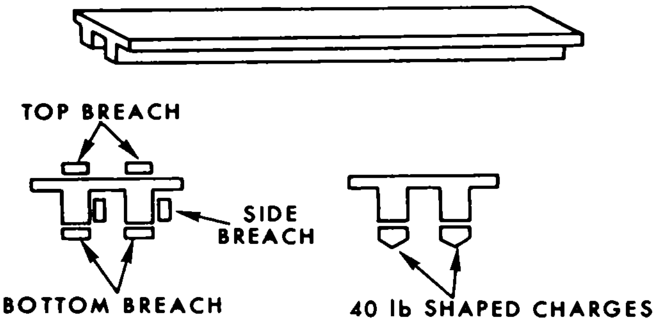


Figure 2–13. Concrete T beam.

j. Concrete Slab (Short Spans) (fig 2-14). Top breach, bottom breach, or breach as a big box beam.

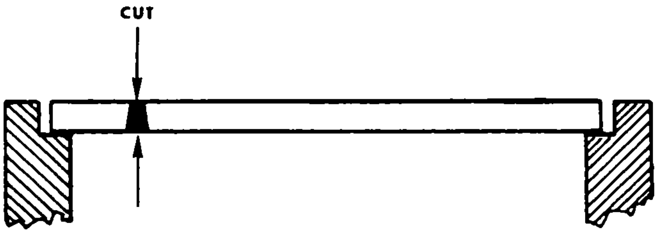


Figure 2–14. Concrete slab (short spans).

k. Concrete I Beams (fig. 2–15). As a result of the thin webs and high strengths, a special means is needed to destroy these prestressed beams.

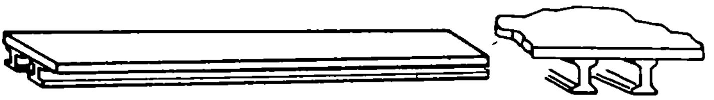


Figure 2–15 Concrete I beams (prestressed).

(1) Method 1 – For beams with a height of 1 meter or less, place charges as shown in figure 2–16 (side breaching charges) with 3 lbs on the bottom flange and 2 lbs on the top flange. Detonate simultaneously. Charges should be placed at mid–span to take maximum advantage of bridge weight.

(2) Method 2 – Totally destroy the web with a shaped charge placed at either the top or the bottom.

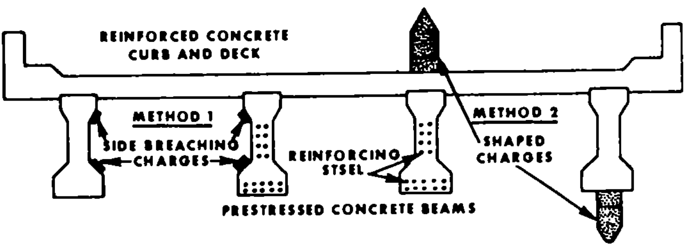


Figure 2–16. Concrete I beams.

2–10. ABUTMENT AND PIER DEMOLITION

a. *Over* 5 feet in thickness and *over* 20 feet in height (see fig. 2–17).

T = more than 5 ft.

Breaching formula $P = R^3KC$ (para 2–12)

Compute the charges for the river face and for behind the abutment separately.

Number of charges $(N) = \frac{W}{2R}$

W = Abutment width

R = Breaching radius

Place on both sides of abutment, as shown in figure 2–17, and fire simultaneously.

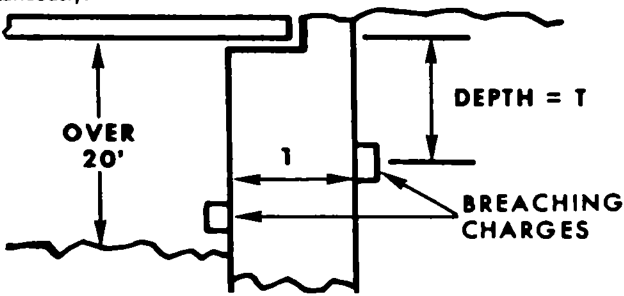


Figure 2–17. Abutment demolition (T > 5').

b. *Over* 5 feet in thickness but 20 feet or *less* in height. Use the solution in 2–10a but delete the charges on the river face.

c. 5 feet or *less* in thickness and *over* 20 feet in height (see fig. 2–18).

T = 5 ft. or less

Space 40 lb charges, 5 ft. back from the river face, 5 ft. deep, and 5 ft apart.

Breaching charges $P = R^3KC$ (river face)

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

Fire charges simultaneously.

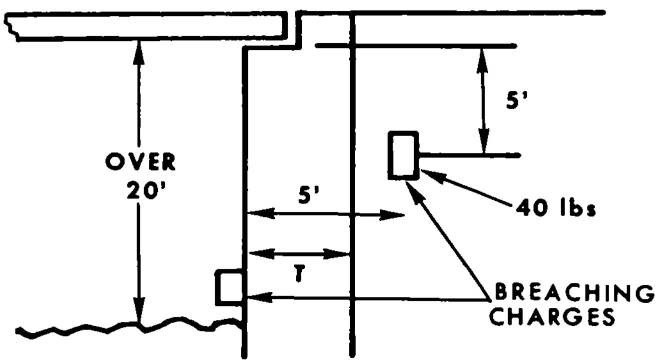


Figure 2–18. Abutment demolition ($T \leq 5'$).

d. Five feet or *less* in thickness and 20 feet or *less* in height. Use solution in 2–10c but delete the charges on the river face.

e. Pier Demolition. Piers must be breached on an angle and as low as possible to maximize engineer repair effort (fig. 2–19).

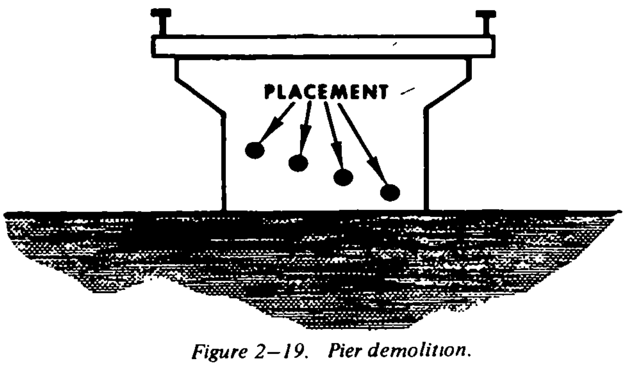


Figure 2–19. Pier demolition.

f. Counterforce Charge (fig 2–20). The counterforce charge is a pair of opposing charges used to fracture small concrete or masonry cubes and cylindrical columns with thicknesses of *4 feet or less.* It is not effective against reinforced concrete piers or long obstacles such as walls. P = 1½ x T (thickness in feet)

Example

Column 3 ft. by 3 ft.

P = 1½ x 3

P = 4.5 lbs total C–4 or sheet explosive

(1) Round fractional measurements to the next higher foot prior to multiplying.

(2) Divide the calculated amount of explosive into two identical charges and place opposite each other.

(3) Place cap or Uli knot in the exact rear centers of charges and detonate simultaneously.

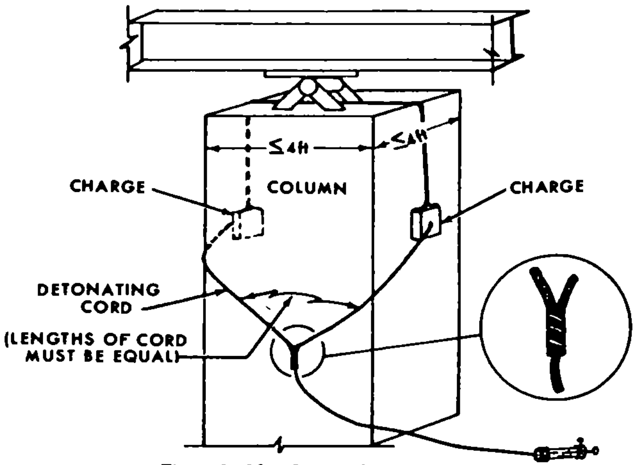


Figure 2–20 Counterforce charge

g. Breaching Hard–Surfaced Pavements.

(1) Use 1 pound of explosives for each 2 inches of pavement. Tamp with material twice as thick as the pavement.

(2) Use a shaped charge. See paragraph 2–19 for sizes.

Section III. CHARGE CALCULATIONS

2–11. STEEL CUTTING CHARGES

Optimum target to explosive contact and dimensions are the most critical factors in steel cutting. The following methods, based on explosive availability, are recommended for demolition steel cutting missions.

a. Ribbon Charge. Used on flat, structural steel (I–beams, wide flange beams, plates, etc.) up to 3 inches in thickness with the following parameters:

Charge Thickness (T_c) = one–half the thickness of steel member (T_s)

$$T_c = \frac{1}{2} T_s$$

Charge Width (W_c) = three times charge thickness (T_c)

$$W_c = 3T_c$$

Charge Length (L_c) = length of desired cut (L_s)

$$L_c = L_s$$

(1) Charge thickness must be a minimum of ½ inch regardless of steel thickness. Plastic explosive (C–4) *must be cut* rather than molded to preserve explosive density.

(2) Ribbon charges may be constructed using entire sheets of M118 sheet explosive or blocks of M112 C–4 explosive as long as the minimum charge dimensions are equal to or larger than those specified above in paragraph 2–11a.

(3) Correct placement of the ribbon charge requires close target–to–explosive contact over the entire length of steel to be cut (fig. 2–21).

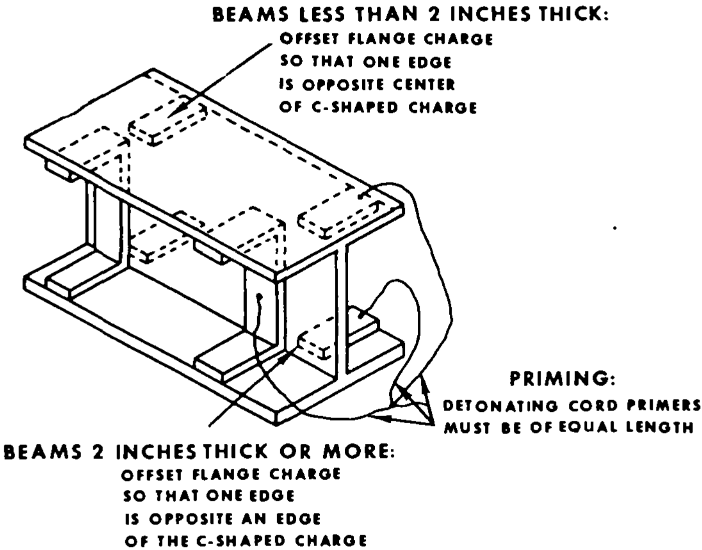


Figure 2–21. Ribbon charge.

b. Saddle Charge. Used on solid cylindrical structural steel bars up to 6 inches in diameter. It is triangular in shape and 1 inch thick with the long axis equal to the bar circumference and the short axis equal to one–half the bar circumference. It may also be used on solid rectangular or square bars (up to 8 inches square) but with slightly greater charge placement difficulty. Detonation is initiated by a blasting cap or Uli knot at the apex of the long axis. The explosive should be cut rather than molded (fig. 2–22).

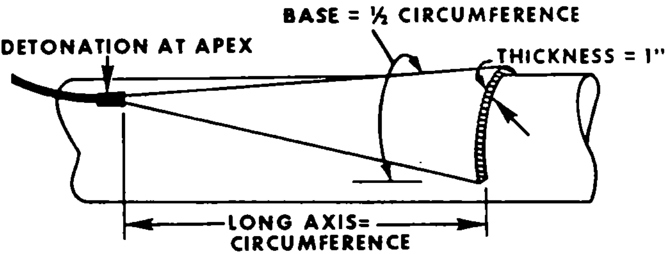


Figure 2–22. Saddle charge.

c Diamond Charge Used on solid cylindrical steel bars up to 6 inches in diameter. It is diamond shaped, 1 inch thick, with the long axis equal to the circumference of the bar and the short axis equal to one–half the bar circumference. It may be used on rectangular or square bars, but placement around corners is extremely difficult. It is primed at the apex of both ends of the short axis with exactly equal lengths of detonating cord in conjunction with either nonelectric caps or Uli knots. The detonating cord is then joined together at the ring main. The explosive should be cut rather than molded (fig. 2–23).

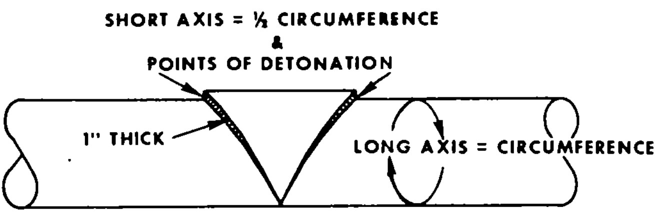


Figure 2–23. Diamond charge.

d. The steel cutting formula is still acceptable when only hard block explosives are available.

Steel cutting formula $P = (3/8)A$

P = pounds of TNT required

$3/8$ = constant

A = cross–sectional area of member in square inches.

See problem–solving format, paragraph 2–2.

e. *Rules of Thumb (Steel Cutting)* Rules of thumb for steel cutting give the required explosive quantities in pounds of TNT and *do not* require dividing by an RE factor.

(1) *Rails (cut preferably at crossings, switches, frogs, or curves).* Cut at alternate rail splices for a distance of 500 feet.

(a) Less than 5 inches high – use ½ pound.

(b) Five inches or higher – use 1 pound.

(c) Crossings and switches – use 1 pound.

(d) Frogs – use 2 pounds.

(2) *Cables, chains, rods, and bars.*

(a) Up to 1–inch diameter – use 1 pound.

(b) Over 1 inch to 2 inches – use 2 pounds.

(c) Over 2 inches – use $P = (3/8)A$ or suitable dimensional–type charge.

(3) *Note.* Chain and cable rules are for those under tension; both sides of chain link must be cut.

2–12. BREACHING CHARGE COMPUTATIONS

a. *Breaching Formula.*

$P = R^3KC$ where

P = pounds of TNT required

R = breaching radius in feet

K = material factor (strength); table 2–3

C = tamping factor; table 2–4

Note

(1) For external charges based on $P = R^3KC$, use a minimum of 5 pounds for reinforced concrete and 3 pounds for dense concrete.

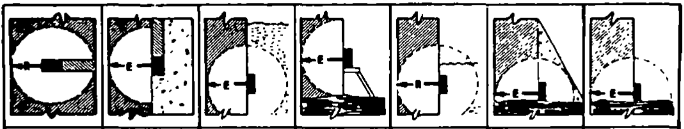
(2) Round up "R" to nearest ½ foot.

(3) When type of concrete is unknown, always assume it to be reinforced.

Table 2–3. Values of K (Material Factor) For Breaching Charges

Material	Breaching radius	K
Ordinary earth	All values	0.07
Poor masonry, shale, hardpan: Good timber and earth construction	Less than 5 ft 5 ft or more	0.32 0.29
Good masonry ordinary concrete rock	1 ft or less 1.5–2.5 ft 3.0–4.5 ft 5.0–6.5 ft 7 ft or more	0.88 0.48 0.40 0.32 0.27
Dense concrete first–class masonry	1 ft or less 1.5–2.5 ft 3.0–4.5 ft 5.0–6.5 ft 7 ft or more	1.14 0.62 0.52 0.41 0.35
Reinforced concrete (concrete only: Will not cut reinforcing steel)	1 ft or less 1.5–2.5 ft 3.0–4.5 ft 5.0–6.5 ft 7 ft or more	1.76 0.96 0.80 0.63 0.54

Table 2–4. Values of Tamping Factor "C"



INTERNAL	STEMMED	DEEP WATER	ELEVATED UNTAMPED	SHALLOW WATER	GROUND PLACED TAMPED	GROUND PLACED UNTAMPED
C=1.0	C=1.0	C=1.0	C=1.8	C=2.0	C=2.0	C=3.6

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

b. Breaching Table. Table 2–5 gives the pounds of TNT required to breach reinforced concrete targets, calculated from the formula $P = R^3KC$. For material other than reinforced concrete, multiply by the conversion factor in table 2–6.

2–13. TIMBER CUTTING CHARGES

a. Test shots are made to determine the required amount of explosives to cut specific types of timber. This section provides charge calculations for initial *test shots only.*

b. External Placement. $P\ (TNT) = \frac{D^2}{40}$. Use to cut trees, poles, piles, posts, beams, and other timber with external untamped charges. Use graph (fig. 2–24) to calculate amount required, and place as shown in figure 2–25 (D = diameter in inches).

Table 2-5. Breaching Charges, Reinforced Concrete Only

THICKNESS OF CONCRETE	METHODS OF PLACEMENT				
					
	C=1.0		C=1.8	C=2.0	C=3.6
FEET	POUNDS OF TNT				
2	2	8	14	16	28
2½	2	15	27	30	54
3	4	22	39	44	78
3½	6	35	62	69	124
4	8	52	93	103	185
4½	11	73	132	146	263
5	15	79	142	158	284
5½	20	105	189	210	378
6	22	136	245	273	490
6½	28	173	312	346	623
7	35	186	334	371	667
7½	43	228	410	456	821
8	52	277	498	553	996

TO USE TABLE:

1. MEASURE THICKNESS OF CONCRETE
2. DETERMINE METHOD OF PLACEMENT
3. NOTE TNT REQUIRED ACCORDING TO METHOD OF PAYMENT
4. IF USING EXPLOSIVE OTHER THAN TNT DIVIDE BY RE FACTOR FOR ALL METHODS OF EMPLACEMENT EXCEPT INTERNAL
5. TO DETERMINE REQUIRED NUMBER OF CHARGE:

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

WHERE: W=WIDTH OF TARGET
R=BREACHING RADIUS (1)

NOTES:

(1) PLACE FIRST CHARGE "R" DISTANCE FROM END OF TARGET AND ALL OTHER CHARGES "2R" DISTANCE APART.

(2) FOR BEST RESULTS PLACE CHARGE IN SHAPE OF A FLAT SQUARE

(3) FOR CHARGES LESS THAN 40 LBS USE CHARGE THICKNESS OF 2 INCHES

(4) FOR CHARGES 40—300 LBS USE CHARGE THICKNESS OF 4 INCHES

Table 2–6. 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

c. Internal Placement. P (ANY) $= \frac{D^2}{250}$. Use graph (fig. 2–24) for proper calculation of explosive required. (D = diameter in inches).

d. Abatis P (TNT) $= \frac{D^2}{50}$. To create an abatis, use graph for initial calculation and place as an external charge. Results should leave tree attached to stump at a height of 3–5 feet. Minimum tree diameter for an effective abatis is 18 in. for wheeled vehicles and 24 in. for tracked vehicles (D = diameter in inches).

e. Ring Charges. (For diameters 30 in. or less)

(1) *Calculations*

(a) M118 or M186 sheet explosive; ½ x circumference (ft) x No. wraps = lbs.

(b) C–4; 1.36 x circumference (ft) x No. wraps = lbs.

(c) As an alternate method, use $P = \frac{D^2}{40}$ (D = diameter in inches)

(2) *Placement (fig. 2–25).*

(a) Explosive must be wrapped completely around timber in order to be effective, tamp if possible.

(b) Direction of fall can be controlled only with ropes and cables.

2–14. CRATERING CHARGES

a Requirements. Road craters, in order to be effective obstacles, must be too wide to be spanned by tracked vehicles and too deep and steep–sided for any vehicle to pass through them. Blasted road craters will not stop modern tanks indefinitely but are considered effective antitank obstacles if

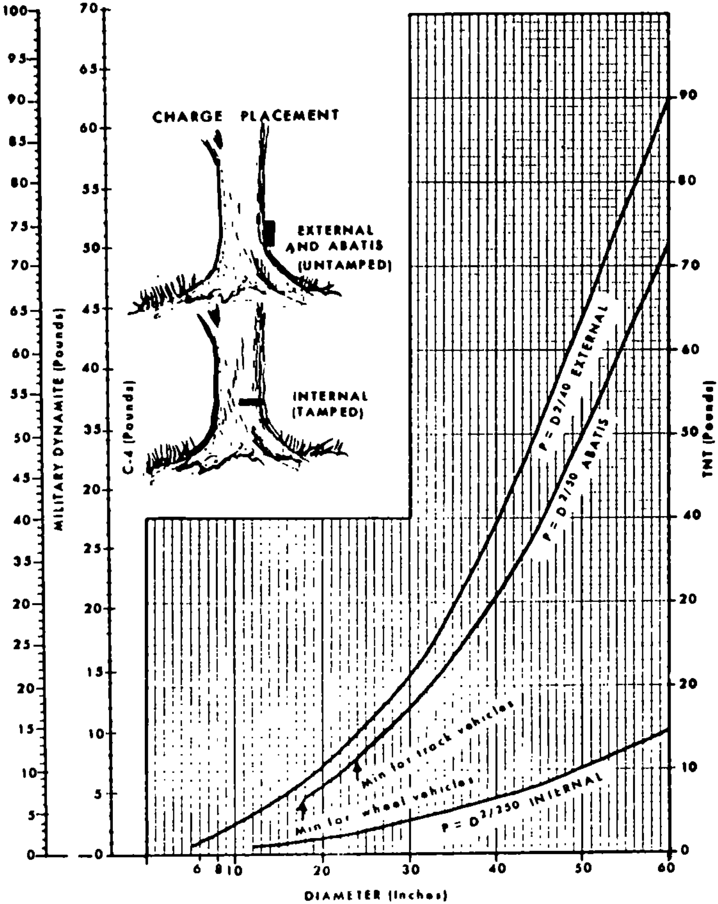


Figure 2–24. Timber cutting calculations

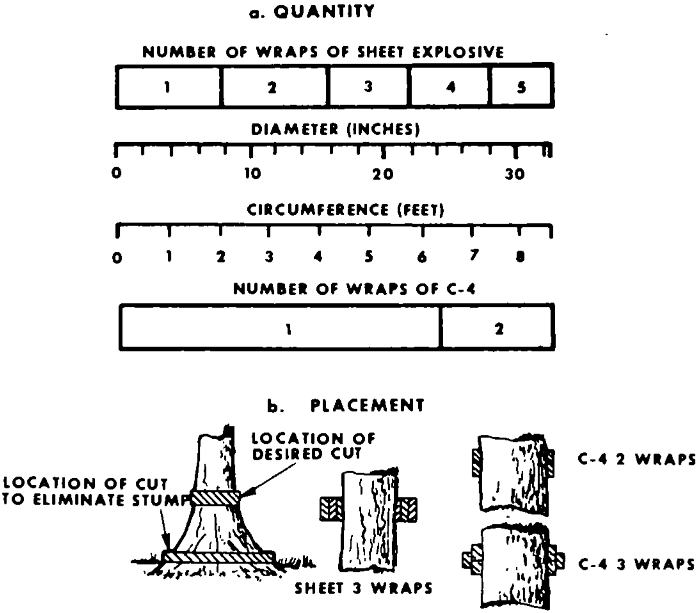


Figure 2—25. Timber cutting charges.

the tank requires three or more passes to cross the crater. Three passes will provide sufficient time for antitank weapons to disable the tank. Road craters must tie in with natural or man-made obstacles at each end. Antitank and antipersonnel mines are often placed at the site to hamper repair operations and thus increase the effectiveness of the crater. Road craters angled at about 45° to the roadway are more effective obstacles than craters blasted perpendicular to the roadway. Holes for cratering charges may be dug by:

(1) Handtools
(2) Earth auger
(3) 40 lb shaped charges with a 5—ft. standoff
(4) 15 lb shaped charges with a 3.5—ft. standoff

b *Deliberate Crater.* See figure 2—26.

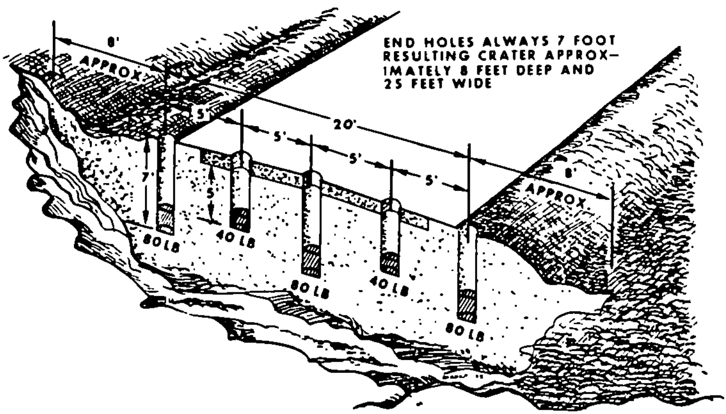


Figure 2—26. Charge placement for deliberate road crater.

(1) Number of holes (N) = $\frac{L-16}{5} + 1$, where L = total length of the crater in feet.

(2) Holes are 5 feet apart with both end holes 7 feet deep; holes alternate between 5 and 7 feet in depth, but no two 5 ft. holes may be next to each other.

(3) Place 80 pounds of explosive in 7–foot holes; 40 pounds of explosive in 5–foot holes.

(4) Excavation will result with approximately 8 feet of overblast on each end.

c. *Relieved Face Crater.* See figure 2–27.

(1) Number of holes (friendly side): N = $\frac{(L-10)}{7} + 1$, where L = length of crater in feet (5 ft. deep).

Number of holes (enemy side): N – 1 (4 ft. deep).

(2) Place 2 rows 8 ft. apart, spacing boreholes 7 ft. apart in each row. See figure 2–27.

(3) Enemy side is detonated first, friendly side second with a 1 to 1½ second delay. Insure that the first detonation will not cut the firing system on the second row.

d. *Hasty Crater.* Figure 2–28.

(1) Holes of equal depth spaced at 5–foot intervals: Place 10 pounds of explosives per foot of depth; resulting crater will be approximately 1½ times the depth of boreholes and 5 times the borehole depth in width (fig. 2–28).

(2) Boreholes should be a minimum of 5 feet in depth.

(3) Number of holes = N = $\frac{L-16}{5} + 1$

(4) This crater is not as effective as a deliberate or relieved face crater but is excellent when preparing surfaced areas for mining.

2–15. DESTRUCTION OF ENEMY OBSTACLES

a. *Combat Engineer Vehicle (CEV).* The CEV provides engineer combat support to ground operations in the destruction and removal of roadblocks, the filling of gaps, ditches, and craters, and in performing other

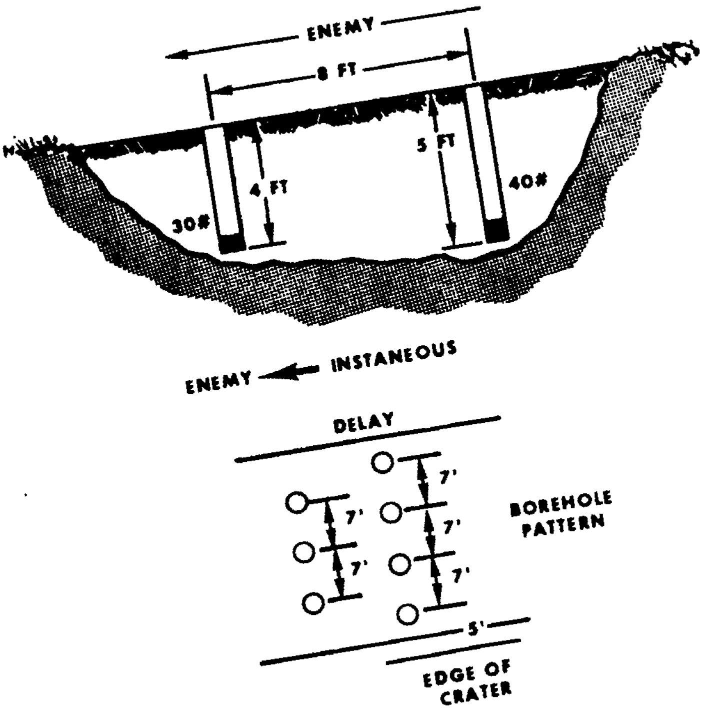


Figure 2–27. Relieved face crater.

HOLES OF EQUAL DEPTH, SPACED AT 5–FOOT INTERVALS.
USE 10–POUNDS OF EXPLOSIVES PER FOOT OF DEPTH.
RESULTING CRATER DEPTH APPROX. 1½ TIMES DEPTH OF BOREHOLES. WIDTH APPROX. 5 TIMES DEPTH OF BOREHOLES.

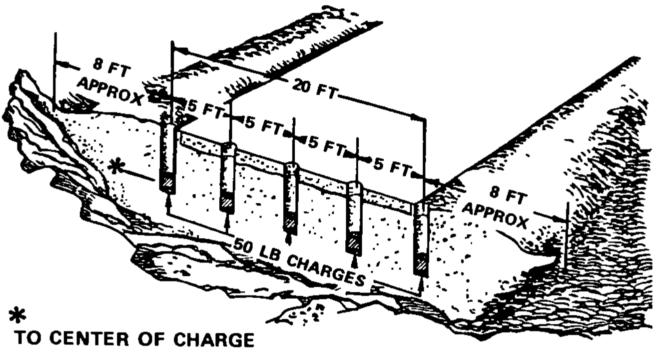


Figure 2–28. Charge placement for hasty road crater.

engineer tasks. The CEV has a 165–mm demolition gun, which has a maximum effective range of 900 meters. It can hit a 6 ft. by 6 ft. target consistently. The minimum safe distance from the impact area for personnel in the open is 1200 meters. The primary use of the gun is to remove obstacles such as roadblocks, log cribs, trees, and to destroy enemy bunkers without exposing personnel to enemy small arms fire. If a dud round occurs, the round remains armed and should be blown in place.

b. Rules of Thumb For Destroying Obstacles (Combat Situation).

(1) *Concrete block obstacles.* Use 1 pound of explosive per cubic foot of volume up to 100 cubic feet.

(2) *Log obstacles.* Generally the charge should be placed at a joint. Against log cribs, place 30 to 40 pounds of explosives in the center of the earth fill, two–thirds down the depth of the crib, and tamp, if possible. Charges should be placed at 8 foot intervals throughout the length of the obstacle. Charges placed on obstacles driven into the ground should be attached below or as close to the surface of the ground as possible.

c. Walls.

(1) Concrete walls not backfilled: use breaching formula in paragraph 2–12.

(2) Backfilled walls: multiply by 1.2 the charges specified for walls not backfilled.

Section IV. ROCK BREAKING, DITCHING, AND STUMPING

2–16. BLASTING BOULDERS

See table 2–7 for charge size for blasting boulders. See figure 2–29 for placement of charges. External breaching charges may be used as an expedient.

Table 2–7. Charge Size For Blasting Boulders

Boulder diameter (ft)	Pounds of explosive required		
	Blockholing	Snakeholing	Mudcapping
3	¼	¾	2
4	⅜	2	3½
5	½	3	6

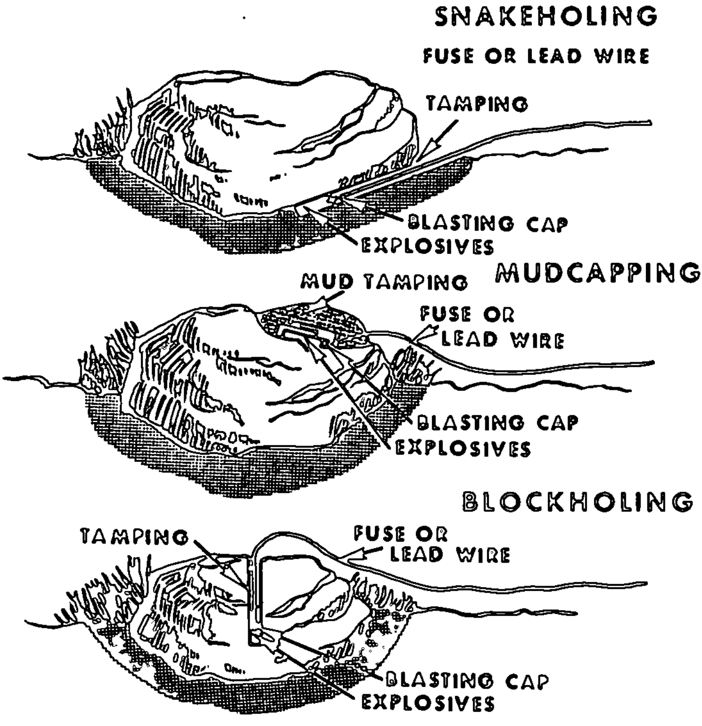


Figure 2–29. Methods of blasting boulders.

2–17. DITCHING

a. Conditions. Rough open ditches 1 to 4 m deep and 1 to 20 m wide can be blasted in most types of soil, other than gravel or sand. Trees, stumps, and large boulders are charged separately, but are fired with the ditching charges.

b. Test Shots. Before beginning the ditching, test shots are required to determine the proper depth, spacing, and weight of charges needed for the desired results.

c. Detonation. Begin with holes 2 feet deep and 18 inches apart for soft ground. The depth of the hole is normally 1 foot above the gradeline of the ditch.

d. Use 1 pound of explosive per cubic yard of material to be removed. Test and adjust as needed.

2–18. STUMPING

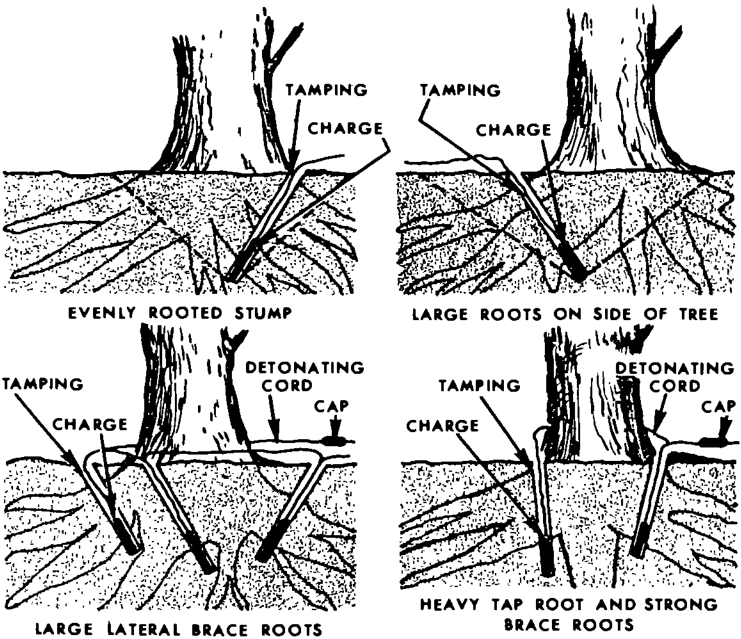
a. Use a ring charge at ground level if speed is important and the roots can remain in place.

b. The size of the charge required varies with the size, variety, and age of the tree or stump and with soil conditions. The rules of thumb (fig. 2–30) must be adjusted based on test results.

2–19. BREACHING HARD SURFACE PAVEMENTS

a. Shaped Charges. Table 2–8 shows the size of boreholes obtained by using the standard shaped charges.

b. If shaped charges are not available, follow instruction outlined in paragraph 2–10g. Pavement breaching charges should not be placed at an expansion joint in the concrete.



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—30. Stump blasting methods for various root structures

Table 2-8 Size of Boreholes Made by Shaped Charges

Material		15 lb. shaped charge (M2A4)	40 lb. shaped charge (M3A1)
Reinforced Concrete	Max wall thickness thet can be perforated	36"	60"
	Depth of penetration in thick walls	30"	60"
	Average diameter of hole	2¾"	3½"
	Minimum diamatar of hola	2"	2"
Armor Plate	Penetration	12"	20" (at least)
	Average diametar of hole	1½"	2½"
3" concrete pavement with 24" rock base course	Optimum standoff	3½'	Equal to or greater than shown below for 10" concrete
	Min. depth of penetration	38" – 90"	
	Min. diameter of hole	3¾"	
10" concrete pavement with 21" rock base course	Optimum standoff	3½'	5'
	Depth of penetration	44" – 91"	71" – 109"
	Min. diameter of hole	1¾"	6¾"
Soil	30" standoff.		
	Diameter of hole	7"	
	Depth of hole	7'	
	48" standoff.		
	Diameter of hole		14½"
	Depth of hole		7'
Permafrost	Diameter of hole w/30" standoff	1½" to 6"	
	Depth of hole w/30" standoff	6'	
	Depth of hole w/42" stendoff	5'	
	Diameter w/50" standoff		5" to 8"
	Depth w/50" standoff		6'
Ice	Diameter w/42" standoff	3½"	6"
	Depth w/42" standoff	7'	12'

CHAPTER 3

LANDMINE WARFARE

Section I. INTRODUCTION

3–1. TYPES OF MINES

See table 3–1 for standard U.S. mines and firing devices.

3–2. TYPES OF MINEFIELDS AND EMPLOYMENT

Minefields are classified into five types according to their function and method of employment.

a Types

(1) *Protective minefield (hasty or deliberate)* No set pattern. Antihandling devices and nonmetallic mines should not be used. Protective minefields are particularly suitable for directional mines.

(a) Hasty. Used to provide local close–in protection. Mines should be readily detectable and facilitate rapid removal by the laying unit. Boobytraps and antidisturbance and antihandling devices *will not* be used. Authority to lay is battalion – can be delegated to company or platoon for a specific operational mission.

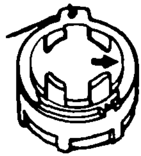
(b) Deliberate. Used to provide local protection for semifixed installations. Normally, mines are buried and the minefield is semipermanent in nature. Authority to lay is the installation commander.

(2) *Tactical minefield.* Used to stop, delay, or disrupt an enemy attack, to reduce enemy mobility, to block penetrations, and to strengthen manned positions. May be used behind enemy forces in order to deny withdrawal, prevent reinforcement, or protect friendly flanks. Conventional mines will be laid in a standard minefield pattern, but scatterable mines may also be integrated into the minefield. Authority to lay is division – can be delegated to brigade.

Table 3–1. Mine Data

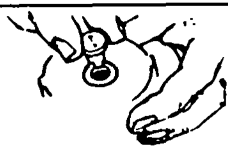
M14 BLAST ANTIPERSONNEL MINE

1



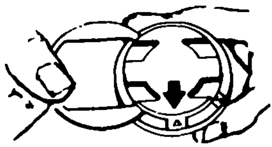
2
Wt . . . . 3 1/3 oz.
Explosive . . 1 oz. TETRYL
Fuze . . . . integral
(with Belleville Spring)
Functioning 20 to 35 lb.
Penetrate Boot & Foot

3



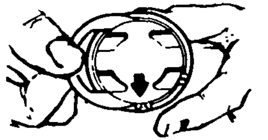
Unscrew shipping plug from bottom of mine. Turn pressure plate to ARMED position with arming tool.

4



Remove safety clip and check for malfunctioning.

5

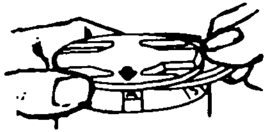


Replace safety clip.

6

Screw detonator into detonator well.

7



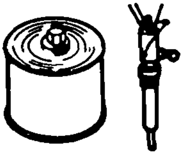
Bury mine and remove safety clip.

8 TO BURY: Pressure plate should be slightly above ground level.
TO DISARM: Insert safety clip and remove detonator.
CAUTION: Repeated turning of arming dial may cause excessive wear.

Table 3-1. Mine Data (Con't)

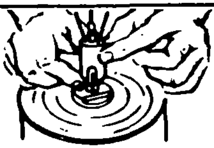
M16A1 BOUNDING ANTIPERSONNEL MINES

1



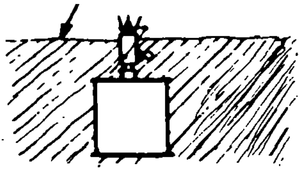
2 Wt .... 8.25 lb.
Projectiles .... Steel
Fuze .... M605 (Combination)
Functioning:
Pressure ... 8 to 20 lbs
Pull .... 3 to 10 lbs
Bounding Ht .6–1.2m
Casualty radius 30m

3



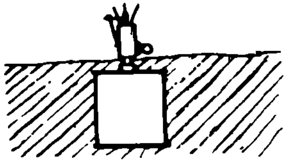
Remove shipping plug and screw in fuze.

4 GROUND LEVEL



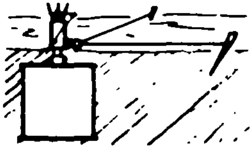
Pressure installation

5



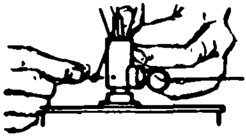
Tripwire installation

6



Attach tripwires — first to anchor, then to pull ring.

7



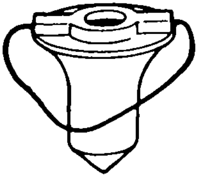
Remove locking safety pin first. The interlocking pins should fall free. Then remove positive safety.

8 TO DISARM: Reverse arming procedure.

Table 3–1. Mine Data (Con't)

M25 BLAST ANTIPERSONNEL MINE (ELSIE)

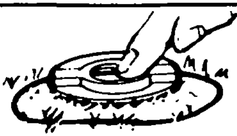
1



2

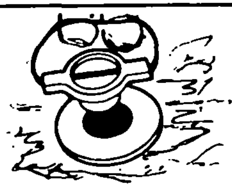
Wt .... 2 3/4 oz.
Explosive ... 1/3 oz. shape charge
Fuze ....integral (w/ball release)
Functioning.. 14 to 26 lbs
Penetrate Boot & Foot

3



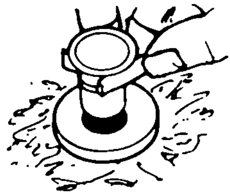
Push mine into ground. Keep dust cap in place. If ground is hard, dig hole with bayonet.

4



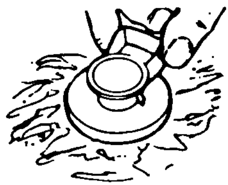
Remove dust cap.

5



Insert charge.

6



Remove safety clip.

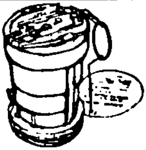
7

TO DISARM: Reverse arming procedure.

Table 3-1. Mine Data (Con't)

M26 ANTIPERSONNEL MINE

1



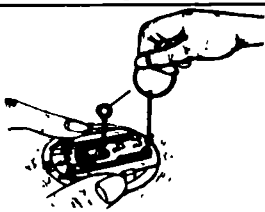
2

Wt	2.2 LBS
Projectiles	Pellets
Fuze	integral
Functioning:	
Pressure	14–28 lbs
Pull	4–8 lbs
Bounding Ht	3m
Casualty Radius	17m

3

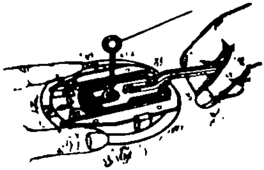
Remove arming handle. (If tripwire is to be used install trip-lever; attach slack wire to lever; and) place mine in ground flush with top of ground.

4



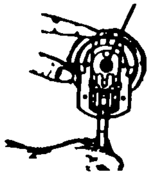
Remove arming latch retaining pin.

5



Attach arming handle to lugs on arming latch, rotate the cover clockwise until it comes to a positive stop (the arrow will point to the red letter "A" armed).

6



Remove arming latch by pulling straight out with the arming handle.

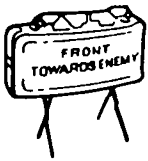
7

TO DISARM: Reverse arming procedure.

Table 3-1. Mine Data (Con't)

M18A1 FRAGMENTATION ANTIPERSONNEL MINE

1



2 Wt .... 3.5 lbs.
Explosive ..... 1.5 lb. C4
Projectiles .... 700 (steel balls)
Equipment: One electric cap 30m firing wire per mine. One electric firing device per mine. One Tester per 6 mines.

3

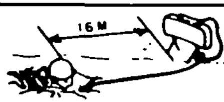
TEST CIRCUIT: Mate firing device, circuit tester and blasting cap. Depress handle. Light should show in window. Separate test components.

4 AIMING. IN AIMING THE M18A1, WHEN USING THE SLIT TYPE PEEP SIGHT, AIM THE MINE AT AN INDIVIDUAL'S HEAD WHEN STANDING 45M FROM THE MINE. WHEN USING THE KNIFE EDGE SIGHT, AIM THE MINE AT AN INDIVIDUAL'S FEET WHEN STANDING 50M FROM THE MINE

5

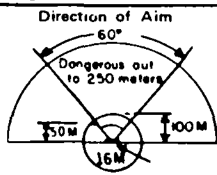
Remove shipping plug-priming adapter, insert blasting cap and screw into either cap well.

6



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

7



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.

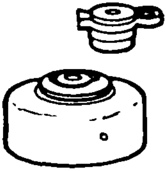
8 TO FIRE: Disengage safety bail and depress handle.

9 TO DISARM: Reverse arming procedure.

Table 3–1 Mine Data (Con't)

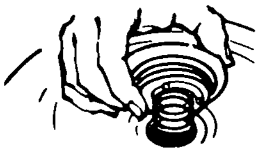
M15 HEAVY ANTITANK MINES

1



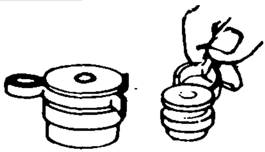
2 Wt .... 30 lbs.
Explosive .... 22 lbs.
Fuze M603
Secondary fuze wells ... 2
Functioning:
300 to 400 lbs.

3



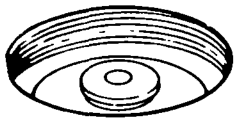
Remove plug and inspect fuze well.

4



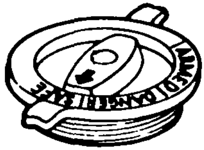
Inspect fuze and remove safety.

5



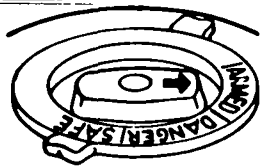
Insert fuze

6



Replace plug with dial in safe position.

7



Turn dial to ARMED.

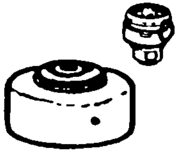
8 TO BURY: Put mine in hole with pressure plate at or slightly above ground level.

9 TO DISARM: Reverse arming procedure.

Table 3-1. Mine Data (Con't)

M15 ANTITANK MINE USED WITH M608 FUZE

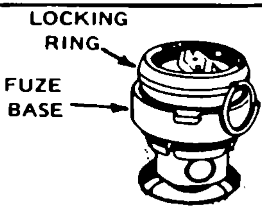
1



2 Functioning . . . .200-350 lbs for 250-450 milliseconds.

Resistant to blast type countermeasures.

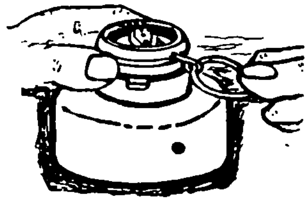
3



Remove plug and inspect fuze well. Insure fuze is in SAFE position. Thread fuze into mine.....HAND TIGHT

4 Hold fuze to prevent rotating, turn locking ring down until it locks against pressure plate.

5



Place mine in hole and remove pull pin from fuze.

6

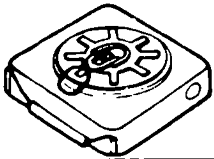
Turn dial from SAFE to ARMED.

7 TO DISARM: Reverse procedure except DO NOT replace pull pin.

Table 3-1. Mine Data (Con't)

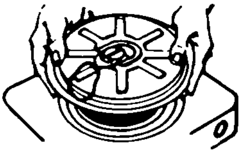
M19 PLASTIC HEAVY ANTITANK MINE

1



2 Wt .... 28 lbs.
Explosive .... 21 lbs.
Fuze ....M606 integral
(with pressure plate)
Secondary fuze wells ... 2
Functioning:
350 to 500 lbs.

3

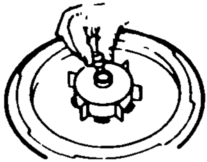


Remove pressure plate-fuze.

4

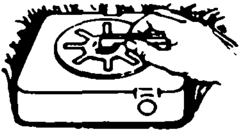
Remove shipping plug; check position of striker (offset). Remove safety fork, then turn dial to ARMED position. Check position of striker (center). Turn to SAFE and replace safety fork.

5



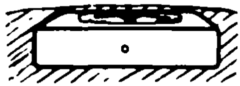
Screw threaded detonator into detonator well.

6



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

7



Complete camouflage

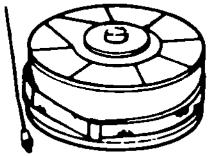
8 TO BURY: Put mine in hole with pressure plate at or slightly above ground level.

9 TO DISARM: Reverse arming procedure.

Table 3–1. Mine Data (Con't)

M21 METALLIC (KILLER) ANTITANK MINE

1



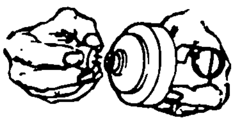
2

Wt .... 18 lbs.
Explosive .... 10.5 lbs.
Fuze M607
Functioning ..... 290 lbs.
(Pressure on pressure ring or 20° deflection of tilt rod)

3

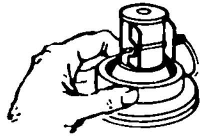
Remove closing plug, insert M120 booster in bottom, and replace closing plug.

4



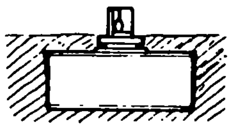
Remove closure assembly from fuze.

5



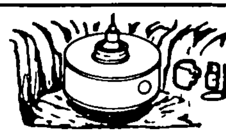
Remove shipping plug from mine and screw in fuze, then screw in tilt rod extension.

6



Bury mine

7



Remove safety (pull ring assembly) and complete camouflage.

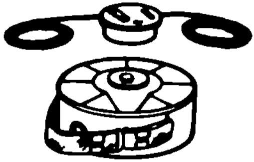
8 For pressure type mine bury with fuze cap flush with ground surface.
Tilt Rod-mines should be seated firmly in snug-fitting hole. Most effective in tall brush or grass.

9 TO DISARM: Reverse arming procedure.

Table 3–1. Mine Data (Con't)

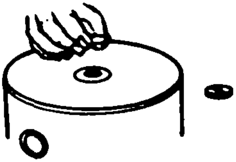
M21 ANTITANK MINE USED WITH M612 FUZE

1



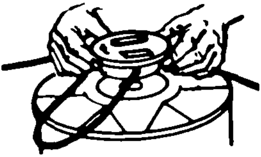
2 Has two 2.7m pneumatic leads, safety latch and arming lever.

3



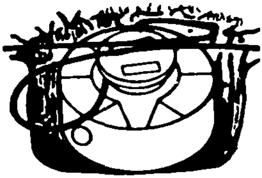
Remove closing plug, insert M120 booster.

4



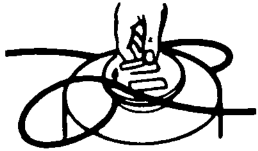
Remove shipping plug from mine. Screw in fuze.

5



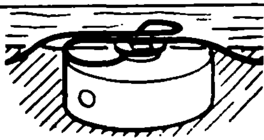
Bury mine. Cross and extend hoses.

6



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

7



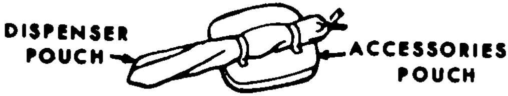
Complete camouflage.

8 Timer provides a 30 ± 5 minute safe separation period. Both leads must be depressed for initiation.

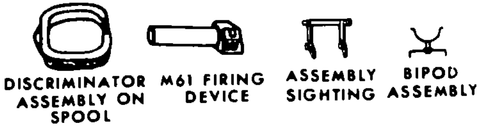
9 TO DISARM: Reverse arming procedure.

M24 OFF-ROUTE ANTITANK MINE

1 INSTALLING AND ARMING

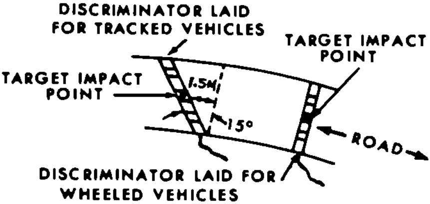


2



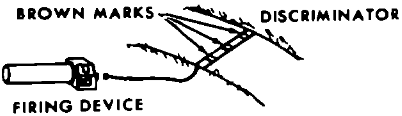
Remove above items from accessories pouch. Insert batteries (issued separately) in firing device.

3



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

4

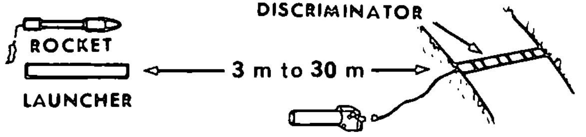


Attach discriminator wire to DETECTOR of firing device (toggle switch on SAFE). Stand on two brown marks on discriminator nearest firing device. If lamp lights, circuit is good; otherwise, discard system.

Table 3–1. Mine Data (Con't)

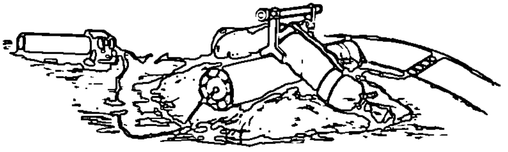
M24 OFF-ROUTE ANTITANK MINE (CON'T)

5



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.

6

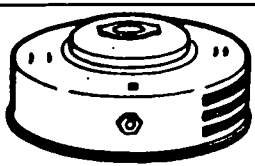


Position launcher on bipod assembly or mound of earth. Mount sighting assembly and sight along discriminator to target impact point about 1m above road (soldier's belt buckle.) To aim, move launcher, not sight. Fill poucher with dirt, lay over launcher, recheck sight, remove sight, re-connect discriminator 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. Mine Data (Con't)

M23 AND M1 1 GALLON CHEMICAL LANDMINES

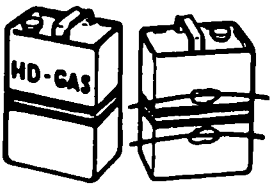
1



2

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

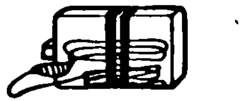
3



4

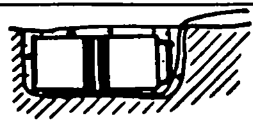
Wt. 11 lb. loaded; has a 1.2m length of detonating cord for burster charge. May be armed for electric or tripwire actuation.

5 Electric Firing



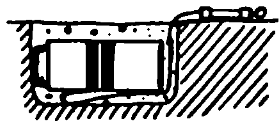
Attach burster charge—1.2m length of detonating cord—to side of mine.

6



Bury mine 10cm and attach detonating cord to controlled firing system.

7 Nonelectric Firing

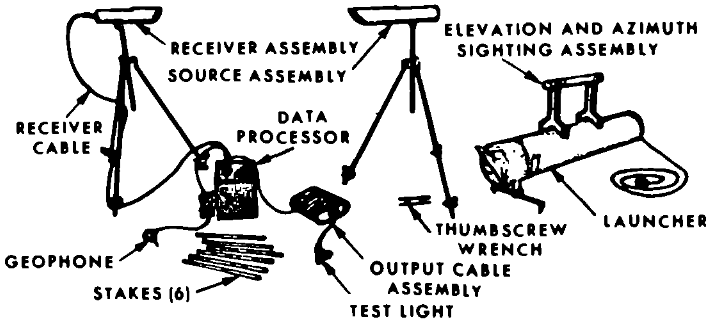


Bury mine as above and attach nonelectric detonator to burster.

8 WARNING: Soldiers preparing, laying, and removing chemical landmines, must wear protective clothing.

M66 OFF-ROUTE ANTITANK MINE

1

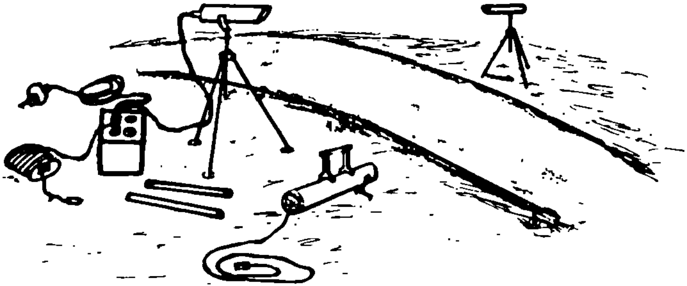


Assemble tripods, source and receiver assemblies. Install battery in source assembly.

Table 3–1. Mine Data (Con't)

M66 OFF-ROUTE ANTITANK MINE (CON'T)

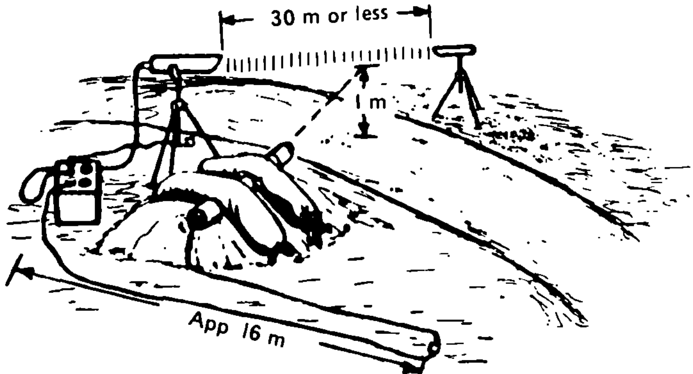
2



Select well camouflaged sites across road. Aim source assembly at receiver and about 1 meter above road center. Stake legs of tripod to ground. Aim receiver at source assembly. Connect Geophone cable, output cable w/test light, and receiver assembly cable to data processor. Install batteries in data processor. Hold Geophone steady and place hand in front of receiver. If test light functions system is operative (If light does not function check connections and source/receiver alignment). Disconnect Geophone and place hand in front of receiver. Test light should not function (If light functions system is inoperative and should not be used). If light does not function connect Geophone cable and press spike into ground

M66 OFF-ROUTE ANTITANK MINE (CON'T)

3



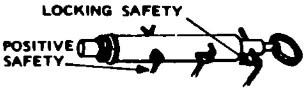
Unwind firing cable from rocket, slide rocket forward from launcher enough to remove safety. Depress ejection pin and slide back into launcher. Position launcher and sight on impact point 1m above road center on source/receiver line. Secure launcher with sandbags. Position output cable and firing cable as shown. Test light should not function. If it does recheck connections and source/receiver alignment. Remove shorting plug and connect cables.

4 WARNING: Make sure all personnel are clear of launcher when testing circuits.

Table 3- 1. Mine Data (Con't)

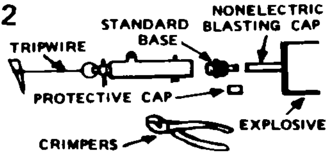
M1 PULL FIRING DEVICE

1



INITIATING ACTION: 3 to 5 lb pull on tripwire.

2



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

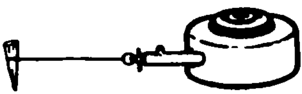
3

TO ARM: Remove locking safety pin first, and positive safety pin last.

4

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 tripwire, and separate firing device and expolsive. Unscrew standard base.

5



The M1 pull firing device can be used as an antihandling device on the M15 or M19 AT mines. The arming procedures are the same as above. The device is employed in the side fuze well and a tripwire attached from the M1 to a stake secured underground near the mine.

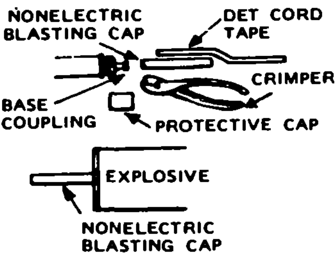
Table 3-1. Mine Data (Con't)

M1A1 PRESSURE FIRING DEVICE

1

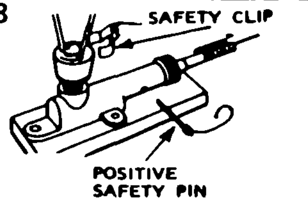
Initiating pressure: 10 lbs or more.

2



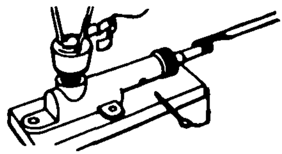
Remove protective cap from base and crimp on nonelectric blasting cap. Assemble det cord, nonelectric blasting cap, and firing device.

3



TO ARM: Remove safety clip. Then positive safety pin.

4

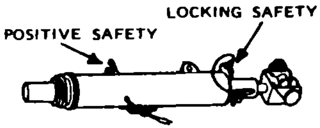


TO DISARM: Insert wire, nail, original pin in positive safety hole. Replace safety clip, if available. Unscrew base assembly from firing device.

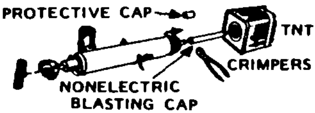
Table 3-1. Mine Data (Con't)

M3 PULL-RELEASE FIRING DEVICE

1

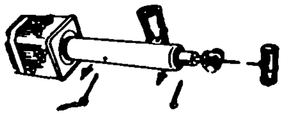


2



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 tripwire). Put free end of anchored tripwire in hole in winch with knurled knob, draw up tripwire until locking safety is pulled into wide part of safety pin hole.

3



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.

4

TO DISARM: THE M3 IS DANGEROUS TO DISARM. IT SHOULD BE BLOWN IN PLACE.

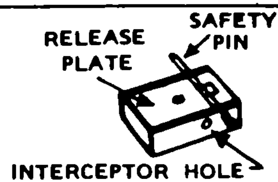
NOTE:

If the device must be disarmed proceed as follows: 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 tripwire, firing device and explosive.

Table 3–1. Mine Data (Con't)

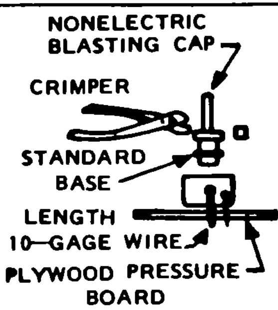
M5 PRESSURE-RELEASE FIRING DEVICE

1



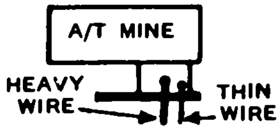
INITIATING ACTION: Lifting 1.59cm or removing restraining weight (5lb or more).

2



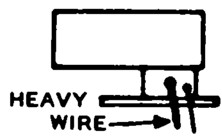
Insert length of 10-gage wire in interceptor hole and holding release plate down, remove safety pin. Replace safety pin with length of No. 18 wire. Assemble cap, firing device and mine.

3



TO ARM: Remove thin wire (locking safety) and then heavy wire (positive safety) from interceptor hole. FOLLOW ARMING PROCEDURE CAREFULLY.

4

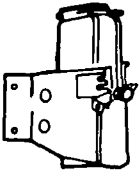


TO DISARM: Insert length of heavy gage wire in interceptor hole. Bend wire to prevent dropping out. Proceed carefully, as the slightest disturbance of restraining weight may detonate mine. Disassemble firing device and mine.

Table 3 - 1 Mine Data (Con't)

M49A1 TRIP FLARE

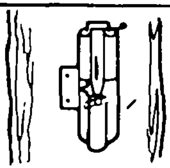
1



2 Burning period . . . . 55 to 70 sec
Illumination radius 300m

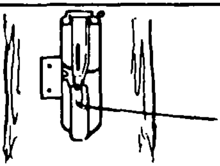
Initiated by taut or loose tripwire.

3



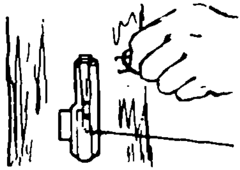
Attach flare to post, tree, etc.

4



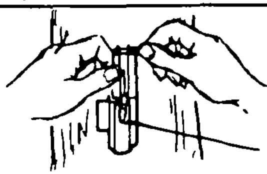
Attach tripwire to anchor, then to trigger. Pull trigger to vertical position and secure.

5



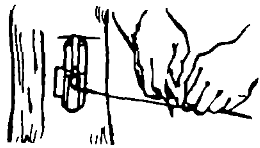
TO ARM: Remove safety clip.

6



TO DISARM: Insert safety pin.

7



Check both ends of tripwire and cut near trigger.

8 WARNING: Never look directly at burning flare. Note: For loose tripwire initiation, attach tripwire to eye of safety pin.

(3) *Point minefield.* Used to delay and disorganize the enemy or to hinder his use of key areas. Generally irregular in size and shape, ranging from a single group of mines to successive mined areas. Both conventional and scatterable mines may be employed. Authority to lay is division – can be delegated to brigade.

(4) *Interdiction minefield* Used in the enemy rear to harass and disrupt normal activities, and to deny the enemy the use of key facilities. Normally consists of scatterable mines. Authority to lay is corps – can be delegated to division.

(5) *Phony minefield.* Used as part of a barrier system to deceive the enemy when the lack of time, personnel, or material prevents the use of real mines. Effectiveness depends upon resemblance to the type of minefield being simulated. They are of no real value until the enemy has become mine conscious. Authority to lay is the same as the type of minefield being simulated.

b Employment

(1) All minefields should be covered by fire.

(2) Minefield effectiveness can be increased by varying types of mines, fuzes, and tripwires.

(3) Warning devices such as sensors, tripwires, smoke or flame devices, and noise makers should be used to alert troops to enemy breaching attempts.

3–3. MINEFIELD PATTERNS

a Standard Minefield Pattern The standard minefield pattern is a defined regular pattern which provides optimum effectiveness against enemy passage and/or breaching. It also allows for ease of removal by friendly troops (fig. 3–1).

(1) *Strip centerline* A measured, predetermined line along which no mines are placed. It is paralleled on each side by two rows of mines or clusters at a distance of 3 meters (fig. 3–2).

(2) *Row.* A single row of mines or clusters laid in a generally straight line. Mine rows parallel the strip centerline at a distance of 3 meters (or paces) and are laid at 6 meter (or pace) intervals. (fig. 3–2)

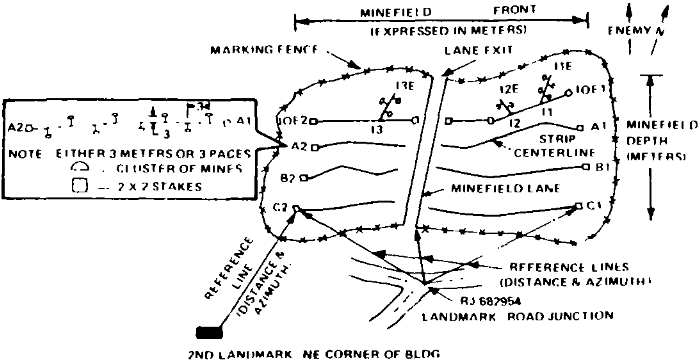


Figure 3–1 Minefield, standard pattern, fenced, marked and referenced

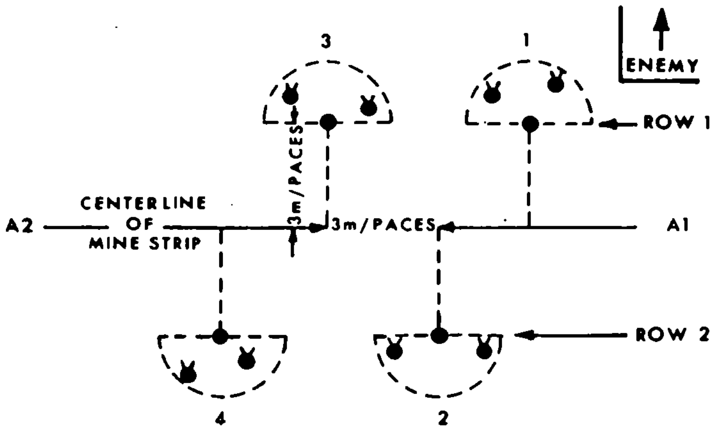
(3) *Minefield strip* Two parallel rows of mines or clusters including a strip centerline (fig. 3–2).

(4) *Cluster* A semicircular grouping of mines spaced along the minefield rows at specified intervals (fig. 3–2). Clusters are numbered to aid in identification for removal purposes and to identify those mines having tripwires or antihandling devices (fig. 3–3).

Clusters may be either live (those containing mines) or omitted (those not containing mines). Clusters are normally omitted because of irregularities in the terrain. These irregularities may also necessitate a slight change in the direction of the minefield strip These changes of direction occur at turning points. (fig. 3–4)

(5) *Irregular outer edge (IOE)* The purpose of the IOE is to confuse the enemy as to the exact trace of the minefield and to block likely avenues of approach. There can be any number of short strips in the IOE, but they should be no closer to each other than 15 meters (fig. 3–3).

(6) *Density* A three-number sequence depicting number and type of mines per meter of minefield front. (1–2–2 depicts 1 AT mine, 2 APF mines, and 2 APB mines.)



NOTES: 1. AT Mine ● AP Mine

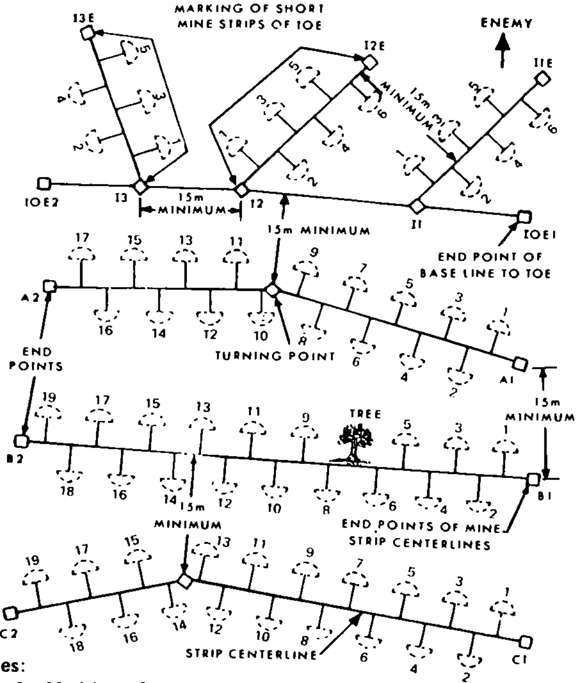
2. Cluster with AT mine and 4 AP mines within 2m/pace sem-circle.

3. Cluster with AP base mine and 4 additional AP mines.

4. Within a mine strip:
   (a) The number of AP mines in each cluster must be the same.
   (b) Different types of AP mines may be used in a cluster.
   (c) Different clusters may contain different types of AT mines.

5. No cluster can exceed 5 mines with only 1 AT mine per cluster.

Figure 3–2. Minefield strip with strip centerline, rows, and clusters.



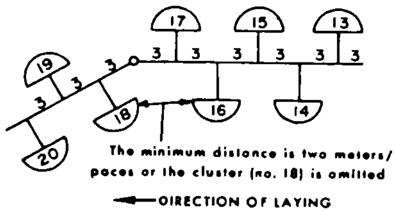
Notes:

1. Marking of end points with A1 and A2, for example, will indicate laying direction of a minefield.
2. Laying will always begin at point No. 1.
3. Odd numbers on enemy side of the strip.
4. Strip start and end points, and turning points will be marked with a 2" x 2" wooden stake.

Figure 3–3. Method of numbering clusters in a minefield laid from right to left.

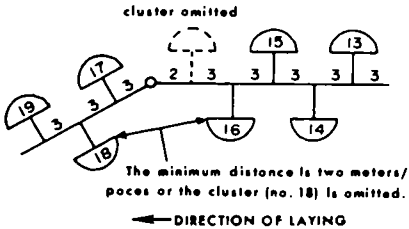
THE LAST CLUSTER BEFORE AND THE FIRST CLUSTER AFTER THE TURNING POINT WILL HAVE A DISTANCE OF 3 METERS/PACES FROM THE TURNING POINT AND ARE LAID ON OPPOSITE SIDES OF THE STRIP CENTERLINE

AN OMITTED CLUSTER IS NUMBERED WHEN IT IS NECESSARY TO MAINTAIN THE NORMAL NUMBERING SEQUENCE AND OMITTED CLUSTERS SO NUMBERED MUST BE NOTED IN THE "NOTES" SECTION OF THE MINEFIELD RECORD (DA FORM 1355)



IF THE DISTANCE IS LESS THAN 3 METERS/PACES BETWEEN THE LAST POSSIBLE CLUSTER AND THE TURNING POINT THE CLUSTER WILL BE OMITTED.

THE FIRST CLUSTER AFTER THE TURNING POINT WILL BE LAID ON THE OPPOSITE SIDE OF STRIP CENTER CENTERLINE FROM THE LAST LAID CLUSTER AND THREE METERS/PACES FROM THE TURNING POINT



FIRST CLUSTER OF STRIP WILL NOT BE CLOSER THAN 2 METERS TO THE LINE JOINING THE END POINTS OF MINE STRIPS

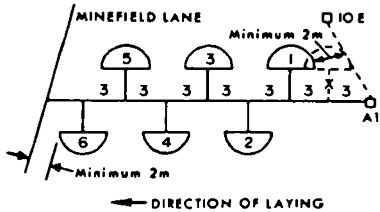


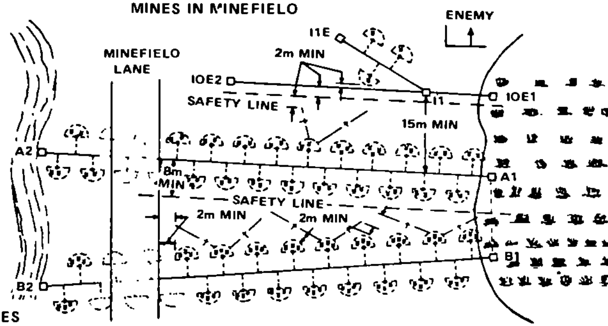
Figure 3–4. Turning points on a minefield strip.

(7) *Minefield gap* A cleared area through a minefield wide enough for the passage of a friendly force in tactical formation. Width of a minefield gap is seldom less than 100 meters

(8) *Minefield lane* A cleared path through a minefield for passage of troops (2 meters wide) or vehicles (8 meters wide – one–way, 16 meters wide – two–way)

(9) *Tripwires* Tripwires are employed only with APF mines. Employment procedures are defined in figure 3–5.

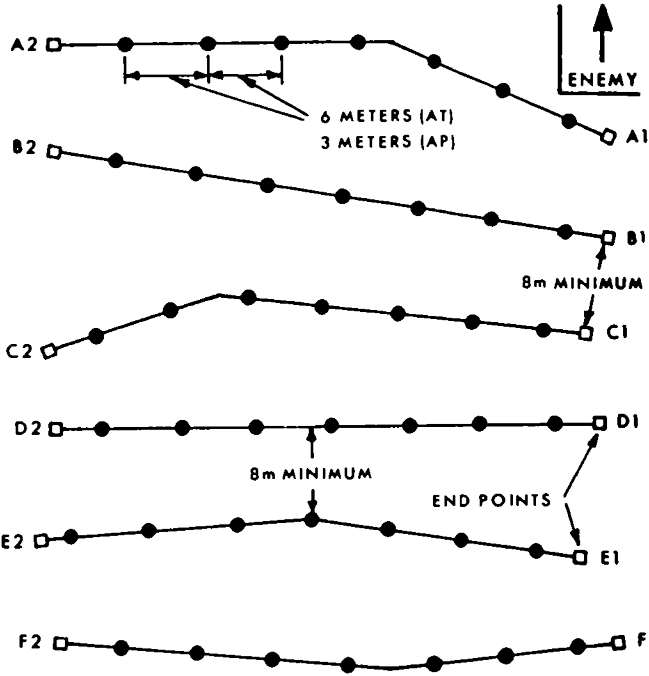
SAFETY LINE ANO SAFETY OISTANCES
REOUIRED WHEN USING WIRE ACTUATED
MINES IN MINEFIELO



NOTES

1. – + – = TRIPWIRE EMPLOYED ON MINE ROW ON ENEMY SIOE OF STRIP, ONLY!
2. TRIPWIRE LENGTH WILL NOT EXCEED THE CASUALTY RAOIUS OF THE MINE.
3. NO TRIPWIRES IN THE IOE.
4. ONLY ONE MINE PER CLUSTER WILL EMPLOY A TRIPWIRE (FDR SAFETY PURPOSES IT IS RECOMMENDEO THAT THE MINE CLDSEST TO THE ENEMY BE TRIPWIRED. BASE MINE OF CLUSTER SHOULO NOT BE TRIPWIRED.)
5. TRIPWIRES = $\leq$ 2 PER MINE.
6. TRIPWIRES WILL BE EMPLOYED NO CLOSER THAN EVERY THIRO CLUSTER.
7. TRIPWIRES WILL BE ANGLEO TOWARO THE ENEMY ANO WILL BE NO CLOSER THAN 2 METERS TO ANOTHER TRIPWIRE, ANOTHER CLUSTER, THE SAFETY LINE, THE IOE, MINEFIELD LINE OR GAP, OR THE MINEFIELO BOUNOARY.

b Row Mining. Row mining is the emplacement of AT mines in a row by use of the M–57 antitank mine dispensing system (fig. 3–6).



NOTES

Distances may vary according to the tactical objective, the technical effectiveness desired and the characteristics of the mines used, but should remain the same within one mine row.

Figure 3–6. Row mining.

Section II. MINEFIELD INSTALLATION

3–4. MINE AND MAN–HOUR COMPUTATIONS

Material and manpower requirements and logistical and planning data are found in tables 3–2 and 3–3.

Table 3–2. Mine and Man-Hour Computations and Strip Cluster Composition (Sample Problem)

I SITUATION

		Apers	Apers
Desired Density	AT a. 1	Frag b. 4	Blast c. 8
IOE Representative Cluster	AT a. 1	Frag b. 2	Blast c. 2

Meters of Front 200

Note 1. If using paces as the unit of measurement, adjust the density by multiplying by 0.75. (Round each figure obtained up to the next whole number.) Then convert the front to paces by multiplying the front, in meters, by 1.34.

Example: Desired density of mines/meter of front is 1–4–8.

Desired density using paces	*Desired front using paces*
1 x .75 = round up to 1	200 x 1.34 = 268 paces
4 x .75 = 3	
8 x .75 = 6	

Table 3–2. Mine and Man-Hour Computations and Strip Cluster Composition (Sample Problem) (Continued)

Adjusted density is 1-3-6

Note 2. If paces are used as the unit of measure, you must use the *adjusted density* and the front, *in paces*, in your calculations.

II MINE COMPUTATION

NOTE: This example is computed using meters as unit of measure.

(1) Meters of front divided by 9 equals the approximate number of IOE Clusters.

$$\frac{200}{9} = 22.2 \text{ (round up to 23)}$$

(2) Multiply the number of IOE clusters (line 1) x IOE representative cluster (1–2–2).

a. 23 b. 46 c. 46

(3) Meters of front x desired density, if installing in meters (or paces of front x adjusted density, if installing in paces) = mines in minefield.

a. 200 b. 800 c. 1600

(4) Add line 2 and line 3 (subtotal of mines).

a. 223 b. 846 c. 1646

(5) Compute 10% of line 4 for mine rejections, and strip length variances (round up).

a. 23 b. 85 c. 165

Table 3–2 Mine and Man-Hour Computations and Strip Cluster Composition (Sample Problem) (Continued)

(6) Add line 4 plus line 5 = total mines needed.

a. 246 b. 931 c. 1811

(7) Divide total mines needed (by type) by laying rate figures.

AT: 4 mines/hour/man

APF: 8 mines/hour/man

APB: 16 mines/hour/man

Then take sum of man-hours of all three types and multiply by 1.2 to obtain total installation man-hours (includes marking, siting, and recording).

EXAMPLE:

$$\frac{246}{4} = 62$$

$$\frac{931}{8} = 117$$

$$\frac{1811}{16} = 114$$

293 Total

293
x 1.2

352 Total Man-Hours Required*

*This figure is only work time. If working in darkness, multiplying by 1.5.

(8) Add a + b + c of desired (or adjusted) density.

(1 + 4 + 8) = 13

Table 3–2 Mine and Man-Hour Computations and Strip Cluster Composition (Sample Problem) (Continued)

(9) Multiply line 8 by $\frac{3}{5}$

$$\frac{3}{5} \times \frac{13}{1} = \frac{39}{5} = 7.8 \text{ (round up to 8)}$$

(10) 3 x AT density (3 x 1) = 3

(11) Number of strips (highest from line 9 or 10) = 8.

(12) Desired density x 3 (by type) gives total needed to maintain that density.

AT: 3 x 1 = 3

APF: 3 x 4 = 12

AP8: 3 x 8 = 24

(13) Distribute total from line 12, as desired, between lettered strips needed (line 11) to get strip cluster composition.

Given	IOE	AT 1	APF 2	APB 2	Total across (max 5) 5
	A	1	1	3	5
	B	0	2	3	5
	C	0	1	3	4
	D	1	1	3	5
	E	0	2	3	5
	F	1	1	3	5
	G	0	2	3	5
	H	0	2	3	5
	Total **	3	12	24	

** same as line 12

Table 3-2 Mine and Man-Hour Computations and Strip Cluster Composition (Sample Problem) (Continued)

MINEFIELD LOGISTIC RULES OF THUMB

(1) *Fence Trace* Formula for fencing 4 sides (meters) one strand. [2 0 (depth) + 2.0 (front) + 160 meters] x 1.40 = total length of fence (meters)

(2) If using a two-strand fence, multiply by two to obtain meters of wire required.

(3) *Pickets* $\frac{\text{4 sides total length of fence}}{15}$ (see 1 above) = number of pickets required.

(4) *Mine signs* The number of signs (4 sides of minefield fenced) equals the number of pickets.

(5) *Engr tape* Comes 170 (M)/roll. Used for

(a) Boundaries

(b) Strip centerlines (incl IOE short strips)

(c) Lanes

(d) Gaps

(e) Tripwire safety lines

(6) *Sandbags* (Avg 3/Cluster) (Used for removal of spoil.)

Step 1. Number of IOE clusters x 3.

Step 2. Number of lettered strips x answer obtained in Step 1.

Table 3–2 Mine and Man-Hour Computations and Strip Cluster Composition (Sample Problem) (Continued)

Step 3. 3 x answer obtained in Step 2.

Step 4. Add answer from Step 1 and Step 3.

(7) 2" x 2" x 12" wood stakes. Used:

(a) Right and left end points of mine strips

(b) Each turning point

(c) Beginning and end points of IOE short strips

Table 3–3. Mine-Carrying Capacity of Military Vehicle

TYPE MINE	2½ T CGO	2½ T DMP	5 T DMP	1½ T TRL
M15	103	56	90	61
M19	126	80	196	74
M21	224	160	192	132
M14	10,260	4,320	6,480	6,120
M16A1	448	320	672	264
M18A1	1,165	480	1,260	700
M24	1,260	900	1,440	774
M25	12,000	6,720	9,216	7,200

Note. Figures shown are for crated mines only.

3–5. MINEFIELD MARKING

a Marking Location of Minefield. Minefields are marked (normally fenced) according to the tactical situation to protect friendly personnel from inadvertently entering a minefield. Marking usually consists of a standard two–strand fence with signs indicating mines. Marking is also used to mark lanes or gaps in a minefield. See figures 3–7, 3–8, and 3–9. The U.S. minefield marking set contains components for marking a safe lane 400 meters through a minefield.

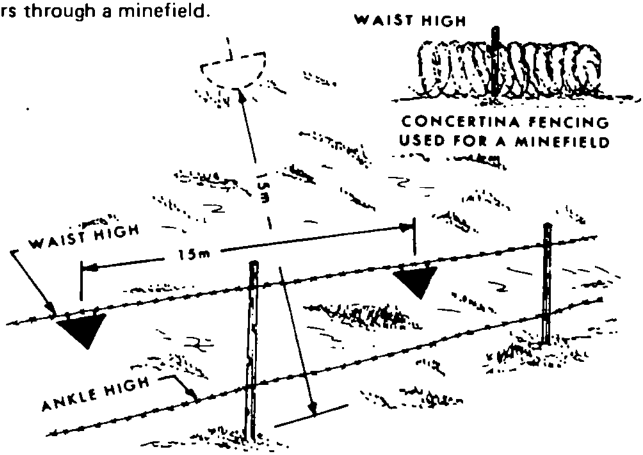


Figure 3–7 Minefield marking fence.

b Marking and Referencing Mine Strips. The beginning and end of each mine strip and all turning points in the strip are marked with wooden stakes or pickets driven flush with the ground. When available, nails should be driven into each stake to enable the metallic mine detector to find the stake. Beginning and end points are identified with alphmeric characters (i.e. A1 and A2, B1 and B2, etc.) for identification purposes on the recording form.

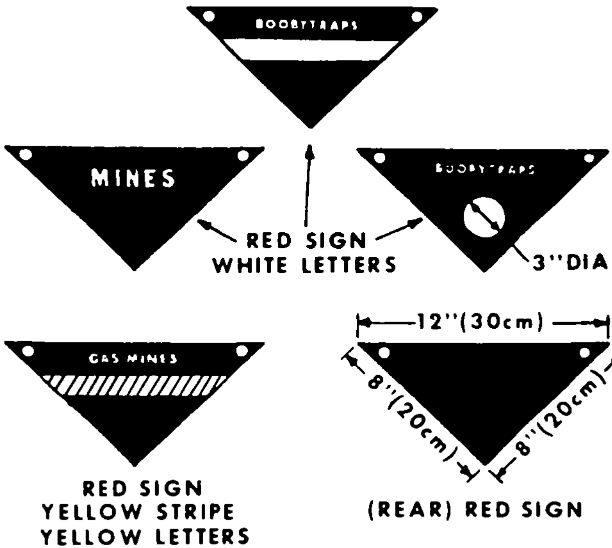


Figure 3–8 Standard marking signs

3–6. ORGANIZATION OF MINELAYING UNIT

a *Platoon Organization.* The organization and duties of members are listed in table 3–4.

b. *Safety* See paragraph 3–14.

c. *Camouflage* Camouflage discipline must be strictly enforced (i.e., dispersion of men, vehicles, mine dumps).

d *Mine Dumps.* Mine dumps should be located no closer than 150m to each other.

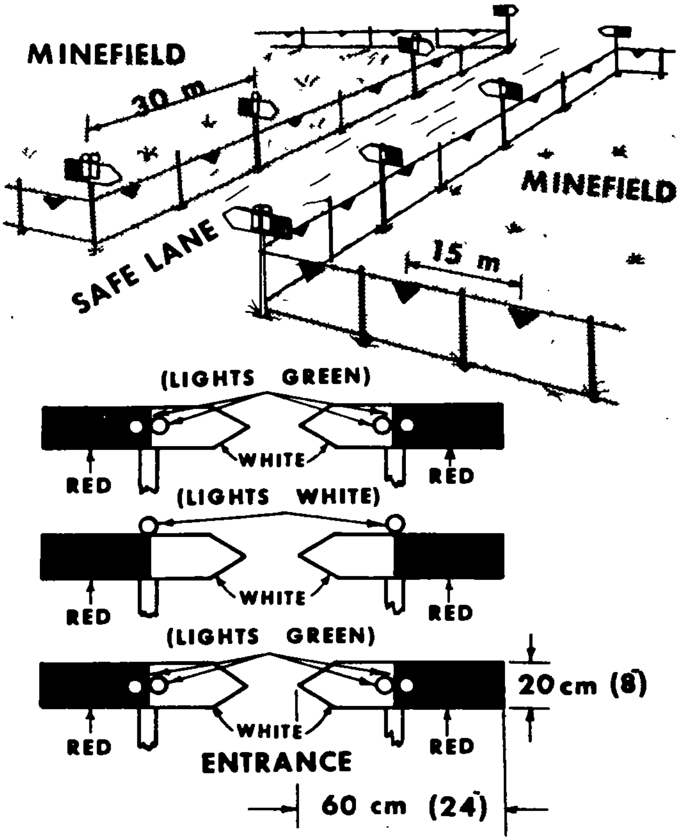


Figure 3–9. Standard lane markings

Table 3–4. Organization of the Mine Laying Party

Personnel	Officer	NCO	EM	Equipment
Supervisory personnel	1	1		Officer: Map, lensatic compass, notebook, and mine-field record forms. NCO: Map, notebook, and lensatic compass.
Siting party		1	3	Stakes or pickets, sledges, hammers, tracing tape on reels, and nails to peg tape.
Marking party		1	2	Barbed wire on reels, marking signs, lane signs, wire cutters, gloves, sledges, pickets.
Recording party		1	2	Sketching equipment, lensatic compass, minefield record forms, map, and metric tape.
1st laying party		1	6 to 8	Notebook for squad leader, picks, shovels, and sandbags.
2nd laying party		1	6 to 8	Same as 1st laying party.
3rd laying		1	6 to 8	Same as 1st laying party.
Total	1	7	25 to 31	

NOTE: Organization may vary depending on terrain, men, and materials available and the proximity of the enemy.

Section III. REPORTING AND RECORDING

3–7. MINEFIELD REPORTS

A minefield report is any message or communication, either oral or written, concerning either friendly or enemy mining activities. Reports of friendly minefields are classified and will be transmitted by some secure means.

a Mandatory Minefield Reports

(1) *Report of intention to lay (table 3–5)*

(2) *Report of initiation of laying*

(3) *Report of completion of laying (table 3–6)*

b Additional Reports (submit as needed).

(1) *Progress reports*

(2) *Report of transfer*

(3) *Report of change*

(4) *Enemy minefield report (table 3–7)*

3–8. MINEFIELD RECORDS

a DA Form 1355. This form is used to record all minefields except the hasty protective minefield. 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. When completed, the DA Form 1355 is classified SECRET. When used for training purposes, the word SECRET must be crossed out and the word SPECIMEN printed on the form in each place the word SECRET appears. (See figs. 3–10 through 3–12). When properly completed the DA Form 1355 should be clear enough to facilitate minefield removal by other units.

Table 3–5. Report of Intention to Lay w/Example

Explanation	Letter designation	(1)a
Tactical Objectives (Temporary Security Roadblock or Other).	ALPHA	Bridge Work Site Security
Type of Minefield	BRAVO	Hasty Protective
Estimated number and types of mines and whether surface laid mines or mines with antihandling devices	CHARLIE	10 ea. M18A1 No A.H.D.
Location of Minefield by Coordinates	DELTA	UT 0976
Location and Width of Minefield Lanes and Gaps	ECHO	Rt. 67 No.–– So. Approach to Bridge
Estimated Starting and Completion Date/Time/Group	FOXTROT	Start 190700 May 74 Completion 190800 May 74

a. First minefield in report.
b. Additional minefields in report.

Table 3–6. Report of Completion of Minefield w/Example

Explanation	Letter designation	(1)a	(2)b	(3)b
Changes in Information Submitted in Intention to Lay Report	ALPHA	None		
Total Number and type of AT and Apers Mines Laid	BRAVO	M15–299 M26–865 M14–601		
Date and Time of Completion	CHARLIE	231800 Mar 72		
Method by Laying Mines (Buried, by Hand, by Machine)	DELTA	Buried by Hand		
Details of Lanes and Gaps Including Their Marking.	ECHO	WD1 wire on ℄ AZ. 270° Ent & Ex marked w/2U pickets		
Details of Perimeter Marking	FOXTROT	Standard fence		
*Overlay Showing Perimeter, Lanes, and Gaps	GOLF	N/A		
Laying Unit and *Signature of Individual Authorizing Laying of the Field.	HOTEL	2d Plt, Co "A", 546th Engr Bn (C)		

a. First minefield in report.
b. Additional minefields in report.
*N/A if transmitted by electrical means.

Table 3–7. Report of Enemy Minefield

Explanation	Letter designation	(1)a*	(2)b*	(3)b*	(4)b*
Map Sheet(s) Designation	ALPHA				
Date and Time of Collection of Information	BRAVO				
Type of Minefield (AT, Apers)	CHARLIE				
Coordinates of Minefield Extremeties	DELTA				
Depth of Minefield	ECHO				
Enemy Weapons or Surveillance	FOXTROT				
Estimated Time to Clear Minefield	GOLF				
Estimated Material and Equipment required to Clear Minefield	HOTEL				
Routes for Bypassing the Minefield, if any	INDIA				
Coordinates of Lane Entry	JULIETT				
Coordinates of Lane Exit	KILO				
Width of Lanes (Meters) C*	LIMA				
Other, Such as Type of Mines New Mines or Boobytraps	ZULU				

NOTES:

a. First minefield in report.

b. Additional minefields in report.

c. Additional lanes or/and gaps are reported under an extended alphabetical listing.

b. DA Form 1355–1–R. Hasty Protective Minefield Record. 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. The Hasty Protective Minefield Record is unclassified as long as the minefield is temporary in nature. However, when the field is declared a deliberate protective field or incorporated into a larger field, it must be classified SECRET and the information transferred to the DA Form 1355. The reverse side of the Hasty Protective Minefield Record (DA Form 1355–1–R) consists of full instructions to the recorder and an example of a recorded minefield.

c. 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 marking and a sketch or overlay showing location and other information. The record must be marked at the top with the words ENEMY MINEFIELD.

Section IV. REMOVAL OF MINES

3–9. CLEARING MINED AREAS

a. Detection Methods.

(1) Visual.

(2) Probing.

(3) Dogs.

(4) Mine Detectors. Both types of detectors, metallic and nonmetallic, may give signals 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 from each type mine. Since this is a very exacting task, no individual should be permitted to operate a detector for more than 20 minutes at a time.

b. Mine Removal The following methods are used to remove or neutralize mines. These are listed in relative order of use. Where possible, hand neutralization will be avoided.

(1) Explosives.

(2) Rope and hooks.

(3) Mechanical means.

(4) Hand neutralization.

(when completed) SPECIMEN

MINEFIELD RECORD

Copy No. 1 OF 1
Sheet 1 of 1 Sheets

Authority for laying	CG 11TH ARMD CAV DIV
Laying Unit	1ST PLT, CO "A", 547TH ENGR BN (CBT)
Officer in Charge	LT RONALD A ADSITT 537-32-52[illegible]
Date & Time — Start	060500Z JAN 1975
Completion	061800Z JAN 1975
Recorder	PSG RONALD E WIESE 398-403966
[illegible]	6333/AC14-6
Type	TACTICAL
Map Name and Scale	TALBOTVILLE 1:50,000
Sheet No.	L II N6721

LANDMARKS

No.	Co-ordinates	Description
1	UT 22609900	NORTHEAST CORNER OF ROAD JUNCTION 1 U SHAPE PICKET DRIVEN FLUSH WITH THE GROUND
2	UT 22059761	NORTH WEST CORNER OF BRICK BUILDING
3	X	X
4	X	X

INTERMEDIATE MARKERS

No.	Description
1	THREE SHORT U SHAPE PICKETS WITH 12" LEFT ABOVE GROUND WRAPPED WITH BARBED WIRE
2	X
3	X
4	X

Description of boundary fence or marker: STANDARD MARKING FENCE (2 STRANDS) THREE SIDES OF MINEFIELD ONLY ENEMY SIDE LEFT OPEN

No. of Strips/Groups 4 Description of Strip/Group Markers: 2"x2" WOODEN STAKES DRIVEN FLUSH WITH THE GROUND WITH AN 8 PENNY NAIL DRIVEN INTO TOP OF STAKE

LANES

No.	Width	How Marked	Provisions for Closing
1	3M	COMD WIRE PEGGED ON £ 2 U SHAPED PICKETS AT ENTRANCE AND AT EXIT	MINES STORED IN LANDMARK 2 9-M15 27-M26 18-M14

Method of Laying & Types of Mines	Anti-Tank Mines: Type M15	Type X	Type X	Total of Mines	Anti-Handling Devices	Anti-Personnel Mines: Type M16	Type M14	Type X	Type X	Total of Mines
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
IOE	34			34	6	68	68			136
I	93			93	2	186	186			372
A	86			86	1	172	172			344
B	86			86	2	172	86			258
C	∅			6	∅	267	89			356
Total	299			299	11	865	601			1466

NOTES

1 IOE LINE CLUSTERS (ALL OTHERS ARE NUMBERED BUT OMITTED)
I1-1 4, 10 15, 18, 24, 27, 28 29 30 ; I2-3 5, 8, 13 19 22 26, 27, 28 29
I3-2, 7, 11, 16, I4-1, 3, 4, 9 11 14, 21, 25 30 33

2 NUMBERED OMITTED CLUSTERS
(a) FOR LANE - IOE . NONE , A-57 58 59 , B 46 47 48 , C-47, 48 49 ,
D-49 50, 51
(b) OTHERS EXCEPT IOE . A-1, 5 - TREES ; B-90 - TREE
C-87 - ROCK , D-90 - CONCRETE SLAB

3 CLUSTERS WITH ANTI HANDLING DEVISES ON AT MINES
IOE . I1-27, 29 , I2-19, 28 , I3-16 , I4-21 , A-12, 56 , B-35 , C-25, 70 ,
D- NONE

4 CLUSTERS W/TRIP WIRED AP MINES A-11, 57, B-35, 81 ; C-3, 15, 21, 27, 91 , D- NONE

5. STRIP CLUSTER COMPOSITION . IOE, A, B ALL CLUSTERS 1-2-2 , C-1-2-1 , D-0-3-1

6 ALL SAFETY CLIPS/PINS FOR EACH STRIP ARE BURIED 30CM (13 INCHES) TO THE REAR OF EACH STRIP MARKER ON LEFT BOUNDARY

Figure 3–10a. Standard detailed minefield record (DA Form 1355), (top half, front)

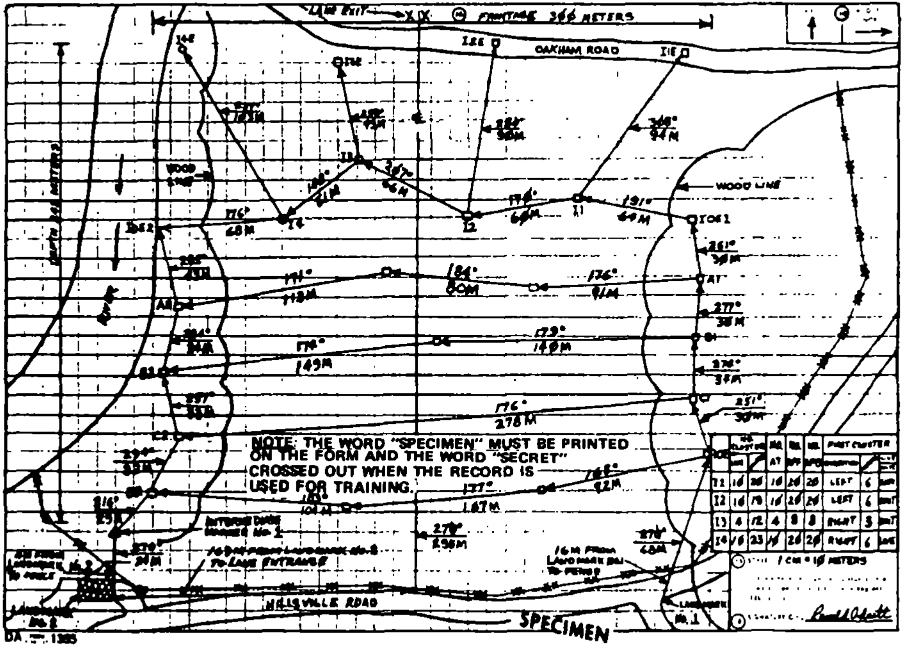


Figure 3–10b. Standard detailed minefield record (DA Form 1355) (bottom half, front).

(17) [redacted] (when completed) SPECIMEN

MINEFIELD RECORD

(2) Copy No. 1 of 7 — Serial 1 of 1 Sheets

(1) Authority for laying: CG 19th U.S. ARMY CORPS
Laying Unit: 3rd PLT Co A, 92nd ENGR. BN.
Officer in Charge: 2LT RUTLEDGE W. J. 217-86-7123

(3) Date & Time — Start: 130645 MARCH 1975
Completion: 191755 MARCH 1975
Recorder: RONALD CORPOS SGT 413-86-9111

(4) Minefield No.: 19TH - 59-5

(5) Type: POINT

(6) Map Name and Scale: TALBOTSVILLE 1:50,000
Sheet No. or Number: 7739

(7) LANDMARKS

(8) INTERMEDIATE MARKERS

(9)

(10) LANES

(12)

(13)

	ANTI TANK MINES					ANTI-PERSONNEL MINES				
	Type M19	Type	Type	Total AT Mines	AT Handling Devices	Type M-16	Type M-14	Type Improvised mine	Type	Total AP Mines
A	24			24	24	15	47	Ø		62
B	17			17	17	40	52	Ø		92
C	21			21	21	32	18	Ø		50
D	Ø			Ø	Ø	Ø	Ø	1		1
Total	62			62	62	87	117	1		205

(11) NOTES

(1) MINES EQUIPPED WITH ANTIHANDLING DEVICES
GROUP A (AROUND BRIDGE) M19 MINES
24 W/M5 DEVICE IN BOTTOM FUZE WELL
GROUP B: (ENTRANCE TO WOODS) M19 MINES
17 W/M5 DEVICE IN BOTTOM FUZE WELL
GROUP C (INTERSECTION) M19 MINES
W/M1 DEVICE IN SIDE FUZE WELL
GROUP D. (CITY HALL) NONE

(2) MINE ACTIVATED BY TRIP WIRE (M16 MINE ONLY)
GROUP A 5
GROUP B 10
GROUP C: 8
GROUP D: NONE

(3) IMPROVISED MINES
GROUPS A, B AND C - NONE
GROUP D.
5 LBS C-4 IN MAYOR UNDER MAYORS DESK.
ACTIVATED ELECTRICALLY BY BUZZER BUTTON ON MAYORS DESK OR NON-ELECTRICALLY BY PULL ON MAYORS CHAIR RIGGED WITH M1 PULL DEVICE.

(4) ALL SAFETY PINS/CLIPS ARE BURIED UNDER FRONT STEPS TO CITY HALL.

(5) TEMPORARY MARKERS REMOVED 132201 MAR 69

Figure 3–11a Record of point minefield with minimum information (top half, front).

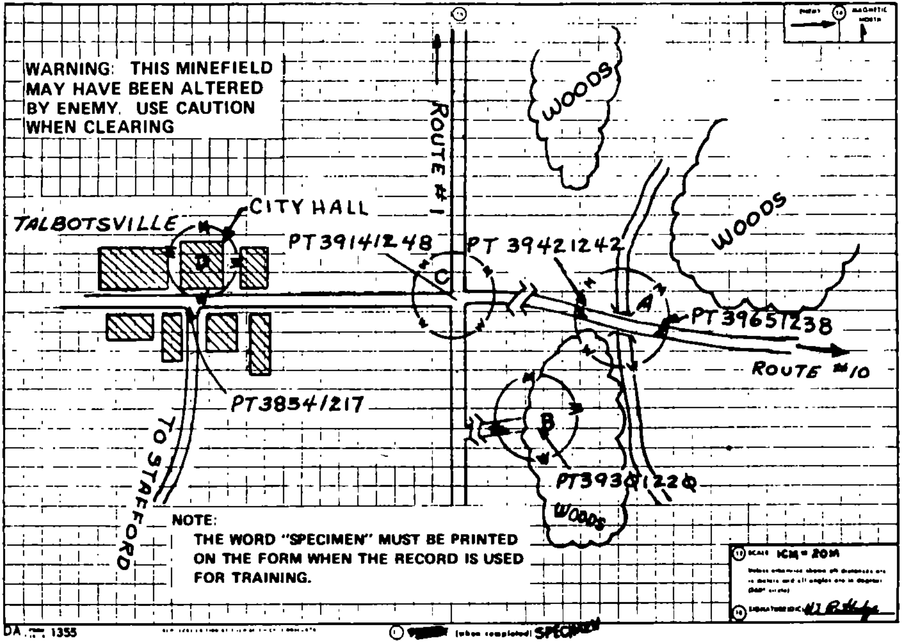


Figure 3–11b. Record of point minefield with minimum information (bottom half, front).

[redacted] (when completed) **SPECIMEN**

MINEFIELD RECORD

Copy No 1 — Sheet 1 of 1 Sheets

Authority for Laying: C.G. 8 XX (INF)

Laying Unit: 3 PLT, Co "A", 54TH ENGR. BN

Officer in Charge: 2LT JERRY D. WILLIAMS 123-45-6789

Date & Time — Start: Ø71ØØ MARCH 1975

Completion: Ø72ØØØ MARCH 1975

Recorder: SGT. M.B. DAVIS 307-286-1943

XXX (INF) - 1E

Type: POINT

Map Name and Scale: TALBOTVILLE 1:5Ø,ØØØ

Sheet No.: 721

REFERENCE STAKE

LANDMARKS

No	Coordinates	Description
1	UT7826 777Ø	BRICKCHURCH BUILDING N.W. CORNER
2	UT78277771	EAST SIDE ROAD INTERSECTION

No	Description
1	U-SHAPED PICKET EX-LONG 3 WRAPS WHITE ENGR. TAPE

LANES

No. ROWS 4

ANTI-TANK MINES / **ANTI-PERSONNEL MINES**

Row	Type: M19	Type	Type	Total of Mines	Anti-handling Devices
A	7			7	
B	7			7	
C	7			7	
D	7			7	
Total	28			28	

NOTES

1. ALL MINES EQUIPPED WITH OUTRIGGERS.
2. ALL MINES ARE WATER RESISTANT TREATED.
3. ALL SAFETIES BURIED $\frac{1}{3}$ METER SOUTH OF REFERENCE STAKE.
4. AVERAGE DEPTH OF STREAM IS ONE METER.
5. ARROWS SHOW DIRECTION AZIMUTHS WERE TAKEN.
6. MINES ARE NUMBERED IN SEQUENCE THEY WERE INSTALLED.
7. CLUSTERS OMITTED, NONE.

Figure 3–12a Record of mines implaced in a ford deeper than 0.6 meters (top half, front).

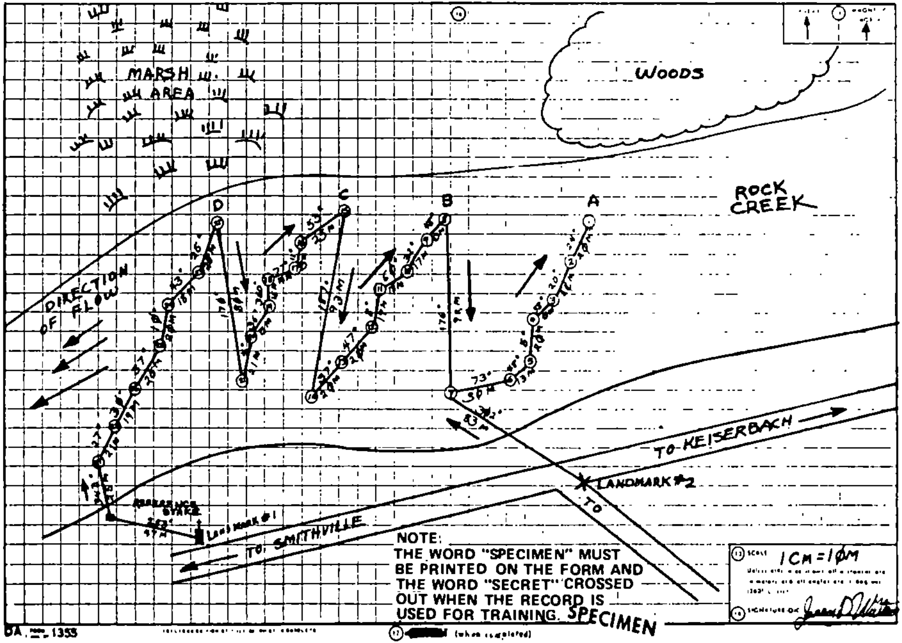


Figure 3–12b   Record of mines implaced in a ford deeper than 0.6 meters

3–10. HASTY BREACH OPERATIONS

A hasty breach operation is performed when the tactical situation requires maintaining the momentum of an attack. It will result in a safe lane through a mined area. Two methods of hasty breaching are:

a. Bangalore Torpedo Train. Two–inch diameter by 1.5–meter–long sections. Pushed into obstacle by hand or propelled by rocket motor. Clears a narrow footpath. For detailed information see TM 9–1375–213–12.

b. Demolition Kit Projected Charge M157. Approximately 7 inches high, 12 inches wide, and 400 feet long. Weight – 11,000 pounds. Pushed or towed by medium tanks. Detonated by impact fuze. In most soils, it creates a crater approximately 320 feet long, 12 to 16 feet wide, and 3 to 5 feet in depth. For detailed information see TM 9–1375–204–10.

3–11. DELIBERATE BREACH OPERATIONS

Deliberate breach operations are carried out by manual methods with mine detectors and/or probes (fig. 3–13 and tab!e 3–8).

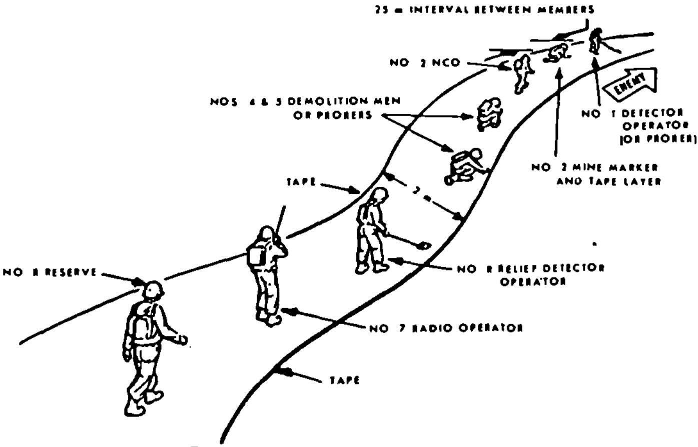


Figure 3–13. Deliberate, manual, minefield breaching party.

Table 3–8. 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 without radio.
No. 1 Breaching Party		1	7	Two portable detectors, two probes, mine markers, marking tape or wire on reels, safety pines, clips, smooth wires(18" lengths) ½–lb blocks of explosives, blasting caps, detonating cords, 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, wire cutters, 2" by 4" stakes at least 6' long, individual weapons, litters, lane-marking signs, gauntlets, barbed wire, stakes, and pickets.
Totals	1	5	31	

3–12. AREA CLEARING OPERATIONS

a. Manual method with mine detectors and/or probes (fig. 3–14 and table 3–9).

b Friendly fields. By use of minefield record.

c. Route clearance (fig. 3–15).

d. Helicopter L.Z. clearance (fig. 3–16).

e Average breaching/clearing time and material requirements (table 3–10).

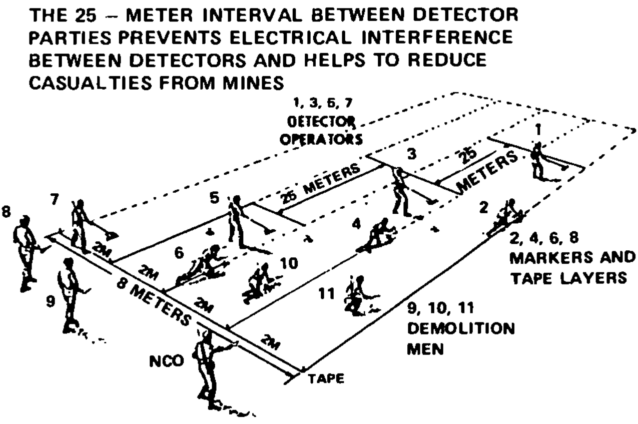


Figure 3–14. Clearing party using electronic detectors.

Table 3–9. Platoon Organization and Equipment for Manual Clearing

Personnel	Officer	NCO	EM	Equipment
Officer in Charge	1			Map, lensatic compass, portable radio, and all avaialble information on mines in area.
No. 1 Clearing Party		1	10	Mine probes, tracing tape on reels, mine markers, grapnels, rope, or wire in 50–meters lengths, 18–in. lengths of 10– and 16–gauge 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 for company net).
Totals	1	4	32	

3–13. TACTICAL EMPLOYMENT OF CLAYMORE MINE M18A1

a. General. The CLAYMORE is primarily a defensive weapon which may be directionally sighted to provide fragmentation over a specific area. The major advantage of the CLAYMORE is that it is adaptable to controlled detonation and does not rely solely upon chance detonation by the enemy. The CLAYMORE is particularly suitable for use in the hasty protective minefield.

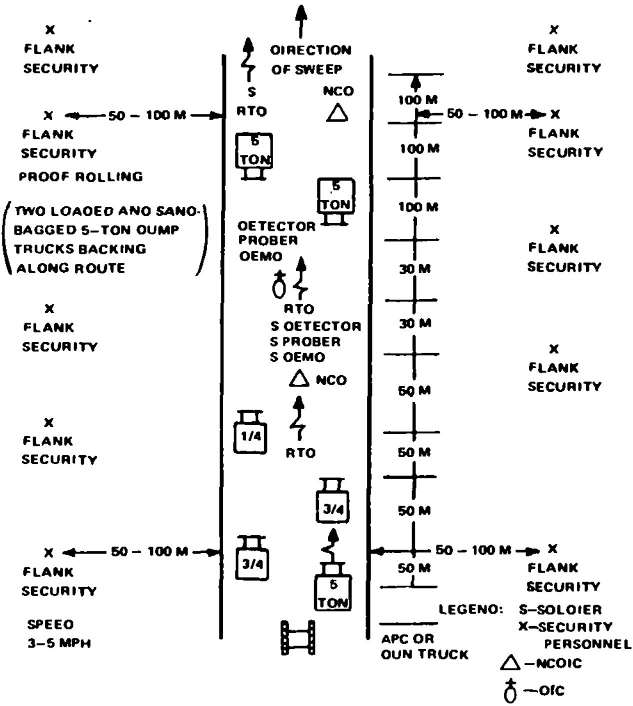
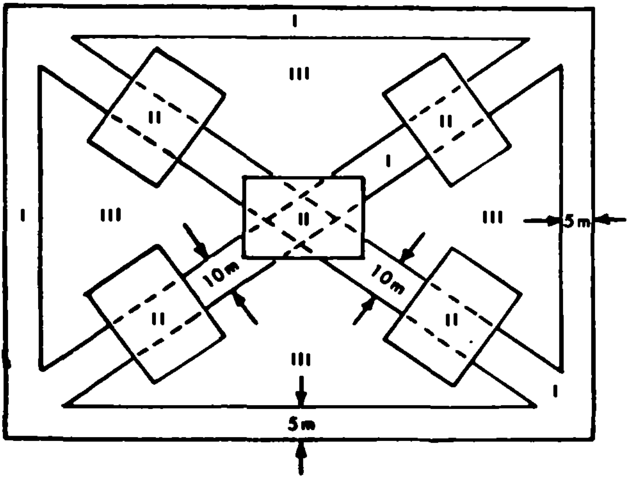


Figure 3–15. Typical sweep team formation.

HELIPORT CLEARING METHOD



I = PHASE I CLEARANCE. TWO 10 METER WIDE DIAGONALS AND A 5 METER WIDE PERIMETER STRIP.

II = PHASE II CLEARANCE. FIVE HELICOPTER PADS.

Note: The size of and distance between landing pads should be determined by coordination with the aviation unit which will use the heliport.

III = PHASE III CLEARANCE. REMAINING AREA.

Table 3–10. Minefield Average Breaching/Clearing Time and Material Requirements

Method	Width of cleared lane (in meters)	Man-hours req'd per 100 meters	Remarks
MANUAL			
Location by probing	1 (footpath)	16–22	See note.
Removal by rope or explosives	1 (footpath)	38–44	See note.
Location by detector, assisted by probing	8 (one-way vehicle lane)	27–33	See note.
Removal by rope or explosives	8 (one-way vehicle lane)	220–247	See note.
EXPLOSIVES			
Demolition snake M157 Diamond Lil)	4.0–6.0	6–8*	6 to 8 man hours to assemble
Bangalore torpedo	1 (footpath)	3.5–4.5	See note.

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

*Per 90 meters (set is only 90 meters long.)

b. Defensive Uses.

(1) To cover the range between maximum hand grenade throwing distance and the minimum safe distance of mortar and artillery supporting fire.

(2) To supplement other minefields when equipped with tripwires.

(3) To fill the dead space of the final protective fires of automatic weapons in defensive positions.

(4) To provide security of outposts, command posts, halted columns, etc.

(5) To cover roadblocks and obstacles.

(6) To cover retrograde operations.

c Offensive Uses (ambushes).

(1) Laterally along the killing zone.

(2) At the front and rear of the killing zone.

(3) Laterally along the killing zone on the far side of the killing zone from the ambush element. This method is particularly effective in countering enemy immediate action that includes maneuver or withdrawal from the killing zone. *Care must be taken to insure the ambush element is protected from fragmentation.*

d. Safe Distances. See table 3–1.

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 officers.

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 antilift devices.

e. Hand removal of mines is undertaken only when no other means of disposal is feasible (i.e., minefield being cleared at night to keep enemy from finding out it is being cleared).

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 stored separately.

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

i. All minefields are reported and recorded no matter what the size or type of hardware used. **One mine, placed in front of an outpost, is a minefield.**

CHAPTER 4

FIELD FORTIFICATIONS

Section I. GENERAL DATA

4–1. PRIORITY OF TASKS

The tasks involved in organizing a defensive position are carried out concurrently, but the situation may require that priority be attached to some. The unit commander specifies the sequence for the preparation of the positions with as many tasks being accomplished simultaneously as possible. The normal sequence of tasks is:

a. Establish security.

b. Position weapons.

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

d. Prepare weapons emplacements and individual positions to include overhead cover and camouflage.

e. Provide for signal communications and observation systems.

f. Emplace obstacles.

g. Prepare routes for movement, supply, and evacuation.

h Improve primary positions to include protection from CBR attack.

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

4–2. CLEARING FIELDS OF FIRE

a. *Principles.*

(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) Restrict work to thinning the undergrowth and removing the lower branches of large trees when clearing in heavy woods. 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 felled limbs, brush, and weeds to areas where they cannot be used to conceal enemy movements or disclose your position.

(6) Do only a limited amount of clearing at one time. Overcommitting the unit may result in a field of fire improperly cleared. This would benefit the enemy.

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

c Man–hours Required.

(1) Approximately 5 man–hours per hundred square meters are required to clear average growth.

(2) Add 50 percent if working in darkness.

Section II. TYPES OF FORTIFICATIONS

4–3. EMPLACEMENTS

a Requirements Emplacements should be constructed to:

(1) Permit each individual to accomplish assigned fire missions.

(2) Be simply 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 and Dimensions – Frontal Parapet Fighting Positions (figures 4–1 through 4–7)

Figure 4–1. Measurements, one–man emplacement

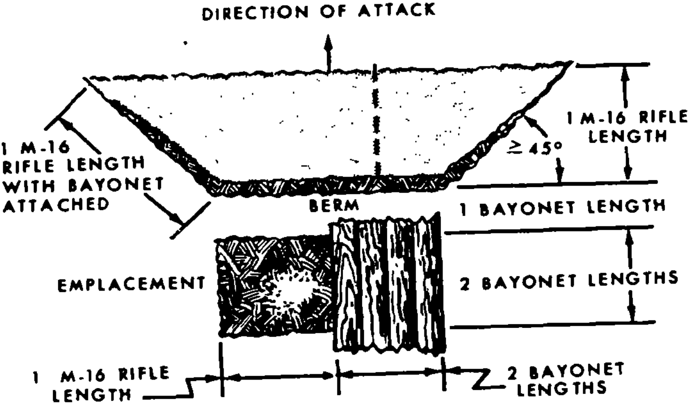
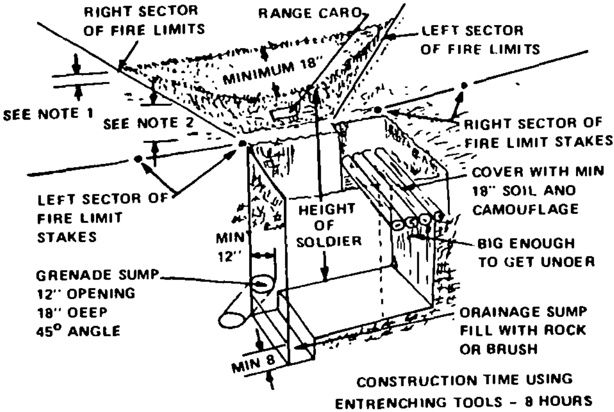


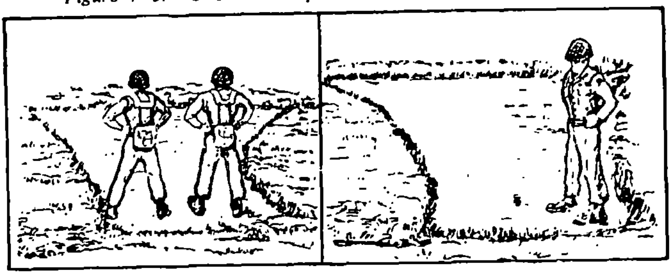
Figure 4–2. One–man emplacement (vertical view)



NOTES.

1. END OF PARAPET MUST BE AT LEAST 4" HIGHER THAN MUZZLE OF WEAPON WHEN IN FIRING POSITION.
2. REAR OF PARAPET MUST BE HIGH ENOUGH TO PROTECT A MAN'S HEAD.

Figure 4–3. One–man emplacement (cross–sectional view).



FEET ARE PLACED MORE THAN SHOULDER WIDTH APART

Figure 4–4. Measurements, two–man emplacement.

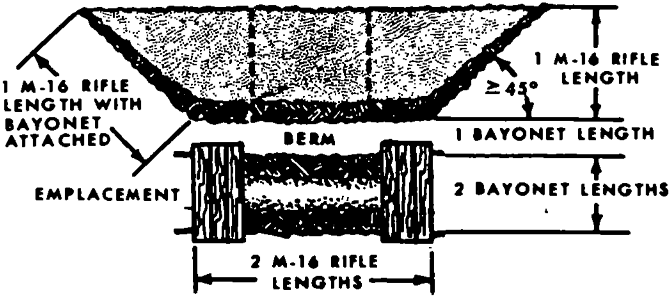
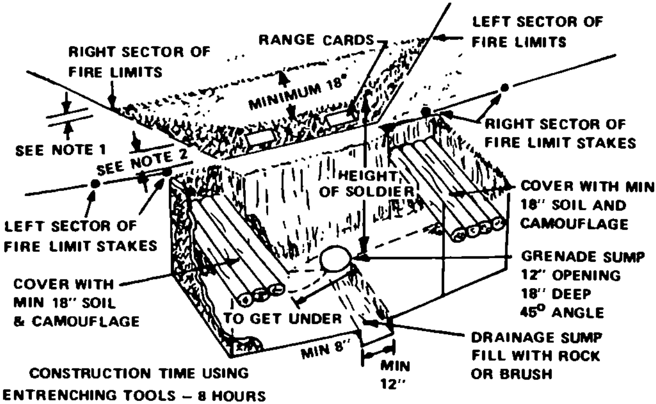


Figure 4–5. Two–man emplacement (vertical view).



NOTES:

1. END OF PARAPET MUST BE AT LEAST 4" HIGHER THAN MUZZLE OF WEAPON WHEN IN FIRING POSITION.
2. REAR OF PARAPET MUST BE HIGH ENOUGH TO PROTECT A MAN'S HEAD.

Figure 4–6. Two–man emplacement (cross–sectional view).

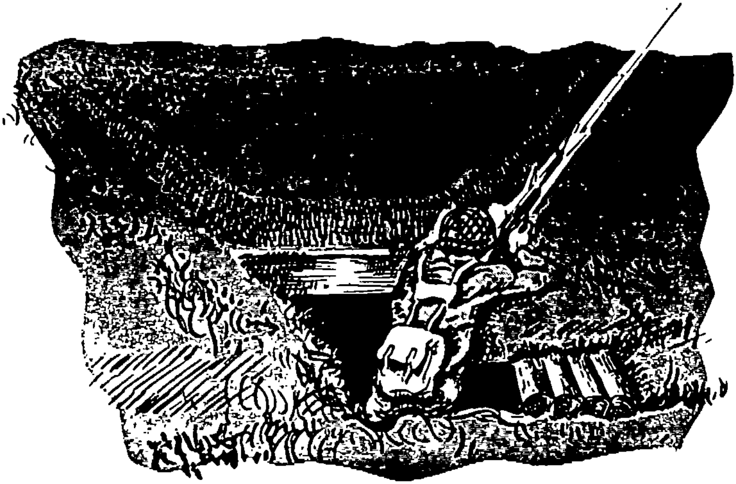


Figure 4–7. Occupied one–man emplacement.

c. Foxhole Digger Explosive Kit. This item greatly increases a unit's capability to create emplacements with a minimum of time and labor. See figure 4–8.

(1) *Characteristics*

(a) Case.
Material–Plastic
Shape–Tubular
Size–7.38 x 2.28 in.

(b) Shaped charge.
Material–Plastic and copper
Shape–Tubular
Size–7.37 x 2.0

(c) *Cratering charge.*
Material—Pressed explosive inside sleeve
Shape—Tubular
Size—8.21 x 1.0 in.

(d) *Fuze.*
Material—Steel
Shape—Tubular
Size—4.25 x 0.56 in.

(e) *Basis of issue.* Individual combat soldier

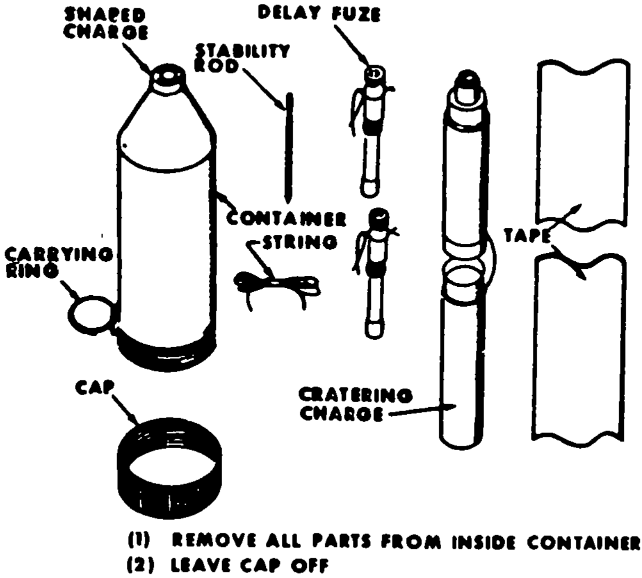


Figure 4–8. Foxhole digger explosive kit.

Type of emplacement or shelter	Total construction time in man hours for construction with D-handle shovels and ordinary carpentry tools				
	Revetment materials for cover support only		Complete revetment		No revet-ment mate-rials used
	Corru-gated metal constr.	Sized lumber constr.	Corru-gated metal constr.	Sized lumber constr.	
Improved crater	N/A	N/A	N/A	N/A	0.5
Skirmishers trench	N/A	N/A	N/A	N/A	0.5
Prone emplacement	N/A	N/A	N/A	N/A	1.5
Open one man foxhole	N/A	N/A	3.5	4.5	2.0
Open one man foxhole with offset	9.0	14.0	10.0	16.0	N/A
One man foxhole with half cover	2.5	3.0	4.5	5.5	N/A
One man foxhole with half cover and offset	10.0	14.0	12.0	18.0	N/A
Open two man foxhole	N/A	N/A	6.0	8.0	3.0
Deepened two man foxhole	N/A	N/A	8.0	10.0	5.0
Two man foxhole with half cover	4.0	4.0	8.0	10.0	N/A
Two man foxhole with half cover and two offsets	20.0	30.0	22.0	35.0	N/A
Two man foxhole with half cover and adjoining shelter	11.0	17.0	13.0	22 0	N/A
Open fighting trench (25' length)	N/A	N/A	28.0	32 0	21.0
Fighting trench with full cover (25' length)	27.0	29.0	35.0	40.0	N/A

Figure 4–9. Time required to construct individual, crew-served, 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				
	Revetment materials for cover support only		Complete revetment		No revetment materials used
	Corrugated metal constr.	Sized lumber constr.	Corrugated metal constr.	Sized lumber constr.	
Open automatic rifle emplacement	N/A	N/A	7.0	8.0	4.0
Automatic rifle emplacement with 18" of cover	4.0	5.0	6.0	7.0	N/A
Open horseshoe type M60 machinegun emplacement	N/A	N/A	8.0	10.0	4.0
Open 2 one-man foxhole type light machinegun emplacement.	N/A	N/A	6.0	7.0	4.0
Horseshoe type light machinegun emplacement with full cover.	9.0	11.0	11.0	14.0	N/A
2 one-man foxhole lt. machinegun type emplacement with ½ cover and adjoining shelter	15.0	22.0	19.0	28.0	N/A
Circular type .50 cal machinegun emplacement	N/A	N/A	14.5	16.5	10.0
Pit type emplacement for recoilless weapons	N/A	N/A	5.0	6.0	3.0
81-mm mortar emplacement	N/A	N/A	12.0	N/A	N/A
4.2-inch mortar emplacement	N/A	N/A	29.0	N/A	N/A
Recoilless rifle position (mounted)	N/A	N/A	N/A	N/A	30.0
Recoilless rifle position (dismounted)	N/A	N/A	N/A	N/A	17.0
105-mm howitzer emplacement	N/A	N/A	N/A	N/A	100.0
155-mm howitzer emplacement	N/A	N/A	N/A	N/A	170.0

Figure 4–9. Time required to construct individual, crew-served, and artillery weapons emplacements (Con't).

(2) *Effect.*

(a) The shaped charge will penetrate soil, depending on the density, to depths varying from 50 to 85 cm. (19.7 to 33.5 in.), forming a tapered hole 6 cm. (2.4 in.) in diameter at the top and 1.5 cm. (0.6 in.) at the bottom.

(b) The cratering charge will form a crater in soil about 107 cm (42 in.) in diameter and about 80 cm (31.5 in.) deep.

4–4. REVETMENTS

a. Retaining Wall Type Used in relatively unstable soils. The horizontal layers of the walls are tied together so that the wall acts as a structural unit. Revetments may be constructed of sandbags, sod blocks, and other expedients. The methods of construction are as follows:

(1) *Sandbags (fig 4–10)*

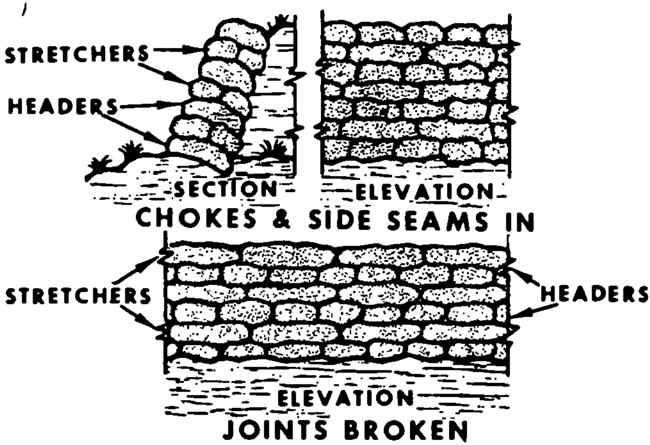


Figure 4–10. Sandbag retaining wall.

(a) Fill three—fourths full.

(b) Stabilize bags by filling with 1 part cement to 10 parts dry earth. In a sand—gravel mixture, increase ratio to 1 to 6.

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

(d) Place all bags on bottom row as headers (fig. 4—10).

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

(f) Alternate intermediate rows as headers and stretchers.

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

(h) Place bags perpendicular to slope.

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

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

(3) Expedients, such as ice blocks, may be used in cold weather. Stack them in the same way as sandbags or sod, and run water over them in order to bind them by freezing. Another expedient is earth—filled packing cases or ammunition boxes which are placed in position and nailed to the layer below. The boxes are then filled with earth or rock. In wooded areas, small timber may be used as revetting material.

b. Facing Type. Serves mainly to protect surfaces from weather and damage caused by occupation. It consists of facing materiel, the top of which is set below ground level so that the revetting material is not damaged by tanks crossing the emplacement.

(1) *Types of material* Materials used in facing may be brushwood hurdles, continuous brush, pole and dimensional timbers, corrugated metal, or burlap and chicken wire. Construction methods are described in paragraph 4—4—b—(3) below.

(2) *Methods of support*

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

(b) Pickets are driven into the ground on the position side of the facing material and held tightly against the facing by bracing the pickets apart or fastening their tops to stakes or holdfasts (fig. 4–11).

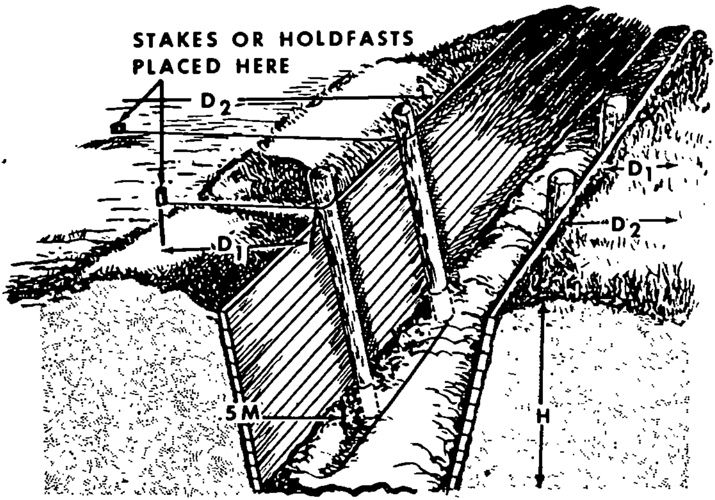


Figure 4–11 Method of anchoring retaining wall posts/pickets.

(3) *Methods of constructing facing type revetments*

(a) The size of pickets depends upon the soil type and the kind of facing material, but timber pickets should not be smaller than 8.0 centimeters in diameter. Maximum spacing between pickets should be 1.75 meters. U–shaped pickets are excellent for revetting. Pickets are driven at least 0.5 meters into the floor of the position. Where the pickets are anchored at the top, proceed as shown in figure 4–11.

(b) A brushwood hurdle is a woven revetment unit, usually 1.75 to 2.0 meters long and of required height.

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

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

4–5. BUNKERS

a In bunker design two basic criteria must be considered:

(1) The purpose of the bunker (CP, firing positions, etc.).

(2) Weapons from which protection is desired (small arms, mortars, bombs, etc.).

b. A bunker should be constructed wholly or partly below ground level. If above ground level, columns or posts should extend belwo ground level for anchoring.

c The protective cover and roof of a bunker should be designed so that it moves freely but is rigid enough to displace as a unit. It must also be able to absorb the shock of an exploding shell. To accomplish this, sandwich type construction is used. See figures 4–12 and 4–13. The burster course and roof structure must be both rigid and resilient and the middle layer be porous and capable of cushioning against shock.

d In timber construction, notching of lumber should be avoided.

e. All bunkers should have overhead cover of at least 18 inches in order to defeat an 81–mm mortar surface burst.

4–6. SHELTERS

The most effective shelters are underground cut and cover. Typical shelters, including an air transportable recoverable shelter, are shown in figures 4–14 thru 4–17 and table 4–1. See FM 5–15 for other, more permanent types.

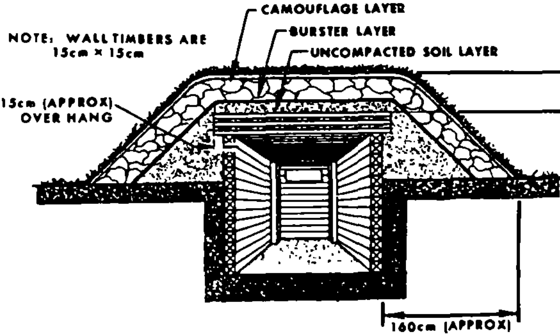


Figure 4–12a Bunker (interior view)

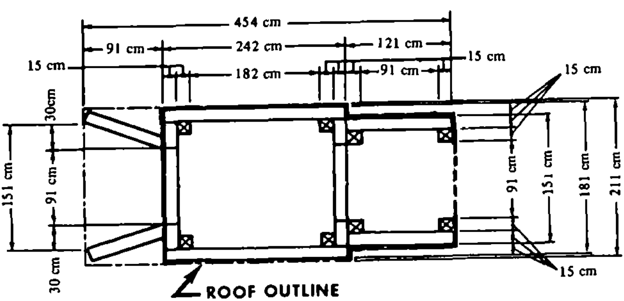


Figure 4–12b. Bunker (plan view).

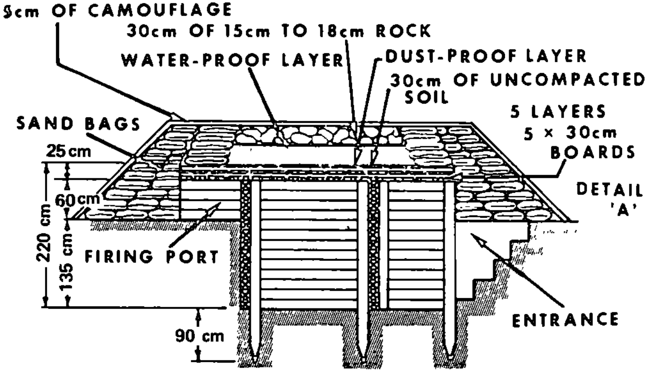


Figure 4–12c Bunker

ITEM	DESCRIPTION	NO.PCS
ROOF	5 CM X 30 CM X 2.11 M LONG	48 PCS
	5 CM X 30 CM X 4.54 M LONG – WOOD	14 PCS
SIDE WALLS	15 CM X 15 CM X 2.42 M LONG – WOOD	26 PCS
ENTRANCE WALL	15 CM X 15 CM X 1.21 M LONG – WOOD	26 PCS
FIRING PORT AND ENTRANCE DOOR	15 CM X 15 CM X 30 CM LONG – WOOD	26 PCS
FRONT AND REAR WALLS	15 CM X 15 CM X 1.51 M LONG – WOOD	13 PCS
FIRING PORT AND RETAINING WALL	15 CM X 15 CM X 1.00 M LONG – WOOD	8 PCS
SIDE POST	15 CM X 15 CM X 2.85 M LONG –WOOD	6 PCS
SIDE POST	15 CM X 15 CM X 1.95 M LONG – WOOD	2 PCS

Figure 4–12d Bunker (bill of materials)

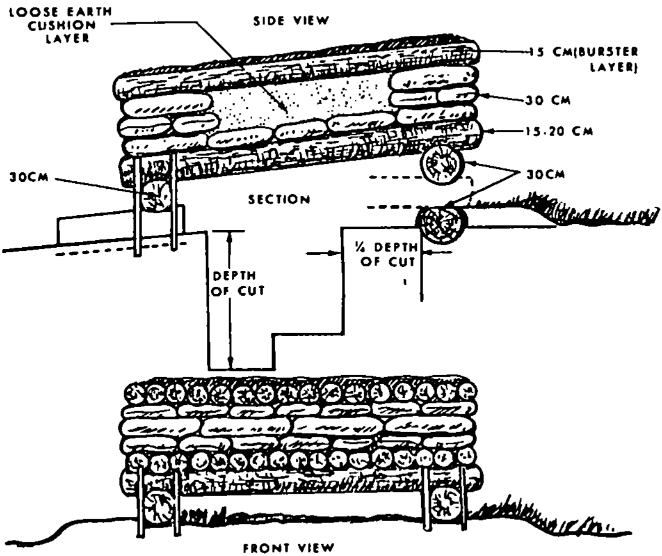
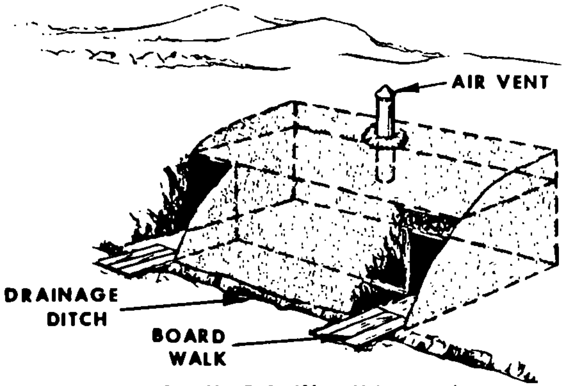
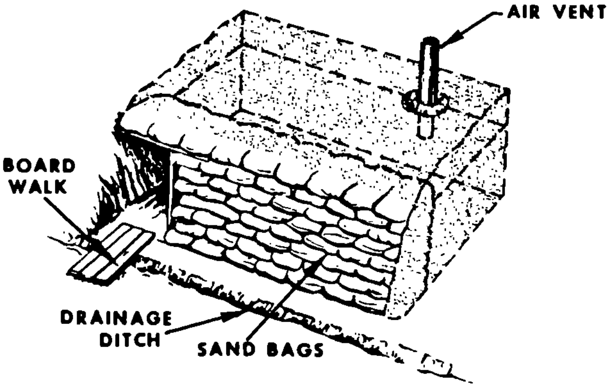


Figure 4–13. Fighting bunker with overhead cover.



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 ACUT BANK SHOWING SAND-BAGGED OUTER WALL. SHADED AREA AND BROKEN LINES SHOW AREA OF CUT—AND—FILL.

Figure 4—14. Cut and cover shelter.

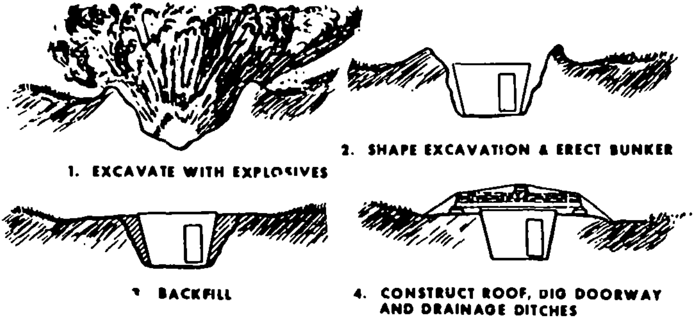


Figure 4–15. Air transportable underground assault bunker (prefab)

BILL OF MATERIALS

4′ x 8′ x ¾″ PLYWOOD	20 EA
4″ x 8″ x 14′ TIMBERS	13 EA
4″ x 4″ x 8′ TIMBERS	10 EA
4″ x 4″ x 10′ TIMBERS	2 EA
2″ x 4″ x 12′ TIMBERS	4 EA
2″ x 4″ x 10′ TIMBERS	9 EA
2″ x 4″ x 8′ TIMBERS	10 EA
TRIM (METAL EDGING)	190 FT
OPTIONAL	
BOLTS (FOR HINGES)	128 EA
WOOD SCREWS (OR # 8 NAILS)	5 LB
PAINT (O. BRAB)	1 GAL
HINGES	16 EA
U–BOLTS W/BEARING PLATES	4 EA

Figure 4–16. Bill of materials (air transportable underground bunker)

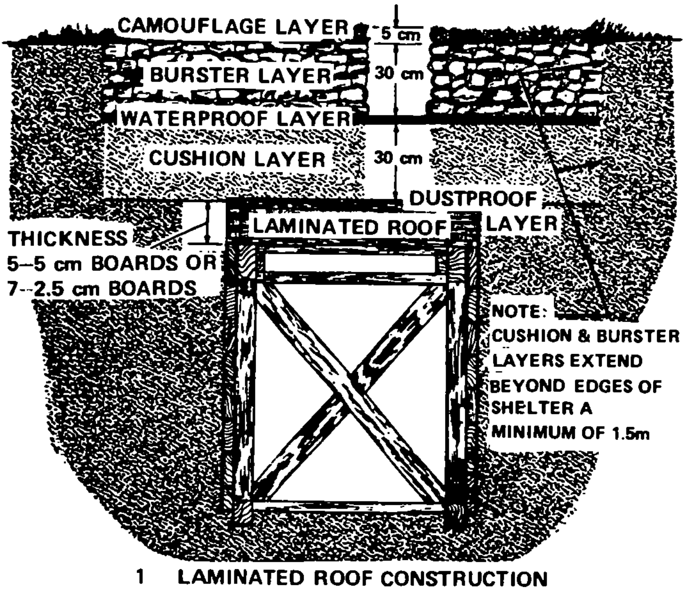
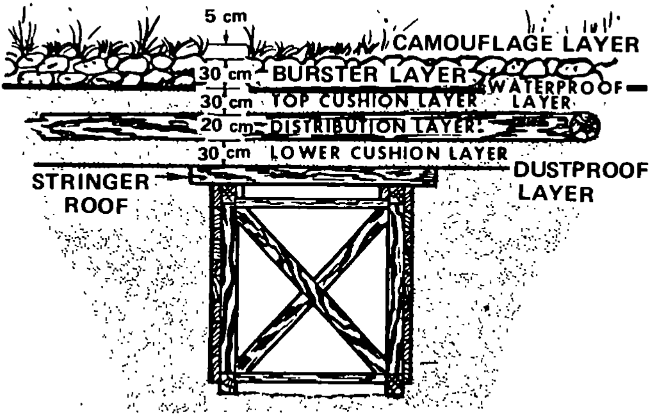


Figure 4–17a. Heavy overhead cover (laminated roof construction).



NOTE: THE CONSTRUCTION IS SIMILAR TO LAMINATED ROOF CONSTRUCTION WITH THE ADDITION OF—

(1) A LOWER CUSHION LAYER 30 cm THICK ON TOP OF THE DUSTPROOF LAYER. THIS LAYER OF UNTAMPED EARTH DOES NOT EXTEND BEYOND THE SIDES OF THE SHELTER.

(2) A DISTRIBUTION LAYER CONSISTING 20 cm TIMBERS. THIS LAYER EXTENDS BEYOND EACH SIDE OF THE SHELTER A MINIMUM OF 1.5 METERS AND RESTS ON UNDISTURBED EARTH TO TRANSMIT PART OF THE LOAD OF THE TOP LAYERS TO THE UNDISTURBED EARTH ON EACH SIDE OF THE SHELTER.

Figure 4—17b. Heavy overhead cover (stringer roof construction).

Table 4–1. 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"	4
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"	41⅓ 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	½" 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. 4–17–a) may be substituted if desired.

Section III. BARBED WIRE ENTANGLEMENTS

4–7. TYPES

Obstacles are classified as either antipersonnel or antivehicular and may be deliberate or expedient.

4–8. PRINCIPLES OF EMPLOYMENT

In order to be effective, obstacles should be:

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

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

c. Erected in irregular traces.

d. Employed in depth.

e. Coordinated with other elements of the defense.

f. Tied in with other obstacles.

g. Provided with lanes and gaps.

h Of no advantage to the enemy.

4–9. CLASSIFICATION OF BARBED WIRE

a. *Belt.* One entanglement, one fence in depth.

b. *Band.* Two or more belts with no interval between them. The band may be composed of two or more fences of different types, in which case it would be called a combination band.

c. *Zone.* Two or more bands or belts in depth with intervals between them.

4–10. ESTIMATING BARBED WIRE REQUIREMENTS

a. Conventional Deployment.. (along FEBA) Rules of Thumb.

(1) Tactical wire; (front) x (1.25) x (number of belts).

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

(3) Supplementary wire.

(a) Forward of FEBA, (front) x (1.25) x (number of belts).

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

b. Base Camp Defense (fig 4–18). (along perimeter) Rules of Thumb.

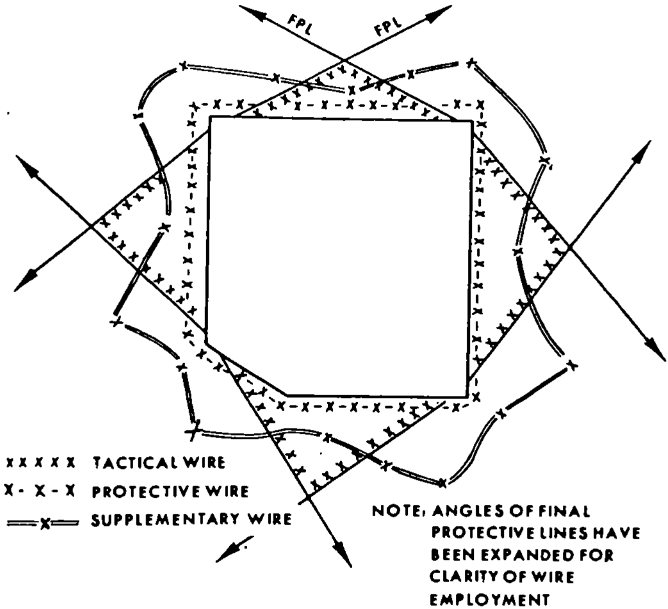


Figure 4–18 Perimeter defense wire

(1) Tactical wire; (mean perimeter) x (1.25) x (number of belts).

(2) Protective wire; (perimeter) x (1.10) x (number of belts).

(3) Supplementary wire; (mean perimeter) x (1.25) x (number of belts).

c Supply and Labor. For construction estimates of man-hours and materials, see tables 4–2 and 4–3.

4–11. BARBED WIRE TIES

Various barbed wire ties are shown in figure 4–19.

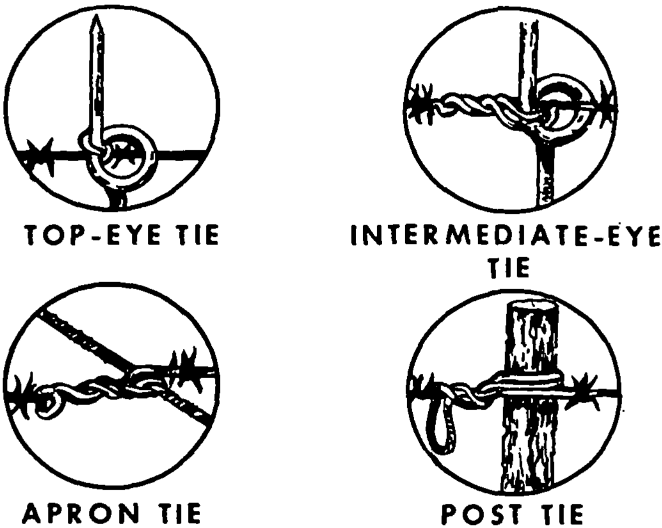


Figure 4–19. Barbed wire ties.

Table 4–2 Wire and Tape Entanglement Materials

Materials	Approx weight, kg	Approx length, m	No. carried by one man	Approx weight of man-load kg
Barbed wire reel	41.5	400	½	21
Bobbin	3.5--4.0	30	4–6	14.5–24.5
Barbed tape dispenser	0.77	0.45	20	15.5
Barbed tape carrying case	14.5	300	1	14.5
Standard barbed tape concertina	14	15.2	1	14
Standard barbed wire concertina	25.4	15.2	1	25
Expedient barbed wire concertina	13.5	6.1	1	13.5
General purpose barbed tape obstacle				
Hand	16	20	2	32
Vehicular	112	140	1	112
Screw pickets:				
Long	4	1.6	4	16.3
Medium	2.7	0.81	6	16.3
Short	1.B	0.53	B	14.5
U–shaped pickets:				
Extra long	7.25	2.4	3--4	21.B–19.0
Long	4.5	1.5	4	18.1
Medium	2.7	0.B1	6	16.3
Short	1.8	0.61	8	14.5
Wooden pickets:				
Extra long	7.7–10.5	2.13	2	15.4–20.8
Long	5.4–7.25	1.5	3	16.3–21.7
Short	1.4–2.7	0.75	B	11.0–21.7

Table 4–3 Material and Labor Requirements for 300–Meter Sections of Various Barbed Wire Entanglements

Type of entanglement	Pickets Long	Pickets Med	Pickets Short	Reels of barbed wire (a)	No. of GPBTO (f)	No. of concertinas	Staples	Man-hours to erect (c)	Kgs of materials per lin m of entanglement (b)
Double-apron, 4- and 2-pace	100		200	14–15 [d](19)				59	4.6 [e](3.5)
Double-apron, 6- and 3-pace	66		132	13–15 [d](18)				49	3.6 [e](2.6)
High wire (less guy wires)	198			17–19 [d](24)				79	5.3 [e](4.0)
Low wire, 4- and 2-pace		100	200	11				49	3.6 [e](2.8)
4-strand fence	100		2	5–6 [d](7)				20	2.2 [e](1.8)
Triple standard concertina	160		4	3 [d](4)		59	317	30	8.2 [e](7.3)
General purpose barbed tape obstacle (GPBTO)					[f](8)			[f](1)	2.7

a. 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.
b. Average weight when any issue metal pickets are used (1 truckload = 2268 kgs).
c. Man-hours are based on the use of screw pickets. Multiply these figures by .67 if experienced troops are being used, and by 1.5 for night work. With the exception of triple standard concertina and GPBTO, multiply these figures by 1.2 when using any type driven picket.
d. Number of barbed tape carrying cases required if barbed tape is used in place of barbed wire.
e. 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.
f. Based on vehicular emplaced obstacles installed in triple belts.

4–12. BARBED STEEL TAPE

Barbed steel tape (fig. 4–20) and barbed tape concertina can be used in the same manner as standard barbed wire and concertina for the construction of barbed wire entanglements. Wrap around ties are used with barbed steel tape similar to the post tie used with barbed wire (fig. 4–19). However, barbed tape must not be pulled tight as it will break when bent sharply. A special dispenser is used to impart a twist to the tape when constructing fences. Recovery of the barbed steel tape for reuse in a standard fence is usually not practical. However, it should be recovered and used to increase the density of other existing entanglements.

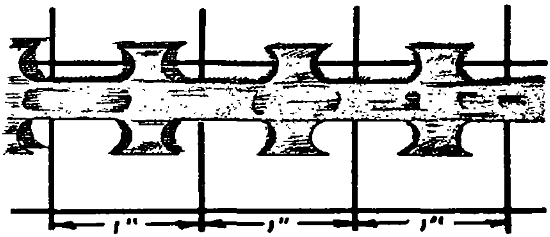


Figure 4–20 Barbed steel tape.

4–13. DOUBLE–APRON FENCE, FOUR– AND TWO–PACE

a. Erect from right to left as you face the enemy (fig. 4–21).
b. Space pickets as follows:
(1) Long pickets are 4 paces apart.
(2) Anchor pickets are placed 2 paces from the centerline at midpoint between center pickets and at each end of fence 4 paces from the first and last center picket.

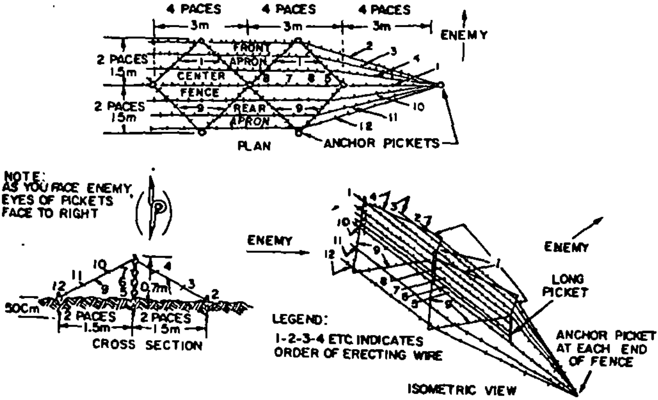


Figure 4–21. Double–apron fence.

4–14. DOUBLE–APRON FENCE, SIX–AND THREE–PACE

Erection is the same as in paragraph 4–13 using 6 paces instead of 4 and 3 paces instead of 2.

4–15. 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 organized into two crews of four men each.

(1) First wire, enemy diagonal.

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

(3) Third and fourth wire, enemy apron.

(4) Fifth, sixth, seventh, eighth, center fence (install from the bottom up).
(5) Ninth wire, friendly diagonal.
(6) Tenth and eleventh wire, friendly apron.
(7) Twelfth wire, friendly tripwire.

4–16. TRIPLE STANDARD CONCERTINA

a. Erect from right to left as you face the enemy (fig. 4–22).
b. Space pickets as follows:
(1) Long pickets are 5 paces apart.
(2) Anchor pickets are placed 2 paces from the end of long pickets.
(3) Enemy and friendly rows of pickets are 3 feet (0.9m) apart.
(4) Friendly picket row is offset from the enemy row.

c. Concertina fences are constructed of barbed wire concertina, barbed tape concertina, or general purpose barbed tape obstacle. There is no difference in construction methods for the first two types. Construction methods for the tape obstacle are given in paragraph 4–18.

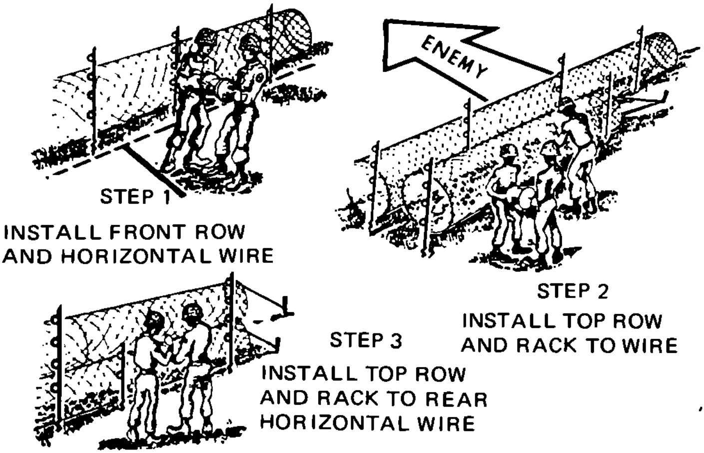


Figure 4–22. Installing concertinas.

4–17. 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) Lay one concertina in front of third picket on enemy side.

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

(c) Remove binding wire and place on handles.

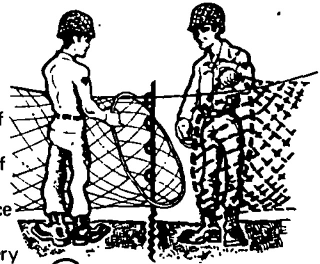
(d) Repeat same performance every fourth picket thereafter.

b Second Operation (All Personnel).

(1) Install front row concertina and horizontal wire.

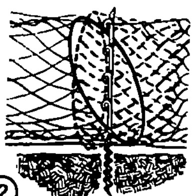
(a) Drop concertinas over pickets.

(b) Join concertina (fig. 4–23).



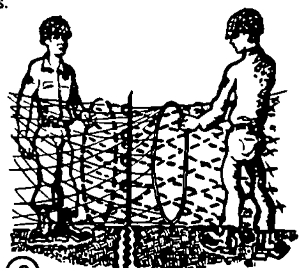
1

PLACE BOTTOM PORTION OF FIRST COIL OVER PICKET



2

PLACE BOTH BOTTOM AND TOP PORTION OF SECOND COIL OVER PICKET



3

PLACE TOP PORTION OF FIRST COIL OVER PICKET

Figure 4–23. Joining concertinas.

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

4–18. GENERAL PURPOSE BARBED TAPE OBSTACLE (GPBTO)

a. Description. The GPBTO consists of two concentric helical coils of steel spring tape which are 30 and 24 inches in diameter, respectively (fig. 4–24). The GPBTO is available in a seven–module package containing sufficient tape to erect an obstacle 140 meters long. The obstacle may be emplaced by vehicle, or individual sections may be detached and manually erected. Recovery tools and anchor stakes are included in each container. GPBTO should be employed as a band, 3 belts in depth.

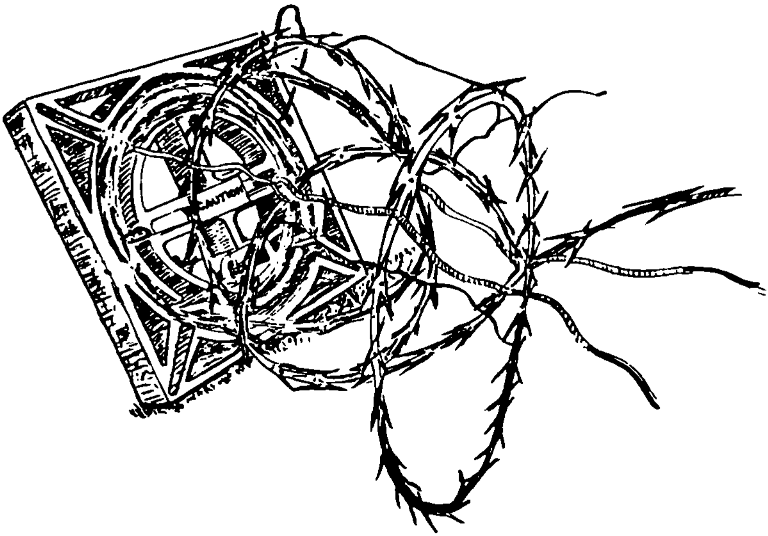


Figure 4–24. General purpose barbed tape obstacle

b. Emplacement. GPBTO is erected by anchoring one end of the obstacle to the ground and carrying the package along the desired obstacle path until all the tape is dispensed. Hand emplacement requires one–twentieth the time and vehicular emplacement one–fiftieth the time required to erect concertina. Further instructions are included with each container.

c. Safety. Gloves should *NOT* be worn when handling the GPBTO. While gloves will reduce minor scratches, they tend to give a false sense of security. The GPBTO barbs are so sharp that they easily penetrate gloves without sufficient resistance to give a warning. Consequently, the hand can be punctured easily when the glove is worn and it can be very difficult to extract the barb from the hand if other barbs are tangled in the glove.

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. This results in all apron and diagonal wires being much closer to the ground. The numbers 5, 6, and 7 wires are not used. 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

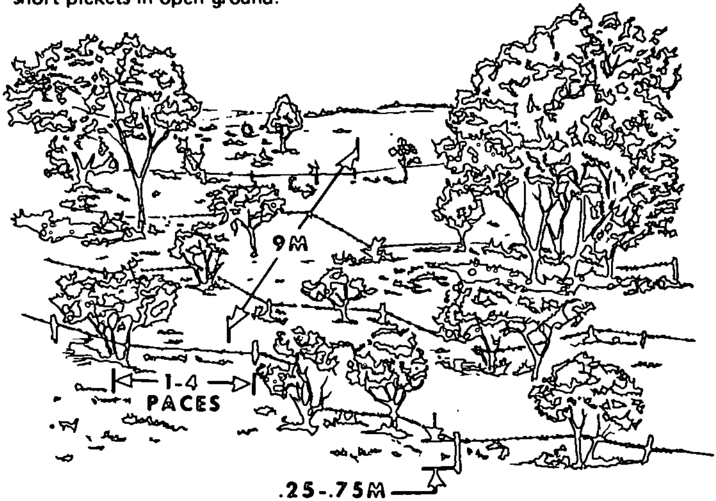
This is the four–strand center section of a double–apron fence. In farm country this obstacle blends in with the landscape. If guy wires are used, estimate separately because this material is not included in table 4–3.

a. The working party is divided into two 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.

b. Teams of two or four men are then 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 5- to 100 meters before ties are made. The wires are installed from the bottom up.

4–21. TANGLEFOOT

Tanglefoot is used where concealment is needed (fig. 4–25). 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. Use short pickets in open ground.



NOTE: TANGLEFOOT, AS PICTURED, IS DESIGNED TO DISRUPT ENEMY DURING AN ASSAULT. WHEN USED AS A COUNTER–SAPPER MEASURE THE TANGLEFOOT SHOULD BE STRUNG OUT AT IRREGULAR CRISS-CROSS PATTERNS SO AS TO CREATE RECTANGLES OR SQUARES OF ABOUT .6 x .6 METERS AT VARYING HEIGHTS OF 10–15 CENTIMETERS. DOING THE ABOVE SHOULD CAUSE THE SAPPER TO HAVE TO RISE OVER THE WIRE EXPOSING HIM TO FIRE.

Figure 4–25. Tanglefoot.

4–22. PORTABLE BARBED WIRE OBSTACLES

a. Standard concertinas are considered portable as they are readily moved.

b The knife rest (fig. 4–26) 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.

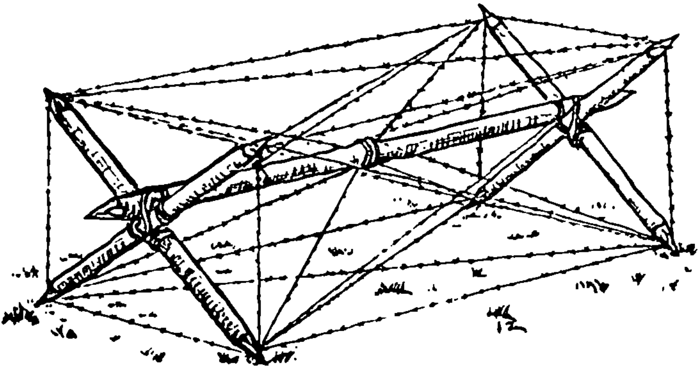


Figure 4–26. Knife rest.

Section IV. EXPEDIENT OBSTACLES

4–23. EXPEDIENT OBSTACLES

See figures 4–27 through 4–34

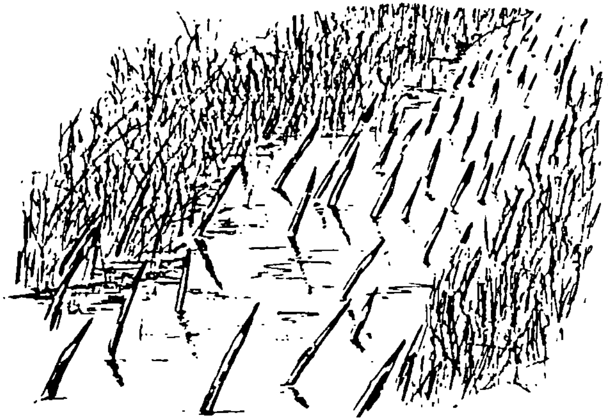


Figure 4–27 Belt of imbedded sharpened stakes

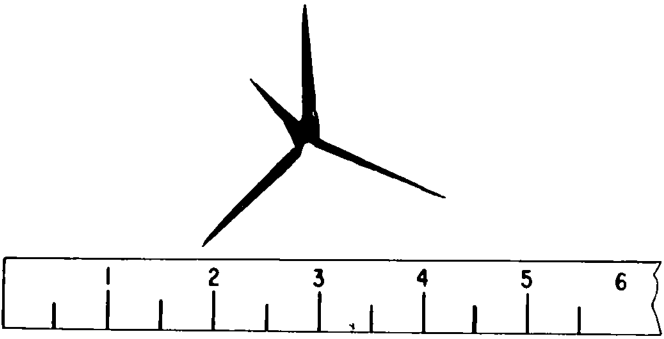


Figure 4–28. Caltrop

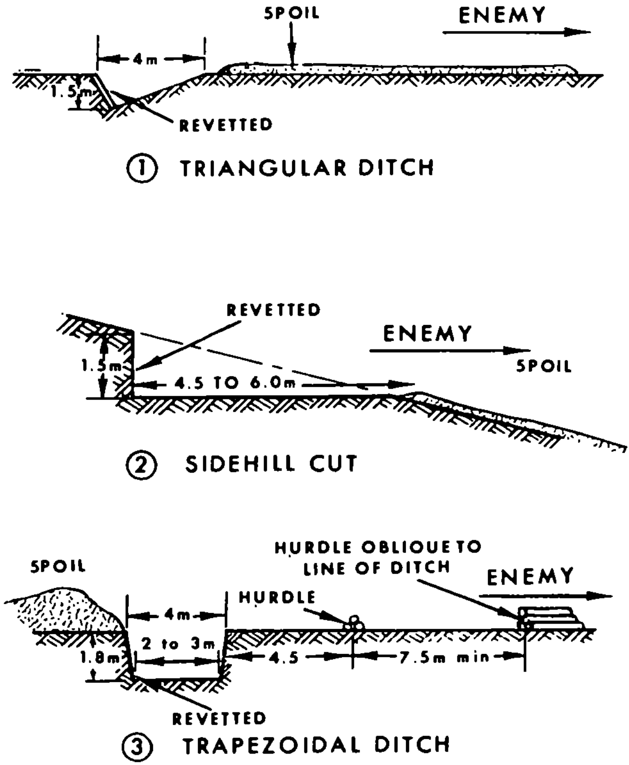
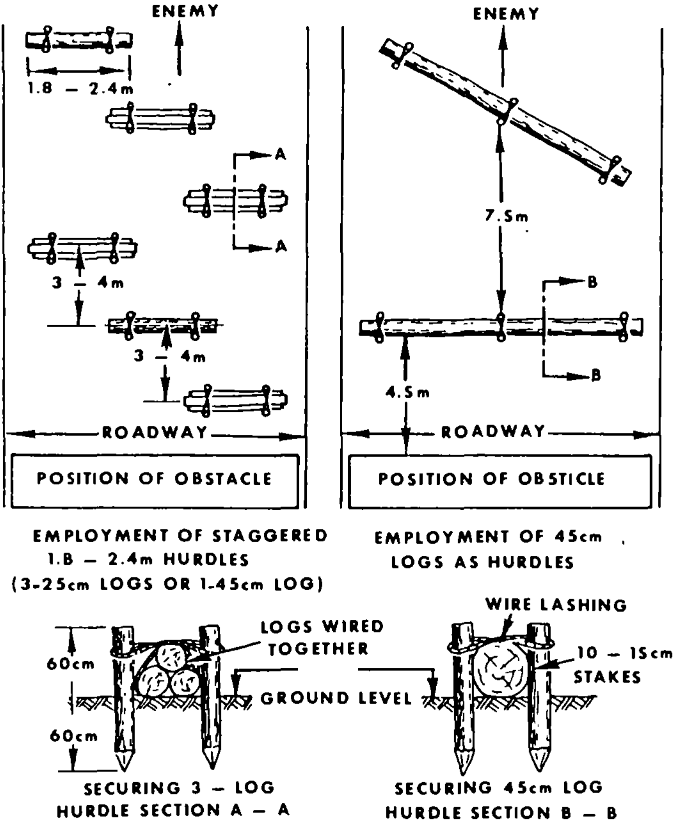
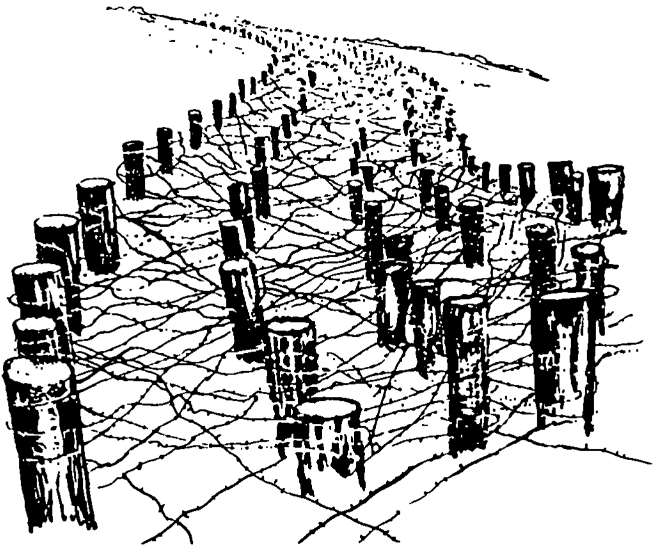


Figure 4–29. Trapezoidal ditch



Employ a minimum of three hurdles per site.

Figure 4–30 Log hurdles



MIN DEPTH: 4 ROWS

SPACING: IRREGULAR, 1 TO 2m BETWEEN POSTS (AVG 1.5m)

HEIGHT: IRREGULAR 78cm TO 120 cm ABOVE GROUND
AND 150 cm BELOW GROUND.

$$\text{NUMBER OF POSTS} = \frac{\text{(FRONT) } 4}{1.5}$$

DIAMETER OF LOGS, 40 cm

Figure 4–31. Post obstacles.

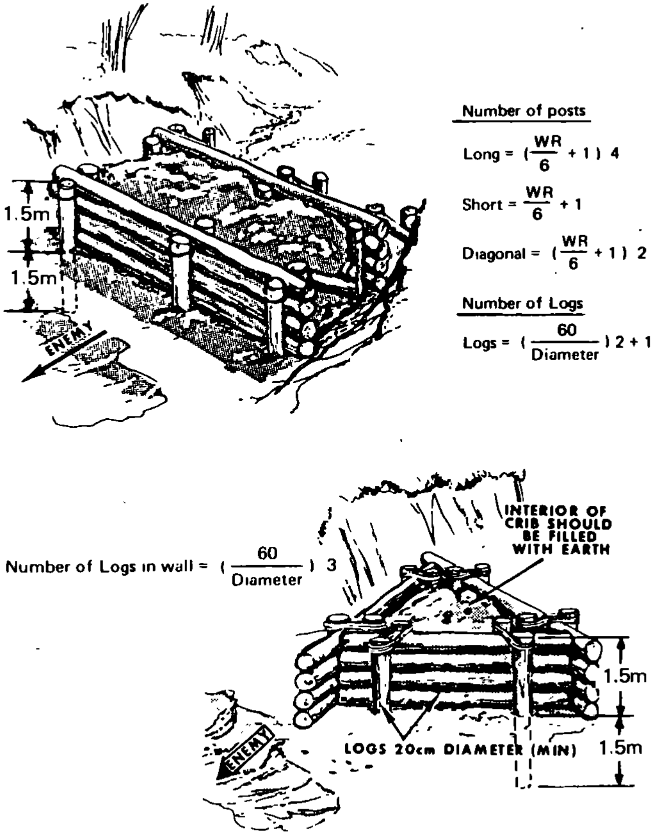


Figure 4–32 Log cribs.

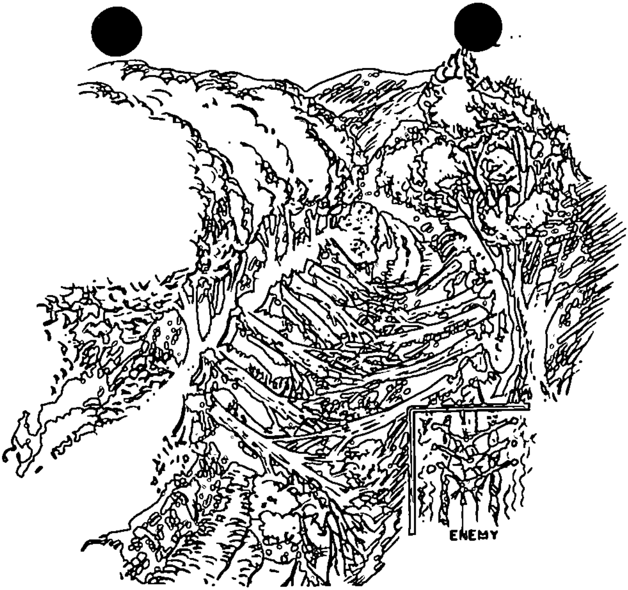


Figure 4–33. Abatis used as a roadblock

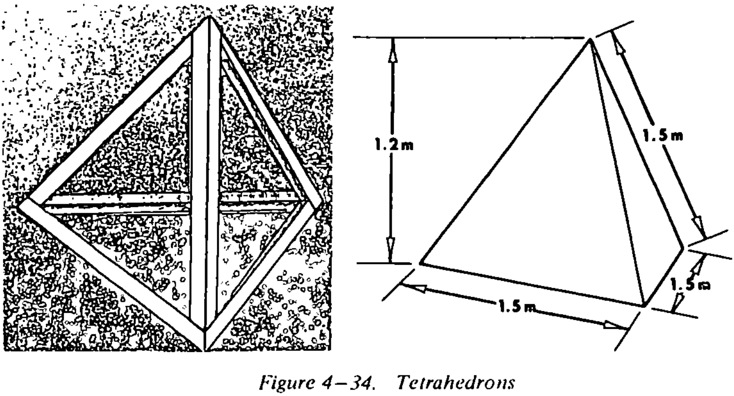


Figure 4–34. Tetrahedrons

CHAPTER 5

MARKING OF BRIDGES AND VEHICLES

Section I. BRIDGES

5–1. MARKING OF BRIDGES

a. Classification.

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

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

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

(4) Width requirements. See table 5–1.

Table 5–1. Bridge Width Requirements – m (ft.).

Bridge class	4–12	13–30	31–60	61–100
One-lane width	2.74 (9)	3.35 (11)	4 (13'2")	4.5 (14'9")
Two-lane width	5.5 (18)	5.5 (18)	7.32 (24)	8.23 (27)

b. Bridge Signs.

(1) For prefabricated bridges and ferries, bridge signs indicate the class number as given in technical manuals. For bridges fixed in place or for nonstandard fixed bridges designed in the field, bridge signs shall indicate the class number as determined by methods shown in chapter 7 or TM 5–312.

(2) All single–lane bridge signs are a minimum of 16 inches in diameter. Multilane and dual class bridge signs are at least 20 inches in diameter. Numerals are black on a yellow background with a black border 1½ inches wide.

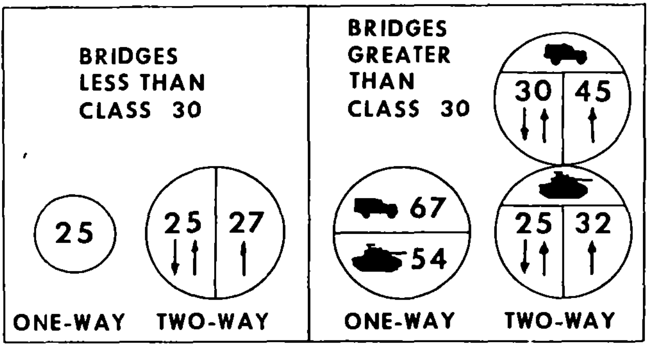


Figure 5–1. Bridge classification signs.

(3) A multilane bridge has a road way wide enough to carry at least two lanes of traffic simultaneously. If each lane has the same class, the signs are the same as for single–lane bridges. If the lanes are of different classes, each lane has a class sign. Two--lane bridges may carry a combination circular sign (fig. 5--1) which gives the normal two–way classification on the left and the computed one–way classification on the right.

(4) Dual classification is used for bridges with a capacity greater than class 30. Two numbers are then shown on the sign; the upper one for wheeled vehicles, the lower one for tracked vehicles (fig. 5–1). Dual class two–lane bridges may be designated by a composite sign indicating both dual class and combination classes (fig. 5–1).

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

(1) A traffic park is set up where vehicles can be halted and dispersed in order to avoid congestion. (fig. 5-2)

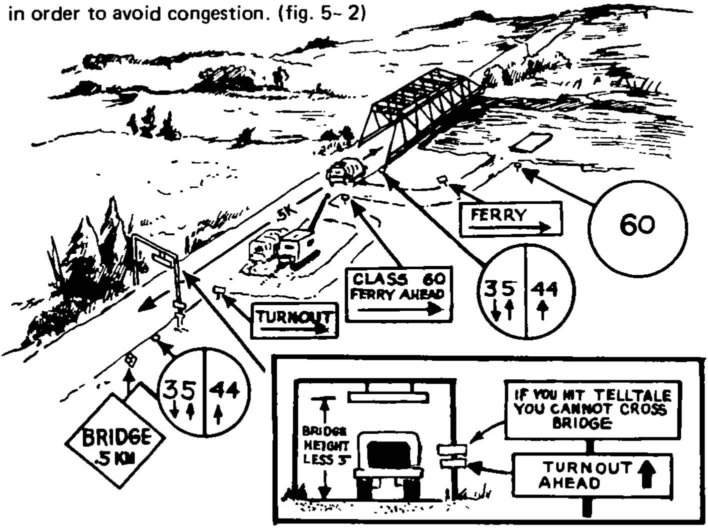


Figure 5-2. Example of telltale, turnout, and sign arrangement for single-lane bridges.

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

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

(4) A normal crossing is defined as one in which the vehicle class number is equal to or less than the bridge classification number, where vehicles maintain 30.5–meter intervals, and where speed is restricted to 40 kph (25 mph). On floating bridge, sudden stopping or acceleration is forbidden.

(5) Special crossings are authorized by the local tactical commander, under exceptional operating conditions in the field. Special crossings permit a vehicle to cross a bridge (or other crossing means) whose class number is less than that of the vehicle. Special crossings are either caution crossings or risk crossings.

(a) In a caution crossing, vehicles with a classification exceeding the capacity of the bridge by 25 percent are allowed to cross under strict traffic control. Caution crossings require that the vehicle remain on the centerline, maintain a 50–meter distance from other vehicles, not exceed 12 kph (8 mph), not stop, not accelerate, and not shift gears on the bridge.

(b) A risk crossing may be made only on standard prefabricated fixed and floating bridges. Risk crossings are made only in the greatest emergencies. The vehicle moves on the centerline, is the only vehicle on the bridge, does not exceed 5 kph (3 mph), does not stop, does not accelerate, and does not shift gears on the bridge. The vehicle class number must not exceed the published risk class for the type bridge being crossed. After the crossing, and before other traffic is permitted, the engineer officer should reinspect the entire bridge for any damage.

Section II. VEHICLES

5–2. MARKING OF VEHICLES

a. Weight Classification. All vehicles with a gross weight over 3 tons and all trailers with rated payload over 1½ tons are assigned classification numbers. These numbers indicate a relationship between the load–carrying capacity of a bridge and the effect produced on it by a vehicle. The effect of the vehicle on the bridge depends upon the gross weight of the vehicle, the weight distribution to the axles, and the speed at which the vehicle crosses the bridge.

b. Vehicle Signs.

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

(2) *Combination Classification* With a combination vehicle (two or more single vehicles spaced less than 30.5m apart), the front sign shows the normal vehicle class for the combination with the letter "C" in red above the class number. Each vehicle in the combination carries a side sign which shows its class as a single vehicle. If one vehicle is towing another, they are considered separate, unless they are both on the same span and the distance between them is less than 30.5m. Combination classes are determined as indicated in paragraph 5–3c below.

5–3. 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 as outlined in TM 5–312 or by reference to FM 5–36 as soon as possible to obtain a permanent classification number.

a. Wheeled Vehicles. Expedient classification for wheeled vehicles may be accomplished by the following methods:

(1) Compare the wheel and axle loadings and spacings of the unclassified vehicle with those of a classified vehicle of similar design and then 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 outlined in STANAG 2021, is required.

b. Tracked Vehicles. Expedient classification for tracked vehicles may be accomplished by the following methods:

(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 is 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 of nonstandard combinations of vehicles may be obtained expeditiously as follows:

Combination class = 0.9 (A + B) if A + B 60

Combination class = A + B if A + B 60

A = Class of first vehicle

B = Class of second vehicle

d. Adjustment for Other Than Rated Load. An expedient class may be given to overloaded or underloaded 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 5–3.

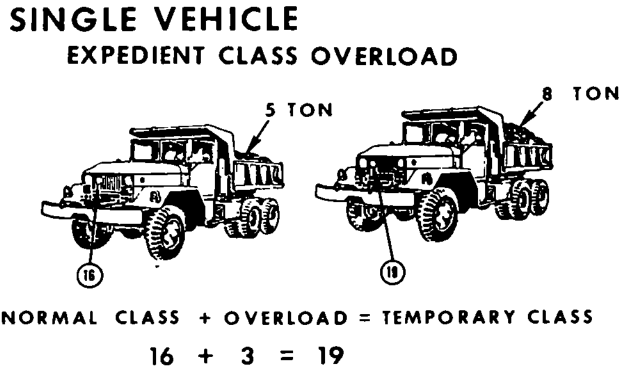


Figure 5–3. Expedient class overload.

CHAPTER 6

FLOATING EQUIPMENT

Section I. BRIDGING AND RAFTING EQUIPMENT

6–1. RIVER CROSSING EQUIPMENT

See tables 6–1 thru 6–11.

6–2. M4T6 DECK BALK DESIGN

See fig. 6–1 and 6–2.

6–3. OPERATING CHARACTERISTICS OF FLOATING EQUIPMENT

See table 6–12.

6–4. HELICOPTER EMPLOYMENT OF FLOAT MATERIAL

See tables 6–13 and 6–14.

Table 6–1 River Crossing Equipment

EQUIPMENT	TRANS-PORTATION	PROPULSION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION		ASSEMBLY TIME	REMARKS
PNEUMATIC ASSAULT BOAT	W/1 2 1/2-TON TRUCK- 20 BOATS W/8 MEN- 1 BOAT	11 PAODLES OR 25-HP OBM	MANUAL, W/ FURNISHED PUMPS (3)	PAODLE-ENGR CREW (3). OBM ENGR CREW (2)	15 MEN W/EDUIPMENT OR 3,375 POUNOS		10 MIN	FULLY LOADEO MAINTAINS HEADWAY BY PADDLES IN 5 fps CURRENT; BY OBM, IN 11 fps CURRENT
ENGINEER RECON BOAT	ONE MAN, BY BACK PACK	PAODLES (3)	MANUAL, W/ FURNISHED PUMPS (3)	PAODLE-ENGR CREW (3)	3 MEN W/EOUIPMENT OR 600 POUNDS		5 MIN	FULLY LOADEO MAINTAINS HEAOWAY IN 4 fps CURRENT
ARMORED PERSONNEL CARRIER	SELF-PROPELLEO	SELF-PROPELLED			12 MEN W/EDUIPMENT			ORGANIC ARMOREO AND MECH INF UNITS
BRIDGE ERECTION BOAT	ONE 2 1/2-TON W/ POLE TRAILER/BOAT	SELF-PROPELLEO (TWO 90 HP MARINE ORIVE ENGINES)			9 MEN W/EDUIPMENT OR 3,000 POUNOS		20 MIN (TRANS-PORTED IN TWO SECTIONS)	PRIMARY USE IS HEAVY FLOATING BRIDGE ASSEMBLE AND RAFT PROPULSION
ALUMINUM FOOTBRIOGE	TWO 2 1/2-TON TRUCKS W/TWO POLE TRAIL-ERS/ SET		BRIDGE		STEAM VELOCITY fps		15 MIN SITE PREPARA-TION + 1 MIN FOR EACH 15 FT OF BRIDGE	ANCHOREO BY EXPEOIENT OVERHEAD CABLE-BRIDLE LINE SYSTEM
					0-8	8-11		
				DAY	75 MEN/ MIN	60 MEN/ MIN		
				MOONLIGHT	40 MEN/ MIN	32 MEN/ MIN		
				BLACKOUT	25 MEN/ MIN	20 MEN/ MIN		
		PADDLED OR OBM	RAFT		1/4 TON + TRAILER 5fps		10 MIN	CONSIDERED EXPEDIENT RAFT

Table 6–1. River Crossing Equipment (cont)

EQUIPMENT	TRANSPORTATION	PROPULSION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION						ASSEMBLY TIME	REMARKS
					STREAM VEL FPS							
					5	7	8	9	10	11		
LIGHT TACTICAL RAFT/BRIDGE	TWO 2 1/2-TON TRUCKS AND ONE POLE	MINIMUM OF TWO 25-HP OBM	RAFTS									
			4 PONTON/3 BAY W/O ARTICU-LATORS	N	12	12	12	8	4	0	30 MIN	33′ LOADING SPACE[4]
				R	14	14	14	12	8	4		
		ONE OUT-BOARD MOTOR PER PONTON IS RECOM-MENDED	4 PONTONS/3 BAY W/O ARTICU-LATORS	N	18	16	12	8	4	0	25 MIN	33′ LOADING SPACE
				R	20	20	16	12	8	4		
			4 PONTON/4 BAY W/ ARTIC-ULATORS	N	10	10	10	6	2	0	35 MIN	44′ LOADING SPACE
				R	12	12	12	10	6	2		
			5 PONTON/5 BAY W/ ARTIC-ULATORS	N	9	9	9	8	5	2	40 MIN	55′ LOADING SPACE
				R	11	11	11	11	9	6		
			5 PONTON/4 BAY W/ ARTIC-ULATORS	N	16	14	11	8	5	2	35 MIN	55′ LOADING SPACE
				R	19	17	15	12	9	6		
			6 PONTON/4 BAY W/ ARTIC-ULATORS	N	13	13	13	13	12	5	45 MIN	44′ LOADING SPACE
				R	15	15	15	15	15	11		
			6 PONTON/4 BAY W/O ARTIC-ULATORS	N	19	19	19	19	12	6	40 MIN	44′ LOADING SPACE
				R	24	24	24	23	17	11		
			6 PONTON/5 BAY W/O ARTIC-ULATORS	N	18	16	16	18	12	6	45 MIN	55′ LOADING SPACE
				R	22	22	22	22	17	11		
			BRIDGE	N	16	13	11	8	5	2	150 FT PER HR.	
				C	18	15	12	9	6	3		
				R	21	17	14	11	8	5		

Table 6–1 River Crossing Equipment (cont)

EQUIPMENT	TRANSPORTATION	PROPULSION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION: STREAM VELOCITY FPS 3	5	7	8	9	11	ASSEMBLY TIME	REMARKS
M4T6 FLOATING BRIDGE RAFT	ONE BRIDGE TRUCK/ 15' OF BRIDGE; 12 BRIDGE TRUCKS/SET WITH ACCESSORIES		NORMAL BRIDGE	N	50/55	45/55	40/50	35/45	30/40	25/30	SEE TABLE 6-8	KEDGE ANCHORS, SHOREGUYS,OR COMBINATION OVERHEAO CABLE BRIOLELINE MAY BE USED FOR ANCHORAGE
				C	60/61	58/59	54/55	49/51	45/47	35/37		
				R	68/69	66/67	62/63	59/60	54/56	43/45		
			REIN–FORCEO BRIDGE	N	75/75	75/75	70/75	65/70	55/60	27/30		
				C	80/80	80/80	79/79	73/73	66/67	43/45		
				R	90/90	90/90	90/90	87/87	81/81	59/60		
	ONE BRIDGE TRUCK/ FLOAT + ONE TRUCK WITH ACCESSORIES	TWO BRIDGE ERECTION BOATS/RAFT	4-FLOAT NORMAL RAFT	N	50/55	50/55	45/50	40/45	35/40	30/35	2 1/4 HR*	51'8" LOADING SPACE[5]
				R	60/65	60/65	55/60	50/55	45/50	35/40		
			4-FLOAT REIN FORCEO RAFT	N	50/55	50/55	50/55	45/50	40/45	35/40	2 1/4 HR	38'4" LOADING SPACE
				R	60/65	60/65	60/65	55/60	50/55	45/50		

Table 6–1 River Crossing Equipment (cont)

EQUIPMENT	TRANSPORTATION	PROPULSION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION: STREAM VELOCITY FPS 3	5	7	8	9	11	ASSEMBLY TIME	REMARKS
			5-FLOAT NORMAL RAFT	N	55/60	55/60	50/55	45/50	40/45	35/40	3 NR	66'8" LOADING SPACE
				R	65/70	65/70	60/65	55/60	50/55	45/50		*ASSEMBLY TIME BASED ON 3 NCO'S & 30 EM
			5 FLOAT REINFORCED RAFT	N	60/65	60/65	60/65	55/60	55/60	45/50	3 NR	50' LOADING SPACE
				R	70/75	70/75	70/75		65/70	55/60		
			6 FLOAT REINFORCED RAFT	N	65/70	65/70	65/70	65/70	60/65	45/50	3 3/4 NR	53'4" LOADING SPACE
				R	75/80	75/80	75/80	75/80	70/75	55/60		
MOBILE ASSAULT BRIDGE – FERRY [7]	SELF-PROPELLED	SELF-PROPELLED	BRIDGE		62	62	55	55			500 FT/HR	NEED ONLY MAB CREW FOR ASSEMBLY
			FERRY 2 END UNITS		36	36	36	36	36	36	6 MIN	* DISTRIBUTED LOADCAP 36 SHORT TONS
			3 UNITS		47	47	47	47	47	47	8 MIN	54 SHORT TONS
			4 UNITS		60/62	60/62	60/62	60/62	60/62	60/62	10 MIN	72 SHORT TONS
			5 UNITS		60/62	60/62	60/62	60/62	60/62	60/62	12 MIN	90 SHORT TONS
			6 UNITS		60/62	60/62	60/62	60/62	60/62	60/62	12 MIN	108 SHORT TONS
					NOTE. MAB CLASS SHOULD BE REDUCED BY 30% IN CURRENT ABOVE 11 FPS.							

EQUIPMENT	TRANSPORTATION	PROPULSION	TYPE ASSEMBLY	TYPE CROSSING	CAPACITY OR CLASSIFICATION — STREAM VELOCITY FPS 3	5	7	8	9	11	ASSEMBLY TIME	REMARKS
RIBBON BRIDGE/ RAFT	1 EA M812 TRANSPORTER WILL ACCOMMODATE EITHER 1 EA. INTERIOR BAY, 1 EA. RAMP BAY, OR 1 EA. 27' BRIDGE ERECTION BOAT		NORMAL BRIDGE	N	85	85	80	80	45	—	5 MIN/BAY	ANCHORAGE MAY BE BY TRANSPORTER OR ERECTION BOATS (TEMPORARY SEE TABLE B—10) OR BY METHODS DESCRIBED FOR CLASS 60 OR M4T6 AS OUTLINED IN CHAPTER 13, TM 5-210 CLASSES GIVEN ARE FOR TRACKED VEHICLES.
				C	70	70	65	65	50	—		
		2 BRIDGE ERECTION BOATS	3-BAY LONGITUDINAL	N	45	45	40	35	30	25	5 MIN/BAY	44' LOAD SPACE
			4-BAY LONGITUDINAL	N	60	60	60	60	55	45		88' LOAD SPACE
			5-BAY LONGITUDINAL	N	70	70	70	70	80	50		88' LOAD SPACE
			3-BAY CONVENTIONAL	N	45	35	15	10	—	—		22' LOAD SPACE
		(*)3 BRIDGE ERECTION BOATS	4-BAY CONVENTIONAL	N	80	60	(*) 40	(*) 30	(*) 15	—		44' LOAD SPACE
			5-BAY CONVENTIONAL	N	70	70	(*) 45	(*) 30	(*) 20	—		66' LOAD SPACE

Table 6–1. River Crossing Equipment (cont)

[1]ALL ASSEMBLY TIMES ARE ESTIMATED USING TRAINED TROOPS, IN GOOD WEATHER, IN DAYLIGHT. FOR UNTRAINED TROOPS ADD 30%; FOR INCLEMENT WEATHER (40°, 80°, RAIN OR SNOW) ADD 30%; FOR BLACKOUT CONDITIONS ADD 50%. ALL PERCENTAGES CALCULATED FROM ORIGINAL TIME. EX. AT NIGHT WITH UNTRAINED TROOPS = 180% OF GIVEN TIME.

[2]ALL ASSEMBLY TIMES EXCLUDE SITE PREPARATION.

[3]CLASSIFICATION WHEELED VEHICLE/TRACKED VEHICLE.

[4]LTR LOADING SPACE MEASURED FROM END OF NEAR SHORE BAY TO END OF FAR SHORE BAY (EXCLUDES RAMP SECTIONS).

[5]M4T6 LOADING SPACE MEASURED FROM NEAR SHORE END STIFFENER TO FAR SHORE END STIFFENER (EXCLUDES END RAMPS).

[6]DISTRIBUTED LOAD CAPACITY IS THE WEIGHT IN SHORT TONS THAT CAN BE CARRIED BY THE RAFT.

[7]CLASSIFICATION OF MAB REFERS TO HEAVIEST VEHICLE WHICH CAN BE LOADED RESTRICTED BY END RAMP CLASSIFICATION.

Table 6–2 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: PONTONS. 42 TREADWAYS: 42	ONE SET TO EACH ENGINEER FLOAT BRIDGE COMPANY (CORPS)	NEAR-SHORE ANCHOR CABLE		6
		FAR-SHORE ANCHOR CABLE	1	7
		BRIDLE LINE		2
		GUY LINE		5
		SHORE ASSEMBLY	1	6
		ASSEMBLY CARRYING		6
		RIVER ASSEMBLY	1	4
		HANDRAIL		3
		PLUS 2 EM PER 100 FT OF BRIDGE		

Table 6–3 Light Tactical Raft Data

BRIDGE SET	BASIS OF ISSUE	SUGGESTED WORKING PARTY		
		DETAIL	NCO	EM
ASSEMBLY AS BRIDGE: 44 FT OF LIGHT VEHICULAR BRIDGE ASSEMBLY AS RAFT: ONE 4-PONTON 4-BAY OR ONE 4-PONTON 3-BAY RAFT	TWO SETS TO EACH DIV ENGR BN. SIX SETS TO CORPS FLOAT BRIDGE COMPANIES.	RAFT OR BRIDGE		
		PONTON CARRYING	1	10
		DECK PANEL CARRYING	1	10*
		PONTON CONNECTING	1	6
		PONTON DELIVERY		2
		DECK PANEL UNLOADING	1	5
		BRIDGE ONLY		
		BRIDGE CONNECTING	1	4
		NEAR SHORE ABUTMENT	1	8
		FAR SHORE ABUTMENT	1	8
		ANCHORAGE SYSTEM	2	12

*SAME PERSONNEL CAN BE USED FOR PONTON AND DECK PANEL CARRYING CREWS.

Table 6–4. M4T6 Raft/Bridge Data

BRIDGE SET	BASIS OF ISSUE	SUGGESTED WORKING PARTY		
		DETAIL	NCO	EM
ONE NORMAL FLOATING BRIDGE, 141 ft 8 IN, OR ONE 4-FLOAT AND 1 5-FLOAT REINFORCED RAFT, OR TWO FLOATING BRIDGES, 75 FT, ONE WITHOUT REINFORCING BALK ON END FLOAT, OR THREE 38-FT 4-IN FIXED SPANS.	DIVISIONAL ENGINEER BN FLOAT BRIDGE CO, 4 SETS. CORPS ENGINEER FLOAT BRIDGE CO, 5 SETS	FLOAT INFLATION	1	8
		SADDLE ASSEMBLY (W/CRANE)	1	8
		SADDLE ASSEMBLY W/O CRANE)	2	20
		ASSEMBLED FLOAT DELIVERY	2	4
		BALK CARRYING	2	40
		BALK PLACING	1	12
		ANCHORAGE *	2	12
		NEAR SHORE ABUTMENT*	1	8
		FAR SHORE ABUTMENT*	1	8
		*NEEDED FOR BRIDGE ONLY		

Table 6–5. M4T6 Bridge Assembly Time

Length (Feet) (Normal Assembly)	Recommended Unit Size	Number of Assembly Sites	Time (Hours)
150	1 Company	2	4
200	"	2	5
250	"	2	6
300	2 Companies	3	4
350	"	3	5
400	"	4	5½
500	"	5	6
600	3 Companies	6	4
700	"	6	5–7
800	"	6	6–8
1000	"	6	7–10
1200	"	6	8–12

NOTE: **See figure 6–1 for deck balk layout pattern.**

Table 6–6 Deck Balk Fixed Span Data

	Capacity For Specified Span Length (Ft) And Deck/Roadway Ratio														
	23'4"	30'0"			38'4"				45'0"						
Type Crossing	22 16	22 18	22 16	24 16	22 16	22 16	24 18	26 16	20 16	22 16	22 16	24 16	24 16	28 18	26 18
Normal	125 100	85 65	90 70	90 70	45 35	50 40	55 45	65 50	24 25	24 25	30 30	30 30	40 35	40 35	45 40
Caution	120 100	100 80	100 80	105 85	70 51	70 51	75 55	62 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 82	90 87	47 40	54 45	54 45	60 49	60 49	66 53	66 53
Component Parts[2]	Number Of Parts Needed For Assembly														
Normal Balk	22	33	33	36	44	44	48	52	60	55	55	60	80	65	65
Short Balk	22	11	11	12	22	22	24	26	10	11	11	12	12	13	13
Tapered Balk[1]	36	47	43	48	36	32	36	36	42	47	43	48	44	49	45
Balk Connecting Stiffener	4	5	5	5	6	8	6	6	7	7	7	7	7	7	7

[1] Figure includes two complete ramps

[2] All complete spans also require 4 bearing plates, 4 long cover plates, and 4 short cover plates

[3] See figure 6–2 for deck balk layout pattern

OVERALL LENGTH*	42'3"
OVERALL WIDTH*	12'
HEIGHT*	12'
WEIGHT (TONS) – INTERIOR BAY	23.25
WEIGHT (TONS) – END BAY	25.80
TURNING RADIUS*	40'
SPEED – LAND TRAVEL	42 MPH
LENGTH – INTERIOR BAY	26'
LENGTH – END BAY	36'
RAMP ARTICULATION ABOVE HORIZONTAL BELOW HORIZONTAL	 ANY 6'3"

*REFERS TO BRIDGE TRANSPORTER

COMPONENTS	215 M (700') OF CLASS 60 BRIDGE OR 6 EA. 7-BAY RAFTS, OR ANY COMBINATION OF 30 INTERIOR BAYS AND 12-RAMP BAYS.
BASIS OF ISSUE	ONE SET TO EACH RIBBON BR CO
ROADWAY WIDTH	4.1 M (13'6") PLUS 2 EA. 1.2 M (4') WALKWAYS
INTERIOR BAY – LENGTH WIDTH WEIGHT	6.7 M (22') 8.1 M (26'6") 4,631 KG (10,210 LBS)
RAMP BAY – LENGTH WIDTH WEIGHT	5.6 M (18'4") 8.1 M (26'6") 4,445 KG (9,800 LBS)
SITE CONSIDERATIONS WATER DEPTH BANK HEIGHT SHORE SLOPE	 ≥ 112 CM (44") ≤ 1.5 M (5') ≤ 20%

Table 6–9 Ribbon Bridge Assembly Data

BRIDGE LENGTH (APPROX)		BRIDGE BAYS		LAUNCHING SITES	BRIDGE ERECTION BOATS	
METERS	FEET	RAMP	INTERIOR	DESIRED	NEEDED	DESIRED
18	58	2	1	2	3	3
24	80	2	2	2	3	4
31	102	2	3	2	4	4
38	124	2	4	2	4	5
45	146	2	5	2	5	5
51	168	2	6	3	5	6
58	190	2	7	3	6	6
65	212	2	8	3	6	7
71	234	2	9	3	6	7
78	256	2	10	3	7	7

NOTES

1. The number of boats shown in "Needed" column is based on an average stream velocity of about 0.91 to 1 5 meters (3 to 5 feet) per second.

2. Stream velocities determine the number of bridge erection boats to be added for a given increase in bridge length (number of interior bays added)

VELOCITY MPS	FPS	INTERIOR BAYS ADDED	BOATS NEEDED
0 to 0.9	0 to 3	Up to 6	1
0.9 to 1.8	3 to 6	Up to 3	1
1.8 to 2.4	6 to 8	Up to 3	1

3. Safety boats are included; backup boats are not included.

Table 6–10 Ribbon Bridge–Bridge Erection Boats Used for Short-Term Anchorage

STREAM VELOCITY		RATIO OF ERECTION BOATS TO INTERIOR BAYS	SPACING BETWEEN BOATS	
MPS	FPS		METERS	FEET
0–.91	0–3	1 6	40	132
.91– 1 8	3–6	1 4	27	88
1 8– 2 4	6–8	1.3	20	66
Over 2.4	Over 8	As required	As required	As required

NOTES

1 Safety and backup boats are not included

2 Add at least two backup boats and one safety boat for each short-term anchorage

Table 6–11. Ribbon Bridge – Typical Crew Duties and Organization

	BRIDGE OR RAFT LENGTH (Number of Bars)																
	3		4		5		7		9		12		15		18		
NCOIC	1		1		1		1		1		1		1		1		SUPERVISES ENTIRE OPERATION
CREW	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	NCO	EM	
MOTOR PARK	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	PREPARES TRANSPORTERS/ BAYS/BOATS FOR LAUNCHING, PARKS TRANSPORTERS AFTER LAUNCH; CONTROLS TRAFFIC IN PARK.
SHUTTLE	0	3	0	4	0	5	0	7	0	9	0	12	0	15	0	18	DRIVES TRANSPORTERS TO LAUNCHING SITES AND LAUNCHES BAYS/BOATS. (SEE NOTE 1.)
LAUNCHING	1	2*	1	2*	1	2*	1	2*	1	3:	1	3:	1	3:	1	3:	ASSISTS IN BAY/BOAT LAUNCHING.
BRIDGE BOAT	1	9	1	9	1	12	1	15	1	18	1	21	1	24	1	27	OPERATES BRIDGE ERECTION BOATS WITH THREE MEN ASSIGNED TO EACH BOAT TO SECURE BAYS AND ASSISTS IN THE ASSEMBLY AND DISASSEMBLY OF BRIDGE OR RAFT. (SEE NOTE 2.)
ANCHORAGE	2	12	2	12	2	12	2	12	2	12	2	12	2	12	2	12	INSTALLS ANCHOR CABLES, BRIDLE LINES, ANCHOR TOWERS, DEADMEN, AND SHORE GUYS.
BRIDGE CENTER LINE/RAFT ASSY SITE	1	4	1	4	1	4	1	4	1	4	1	4	1	4	1	4	CONNECTS BAYS, PREPARES BRIDGE FOR TRAFFIC, DIRECTS USE OF TRANSPORTERS WHEN USED FOR BRIDGE CLOSURE OR ANCHORAGE (SEE NOTE 3.)
TOTAL	6	33	6	34	6	38	6	43	6	49	6	55	6	61	6	67	

NOTES:

1. DURING LAUNCHING AND RETRIEVING OPERATIONS, AN ASSISTANT OPERATOR IS ASSIGNED TO EACH TRANSPORTER.
2. DOES NOT INCLUDE PERSONNEL FOR SAFETY BOATS OR BACKUP BOATS.
3. EM MAY BE INCREASED TO SIX, DEPENDING ON LENGTH OF BRIDGE AND VELOCITY OF STREAM.

* TWO LAUNCHING SITES.

: THREE LAUNCHING SITES

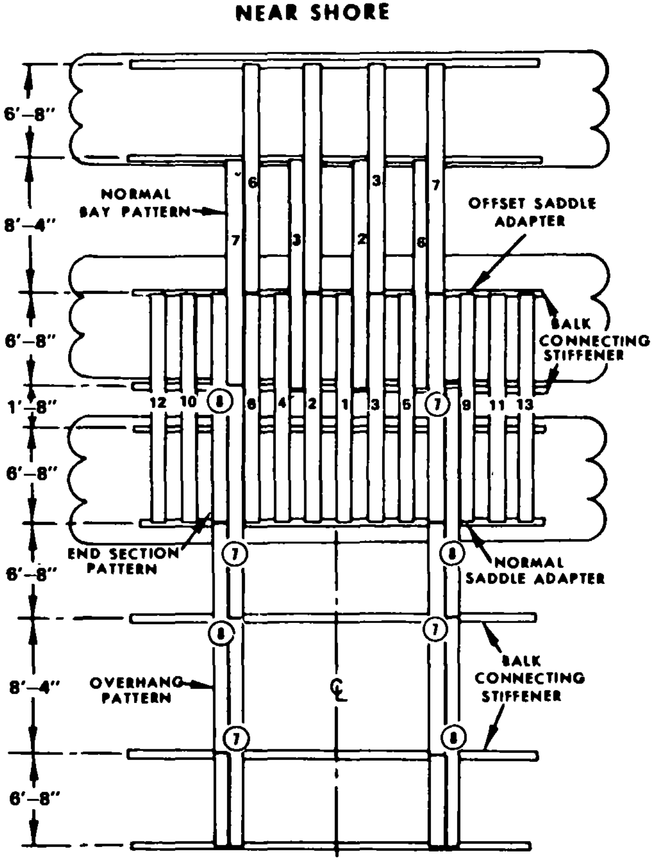
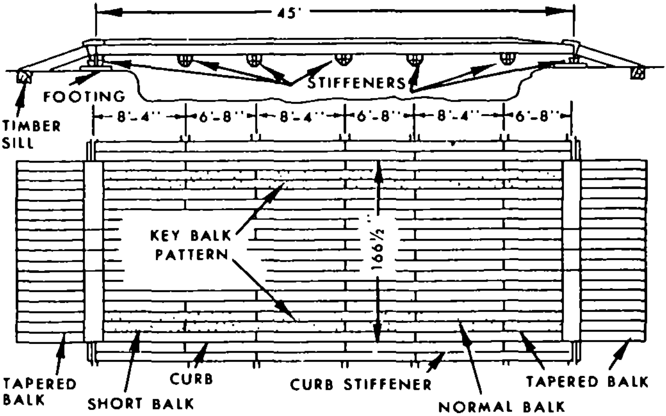
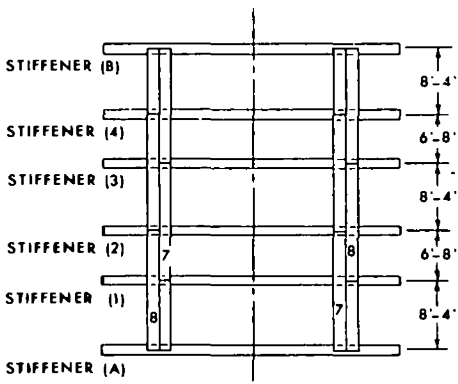


Figure 6–1. Balk pattern, M4T6 floating bridge.



① LAYOUT



② H - FRAME FOR BALK FIXED SPAN

Figure 6–2 Layout of deck balk fixed bridges

Table 6–12. Round–Trip Travel Times

Equipment	Time in Min Per Round Trip		
	Stream Width in Feet		
	250	500	1000
Pneumatic assault Boat – Paddled	4	6	10
Pneumatic assault Boat – Outboard Motors	–	4	5
Ribbon Bridge/Raft	7	10	15
*M4T6/LTR	7	10	15
*Mobile assault bridge	7	10	15

*No. of rafts that can be used efficiently at ona tima = 250' – 1, 500' – 2, 1000' – 3.

Table 6–13. Helicopter Capabilities

Halicopter Capability		
Type Helicopter	Operational Load[1]	Maximum Load[2]
UH-1	3,116	4,000
CH-47	10,144	16,000
CH-54	15,400	20,760

[1] Operational load is the amount that can be carried with a full fuel load on a standard day at sea level.

[2] Maximum load is the amount that can be lifted without structurally damaging the helicopter.

Table 6–14. Typical Loads and Helicopter Requirements

Item of Equipment	Weight (lbs)	Recommended Carrier
M4T6 FIXED SPANS		
23'4" H-Frame	2,800	UH-1
30' H-Frame	3,700	CH-47
38'4" H-Frame	4,500	CH-47
45' H-Frame	5,100	CH-47
23'4" Fixed Span Complete[1]	12,900	CH-54
30' Fixed Span Complete[1] (Load No. 48)[2]	15,600	CH-54
38'4" Fixed Span Complete[1] (Load No. 49)[2]	18,800	CH-54
45' Fixed Span Complete[1]	20,900	CH-54
Single Trestle w/Bracing	3,400	UH-1
15' Trestle Arrangement		
w/22 Normal Balk (Load No. 57)[2]	11,800	CH-54
w/11 Normal Balk	8,100	CH-47
8'4" Trestle Arrangement		
w/22 Short Balk	9,500	CH-47
w/11 Short Balk	8,000	CH-47
HEAVY FLOATING BRIDGE EQUIPMENT		
27' Bridges Erection Boat (Load No. 61)[2]	6,800	CH-47
Bow Section	1,150	
Stern Section		
w/Fuel + Water	5,650	CH-47
w/o Fuel + Water	4,900	CH-47
Aluminum Balk		
Light Bundle (35 Normal Balk) (Load No. 51)[2]	7,900	CH-47
Heavy Bundle (63 Normal Balk) (Load No. 52)[2]	14,200	CH-54
Normal Balk (ea)	225	
Short Balk (ea)	122	
Tapered Balk (ea)	100	

Table 6–14. Typical Loads and Helicopter Requirements (cont)

Item of Equipment	Weight (lbs)	Recommended Carrier
M4T6 Float w/Saddle Assembly and Stiffeners (Load No. 53) [2]	6,700	CH-47
M4T6 Float w/Saddle Assembly, Stiffeners and 22 Normal Balk (Load No. 53) [2]	11,700	CH-54
Two M4T6 Floats w/Saddle Assemblies, Stiffeners, and 10 Normal Balk (Load Nos. 55, 56) [2]	16,900	CH-54
LIGHT FLOATING BRIDGE EQUIPMENT		
Light Tactical Raft		
Ponton Load (8 Half Pontons w/Cradle) (Load No. 58) [2]	6,000	CH-47
Deck Load (4 Bays Complete w/Articulators (Load No. 60) [2]	10,500	CH-47
Aluminum Footbridge		
One Set (472'6") Crated	11,000	CH-54
One Set (472'6") Uncrated	9,100	CH-47
Pneumatic Assault Boat	250	
RIBBON BRIDGE/RAFT		
Interior Bay	10,210	CH-47
Ramp Bay	9,800	CH-47

1 Information refers to 22/18 fixed span including 36 tapered balk for ramps and 4 bearing plates

Load No. refers to loads described in TM 55–450–11 "Helicopter External Loads"

Section II. ANCHORAGE SYSTEMS

6–5. BASIC CONSIDERATIONS

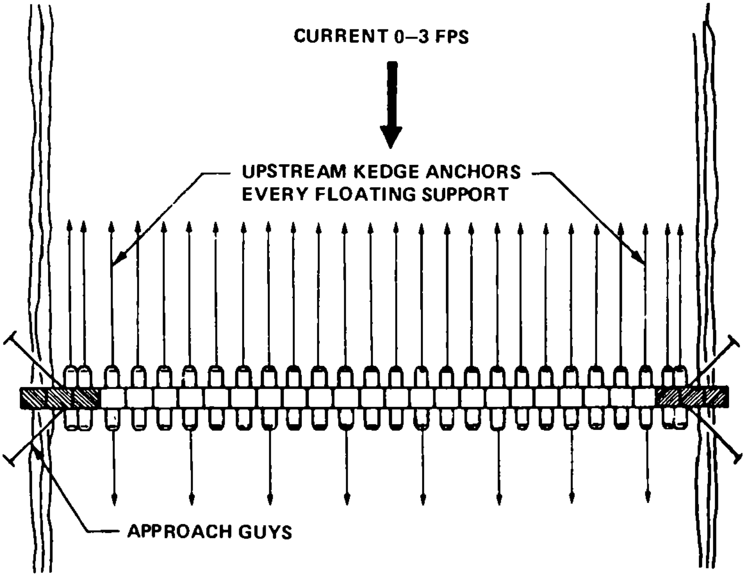
Anchorage must be provided on float bridges to secure the bridges and keep them alined. The selection of an anchorage system is influenced by the width of the river, its current, stage variation, debris flow, the river bed, embankments, and resources available. The anchorage system is designed to withstand the worst conditions anticipated. The basic anchorage systems used are shore guys, kedge anchors, a combination of both, and overhead cable–bridle line systems. The strongest standard method of anchoring a floating bridge is the overhead cable–bridle system supplemented by shore guys. When combinations of anchorage systems are used, the load cannot be divided between systems – one must supplement the other.

6–6. TYPES OF ANCHORAGE SYSTEMS

See fig. 6–3 thru 6–7 and table 6–15.

6–7. OVERHEAD CABLE–BRIDLE LINE SYSTEM DESIGN

a Anchor Cable Layout (fig. 6–8).



DOWNSTREAM KEDGE ANCHORS EVERY 3RD FLOATING SUPPORT.

EVERY FLOATING SUPPORT WITH REVERSAL CURRENT FROM 0 TO 3FPS

Figure 6–3 Location of kedge anchors

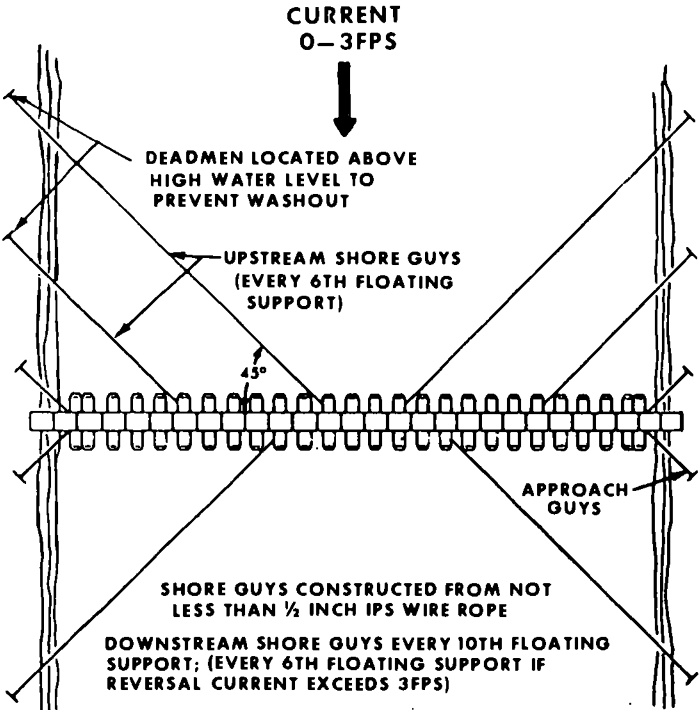


Figure 6–4 Location of shore guys.

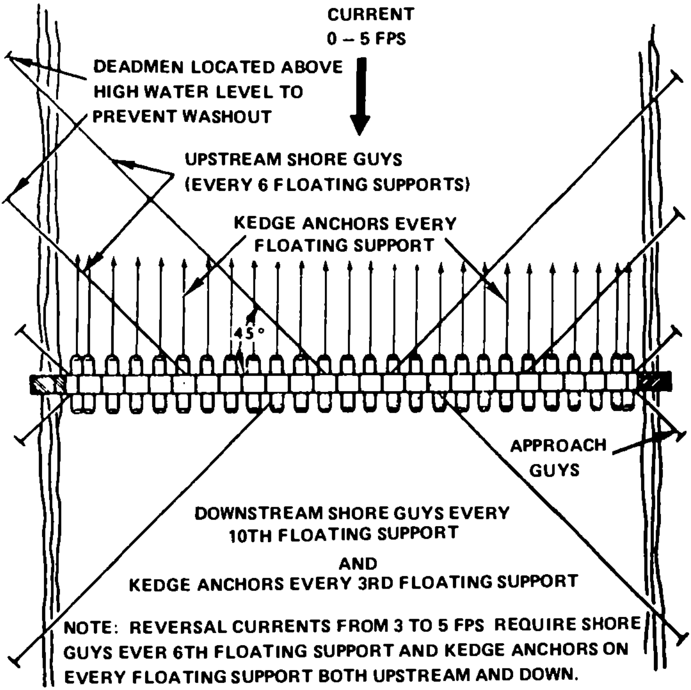
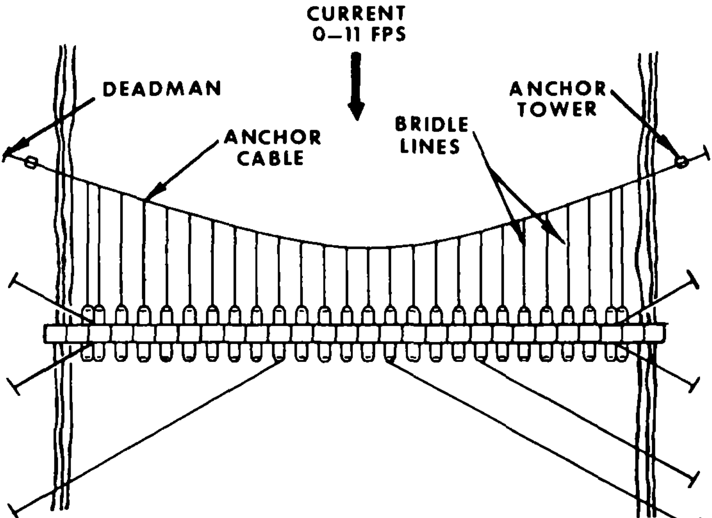


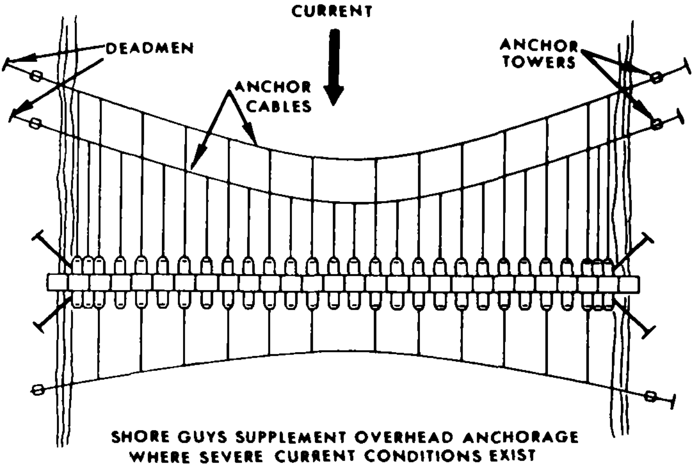
Figure 6–5 Employment of combination system.



NOTE: EITHER SHORE GUYS (EVERY 10th SUPPORT) OR KEDGE ANCHORS (EVERY 3rd SUPPORT) MUST BE USED DOWNSTREAM.

NOTE: REVERSAL CURRENT MAY REOUIRE FULL ANCHORAGE DOWNSTREAM. SHORE GUYS, KEDGE ANCHORS, COMBINATION, OR SECOND CABLE BRIDLE LINE SYSTEM MAY BE USED, DEPENDING ON STRENGTH OF REVERSAL CURRENT.

Figure 6–6. Single upstream overhead cable—bridle line system.



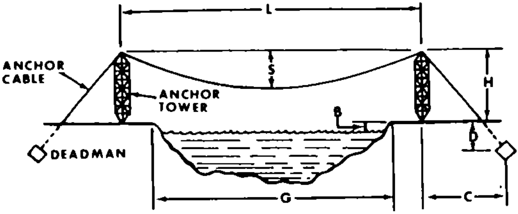
NOTE MULTIPLE CABLES CAN ALSO BE PLACED ON SINGLE SET OF TOWERS. USE OF MORE THAN ONE OVERHEAD CABLE (TABLE 6–16) A DOWNSTREAM ANCHOR CABLE MAY BE NEEDED IF A TIDAL ACTION EXISTS IN A RIVER THE CALCULATIONS FOR A DOUBLE OR TRIPLE OVERHEAD CABLE SYSTEM ARE THE SAME AS FOR A SINGLE CABLE SYSTEM

Figure 6–7. Floating bridge with multiple overhead cable system and downstream overhead cable anchorage

Table 6–15. Anchorage Systems/Characteristics

Type	Capacity	Remarks
Kedge Anchors	0–3 fps	Anchor line must be a minimum of 10 times the depth of the water; 20 times depth is desirable. River bed must permit anchor flukes to dig in. See figure 6–3.
Shore Guys	0–3 fps	Guys attached at 45° angle. Shore anchorage point needed for guy lines (soil must hold dead-man). See figure 6–4.
Combination Kedge & Shore Guys	0–5 fps	See remarks for separate systems. See figure 6–5.
Overhead Cable-Bridle Line	0–11fps	See para 6–7 for design. 1200 ft maximum unsupported cable length. See figure 6–6.

NOTE All anchorage systems require approach guys to the floating supports nearest the shores.



(1) ANCHOR CABLE—ELEVATION LAYOUT

KEY TO SYMBOLS·

B = MEAN BANK HEIGHT
C = DISTANCE TOWER TO DEADMAN ON CENTERLINE
D = DEPTH OF DEADMAN
G = LENGTH OF BRIDGE
H = ANCHOR TOWER HEIGTH
L = DISTANCE BETWEEN TOWER ANCHOR
O^1 = OFFSET BRIDGE CENTERLINE TO ANCHOR TOWER CENTERLINE
O^2 = OFFSET ANCHOR TOWER CENTERLINE TO DEADMAN
S = UNSTRESSED SAG IN ANCHOR CABLE
R = GROUND BEARING STRENGTH IN POUNDS PER SOUARE FOOT
T = CABLE TENSION IN POUNDS

(2) ANCHOR CABLE—BRIDLE LINE LAYOUT PLAN

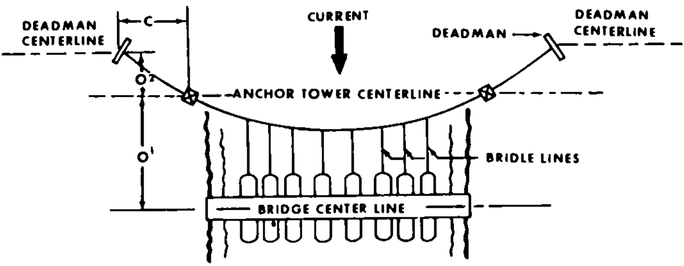


Figure 6–8. Overhead cable–bridle line anchorage system.

b. Anchor Cable Design.

(1) Determine the size and number of anchorage cables that are required (tables 6–16 thru 6–18). Round up to the next higher value for bridge span (G) shown in table 6–16. Using known current or next higher stream velocity, select the cable size for the minimum number of cables.

(2) Determine the distance between towers (L). Place the towers the same distance from each bank.

Rule of Thumb (R of T); L = (1.1 x gap) + 100′

(3) Determine cable sag in feet (S) (fig. 6–8 and 6–9).

R of T; S = 0.02L

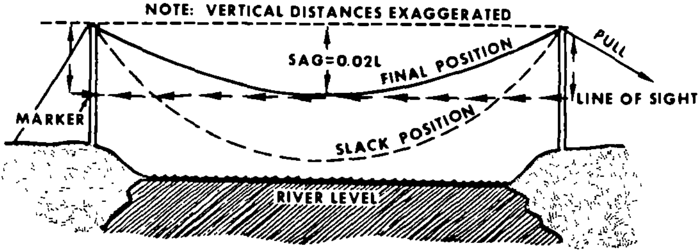


Figure 6–9. Cable sag.

(4) Determine required height of tower (H), when sag (S) and bank height (B) are known.

R of T: H = 3′ + S – B (Minimum allowable H)

Note: Actual height of tower (H) will be the next higher size shown in table 6–19.

(5) Determine the distance from the bridge centerline to the anchor tower centerline (0_1).

R of T

(a) If bank height (B) is less than 15′; 0_1 = H + 50′

(b) If (B) is greater than 15′; 0_1 = H + B + 35′

Table 6–16 Anchor Cable Requirements for Overhead Cable-Bridle Line System – M4T6 Bridge

Bridge Span (G) (ft)	Type Bridge Assembly*	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	Normal	1/2	3/8	3/8	5/8	1/2	1/2	3/4	5/8	1/2	7/8	3/4	5/8
	Reinforced	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	Normal	5/8	1/2	1/2	3/4	5/8	1/2	1	7/8	5/8	1 1/4	1	3/4
	Reinforced	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	Normal	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
	Reinforced	1	3/4	5/8	1 1/8	1	3/4	1 1/2	1 1/4	7/8		1 1/2	1 1/8
800	Normal	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
	Reinforced	1 1/8	7/8	3/4	1 3/8	1 1/8	7/8	***	1 3/8	1	**	**	1 1/4

Table 6–16. Anchor Cable Requirements for Overhead Cable-Bridle Line System – M4T6 Bridge (cont)

BRIDGE SPAN (G) (ft)	TYPE BRIDGE ASSEMBLY	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
1000	NORMAL	1	7/8	3/4	1 1/4	1	7/8	1 1/2	1 3/8	1	**	**	1 1/4
	REINFORCED	1 1/4	1	3/4	1 1/2	1 1/4	1	**	**	1 1/8	**	**	1 3/8
1200	NORMAL	1 1/8	7/8	3/4	1 3/8	1 1/8	7/8	**	1 1/2	1 1/8	**	**	1 3/8
	REINFORCED	1 3/8	1 1/8	7/8	**	1 3/8	1	**		1 1/4	**	**	**

NOTE:

* BASED UPON IMPROVED PLOW STEEL CABLE AND 2 PERCENT INITIAL CABLE SAG.

** UNSAFE. BASED ON CABLE SPAN EQUAL TO 1.1 TIMES WET GAP PLUS 100 FEET.

*** CLASS 60 ANCHORAGE REQUIREMENTS ARE THE SAME AS M4T6. ROUND UP TO NEXT HIGHER BRIDGE SPAN.

Table 6–17. Anchor Cable Requirements – Light Tactical Bridge

Span in feet (Wet gap)	Maximum stream velocity (fps)			
	5	7	9	11
200	3/8	3/8	1/2	1/2
300	3/8	1/2	5/8	3/4
400	1/2	1/2	5/8	3/4
500	1/2	5/8	5/8	3/4
600	5/8	5/8	3/4	7/8

Table 6–18. Anchor Cable Requirements – Aluminum Footbridge

CURRENT VELOCITY	TYPE ANCHORAGE	WHERE ATTACHED TO BRIDGE
STILL WATER	GUY LINE	MIOOLE OF TREAOWAY STRINGER OF EVERY 3d BAY ON BOTH SIDES OF BRIOGE
STILL WATER	ANCHOR CABLE W/BRIDLE LINES	THROUGH THE BOW OF THE PONTON TO THE TREAOWAY STRINGER OF EVERY 3d BAY ON BOTH SIOES OF THE BRIOGE
3 fps OR LESS	ANCHOR CABLE W/BRIOLE LINES	THROUGH THE BOW OF THE PONTON TO THE TREAOWAY STRINGER OF EVERY 2d BAY ON UPSTREAM SIDE.
4 THROUGH 11 fps	ANCHOR CABLE W/BRIOLE LINES	THROUGH THE BOW OF THE PONTON TO THE TREAOWAY STRINGER OF EVERY BAY ON THE UPSTREAM SIOE

Table 6–19. 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

Note Minimum of 3 ft 8¼ in can be used as tower height.

c. Deadman

(1) *Depth of deadman (D).* The deadman should be buried as deep as necessary for good bearing surface against undisturbed soil. R of T; D = 7′ or 1′ less than the depth of the water table – whichever is less. Minimum (D) = 3′. (D) is measured from the ground level to the mean depth of timber. See figures 6- 10 and 6–11. (Always maintain at least 1 foot of undisturbed soil between the bottom of the deadman and the ground water level.)

(2) *Tower to deadman distance* Determine tower to deadman distance (C) and deadman offset (0_2). See figure 6–8.

(a) Select the approximate position for the deadman based upon site conditions.

(b) $C = \frac{(H + D)}{\text{Slope Ratio}}$: Minimum permissible value for C is H + D (slope ratio of 1/1). Try to let $C = \frac{(H + D)}{1/4}$.

(c) Read required value of 0 from table 6–20 (0_{2I}) for C used. The actual value of 0_2 (0_{2A}) for a calculated value of C can be computed using the following formula:

$0_{2A} = \frac{C}{100} \times 0_{2I}$ (0_{2I} read from table 6–20).

Table 6–20. Values of 0_2 Per Hundred Feet of C

Current velocities		
Normal assembly	Reinforced assembly	Offset upstream (0_{2l}) in feet per hundred feet of C
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

NOTE: Use current velocity known or next higher current to determine 0_2.

(3) *Determine deadman size.* Determine lumber available and check length (L), thickness (t), and face height (f) or (d) of available timber. Use the largest dimension of the deadman timber for bearing and refer to it as the face height (f). The face height for a log deadman is its diameter (d) (fig. 6–10 thru 6–12).

(a) Enter nomograph "A" (fig. 6–13) at Column A with D and slope ratio (1/4).

(b) Locate cable diameter and type on Column B. Connect the points from Column A to Column B and extend the line to Column C.

(c) Extend the line horizontally to the face height curve and read the deadman length and thickness from the top and/or bottom of the graph.

(4) *Bearing plate design.*

(a) Flat bearing plate. Enter nomograph "B" (fig. 6–14) with size and cable type. From the deadman face height curve, determine the bearing plate height, thickness, and length.

(b) Formed bearing plate. Enter nomograph "C" (fig. 6–15) with size and cable type. From the deadman face height curve determine the bearing plate thickness and length.

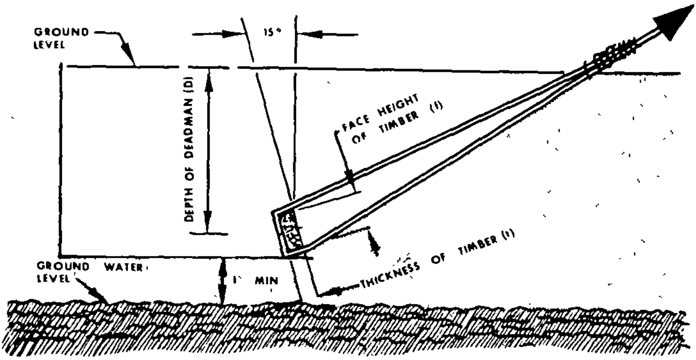


Figure 6–10 Timber deadman.

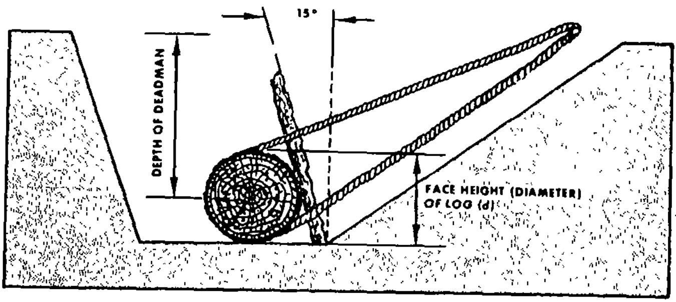
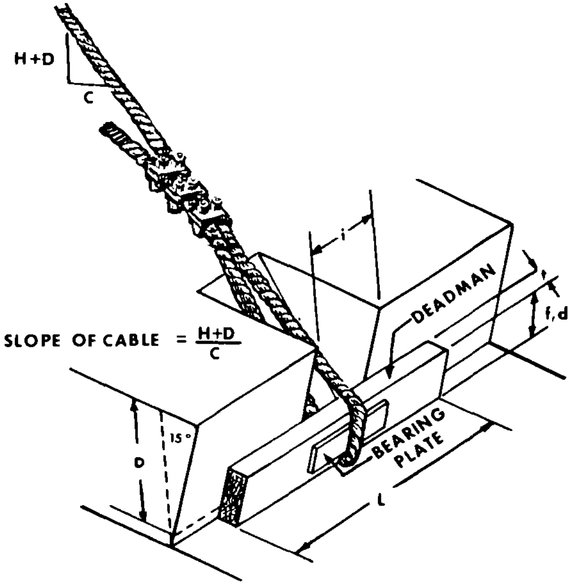
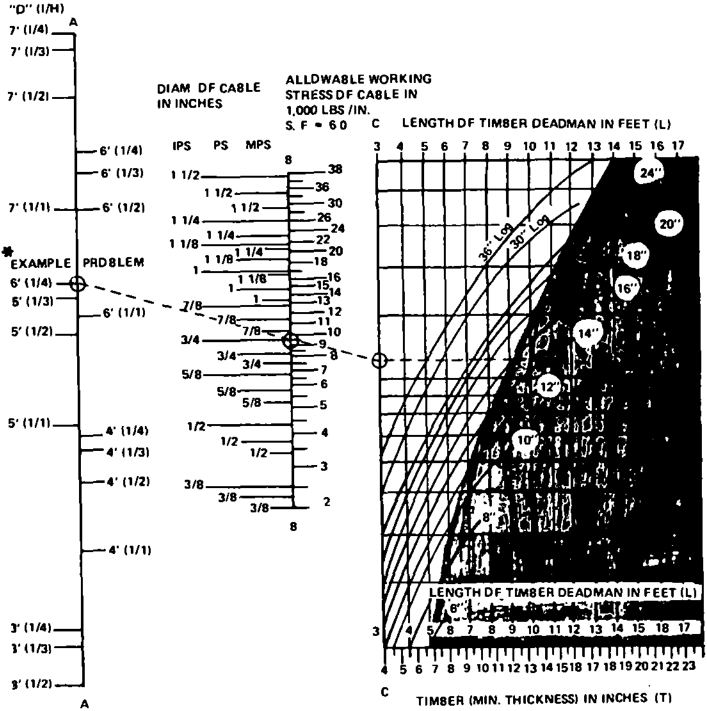


Figure 6–11. Log deadman.



KEY:
- D = MEAN DEPTH OF DEADMAN
- L = LENGTH OF DEADMAN
- f = FACE HEIGHT OF (TIMBER)
- d = DIAMETER FACE HEIGHT 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

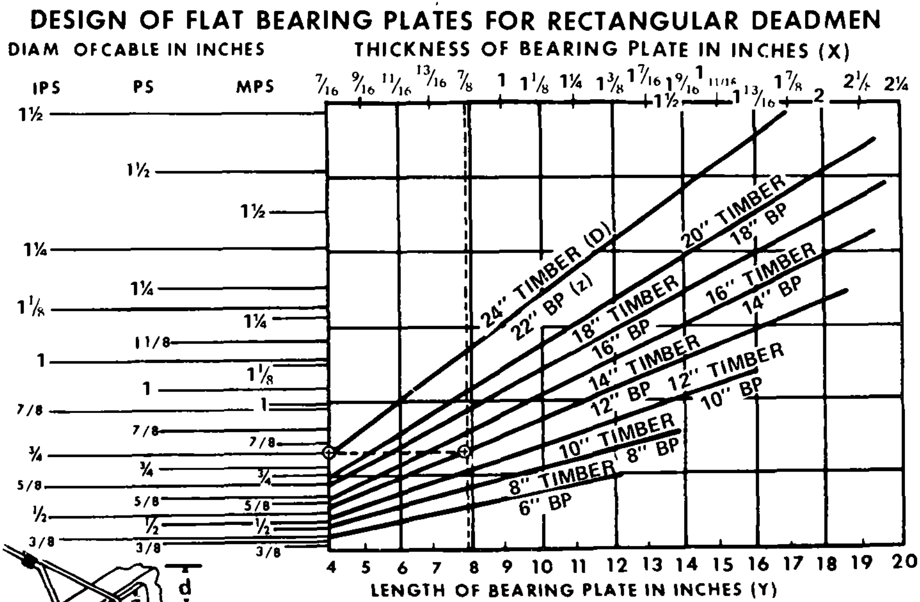
Figure 6–12. Deadman dimensions.

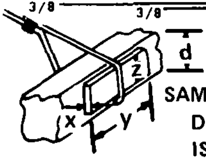


NOTE CARE MUST BE TAKEN NOT TO SELECT A LOG DEADMAN IN THE DARKENED AREA BECAUSE IN THIS AREA THE LOG WILL FAIL IN BENDING

* IN THE ABOVE EXAMPLE PROBLEM THE DEADMAN DEPTH IS 5 FEET. THE SLOPE RATION IS 1:4 AND THE CABLE IS 3/4 INCH IPS A 14-INCH TIMBER IS USED WITH A 14 FOOT LENGTH AND 10 1/2-INCH THICKNESS

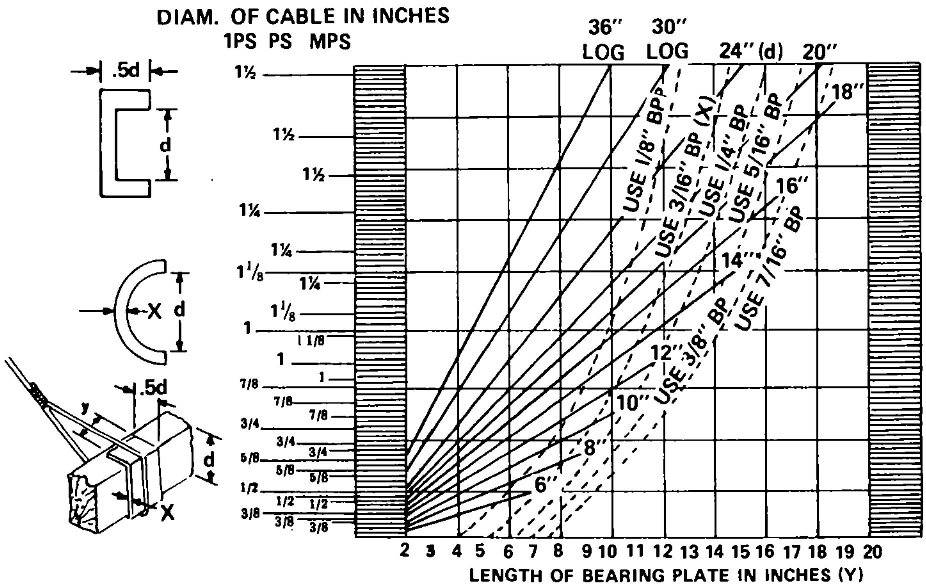
Figure 6-13 Nomograph "A."





SAMPLE PROBLEM: ENTERING THE GRAPH AT ¾" IPS CABLE WITH A 14" DEADMAN IT SHOWS THAT A ⅞" THICK AND 8" LONG BEARING PLATE IS REQUIRED.

Figure 6–14 Nomograph "B."



NOTE: THICKNESS OF BEARING PLATE IS DETERMINED BY FIRST CURVE TO THE RIGHT OF CABLE SIZE/DEADMAN HEIGHT INTERSECT

Figure 6–15. Nomograph "C"

CHAPTER 7

FIXED BRIDGES

Section I. NONSTANDARD BRIDGE DESIGN

7-1. NOMENCLATURE

a. Superstructure. The load-carrying component of the superstructure is the stringer system, which may be rectangular timber, round timber, or steel beams (figs. 7—1 and 7-2).

b. Substructure. Intermediate supports for the superstructure may be timber bents, timber piers, pile bents, or pile piers, or a combination of these supports (fig. 7—1).

7-2. 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 (in)
b_{cap} = Width of cap (in)
b_{sill} = Width of sill (in)
B_{PL} = Width of bearing plate (in)
d = Total depth of stringer (in)
d_c = Depth of corbel (in)
d_{cap} = Depth of cap (in)
D_p = Diameter of pile (in)
H = Height of timber bent post (ft)
H_p = Distance from fixed point to point of lowest bracing
H_m = Max height of post (ft)

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 span (kip–ft)

M_{LL} = Live load bending moment per lane (kip–ft)

m = Total bending moment per stringer (kip–ft)

M_c = Total moment acting on the corbels

m_{DL} = Dead load bending moment per stringer (kip–ft)

m_{LL} = Live load bending moment per stringer (kip–ft)

N_b = Number of braces

N_c = Number of corbels

N_L = Number of lanes

N_p = Number of posts or piles

N_{pr} = Theoretical number of piles required

N_s = Number of stringers

N_1 = Effective number of stringers per lane

N_2 = Effective number of stringers per lane for a 2–lane bridge

$\emptyset$ = Diameter of pile (in)

P_b = Capacity per pile based on end–bearing support

P_f = Capacity per pile for friction support

P_T = Total design load on substructure (kips)

S_b = Maximum spacing of bracing (ft)

S_x = Center to center spacing of component "x" (ft)

t_{PL} = Thickness of bearing plate (in)

V_c = Total shear acting on the corbels
v_c = Shear capacity of one corbel
V_{DL} = Dead load shear for entire span (kips)
V_{LL} = Live load shear per lane (kips)
v_{LL} = 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)
W_S = Width of concrete slab (ft)

ROUND OFF RULE: Round the value down to the nearest whole number if the decimal is 0.09 or less, otherwise round up. Use this rule throughout where noted with an asterisk (*).

7–3. SUPERSTRUCTURE DESIGN (Timber and Steel Stringers)

a. Stringer Selection and Design.

(1) Step 1: Determine the maximum span length, L_m, of the stringers available from table 7–1 or table 7–2. Choose only those stringers with an L_m value ≥ the span length.

NOTE: Designs computed in this chapter are not conservative.

(2) Step 2: Determine the number of required stringers:

$$* \; N_s = \frac{W_R}{6} + 1 \qquad \text{(Minimum } N_s = 4\text{)}$$

Determine the center-to-center stringer spacing:

$$S_s = \frac{W_R}{N_s - 1} \qquad \text{(Do not round off)}$$

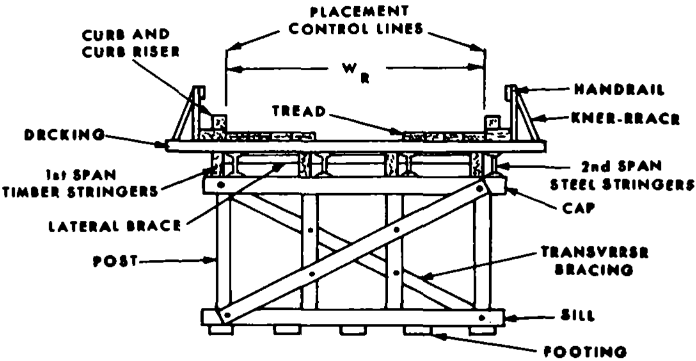


Figure 7–1. Timber trestle bridge.

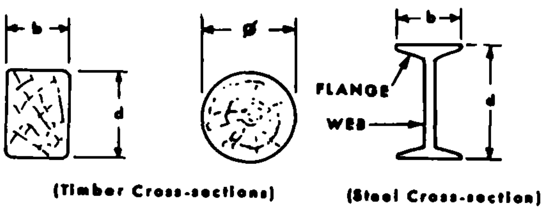


Figure 7–2. Stringer dimensions.

Table 7–1. Properties of Timber Stringers

ACTUAL SIZE (b x d) (in)	(a) MOMENT CAPACITY m (kip ft)	(b) SHEAR CAPACITY v (kips)	(c) MAXIMUM SPAN LENGTH (L_m) (ft)	ACTUAL SIZE (b x d) (in)	(a) MOMENT CAPACITY m (kip-ft)	(b) SHEAR CAPACITY v (kips)	(c) MAXIMUM SPAN LENGTH (L_m) (ft)
4 x 8	8 53	3.2	9.5	12 x 20	160.0	24.0	23 8
* 4 x 10	13 33	4.0	11.9	12 x 22	193.6	26.4	26.2
* 4 x 12	19 20	4.8	14.3	12 x 24	230	28 8	28.6
6 x 8	12 80	4 8	9 5	14 x 14	91.5	19.6	16 7
8 x 10	20 0	6.0	11.9	14 x 16	119.5	22.4	18.1
6 x 12	28.8	7 2	14.3	14 x 18	151 2	25.2	21.5
* 6 x 14	39 2	8.4	16.7	14 x 20	186 7	28.0	23.8
* 6 x 16	51 2	9 6	19.1	14 x 22	226	30 8	26.2
* 6 x 18	64.8	10 8	21 5	14 x 24	269	33 6	28.8
8 x 8	17 07	6 4	9 5	16 x 16	136.5	25 6	19 1
8 x 10	26 7	8 0	11.9	16 x 18	172.8	28.8	21.5
8 x 12	38 4	9.6	14.3	16 x 20	213	32 0	23 8
8 x 14	52 3	11.2	16.7	16 x 22	258	35 2	28.2
8 x 16	68.3	12.8	19.1	16 x 24	307	38.4	28.6
* 8 x 18	86.4	14.4	21.5	18 x 18	194.4	32.4	21.5
* 8 x 20	106 7	16.4	23.8	18 x 20	240	36 0	23.8
* 8 x 22	129.1	17.6	26 2	18 x 22	290	39 6	26.2
* 8 x 24	153.6	19.2	28 6	18 x 24	346	43.2	28 6
10 x 10	33.3	10 0	11.9	8φ	10.05	5 7	9.5
10 x 12	48 0	12.0	14 3	9φ	14 31	7 2	10.7
10 x 14	65 3	14.0	16.7	10φ	19.63	8.8	11.9
10 x 16	85 3	16 0	19.1	11φ	26 1	10.6	13.1
10 x 18	108.0	18.0	21.5	12φ	33.9	12.7	14.3
10 x 20	133 3	20.0	23.8	13φ	43.1	15.0	15.5
*10 x 22	161 3	22.0	26.2	14φ	53 9	17 4	16.7
*10 x 24	192 0	24.0	28.6	16φ	80 4	22 6	19.1
12 x 12	57 6	14.4	14.3	18φ	114.5	28.6	21.5

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 ROUND STRINGER NOT LISTED, $m = .02d^3$
- (b) FOR RECTANGULAR STRINGER NOT LISTED, $v = \frac{bd}{10}$ FOR ROUND STRINGER NOT LISTED, $v = .09d^2$
- (c) FOR STRINGER NOT LISTED, $L_m = 1.19d$

Table 7–2. Properties of Steel Stringers

NOMINAL SIZE	ACTUAL DEPTH (d) (in)	ACTUAL WIDTH (b) (in)	FLANGE THICKNESS (t_f) (in)	WEB THICKNESS (t_w) (in)	MOMENT CAPACITY m (kip-ft)	MOMENT 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	2488	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 1/16	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 3/8	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

Table 7–2. Properties of Steel Stringers (Con't)

NOMINAL SIZE	ACTUAL DEPTH (d) (in)	ACTUAL WIDTH (b) (in)	FLANGE THICKNESS (t_f) (in)	WEB THICKNESS (t_w) (in)	MOMENT CAPACITY m (kip-ft)	MOMENT CAPACITY v (kips)	MAX SPAN LENGTH (L_m) (ft)	MAX BRACING SPACING (S_b) (ft)
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	81	13
24I120	24	8	1 1/8	1 3/16	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 5/8	8 1/2	1 1/4	13/16	634	283	60	15
*22I75	22	7	13/18	1/2	308	168	56	8.5
*21WF39	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	15/16	11/16	337	195	51	11
*20I65	20	6 1/2	13/16	7/16	245	132	51	9
*20WF134	19 5/8	11 3/4	1 3/16	5/8	621	177	50	23 5
18WF60	18 1/4	7 1/2	11/16	11/16	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	15/16	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

Table 7–2. Properties of Steel Stringers (Con't)

NOMINAL SIZE	ACTUAL DEPTH (d) (in)	ACTUAL WIDTH (b) (in)	FLANGE THICKNESS (t_f) (in)	WEB THICKNESS (t_w) (in)	MOMENT CAPACITY m (kips-ft)	MOMENT CAPACITY v (kips)	MAX SPAN LENGTH (L_m) (ft)	MAX BRACING SPACING (S_b) (ft)
*18162	17 3/4	6 7/6	3/4	3/8	238	100	45	6 5
*18177	17 3/4	6 5/6	15/16	5/8	261	163	45	11.6
16WF112	16 3/4	11 3/4	1	6/15	450	138	42	23.5
*16170	16 3/4	6 1/2	15/16	5/8	238	146	42	12
16WF50	16 1/4	7 1/6	5/8	3/8	181	94	41	6
16WF45	16 1/6	7	9/16	3/8	163	85	41	6
16WF64	16	8 1/2	11/15	7/16	234	108	40	12.6
16WF40	16	7	1/2	5/16	145	75	40	7.5
*16150	16	6	11/16	7/16	155	105	40	6.5
16WF36	15 7/6	7	7/15	5/16	127	74	40	6.5
*16WF110	15 3/4	11 3/4	1	6/18	345	127	40	25
*16162	15 3/4	6 1/6	7/6	9/15	200	129	40	11.5
*16145	15 3/4	5 5/6	5/8	7/16	150	104	40	7.6
*15WF103	15	11 3/4	15/16	6/16	369	121	38	24.5
15156	15	5 7/8	13/15	1/2	173	110	38	10.5
15143	15	5 1/2	5/8	7/16	132	93	38	7.5
*14WF101	14 1/4	11 3/4	15/16	9/18	344	114	38	26
*14140	14 1/4	5 3/6	3/6	3/8	116	83	36	8
14151	14 1/6	5 5/8	3/4	1/2	150	104	38	10
14170	14	8	15/16	7/16	204	87	35	16
*14167	14	6	7/8	1/2	153	101	35	12.5
*14140	14	5 1/2	5/8	3/6	121	76	35	6
14WF34	14	6 3/4	7/16	5/16	109	61	35	7.5
14WF30	13 7/6	6 3/4	3/6	1/4	94	58	35	6
*14WF62	13 3/8	11 3/4	7/6	1/2	297	96	34	25.6

Table 7–2. Properties of Steel Stringers (Con't)

NOMINAL SIZE	ACTUAL OEPTH (d) (in)	ACTUAL WIDTH (b) (in)	FLANGE THICHNESS (t_f) (in)	WE8 THICKNESS (t_w) (in)	MOMENT CAPACITY m (kips-ft)	MOMENT CAPACITY v (kips)	MAX SPAN LENGTH (L_m) (ft)	MAX 8RACING SPACING (S_b) (ft)
*14I46	13 3/8	5 3/8	11/18	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	9/18	108	104	32	95
12WF36	12 1/4	6 5/8	9/18	5/18	103	56	31	9.5
*12I65	12	8	15/16	7/18	182	73	30	21
12WF27	12	8 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	82	30	75
*12I34	11 1/4	4 3/4	5/8	7/16	81	72	28	8.5
*11WF76	11	11	13/18	1/2	202	77	28	27
*10I29	10 5/8	4 3/4	8/16	5/16	67	48	27	8.5
10WF25	10 1/8	5 3/4	7/16	1/4	59	38	25	8
*10I40	10	8	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	75
10WF21	9 7/8	5 3/4	5/16	1/4	48	38	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	5/18	51	43	24	8
*9I50	9	7	13/16	3/8	103	45	23	21
*8I35	8	8	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	8 1/4	9/16	3/8	45	31	16	18.5

*THESE NOMINAL SIZES HAVE NO U.S. EOUIVALENT.

FOR STRINGERS NOT LISTEO:

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

$v = 16.5(d_i \times t_w)$

(3) Step 3: Determine the effective number of stringers for one way (N_1) and two- way (N_2) traffic: (For a one–way bridge compute only N_1.)

$N_1 = \frac{5}{S_s} + 1$ (Do not round off)

$N_2 = 3/8\ N_s$ (Do not round off)

Use smaller of N_1 or N_2 for all further calculations.

(4) Step 4: Determine the live load moment per lane, M_{LL}, from figure 7–3.

Calculate the live load moment per stringer, m_{LL}:

Timber Stringer : $m_{LL} = \frac{M_{LL}}{N_1 \text{ or } N_2}$

Steel Stringer : $m_{LL} = \frac{1.15\ (M_{LL})}{N_1 \text{ or } N_2}$

(5) Step 5: Determine the dead load moment, M_{DL}, for the entire span from figure 7- 4.

Calculate the dead load moment per stringer (m_{DL}):

$m_{DL} = \frac{M_{DL}}{N_s}$

(6) Step 6: Calculate the total moment required (m_{REQD}) per stringer:

$m_{REQD} = m_{LL} + m_{DL}$

Compare the total required moment (m_{REQD}) with the moment capacity (m) of the desired stringer found in table 7–1 or table 7- 2.

(a) If the moment capacity (m) is greater than the total required moment (m_{REQD}), a moment failure will not occur. Proceed to Step 7.

(b) If the moment capacity (m) is less than the total required moment (m_{REQD}), add one stringer and return to Step 2 or select a stringer with a moment capacity greater than the required moment.

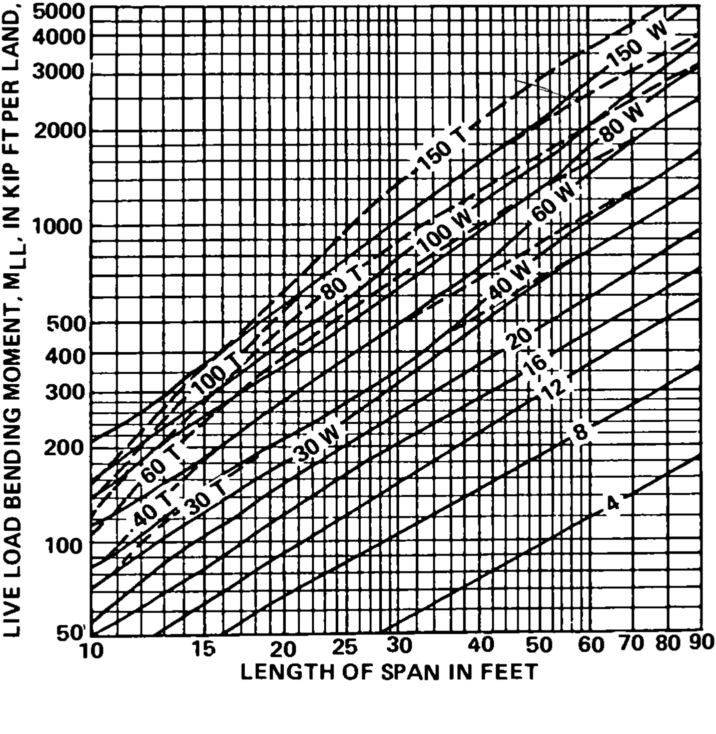


Figure 7–3 Live load moment graph.

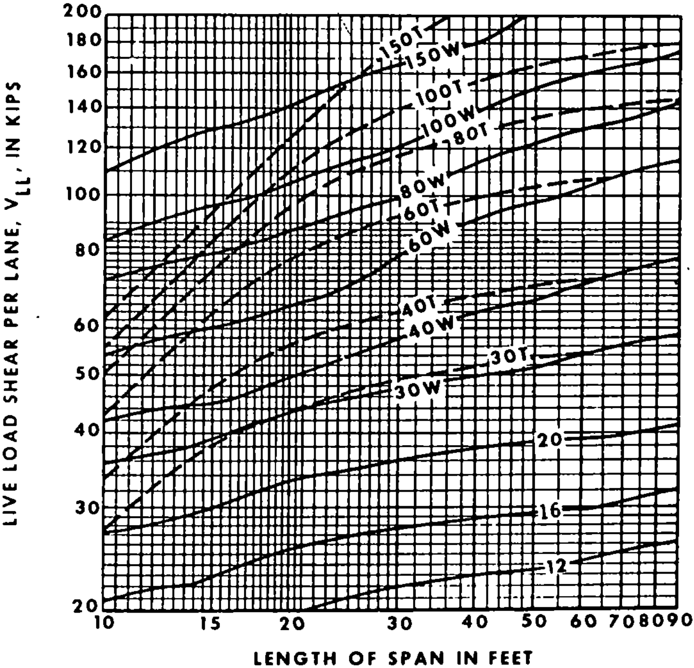


Figure 7–5 Live load shear graph

For an unlisted steel stringer:

$$v = 16.5(d_i t_w)$$

For an unlisted timber stringer:

$$v = \frac{bd}{10}$$

Where:

d = depth of stringer

b = width of stringer

t_w = thickness of web

(10) Step 10: Determine the number of lateral braces required between adjacent stringers:

Timber: Determine if braces are required from table 7–1. Minimum lateral bracing material is 3" by ½d of the stringer.

Steel: Lateral braces are always required with steel stringers. Space braces along span length evenly. Minimum bracing materials is ³⁄₈" by ½d of stringer.

number braces: $N_b = \frac{L}{S_b} + 1$

(11) Step 11: Bearing plate design (fig. 7–6) required for all steel stringers (not required for timber).

$$L_{PL} = b_{cap}$$

$$B_{PL} = \frac{2(v_{REQD})}{L_{PL}}$$ (Round up to nearest whole inch.)

NOTE: Minimum B_{PL} = stringer flange width

$$t_{PL} = \frac{B_{PL} - 2.5}{8.48}$$ (Round up to nearest ¹⁄₈")

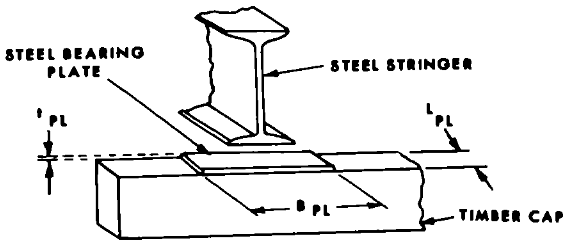


Figure 7–6. Bearing plate.

b. Decking, Treadway, Curbing, and Handrail Design.

Step 12: Determine the required decking thickness from the decking chart, figure 7–7, using the design class and the stringer spacing in inches. Add two inches to the required thickness if two or more layers of plank decking are required. (Two inches is added only ONCE regardless of number of layers stacked.) Absolute minimum decking thickness is 3 inches. For treadway, use at least 2--inch material. For curb and handrail design, see figure 7–8.

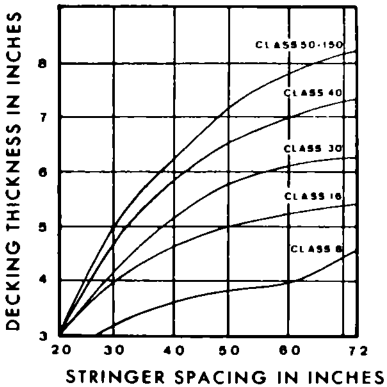


Figure 7–7. Decking chart.

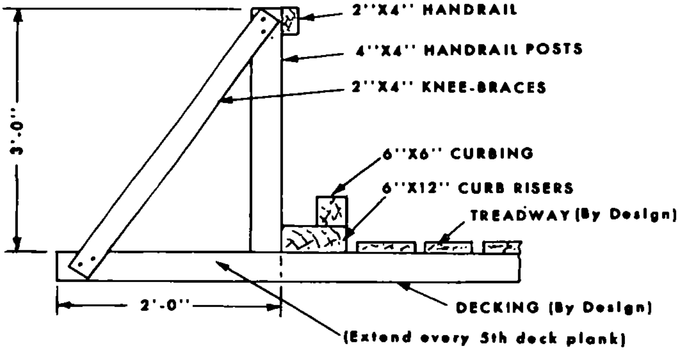


Figure 7–8. Handrail and curbing.

7–4. SUBSTRUCTURE DESIGN (intermediate Supports)

a Timber Trestle Bent Design (fig 7–9).

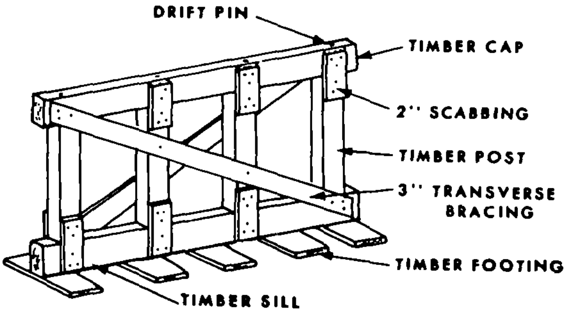


Figure 7–9. Timber trestle bent.

(1) Step 1: Determine critical support by finding the effective span length (L_e) for each intermediate support:
$L_e = L_1 + L_2$ (sum of adjacent span lengths)
The support for which L_e is the greatest will be the critical support, which must be designed.

(2) Step 2: Check the post height (H) of the tallest support against buckling. Post must be chosen from materials available (minimum post size is (6 in. x 6 in.) Find the maximum post height (H_m) in table 7–3.
If $H_m > H$, buckling will not occur. Use horizontal braces at midpoint, or select a larger post if $H_m \leq H$.

NOTE: All bracing on intermediate supports should be bolted to posts, cap, and sill.

Table 7–3. Properties of Timber Posts

Size of Post (in)	Capacity per Post (kips)	Max. Height (ft)	Size of Pile (in)	Capacity Per Pile (kips)	Max. Height (ft)
8 x 6	18	15	8φ	25	18
6 x 8	24	15	9φ	32	20
8 x 8	32	20	10φ	40	22
8 x 10	40	20	11φ	47	25
10 x 10	50	25	12φ	56	27
10 x 12	60	25	13φ	66	29
12 x 12	72	30	14φ	76	31

(3) Step 3: Determine the design load acting on the critical support:

(a) Using the design class and L_e, determine the live load shear per lane (V_{LL}) from figure 7–5.

(b) Using the adjacent span lengths, L_1 and L_2 separately, and the type of superstructure involved, determine the dead load shear (V_{DL}) from figure 7–4.

(c) Using the number of lanes (N_L), the live load shear per lane (V_{LL}), and the dead load shear (V_{DL}), compute the total design load, P_T:

$P_T = V_{LL}(N_L) + V_{DL}$ (in kips)

(4) Step 4: Determine the maximum load that one post can support, "capacity per post", from table 7–3.

(5) Step 5: Determine the number of posts required (N_p) and the center-to-center post spacing (S_p):

$$*N_p = \frac{P_T}{\text{capacity/post}}$$ *(Note: For a pier use ½P_T.)

$$S_p = \frac{W_R \times 12}{N_p - 1} \quad \text{(inches)}$$

(6) Step 6: Check maximum allowable center- to-center spacing of posts:

max S_p = 5 (d_{cap}) (inches)

If max $S_p < S_p$, add posts until max $S_p \geq S_p$ or use a cap with a larger d_{cap} dimension.

NOTE: Absolute minimum size cap and sill is 6 inches by 8 inches.

(7) Step 7: Using the available footing material thickness in inches and the soil-bearing capacity of the soil on which the footing is to rest (table 7-4), determine the "K" value from figure 7–10. Then calculate the maximum allowable footing length, max L_{ftg}:

max L_{ftg} = k + b_{sill} (inches)

Table 7–4 Soil–Bearing Capacity

TYPE SOIL -- SBC (kips/sqft)	
Hardpan overlaying rock	24
Very compact sandy gravel	20
Loose gravel and sandy gravel compact sand and gravelly sand, very compact sand-inorganic silt soils	12
Hard dry consolidated clay	10
Loose coarse to medium sand, medium compact fine sand	8
Compact sand clay	6
Loose fina sand, medium compact sand-inorganic silt soils	4
Firm or stiff clay	3
Loose saturated sand–clay soils, medium solt clay	2

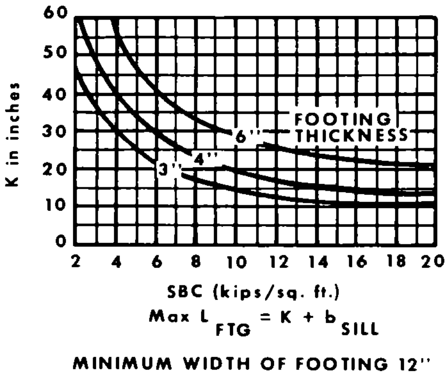


Figure 7–10 Footing chart.

(8) Step 8: Using the soil–bearing capacity, (SBC in kips/sq ft) and the ground contact area of one footing (GCA in sq ft), compute the capacity of one footing.
Capacity/footing = (GCA)(SBC) (kips)

(9) Step 9: Determine the number of footings required (N_{ftg}) and the center–to–center footing spacing (S_{ftg}):

$$* \; N_{ftg} = \frac{P_T}{\text{capacity/footing}}$$

NOTE· For a pier use $\frac{1}{2}P_T$

$$S_{FTG} = \frac{W_R(12)}{(N_{FTG} - 1)} \quad \text{(inches)}$$

NOTE. Minimum number of footings is equal to the number of posts.

b Timber Trestle Pier Design Design of a timber trestle pier is identical to the design of a timber trestle bent EXCEPT that each bent is designed for one–half the total load. Therefore, use $\frac{1}{2}P_T$ in paragraph a, step 5, and step 9. A timber trestle pier, as shown in figure 7–11, will be used when loads are too great to be carried by a single bent or span lengths are greater than 25 feet. In addition to the nine design steps followed for the design of each bent, a common cap and corbel design must be made for a pier.

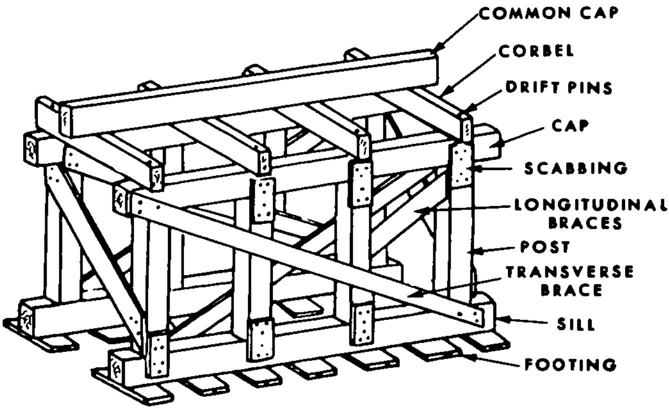


Figure 7–11. Timber trestle pier

(1) Step 1 through Step 9. For cap, sill, posts, and footing design for bents, see paragraph a.

(2) Step 10: Determine the effective corbel length (L_c):
L_c = effective corbel length

NOTE Minimum $L_c = 1/6H_p$ or 1/6 H

(3) Step 11: For design of corbels, check ratic of corbel length (L_c) to depth of corbel (d_c) to determine if moment or shear governs.

If $\frac{L_c}{d_c} \leq$ 12, shear governs, proceed to step 13

If $\frac{L_c}{d_c} >$ 12, moment governs, proceed to Step 12

(4) Step 12: Determine the number of corbels (N_c) required for moment by finding the total moment acting on the corbels (M_c) and the moment capacity of one corbel (m_c).

$$M_c = \frac{P_T(L_c)}{4} \quad \text{(ft-kips)}$$

Determine m_c for one corbel from table 7–1.

$$N_c = \frac{M_c}{m_c}$$ Proceed to Step 14

(5) Step 13: Determine the number of corbels (N_c) required for shear by finding the total shear acting on the corbels (V_c) and and the shear capacity of one corbel (v_c):

$$V_c = \frac{P_T}{2} \text{ (kips)}$$

Determine v_c for one corbel from table 7–1.

$$N_c = \frac{V_c}{v_c}$$

(6) Step 14: Determine the center-to-center spacing of the corbels based on the required number of corbels (N_c) as determined in Steps 12 or 13.

$$S_c = \frac{W_R(12)}{N_c - 1} \text{ (inches)}$$

(7) Step 15: Determine the minimum depth of the common cap (d_{cap}) and the minimum width of the common cap (b_{cap})

$$\min d_{cap} = \frac{S_c}{5}$$

$$\min b_{cap} = \frac{2\,P_T}{N_c b_c}$$

NOTE Absolute minimum size common cap is 6" x 8".

c. *Pile Bent Design (fig. 7–12)*

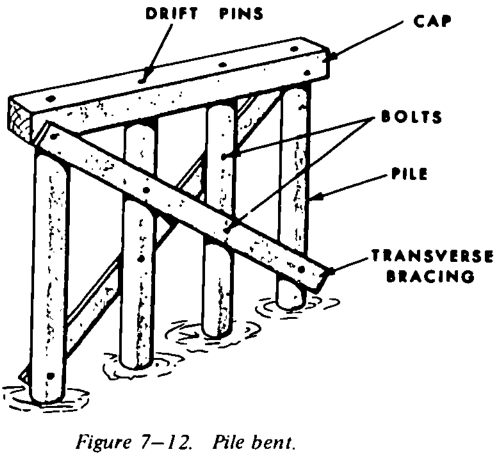


Figure 7–12. Pile bent.

NOTE. Pile type supports should be used instead of footing type supports when site conditions are affected by deep water or swift current causing scour, low capacity soil over- laying rock, or unconsolidated soil with low soil--bearing capacity.

(1) Step 1 through Step 3: Determine total load (P_T) on critical support (para a).

(2) Step 4: Determine the capacity per pile (P_b) based on end–bearing support from table 7–3.

(3) Step 5: Determine the capacity per pile (P_f) for friction support from one of the following dynamic formulas for timber piles (formulas based on test pile data or static formula – use lowest value)

Drophammer $$P_f = \frac{2(W_d)(h)}{(S + 1.0)}$$

Single–Acting Pneumatic or Diesel $$P_f = \frac{2(W_d)(h)}{(S + 0.1)}$$

Double–Acting Pneumatic or Diesel $$P_f = \frac{2E}{(s + 0.1)}$$

Static Formula $$P_f = \Sigma f(\pi D_p L_g)$$

W_d = weight of drophammer (kips)
h = average height of fall (ft)
E = work energy of hammer (ft/kip)
S = penetration of pile per blow for last 6 blows (inches/blow)
f = friction coefficient from TM 5–312
L_g = length of pile in soil layer

(4) Step 6: Using the smaller of the two values obtained from Step 4 and Step 5 for the capacity per pile, determine the effective number of piles required (N_{pr}):

$$N_{pr} = \frac{P_T}{\text{Allowable capacity pile}}$$ (Do not round off)

(5) Step 7: Determine the spacing to diameter of pile ratio (S_p/D_p) to minimize a possible overlapping of pressure bulbs which can reduce the capacity of the piles:

$$\frac{S_p}{D_p} = \frac{W_R(12)}{\frac{(N_{pr} - 1)D_p}{N_R}}$$

NOTE. For a pile PIER, substitute $\frac{N_{pr}}{2}$ for N_{pr}.

If: $\frac{S_p}{D/_p} > 10$ — Each pile develops full capacity. Round N_{pr} off and continue to Step 9.

$\frac{S_p}{D_p} < 3$ — Use a pile pier design.

$3 \leq \frac{S_p}{D_p} \leq 10$ — Capacity is reduced due to pressure bulb overlap. Continue to Step 8.

(6) Step 8: Determine the actual number of piles per row (N_p) from the appropriate chart in figure 7–14, using N_{pr} obtained in Step 6 and S_p/D_p Ratio obtained in Step 7.

NOTE: Minimum $N_p = 4$.

(7) Step 9: Calculate actual center--to- center spacing of piles and check spacing limitations.

Actual $S_p = \frac{W_R \times 12}{(N_p - 1)}$ (inches)

Minimum $S_p = 3(D_p)$ (inches)

Maximum $S_p = 5(d_{cap})$ (inches)

IF: Actual $S_p < 3(D_p)$ Return to Step 7 and design a pile pier.

IF: Actual $S_p > 5(d_{caps})$ Add more piles and check max and min spacing or increase depth of cap.
Calculate new S_p/D_p ratio based on N_p. Use appropriate pile chart to obtain N_{pe} using reverse procedure used for N_p.

$$\frac{S_p}{D_p} = \frac{W_r(12)}{(N_p - 1)D_p}$$

If $N_{pe} \geq N_{pr}$ — OK
If $N_{pe} < N_{pr}$ add 1 pile/row and repeat step 9 until $N_{pe} \geq N_{pr}$

d. Pile Pier Design (fig. 7–13).

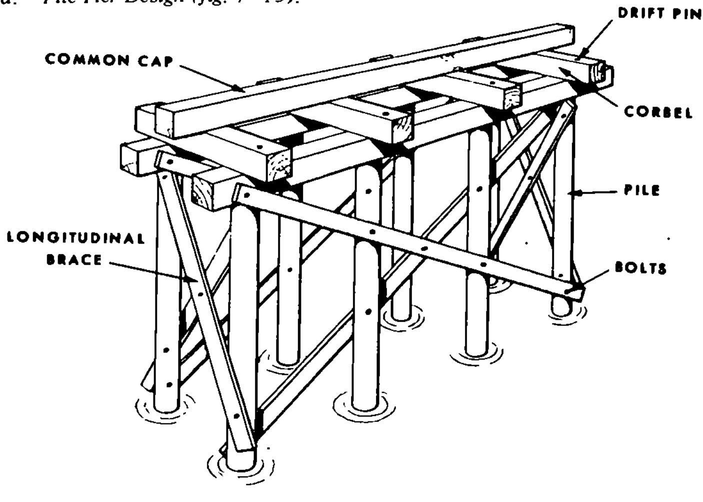


Figure 7–13 Pile pier.

(1) Step 1 through Step 3: Determine total load (P_t) acting on the critical support (see para a).

(2) Step 4 through Step 9 (pile design based on spacing criteria): In Step 7 substitute $\frac{1}{2}N_{pr}$ for N_{pr} and in Step 8 use the two--bent pile pier chart in figure 7--14 to determine the actual number of piles required per row (see para c).

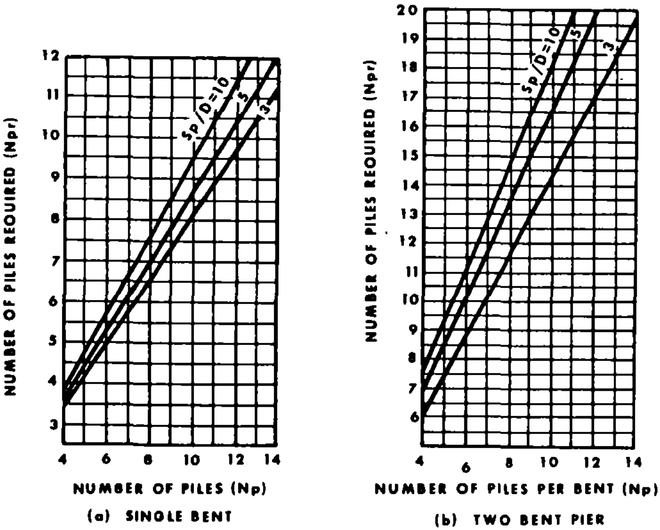


Figure 7–14 Pile charts.

(3) Step 10 through Step 15: Design common cap and corbel system (para b).

NOTE: Pile piers should be used in low capacity soils where pile bents do not give the required support or in situations requiring greater stability due to span lengths, support heights, or available material size.

7-5. SUBSTRUCTURE DESIGN

a. See figures 7–15 through 7–18 and table 7–5 for selection of abutments.

b. Deadman Design. For deadman design, see TM 5-312.

NOTE: If time does not permit a detailed deadman design, use at least 14" diameter deadman at least as long as the roadway width. It should be attached to the abutment with at least ten $^3/_8$" diameter cables. The deadman should be buried 4' deep and placed 20' from the abutment.

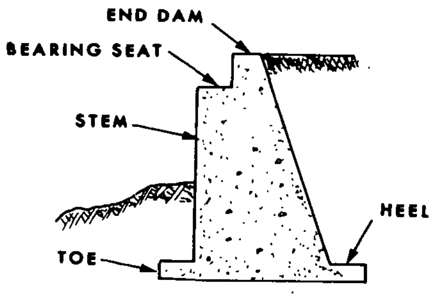


Figure 7–15. Concrete abutment

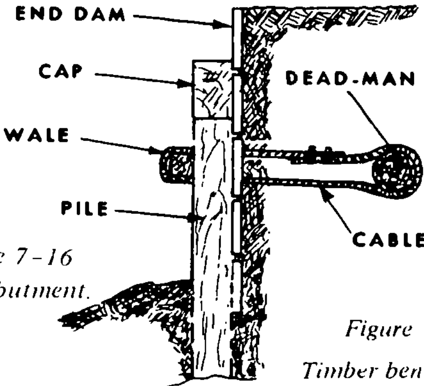


Figure 7-16
Pile abutment.

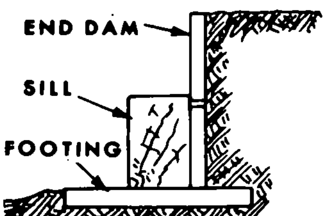


Figure 7-17.
Timber sill abutment.

Figure 7-18.
Timber bent abutment.

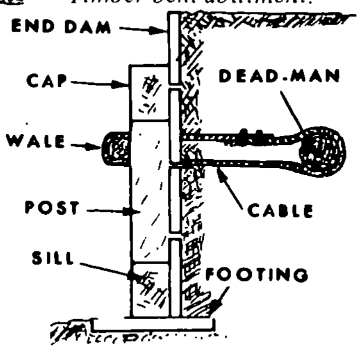


Table 7-5 Abutment Selection Guide

TYPE	HEIGHT	SITE CONDITIONS	DESIGN REMARKS
CONCRETE ABUTMENT	TO 20′	MOST PERMANENT TYPE USE ON FIRM BANKS WITH GOOD SOIL.	FOR DESIGN, SEE TM 5- 312
TIMBER SILL ABUTMENT	TO 3′	MOST ECONOMICAL AND EASILY CONSTRUCTED. USE ON HIGH, FIRM BANKS WITH GOOD SOIL.	DESIGN IS IDENTICAL TO TIMBER TRESTLE BENT WITHOUT POSTS. L_e CONSISTS OF SUPPORTED SPAN ONLY (PAR a).
TIMBER BENT	TO 6′	USE ON FIRM BANKS WITH GOOD SOIL.	DESIGN IS IDENTICAL TO TIMBER TRESTLE BENT L_e CONSISTS OF SUPPORTED SPAN ONLY (PARA d) TO PREVENT OVERTURNING, USE DEADMAN
PILE ABUTMENT	TO 10′	USE ON GENERALLY SLOPING BANKS WITH POOR SOIL CONDITIONS, WHEN STABILITY IS DESIRED, OR WHEN BANKS FLOOD FREQUENTLY.	DESIGN IS IDENTICAL TO PILE BENT. L_e CONSISTS OF SUPPORTED SPAN ONLY (PARA c). TO PREVENT OVERTURNING, USE DEADMAN

Section II. BRIDGE CLASSIFICATION

7-6. TIMBER TRESTLE BRIDGE CLASSIFICATION

Bridge classification is based on the class of the superstructure only, since this is considered to be the controlling feature. However, the condition of both superstructure and substructure components should be examined closely for damage or deterioration and the probable effect on the bridge capacity.

(1) Step 1: Conduct a bridge reconnaissance to obtain the following information on the existing bridge:
Roadway width (W_R) in feet
Span length (L) in feet (critical span)
Type, size, and number of stringers
Type of decking and thickness of decking
Number of lateral braces
Condition of the components

(2) Step 2: Locate the stringer to be classified in table 7–1 or table 7–2 and determine the moment capacity (m) in ft–kips.

(3) Step 3: Obtain the dead load moment per span (M_{DL}) for the type superstructure involved from figure 7-4. (*NOTE.* If $W_R \geq 18'$, bridge is 2–lane.)

(4) Step 4: Calculate the dead load moment per stringer (m_{DL}) using the actual number of stringers (N_s):

$$m_{DL} = \frac{M_{DL}}{N_s} \quad \text{(ft-kips)}$$

(5) Step 5: Calculate the live load moment per stringer (m_{LL}) using the appropriate formula for either steel or timber stringers:

Steel : $m_{LL} = \dfrac{m \cdot m_{DL}}{1.15}$

Timber : $m_{LL} = m - m_{DL}$

Check the maximum span length (L_m) of the stringer from table 7–1 or table 7–2. If $L_m > L$, proceed to Step 6. If $L_m < L$, multiply m_{LL} by the ratio L_m/L to obtain a new and lower value of m_{LL}.

(6) Step 6: Determine the effective number of stringers per lane for one–way traffic (N_1) and for two–way traffic (N_2). (If $W_R \geq 18'$) by first computing the stringer spacing (S_s):

$$S_s = \frac{W_R}{N_s - 1} \quad \text{(feet)}$$

One–way traffic: $N_1 = \frac{5}{S_s} + 1$

Two–way traffic: $N_2 = \frac{3}{8} N_s$

(NOTE: DO NOT ROUND OFF N_1 or N_2.)

For One–Way

If $N_1 > N_2$ use N_1

If $N_2 > N_1$ use N_1

For Two–Way

If $N_1 > N_2$ use N_2

If $N_2 > N_1$ use N_1

(7) Step 7: Determine the live load moment per lane (M_{LL}) using the value of m_{LL} obtained in Step 5 and N_1 and/or N_2 obtained in Step 6:

$M_{LL} = N_1 (m_{LL})$ (ft–kips/lane)

(8) Step 8: Determine the classification of the bridge based on bending moment by entering figure 7–3 with M_{LL} and span length (L) for both wheeled and tracked vehicles.

NOTE: If $N_1 > N_2$, return to Step 7 and calculate M_{LL} using N_2 in place of N_1. Another classification will be obtained from figure 7–3 which will give a class based on two–way traffic.

(9) Step 9: Determine the shear capacity (v) of the stringer in kips from table 7–1 or table 7–2.

(10) Step 10: Obtain the dead load shear per span (V_{DL}) for the type superstructure involved from figure 7–4. Calculate the dead load shear per stringer (v_{DL}):

$$v_{DL} = \frac{V_{DL}}{N_s} \quad \text{(kips per stringer)}$$

(11) Step 11: Calculate the live load shear per stringer (v_{LL}) using values for v and v_{DL} obtained in Step 9 and Step 10:

$$v_{DL} = v - v_{DL} \quad \text{(kips per stringer)}$$

(12) Step 12: Determine the live load shear per lane (V_{LL}) using the appropriate formula for either steel or timber stringers:

$$\text{Steel} : V_{LL} = \frac{2(v_{LL})}{1.15} \quad \text{(kips per lane)}$$

$$\text{Timber} : V_{LL} = \frac{16}{3} (v_{LL}) \frac{N_1}{(N_1 + 1)}$$

(13) Step 13: Determine the classification of the bridge based on shear by entering figure 7–5 with V_{LL} and span length (L) for both wheeled and tracked vehicles.

NOTE: If $N_1 > N_2$, return to Step 12 and calculate V_{LL} using N_2 in place of N_1. Another classification will be obtained from figure 7–5 which will give a class based on two–way traffic.

(14) Step 14: Determine the maximum classification for both one-way and two-way traffic based on the roadway width restrictions (W_R) (table 7–6).

Table 7–6. Minimum Roadway Width Requirements.

Bridge class	4–12	13–30	31–60	61–100
One-Lane	9′–0″	11′–0″	13′–2″	14′–9″
Two-Lane	18′–0″	18′–0″	24′–0″	27′–0″

(15) Step 15: Determine the decking class by first calculating the effective thickness of decking (t_{eff}) for the type of decking involved:

Laminated: $t_{eff} = (t_{actual})(\% \text{ Lam})$

Plank. $t_{eff} = t_{actual} - 2''$
(NOTE Subtract 2" for *multilayered* plank deck only.)

Using the effective thickness (t_{eff}) and the stringer spacing (S_s) in inches, obtain the decking class from figure 7—7.

(16) Step 16: Calculate the number of lateral braces required (N_b) using the maximum spacing of bracing (S_b) from table 7--2 for steel stringers:

Steel : $N_b = \frac{L}{S_b} + 1$

Timber : $N_b = 3$, If $d > 2b$ for stringer

If necessary, add bracing as required before posting final bridge classification sign.

(17) Step 17: Determine the final bridge classification by comparing the classes for moment, shear, two—way width, and deck, and then selecting the lowest critical class for each type crossing, wheeled or track.

Type Crossing	TRACKED		WHEELED	
	One-Way	Two-Way	One-Way	Two-Way
MOMENT	Step 1	Step 8		
SHEAR	Step 9	Step 13		
WIDTH	Step 14			
DECK	Step 15			

Final Class — choose lowest class for each type crossing

NOTE: If the maximum one-way width class determined in Step 14 is less than either of the final one-way classifications, a width restriction sign indicating the maximum width clearance must be posted below the bridge class sign.

7–7. REINFORCED CONCRETE BRIDGE CLASSIFICATION

Due to wide variations in design criteria, it is not possible to calculate the exact capacity of a reinforced concrete bridge based only on the measurable external dimensions. The class will be obtained by correlation to charts in TM 5–312.

Field measurements should be made on a concrete slab bridge as shown in Figure 7–19 and on a concrete T–beam bridge as shown in Figure 7–20, in order to classify the bridge according to TM 5–312.

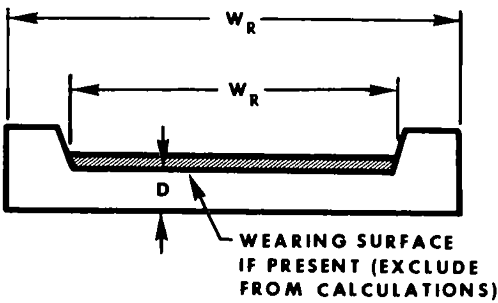


Figure 7–19. Concrete slab bridge.

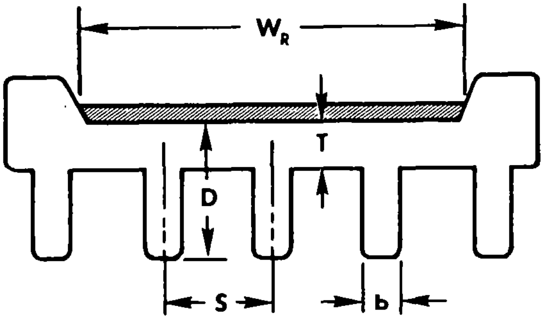


Figure 7–20 Concrete T–beam bridge

7–8. MASONRY ARCH BRIDGE CLASSIFICATION

The masonry arch bridge is difficult to analyze for the purpose of obtaining a satisfactory military class. In order to classify a masonry arch bridge, make the necessary measurements as shown in figure 7–21 and follow the classification procedure as outlined and discussed in TM 5–312.

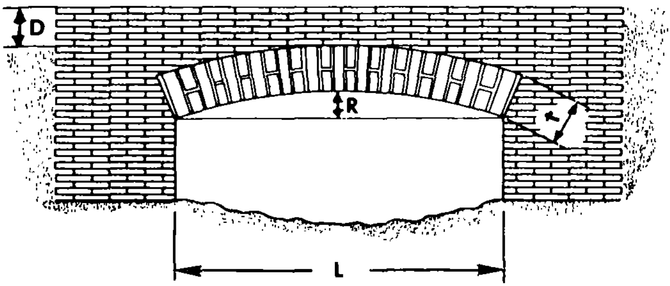


Figure 7–21 Masonry arch bridge.

Section III. STANDARD BRIDGES (BAILEY TYPE, M2, AND MEDIUM GIRDER BRIDGE)

7–9. PANEL BRIDGE, BAILEY TYPE, M2, GENERAL INFORMATION

a. The panel bridge, Bailey type, M2, is a through–truss bridge with the roadway supported between the two main trusses formed from 10–foot steel panels (fig. 7–22).

b. 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 the erection of panel bridging.

c The bridge set contains components required to erect two 80–foot DS bridges or one 130–foot DD bridge. See tables 7–7 and 7–8.

d The cable reinforcement set for panel bridge M2 (Bailey type) increases to class 60 wheel and track, the classification of triple–single Bailey bridge for span lengths from 100 feet to 170 feet. For a span of 180 feet, the class is 50 wheel and 60 track. This system significantly reduces the assembly time and equipment necessary to cross class 60 traffic over spans of between 100 and 180 feet.

e. The cable reinforcement set consists of a system of cables attached to each end of the bridge and offset from under the bridge by posts. The cables are tensioned, causing the bridge to deflect upward. When a vehicle crosses the bridge, the bridge deflects downward, transferring part of the load into the cables.

7–10. SITE RECONNAISSANCE

Site reconnaissance should consider the following as a minimum:

a Road net on which to transport equipment to the assembly area.

b Approaches – a 150' straight approach, with a 10% slope or less, well graded and drained, and permitting two–lane traffic.

c Access roads – roads to and from the bridge capable of carrying traffic for which bridge is required.

d Abutments – check whether prepared or unprepared, assure equal height.

e Assembly areas – sufficient space for material stacking and bridge assembly (fig. 7–23).

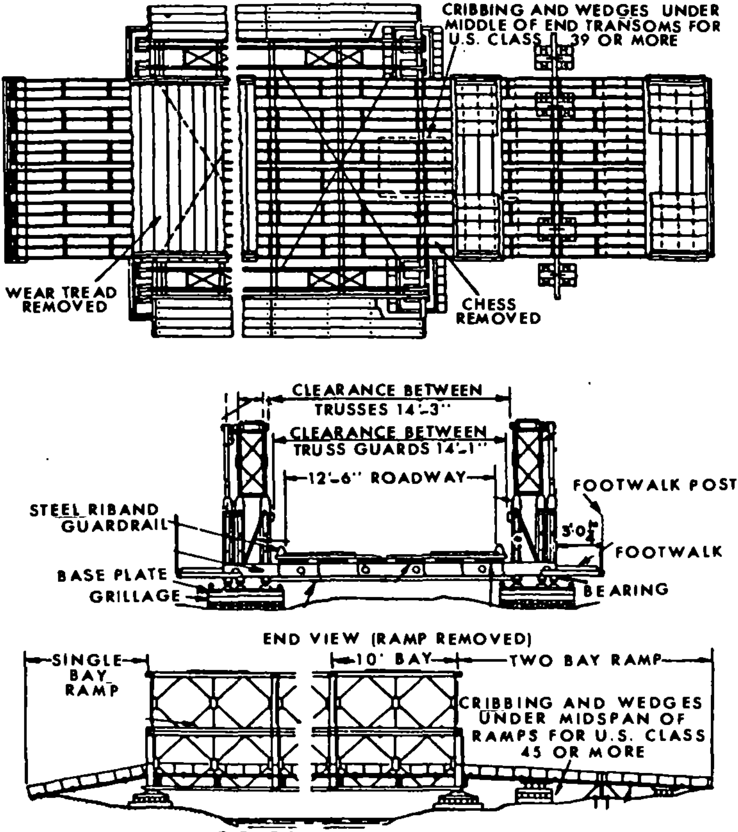


Figure 7–22. Steel panel fixed bridge, Bailey Type, M2

Table 7–7 Critical Dimensions of Bailey Bridge

Road width between steel ribands	12' 6"
Road width between timber truss guards	13' 9"
Lateral distance between centerlines of trusses	
Inner trusses	14' 10"
Middle trusses	17' 10"
Outer trusses	19' 3"
Lateral distance between centerlines of base plates	
S truss bridge	14' 10"
D truss bridge	16' 4"
T truss bridge	17' 3 1/2"
Lateral distance between outside edges of base plates	
S truss bridge	19' 5"
D truss bridge	20' 11"
T truss bridge	21' 10 1/2"
Lateral distance between measuring lugs of rocking roller templates	11' 6 1/2"
Lateral distance between measuring lugs of plain roller templates	
SS, DS bridges	11' 6 1/2"
TS, DD, TD, DT, TT bridges	10' 10 1/2"
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 template to top of plain roller	8 15/16"
Height from base of ramp pedestal to top of ramp chess	17 1/4"
Height from bottom of half round lug under sloping end of ramp to top of ramp chess	5 7/8"
Height from top of chess to overhead bracing	
Normal	14' 7"
Expedient	12' 3"
Height from base of bearing to bottom of panel	5 17/32"
Height from bottom of panel to top of chess	20 11/16"
Height from bottom of half round lug of end post to top of chess	22 13/32"
Height from base of rocking roller bearing to top of rocking roller	13 5/16"

Table 7–8. Weight per Bay of Bridge

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

NOTE:

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

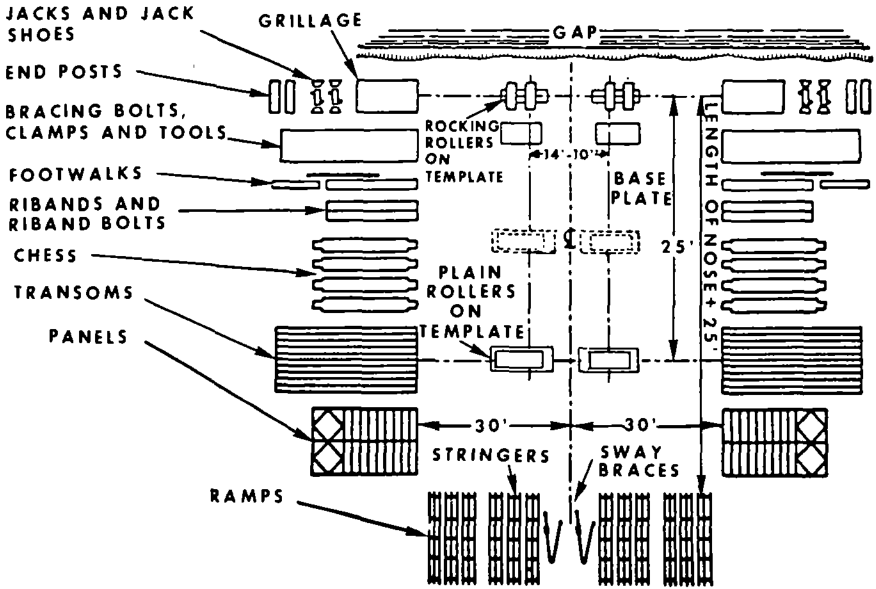


Figure 7-23 Suggested layout of equipment at bridge site

f. Turnaround – permit easy access to bridge assembly area.

g. Equipment park – area large enough to hold all vehicles and close enough to allow proper control.

7–11. BAILEY BRIDGE DESIGN

Design of the Bailey bridge is beyond the scope of this publication and is outlined in detailed in TM 5–277.

7–12. PLANNING DATA

Tables 7–9 and 7–10 contain crew size and breakdown and estimated assembly times for standard bridges.

7–13. SITE LAYOUT DATA

Site layout data is beyond the scope of this publication. It is outlined in detail in TM 5–277.

7–14. ASSEMBLY AND LAUNCHING DATA

Assembly and launch procedures are beyond the scope of this publication and are outlined in TM 5–277.

7–15. MEDIUM GIRDER BRIDGE

Data on the medium girder bridge was not available at the time of publication. It will be incorporated into a change when available.

Table 7–9. Organization of Assembly Crews

	Type of Bridge						
	SS	DS	TS	DD	TD	DT*	TT*
Truck driver						0/1	0/1
Crane operator						0/1	0/1
Hook man						0/1	0/1
Panel carry	12	12	24	28	44	44/24	60/24
Pin	2	2	4	4	6	6/6	8/6
Transom-carry	8	8	8	8	8	24/16	24/16
Clamp	1	2	2	2	2	4/4	4/4
Brace, sway	2	2	2	2	2	6/6	6/6
Raker	2	2	2	2	2	2/2	2/2
Frame		2	2	4	4	8/10	8/8
Chord bolt				4	8	10/10	14/14
Tie plate			2		4		4/4
Overhead support						6/4	6/4
Decking-stringer	8	8	8	8	8	8/8	8/8
Chess & riband	4	4	4	4	4	4/4	4/4
** Total	39	42	58	66	92	122/97	148/103

*First number indicates men required without crane, second if crane is used

**All numbers reflect ideal number of men for each task.

Table 7-10 Assembly Times – Hours

Length	SS	DS	TS	DD	TD	DT (3)	TT (3)
40′	1½						
60′	1¾	2					
80′	2	2½	3				
100′	2¼	3	3½	4¼			
120′		3¼	4	5	6¾		
140′		3¾	4½	5¾	7½	11¾/10¼	
160′			5	6¼	8½	13¼/11¾	19/16¾
180′				7	9½	14¾/13¼	21¼/18¼
200′						16¾/14½	24/20¾

(1) All times assume ideal conditions and footwalks omitted

(a) Blackout - add 50 to 100 percent

(b) Bad weather - add 30 to 50 percent

(c) Untrained troops - add 20 to 30 percent

Example: (60′ss = 1:45) + (poor weather (50%) = 0.52) + (untrained troops (30%) = 0.32) = 3.08 (3 hours, 8 minutes)

(2) Times do not include site preparation. Add 1 to 4 hours, depending on conditions.

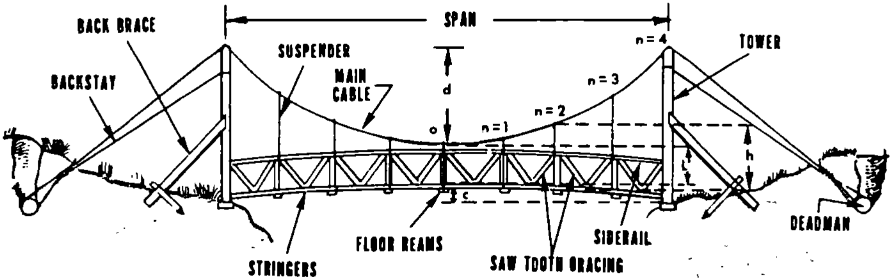
(3) Second number refers to construction using a crane

Section IV. MISCELLANEOUS BRIDGING

7–16. LIGHT SUSPENSION BRIDGE DESIGN

The suspension bridge (fig. 7–24) is used for long spans high above obstacles. The floor system is suspended from cables, which are supported on towers and anchored to abutments.

a. Design Data See table 7–11 and figure 7–24.



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 7–24. Light suspension bridge.

Table 7–11 Light Suspension Bridge Design Data

Item	Data		
Panel length	10 to 15 ft.		
Camber	Approximately 2 ft.		
Stringer design	See paragraph 7–1a.		
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 11 -2 for cable strength.		
Length of suspenders	$h = L + \left(\frac{n}{N}\right)^2 (C + d)$		
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 fore-braces. 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 x 1.35 = 48,600 pounds. If two main cables are used, each must have a tensile strength of 24,300 pounds.

7–17. THREE-ROPE BRIDGE (fig. 7–25)

The three–rope bridge is used to carry personnel with full field packs, but it is limited to a maximum of 7 men at 5 pace intervals. Maximum length is 150 feet. For construction details see TM 5–270.

7–18. 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. See TM 5–270.

7–19. ARMORED VEHICLE LAUNCHED BRIDGE (AVLB)

The AVLB is used to transport vehicles up to class 60. The bridge is 63 feet long and requires 3 feet of bearing on each side of the gap—an effective length of 57 feet. The AVLB may be launched or retrieved from either side of the gap and employed without exposing the operators to fire. It is found in armored Bns (2ea) and Div Engr Bns assigned to armored Divs (4 launchers and 6 bridges).

Figure 7–25. Three–rope bridge.

7–20. M4T6 FIXED SPANS

Data is located in paragraph 6--2.

CHAPTER 8

CONCRETE CONSTRUCTION

8–1. COMPONENTS OF CONCRETE

Concrete consists of a binder known as cement paste (portland cement and water) and filler material called aggregate (sand and gravel).

a. Portland Cement Types.

(1) *Normal portalnd cement (Type I).* This is used for all general types of concrete construction, masonry units, and soil cement mixtures. Concrete made with Type I cement reaches its design strength after 28 days.

(2) *High–early portland cement (Type III).* This is used where high concrete strength is required after a short curing period. Concrete made with Type III cement reaches its design strength after 7 days. Type III is used where it is desired to remove forms as early as possible, to put concrete into service as early as possible, and in cold weather construction to reduce the period of protection against low temperatures.

(3) *Air–entrained portland cement (Types IA and IIIA).* Air–entrained cement increases the workability of plastic concrete and produces hardened concrete with greatly increased freeze–thaw resistance and watertightness. These air–entraining agents, which intentionally introduce minute air bubbles into the concrete mix, are recommended for all concrete construction. Air–entraining agents may also be added to the mix water at the job site.

NOTE· Storage of cement. As a minimum, cement bags should be stored on raised platforms with the top and sides protected by a waterproof covering.

b Mixing Water.

(1) The purpose of water in the concrete mix is to combine with the cement in the hydration process, coat the aggregate, and permit the mix to be worked.

(2) Mixing water should be clean and free from organic materials, alkalies, acids, and oil. In general, water that is fit to drink is suitable to mix with cement.

(3) Seawater may be used as mixing water with the understanding that the strength of the hardened concrete will be about 20 percent less than that mixed with fresh water.

c. Sand. The fine aggregate (sand) should be clean and free of salt, clay, or other materials which might coat the particles and impair binding of the cement paste.

d. Gravel.

(1) Coarse aggregate (gravel) should be hard, durable, and clean.

(2) The most economical concrete mix utilizes the largest gravel size possible. Physical restrictions of the concrete structure, however, restrict the maximum size gravel to the following:

(a) one–third the depth of the concrete slab on grade.

(b) one–fifth the thickness of the concrete wall.

(c) three–fourths of the minimum clear space between reinforcing steel or between reinforcing steel and the form.

8–2. CONCRETE MIX PROPORTIONING

a Mix Proportioning Mix proportioning is the selection of the most economical and practical combination of concrete components (cement, water, sand, and gravel) which will be workable in the plastic state and still develop the properties of strength, durability, and watertightness in the hardened state.

b. Water–Cement Ratio.

(1) The water–cement ratio is expressed in gallons of water per sack of cement. The water–cement ratio is of primary importance in mix proportioning in that the strength of the hardened concrete varies with this ratio. The lower the water–cement ratio, the higher the strength.

(2) Recommended water–cement ratios for concrete work follow:

(a) Use 6 gal/sack for an average mix

(b) Use 5 gal/sack for concrete placed under water, for concrete used in a watertight structure, when seawater is used for mix water, and when air--entraining is used.

(3) Adjust the water–cement ratio for moisture in the sand.

(a) Reduce ½ gal/sack for damp sand (when squeezed in your hand, if forms a ball yet leaves little moisture on your fingers).

(b) Reduce 1 gal/sack for wet sands, usually found after a rain or washing (forms a ball when squeezed in your hand, but leaves moisture on your fingers).

c. Slump.

(1) Slump is a relative measure of:

(a) Workability of a concrete mix — the ease of placement of the plastic concrete and its resistance to segregation.

(b) Uniformity — a measure of similarity between batches made with the same mix proportions.

(2) Procedure for determining the slump of a concrete mix is:

(a) Obtain or construct a slump cone as in figure 8—1.

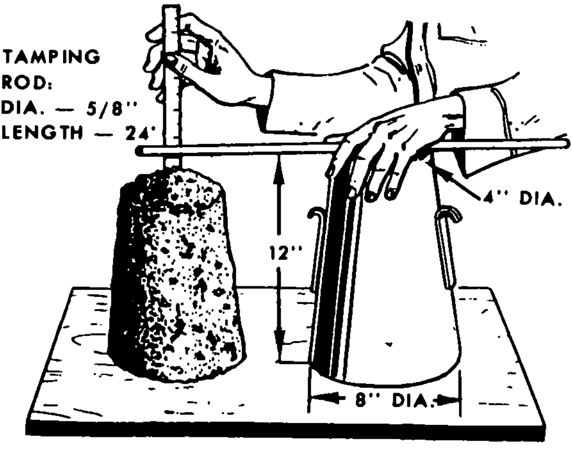


Figure 8—1. Measurement of slumps.

(b) Moisten the slump cone and place on a flat, level, moistened surface.

(c) Fill the cone with plastic concrete in three layers, each layer consisting of approximately one–third the volume of the cone. As each layer is placed, it is rodded 25 times with a 5/8–inch diameter, 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 tamped its entire depth.

(d) When the cone is full, strike off the excess concrete level with the top of the cone.

(e) Carefully lift the cone from the concrete and place the cone beside the concrete pile. Place the tamping rod across the top of the cone and measure the distance between the bottom of the rod and the center of the concrete pile. This measured distance that the concrete has fallen is the slump.

(3) Recommended slump for general concrete construction is 3 inches. Where thin concrete sections are to be cast and where reinforcing steel is present in the structure, it is advisable to use high–speed vibrators in placing the concrete.

d. Sand and Gravel. Recommended quantities of sand and gravel to be used for mix proportioning are listed in table 8–1.

Table 8–1. Concrete Mixes

MAXIMUM SIZE GRAVEL TO BE USED (INCHES)	AGGREGATE – CUBIC FEET PER 1 SACK OF CEMENT		
	SAND		GRAVEL
	AIR–ENTRAINED	NON–AIR–ENTRAINED	
½ inches	1.9	2.0	1.5
¾ inches	1.9	2.0	1.9
1 inch	1.8	1.9	2.1
1½ inches	1.8	1.9	2.5
2 inches	1.8	1 9	2.7

e. Example Problem. Select mix proportion for a concrete footer using air–entrained cement (Type IA).

(1) Select w/c ratio (para 8–2b) – (w/c ratio = 6 gal/sack.)

(2) Select slump (para 8–2c) – (slump = 3").

(3) Select aggregate (table 8–1).

(a) Determine the moisture condition of the sand. (Sand is checked and found to be damp.)

(b) Determine the maximum size gravel to be used. (Maximum size aggregate available is ¾").

(c) Determine the type cement available. (air–entrained).

(d) Mix proportions for a one–sack batch are:

Water = 6 gal/sack minus ½ gal/sack = 5½ gal/sack

Cement = 1 sack air–entrained

Sand = 1.9 cu ft

Gravel = 1.9 cu ft

(e) Mix the one–sack batch selected in (d) above and make a slump test. If the slump measures less than 3 inches, mix a new one–sack batch using less sand and gravel. If the slump measures more than 3 inches, adjust the mix by adding sand and gravel to obtain the 3-inch slump. Never increase water content in an attempt to change a slump measurement. This practice changes the water–cement ratio, resulting in weakened concrete. When suitable proportions have been determined, convert the quantities of each material for the one–sack batch to those for a full mixer–size batch.

8–3. ESTIMATING AMOUNT OF MATERIALS REQUIRED

a Amounts of Materials. The amounts of cement, water, sand, and gravel to be ordered and delivered to the job site may be estimated according to the following steps:

(1) Determine the volume of concrete needed in cubic feet.

(2) Add a loss factor to compensate for handling losses. Add 10% for projects requiring up to 200 cubic yards (5400 cubic feet) of concrete and 5% for projects requiring 200 cubic yards or more.

(3) Determine the total volume of loose, dry material (total cement, sand, and gravel) required. Multiply the volume of concrete (plus the loss factor) times 1.5.

(4) For estimating purposes, assume mix proportions of 1 part cement, 2 parts sand, and 3 parts gravel (1:2:3 = 6). Determine amounts of each material by multiplying the total loose volume (Step 3) by the proportional amount of the total mix:

cement = 1/6 x total loose volume
sand = 2/6 x total loose volume
gravel = 3/6 x total loose volume

(5) The amount of water needed may be determined by using a rule of thumb of 8 gallons of water per sack of cement. This amount will allow for mixing water as well as water used in curing and cleanup.

b. Example Problem. Determine the amounts of materials needed to construct a concrete wall measuring 10 feet long, 3 feet high, and 1 foot thick.

(1) Volume of concrete = 10 ft x 3 ft x 1 ft = 30 cu ft.
(2) Add 10% loss factor (less than 200 cu yd).
30 cu ft + 3 cu ft = 33 cu ft
(3) Volume of loose, dry materials = 33 cu ft x 1.5 = 49.5 = 50 cu ft.
(4) Amount of each material required:
Cement = 50 cu ft x 1/6 = 8.3 = 9 cu ft (bags)
Sand = 50 cu ft x 2/6 = 16.7 = 17 cu ft
Gravel = 50 cu ft x 3/6 = 25 cu ft
(5) Water = 8 gal/bag x 9 bags = 72 gal

8–4. ESTIMATING QUANTITY OF STORED AGGREGATE (fig. 8–2)

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 x height x cone diameter squared. The volume of a tent–shaped pile is: volume = 0.2618 x (height x cone diameter squared) + .5 x height x (width x 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.

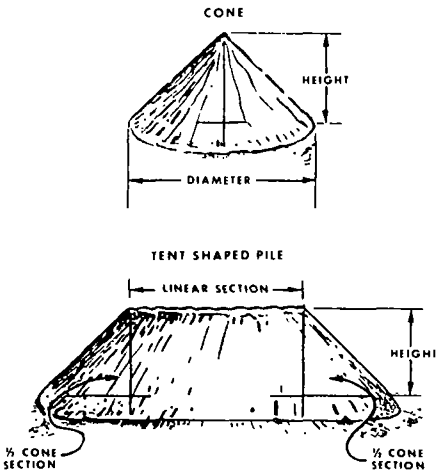


Figure 8–2. Estimating quantity of stored aggregate.

8–5. BATCHING

a. Once a design mix has been determined, lay out the site, placing the cement, sand, gravel, and water as close to the skip (load bucket) of the mixer as possible.

b. The gravel should be placed in the skip first, the cement next, and the sand last. The exact amount can be controlled by constructing measuring boxes which have inside dimensions of 1 cubic foot and then 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 on the mixer or by hand.

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 1 minute for any mix. For a batch exceeding 1 cubic yard, the mixing time is increased 15 seconds for each additional ½ yard or portion thereof.

8–6. CONCRETE PLACING AND FINISHING

a Moisten the grade to prevent absorption of water from the mix.

b. Oil all forms before placing concrete.

c Wheel, shovel, or chute concrete into place—do not flow. Concrete should not be allowed to free fall into forms from heights greater than 5 feet unless suitable drop chutes, baffles, or vertical pipes are provided. As concrete is placed, it should be compacted by vibrators, spades, or rods. Take care not to overvibrate.

d. Level and tamp into place with a strike--off screed.

e. Delay wood floating for 30 to 40 minutes after the concrete is placed.

f. Apply final steel troweling when thumb pressure barely dents the concrete surface. Final troweling compacts the surface and leaves it smooth.

g Start curing as soon as possible without marring the surface.

8–7. CURING

a. Curing is the procedure for preventing the evaporation of mixing water from the surface of freshly poured concrete. Loss of water from the concrete will terminate, or at least limit, the chemical reaction (hydration) of cement and water. Since concrete will gain strength only so long as water is available to react with the cement, evaporation of this water will reduce the actual strength below designed strength.

b To obtain the designed strength, concrete made with Type I cement must be cured (kept continuously wet) a minimum of 7 days. Concrete made with Type III cement must be cured a minimum of 3 days.

c Methods used to properly cure concrete depend upon the type of structure and may be accomplished by spraying or ponding, by covering with continually moistened earth, sand, burlap, or straw, or by covering with a water–retaining membrane.

d If spray–on curing compound is available, spray on the compound in one coat. Do not use the compound if the air temperature is above 100°F and the air is dry.

e. Do not let the temperature of fresh concrete drop below 40°F.

8–8. FORMING

a Elements of Wooden Forms (figs. 8–3 and 8–4)

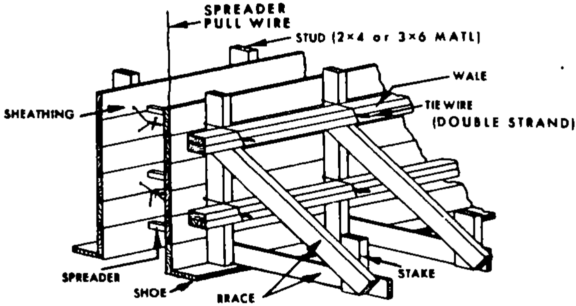


Figure 8–3. Form for a concrete wall

(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 unhardened concrete will cause the sheathing to 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 lumber.

(3) *Wales.* 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 made of the same material as the studs.

(4) *Braces* Bracing is usually required to maintain the vertical alinement of the forms and to resist movement during the concrete–pouring operation. Bracing is not considered a structural component in wall form design; i.e., it does not support the pressure of unhardened concrete.

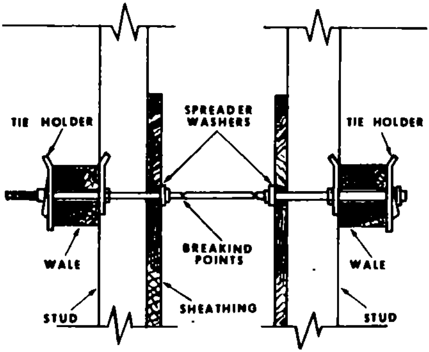


Figure 8–4. Form for a concrete wall

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

(6) *Spreaders.* To maintain the proper distance between the two form sides, small pieces of wood (spreaders) are cut the same length as the wall thickness and placed between the forms. A wire should be securely attached to the spreaders so they can be pulled out from the top after the concrete has exerted its total pressure on the walls. The spreaders must be removed before the concrete hardens.

(7) *Form ties (wire or tie rods).* Ties resist the outward pressure of unhardened concrete. Where wire ties are used, a double strand is necessary.

(8) *End walls (dams).* Dams must provide the same strength as the sides of the wall form. Examples of end wall forming appear as figure 8–5. Note that wall thickness dictates the choice of end wall detail.

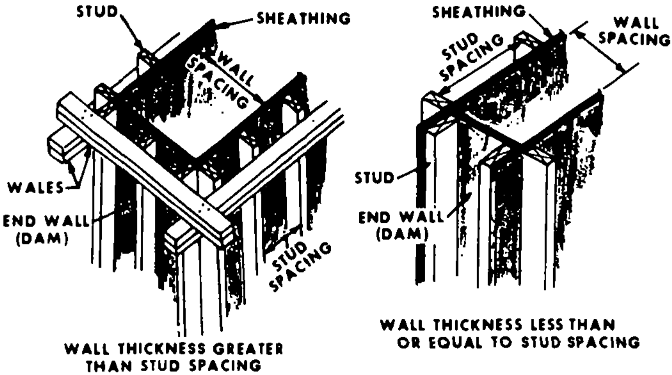


Figure 8–5. Recommended end wall (dam) details.

b. Wall Form Design. When more detailed form design methods are unavailable and 2 x 4 framing lumber is to be utilized (single 2 x 4 studs and double 2 x 4 wales), table 8–2 may be used as follows:

(1) Determine the rate of pour in feet per hour (the height of concrete being placed into the form per hour).

(2) Select the sheathing material to be used.

(3) Read the center–to–center stud spacing in inches.

(4) Read the center--to–center wale spacing in inches.

(5) Select the column for the tie material to be used (8, 9, or 10 gage wire or 3000--lb manufactured tie rods). Read, in inches, the maximum spacing of ties to be placed at each wale.

Table 8-2. Wall Form Design

MAXIMUM RATE OF POUR (FT/HR)	SHEATH MATERIAL	STUD SPACING	DOUBLE WALE SPACING	MAXIMUM TIE SPACING			
				8 GA	9 GA	10 GA	3000 LB TIE RODS
4′	5/8″ Plywood	8″	24″	17″	14″	11″	27″
	1″ Board	16″	16″	25″	21″	17″	29″
8′	5/8″ Plywood	6″	24″	8″	7″	6″	15″
	1″ Board	12″	16″	12″	10″	9″	22″
12′	3/4″ Plywood	6″	16″	8″	7″	6″	15″
	1″ Board	8″	16″	8″	7″	6″	15″
	2″ Board	16″	12″	11″	9″	8″	20″

CHAPTER 9

MILITARY ROAD CONSTRUCTION

9–1. CROSS–SECTION OF A TYPICAL MILITARY ROAD (fig. 9–1)

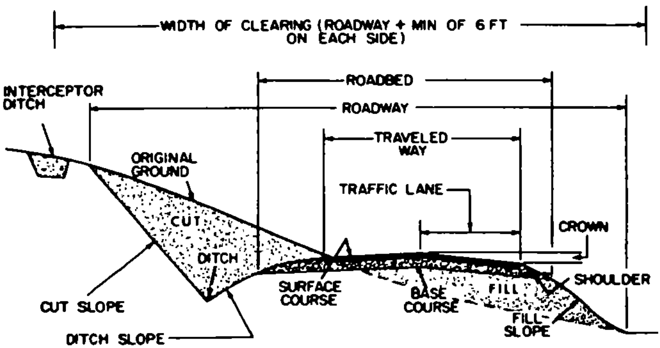


Figure 9–1 Typical cross section illustrating road nomenclature

9–2. MINIMUM DESIGN REQUIREMENTS (table 9–1)

Table 9–1 Military Road Specifications

Characteristics	Specification
Width	
Traveled way (single lane)	Min 11.5 ft (3.5 meters)
Traveled way (two lanes)	Min 23 ft (7.0 meters)
Shoulders (each side)	Min 4 ft (1.5 meters)
Clearing	Min–6 ft (2 meters) on each side of roadway
Grades	
Absolute maximum	Lowest maximum gradability of vehicles for which road is built
Desirable maximum	Tangents and gentle curves, less than 6%, sharp curves, less than 4%
Horizontal curve radius	Desired min - 150 ft (45 meters)
Vertical curve length	
Invert curves	100- ft min (30 meters) for each 4% algebraic difference in grades
Overt curves	125 ft min (40 meters) for each 4% algebraic difference in grades
Sight distance:	
Nonpassing	Absolute minimum–200 ft (60 meters)
Passing	Absolute minimum–600 ft (180 meters)
Load capacity:	
Road proper	Sustain 18,000–lb single axle, dual wheel equivalent load
Bridges	Accommodate using traffic
Slopes:	
Shoulders	¾ to 1½ in per ft
Crown (gravel and dirt)	½ to ¾ in per ft
Crown (paved)	¼ to ½ in per ft
Superelevation	½ to 1 ¼ in per ft
Cut	Variable (Determined by soil types versus compaction)
Fill	Variable (Determined by soil types versus compaction)
Drainage	Adequate crown or superelevation with adequate ditches and culverts in good condition. Take full advantage of natural drainage. Try to locate road at least 5 ft above the ground water table.
Miscellaneous:	
Overhead clearance	Min–14 ft (4.3 meters)
Traffic volume	2,000 vehicles per day
Turnouts (single lane)	Min–every ¼ mile

9-3. CONSTRUCTION STAKES (fig. 9-2)

9-4. SOILS

a. Soils Pertinent to Roads and Airfields (table 9-2).

b. Procedure for Field Identification Tests of Soils (fig. 9-3).

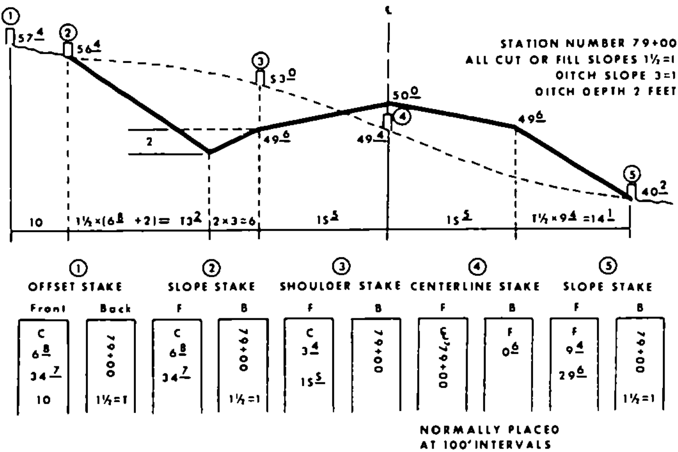


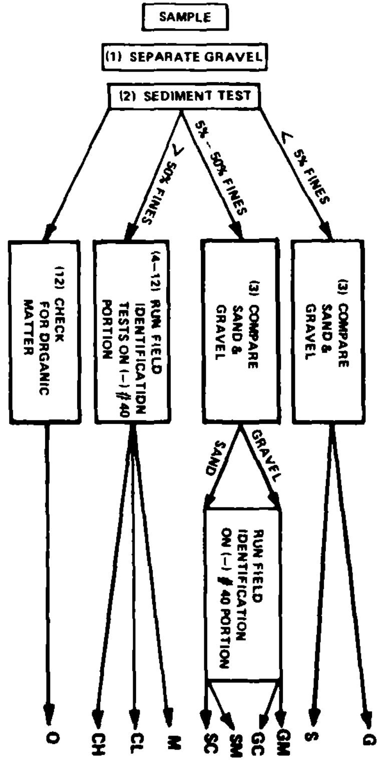
Figure 9-2. Diagram of construction stake placement and marking.

Table 9–2 Soil Characteristics

Symbol	Description	Drainage Characteristics	Airfield Index (Frost Susceptibility)	Value as A Subgrade	Value as A Subbase	Value as A Base	Compaction Equipment
G	Gravels and Sandy Gravel with little or no Fines	Excellent	None to very Slight	Good to Excellent	Good to Excellent	Fair to Good	Crawler Tractor, Rubber Tire Roller, Steel Wheel Roller
GM	Silty Gravels, Gravel-Sand Silt Mixture	Fair to Practically Impervious	Slight to Medium	Good	Fair to Good	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
GC	Clayey Gravels, Gravel, Sand-Clay Mixtures	Poor to Practically Impervious	Slight to Medium	Good	Fair	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
S	Sands and Gravels, Sands with little or no Fines	Excellent	None to very Slight	Fair to Good	Fair to Good	Poor to not Suitable	Crawler Tractor, Rubber Tire Roller
SM	Silty-Sands, Sand-Silt Mixtures	Fair to Practically Impervious	Slight to Medium	Fair to Good	Poor to Fair	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
SC	Clayey Sands, Sand-Clay Mixtures	Poor to Practically Impervious	Slight to High	Poor to Fair	Poor	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller

Table 9–2. Soil Characteristics (Continued)

Symbol	Description	Drainage Characteristics	Airfield Index (Frost Susceptibility)	Value as A Subgrade	Value as A Subbase	Value as A Base	Compaction Equipment
M	Inorganic silts & very fine sand rock flour, clayey silts with slight plasticity	Fair to Poor	Medium to High	Poor to Fair	Not Suitable	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
CL	Inorganic clays low to medium Plasticity, gravelly or sandy clays	Practically Impervious	Medium to High	Poor to Fair	Not Suitable	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
CH	Inorganic clays of high plasticity	Practically Impervious	Medium	Poor to Fair	Not Suitable	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
O	Mineral grains containing highly organic matter	Poor to Practically Impervious	Medium to High	Poor to Very Poor	Not Suitable	Not Suitable	Rubber Tire Roller, Sheepsfoot Roller
PT	Peat and other highly decomposed vegetable matter	Fair To Poor	Slight	Not Suitable	Not Suitable	Not Suitable	Compaction not Practical



NOTE: THIS PROCEDURE WILL GIVE A VERY HASTY CLASSIFICATION OF SOILS, AND SHOULD NOT BE USED FOR DESIGN OF PERMANENT OR SEMIPERMANENT CONSTRUCTION.

Figure 9–3 Procedure for field identification tests of soils.

(1) *Separate gravel*

(a) Remove from the sample all particles larger than ¼" diameter (# 4 sieve).

(b) Estimate the percent of gravel.

(2) *Sedimentation test to determine % sand.* (This test eliminates fines.)

METHOD ONE

(a) Place the sample (less gravel) in canteen cup and mark the level with a grease pencil.

(b) Fill with water and shake the mixture vigorously.

(c) Allow the mixture to stand for 30 seconds to settle out.

(d) Pour off the water.

(e) Repeat steps (b) through (d) until the water poured off is clear.

(f) Dry the soil left in the cup (sand).

(g) Estimate % sand by comparing the new level of sand with the mark. % sand = total beginning volume of sample minus % gravel eliminated in paragraph (1) (b) above minus fines eliminated in (2) (a) thru (2) (f) above.

OR

METHOD TWO

(a) Put approximately 1" of the sample in a flass jar.

(b) Mark the depth of the sample with a grease pencil.

(c) Fill the jar with 5 to 6 inches of clear water. Leave 1" of air at the top.

(d) Shake the mixture vigorously (3 to 4 minutes).

(e) Allow the sample to settle for 30 seconds.

(f) Compare the sediment line with the grease pencil mark.

(g) Estimate % sand settling to the bottom of the jar (by volume, compare the sediment line with the grease pencil mark). % sand = total beginning volume of sample minus % gravel eliminated in (1) (b) above minus fines eliminated in (2) (a) thru (2) (f) above.

(3) *Comparison of gravel, sand, and fines.*

(a) Percent of gravel was estimated in paragraph (1) (b) above.

(b) Percent of sand was estimated in paragraph (2) (g) above by either of two methods.

(c) Percent of fines = 100 minus % gravel minus % sand.

(4) *Dry strength.*

(a) Form a moist pat 2" in diameter by ½" thick.

(b) Allow to dry with low heat.

(c) Place the dry pat between thumb and index finger only and attempt to break.

(d) If the pat breaks easily, it is silt (M). If the pat is difficult to break, it is low compressible clay, (CL). If breakage is impossible, it is high compressible clay (CH).

(5) *Powder Test.*

(a) Rub a portion of the broken pat with the thumb and attempt to flake particles off.

(b) If the pat powders, it is silt (M). If the pat does not powder, it is clay (C).

(6) *Feel Test.*

(a) Rub a portion of dry soil over a sensitive portion of the skin, such as the inside of the wrist.

(b) If the feel is harsh and irritating, sample is silt (M).

(c) If the feel is smooth and floury, sample is clay (C).

(7) *Shine test.*

(a) Draw a smooth surface, such as a knife blade or thumb nail, over a pat of slightly moist soil.

(b) If the surface becomes shiny and lighter in texture, the sample is a high compressible clay (CH). If the surface remains dull, the sample is a low compressible clay (CL). If the surface is very dull or granular, the sample is silt (M) or sand (S).

(8) *Thread test.*

(a) Form a ball of moist soil (marble size).

(b) Attempt to roll the ball into a 1/8" diameter thread (wooden match size).

(c) If a thread is easily obtained, the ball is clay (C). If a thread cannot be obtained the ball is silt (M).

(9) *Ribbon test.*

(*a*) Form a cylinder of moist soil approximately cigar shape in size.

(*b*) Flatten the cylinder over the index finger with the thumb, and try to form ribbon 8 to 9 inches long, 1/8 to 1/4 inch thick, and 1 inch wide.

(*c*) If an 8 to 9 inch ribbon is obtained the sample is high compressible clay (CH). If the ribbon is less than 8 inches, it is low compressible clay (CL). If no ribbon can be obtained, the sample is silt (M) or sand (S).

(10) *Grit, or bite test.*

(*a*) Place a pinch of the sample between the teeth and bite.

(*b*) If the sample feels gritty, it is silt (M). If the sample feels floury, it is clay (C).

(11) *Wet shaking test.*

(*a*) Place a pat of very moist (not sticky) soil in the palm of the hand.

(*b*) Shake the hand vigorously and strike against the other hand.

(*c*) Observe the rapidity of the water rising to the surface. If fast, the sample is silty (M). If there is no reaction, sample is clayey (C).

(12) *Odor test.*

(*a*) Heat the sample with a match or open flame.

(*b*) If the odor becomes musty or foul smelling, this is a strong indication that organic material is present.

c. Determination of Optimum Moisture Content (OMC) To determine whether or not a soil is at or near OMC, mold a golf ball size sample of the soil with your hands. Then squeeze the ball between your thumb and fore fingers. If the ball shatters into several fragments of rather uniform size, the soil is near or at OMC. If the ball flattens out without breaking, the soil is wetter than OMC. If, on the other hand, the soil is difficult to roll into a ball or crumbles under very little pressure, the soil is drier than OMC.

9–5. DRAINAGE

a. Ditches.

(1) A triangular "Vee" ditch is normally used for relatively small volumes of water. It is easily cut with the motorized grader.

(2) A trapezoidal ditch should be used where:

(a) Large quantities of water are expected to be handled.

(b) Fine–grained soils are present, and high water velocities (over 3 to 4 fps) will cause excessive erosion.

(3) Minimum longitudinal slope for ditches is 0.5%, 2% preferred, and 4% is the maximum allowable without erosion controls. In fine–grained soils, erosion controls may be required in ditch slopes much less than 4%.

(4) In the absence of more detailed design, a good roadside ditch is a 2--foot--deep triangular ditch having slopes of 3:1 on the side adjacent to the roadway and 1:1 on the outside.

b Check dams. Check dams are used to slow the water and prevent erosion in ditches that have longitudinal grades of 2% to 8%. They may be made of timber, sandbags, concrete, rock, or similar materials. Figure 9--4 shows the method of computing check dam spacing.

c. 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) By field estimate method (Use for an area of ≤ 100 acres that <u>*does not*</u> have a stream flowing through it.)

$$Q = 2\ ARC$$

Q = The volume of water in cubic feet per second

2 = A constant

A = The area of the drainage basin in acres

R = The design rainfall intensity based on the 1–hour, 2–year frequency rainstorm

C = The ratio of runoff to rainfall

Step 1. *"A" Area* "What area is draining?"

a. Delineation–Determining Area and Converting to Areas

(1) Use a topo map.

(2) Locate the proposed drainage structure.

(3) Confirm the location and topography by reconnaissance.

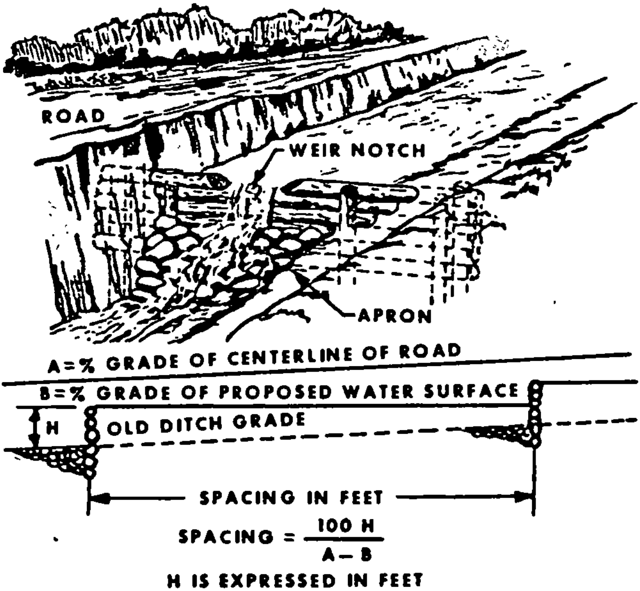


Figure 9–4. Methods of computing check dam spacing

b. *Method of Delineation on Topo Map.*

(1) Locate proposed or existing structures.

(2) Locate the high points.

(3) Draw flowlines from the high points perpendicular to the contours.

(4) Delineate (outline) the drainage basin.

c. Methods of Measuring the Area by Use of a Map Scale

(1) Stripper method

(2) Planimeter method

(3) Geometric method (sum or rectangles and triangles)

(4) Convert to acres (1 acre = 43,560 square feet)

Step 2. *"R" Rainfall* "How much rain can I expect?"

Determine the 1–hour, 2–year frequency rainstorm from the isohyetal map. (inches hour). See figure 9–5.

(1) Locate applicable geographic area.

(2) If the area is close to an isohyet, select its value as "R".

(3) If the area is between two isohyets, select the larger value as "R".

Step 3. *"C" Runoff Coefficient* "What ratio of water is going to run off?"

a. Select one of the following values of "C":

(1) Impervious (asphalt, concrete, "tight" clay) = 1.0

(2) Pervious (well–graded gravel, beach sand) = 0.25

(3) All other = 0.5

b. Or refer to the "C" value, table 9–3.

Step 4. *"Q" Runoff in Cubic Feet per Second* (Q = 2 ARC)

Step 5. *Determine Cross–Sectional Area of Water*

a. Q = AV

b. A = Cross–sectional area of water in square feet

c. V = Velocity, in feet per second; *use 4 fps*

d. $A = \frac{Q}{4}$

Step 6. *Culvert Design*

a. Slope should be 0.4% minimum to 2.0% maximum; *use 1 0%.*

b. Culvert design area = 2 x A (cross–sectional area of water).

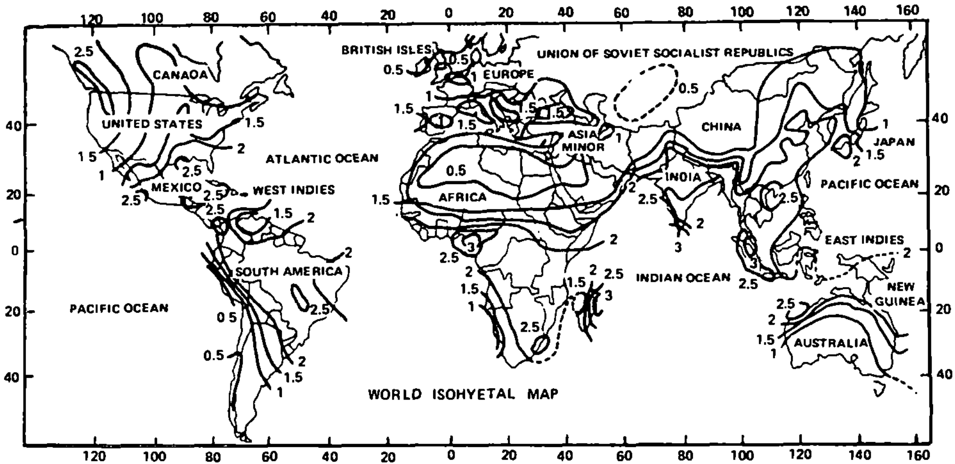
c Find the critical (minimum) fill depth (F_{min}).

d. Compute the maximum pipe diameter ($D_{max} = 2/3\ F_{min}$).

e. Select the maximum pipe diameter that can be used from table 9–4.

f. Compute the most economical pipe size and number of pipes:

$$\frac{\text{Design area}}{\text{End area of one pipe from table 9–4}}$$



ISOHYETS REPRESENTS INCHES OF MAXIMUM RAINFALL IN ONE HOUR FOR STORM OF 2–YEAR FREQUENCY

Figure 9–5. World isohyetal map.

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.

g. Compute the length of one pipe (in place).

NOTE. Round up to an even whole number, then add 2' if there is no headwall downstream.

h Compute the total length of pipe in place. (length of one pipe, in place times the number of pipes required).

i. Compute the order length (total length required, in place, times 1.15).

Table 9–4. Recommended Gages For Nestable Corrugated Metal Pipe (CMP)

Diam In Inches	Cross-sectional area (sq ft)	Gage Pipe required for. 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	10	16	16	16	14	14	14
30	4.61	14	14	14	14	14	12	12
36	7.07	14	14	14	12	12	12	10
42	6.62	14	14	12	12	10	10	8
48	12 57	12	12	12	10	8	6	6
54	15.90	12	12	10	6	6	6	8
60	16.84	12	10	8	6	8	8	6
66	23 76	10	10	8	6	6	8	
72	28.27	10	10	8	6	6		
78	33.16	6	6	8	6	MUST BE DESIGNED FOR THESE FILL HEIGHTS AND OTHERS ABOVE 40 FT.		
84	38.46	8	8	8	8			

NOTES: CULVERTS MUST BE STRONG ENOUGH TO CARRY WEIGHT OF FILL ABOVE PLUS WEIGHT OF THE LIVE LOAD PASSING OVER ROAD.

CULVERTS BELOW LINE SHOULD BE STRUTTED DURING INSTALLATION.

Step 7. *Ditch Design*

a. Guidelines.

(1) If Q $>$ 60 cfs, use a trapezoidal ditch.

(2) If Q $\leq$ 60 cfs, use a triangular (vee) ditch.

(3) Slope should be 0.5% to 2.0% without erosion controls.

(4) Side slope should be 3:1, 1:1 when cut by grader.

(5) Freeboard should be a minimum of 0.5 feet.

b. Trapezoidal. Compute as a rectangle, ignoring side slopes. See figure 9–6. Select width and calculate depth of water (d).

(1) $A = dw \qquad d = \frac{A}{W}$

(2) w = 10 feet when cut by scraper $d = \frac{A}{10}$

(3) Cutting Depth = d + 0.5′

c. Triangular. Select side slopes and calculate depth of water (d). See figure 9–6.

(1) $A = \frac{1}{2}(BH)$

$B = Xd + Yd$

$H = d$

$d = \sqrt{\frac{2A}{x + y}}$

(2) If side slopes 3:1, 1:1

$d = \sqrt{\frac{A}{2}}$

(3) Cutting depth = d + 0.5′

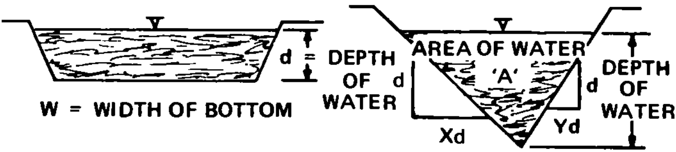


Figure 9–6. Ditch design.

(b) By hasty computation method. (Use for an area that has a stream flowing through it).

Step 1. *Calculating the Design Area* See figure 9--7.

a. Locate the high water mark.

b Measure the width of the stream at the high water mark (W_1).

c Measure the width of the stream at the bottom (W_2).

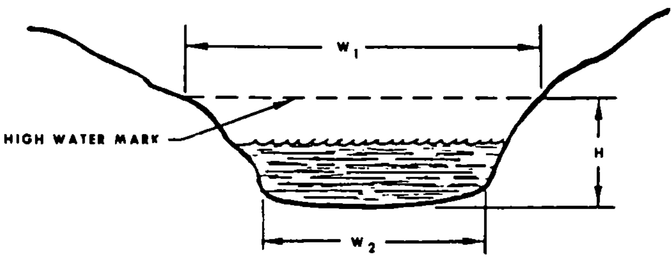
d Measure from the bottom of the stream to the high water mark (H).

e. Calculate the design area (2 x cross--sectional area).

(1) $\frac{(W_1 + W_2)}{2} H \times 2$

or:

(2) $(W_1 + W_2) H$



W_1 = WIDTH OF CHANNEL AT HIGH WATER MARK

W_2 = WIDTH OF CHANNEL AT BOTTOM

H=VERITICAL DISTANCE FROM BOTTOM TO HIGH WATER MARK

$\left(\frac{W_1 + W_2}{2}\right)$ H=AREA OF WATERWAY

SIZE OF CULVERT=AREA OF WATERWAY+SAFETY FACTOR 100%

Figure 9–7. Computation of culvert size by hasty method.

Step 2. *Culvert Design*

a Find the critical (minimum) fill depth (F_{min}).

b Compute the maximum pipe diameter ($D_{max} = 2/3F_{min}$).

c Select the maximum pipe diameter that can be used from table 9–4.

d Compute the most economical pipe size and number of pipes:

$$\frac{\text{Design area}}{\text{End area of one pipe from table 9–4}}$$

e Compute the length of one pipe (in place).

NOTE · Round up to an even whole number, then add 2' if there is no headwall downstream.

f Compute the total length of pipe in place (length of one pipe, in place times the number of pipes required).

g Compute the order length (total length required, in place, times 1.15).

(3) *Culvert alinement* 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 road centerline. Ditch relief culverts should be installed at an angle of 60° to the ditch centerline.

(4) *Design criteria–CMP culvert.* See figure 9–8.

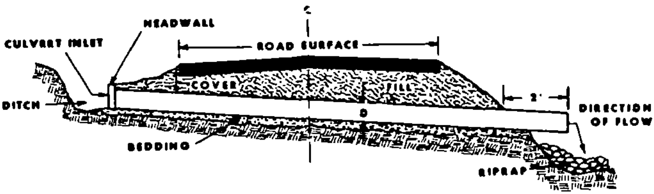


Figure 9–8. Culvert extended beyond fill to prevent erosion

(b) Select the culvert size based on the following:

1 Area of culvert required.

2 Minimum cover of ½D or 12 inches under the road surface. (table 9-4).

3 Culvert available.

(c) Place the inlet elevation at or below the ditch bottom.

(d) Extend the culvert 2 feet minimum downstream beyond the fill slopes.

(e) Use bedding of 1/10D minimum.

(f) Space multiple culverts a minimum of ½D apart.

(g) Desirable slope is 2 to 4%, minimum slope, 0.5%.

(h) Always use a headwall upstream.

(i) Rip—rap downstream to control erosion.

(5) *Corrugated metal pipe—size and strength.* See table 9—4.

(6) *Expedient culvert (fig. 9—9).*

9—6. SOIL STABILIZERS

See table 9—5.

9—7. EXPEDIENT SURFACES

a. When normal means of construction are not available or time is limited, expedients must be used.

b. Expedient surfaces over mud must be structurally strong and spread the load over a wide area of the subgrade.

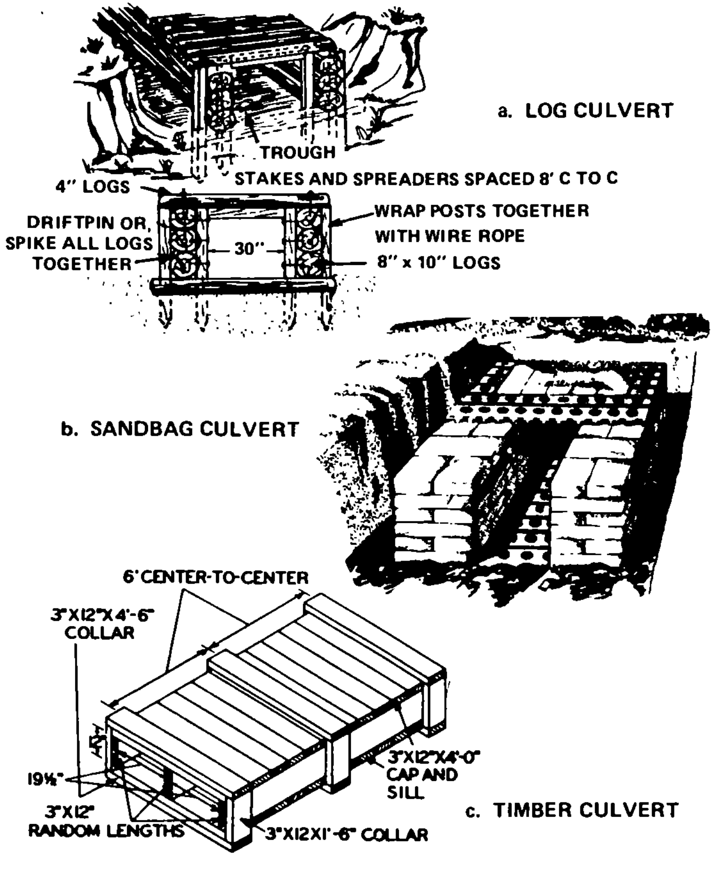


Figure 9–9. Example of expedient culvert.

Table 9–5. Summary of Soil Stabilizers

MATERIAL	FORM OF MATERIAL	APPLICABLE SOIL RANGE	ESTIMATED RANGE OF QUANTITY REQUIREMENTS (%) +	MINIMUM CURING TIME REQUIREMENTS
PORTLAND CEMENT	POWDER	GRAVELS SANDS SILTS, CLAYEY SILTS CLAYS	3—4 3—5 4—6 6—8	24 HOURS
LIME 1. HYDRATED	POWDER	CLAYEY GRAVELS SILTY CLAYS CLAYS	2—4 5—10 3—8	7 DAYS
2. QUICKLIME	POWDER	CLAYEY GRAVELS SILTY CLAYS CLAYS	2—3 3—8 3—6	4 HOURS
BITUMINOUS MATERIAL: 1. ASPHALTIC CUTBACKS A. RC-70 TO RC-800	LIQUID	SANDS SILTY SANDS CLAYEY SANDS	5—7++ 6—10 6—10	1—3 DAYS
B. MC-70 TO MC-800	LIQUID	SANDS SILTY SANDS CLAYEY SANDS	5—7 6—10 6—10	1—3 DAYS
2. ASPHALTIC EMULSIONS	LIQUID	SANDS SILTY SANDS CLAYEY SANDS	5—7 6—10 6—10	1—3 DAYS

+BASED ON DRY DENSITY OF EXISTING SOIL.

++ALL QUANTITIES LISTED FOR ASPHALTS ARE ACTUAL BITUMEN REQUIREMENTS, EXCLUSIVE OF VOLATILES.

(1) *Chespaling.* Chespaling–mat roads (fig. 9–10) are composed of a series of mats 6½ by 12 feet, or larger. The mats are made by placing small saplings 6½ feet long and about 1½ inches in diameter side by side, and wiring them together with chicken wire mesh or strands of heavy smooth wire. A chespaling road is constructed by laying mats lengthwise with a 1–foot side overlap at the junction of the mats. The resulting surface is 12 feet wide. Unless laid on wet ground, this type of road requires periodic wetting down to retain its springiness and to prevent splitting. It also requires extensive maintenance.

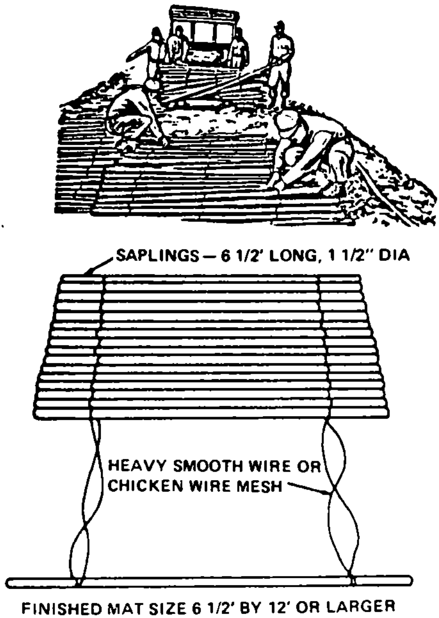


Figure 9–10. Chespaling.

(2) *Corduroy*

(a) Standard corduroy (fig. 9–11a).

Six–to–eight–inch- -diameter logs about 13 feet long are placed adjacent to each other (butt to tip). Along the edges of the roadway thus formed, place 6 inch diameter logs as curbs (drift–pinned in place). Pickets about 4 feet long are driven into the ground at regular intervals along the outside edge of the road to hold the road in place. To give this surface greater smoothness, full up the chinks between logs with brush, rubble, twigs, etc.; then cover the whole surface with a layer of gravel or dirt. Side ditches and culverts are constructed as for normal roads.

(b) Corduroy with stringers (fig 9–11b). The corduroy decking is securely pinned to stringers and then the surface is prepared as (a) above.

(c) Heavy corduroy (fig. 9–11c). Heavy corduroy involves the use of sleepers, heavy logs 10 to 12 inches in diameter and long enough to carry the entire road, placed at right angles to the centerline on 4 foot centers.

(3) *Tread roads (fig. 9–12).* Tread roads are made by preparing two narrow parallel treadways of select material for vehicular wheels to use over otherwise impassable ground. The material used may be anything from palm leaves to 4 inch planks with a consequent wide variation in the capacity and durability of the road. The most important single type of tread road is the plank tread road. Sleepers 12 to 16 feet long are first laid perpendicular to the centerline, on 3 to 4 foot centers, depending on the loads to be carried and subgrade conditions. If finished timber is not available, use logs as sleepers. Then place 4– by 10–inch planks parallel to the line of traffic to form two treads about 36 inches apart. Stagger the joints to prevent the forming of weak spots. Next install 6-- by 6- inch timber curbs on the inside of the treads.

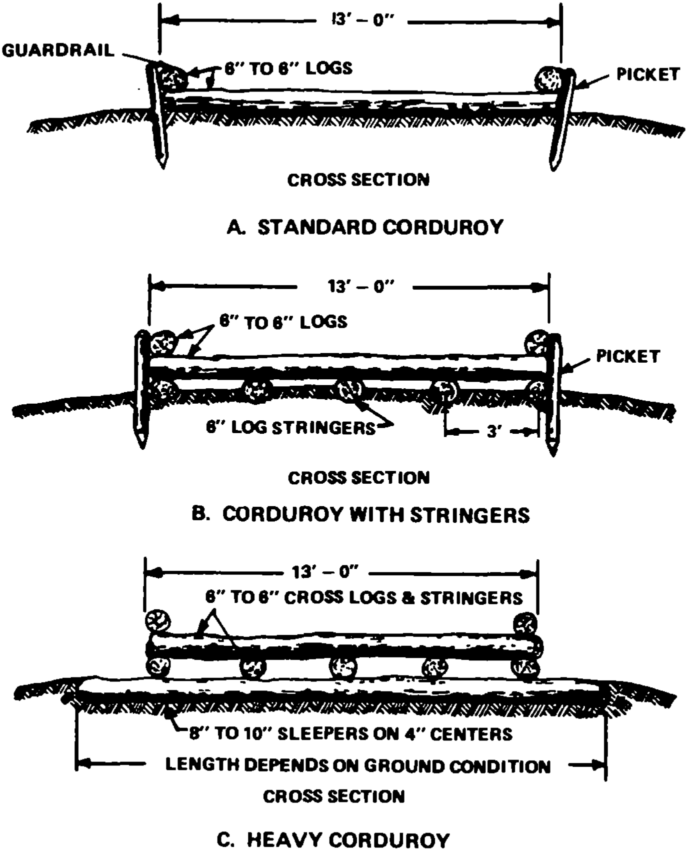


Figure 9–11. Corduroy road surfaces.

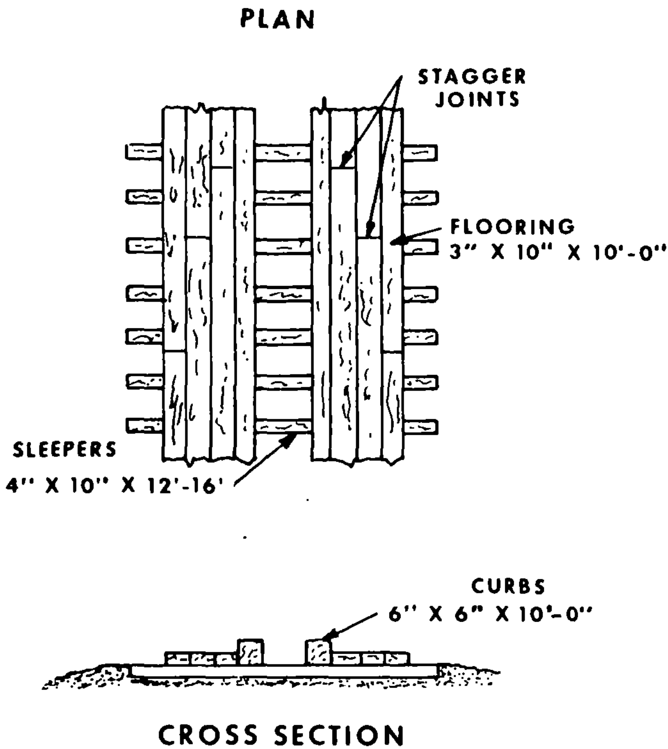


Figure 9–12. Tread road.

c. Expedient surfaces over sand must confine the sand in a manner which will develop the necessary load–carrying capacity.

(1) *Wire mesh.* Chicken wire, expanded metal lath, and chain link wire mesh (cyclone fence) may be used as road expedients in sand. They should not be used on muddy roads since they prevent grading and reshaping of the surface when ruts appear. The addition of a layer of burlap or similar material underneath helps to confine the sand. Any type of wire mesh expedient must be taut. To accomplish this, the edges of the wire mesh road must be picketed at 3–to–4 foot intervals. Diagonal wires, crossing the centerline at 45° angles and attached securely to buried pickets, fortify the lighter meshes. As with all other road surfaces, the more layers used the more durable the road will be.

(2) *Army track (fig. 9–13).* A portable timber expedient known as Army track can be used to pass vehicles across sandy terrain. The track consists of 4 x 4 or larger timbers threaded at each end on a ½–inch wire rope and resembles the ties of a railroad track with a cable running through the ties on each side. The timbers must be spaced not greater than the distance which will allow the smallest wheeled vehicle using the road to obtain traction. Cable holes are drilled at a 45° angle to the centerline so the cable will bend and prevent individual timbers from moving together. Cables are anchored securely at both ends. The spaces between the timbers are filled in with select material to smooth out the surface.

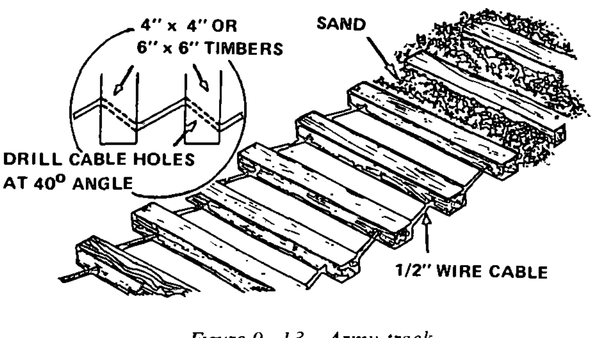


Figure 9–13. Army track.

d Metal Landing Mats (fig. 9–14). Airfield landing mats can be used to form an expedient road surface over either mud or sand. Generally, only M8 and M8A1 would be used in this capacity and, as far as road construction is concerned, their characteristics are the same. When used on sand, the metal landing mats can be placed directly on the sand to the length and width desired, though burlap on straw underneath the planking is desirable. The smoother and firmer the subgrade, the better the resulting road. The mat is placed so that its long axis is perpendicular to the flow of traffic and each section overlaps the previous one enough that the manner of connecting prescribed for the particular mat can be accomplished.

If a width greater than the effective length of one plank is constructed, half–sections are used to facilitate staggering of joints. M8 mat can be used on mud but, being perforated, the mat sinks until it becomes ineffective. Experiments have proven that with the use of an underlying layer of brush on burlap to prevent the pumping of the mud, a fairly effective expedient can be constructed. A second layer of the steel mat, laid as a treadway over the initial layer, will further increase its effectiveness. In either case, the foundation should be as smooth as possible.

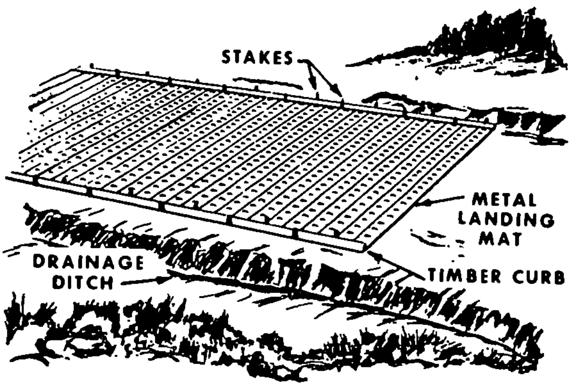


Figure 9–14 Metal landing mat road.

CHAPTER 10

ARMY AIRFIELDS, HELIPADS, AND HELIPORTS

10–1. GENERAL

Information listed for airfields is for reference only. For design specifications refer to TM 5--330.

10–2. ARMY AIRCRAFT AND HELICOPTER CHARACTERISTICS

Aircraft and helicopter characteristics are shown in tables 10–1 and 10--2.

10–3. HELIPADS IN HEAVILY FORESTED AREAS

a. Personnel. The suggested work crew consists of an officer in charge and two teams, each composed of a noncommissioned officer and five enlisted men -- two chain saw operators, two axemen men, and one brush hook man. Weight of an individual is assumed to be 200 pounds.

b. Equipment. The following equipment per team is to be contained in the equipment box. The weight of the box loaded with the equipment is approximately 333 pounds.

2	Chain saws
1	Brush hook
3	Axes
1	Block and tackle set (1 single and 1 double)
1	Set climbers with safety straps
1	Can gasoline
16	2½ lb. Blocks of C--4
2	Cans of oil
250	Meters of Demo wire
1	Galvanometer
1	Ten-cap blasting machine

20 Electric blasting caps
1 Brace with bits
1 Sledge hammer
2 Wedges
2 Screwdrivers
2 Pliers

c. Procedure.

(1) *Equipment and personnel delivery.* Equipment is delivered into the proposed landing area by lowering it in a box. Modification of the equipment requirements may be desired depending upon the expected area of employment. The box is slung beneath the helicopter by the aircraft cargo hook. Rappelling ropes are then attached to the box and secured to the floor–mounted D–rings inside the helicopter. Since, in the event of an in–flight emergency, the pilot cannot jettison the external load, engineers within the cargo compartment are responsible for cutting or releasing the ropes upon direction by the pilot or copilot. To lower the box to the ground, the cargo hook is released and the box is lowered by hand using the attached rappelling ropes. All personnel in the team are equipped with field equipment, machetes, weapons, and other items which are carried on the person during rappelling activities. Other field gear, if utilized, is inclosed in the equipment box lowered from the helicopter.

(2) *Preparation of landing zone.*

(a) The first man on the ground removes the rappelling ropes from the equipment box. The officer in charge starts laying out strips of engineer tape to mark the perimeter of the proposed landing area.

(b) The chain saw crews, axe crews, and brush hook man move into the proposed landing area, felling and clearing all vegetation within the perimeter of the tape--marked landing area.

(c) Upon felling the trees as close as possible to ground level, necessary limbing and bucking is done for easier removal. It is imperative that in felling and cutting, any vegetation that may be sucked up into the helicopter blades must be removed from the landing area proper. Vegetation should not be burned. Time permitting, or under marshy conditions, the timbers felled may be used to prepare a hardened landing pad. Landing pad logs are leveled to insure a satisfactory surface upon which the helicopter skids can rest without danger of skid damage. The perimeter of the landing area must be checked to assure vertical clearance. In densely wooded areas

Table 10–1. Aircraft Characteristics Used in Design of Theater of Operations Airfields

Airfield type	Anticipated service life	Possible using aircraft U.S. type	Gross weight	Ground run at sea level and 59°, ft[b]	Minimum length required, ft	Width ft
Battle area	3 days					
Light lift		C 7A[a]	25,000	625	1,000	50
Medium lift		C–130[a]	100,000	1,600	2,000	60
		C-123	48,000	1,600		
Forward area:	2 weeks					
Liaison		O-1[a]	2,400	390	750	50
Surveillance		OV-1[a]	15,800	2,000	2,500	60
Light lift		C-7A[a]	28,500	825	1,200	60
Medium lift		C-130[a]	110,000	2,000	2,500	60
		C-7A	28,500	825		
Support area.	1-2 mos					
Liaison		O–1[a]	2,400	390	1,000	50
Surveillance		OV-1[a]	15,800	2,000	3,000	60
Light lift		C-7A[a]	28,500	625	1,500	60
Medium lift		C 130[a]	130,000	2,800	3,500	60
		C-7A	28,500	625		
Heavy lift		C-124[a]	190,000	4,000	6,000	100
		C-141[a]	260,000	2,400		
Tactical		F-4C[a]	56,000	4,000	5,000	60
		F–101	51,000	4,000		
Rear area:	6-12 mos					
Army		OV–1[a]	15,800	2,000	3,000	72
		C-7A	28,500	625		
		O–1	2,400	390		
Medium lift		C-130[a]	155,000	4,000	8,000	72
Heavy lift		C-141[a]	316,000	3,900	10,000	156
		C-135[a]	250,000	6,700		
		C-133	300,000	5,300		
Tactical		F-4C[a]	56,000	4,000	8,000	108
		F 105[a]	53,000	5,300		
		F–100	37,800	5,000		
		F–101	51,000	4,000		
		F-104	28,000	5,200		

[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 correction, temperature correction and local conditions.

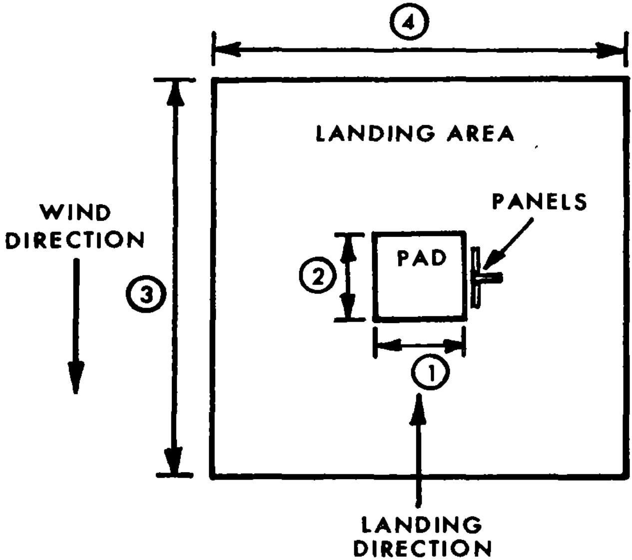
Table 10–2. Helicopter Characteristics

Helicopter Designation		Overall Dimensions Ft			Weight, Kips		
Design	Name	Length	Width	Height	Basic	Maximum takeoff	Gear Type
OH–8A*	Cayuse	30.30	26.30	8.20	1.16	2.70	Skid
OH–13S	Sioux	43.25	37 00	12 00	1 81	2.85	Skid
OH–23G	Raven	43 25	35 16	10 16	1.91	2.80	Skid
OH–58A	Kiowa	41.00	35.30	9 60	1.59	3.00	Skid
UH–1B	Iroquois	52 83	44.00	18 41	5.08	8.50	Skid
UH–1C	Iroquois	52.83	44.00	12.67	4.82	8.50	Skid
UH–1D*	Iroquois	57.01	48.00	17.16	4.82	8.50	Skid
CH–34	Choctaw	65.83	56.00	15.83	7.78	13.30	Single-conventional
CH–37B	Mojave	88.00	72.00	22.00	21.50	31.00	Twin-conventional
CH–47A	Chinook	98.01	59 18	18.50	18.04	33.00	Twin-quad
CH–47B	Chinook	99.00	60 00	18.87	18.59	40.00	Twin-quad
CH–47C	Chinook	99.00	60.00	16.67	20.48	48.00	Twin-quad
CH–54A*	Flying Crane	88.41	72.00	25.33	19.82	42.00	Single-tricycle
AH–1G	Huey Cobra	52.97	44.00	11.00	....	....	Skid

and jungle forest, it will be necessary to fell additional trees to provide an approach and departure zone. The normal time for clearing such a landing zone in tropical zone forests by well–trained troops should not exceed 3 hours for a UH–1 and smaller helicopter landing zones.

10–4. LAYOUT AND NOMENCLATURE

Landing reference panels serve as a visual guidance system during approaches. They must be positioned and firmly secured adjacent to the touchdown point before the landing of a helicopter. Figure 10–1 shows correct placement of landing reference panels on the ground. The general layout and nomenclature of Army helipads and heliports is illustrated in figures 10–1 thru 10–3.



PANELS ARE LAID OUT ON THE RIGHT SIDE OF THE LANDING PAD.

FOR DIMENSIONS OF THE LANDING AREA CORRELATE

ITEM NUMBERS TO TABLE 10–3

Figure 10–1. Panel layout of landing zones.

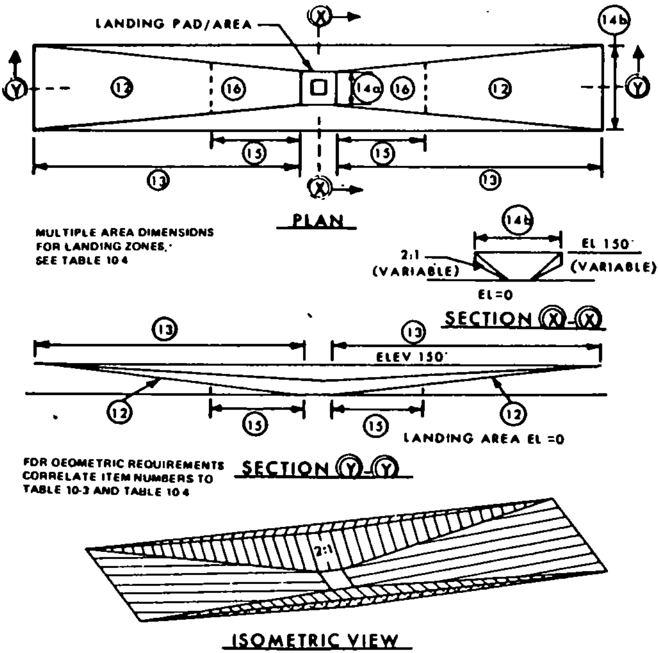


Figure 10—2. Geometric layout of landing zones

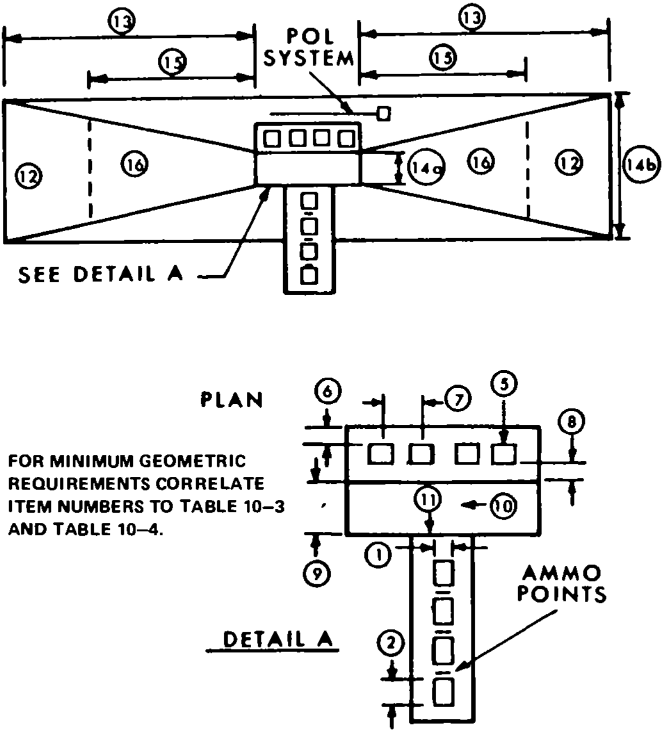


Figure 10–3. Geometric layout of forward area refueling and rearming heliports

10-5. DESIGN FOR LANDING ZONES

The general design requirements for landing zones and multiple area landing zones are shown Tables 10–3 and 10–4.

10-6. DUST CONTROL/SOIL WATERPROOFING

Sprinkling with water, lime solutions, and oils provide temporary relief from dust. Longer relief is achieved by use of asphaltic materials, such as Peneprime (APSB), 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 for approximate area to be sprayed.

10-7. MARKING IMPROVED HELIPADS AND HELIPORTS

The touchdown area marker for helipads is shown in figure 10–4. The dimensions of the pattern relative to the pad size are shown in this figure. The center of the marking pattern will always be placed at the center of the pad. This marking pattern will also be placed at both ends of all runways and taxi–hoverlanes used for landings. This pattern is intended as an indication of a safe touchdown point and is not to be placed at locations, such as parking areas, at which helicopters normally do not land or take off. The marking pattern will be white, but should be edged in black when placed on a light–colored surface. The broken line border around the perimeter of the pad will also be included on all helipads.

10-8. LANDING MATS

The types of landing mats and membrane are classified as follows:

a. Light duty landing mat– M6, M8, M8A1, and M9.

b. Medium duty landing mat– MX18B, MX19, and AM2.

c. Membrane– T17.

Table 10–3. Minimum Geometric Requirements for Landing Zones.

Item No.	Description	FORWARD AREA					
		OH 6A	OH-58	AH-1G	UH-1H	CH-47	CH-54
	LANDING PAD AND LANDING AREA						
1	Length, ft	12	15	20	20	50	50
2	Width, ft	12	15	20	20	25	50
3	Landing area length, ft	72	84	100	100	150	150
4	Landing area width, ft	72	84	100	100	125	150
5	Parking pad grade in any direction, % Maximum	3	3	3	3	3	3
6	Lateral clearance from rear and sides of parking pad to fixed and/or movable obstacles except other aircraft, ft	25	30	45	45	85	85
7	C–C spacing of parking pads, ft	40	50	75	75	150	150
8	Spacing from edge of Taxi-Hoverlane to edge of parking pad, ft	25	30	45	45	65	85
	TAXI HOVERLANE						
9	Width, ft[1]	75	90	140	140	180	200
10	Longitudinal grade of Taxi Hoverlane, % Maximum	10	10	10	10	10	10
11	Transverse grade of Taxi-Hoverlane % Maximum	5	5	5	5	5	5
	HELIPORT APPROACH AND DEPARTURE ZONE						
12	Approach-departure surface ratio	10 1	10:1	10 1	10 1	10:1	10:1
13	Length, ft	1500	1500	1500	1500	1500	1500
14	Widths, ft						
	a At end of clear zone or Taxi-Hoverlane	75	90	140	140	180	200
	b At outer end	850	850	850	850	850	850
	HELIPORT TAKEOFF SAFETY ZONE						
15	Length, ft	500	500	500	500	500	500
18	Width, ft	SAME AS APPROACH DEPARTURE ZONE					
	SERVICE ROADS						
17	Width, ft[2]	11 5	11 5	11 5	11 5	11 5	11.5

1 Taxi Hoverlane is used for take off and landing
2 Roads should be located so as to require the least effort

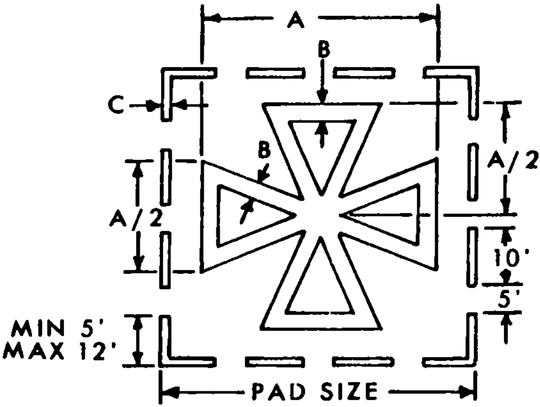
Table 10–4 Minimum Geometric Requirements for Multiple Area Landing Zones.

Item No.	Description	Forward area	
		UH–1	CH–47
1	One-ship landing zone		
	Length	100	150
	Width	100	125
2	Two-ship trail landing zone		
	Length	180	250
	Width	100	125
3	Two-ship side-by-side landing zone		
	Length	100	150
	Width	170	220
4	Three-ship trail landing zone		
	Length	260	375
	Width	100	125
5	Four-ship side-by-side trail		
	Length	180	250
	Width	170	220

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.



PATTERN SIZE (A) IS 0.80 HELIPAD SIZE

DIMENSIONAL CRITERIA

HELIPAD SIZES	PATTERN LINE WIDTH (B)	BORDER EDGE WIDTH (C)
FEET	FEET	FEET
12-19	1.0	0.5
20-40	2.0	1 0
41-60	3.0	1.5
61-80	4.0	2.0
81-99	5.0	2.0

Figure 10–4. Touchdown area marker.

10–9. REPAIR OF ARMY AIRFIELDS

a T–17 Membrane. When a tear occurs in the membrane surfacing on which antiskid compounds have been applied, the failed area should be repaired by slitting it in the form of an X and folding the four flaps back. Adequate membrane surfacing should then be removed from a roll of membrane and placed beneath the antiskid coated membrane so that it extends beyond the failed area of surfacing for approximately 2 ft on all sides. Adhesive should then be applied to the top of the membrane removed from the membrane roll and to the bottom of the surfacing coated with antiskid compound. Adhesive can be spread over the membrane with long handled paint rollers. After the adhesive becomes tacky (2 to 5 minutes), the flaps that were folded back previously should be placed in their original positions, and the adhesive should be allowed to set for approximately 15 minutes. The patched area should then be rolled with a jeep. This manner of patching should also be used for areas of surfacing that are not coated with antiskid compound, but surface patches can be used on uncoated membrane, particularly when the opening being patched is small.

b M8A1 and M8 Mats.

(1) *Removal.*

(a) Unlock the end connector bars (hooks) at both ends of the panel to be removed.

(b) Remove the 12 (6 per side) side connector locking lugs that hold the panel. (Break the weld on the locking lugs of the M8.)

(c) Drive the panel laterally (approximately 1 inch) until the side connector hooks are centered in the side connector slots.

(d) Pry the side connector hooks out of the slots.

(e) Drive the panel laterally to clear the end from the overlapping end of the adjacent panel.

(f) Remove the panel from the runway.

(2) . *Replacement.*

(a) Remove the side connector locking lugs of a new panel (break the welds on the M8) to allow the panel to slide laterally when positioned properly. Orient the new panel in all respects so that it will be in the approximate position in the run of that of the damaged panel.

(b) Drive the end of the new panel under the end of the adjacent panel so that the adjacent panel will overlap the new panel. (The panel will then be in its approximate final position.)

(c) Adjust the panel to aline the side connector hooks with the side connector slots. Engage the two by hammering together.

(d) Drive the panel laterally (in the same direction in which panels in the same run were slid during initial placement) to hook the side connectors.

(e) Lock the end connectors bars (hooks on the M8) at both ends of the panel.

(f) Replace and engage the side connector locking lugs in the locking lug slots (reweld on the M8).

c. *AM2 Mat and XM18B.*

(1) *Sliding method.*

(a) With a tooth of the harrow on a motor patrol or with other power equipment, engage a panel end in the same run with the damaged panel and force the entire run to slide out until the damaged panel clears the runway or taxiway edge.

(b) Disconnect the ends of all panels that have been slid from the runway by removing the end connector bars.

(c) Discard the damaged panel. Connect a new panel it its place and lock at the end with the adjacent panel in the run. With a tooth of the motor patrol harrow, engage the panel end and slide the panel until only 2 to 4 in. of the new panel protrude past the edge of the runway.

(d) Reinstall succeeding panels as in step (c) until all panels in the run are in their original position.

(2) *Cutting method.*

(a) Cut the damaged panel in seven places, as shown in figure 10--5.

(b) With a pry bar, force up cut No. 4 and hinge out one side of the cut panel.

(c) Force up and hinge out the opposite side.

(d) Force out the end connector bars, and remove the two triangular parts by forcing down or up and out. (The adjacent panels can be pried up so that the triangular parts can be removed more easily.)

(e) Use a special panel and accessories to replace the damaged panel.

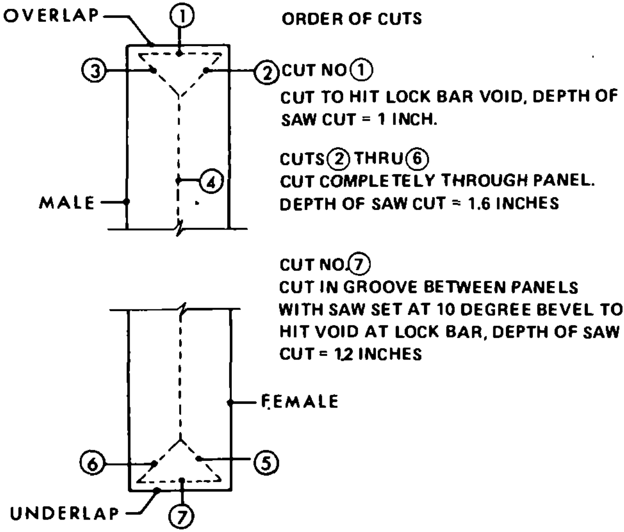


Figure 10–5. Cutting method for removing AM2 or XM18 landing mats.

(f) Place the accessories in the void and connect and aline in such a way that the panel will fit on top of (overlap) two edges and hinge on a third edge.

(g) Engage the hinge on the panel and drop into position. (The normal underlapping end of the panel contains an end connector bar, recessed to prevent interference when dropped into position and secured with two setscrews.) Remove the screws and use a pointed rod to work the end connector bar into the slot of the adjacent panel. Replace the setscrews and screw down along the side edge of the end connector bar to prevent the bar from disengaging.

(h) Place the top rail for the side and secure with countersunk allen screws.

d XM19 Mat.

(1) *Cutting method.*

(a) Cut the damaged panel in four places as shown in fig. 10–6.

(b) With a pry bar, force up one of the triangular cuts.

(c) Pry up the remaining three pieces.

(2) *Replacement.*

(a) Place the replacement panel in the void and engage the hinges.

(b) Place the connector bar in the slot and secure the countersunk allen screws.

e. Subgrade Failure. Subgrade failure normally requires removal of material and replacement with a better quality material. When subgrade failure occurs in an area that is not readily accessible by disassembly of matting, then procedures stated in paragraph 10–9 a thru d can be utilized to gain access to the area to be repaired.

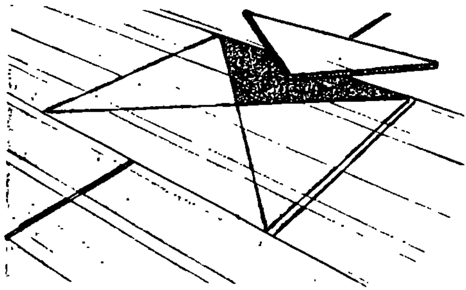


Figure 10–6 Damaged panel of XM19 landing mat cut for removal from mat field.

10–10. USERS OF FM 5–34

Users of this manual should always check construction criteria with local command standards, particularly in situations involving aircraft with which the Army has little or no experience.

CHAPTER 11

RIGGING

11–1. FIBER AND WIRE ROPES

a. Data. See tables 11–1 and 11–2 for data on manila, sisal, and wire rope.

b. Safety Factors. The safety factors normally used with wire rope are given in table 11–3. Where age and condition of rope are doubtful, or where human life or expensive equipment may be endangered by rope failure, apply a safety factor of at least 8.

c. Safe Working Capacity. The following general formula can be used to compute safe working capacities.

$$\text{Fiber Rope: } T = \frac{4D^2}{\text{Safety Factor}}$$

$$\text{Wire Rope: } T = \frac{32D^2}{\text{Safety Factor}}$$

Where:

T = Safe working capacity in tons

D = Nominal rope diameter in inches

11–2. MECHANICAL ADVANTAGES OF VARIOUS BLOCK ARRANGE–MENTS

a. Block and Tackle. Figure 11–1 shows examples of typical tackle systems. A simple tackle system advantage is figured by counting the number of lines leaving the load (fig. 11–1).

(1) ① – Mechanical advantage of 2

(2) ② – Mechanical advantage of 3

(3) ③ – Vechanical advantage of 5

(4) In a compound system with 5 lines leaving the load (④, fig. 11–1), and the fall line of this tackle attached to a traveling block with 2 lines supporting it, the mechanical advantage is 2 times 5, or 10.

Table 11–1. Properties of Manila and Sisal Rope

Nominal diametar, in.	Circum-farence, in.	Lbs. per ft.	No. 1 manila		Sisal	
			Breaking strength, tons	Safa working capacity tons (F.S. = 4)	Braaking strangth, tons	Safa load, tons (F.S. = 4)
¼	¾	0.20	0.30	0.07	0.24	0.06
⅜	1⅛	.040	0.67	0.16	0.54	0.13
½	1½	.075	1.32	0.33	1.06	0.26
⅝	2	.133	2.20	0.60	1.76	0.44
¾	2¼	.167	2.70	0.67	2.16	0.54
⅞	2¾	.186	3.85	0.96	3.08	0.77
1	3	.270	4.50	1.12	3.60	0.90
1⅛	3½	.360	6.00	1.50	4.80	1.20
1¼	3¾	.418	6.75	1.69	5.40	1.35
1½	4½	.600	9.25	2.31	7.40	1.85
1¾	5½	.895	13.25	3.31	10.60	2.65
2	6	1.08	15.50	3.87	12.40	3.10
2½	7½	1.35	23.25	5.81	18.60	4.65
3	9	2.42	32.00	8.00	25.60	6.40

NOTES.

1. Breaking strength and safe loads given are for new rope used under favorable conditions. As rope ages or deteriorates, progressively reduce safe loads to one-half of values given.
2. Cordage rope is issued by circumference sizes.

Table 11–2 Breaking Strength of 6 x 19 Standard Wire Rope

Diameter in.[2]	Approximate weight lb/ft	Iron	Breaking strength, tons of 2000 lbs			
			Traction steel	Plow steel	Improved plow steel	Extra improved plow steel
¼	0.10	1.4	2.6	2.39	2.74	
⅜	0.23	2.1	4.0	5.31	6.10	7.55
½	0.40	3.6	6.8	9.35	10.7	13.3
⅝	0.63	5.5	10.4	14.5	16.7	20.6
¾	0.90	7.9	14.8	20.7	23.8	29.4
⅞	1.23	10.6	20.2	28.0	32.2	39.8
1	1.60	13.7	26.0	36.4	41.8	51.7
1⅛	2.03	17.2	32.7	45.7	52.6	65.0
1¼	2.50	21.0	40.6	56.2	64.6	79.9
1½	3.60	29.7	56.6	80.0	92.0	114.0
1¾				108.0	124.0	153.0
2				139.0	160.0	198.0

[1]6 x 19 means rope composed of 6 strands of 19 wires each.

[2]Breaking Strength of 6 x 7 or 6 x 37 wire rope is 94% of the breaking strength of a 6 x 19 rope of an equal diameter and identical material.

Example:

Find breaking strength of 1¼ inch, 6 x 7, Improved Plow Steel wire rope

Breaking strength of 8 x 19, 1¼ inch, Improved Plow Steel wire rope = 64.6 tons

Breaking strength (6 x 7) = .94 x 64.6 = 60.7 tons

Table 11--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.

(5) A more complicated compound system (⑤, fig. 11--1) is made up of two simple systems, each of which has 4 lines supporting the load. The traveling block of the first simple system is fastened to the fall line of the second simple system, and the mechanical advantage of this compound system is 4 times 4, or 16.

b Chain Hoists. With a chain hoist, a load can remain stationary without requiring attention, and the hoist can be operated by one man to raise loads of several tons.

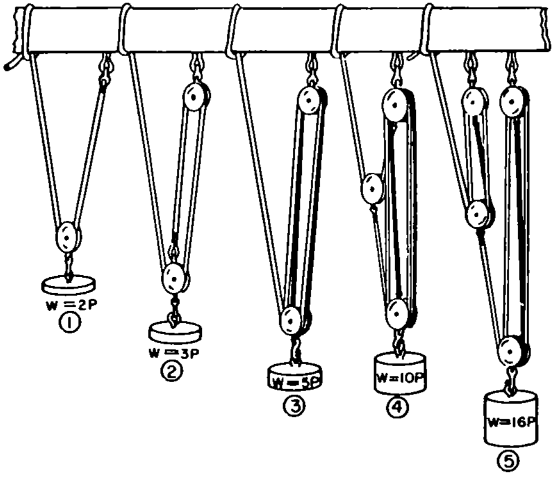


Figure 11–1. Mechanical advantage of various tackle riggings

c Determining Actual Pull.

FL = friction loss, the amount of force lost to friction in the system.

AP = actual pull, the amount of force required on the fall line to lift the load.

Ff = friction factor, varies with conditions of the blocks.

1/10, excellent condition (new)

1/8, good condition

1/5, fair condition

N_s = number of sheaves, total number of sheaves in the system including change-of-direction blocks.

MA = theoretical mechanical advantage

W_L = weight of the load

Example: Assume

W_L = 2500 lbs

N_S = 6

MA = 6:1

Ff = 1/5

Then

$$FL = W_L \times N_S \times F_f$$

$$= 2500 \text{ lbs } (6)\ (1/5)$$

$$= 3000 \text{ lbs}$$

And

$$AP = \frac{WL + FL}{MA}$$

$$= \frac{2500 + 3000}{6}$$

$$= 916.67 \text{ lbs}$$

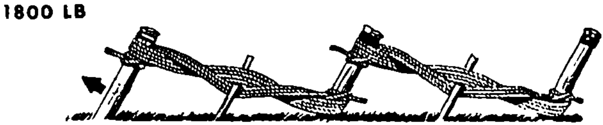
11-3. PICKET HOLDFAST

a. Holding Power. Sound pickets, 5 feet long, 3 in. in diameter, driven 3 feet into the earth, spaced 3 to 6 feet apart, and inclined away from the load at an angle of 15°, should stand the pull indicated in table 11–4.

Table 11–4. Picket Holdfast Capacities

Type of holdfast	Undisturbed earth	Wet clay and gravel	Wet river clay and sand
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 holdfast	4000	3600	2000

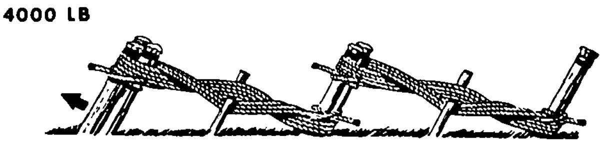
b. Picket Holdfast, 1–1–1 Combination (fig. 11–2)



1–1–1 COMBINATION

Figure 11–2 Picket holdfast 1–1–1 combination

c Picket Holdfast, 3–2–1 Combination (fig 11–3)



3–2–1 COMBINATION

Figure 11–3. Picket holdfast, 3–2–1 combination.

11–4. DEADMAN (fig. 11–4)

Deadman may be constructed of logs, timbers, or steel beams. For complete design procedures refer to TM 5–210.

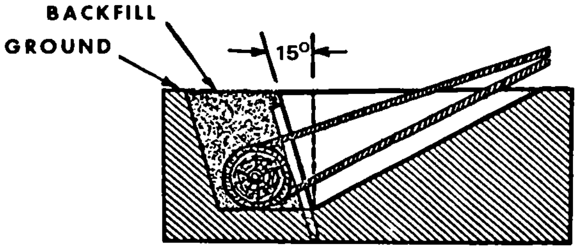


Figure 11–4 Log deadman.

11-5. ATTACHMENTS

a. Clips. Clips are used in making eyes in wire ropes. The correct method of attaching clips is shown in figure 11–5. The base of each clip should bear against the running end or long line, and the U–bolt against the standing end or short line. The number and spacing of clips and the proper torque to be applied are shown in table 11–5.

b. Wedge Socket (fig 11–6). The wedge socket is used when the fitting must be changed at frequent intervals. This socket has two parts, the socket proper with a tapered opening for the wire rope and a small wedge to go into this socket. The wire rope must be inserted in the wedge socket so that the running part of the 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.

Table 11-5. *Number, Size, Spacing, and Torque of Clips for Wire Rope Assembly (Probable Efficiency Factor = 80%)*

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 x 0.1382)
5/16	(7 95)	3/8	3	2	(50)	25	(3 5)
3/8	(9.52)	3/8	3	2 1/4	(57)	25	(3 5)
7/16	(11.11)	1/2	4	2 3/4	(70)	40	(5 5)
1/2	(12 70)	1/2	4	3	(76)	40	(5 5)
5/8	(15.85)	5/8	4	3 3/4	(95)	65	(9 0)
3/4	(19.05)	3/4	4	4 1/2	(114)	100	(14)
7/8	(22.22)	1	5	5 1/4	(133)	165	(23)
1	(25.40)	1	5	6	(152)	165	(23)
1 1/4	(31.75)	1 1/4	5	7 1/2	(190)	250	(35)
1 3/8	(34.92)	1 1/2	6	8 1/4	(210)	375	(52)
1 1/2	(38.10)	1 1/2	6	9	(230)	375	(52)
1 3/4	(44.45)	1 3/4	6	10 1/2	(267)	560	(78)

NOTE: The spacing of clips should be six times the diameter of the wire rope. To essemble end-to-end connection the number of clips indicated above should be increased by two, end the proper torque indicated ebove should be used on ell clips; U-bolts ere reversed et the center of connection so thet the U-bolts are on the deed (reduced load) end of each wire rope.

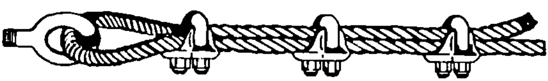


Figure 11-5. Wire rope clips

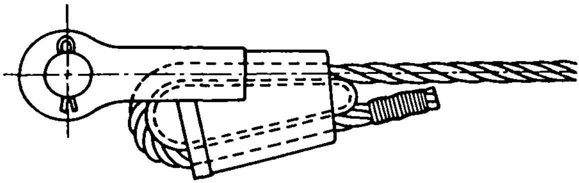


Figure 11–6. Wedge socket and fitting.

11–6. SLINGS

a. Single Slings.

(1) A basket hitch is a single sling passed under the load with both ends hooked over the hoisting hook (A, fig. 11–7).

(2) Single slings with two hooks are sometimes used for lifting stone and 55 gallons drums (B, fig. 11–7).

(3) The double anchor hitch is used sometimes for hoisting cylindrical objects (C, fig. 11–7).

b Endless slings.

(1) The anchor, or choker, hitch is a common method of using an endless sling by casting the sling under the load and inserting one loop through the other and over the hoisting hook (D, fig. 11–7).

(2) For a basket hitch, the endless sling is passed around the object and both remaining loops are slipped on the hook (E, fig. 11–7).

(3) The toggle hitch is a modification of the basket hitch and is used only for special application (F, fig. 11–7).

11–7. 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.

$$t = \frac{W}{N} x \frac{L}{v}$$

where

T = tension, in lbs

N = number of legs

W = weight of load in lbs

V = vertical distance, in ft

L = length of leg, in ft

c. Example Problem. Is it safe to use a ¾–inch–diameter manila rope sling to lift a 2,000–pound load with a 4–leg sling which has a vertical distance of 6 feet and length of leg of 12 feet (fig. 11–8)?

$$T = \frac{W}{N} x \frac{L}{V}$$

$$T = \frac{2,000}{4} x \frac{12}{6} = 1,000 \text{ pounds.}$$

The tension on each leg will be 1,000 pounds. The safe working capacity of ¾--inch–diameter manila rope from table 11–1 is 0.67 tons or 1,340 lbs. Since the safe working capacity is greater than the tension, the rope is safe to use.

11--8. HELICOPTER SLING DESIGN

a Strength of Sling.

(1) For a single leg sling, the minimum safe load capacity should be twice the weight of the load.

(2) For a multiple leg sling, *each leg* should have a minimum safe load capacity equal to the weight of the load.

b. Length of Sling Legs. The length of each sling leg should be the same as the greatest dimension of the load (L max).

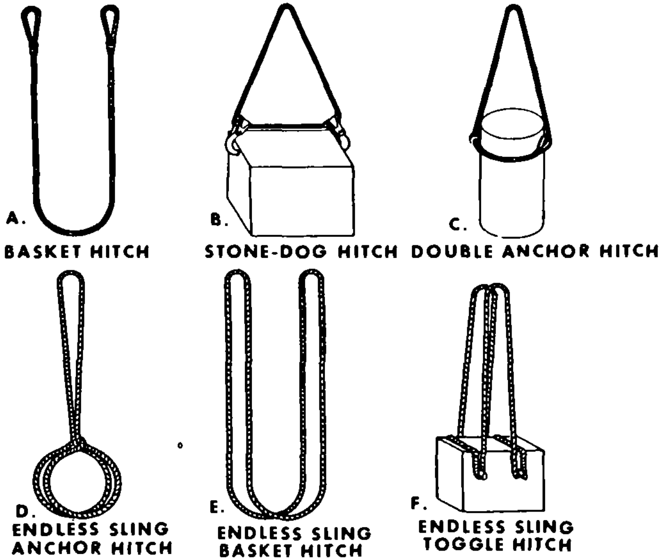


Figure 11–7. Hitches.

c. Stabilization of Loads. Helicopter sling loads are stabilized by one or more of the following methods:

(1) Reduce the air speed of the helicopter.

(2) Increase the weight of the load.

(3) Increase the surface area to the rear of the center of gravity of the load by using a drone chute or by adding weight to the front 1/3 of the load.

d *Safety.*

(1) Padding should be placed on the sling where rubbing may occur.

(2) To prevent in–flight "flapping" of prefabricated nylon slings, twist each sling leg one turn for every 3 feet of length.

(3) The distance between the top of the load and the bottom of the helicopter should be a minimum of 9 feet.

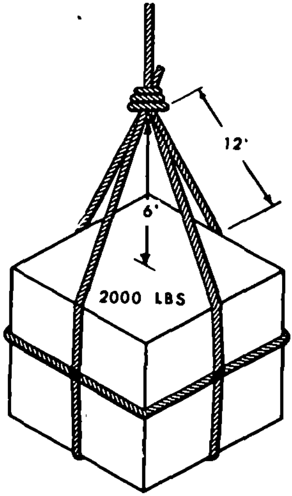
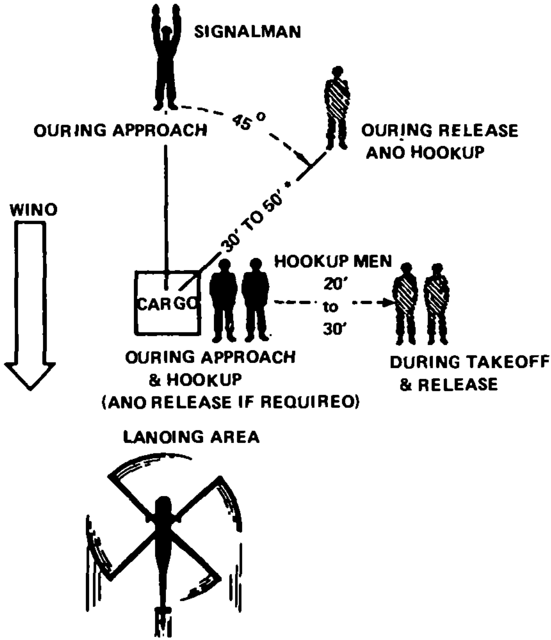


Figure 11–8. Sling Stresses.

11–9. GROUND CREW

a. *Positioning.* See figure 11–9.

b. *Hand Signals.* See figure 11–10.



EMERGENCY HELICOPTER MOVES LEFT

EMERGENCY ALL GROUND PERSONNEL MOVE RIGHT

*THIS OISTANCE MAY VARY, OEPENOENT UPON THE SPECIFIC ENVIRONMENT, E.G., TERRAIN FEATURES', WEATHER CONDITIONS, ANO TYPE OF HELICOPTER EMPLOYEO.

Figure 11-9 Position diagram for hook-up/release of helicopter sling loads

SIGNALS FOR DIRECTING HELICOPTERS

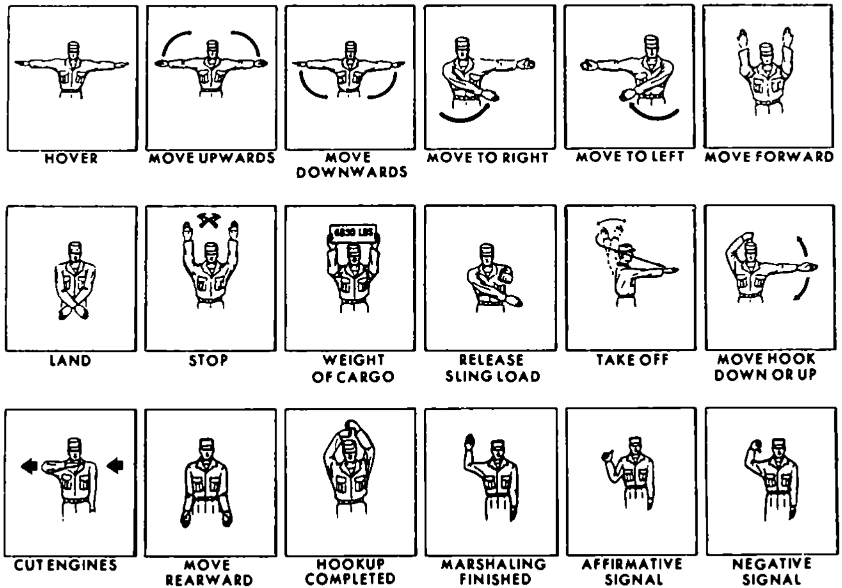


Figure 11–10. Hand signals

c. *Safety.* Police area thoroughly.

(1) Ground personnel should wear:

(a) Steel helmets.

(b) Protective masks, 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, thus grounding out the stored electrical charge. The ground crewman should not grasp the hook to released the probe. Likewise, the sling should be attached without grasping the hook.

11–10. SAFE CAPACITY OF SPRUCE TIMBER AS A GIN POLE

See table 11–6 for these capacities. Approximate weight of timber is 40 pounds per cubic foot.

Table 11–6. 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 (18m)
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-eights of the value given for a gin pole.

11-11. SHEARS

Shears are used to erect heavy machinery and bulky objects. Figure 11--11 shows the proper construction of shears. Shears must be guyed to hold their position and are designed to work inclined from the vertical.

a Material Maximum shear leg length is 60 times the least diameter of the leg. This ratio must be reduced for extremely heavy loads.

b Erection. Holes should be dug and the shear legs placed in them. This will prevent spreading of the legs. On hard surfaces, the legs should be level and lashed together to prevent spreading. Maximum spread at the base of the legs should not exceed ½ the height.

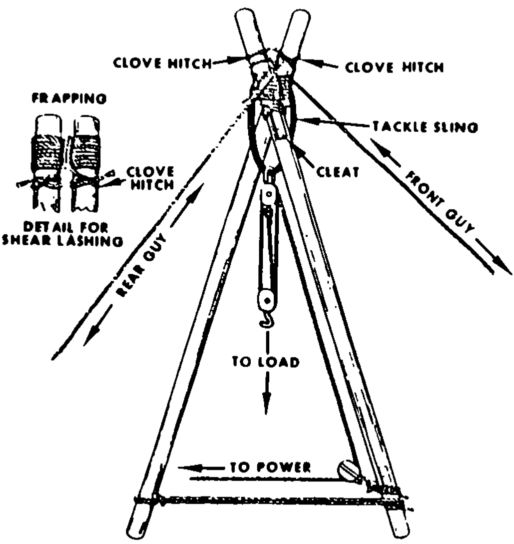


Figure 11–11 Lashing for shears

11-12. 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. 11-12).

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 11-12 shows the gin pole in position for operation, while the necessary rigging is illustrated in figure 11-13. The maximum allowable length is 60 times the minimum diameter. Guys are 3 to 4 times the pole length.

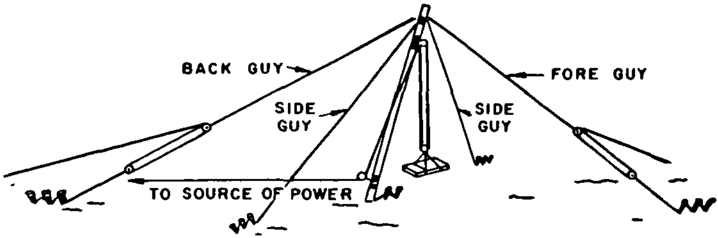


Figure 11-12 Gin pole ready for operation.

11-13. 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 the butt of the boom to the ground. Raise if for lighter loads; however, it must not bear against the upper two-thirds of the pole.

b. Operations. It is a convenient means for loading and unloading trucks and flatcars, and for use on docks or piers. Figure 11-14 shows the boom derrick in position for operations.

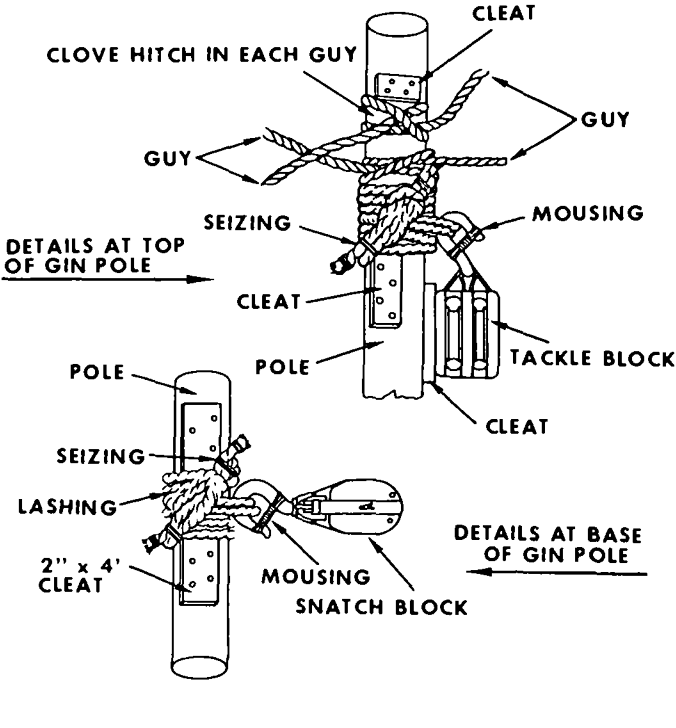


Figure 11–13. Lashing for gin pole

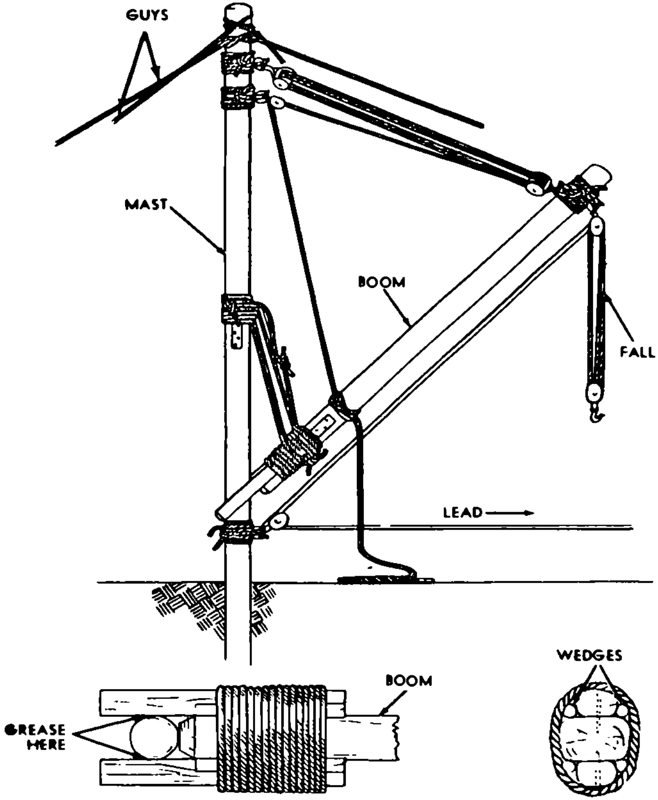


Figure 11–14. Boom derrick.

11–14. GUY LINE TENSION FOR SHEARS AND GIN POLES

a. Tensions. The most stress on a guy line occurs when a guy line is in direct line with the load and the structure. This would always be the case when a single guy line is used. To compute the tension on the single guy line (fig. 11–15), use the following formula:

$$T = \frac{(W_L + \frac{1}{2}W_S)D}{Y}$$

Where:

T = tension in guy line

W_L = weight of load

W_S = weight of spar

D = drift distance

Y = perpendicular distance

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 lbs.

11–15. KNOTS

For the more common knots, see figure 11–16.

11–16. CHAINS

For safe working loads, see table 11–7.

11–17. HOOKS

For safe loads on hooks, see table 11–8 and figure 11–17.

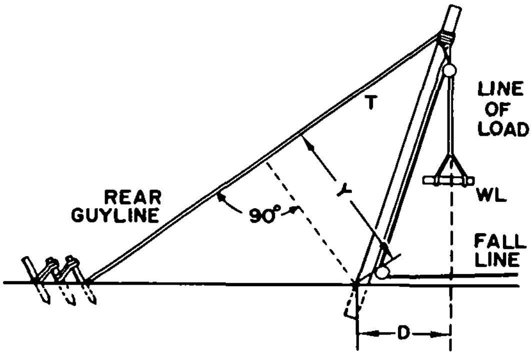


Figure 11–15. Computing tension in single guylines

Table 11–7. Properties of Chains (Factor of Safety 6)

Size*	Approximate weight per linear foot in pounds	Safe working load in pounds			
		Common iron	High grade iron	Soft steel	Special steel
1/4	0.8	512	563	619	1,240
3/8	1.7	1,350	1,490	1,650	3,200
1/2	2 5	2,250	2,480	2,630	5,250
5/8	4.3	3,470	3,810	4,230	7,600
3/4	5.8	5,070	5,580	6,000	10,500
7/8	8.0	7,000	7,700	8,250	14,330
1	10.7	9,300	10,230	10,600	18,200
1 1/8	12.5	9,871	10,858	11,944	21,500
1 1/4	16.0	12,186	13,304	14,634	26,300
1 3/8	18.3	14,717	16,188	17,807	32,051

*SIZE LISTED IS THE DIAMETER IN INCHES OF ONE SIDE OF A LINK.

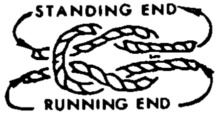
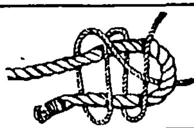
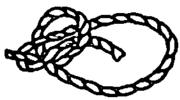
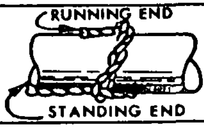
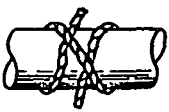
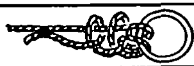
NAME	ILLUSTRATION	USE
SQUARE		JOIN TWO ROPES OF SAME SIZE. (WILL NOT SLIP, BUT WILL DRAW TIGHT UNDER STRAIN.) TO END BLOCK LASHING.
DOUBLE SHEET BEND		JOIN WET ROPES, OF UNEQUAL SIZE, OR ROPE TO AN EYE.(WILL NOT SLIP OR DRAW TIGHT UNDER STRAIN.)
BOWLINE		FORM A LOOP.(WILL NOT SLIP UNDER STRAIN AND IS EASILY UNITED.)
TIMBER HITCH		LIFTING OR DRAGGING HEAVY TIMBERS. (IS MORE EASILY CONTROLLED IF SUPPLEMENTED BY HALF HITCHES.)
CLOVE HITCH		FASTEN ROPE TO PIPE, TIMBER, OR POST. (IT IS USED TO START AND FINISH ALL LASHINGS AND MAY BE TIED AT ANY POINT IN ROPE.)
SHEEP SHANK		SHORTEN ROPE OR TAKE LOAD OFF WEAK SPOT IN ROPE.
FISHERMAN'S BEND		TO FASTEN CABLE OR ROPE TO ANCHOR.

Figure 11–16. Knots.

Table 11—8 Safe Loads on Hooks

DIAMETER OF METAL A,* IN.	INSIDE DIAMETER OF EYE B, IN.	WIDTH OF OPENING C, IN.	LENGTH OF HOOK D, IN.	SAFE WORKING CAPACITY OF HOOKS, LB.
11/16	7/8	1 1/16	4 15/16	1,200
3/4	1	1 1/8	5 13/32	1,400
7/8	1 1/8	1 1/4	6 1/4	2,400
1	1 1/4	1 3/8	6 7/8	3,400
1 1/8	1 3/8	1 1/2	7 5/8	4,200
1 1/4	1 1/2	1 11/16	8 19/32	5,000
1 3/8	1 5/8	1 7/8	9 1/2	6,000
1 1/2	1 3/4	2 1/16	10 11/32	8.000
1 5/8	2	2 1/4	11 27/32	9,400
1 7/8	2 3/8	2 1/2	13 9/32	11,000
2 1/4	2 3/4	3	14 13/16	13,600
2 5/8	3 1/8	3 3/8	16 1/2	17,000
3	3 1/2	4	19 3/4	24,000

*FOR REFERENCE TO A, B, C, OR D, SEE FIGURE 11—17.
NOTE: FORMULA FOR SAFE WORK LOAD FOR HOOKS:

$$T\ (TONS) = D^2\ (IN^2).$$

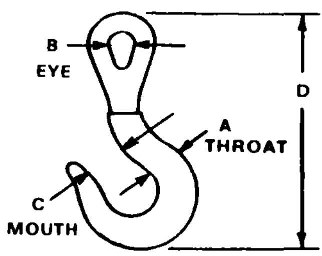


Figure 11-17 Slip hook

CHAPTER 12

UTILIZATION OF HEAVY EQUIPMENT

12–1. GENERAL

a. This chapter should be used as a general guideline when estimating construction equipment requirements and production. Production estimates given are based on average conditions, and may vary considerably with actual job site conditions. More detailed information may be found in TM's 5–331 A through E.

b. Good jobsite management requires constant monitoring of the operation, adjusting resources based on actual production to insure maximum utilization of equipment, and proper sequence and coordination of all related operations.

12–2. CONSTRUCTION CLEARING

Crawler tractor clearing production. See table 12–1.

12–3. STRIPPING, EXCAVATING, AND HAULING

a. *Equipment Selection and Production.* See table 12–2.

b. *Crawler Tractor/Dozer*

(1) Crawler tractors are the most economical equipment for moving earth for short distances (0 to 300 feet). A medium–sized dozer has a blade capacity of 5.0 cubic yards and will consume approximately 9 gallons of fuel per hour of normal operation.

(2) Dozer production may be maximized by slot dozing, blade–to–blade dozing, downhill dozing, and ripping the soil prior to dozing.

(3) Dozers should be used to push–load towed scrapers by one of the following procedures.

(a) Backtrack loading. The dozer pushes the scraper until loaded, backs through the area just cut, positions itself behind the second loader, and repeats the loading cycle.

*Table 12–1. Estimates for Area Clearing**

Production Estimates in Acres per hour			
Equipment	Vegetation Density		
	Light	Medium	Heavy
Medium size dozer w/bull blade	.40	.20	.10
Medium size dozer w/tree dozer blade	2.50	1.25	.77

*Reference DA PAM 525–6, June 1970.

(b) Shuttle loading After the dozer push–loads the first scraper, another scraper is positioned so the dozer can reverse direction and load the second scraper while traveling in the opposite direction.

(c) Chain loading In long cuts, the dozer push-loads the first scraper, then moves behind and pushes the second scraper which is moving in the same direction and adjacent to the first.

c. Scraper Production. Scraper production can be maximized by downhill loading, straddle loading, and ripping the soil prior to loading.

d. Haul Roads. All haul roads should be maintained with a grader to lower rolling resistance and insure that all loaded units can leave the cut area as fast as possible.

12–4. LIFTING AND LOADING

a. Power Shovel and Dragline Production. See table 12–3.

b. Scoop Loader Production See table 12–4.

c. Soil Conversion Factors. See table 12–5.

Table 12–2. Stripping, Excavating, and Hauling

Production Estimates in Bank Cubic Yards Per Hour			
	EQUIPMENT		
Distance	Dozer Med, Ft	R/T Tractor Scraper - 18 Cu Yd	Scraper-24 Cu Yd
15 ft	1600		
30 ft	870		
50 ft	512	259	345
75 ft	350	288	374
100 ft	263	288	374
150 ft	175	240	354
300 ft	87	183	336
500 ft		226	285
1000 ft		181	225
1500 ft		149	182
3000 ft		97	114
1 mi		62	71
2 mi		34	39
3 mi		24	27
5 mi			17

*AT HAUL DISTANCES GREATER THAN 3000 FT, THE POSSIBILITY OF USING A LOADER AND DUMP TRUCKS SHOULD BE EVALUATED (SEE SECTION 12–4–d). IF LOADERS ARE USED, A DOZER IS NORMALLY REQUIRED TO STOCKPILE MATERIAL.

*Table 12–3 Power Shovel and Dragline Production**

PROOUCTION ESTIMATES IN BANK CUBIC YAROS PER 60 MINUTE HOUR**				
ATTACHMENT/TYPE MATERIAL	BUCKET SIZE CU. YO.	JOB AND MANAGEMENT FACTORS		
POWER SHOVEL		POOR	GOOO	EXCELLENT
MOIST LOAM– LIGHT SANOY CLAY	3/4	86	124	139
	2	185	266	298
SAND ANO GRAVEL	3/4	81	116	130
	2	172	248	277
GOOO COMMON EARTH	3/4	70	101	113
	2	156	225	252
CLAY, HARO, TOUGH	3/4	57	83	95
	2	138	199	223
CLAY, WET, STICKY	3/4	36	53	59
	2	96	139	155
ROCK, WELL BLASTEO	3/4	49	71	80
	2	120	173	193
ROCK, POORLY BLASTED	3/4	26	38	42
	2	83	120	134
DRAGLINE				
MOIST LOAM– LIGHT SANOY CLAY	3/4	68	98	109
	2	138	199	223
SANO AND GRAVEL	3/4	65	94	105
	2	133	191	214
GOOO COMMON EARTH	3/4	55	79	88
	2	120	173	193
CLAY, HARO, TOUGH	3/4	47	68	76
	2	101	146	164
CLAY, WET, STICKY	3/4	29	41	46
	2	75	109	122

*REF: TM 5–331-B, May 1968 ANO PSCA TECHNICAL BULLETIN NO. 1
**BASEO ON SUITABLE OEPTH OF CUT FOR MAXIMUM EFFECT ANO A SWING ANGLE OF 90°. TO CONVERT TO LOOSE CUBIC YAROS, USE SOIL CONVERSION FACTORS FROM TABLE 12–5.

Table 12–4. Scoop Loader Production

Production Estimates In Loose Cubic Yards Per 60–Minute Hour												
SAE Rated Bucket Capacities	Cycle time in seconds											
	20	30	40	50	60	80	100	120	140	160	180	200
1½ cu yd	270	180	135	108	90	67	54	45	38	34	30	27
2½ cu yd	450	300	225	180	150	112	90	75	64	56	50	45
5 cu yd	900	600	450	360	300	225	180	150	128	112	100	90

Table 12–5 Soil Conversion Factors (Estimated)

Soil Type	Initial Soil Condition	Converted to:		
		In Place	Loose	Compacted
Sand	In Place		1.11	.95
	Loose	.90		.86
	Compacted	1.05	1.17	
Loam	In Place		1.25	.90
	Loose	.80		.72
	Compacted	1.11	1.39	
Clay	In Place		1.43	.90
	Loose	.70		.63
	Compacted	1.11	1.59	
Rock (blasted)	In Place		1.50	1.30
	Loose	.67		.87
	Compacted	.77	1.15	

d. Estimating Dump Truck Requirements. The following formula is used to make a preliminary estimate of the number of trucks required to keep loading equipment in operation at maximum capacity.

$$N = \frac{1 + \text{travel time (min)}}{\text{loading time (min)}}$$

N = number of trucks required

(1) The travel time is the time that is required for a hauling unit to complete one cycle of operation and may be determined by actual measurement or by estimation. The time required for a loaded dump truck to pull away from the loading equipment, travel to the site where the material is required, unload, return to the loading unit, and be reloaded is one complete cycle.

(2) The loading time is the time required for the loading equipment to actually load the truck. This is determined by dividing the truck size (in cubic yards) into the loading unit production (in cubic yards per hour) to get loads per hour. Divide loads per hour into 60 to obtain loading time in minutes.

(3) Example: How many 5-cubic-yard trucks would be required to haul 150 cubic yards per hour with a travel cycle time of 30 minutes?

Solution:

$$\frac{150 \text{ cu yds/hour}}{5 \text{ cu yds/load}} = 30 \text{ loads per hour}$$

$$\frac{60}{30} = 2 \text{ minutes loading time}$$

$$N = 1 + \frac{\text{travel time (min)}}{\text{loading time (min)}} = 1 + \frac{30}{2} = 1 + 15 = 16$$

N = 16 trucks

12–5. GRADING AND DITCHING

a Production Capabilities of Graders See table 12–6.

Table 12–6 Production Capabilities of Graders

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 Preparation	200 450	Cu Yd Cu Yd	Spreading material Shaping surface
Surface Treatment	150	Sq Yd	Mixing in place 2 inches of bituminous material

NOTE For working distances up to 1000 feet, graders should back up to beginning of project. For longer distances, turn grader around.

b Steps in hasty road construction:

(1) *Marking cut.* Place right front wheel in line with ditch stakes. Set mold board at outside of right front wheel and make a 3 to 4 inch cut along 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.

(3) *Moving windrow* Angle mold board and move windrow from ditch cut to center of road.

(4) *Level windrow* Make road surface and crown.

(5) *Slope.* Slope banks to prevent erosion.

(6) *Police.* Clean and clear ditches.

12–6. COMPACTION

a. Selection of Compacting Equipment The type of soil to be compacted generally governs the type of compactor to be used. For compaction purposes, soils may be divided into two major types; (1) cohesionless, or granular soils, and (2) cohesive soils. Granular soils generally limit the compactors to pneumatic–tired, vibratory, or (rarely) smooth drum compactors. Cohesive soils generally require a footed type compactor.

b. Production Capabilities of Sheepsfoot Rollers. See table 12–7.

c. Limitations. A compaction test strip is necessary to determine the depth of lift and the required number of passes. Compactor production may limit cut and fill operations, and should be determined prior to calculating haul unit requirements.

Table 12–7. Compacting Fill–Sheepsfoot Roller

Production Estimates in Cubic Yards Per Hour				
	Number of passes			
Equipment	5	7	9	10
Sheepsfoot roller	880	628	488	440

12–7. PRODUCTION AND JOB DURATION ESTIMATION

General estimates of production for engineer construction equipment may be obtained in the following manner:

a. Select an efficiency factor (E) from table 12–8.

Table 12–8. Efficiency Factors

	Type Tractor	Working Hours	Efficiency Factor
Day Operation	Track	50 min/hr	0.83
	Wheel	45 min/hr	0.75
Night Operation	Track	45 min/hr	0.75
	Wheel	40 min/hr	0.67

b. Estimate the cycle time for the operation in question. Cycle time is a combination of fixed time and variable time. Fixed time is the time required for positioning, loading, and unloading, and is best determined by actual measurement. Variable time is normally the hauling or travel time. Travel time may be calculated by the following equation:

$$\text{Dozer Travel time (min)} = \frac{\text{travel distance (ft)}}{\text{speed (mph)} \times 88}$$

Round trip distance must be used to determine travel time both ways. Variable time plus fixed time would equal cycle time.

c. Determine the equipment capacity.

d. If necessary, convert the equipment capacity to bank cubic yards (See table 12--5).

e. Estimate hourly production (P) by the following formula. (Scraper Production)

$$P = \frac{\text{capacity} \times 60 \text{ min/hr} \times E \text{ (eff factor)}}{\text{cycle time (min)}}$$

f. Estimate time required by the following formula:

$$\text{Time (hours)} = \frac{\text{total job requirement in machine--hours}}{P \times N}$$

N = Number of like equipment units used.

P = Hourly production for one unit.

CHAPTER 13

FIELD SANITATION

13–1. SANITATION FACILITIES

For details on field sanitation see FM 21–10.

13–2. WASHING FACILITIES

a. Hand–washing devices should be set up near latrines and kitchens. See figure 13–1.

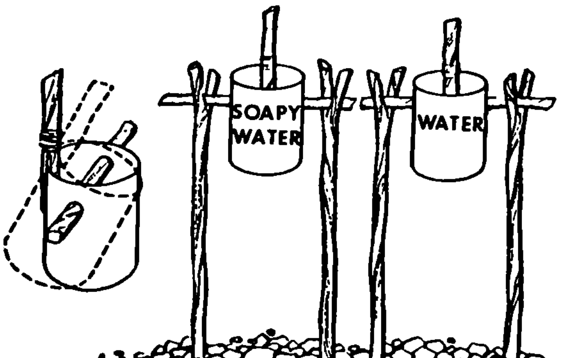


Figure 13–1. Hand–washing device, using number 10 can.

b. Showers should be set up whenever possible for personal hygiene and morale. See figure 13–2.

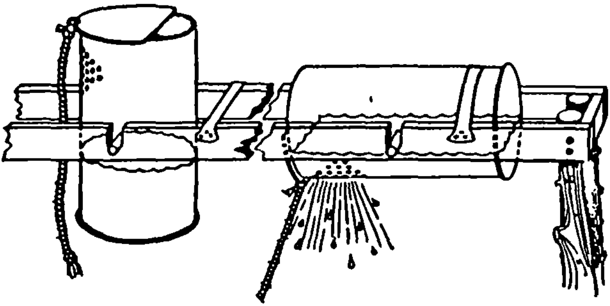


Figure 13–2 Shower unit, using metal drums

13–3. 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 13–3, 13–4, and 13–5.

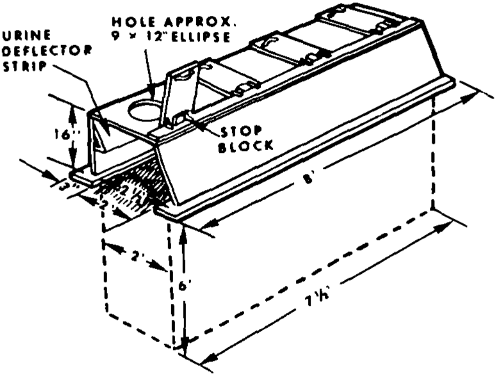


Figure 13–3 Box latrine for 50 men

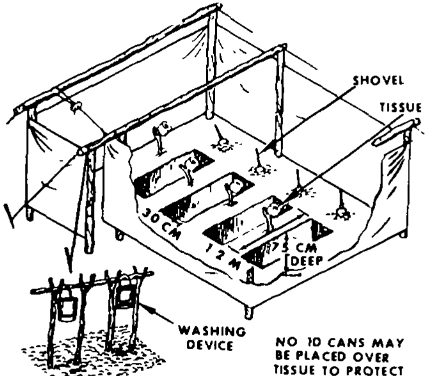
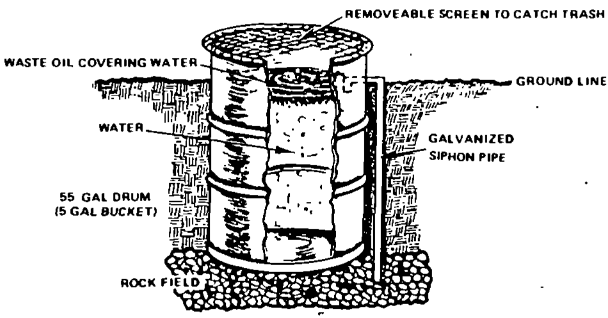


Figure 13–4 Straddle trench latrine for 100 men, with hand-washing device.



NOTE USE A SQUIRT CAN DAILY TO SPRAY OIL ON CATCHSCREEN AND AROUND DRUM TO KEEP FLIES AND OTHER INSECTS FROM GATHERING. OIL WILL CURTAIL ANY BAD ODORS

Figure 13-5 Urinoil

(4) Police the latrines properly and maintain a good fly--control program in the entire camp area to prevent fly bredding and to reduce odors.

(a) Keep the lids to the latrines seats closed and all cracks sealed.

(b) Scrub the latrine seats and boxes with soap and water daily.

(c) Spray the inside of the shelters with a residual insecticide twice weekly. If a fly problem exists, also spray the pit contents and the interior of the boxes twice weekly with a residual insecticide. Using lime in the pits or burning out the pit contents, except in burn--out, is not effective for fly or odor control. Therefore, these methods are not recommended.

(5) At such time as a latrine pit becomes filled with wastes to a point 1 foot from the surface or is to be abandoned, remove the latrine box and close it as follows:

(a) Using an approved residual insecticide, spray the pit contents, the side walls, and the ground surface extending 2 feet from the side walls.

(b) Fill the pit to the ground level with successive 3--inch layers of earth, packing each layer down before adding the next one; then mound the pit over with at least 1 foot of dirt and spray it again with insecticide. This prevents any fly pupa, which may hatch in the closed latrine, from getting out.

(c) Place a rectangular sign on top of the mound. The sign must indicate the type of pit and the date closed as well as the unit designation in non-operational areas.

(6) 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. 13-6). 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.

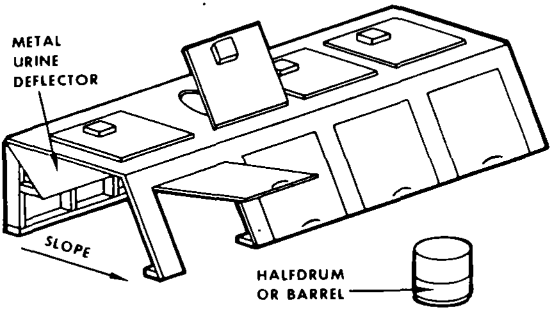


Figure 13–6 Burn–out latrine.

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 urinoil (fig. 13–5) except that a grease trap must be provided (fig. 13–7) 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.

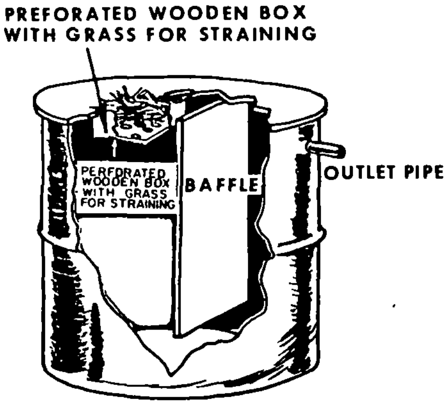


Figure 13–7 Baffle grease trap (barrel type).

CHAPTER 14

RECONNAISSANCE

14–1. ROUTE RECONNAISSANCE

a Definition Route reconnaissance provides information to aid in route selection for the movement of troops, equipment, and supplies. It is governed by the same fundamentals that apply to all reconnaissance and is made on the ground, but should be supplemented by air reconnaissance when practicable. Information sought in this type of reconnaissance includes:

(1) Nature of terrain.

(2) Existing roads and their characteristics, including loadbearing capabilities. See TM 5–330 for more detailed information.

(3) Obstructions.

(4) Bridges and other stream crossing means

(5) Tunnels.

b Mission. Route reconnaissance must consider the mission of the parent unit. Reconnaissance factors include the weight, width, and height of the vehicles that will be used, the classification of these vehicles, the approximate number of each class to be moved per hour, and the approximate length of time the route will be used.

c. Report. A reconnaissance report should be accurate, concise, and clear. The preferred method of preparation is in simplified map form or overlay (fig. 14–1), using symbols (table 14–1) to show the limiting features. A route reconnaissance report is accompanied by an engineer reconnaissance report form, a road reconnaissance report, and bridge, tunnel, ferry, and ford reconnaissance reports as needed. (Fig. 14–2). Military sketches of limiting features, local maps, and photographs of significant factors (terrain, roads, tunnels, bridges, ferries, fords, and so forth) support the route report.

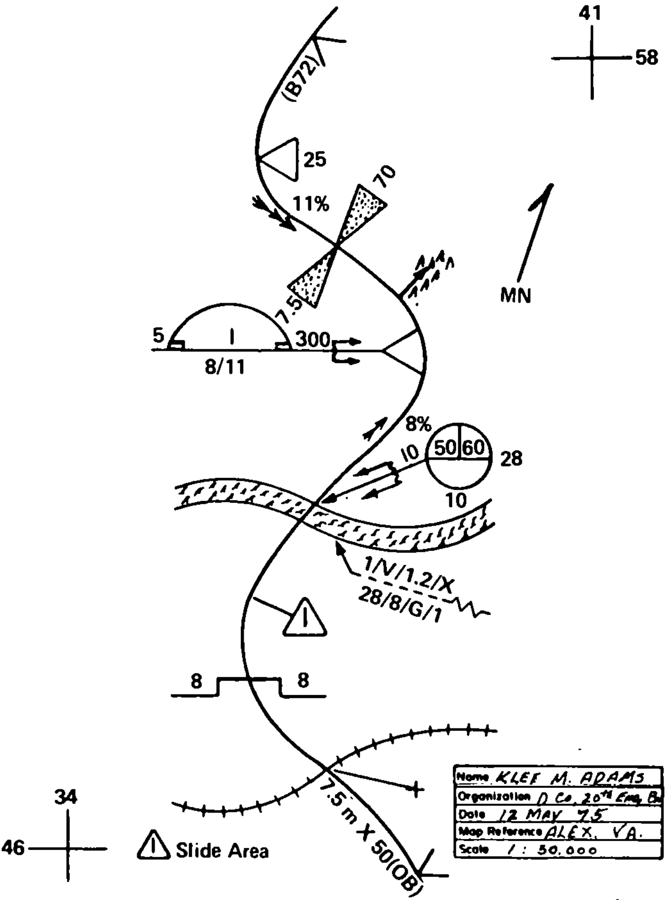


Figure 14–1. Example of a route reconnaissance overlay.

Table 14–1. Overlay Symbols

SYMBOLS FOR USE IN THE RECONNAISSANCE REPORT

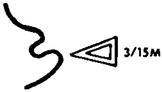
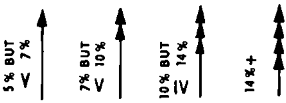
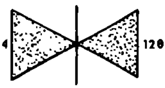
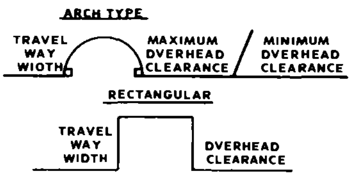
SYMBOL	OESCRIPTIDN & CRITERIA
	SHARP CURVE (DB) ANY RADIUS LESS THAN OR EQUAL TD 30 METERS. HOWEVER, ANY CURVE GREATER THAN 30 METERS, BUT LESS THAN 45 METERS IS REPDRTABLE
	SERIES OF SHARP CURVES. THE FIGURE TD THE LEFT INDICATES THE NUMBER DF CURVES, THAT TO THE RIGHT, THE MINIMUM RADIUS OF CURVATURE IN METERS.
	STEEP GRADES (DB) ANY GRADE 7% DR HIGHER. ACTUAL % DF GRADE WILL BE SHDWN ARRDWS ALWAYS PDINT UPHILL, AND LENGTH OF ARROW REPRESENTS LENGTH DF GRADE IF MAP SCALE PERMITS
	CDNSTRICTION (DB) ANY REOUCTIDN IN THE TRAVELED WAY BELDW THE STANDARDS DF TABLE 14—2. THE FIGURE TD THE LEFT INDICATES THE WIOTH DF THE CDNSTRICTIDN; THAT TO THE RIGHT, THE TDTAL CONSTRICTED LENGTH, BDTH IN METERS
	UNDERPASSES. SHDW SHAPE DF STRUCTURE (DB) WHEN DVERHEAD CLEARANCE IS LESS THAN 4.30 M DR WHEN THE TRAVELED WAY IS BELDW THE STANDARDS OF TABLE 14—2. SEE FIG 14—2, NDTE 4.

Table 14–1. Overlay Symbols (Con't)

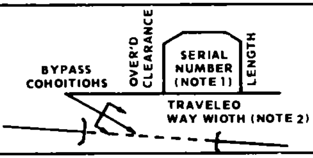
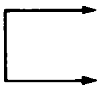
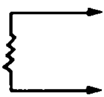
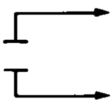
SYMBOL	DESCRIPTION & CRITERIA
	TUNNEL. (INCLUDES MANMADE SNOWSHEDS). SHOW SHAPE OF STRUCTURE. (OB) WHEN OVERHEAD CLEARANCE IS LESS THAN 4.30 M OR WHEN THE TRAVELED WAY IS BELOW THE STANDARDS OF TABLE 14—2 SEE FIG 14—2, NOTE 4.
	BYPASSES ARE LOCAL ALTERNATE ROUTES WHICH ENABLE TRAFFIC TO AVOID AN OBSTRUCTION. 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:
	BYPASSES EASY. THE OBSTACLE CAN BE CROSSED WITHIN THE IMMEDIATE 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
	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

Table 14–1. Overlay Symbols (Con't)

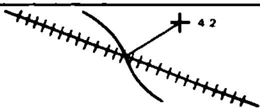
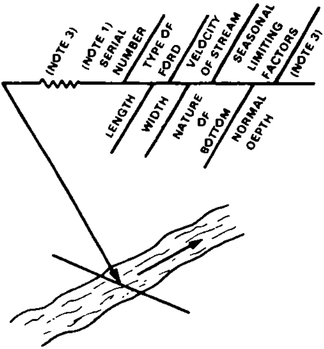
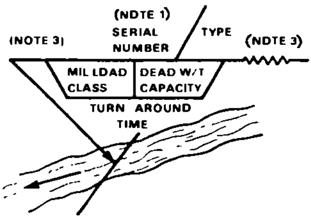
SYMBOL	DESCRIPTION & CRITERIA
	RAILROAD (RR) LEVEL GRADE CROSSING PASSING TRAINS WILL INTERRUPT TRAFFIC FLOW THE FIGURE INDICATES OVERHEAD CLEARANCES
	FORD ALL FORDS ARE CONSIDERED AS OBSTRUCTION (OB) TO TRAFFIC TRAFFICABILITY CONDITIONS SHOWS IN TABLE 14-6 INDICATE CONDITIONS ON BOTH APPROACHES SEE FIGURE 14-2, NOTE 3 TYPE OF FORD V — VEHICULAR P — PEDESTRIAN SEASONAL LIMITING FACTORS X – NO SEASONAL LIMITATION EXCEPT FOR DURATION SUDDEN FLOODING Y — SIGNIFICANT SEASONAL LIMITATIONS APPROACH CONDITIONS DIFFICULT EASY NATURE OF BOTTOM M — MUD C — CLAY S — SAND G — GRAVEL R — ROCK P — ARTIFICIAL PAVING
	FERRY ALL FERRIES ARE CONSIDERED AS OBSSTRUCTIONS (OB) TO TRAFFIC APPROACH CONDITIONS DIFFICULT EASY TYPE OF FERRY V — VEHICULAR FERRY P — PEDESTRIAN FERRY

Table 14–1. Overlay Symbols (Con't)

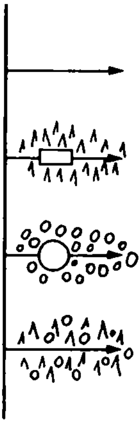
SYMBOL	OESCRIPTION & CRITERIA
(495)	ROUTE DESIGNATION CIVIL OR MILITARY ROUTE OESIGNATION WRITTEN IN PARENTNESES ALONG RDUTE.
 (1) (2) (3) (4)	OFF—ROUTE MOVEMENT (TURN OFF'S) & CONCEALMENT (ARROWS POINT TO LEFT OR RIGNT OF ROAD WNERE TURN OFF EXISTS) (1) POSSIBLE TURN OFF (2) TRACKEO VENICLE TURN OFF WITH CONIFEROUS CONCEALMENT (3) WNEELED VENICLE TURN OFF WITN DECIOUDUS CONCEALMENT. (4) POSSIBLE TURN OFF IN MIXEO CONCEALMENT. NOTE RECORD OISTANCE ON STEM OF ARROWS WHEN OFF ROUTE MOVEMENT IS LESS TNAN ONE KM

Table 14—1. Overlay Symbols (Con't)

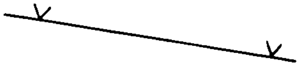
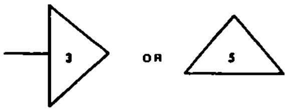
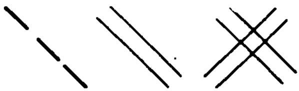
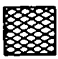
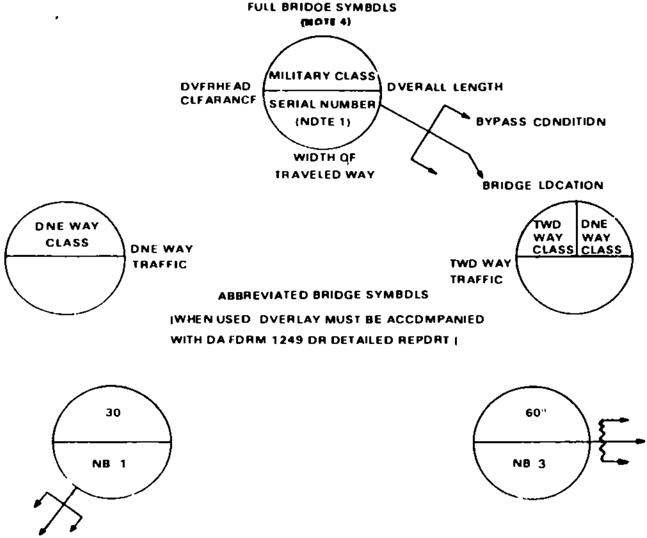
SYMBOL	OESCRIPTION & CRITERIA
	LIMITS OF SECTOR LIMITS OF RECONNOITEREO SECTOR OR OF ROUTE HAVING THE SAME ROAO CLASSIFICATION FORMULA
	CULVERT REGAROLESS OF TYPE, LENGTH, SIZE, OR NUMBER OF PIPES IN THE SYSTEM
	CRITICAL POINTS: ARE USED AS NUMBERED KEYS TO DESCRIBE IN DETAIL, ON ATTACNED RECONNAISSANCE FORMS OR DOCUMENTS, TNOSE FEATURES TNAT CANNOT BE AOEQUATELY COVERED BY OTNER RECONNAISSANCE SYMBOLS ON TNE OVERLAY.
 (1) (2) (3)	OBSTACLES (ROAD BLOCKS, CRATERS, BLOWN BRIDGES, LANDSIDES, ETC.): 1. PROPOSED OBSTACLE 2. PREPARED BUT PASSABLE OBSTACLE 3. COMPL[illegible] OBSTACLES
?	UNKNOWN OR DOUBTFUL INFORMATION: USED IN ALL SYMBOLS WNERE INFORMATION IS NOT KNOWN, OR DOUBTFUL

Table 14–1 Overlay Symbols (Con't)

ENGINEER RESOURCE SYMBOLS

Symbol	Resource	Symbol	Resource
	SAWMILL		ELECTRICAL SUPPLY EQUIPMENT
	LUMBER YARD		WATER POINT (MILITARY)
	AGGREGATE (INCLUDING GRAVEL,SLAG)ETC.		FORESTRY EQUIPMENT
	SAND		PAINT
	IRON & STEEL STOCK		GYPSUM & LIME PRODUCTS
	WIRE STOCK		CEMENT CONCRETE PRODUCTS
	MOBILE HEAVY CONSTRUCTION EQUIPMENT		BRICK & OTHER CLAY PRODUCTS
	QUARRING EQUIPMENT		FACTORIES
	POWERED HAND TOOLS		ASPHALT & BITUMINOUS STOCK
	UTILITY (CIVILIAN)  WATER  GAS  ELECTRIC		CORDAGE, NETS & YARN



• ONLY 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, 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
NOTE 3 BANK ORIENTATION	THE LEFT AND RIGHT BANKS OF A STREAM ARE DETERMINED BY LOOKING IN THE RIGHT DIRECTION OF THE CURRENT DOWNSTREAM
NOTE 4 CRITICAL DIMENSIONS	ANY OVERHEAD CLEARANCE LESS THAN THE STANDARDS OF TABLE 14–2 IS UNDERLINED. ANY WIDTH OF A BRIDGE WHICH IS LESS THAN THE STANDARDS OF TABLE 14–2 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 14–3. THE WIDTH OF THE TRAVELED WAY OF TUNNELS OR UNDERPASSES WHICH IS LESS THAN THAT OF THE OUTSIDE ROUTE IS UNDERLINED

Figure 14–2. Bridge reconnaissance symbols

d. Overlay. Important features to be included on an overlay are shown below. The first five items are required:

(1) Two grid references.

(2) Magnetic north arrow.

(3) Route drawn to scale.

(4) Title block.

(5) Route classification formula.

(6) Length (in kilometers) between well marked points.

(7) Curves having radii of less than 45 meters or 150 feet.

(8) Steep grades, with their maximum gradients in percent, and length of any grade of 5 percent or greater.

(9) Road width of constrictions (bridges, tunnels and so forth), with the widths and lengths of the traveled ways in meters.

(10) Underpass limitations, with their limiting heights and widths in meters.

(11) Bridge bypasses, classified as easy, difficult, or impossible.

(12) Civil or military road numbers, or other designations.

(13) Feasibility of driving off roads, including shoulders.

(14) Location of fords, ferries, and tunnels including limiting information.

(15) Causeways, snowsheds, and galleries which constitute an obstruction to traffic should be included in the route reconnaissance report. Limit the data to clearance and load–carrying capacity. If possible, support the information with photographs or sketches of each structure. Also, include enough descriptive information to permit an evaluation concerning the strengthening or removal of these structures.

e. Route Classification Formula. It is a standardized sequence of:

(1) *Width.* Narrowest width of the route expressed in meters (m) or feet (ft).

(2) *Route type.* Determined by worst section of the route.

(a) (X) All–weather. Any road which, with reasonable maintenance, is passable throughout the year to a volume of traffic never appreciably less than its maximum capacity. This type of road has a waterproof surface and is only slightly affected by rain, frost, thaw, or heat. At no time is it closed to traffic due to weather effects other than snow blockage. Examples of this category are concrete, bituminous, brick, or stone.

(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. Examples of this category are 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. Examples of this type are natural or stabilized soil, sand or clay, shell, cinders, or disintegrated granite.

(3) *Military route classification.* Normally it is the lowest one--way bridge load classification along the route. If no bridges exist the worst section of the route governs.

(4) *Obstructions (OB).* Any factors which restrict tye type, amount, or speed of traffic flow, e.g., overhead clearances, traveled way widths, steep gradients, sharp curves, ferries, and fords which may cause obstructions, denoted by (OB) in the route classification formula. Consult tables 14--1 and 14—2 for limiting values.

(5) *Special conditions.* Snow blockage (T) and flooding (W) are used when the condition is regular, recurrent, and serious.

Example:

6.7 m Y 30 (OB) (W). Route is 6.7 meters wide, limited all—weather route with a load carrying capacity of class 30. Obstructions do exist and route is subject to flooding.

14-2. ROAD RECONNAISSANCE

Road reconnaissance is performed in order to obtain 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 kinds 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 14—3 and 14—4.

Table 14–2. Critical Dimensions of Route Classification

—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 (19 1/2 FT TO 26 FT)
DOUBLE FLOW	OVER 7 METERS (23 FT)	OVER 8 METERS (26 FT)

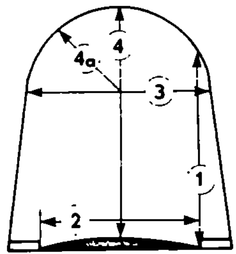
—MINIMUM ROUTE WIDTHS FOR BRIDGES

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")

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)

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 LEASE 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
For use of this form, see FM 5-36; proponent agency is TRADOC

DATE	29 OCT 72
TO: (Headquarters ordering reconnaissance)	CO, 20th ENGR BN ATTN S-2
FROM: (Name, grade and unit of officer or NCO making reconnaissance)	LARRY B BRUNER CPT CE CO C, 20th ENGR BN

1 MAPS	a COUNTRY	b SCALE	c SHEET NUMBER OF MAPS	2 DATE/TIME GROUP (Of signature)
		1:50,000	5567-III AMS V 733	291200 OCT 72

SECTION I - GENERAL ROAD INFORMATION

3 ROAD GRID REFERENCE FROM	TO	4 ROAD MARKING (Civilian or military number of road)	5 LENGTH OF ROAD (Miles or kilometers, specify)
UT052703	UT083701	VIRGINIA 132	29 KM

6 WIDTH OF ROADWAY (Feet or meters, specify)	8 WEATHER DURING RECONNAISSANCE (Include last rainfall, if known)
67M - 90M	CLEAR - TEMP 35°
7 RECONNAISSANCE DATE: 29 OCT 72 TIME: 1200	LAST RAINFALL - APPROX 17 OCT 72

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)		10 DRAINAGE (Check one ONLY)	
	(1) FLAT GRADIENTS AND EASY CURVES		(1) ADEQUATE DITCHES, CROWN/CAMBER WITH ADEQUATE CULVERTS IN GOOD CONDITION
	(2) STEEP GRADIENTS (Excess of 7 in 100)		
	(3) SHARP CURVES (Radius less than 100 ft (30m))	✓	(2) INADEQUATE DITCHES, CROWN/CAMBER OR CULVERTS OR CULVERTS OR DITCHES ARE BLOCKED OR OTHERWISE IN POOR CONDITION
✓	(4) STEEP GRADIENTS AND SHARP CURVES		

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

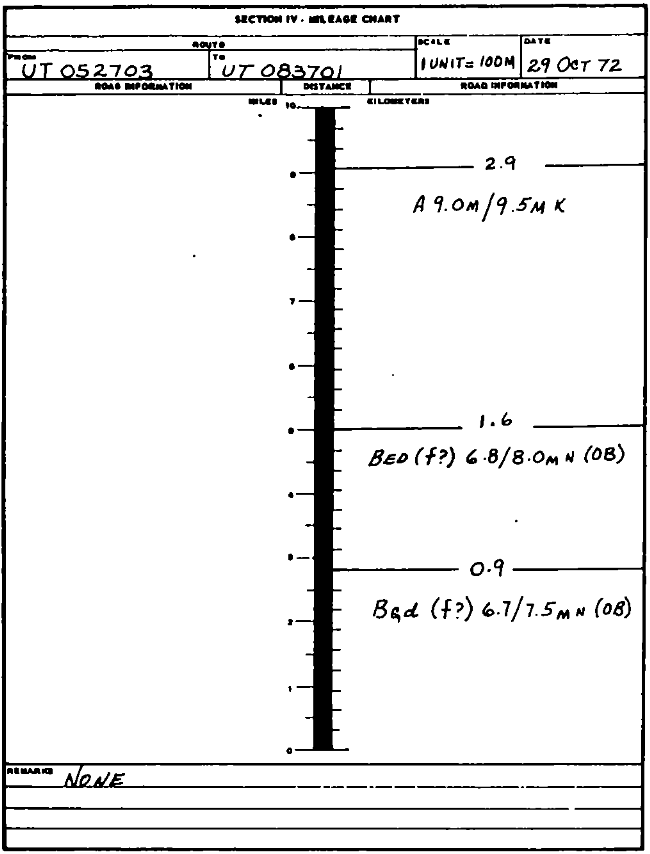
b TYPE OF SURFACE (Check one ONLY)			
	(1) CONCRETE		(6) WATERBOUND MACADAM
	(2) BITUMINOUS (Specify type where known)		(7) GRAVEL
			(8) LIGHTLY METALLED
	(3) BRICK (Pave)	✓	(9) NATURAL OR STABILIZED SOIL, SAND CLAY, SHELL, CINDERS, DISINTEGRATED GRANITE OR OTHER SELECTED MATERIAL
	(4) STONE (Pave)		(10) OTHER (Describe)
	(5) CRUSHED ROCK OR CORAL		

SECTION III - OBSTRUCTIONS *(List in the columns below particulars of the following obstructions which affect the traffic capacity of a road. If information of any factor cannot be ascertained, insert "NOT KNOWN")*
(a) Overhead obstructions, less than 14 feet or 4.25 meters, such as tunnels, bridges, overhead wires and overhanging buildings
(b) Reductions in road widths which limit the traffic capacity, such as craters, narrow bridges, archways, and buildings.
(c) Excessive gradients (Above 7 in 100)
(d) Curves less than 100 feet (30 meters) in radius)
(e) Fords

SERIAL NUMBER a	PARTICULARS b	GRID REFERENCE c	REMARKS d
1	STEEP GRADE - 8% UPHILL-EAST	UT056698	200 M LONG
2	SHARP CURVE	UT061688	R = 27M

DA FORM 1 JUL 66 1248 PREVIOUS EDITION OF THIS FORM IS OBSOLETE

Figure 14-3 Road reconnaissance report (front)



SECTION IV - MILEAGE CHART

ROUTE		SCALE	DATE
FROM UT 052703	TO UT 083701	1 UNIT = 100M	29 OCT 72

ROAD INFORMATION	DISTANCE (MILES / KILOMETERS)	ROAD INFORMATION
	2.9	A 9.0M/9.5M K
	1.6	Bed (f?) 6.8/8.0M N (OB)
	0.9	Bqd (f?) 6.7/7.5M N (OB)

REMARKS NONE

Figure 14–4. Road reconnaissance report (back).

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. (para 14- 3).

(5) Tunnel locations, together with their lengths, widths, and heights. (para 14–5 and table 14–1.)

(6) Snowshed locations and estimated coverage.

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, obstructions, and special conditions.

(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 30m or less)	c
Gradients (7% or greater)	g
Drainage (inadequate)	d
Foundation (unstable)	f
Surface Condition (rough)	s
Chamber or superelevation (excessive)	i

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 surface material* Road surface material 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, 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, asphalt, or tar cover.
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 of road (in km) may or may not be shown. If shown place in parentheses, e.g., (7.2 km).

(6) *Obstructions.* Expressed as (OB) when existing on road, e.g., overhead clearance less than 4.30 m, reduction in the traveled way widths below the standards of table 14–2, gradients of 7 percent or greater, and curves with radii of 30 m (100 ft) or less.

(7) *Special conditions* Snow blockage (T) and flooding (W) are used when the condition is regular, recurrent, and serious.

Example:

Bcgd (f?)s 3.2/4.8 nb (4.3 km) (OB) (T): Road has limits of sharp curves, steep grades, bad drainage, unknown foundation and rough surface; 4.3 km long, and contains obstructions. The road is subject to snow blockage.

c. Measuring Radii of Curves (fig 14–5) A method of determining the radius of a curve is based on the formula–

$$R = \frac{c^2}{8m} + \frac{m}{2}$$

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.

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.

d. Determining road gradient.

$$\frac{\text{Vertical distance}}{\text{Horizontal distance}} \times 100 = \%\ \text{of slope}$$

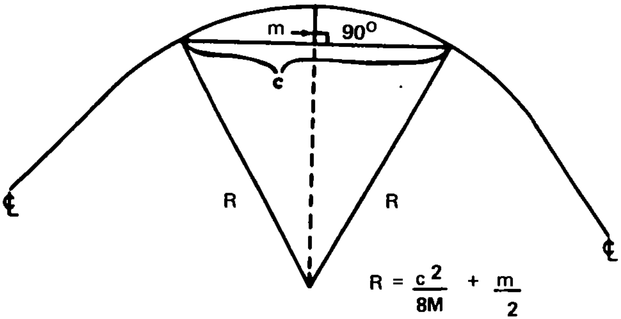


Figure 14–5. Measuring the radius of a curve

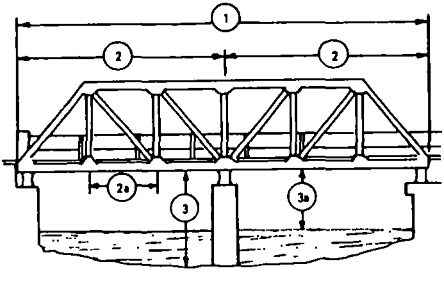
14–3. FIXED BRIDGE RECONNAISSANCE

The limiting features of bridges are of basic importance to the selection of a route for normal troop movements. See tables 14–3 and 14–4.

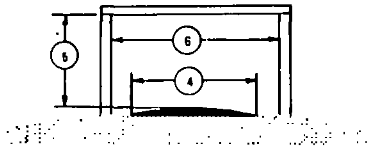
Table 14–3. General Dimension Data Required for Each of the Seven Basic Types of Bridges

NUMBER ON FIGURE	DIMENSIONS 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	PANEL LENGTH	...	...	...	...	...	...	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	TRAVELED 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



SIDE VIEW



END SECTION

Table 14–4. Capacity Dimension Data Required for Each of The Seven Basic Types of Bridges

CAPACITY (1) DIMENSIONS DATA	BASIC TYPES OF BRIDGE										
	SIMPLE STRINGERS					SLAB	T-BEAMS	TRUSS	GIRDER	ARCH	SUSPENSION
	TIMBER		STEEL								
	RECTANG	LOG	I-BEAM	CHANNEL	RAIL						
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
DISTANCE, C - TO - C, BETWEEN T-BEAM, STRINGERS, OR FLOOR BEAMS	X	X	X	X	X		X	X	X	X	X
NO. OF T-BEAMS OR STRINGERS	X	X	X	X	X		X	X	X		X
DEPTH OF EACH T-BEAM OR STRINGER	X	(2)	X	X	X		X	X	X		X
WIDTH OF EACH T-BEAM OR STRINGER	X		(3)	(3)	(3)		X	X	X		X
THICKNESS OF WEB OF I-BEAMS, WF-BEAMS, CHANNELS, OR RAILS			X	X	X			X	X		X
SAG OF CABLE											X
NO. OF EACH SIZE OF CABLE											X
THICKNESS OF ARCH RING										X	
RISE OF ARCH										X	
DIAMETER OF EACH SIZE OF CABLE											X
DEPTH OF PLATE GIRDER									X		
WIDTH OF FLANGE PLATES									X		
THICKNESS OF FLANGE PLATES									X		
NO OF FLANGE PLATES									X		
DEPTH OF FLANGE ANGLE									X		
WIDTH OF FLANGE ANGLE									X		
THICKNESS OF FLANGE ANGLE									X		
DEPTH OF WEB PLATE									X		
THICKNESS OF WEB PLATE									X		
AVERAGE THICKNESS OF FLANGE			X								

NOTE: "X" INDICATES REQUIRED DIMENSION.

1. CAPACITY IS COMPUTED BY THE USE OF FORMULAS AND DATA IN BRIDGE MANUALS.
2. DIAMETER.
3. WIDTH OF FLANGE.

a There are two methods of bridge reconnaissance.

(1) Hasty reconnaissance used to fulfill immediate requirements.

(2) Deliberate reconnaissance when time and personnel are available to make a thorough analysis and classification of the bridge, including necessary repairs or demolition procedures.

b. Bridge reports include the location of the bridge, bridge number, the military load classification number, length of the bridge, roadway width, vertical clearance, bypasses, horizontal clearance, underbridge clearance, number of spans, type of span construction material, and length and condition of spans (fig. 14–6). Information should be obtained to complete the Bridge Reconnaissance Report Form (DA Form 1249) (figures 14–7 and 14–8). Consult chapter 7 to determine military bridge classification.

c Bridge bypasses are detours, which are classified as easy, difficult, or impossible. Table 14–1 shows the symbols and requirements for each classification.

14–4. RIVER RECONNAISSANCE

a Engineer plan must include:

(1) Tactical requirement.

What must cross: when and where.

(2) Resources available.

i.e., Bridging, men and support equipment.

(3) Riverline data–(see b below).

b Eight common factors for reconnaissance.

(1) Road nets.

(a) At least same class 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.

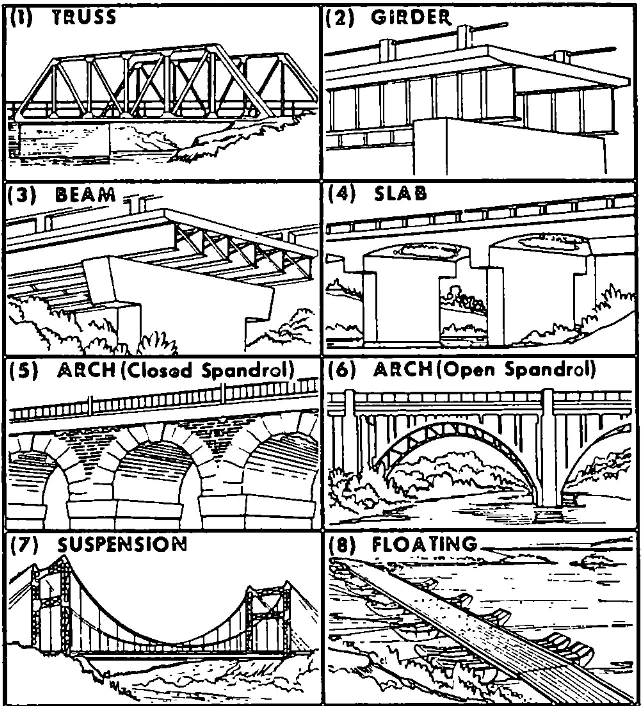
(a) Same class as bridge.

(b) Protect from scouring, using local material.

(c) 30" to 40" high to adjust for approach ramps.

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 14–6. Common types of span construction.

BRIDGE RECONNAISSANCE REPORT

DATE: 10 JUN 64

SIGNATURE: RA Adsitt 2/LT CE

TO: 35TH ENGR BN, ATT 52

FROM: R.A. Adsitt 2/LT CE Co A, 35th ENGR BN

MAPS: VIRGINIA ALLANDALE 1:2500 SHEET 5561

DATE/TIME GROUP: 1Ø1536Z

ESSENTIAL BRIDGE INFORMATION								ADDITIONAL BRIDGE INFORMATION					
		CLEARANCE		SPANS									
SERIAL NO 1	LOCATION 2	HORIZONTAL 3	UNDER-BRIDGE 4	NUMBER 5	TYPE OF CONSTRUCTION 6	TYPE OF SPAN MATERIAL 7	LENGTH AND CONDITION 8	MILITARY LOAD CLASSIFICATION	OVERALL LENGTH	TRAVEL WIDTH	OVERHEAD CLEARANCE	BRIDGE BY-PASS	REMARKS
1.	LAØ72687	5.5M	2M	1	3	K	4.2M	30	4.2M	5.5M	∞	EASY	NONE
2.	LA118759	9.5M	6.5M	1	4	K	4M	40 50	24M	7.5M	4M	DIFFICULT	NONE
				1	1	a	16M						
				1	4	K	4M						
3	LA16565Ø	14.0M	2.5M	5	3	8K	25M	[illegible]	12.5M	12M	∞	IMPOSSIBLE	NONE
4.	LA156643	10.5M	8.5M	3	6	K	10M	[illegible]	100M	10M	10.5M	IMPOSSIBLE	NONE
				2	2	a	20M						
				3	6	K	10M						

DA FORM 1249

Figure 14–1. Bridge reconnaissance report form (front)

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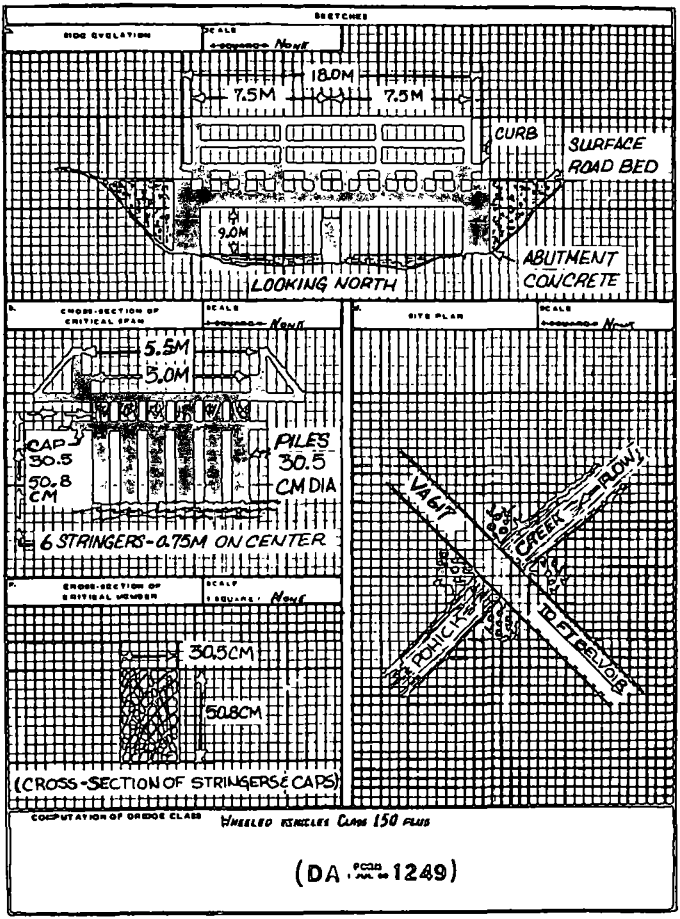


Figure 14–8. Bridge reconnaissance report form (back).

(4) Width.

(a) Direct measurement.

(b) Stadii and transit.

(c) Triangulation—see number 1, figure 14—9.

(d) Scaling from map or aerial photo.

(5) Depth.

Sounding or expedient methods.

(6) Current (tide variation)--see number 2, figure 14—9.

(7) Assembly sites--desire 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.

14--5. TUNNEL RECONNAISSANCE

Because tunnels are sometimes used for storage, maintenance, or other purposes, their limitations must be known. (See Table 4—1 and FM 5—36)

14—6. FORD RECONNAISSANCE

a. The composition of the stream bottom determines its passability.

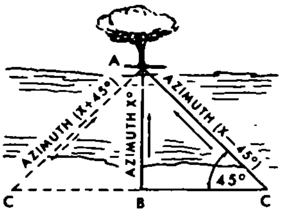
b. *Stream Width.*

(1) With a compass, determine the azimuth from a point on the near shore close to the water's edge to a point near the water's edge on the far shore of the stream directly opposite. Then another point, either upstream or downstream from the previously marked azimuth. The distance between the two points on the near shore is equal to the distance across the stream (fig. 14—9).

(2) Stretch a string across the stream, then measure the distance on the string. A measuring tape may be used if one long enough is available.

c. *Stream Velocity.* Stream velocity is calculated by measuring a distance along the riverbank, then determining the time it takes a light object to float this measured distance (fig. 14--9). Velocity is computed as follows:

. 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 14–9. Methods of veasuring stream width and velocity

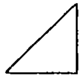
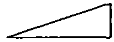
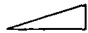
$$\frac{\text{Measured distance (m or ft)}}{\text{Time (sec)}} = \text{velocity in meters or feet per second}$$

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), r slow (less than 1 meter per second).

d. Ford Reconnaissance Report. This report is made on DA Form 1251, (Ford Reconnaissance Report). If required, worksheets may be used for rapid field work; details are later transferred to DA Form 1251.

e. For detailed information on ford reconnaissance see FM 5–36.

f. General data can be seen in table 14–5.

TYPE OF TRAFFIC	SHALLOW FORDABLE DEPTH (METERS)	MINIMUM WIDTH (METERS)	MAXIMUM DESIRABLE SLOPE FOR APPROACHES [1]	SYMBOL
FOOT	1(39")	1(39") (SINGLE FILE) 2(70") (COLUMN OF 2'S)	1:1	
TRUCKS AND TRUCK-DRAWN ARTILLERY	0.75(30")	3.6(12')	3:1	
LIGHT TANK MEDIUM TANKS [2]	1(39") 1.05(42")	4.2(14') 4.2(14')	2:1 2:1	

[1] BASED ON HARD, DRY SURFACE
[2] DEPTHS UP TO 4.3 METERS CAN BE NEGOITATED WITH DEEP WATER FORDING KIT

Table 14–5. Trafficability of Fords

14–7. FERRY RECONNAISSANCE

Ferries differ widely in appearance, capacity, propulsion, construction, etc. For information on ferry reconnaissance, see FM 5–36.

14–8. WATER RECONNAISSANCE

a. Source. When troops are in combat there is usually no time to search for the best water. Units must take whatever is available and purify as needed. For quantities of water required see table 16–2. Principal sources are: surface water (streams, lakes, and ponds), springs, wells, rain, snow, and ice.

b. Capacity of Source (Quantity). Determine the volume of streams, wells or springs, and the dimensions and depths of lakes or ponds, with their rate or outflow. 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) x (correction factor of 0.85).

c. 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, dead fish, or poisoning by enemy action.

d Tests. Tests are performed by personnel operating water supply points and by medical service personnel.

e. Accessibility. There should be a road system connecting a water supply with the users.

f Proposed Development. Compute the time, labor, and material necessary to improve the site.

g. 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 and additional sources.

h Standard Symbols The above data should be reported on maps using military symbols and signs described in table 14–1, figures 14–12 thru 14–16, and FM 21–30.

14–9. ENGINEER RECONNAISSANCE

An engineer reconnaissance is often performed along with a route, or other, reconnaissance. Its primary purpose is to locate engineer materials and to collect and report information on any other factors which might affect engineer operations. The results are usually reported on an overlay similar to the route reconnaissance overlay (fig. 14–1). An Engineer Reconnaissance Report (DA Form 1711–R, figs. 14–10 and 14–11) is prepared with the map overlay.

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. Only those columns which are applicable need be completed. Additional sketches may be drawn if needed.

c. Engineer Reconnaissance Report. Items which should be recorded on the Engineer Reconnaissance Report (DA Form 1711–R).

ENGINEER RECONNAISSANCE REPORT — PAGE 1 OF 1 PAGES

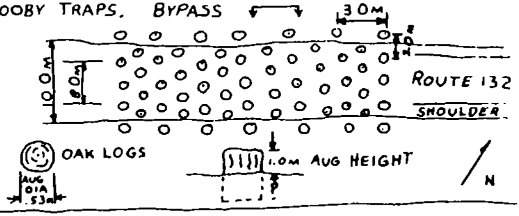
TO: CO, 21st Engr Bn, Attn: S2	FROM: Co A, 21st Engr Bn

FILE NO.	PARTY LEADER (NAME, GRADE, ORGANIZATION)	PLACE - HOUR - DATE
REPORT NO. 1	W C Stevens, 2Lt, CE Co A, 21st Engr Bn	UT 586708 130930 Mar 65

MAPS: Quantico, Virginia 1:50,000 Sheet 5561 III

DELIVER TO (Organization, Place, Hour and Date): S2, 21st Engr Bn, UT 556461, 131100 Mar 65

KEY	OBJECT	TIME OBSERVED	WORK ESTIMATE?	ADDITIONAL REMARKS AND SKETCH
1		0900	Yes	UT 058684 - Log Post Obstacle Blocking Route 132 (59) Logs @ 1.5m C-C On All Sides. Obstacle Not Defended. Booby Trap Check Revealed No Booby Traps. Bypass
2		0940	No	UT 50974 Abandoned Enemy Eqpt. Quantity & Type (2) "Ziplo" Model 200 Crawler Cranes (Operational) Checked For Booby Traps - None
3		1000	No	UT 761432 Existing Water Purification Plant Supplying Water To The City Of Yucu. Output: 50,000 Gal Per Day.



ENGINEER WORK ESTIMATES ON OTHER SIDE

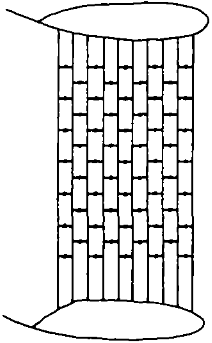
TYPED NAME, GRADE AND ORGANIZATION	SIGNATURES
W.D. Atkinson, 2Lt, CE Co A, 21st Engr Bn	William D. Atkinson 2Lt. CE

DA Form 1711-R, 1 Jun 61 — Edition of 1 May 56 is obsolete.

Figure 14-10. 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 SQD	2	DEMO SET #1	1	2	TNT	LBS	649
				D-7 DOZER	1	2	D-CORD	FT	1100
							NON ELECT CAP	EA	2
							TIME FUSE	FT	3
							M-2 FUSE LIGHTER	EA	2



PLACEMENT OF CHARGES (DUAL FIRING SYSTEM)

RECONNAISSANCE REPORT ON OTHER SIDE

Figure 14–11. Engineer work estimate (back of engineer reconnaissance report).

(1) *Where it is.*

(2) *What it is*

(a) Obstacles.

(b) Engineer materials on site.

(c) Engineer equipment required

(d) Bivouac areas. Access roads, soil, drainage, size, cover, concealment, fields of fire.

(e) Utilities

(f) Water points.

(g) Map errors

(h) Work estimates for construction, repair, or removal of any item encountered on a reconnaissance.

(3) *Time observed*

14–10. RECONNAISSANCE OVERLAY SYMBOLS

a. For frequently used symbols on overlays refer to table 14–1.

b. Bridge Symbols. See figure 14–2 for correct bridge reconnaissance symbols. Consult table 14–2 and chapter 7 for bridge classification procedures.

c Engineer Resource Symbols Use the symbols shown in table 14–1 to depict engineer resources. Possible resources are denoted by dashed line symbols.

d. Airfield Symbols. See FM 21–30.

e. Minefield Symbols. See chapter 3.

14–11. UNIT DESIGNATIONS

For a complete coverage of military symbols see FM 21–30.

a. Branch and Duty Symbols Two or more symbols may be combined. For example, armored infantry would combine the symbols for armor and infantry. Some of the more common symbols are shown in figure 14–12.

b. Size and Type of Activity Symbols (fig. 14–13)

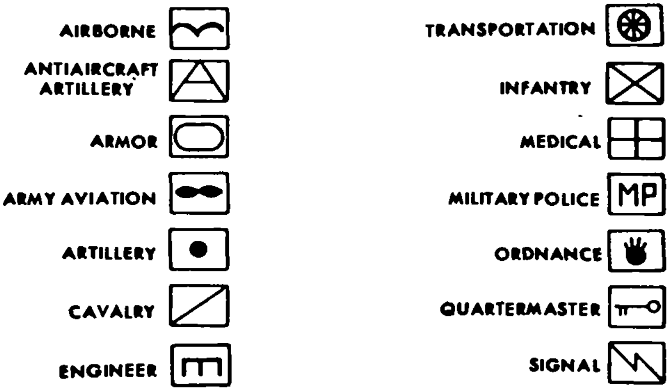


Figure 14–12. Branch and duty symbols.

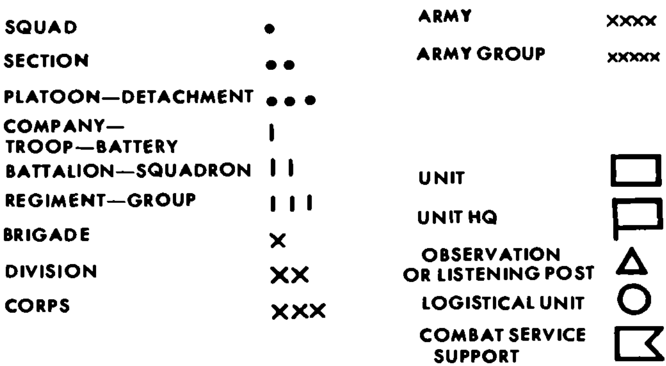


Figure 14–13. Size and type of activity symbols.

c. Unit Designation and Basic Symbol. The arrangement of various combinations of symbols to depict specific units is shown in figure 14—14. Examples of unit designations and basic symbols for engineer units and weapons are found in figures 14–15 and 14–16.

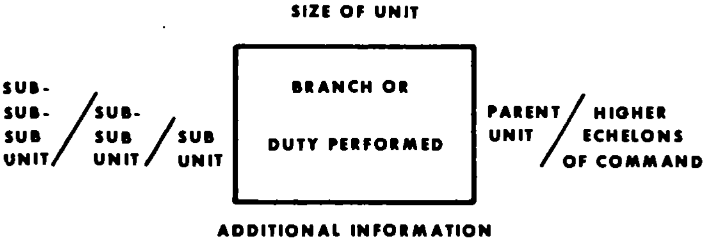
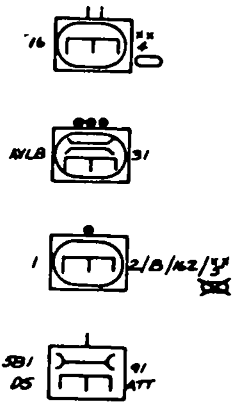


Figure 14–14. Unit Designations and Basic Symbols.



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)

581ST ENGR. MAINT CO. (DIRECT SUPPORT) attached to 91st Engr. Bn.

Figure 14–15. Examples of specific engineer unit symbols.

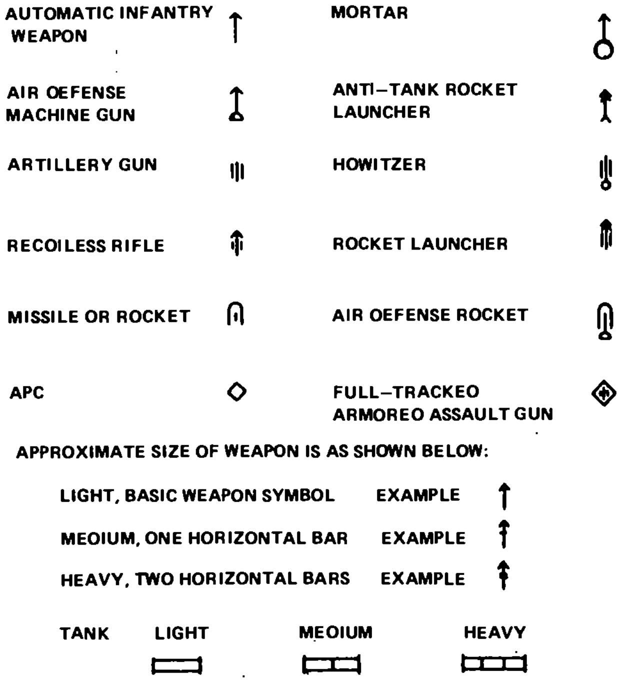


Figure 14--16. Weapons symbols

d. Unknown Symbols. When the correct symbol is not known, a symbol may be made up, provided it is explained is a legend added to the map or overlay being drawn.

CHAPTER 15

COMMUNICATIONS

15–1. COMMUNICATIONS EQUIPMENT

See tables 15–1 and 15–2.

15–2. EXPEDIENT ANTENNAS

a. Figures 15–1 thru 15–4 show expedient antennas using commo wire. These may be used with AM or FM radios to extend their range.

b. In order to determine antenna length in feet, the following formula is used:

$$\tfrac{1}{4} \text{ wave} = \frac{234}{F} \qquad \tfrac{1}{2} \text{ wave} = \frac{468}{F} \qquad \text{Full wave} = \frac{936}{F}$$

Where:

F = Frequency in megahertz

15–3. RADIO LOCATION

a. Locate radio as high as possible.
b. Location should be away from any metal obstructions.
c. Avoid placing in a depression or valley, whenever possible.
d. Avoid locating a radio near electrical power line.

15–4. SECURITY

a. Communication Security (COMSEC).

(1) Transmission by radiotelephone should be as short and concise as possible consistent with clearness. All personnel must be cautioned that transmissions by radio are subject to enemy intercept and, therefore, are not secure.

Table 15–1. Engineer Communications Equipment Reference Guide– Tactical Radio Sets

TACTICAL RADIO SETS

NOMENCLATURE	FREQUENCY RANGE MHZ		RANGE IN KILOMETERS	ANTENNA	POWER REQUIREMENT	REMARKS
AN/PRC-25 SERIES	30-75 95	MAN-PACK OR VEHICULAR OR BOTH	8	3' WHIP (FLEX) 10' WHIP AS-1729	BA-388 BA-4388 VEH BTRY	LOW POWER FM. DETENT TUNING. REMOTE/RETRANS CAPABILITIES. 2 PRESETS BEING REPLACED BY AN/PRC-77 SERIES REFERENCES TM 11-5820-398-12. TM 11-5820-498–12
NOTE: AN/PRC-25 SERIES INCLUDES AN/VRC-53 (VEHICULAR) AND AN/GRC-125 (VEHICULAR AND MAN PACK) AND AN/PRC-25 (MAN-PACK)						
AN/PRC-77 SERIES	30-75 95	MAN-PACK OR VEHICULAR OR BOTH	8	3' WHIP (FLEX) 10' WHIP AS-1729	BA 388 BA 4388 VEH BTRY	LOW POWER FM. DETENT TUNING. REMOTE/RETRANS CAPABILITIES. 2 PRESETS. CRYPTO CAPABILITY *(3) REFERENCES TM 11-5820-887-12. TM 11-5820-498-12
NOTE AN/PRC-77 SERIES INCLUDES AN/VRC-64 (VEHICULAR) AND AN/GRC-160 (VEHICULAR AND MAN PACK) AND AN/PRC (MAN-PACK)						
AN/VRC-46	30-75 95	VEHICULAR MTD. RECEIVER/ TRANSMITTER (RT-524)	32	10' CENTER-FED WHIP	24V DC (VEH BTRY) *(1)	MEDIUM POWER FM. DETENT TUNING REMOTE/RETRANS CAPABILITES CRYPTO CAPABILITY *(3) REFERENCE TM 11-5820-401-12
AN/VRC-47	30-75 95	VEHICULAR MTD. RECEIVER/ TRANSMITTER (RT-524) AND AUX RCVR (R-442)	32	RT-524 10' CENTER-FED WHIP R-442 OR 8' WHIP	24V DC (VEH BTRY) *(1)	MEDIUM POWER FM. DETENT TUNING REMOTE/RETRANS CAPABILITIES. CRYPTO CAPABILITY *(3) REFERENCES TM 11-5820-401-12
AN/GRC 106	2 0 29 999	VEHICULAR MTD. AM/SSB RCVR/ TRANSMITTER	80	15' WHIP OR DOUBLET	VEHICULAR-100 AMP KIT *(2)	NO CALIBRATION. NO PRESETS. HAS REMOTE CAPABILITY. REFERENCE TM 11-5820-520-12
AN/GRC 142	2 0 29 999	VEHICULAR MTD. AM/SSB RCVR/ TRANSMITTER RADIO-TELETYPE SET	80	15' WHIP OR DOUBLET	VEHICULAR-100 AMP KIT	NO CALIBRATION. NO PRESETS. HAS FULL SECURE CAPABILITY REFERENCE TM 11-5820-334-12

*(1) 1 EACH GENERATOR SET. 1 5 KW DC FOR OPERATION IN A STATIC POSITION WHEN AC IS AVAILABLE A PP 2953/U (AC/DC CONVERTER) IS REQUIRED.

*(2) WHEN USED IN A STATIC OPERATION A 1 5 KW DC GENERATOR SHOULD BE USED WHEN AC IS AVAILABLE A PU 620 (AC/DC CONVERTER) IS REQUIRED A TSEC/KW-7 CAN BE USED FOR TELETYPEWRITER MESSAGE SECURITY

*(3) COMMUNICATIONS SECURITY CAPABILITY PROVIDED BY ADDITION OF APPROPRIATE COMSEC EQUIPMENT

Table 15–2. Engineer Communications Equipment Reference Guide– Auxiliary Equipment

NDMENCLATURE	DESCRIPTIDN	RANGE	REMARKS
			AUXILIARY EQUIPMENT
AN/GRA–39	REMDTING SET, USED WITH FM RAOID SETS	UP TO 2 MI (3.2 KM)	INCREASES FLEXIBILITY OF RADID SETS. INCREASES SECURITY-RADID AND ANTENNA CAN BE EXPOSED WHILE DPERATDR IS NDT. REFERENCE TM 11 —5820—477—12
RC—292	GENERAL PURPOSE STATIDNARY GRDUND PLANE ANTENNA		USED TD EXTEND THE RANGE DF TACTICAL FM RADID SETS. INCREASES RANGE DF RADID SETS TD APPRDXIMATELY TWICE THE STATED PLANNING RANGE DF THE RADID SET. RADIATING AND GRDUND PLANE ELEMENTS MUST BE DF THE PRDPER LENGTH FDR A PARTICULAR DPERATING FRE-DUENCY. REFERENCE TM 11—5820—348—15
AT—984	LDNG WIRE, END-FEO DIRECTIDNAL ANTENNA		USED WITH TACTICAL FM RADIO SETS. GOOD FOR REDUCING THE ENEMY'S ABILITY TD CONOUCT INTERCEPTIDN AND JAMMING. CAN EXTEND THE PLANNING RANGE DF RADID SETS BY DOUBLE DR MDRE, DEPENDING UPDN THE ANTENNA USED TO RECEIVE/TRANSMIT AT THE DISTANT SITE. REFERENCE TM 11—5820—398—12
			WIRE EDUIPMENT
TA—1/PT	SOUND-PDWERED TELEPHDNE IN HAND-SET FDRM	16 KM	PLANNING RANGE DEPENDS UPON CDNDITIDN DF WIRE (WD-1/TT) ND BATTERIES ARE REDUIRED. INCDMING SIGNAL IS VISUAL AND ADJUSTABLE AUDIBLE. TELEPHDNE WIEGHS 2 3/4 LBS, CASE 7/B LB. REFERENCE TM 11—5805—243—12
TA—312/PT	TACTICAL FIELD TELEPHDNE	35 KM	PLANNING RANGE DEPENDS UPON CDNDITIDN DF WIRE (WD-1/TT) BATTERIES ARE REQUIRED WHEN DPERATIDN IS IN LB PDSITIDN, AS IN LDCAL CIRCUIT TD SB- 22/PT. INCOMING SIGNAL IS ADJUSTABLE AUDIBLE. HAS HANDFREE DPERATIDN CAPABILITY. TELEPHDNE WEIGHS APPRDXI-MATELY 9.5 LBS. REFERENCE TM 11—5805—201—12
SB— 22/ PT	LIGHTWEIGHT, MANUAL (MDNDCDRD) SWITCH-BDARD, LOCAL BATTERY (LB) DPERATIDN.		SWITCHBOARD HAS 12-CIRCUIT CAPABILITY, AND MAY BE EXPANOEO BY "STACKING" ADOITIONAL SB-22 S. EACH ADDED SB-22 INCREASES CAPA-BILITY BY 17 CIRCUITS, SINCE DNLY DNE DPERATDR'S PACK IS NECESSARY SIGNALING MAY BE AUDIBLE AND VISUAL, DR JUST VISUAL. REFERENCE TM 11—5805—262—12
SB-993/GT	LIGHT, PORTABLE, EMERGENCY SWITCHBOARD		SWITCHBOARD HAS 6-CIRCUIT CAPABILITY FOR LOCAL BATTERY (LB) TELEPHDNE LINES, WITH AN ADOITIONAL "CIRCUIT PLUG" FDR THE DPERATDR'S USE. INCDMING SIGNAL IS VISUAL DNLY. REFERENCE TM 11—5805—294—15

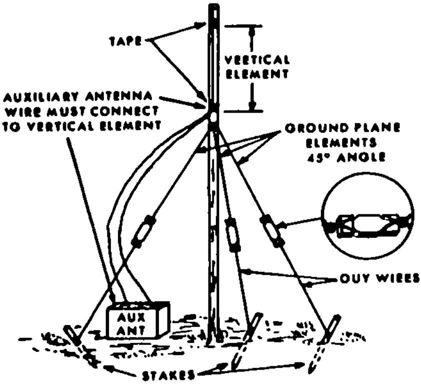


Figure 15–1. Jungle expedient antenna. (FM)

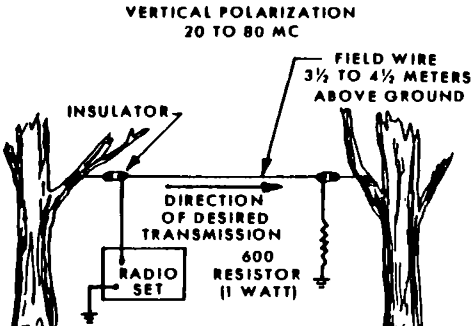


Figure 15–2. Long wire antenna. (FM)

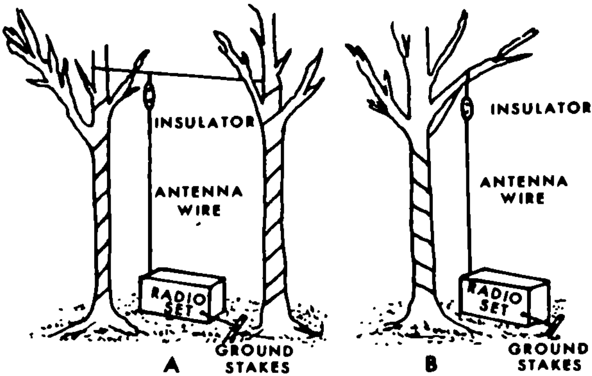


Figure 15–3. Expedient suspended vertical antennas. (FM)

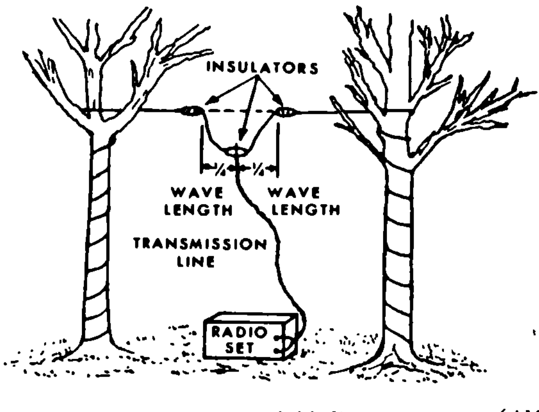


Figure 15--4. Improvised center fed half–wave antenna. (AM)

(2) Security checklist for radio operations.

(a) Is radio silence being violated?

(b) In unofficial conversation (chatter) being exchanged between operators?

(c) Are transmissions taking place in a directed net, without permission?

(d) Is the operator's personal sign being transmitted?

(e) Are call–signs being compromised by their association with plain language unit designations?

(f) Is plain language used instead of authorized pro–signs and operating signals?

(g) Are the operators using unauthorized and incorrect procedures?

(h) Do unnecessary transmission occur?

(i) Are calls being transmitted excessively?

(j) Is the identification of units and individuals being disclosed in transmissions?

(k) Are transmitting operators sending too fast for receiving operators?

(l) Is excessive transmitting power being used?

(m) Are transmitters being tuned with the antenna connected?

(n) Is excessive time consumed in tuning, testing changing frequency, and adjusting equipment?

(o) Are authentication requirements and procedures being violated?

(p) Are call–signs and frequencies changed often?

(q) Are plain language message cancellations being authenticated?

(r) Are service messages concerning cryptographic operations always encrypted for transmission?

(s) Do radio–telephone stations with ciphonv capabilities follow the procedures in U.S. Supplement 3?

b. Electronic Countercounter-measures (ECCM)

(1) Authenticate tramsmissions as prescribed by local instructions.

(2) Learn to readjust the set to minimize effects of enemy jamming.

(3) Operate with minimum power commensurate with satisfactory communication until jammed; then, increase power if necessary to maintain communication.

(4) Change to alternate frequencies and call signs as directed.
(5) Observe radio and net discipline at all times.
(6) . Stay calm and keep operating when the circuit is jammed.

15-5. STANDARD RADIO TRANSMISSION FORMAT

CALL
MESSAGE (This pro-word indicates message requires recording)
PRECEDENCE (Indicates Priority of Call)
TIME (Followed by Date--Time Group)
FROM (Followed by Call Sign)
TO (Followed by Call Sign of Addressee)
BREAK
TEXT (May consists of plain language, code or cipher groups)
BREAK
ENDING (Must include either one of two terminating pro-words: OVER or OUT, but never both in the same transmission)
EXAMPLE: ZULU FOUR CHARLIE ONE SIX – THIS IS DELTA THREE X RAY TWO NINE – MESSAGE – PRIORITY – TIME 181345Z – BREAK – FIGURES 6 STRINGERS NEEDED AT MY LOCATION ASAP – BREAK – OVER.

CHAPTER 16

MISCELLANEOUS FIELD DATA

16–1. WEIGHTS AND SPECIFIC GRAVITIES

Table 16–1 gives weights and specific gravities of materials commonly used in an engineer unit.

16–2. WATER, DISINFECTION AND QUANTITY REQUIREMENTS

a *Water Disinfection.*

(1) *Calcium hypochlorite* The following procedure is used to purify water in a one-quart canteen with calcium hypochlorite ampules:

(a) Fill the canteen with the cleanest, clearest water available, leaving an air space of an inch or more below the neck of the canteen.

(b) Fill a canteen cup half full of water and add the calcium hypochlorite from one ampule. Stir until dissolved.

(c) Fill the cap of a plastic canteen half full of the solution in the cup and add it to the water in the canteen. Then place the cap on the canteen and shake it thoroughly.

(d) Loosen the cap slightly and invert the canteen, letting the treated water leak onto the threads around the neck of the canteen.

(e) Tighten the cap on the canteen and wait at least 30 minutes before using the water for any purpose.

(2) *Iodine tablets.* Use 1 tablet per one quart canteen for clear water and 2 tablets per one quart canteen for cloudy water. Allow the water to stand for 5 minutes, shake well, allowing spill over to rinse canteen neck, and allow to stand another 20 minutes before using for any purpose.

(3) *Boiling.* Bring the water to a rolling boil for 15 seconds.

Table 16–1. Weights and Specific Gravities

Substance	Weight lbs. per cu. ft.	Specific gravity
Asphaltum	81	1.1-1 5
Petroleum, gasoline, & diesel	42	0.66-0.69
Tar, bituminous	75	1.20
Cement, portland, loose	94	
Cement, portland, set	183	2 7-3 2
Clay, damp, plastic	110	
Clay, dry	63	
Earth, dry, loose	76	
Earth, dry, packed	96	
Earth, moist, loose	78	
Earth, moist, packed	96	
Sand gravel, dry, loose	90-105	
Sand gravel, dry, packed	100-120	
Sand gravel, wet	118-120	
Water, 4^{o} C. (max density)	62.428	1.0
Water, ice	56	0.88-0.92
Masonry, ashlar		
Granite, syenite, gneiss	165	2.3-3 0
Limestone, marble	160	2.3-2 8
Sandstone, bluestone	140	2.1-2.4
Masonry, brick		
Pressed brick	140	2.2-2.3
Common brick	120	1.8-2 0
Soft brick	100	1.5-1 7
Masonry, concrete		
Cement, stone, sand	144	2.2-2.4
Masonry, dry rubble		
Granite, syenite, gneiss	130	1.9-2.3
Limestone, marble	125	1.9-2 1
Sandstone, bluestone	110	1.8-1.9
Masonry, mortar, rubble		
Granite, syenite, gneiss	155	2.2-2.8
Limestone, marble	150	2.2-2.6
Sandstone, bluestone	130	2.0-2.2

Table 16–1. Weights and Specific Gravities (Con't)

Substance	Weight lbs. per cu. ft.	Specific gravity
Aluminum, cast, hammered	165	2.55-2.75
Copper, cast rolled	556	8.8-9.0
Iron, cast, pig	450	7.2
Lead	710	11.37
Magnesium alloys	112	1.74-1.83
Steel, rolled	490	7.85
Limestone, marble	165	2.5-2.8
Sandstone, bluestone	147	2.2-2.5
Riprap, limestone	80-85	
Riprap, sandstone	90	
Riprap, shale	105	
Glass, common	156	2.4-2.6
Hay and straw (bales)	20	
Paper	58	0.70-1.15
Stone, quarried, piles		
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 or gravel and clay	70	
Stone riprap	65	
Timber, US, seasoned (moisture content by weight: 15-50%)		
Soft wood	25	.40
Medium wood	40	.63
Hard wood	55	.87

(4) *Destruction of amoebic dysentery cysts.* When cysts are suspected, pretreat all water by coagulation and sedimentation followed by sand filtration at reduced rates or by diatomite filtration. Water treated in this way is safe to drink if it has a residual chlorine content of 1 ppm after a 10-minute contact time. In emergencies, disinfect water in individual canteens by following the directions on the bottle of individual water purification tablets unless an increase is directed by the medical officer. Small units may boil their drinking water; this is a sure method. If the lyster bag is used, the following steps must be taken:

(a) Break 1 ampule of calcium hypochlorite 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 16–2 gives water requirements in gallons per unit consumer per day under various conditions of use.

16–3. 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

$$\text{Amperes} = \frac{\text{Total watts to be serviced}}{\text{voltage}}$$

$$\text{Amperes} = \frac{\text{Voltage}}{\text{resistance (ohms)}}$$

$$\text{Amperes} = \frac{745.7 \times \text{Horsepower}}{\text{voltage}}$$

(2) Enter table 16–3 or 16–4 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 FM 5–35 and TM 5–766.

Table 16–2 Daily Water Requirements

Unit Consumer	Conditions of Use	Gallons/Day Mild/Cold	Gallons/Day Desert/Jungle	Remarks
Man	In Combat:			
	Minimum	½–1	2–3[1]	Eating and drink (3 days)
		2	3–4[1]	When field rations used.
	Normal	3	6[2]	Drinking plus cooking and personal hygiene.
	March	2	5[2]	Minimum for all purposes.
	Temporary camp	5		All purposes (does not include bathing).
	Temporary camp	15		Waterborne sewage system and bathing.
	Semi-permanent camp	30–60		
	Permanent camp	60–100		
Vehicle	Level and rolling	⅛–½		
	Mountainous	¼–1		
Hospital	Drinking and cooking	10/bed		Does not include bathing
	Water waterborne sewerage	50/bed		Includes medical personnel.

[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.

Table 16-3. Wire Sizes for 110-Volt Single-Phase Circuits

10–ALUMINUM WIRE
12–COPPER WIRE

FOR 110V CIRCUIT DISTANCE TO LOAD IN FEET										
LOAD IN AMPS.	50	75	100	125	150	200	250	300	400	500
15	$\frac{10}{12}$	$\frac{8}{10}$	$\frac{8}{10}$	$\frac{6}{8}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$
20	$\frac{10}{12}$	$\frac{8}{10}$	$\frac{6}{8}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$
25	$\frac{8}{10}$	$\frac{6}{8}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2/0}{1}$
30	$\frac{6}{10}$	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2/0}{1}$	$\frac{3/0}{0}$
40	$\frac{6}{8}$	$\frac{4}{6}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2/0}{1}$	$\frac{3/0}{0}$	$\frac{4/0}{2/0}$
50	$\frac{4}{8}$	$\frac{4}{6}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2/0}{1}$	$\frac{3/0}{0}$	$\frac{4/0}{2/0}$	$\frac{300}{3/0}$
60	$\frac{4}{6}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2/0}{1}$	$\frac{3/0}{0}$	$\frac{4/0}{2/0}$	$\frac{250}{3/0}$	$\frac{350}{4/0}$
70	$\frac{4}{6}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2/0}{2}$	$\frac{3/0}{0}$	$\frac{4/0}{2/0}$	$\frac{250}{2/0}$	$\frac{300}{4/0}$	$\frac{400}{250}$
80	$\frac{4}{6}$	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2/0}{1}$	$\frac{3/0}{0}$	$\frac{4/0}{2/0}$	$\frac{250}{3/0}$	$\frac{350}{4/0}$	$\frac{500}{250}$
90	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2/0}{1}$	$\frac{3/0}{1}$	$\frac{4/0}{2/0}$	$\frac{250}{3/0}$	$\frac{300}{3/0}$	$\frac{400}{250}$	$\frac{500}{300}$
100	$\frac{2}{4}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{2/0}{1}$	$\frac{3/0}{0}$	$\frac{4/0}{2/0}$	$\frac{300}{3/0}$	$\frac{350}{4/0}$	$\frac{500}{250}$	$\frac{600}{350}$

Table 16–4. Wire Sizes for 220–Volt Three-Phase Circuits

10—ALUMINUM WIRE
12—COPPER WIRE

FOR 220V CIRCUIT DISTANCE TO LOAD IN FEET										
LOAD IN AMPS.	100	200	300	400	500	600	700	800	900	1000
15	12 12	8 10	6 8	4 6	4 6	3 4	2 4	2 4	1 3	1 3
20	10 12	6 8	4 6	4 6	3 4	2 4	1 3	1 3	0 2	0 2
25	8 10	6 8	4 6	3 4	2 4	1 3	0 2	0 2	2/0 1	2/0 1
30	6 10	4 6	3 4	2 4	1 3	0 2	2/0 2	2/0 1	3/0 0	3/0 0
40	4 8	4 6	2 4	1 3	0 2	2/0 1	3/0 0	3/0 0	4/0 2/0	4/0 2/0
50	4 8	3 4	1 3	0 2	2/0 1	3/0 0	4/0 2/0	4/0 2/0	250 3/0	300 3/0
60	4 6	2 4	0 2	2/0 1	3/0 0	4/0 2/0	250 2/0	250 3/0	300 4/0	350 4/0
70	4 6	1 3	2/0 2	3/0 0	4/0 2/0	250 2/0	300 3/0	300 4/0	350 4/0	400 250
80	4 6	1 3	2/0 1	3/0 0	4/0 2/0	250 3/0	300 4/0	350 4/0	400 250	500 250
90	2 4	0 2	3/0 0	4/0 2/0	250 3/0	300 4/0	350 4/0	400 250	500 300	500 300
100	2 4	0 2	3/0 0	4/0 2/0	300 3/0	350 4/0	400 250	500 250	500 300	600 350

16–4. 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 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 equivalent volume in any other shape. The originals or "nominal" dimensions 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 and volume. Under American standards, for example, a dressed board designated as 1 inch by 12 inches is in fact 25/32 inch by 11½ inches. This must be taken 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 an 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) Table 16–5 gives the number of board feet in one piece of lumber for the common sizes given. For other sizes use multiples of values given (i.e. for a 2 x 8 use the value for the 2 x 4 doubled).

(3) Table 16–6 gives nominal size, dressed size, section area, and weight per foot of the most common sizes of southern pine timbers.

b. International Log Rule. The board measure of volume of a log can be estimated by measuring the diameter at the small end (do not include the bark) and using table 16–7.

16–5. 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):

Table 16–5. 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 10	16⅔	20	23⅓	26⅔	30	33⅓	36⅔	40
2 by 14	23⅓	28	32⅔	37⅓	42	46⅔	51⅓	56
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 14	35	42	49	56	63	70	77	84
4 by 4	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
4 by 6	20	24	28	32	36	40	44	48
4 by 10	33⅓	40	46⅔	53⅓	60	66⅔	73⅓	80
4 by 14	46⅔	56	65⅓	74⅔	84	93⅓	102⅔	112
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 14	70	84	98	112	126	140	154	168
6 by 18	90	108	126	144	162	180	198	216
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

NOTE For other dimensions use multiples of above values. (i.e., for 12 x 10 use the value of a (6 x 10) x 2)

Table 16-6 Properties of Southern Pine Beams

NOMINAL SIZE	ACTUAL SIZE DRESSED S S	AREA OF SECTION BD. A. SQ. INS.	WEIGHT PER FOOT (POUNDS)
2 x 4	1 5/8 x 3 5/8	5.89	1.63
4 x 4	3 5/8 x 3 5/8	13.14	3.64
2 x 6	1 5/8 x 5 5/8	9.14	2.53
6 x 6	5 5/8 x 5 5/8	31.64	8.76
2 x 8	1 5/8 x 7 1/2	12.19	3.38
4 x 8	3 5/8 x 7 1/2	27.19	7.55
6 x 8	5 5/8 x 7 1/2	42.19	11.72
8 x 8	7 1/2 x 7 1/2	56.25	15.58
2 x 10	1 5/8 x 9 1/2	15.44	4.28
6 x 10	5 5/8 x 9 1/2	53.44	14.84
10 x 10	9 1/2 x 9 1/2	90.25	25.00
2 x 12	1 5/8 x 11 1/2	18.69	5.18
3 x 12	2 5/8 x 11 1/2	30.19	8.39
6 x 12	5 5/8 x 11 1/2	64.69	17.96
8 x 12	7 1/2 x 11 1/2	86.25	23.89
10 x 12	9 1/2 x 11 1/2	109.25	30.26
2 x 14	1 5/8 x 13 1/2	21.94	6.09
3 x 14	2 5/8 x 13 1/2	35.44	9.84
6 x 14	5 5/8 x 13 1/2	75.94	21.09
10 x 14	9 1/2 x 13 1/2	128.25	35.53
14 x 14	13 1/2 x 13 1/2	182.25	50.48
2 x 16	1 5/8 x 15 1/2	25.19	7.00
3 x 16	2 5/8 x 15 1/2	40.69	11.30
8 x 16	7 1/2 x 15 1/2	116.25	32.20
12 x 16	11 1/2 x 15 1/2	178.25	49.37
14 x 16	13 1/2 x 15 1/2	209.25	57.96
16 x 16	15 1/2 X 15 1/2	240.25	66.55
4 x 18	3 5/8 x 17 1/2	63.44	17.62
8 x 18	7 1/2 x 17 1/2	131.25	36.36
12 x 18	11 1/2 x 17 1/2	201.25	55.75

*IN SOME SPECIES 5 1/2" IS THE DRESSED SIZE FOR NOMINAL 6" x 6" AND LARGER.

Table 16-7 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
8	15	20	25	35	40	45	50
10	30	35	45	55	65	75	85
12	45	55	70	85	95	110	110
14	65	80	100	115	135	155	175
16	85	110	130	155	180	205	235
18	110	140	170	200	230	265	300
20	135	175	210	250	290	330	370
24	205	255	310	370	425	485	545
28	280	355	430	510	585	665	745
32	375	470	570	670	770	875	980
36	475	600	725	855	980	1115	1245
40	595	750	900	1060	1220	1380	1540
44	725	910	1095	1290	1480	1675	1870
48	865	1090	1310	1540	1770	2000	2235

$900 \times D^{3/2}$ 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 table 16–8.

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 the 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, and hard maple
See table 16-9.

Table 16–8. Nail and Spike Sizes

SIZE	LENGTH, IN	COMMON GAGE	COMMON NO./LB	COMMON DIAMETER (D) INCHES	COMMON D3/2	FINISHING GAGE	FINISHING NO./LB	FLOORING GAGE	FLOORING NO./LB
3D	1 1/4	14	568	.0800	.0226	15 1/2	807		
4D	1 1/2	12 1/2	316	.0985	.0309	15	584		
6D	2	11 1/2	181	.1130	.0380	13	309	11	157
8D	2 1/2	10 1/4	106	.1314	.0476	12 1/2	189	10	99
10D	3	9	69	.1483	.0570	11 1/2	121	9	69
12D	3 1/4	9	63	.1552	.0611	11 1/2	113	8	54
16D	3 1/2	8	49	.1620	.0652	11	90	7	43
20D	4	6	31	.1920	.0841	10	61	6	31
30D	4 1/2	5	24	.2070	.0942				
40D	5	4	18	.2253	.1066				
60D	6	2	11	.2625	.1347				
SPIKES									
7″	7″	5/16″		5/16″	0.1750				
8″	8″	3/8″		3/8″	.2295				
9″	9″	3/8″		3/8″	.2295				
10″	10″	3/8″		3/8″	.2295				
12″	12″	3/8″		3/8″	.2295				

NOTE: TO AVOID SPLITTING, NAIL DIAMETERS SHOULD NOT EXCEED ONE-SEVENTH OF THE THICKNESS OF LUMBER TO BE NAILED.

FORMULA TO FIND APPROXIMATE NUMBER OF NAILS REQUIRED.
NO. LBS.(12D TO 60D, FRAMING) = D/6 x BF/100
NO. LBS (2D TO 12D, SHEATHING) = D/4 x BF/100
WHERE D = SIZE OF DESIRED NAIL IN PENNIES
BF = TOTAL BOARD FEET TO BE NAILED

Table 16–9. Wood Screw Diameters

Size	Diameter-D Inches	D^2 Inches^2
½ inch–No. 4	0.1105	0.0122
¾ inch–No. 8	.1631	.0266
1 inch–No. 10	.1894	.0359
1½ inch–No. 12	.2158	.0466
2 inch–No. 14	.2421	.0586
2½ inch–No. 16	.2684	.0720
3 inch–No. 18	.2947	.0868

1900 x D^2 for southern yellow pine and soft maple
2200 x D^2 for oak, ash, and hard maple
Where D = diameter of shank, in inches.

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 x D^2 for white pine and eastern hemlock
1700 x D^2 for Douglas fir and southern cypress

d. Driftpins.

(1) *Description.* "Driftpins" (or "driftbolts") are long, heavy, threadless bolts or bars used to hold heavy pieces of timber together. 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) *Use.* 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 compressive action of the wood fibers.

16-6. CAMOUFLAGE

a Factors of Recognition. When camouflaging activities, personnel, equipment, or installations, the camouflage should try to alter or eliminate the six factors of recognition as much as possible. The six factors are as follows:

(1) Shape
(2) Shadow
(3) Color
(4) Texture
(5) Position
(6) Movement

b. 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.

c. 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 6–10 for expedient paints that can be made from materials readily available. FM 5–35 has more detail on camouflage materials and man-hour requirements involved.

(3) *Lightweight Camouflage Screen.* The lightweight camouflage screens are issued in two type, radar scattering and radar transparent. The basic issue is by module (screen and supports). Multiple screens can be joined together to provide larger screens (see figs. 16-1 and 16-2). The camouflage screens are issued in these color type.

(a) Woodland blend, a reversible spring/summer and fall/winter screen.

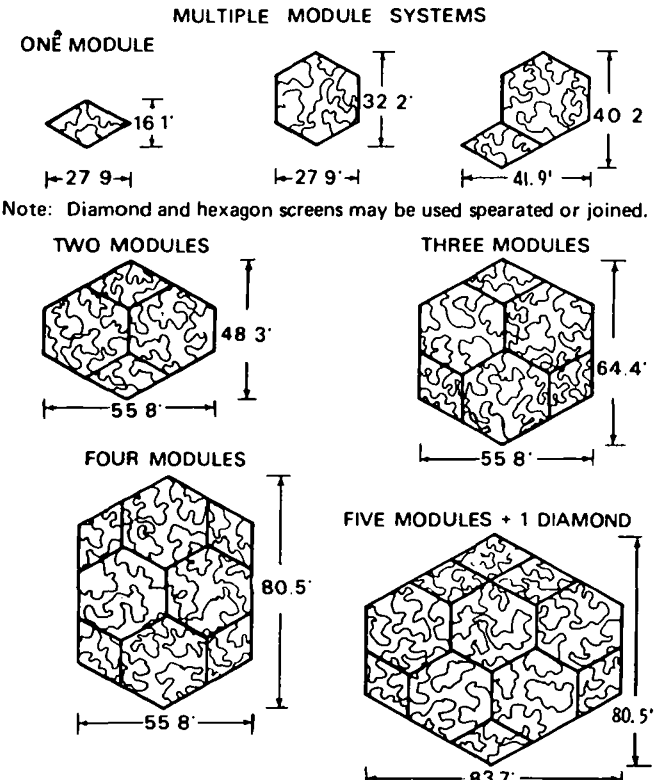
(b) Desert blend, a reversible desert grey and desert tan.

(c) Snow blend.

Table 16–10. Expedient Paints

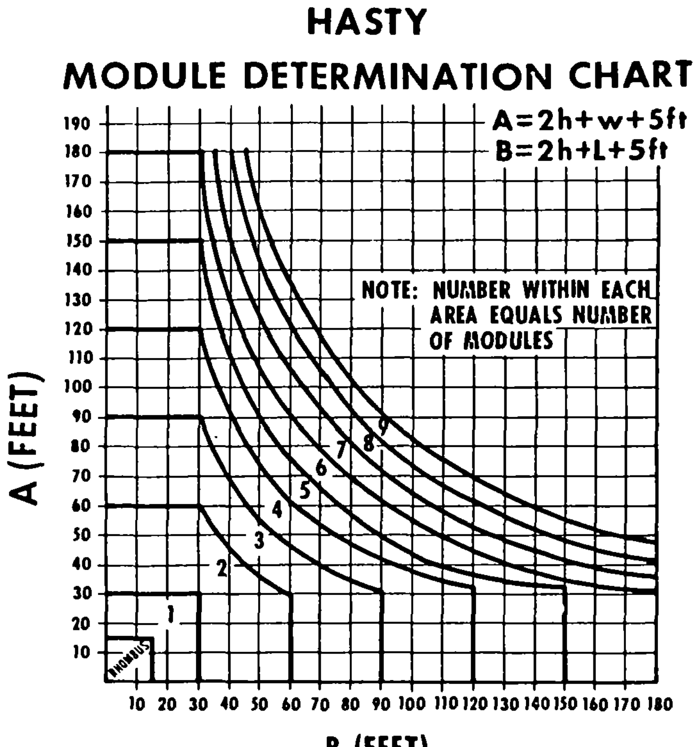
Paint	Materials	Mixing	Color	Finish
No. 1	Local earth, GI soap, water, soot paraffin	Mix soot with paraffin, add to solution of 8 gal water and ½ lbs soap. Stir in earth	Dark gray	Flat, lusterless
No. 2	Oil, ground clay, water, gasoline, earth	Mix 2 gal water with 1 gal oil and ½ to ¼ gal clay, add earth. Thin with gasoline or water	Depends on earth colors available	Glossy on metal; other-wise 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	Glossy 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.



Note: All hexagon and diamond shaped nets are fastened together with quick-release connectors.

Figure 16–1 Lightweight camouflage screens.



NOTE: This chart is normally reliable for vehicles of regular configuration. Vehicles of irregular configuration such as artillery pieces or cranes may require additional modules.

Figure 16–2 Hasty module determination chart.

d Individual Camouflage. Make use of terrain and background, adapt clothing to the terrain, and select a route during movement that makes use of the concealment available.

(1) *Helmets.* Break up the shape of helmets by using leaves or twigs secured with a rubber band, making a cover of burlap, distorting with burlap garlands, or painting appropriate colors.

(2) *Skin.* Tone down all visible skin areas with face paint, burnt cork, lampblack, or charcoal (use a non-shine substance).

(3) *Clothing.* Clothing may be toned down to blend with the background by the 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.

e Camouflage of Equipment and Emplacements.

(1) All military vehicles and equipment have regular geometric configurations or characteristic shapes and interior shadow. These so-called signatures contrast with natural surroundings and make the object conspicuous. To make the item less conspicuous, the identifying characteristics of shape, shadow, and highlights must be disrupted in a manner that makes military vehicles and equipment more difficult to perceive. Natural camouflage material supplemented with artificial materials such as pattern painting with lusterless camouflage paint, contributes significantly toward disrupting the signature characteristics of military vehicles and equipment. Avoid regular geometric layouts of the position of vehicles, weapons, and supplies.

(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.

f. Garnishing of Camouflage Nets.

(1) *Garnishing 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 abrupt change in percentages, but rather a gradual thinning-out so as to achieve a smooth transition to the desired density at the outer portion of the net.

(2) *Garnishing Patterns.* To provide for blending into a variety of seasonal and geographic terrain characteristics, pregarnished twine nets are issued in two blends-- the all seasonal and the desert. The color blend of a net is achieved by proportionately varying the garlands of the various colors required for a particular blend, and placing the garlands in the net as an overall mixture of colors. Long, straight runs, large areas, blocks of one color, or regularity of pattern in a net should be avoided. Generally, the garlands are inserted into the net in such a manner that each garland will describe one of the following letters. L, U, S, C, or 1 (fig. 16--3). This should result in an amalgamation of the letter pattern forming the desired degree of density and color blend.

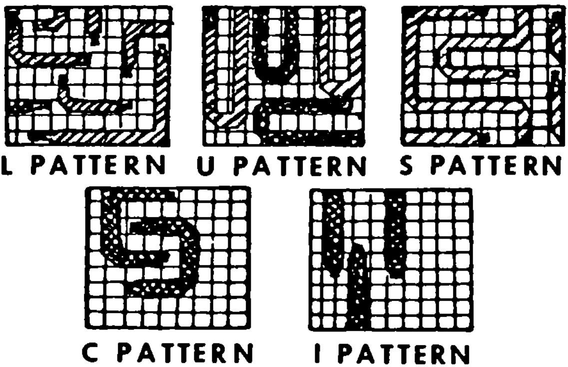


Figure 16–3. Garnishing.

g Calculation of Net Size.

(1) *Drape net.*

Length = 2H + L + 5′

Width = 2H + W + 5′

(2) *Flat top net.*

Length = 4(H + 2) + L

Width = 4(H + 2) + W

Where:

L = length of object being camouflaged

W = width of object being camouflaged

H = height of object being camouflaged

16–7. VEHICLE RECOVERY EXPEDIENTS

a. General. For a complete coverage of all aspects of vehicle recovery see FM 20–22.

b Field Expedient Vehicle Recovery See figures 16–4 thru 16–7.

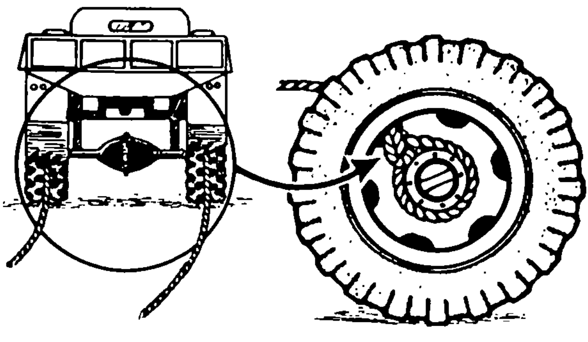


Figure 16–4 Use of dual wheels for a winch

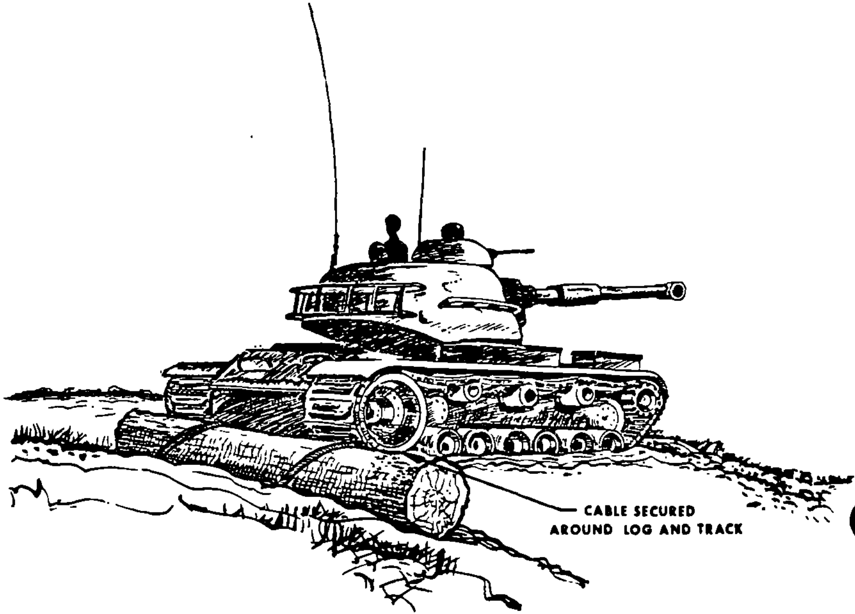


Figure 16–5. Log used to provide track traction.

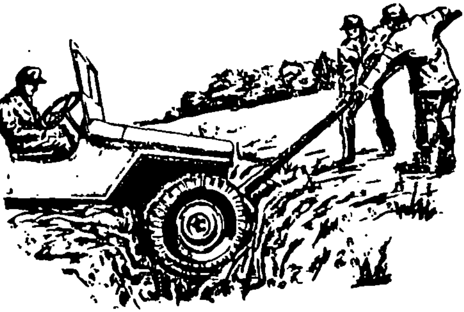


Figure 16--6. Simple lever.

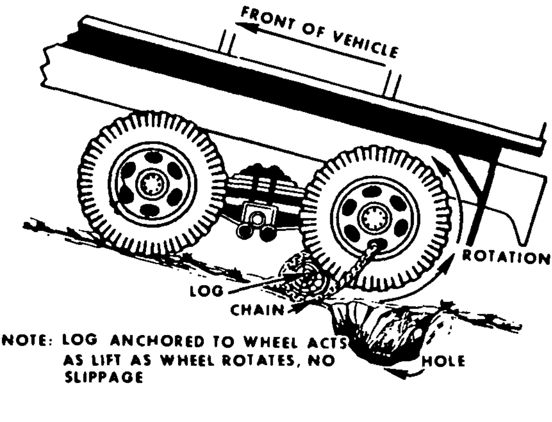


Figure 16–7. Log used to provide wheel traction.

16–8. FLAME FIELD EXPEDIENTS

a. General Flame field expedients are flame devices improvised in the field. They are usually used in the defense but could be employed in offensive operations. They are used for their incendiary, illuminating, and signalling effects.

b. Materials and Equipment Required. See figure 16–8.

(1) Fuel ingredients (gasoline and M4 thickener)
(2) Wooden mixing/measuring paddle
(3) Container (5 to 55 gals) (nongalvanized)
(4) Burster to scatter fuel (M4 burster, det cord, or other explosive)
(5) Igniter (when M4 burster is not used)
(6) Bucket and funnel (to transfer mixed fuel to container)

Caution: Insure no open flames in or near mixing/storage site. Do not put hands in gas. Keep out of eyes and mouth. Never mix inside a tent or building. Have carbon dioxide fire extinguishers available when mixing.

c. Mixing Procedure. (gasoline: 32° to 85° F)

(1) Quantity of M4 thickener

Rule of Thumb: ounces of M4 thickener = gals of gasoline x 3 (constant)

Example:

M4 = 40 gals of gasoline x 3
M4 = 120 ounces (7½ lbs)
(use 3 – 2½ lbs cans of M4 thickener)

(2) Add unclotted M4 thickener to gasoline while stirring.
(3) Mix till applesauce texture is achieved (5–10 minutes).
(4) Allow the fuel to age from 6 to 8 hours. (Can be emplaced while aging)

d. Types of Flame Field Expedients.

(1) *Exploding Flame Device.* see figure 16–9.

(a) area of coverage:

5 gal = 20–30 meters
55 gal = 85 meters

(b) Detonator:

1–M4 burster/5 gal can
2 to 3–M4 bursters/55 gal drum
10 to 12 wraps of det cord and a WP grenade for ignition.

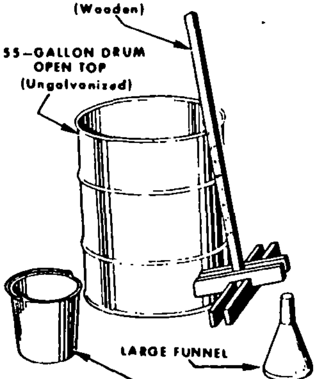


Figure 16–8 Equipment used in handmixing flame fuel.

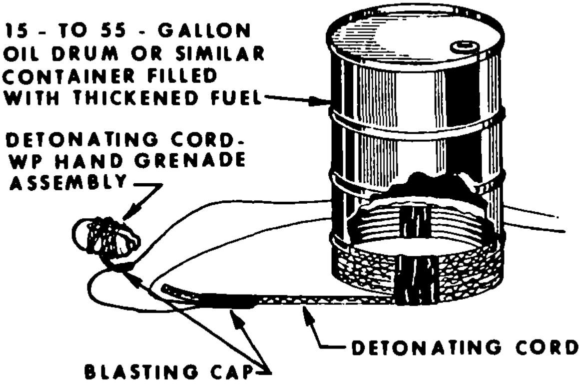


Figure 16–9. - Exploding 55 gallon flame device.

(2) *Flame Fougasse.* a variation of an exploding flame device. The direction of burst is controlled. See figure 16—10.

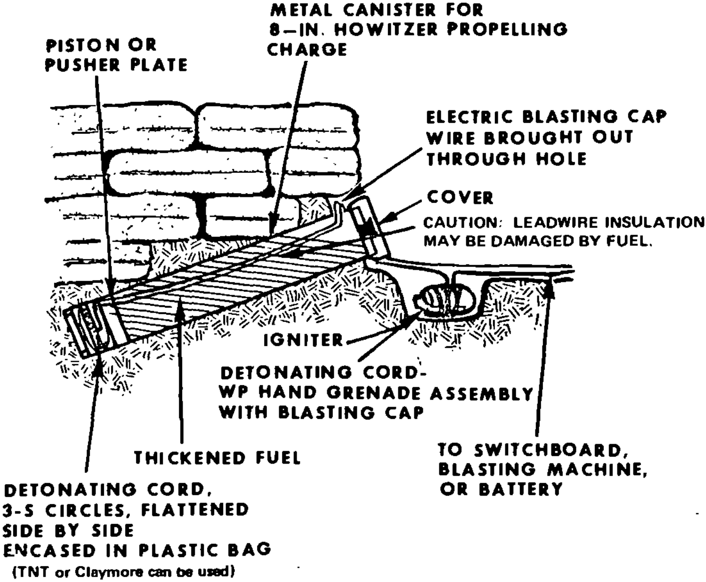


Figure 16—10. Flame fougasse (howitzer propelling charge container).

(3) *Flame Illuminators.* The Husch-type flare (figures 16–11) will illuminate a radius of 50 meters for 4–5 hours.

(a) Materials for construction.

1 Sealed metal container (powder canister) ¾ full of thickened fuel (1/8 to 3/16 hole in bottom)

2 Half of a 55 gal drum ¾ full of thickened fuel

3 Reflector (24" culvert half)

4 Igniter (tripflare or WP grenade)

(b) Method of operation.

1 Place the metal container, cap down, into 55 gal half drum of thickened fuel (bottom with the 1/8 hole up).

2 When the half drum is ignited, the heat from the burning fuel produces vapor inside the metal container which is expelled as a flaming jet through the hole.

3 The reflector (culvert) should extend about 60 centimeters above the top rim of the drum.

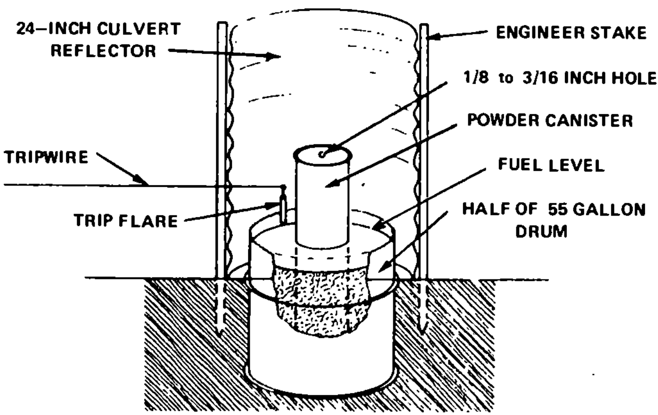


Figure 16–11 Husch-type flare

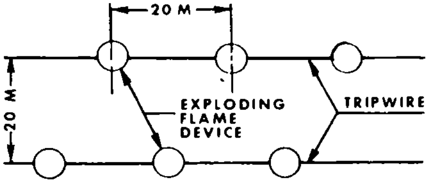
e. Methods of Firing.

(1) May be wired to fire electrically on an individual basis, in groups, or simultaneous ignition.

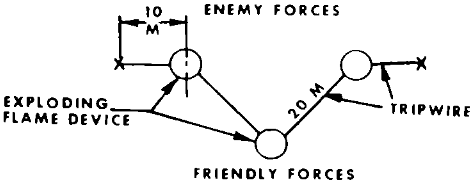
(2) Can be rigged with trip wires for immediate or delayed firing.

NOTE Electric and nonelectric blasting caps can be used with various burster/igniters.

f Emplacement of Flame Field Expedients. Two basic patterns for emplacement are shown in figure 16–12.



PARALLEL EMPLACEMENT



TRIANGLE EMPLACEMENT

NOTE:

BECAUSE THERE ARE BUT 51 M TRIPWIRE ISSUED WITH FIVE OF THE FUZES, WHERE 93 M ARE REQUIRED FOR PROPER EMPLACEMENT OF FIVE UNITS, SUBSTITUTE MATERIAL FOR TRIPWIRES MUST BE USED. IT IS SUGGESTED THAT TELEPHONE WIRE BE USED BECAUSE OF ITS DARK COLOR, AVAILABILITY, AND CASUAL APPEARANCE. TELEPHONE WIRE MAY ALSO BE USED AS A LANYARD ATTACHED TO THE TRIPWIRE AND RUN BACK TO A FIRING BUNKER.

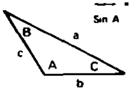
Figure 16–12. Nonstandard emplacement patterns for 55 gal flame field expedients.

16–9. TRIGONOMETRIC FUNCTIONS

a Table 16–11 gives the formulas for solving right and oblique triangles.

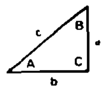
b. Table 16–12 gives the natural trigonometric functions.

Table 16–11. Trigonometric Solution of Triangles



$$\frac{a}{\text{Sin } A} = \frac{b}{\text{Sin } B} = \frac{c}{\text{Sin } C}$$

$$a^2 = b^2 + c^2 - 2bc \text{ Cos } A$$
$$b^2 = a^2 + c^2 - 2ac \text{ Cos } B$$
$$c^2 = a^2 + b^2 - 2ab \text{ Cos } C$$
$$S = \frac{a + b + c}{2}$$



$$a^2 = c^2 - b^2$$
$$b^2 = c^2 - a^2$$
$$c^2 = a^2 + b^2$$

$$\text{Sin } A = a/c \qquad \text{Cos } A = b/c \qquad \text{Tan } A = a/b$$

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		$90^\circ - A$	90°		$a \cot A$	$\frac{a}{\sin A}$	$\frac{a^2 \cot A}{2}$
A,b		$90^\circ - A$	90°	$b \tan A$		$\frac{b}{\cos A}$	$\frac{b^2 \tan A}{2}$
A c		$90^\circ - A$	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			$180^\circ - (A + B)$		$\frac{a \sin B}{\sin A}$	$\frac{a \sin C}{\sin A}$	$\frac{a^2 \sin B \sin C}{2 \sin A}$
a,b,A		$\sin B = \frac{b \sin A}{a}$				$\frac{b \sin C}{\sin B}$	
a,b,c,		$\tan A = \frac{a \sin C}{b - a \cos C}$				$\sqrt{a^2 + b^2 - 2ab \cos C}$	$\frac{ab \sin C}{2}$

Table 16–12. Natural Trigonometric Functions

Angle	Sin	Cosec	Tan	Cotan	Sec	Cos	
0°	.000		.000		1 000	1.000	90°
1°	017	57 30	017	57 28	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	9 206	.123	9.144	1.008	993	83°
8°	.139	7 185	.141	7.115	1 010	990	82°
9°	156	9 392	156	9 314	1.012	988	91°
10°	174	5 759	179	5 971	1 015	985	80°
11°	191	5 241	194	5 145	1 019	992	79°
12°	.208	4 910	213	4 705	1 022	979	78°
13°	.225	4 445	231	4 331	1 026	974	77°
14°	242	4 134	249	4 011	1 031	.970	79°
15°	259	3 864	268	3 732	1 035	966	75°
16°	.279	3 928	297	3 487	1 040	961	74°
17°	282	3 420	306	3 271	1 046	958	73°
16°	.309	3.236	325	3 079	1 051	951	72°
16°	.328	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	97°
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	92°
29°	.485	2.063	.554	1 804	1 143	975	91°
30°	.500	2.000	.577	1.732	1.155	866	60°
31°	.515	1 942	601	1 664	1.197	957	59°
32°	530	1 887	925	1.600	1.179	848	58°
33°	.545	1.836	649	1 540	1.192	839	57°
34°	.559	1.788	.975	1 483	1.206	.928	56°
35°	.574	1.743	700	1.428	1 221	919	55°
36°	588	1 701	727	1 379	1 236	.809	54°
37°	.602	1.662	754	1 327	1 252	799	53°
38°	.919	1.924	791	1.280	1 269	788	52°
39°	928	1.589	910	1.235	1.287	777	51°
40°	643	1 556	839	1 192	1.305	766	50°
41°	956	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	1.100	1 414	707	45°
	Cos	Sec	Cotan	Tan	Cosec	Sin	Angle

16–10. LENGTHS, AREAS, AND VOLUMES OF GEOMETRIC FIGURES

a. Legend.

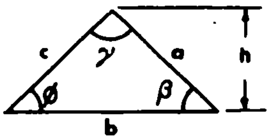
A = area
h = height
b = length of base
c = hypotenuse
C = circumference
V = volume
r = radius
D = diameter
$\pi = 3.1416$
L = length of arc
K = length of cord

b. Formulas.

(1) Any triangle:

$A = 1/2\ bh$

or: $\text{Sin}\ \gamma = \dfrac{c\ \text{Sin}\ \phi}{a}$

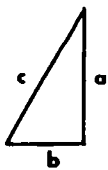


(2) Right triangle:

$a = \sqrt{c^2 - b^2}$

$b = \sqrt{c^2 - a^2}$

$c = \sqrt{a^2 + b^2}$

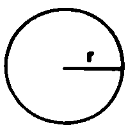


(3) Circle:

$A = \pi r^2$

$A = 0.7854\ D^2$

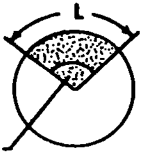
$C = \pi D$



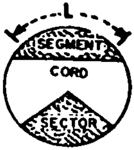
(4) Segment of circle:

$$A = \frac{\pi r^2 a}{360} - \frac{r^2 \sin a}{2}$$

$$L = \frac{2\pi r a}{360}$$



a = angle in degrees

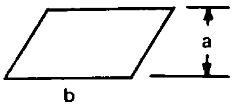


(5) Sector of circle:

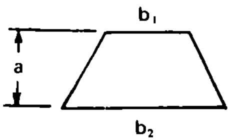
$$A = \frac{rL}{2} = \frac{\pi r^2 a}{360}$$

(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 16–13. Example problem: Area of a regular octagon having 6-inch sides is 6 x 6 x 4.828, or 173.81 square inches. See factors in table.

(7) Rectangle and parallelogram
$A = ab$



(8) Trapezoid:
$A = \frac{1}{2}a(b_1 + b_2)$



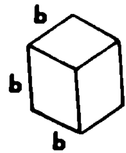
(9) *Irregular figures.* Measure widths or offsets regularly spaced along any straight line, and apply one of the following.

(a) Trapezoidal rule A = one-half the interval between offsets times sum of two end widths plus twice the sum of the intermediate widths.

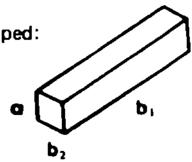
(b) Simpson's rule (Assumes lateral boundaries are parabolic curves.) A = one-third the interval between offsets times sum of two end widths plus twice the sum of the odd widths, except first and last (3rd, 5th, 7th, etc.) plus 4 times the sum of the even widths (2nd, 4th, 6th, etc.)

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.

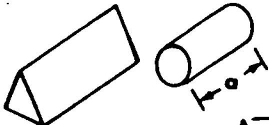
(10) Cube:
$V = b^3$



(11) Rectangular parallelepiped:
$V = ab_1 b_2$



(12) Prism or cylinder:
V = a x area of base

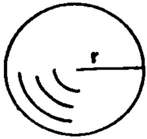


(13) Pyramid or cone:
V = (1/3)a x area of base

(14) Sphere:

$V = (4/3)\pi r^3 = \frac{\pi D^3}{6}$

$A = 4\pi r^2$



(15) *Prismoidal section.* V = one-sixth the length times (sum of the end areas plus 4 times the midsection area)

Table 16–13 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

16–11. TROOP MOVEMENT FACTORS

a. *Rates of March* See table 16–14.

b *March Formulas.* See table 16–15.

16–12. INFANTRY WEAPONS

See table 16–16.

Table 16–14 Rates of Marches

Unit	Average Rates of March (KMPH)[2]				Days March Kilo meters
	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 (black-out)	12	8	280
Tracked vehicles	24	24 (lights) 16 (black-out)	16	8	240
Truck-drawn artillery	40	40 (lights) 16 (black-out)	12	8	280
Tractor- drawn artillery	32	32 (lights) 16 (black-out)	16	8	240

[1]This table is for general planning and comparison purposes. All rates given are variable in accordance with the movement conditions as determined by reconnaissance.

[2]These rates include normal periodic rest halts.

Table 16–15. March Formulas and Factors

METRIC CONVERSION FACTORS
SEE TABLE 16—19

FOR TIME OISTANCE (TO). TO (HOURS) = $\frac{\text{O (KILOMETERS)}}{\text{R (KILOMETERS PER HOUR)}}$

FOR TIME LENGTH (TL) (FOOT COLUMN). TL (MIN) = RS (ROAO SPACE) X FACTOR

RATE (KMPH)	FACTOR
4.0	.0150
3.2	.0187
2.4	.0250
1.6	.0375

FOR ROAO SPACE (RS) OF FOOT TROOPS: RS (METERS) = (NO. OF MEN X FACTOR) + OISTANCES BETWEEN UNITS

FORMATION	2M/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). TL (MINUTES) = (NO. OF VEHICLES X FACTOR) + TI'S (TIME INTERVALS BETWEEN UNITS)

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). TL (MINUTES) = (NO OF VEH:CLES X 12) + TI'S

FOR COMPLETION TIME (CT): CT = IP TIME + TL + TO + SCHEOULEO HALTS

EXAMPLE:	HR	MIN	
	07	45	IP TIME (CLOCK TIME)
	01	12	TL OF COLUMN (1 HR /% 12 MIN)
	05	55	TO (IP TO RP, 5 HRS 55 MIN)
	01	00	MEAL HALT (ONE HOUR)
CT =	14	112	OR 1552 HOURS

FOR ROAD SPACE (RS) OF VEHICLES.

RS (KILOMETERS = $\frac{\text{TL (MIN) X R (KILOMETERS PER HOUR)}}{\text{60 (MINUTES/HOUR)}}$

Table 16--16. Characteristics of Infantry Weapons and Ammunition

WEAPON	UNLDAOED WEIGHT LBS	TYPE OF FEEO	METHOO OF OPERATION	CYCLIC (C)/ OR MAX (M) RATE OF FIRF	MAX/MAX EFFECTIVE RANGE (METERS)	AMMUNITION PACK	AMMUNITION WEIGHT (LBS) (PACKEO)	BASIC LDAD OF AMMO PER MAN'/ WPN	REMARKS
PISTOL M1911A1 CAL.45	2 1/2 LBS	7 RO MAG	RECDIL SEMI-AUTO	35—42(M)	1500/50	50 RDS/BDX 20 BOX/CAN 2 CAN/CASE	113	21	
RIFLE M 14 M 14 A1 7.62 MM	9.84 12.12	20 RO MAG	GAS SEMI-AUTO & AUTO	700—750(C)	3725/460 3725/700(SA) /460(A)	5 RO CLIPS 12 CLIPS/BANO 7 BANO/CAN 2 CANS/CASE	69	160 160/760	SELECTOR MUST BE INSTALLEO BYPOO AVAILABLE WHEN USEO AS AUTOMATIC RIFLE.
RIFLE M16 A1 5.56 MM	6 1/2	30 RO MAG	GAS SEMI-AUTO & AUTO	700—800	2653—460	10 RO CLIPS 14 CLIPS/BANO 6 BANO/CAN 2 CANS/BOX	85	210	MAY BE ISSUED WITH A BYPOD WHEN USEO AS AR
MACHINE GUN, M60 7.62 MM	23	BELT-METALIC SPLIT LINK	GAS AUTO	550(C)	3725/1100	220/BELT 1 BELT/CAN 4 CANS/BOX	75	2,200	EFFECTIVE RANGE BASEO ON GUNNERS ABILITY
MACHINE GUN, HB, M2, CAL	MG-84 MT-44	BELT-METALIC SPLIT LINK	RECOIL SEMI-AUTO & AUTO	450—500	6800/725AA* /1830GNO	105/BELT 1 BELT/CAN 2 CANS/CASE		2,100/ WPN	*USEO IN ANTI-AIRCRAFT OR GROUNO ROLE
SHOTGUN RIOT TYPE 12 GAGE PUMP	7 1/2	5 RO TUBE	MANUAL (PUMP)	5	OEPENOS ON TYPE OF SHOT	12/CARTON 20 CARTON/ CASE	45	10	
GRENAOE LAUNCHER M79/M203 40 MM	6/3	SINGLE SHOT	PERCUSSION	2—4	400/150-PT TGT /350-AREA TGTS	12/BANO 12 BAND/BOX	9/BANDO— LEER	30	MINIMUM SAFE RANGE; COMBAT, 31M TRNG: 80 M ARM OISTANCE 14—28 M EFFECTIVE BURST RAOIUS 5M

Table 16 – 16. Characteristics of Infantry Weapons and Ammunition (Con't)

WEAPON	UNLOADED WEIGHT LBS	TYPE OF FEED	METHOD of OPERATION	CYCLIC (C)/OR MAX(M) RATE OF FIRE	MAX/MAX EFFECTIVE RANGE (METERS)	AMMUNITION PACK	AMMUNITION WEIGHT (LBS) (PACKED)	BASIC LOAD OF AMMO PER MAN/WPN	REMARKS
HAND GRENADE FRAG-- M 67 M 68 WP M 34	 1 1 1 1/2		ELECTRICAL IMPACT FUZE 4—5 SEC DELAY		APPROX 25 M DEPENDENT ON THROWING DISTANCE OF INDIVIDUAL	1 /CTN 30 CTNS/BOX	2/GRENADE	4	BURSTING RADIUS 15 M 15 M 25M (60SEC BURN TIME)
MINE ANTI-PERS M18 A1 CLAYMORE	2.5		CONTROLLED ELECTRIC OR TRIPWIRE DETONATION	ONE SHOT	250/50	1/KIT (COMPLETE) 6 KITS/CTN	6.8	10/NON-DIV ENGR BN 2/ TRACK VEH (MECH DIV ENGR BN) 15/ DIV ENGR BN	WHEN EMPLOYED WITH TRIPWIRE MUST BE TREATED AS A MINE AND ITS LOCATION RECORDED & REPORTED DIRECTIONAL FRAG—60° SECTOR WITH 50 METER RADIUS 16M LETHAL ZONE (BACK & SIDES) AND 100 M BACK BLAST DANGER ZONE
ROCKET, HEAT M72 A1 (LAW) 66 MM	4.7*	SINGLE SHOT THROW AWAY	MANUAL	1 SHOT	1000/200	6/ CTN 3 CTNS/BOX	27 1/2 120	BY TOE	BACK BLAST AREA: 15 M DANGER ZONE, 25 M CAUTION ZONE FRONT SITE GRADUATED TO 325 M. M72 ISSUED AS AMMUNITION *WEIGHT IS LOAD-
ROCKET LAUNCHER M202 & M202 A1 4 TUBE 66 MM (FLAME)	11.5	4 RD CLIP	RECOILESS SEMI-AUTO	1 CLIP	200 PT TGTS 750/ AREA TGTS 20 MINIMUM	4 RDS/CLIP 4 CLIPS/BOX	15.1 EA 122		M74 ROCKET IS A FLAME ENCAPSULATED RD 5.5—12 M ARMING RANGE. BURSTING RADIUS 20 M BACK BLAST ZONE 40 M

Table 16–16. Characteristics of Infantry Weapons and Ammunition (Con't)

WEAPON	UNLOADED WEIGHTS LBS	TYPE OF FEED	METHOD OF OPERATION	CYCLIC (C)/OR MAX (M) RATE OF FIRE	MAX/MAX EFFECTIVE RANGE (METERS)	AMMUNITION PACK	AMMUNITION WEIGHT (LBS) (PACKED)	BASIC LOAD OF AMMO PER MAN/WPN	REMARKS
PORTABLE FLAME THROWER ABC, M 9—7	25	FUEL PROPELLED BY GAS UNDER PRESSURE	MANUAL	5—8 SECONDS CONTINUOUS	40—50	4 GALS OF THICKENED FUEL	25	IGNITION CYL—8, PEPTIZER-1 GAL, THICKENER-10 LBS	
SELF PROPELLED FLAME THROWER M132 A—1	21,000*	FUEL PROPELLED BY GAS UNDER PRESSURE	ELECTRICAL	32 SECONDS FOR CONTINUOUS DISCHARGE	150—170	200 GALS OF THICKENED FUEL	1260		*INCLUDES WEIGHT OF M113 PERSONNEL CARRIER
MORTAR M 29, WITH MOUNT M 23 A2 81MM	BARREL 28 BIPOD 40 SIGHT 4 BASE 26	MUZZLE LOADING BY HAND	DROP FIRE	12 (M) FOR 2 MIN	4512/4512	1/PER CARTON 4/CTNS/BOX	20 EA	120	EFFECTIVE BURSTING AREA: 25 X 20 M
MORTAR M 30, WITH MOUNT-M24A 1 4—2 IN.	BARREL-157 BRIDGE-170 BASE-193 STANDARD-60 ROTATOR-90	MUZZLE LOADING BY HAND	DROP FIRE	18 (M) FOR 1 MIN & 8/MIN FOR 5 MIN	920 MIN—IMUM 5650/5650 MAX	1 RD/ PER CTN HE ILLUM SMOKE GAS	 27 26 28 24	160	 40 x 20 40—90 SECONDS WP H, HD, & HT

16–13. REQUESTING AND ADJUSTING FIELD ARTILLERY FIRE

a. For details refer to TC 6–135.
b. The call for fire:

Element	Example
Identification of Observer	"DELTA SIX FOXTROT ONE EIGHT, THIS IS ALPHA FIVE CHARLIE TWO FOUR"
Warning Order Direction *1 (in mils)	FIRE MISSION "DIRECTION 4760" (Between 0–6400)
Location (Grid Coordinate or Shift from Known Point *2)	"GRID NV 64353797" or "FROM HILL 479, RIGHT 110, ADD 400"
Description of Target	"15 MAN PATROL IN OPEN"
Method of Engagement	
(1) Type of Adjustment	Area Fire
(2) Trajectory	High Angle
(3) Ammunition	
(a) Type of Projectile	HE
(b) Type of Fuze	VT IN Effect
(4) Distribution of Fire	Converge
(5) Methods of Fire	Adjust Fire

NOTE. 1. In the Field Artillery, azimuth is stated as direction and is given in degrees or in mils (1 mil = 1/6400 of a circle). Direction can be taken from a map or compass. The following are examples of reporting the direction to the target:

1. Grid azimuth from observer to target—Direction 4310.
2. Magnetic azimuth from observer to target—Magnetic Direction 2450.

NOTE: 2. In order to locate a target by a shift from a known point, fire direction center personnel must have the location of the known point plotted on their charts or must be able to identify the known point on their maps. Prominent terrain features, registration points, and previously fired targets are commonly used as known points.

NOTE: 3. Desired accuracy

azimuth - nearest 10 mils
grid -- 8 digit coordinate
distance -- nearest 100 meters

c. Mil Relation for Computing Deviation Corrections. (See figure 16-14)

W = R x m

W = Distance in maters from burst/known point to target

R = Range to target in thousands of metars

m = Anguler deviation in mils

W = 3.3 x 20

W = 66 meters - round up to 70

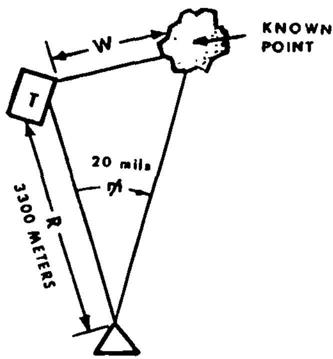


Figure 16—14. Mil relation for computing deviation corrections

d After initial call for fire to the fire direction center (FDC), subsequent corrections are requested as shown in figure 16–15.

ROUND NO. 1: **Left 70, drop 400**

ROUND NO. 2: **Add 200**

ROUND NO. 3: **Drop 100**

ROUND NO. 4: **Add 50, Fire for effect**

RULES:

- **(1) Keep rounds on observer-target line.**
- **(2) Bracket target during adjustment.**
- **(3) Confirm for effect during adjustment when:**
  - **(a) Split a 100 meter bracket**
  - **(b) Obtain a target hit**
  - **(c) Obtain a correct range spotting**

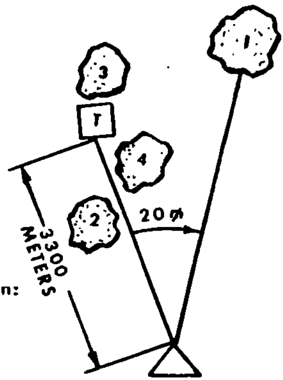
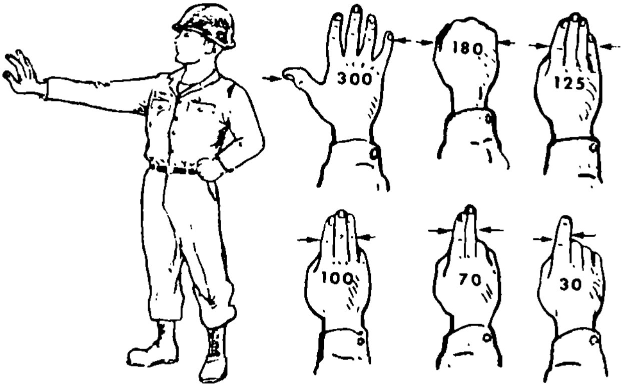


Figure 16–15. Observer procedures for adjusting field artillery fires.

e. Angle between target and burst is read in mils, and then distance is determined by multiplying mils by range and then dividing by 1000.

$$\text{Example: } \frac{20 \text{ mils} \times 3300 \text{ meters}}{1000} = 66 \text{ meters}$$

See figure 16–16 for hasty method for estimating angle in mils:



NOTE: ARM MUST BE FULLY EXTENDED.

Figure 16–16. Hasty method for estimating angle in mils.

f. Field Artillery Weapons

Type	Range
105 mm	11,500 meters
155 mm	14,600 meters
155 mm SP	18,100 meters
175 mm	32,700 meters
8 inch	16,800 meters

g. Field Artillery Ammunition.

HE — high explosive
WP — white phosphorous
SMK — smoke, all colors
HEAT/HEPT — antitank
APERS — beehive
GAS — persistant and nonpersistant
Illumination

h. Fuzes.

Type Fuze	Usage
Impact	Personnel/material
Quick	Pill boxes, bunkers, and dugouts.
Concrete Piercing	
Delay	
Time (airburst)	Personnel in open or in entrenchments
Mechanical	
Variable (VT)*	

*Preferred

16–14. MAP READING

A map is a graphic representation of a portion of the earth's surface drawn to scale on a plane.

a. Types of Maps.

(1) *Planimetric Map.* Presentation of only the horizontal positions for the detail plotted, with the omission of relief in a measurable form.

(2) *Topographic Map* A map which portrays relief in a measurable form, as well as the horizontal positions of the details plotted.

(3) *Plastic Relief Map.* A topographic map preprinted on plastic materials in a three dimensional form so that the user can readily see variation in elevation.

(4) *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. Usually supplement other maps of an area.

(5) *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 (usually published at 1:25,000 scale and larger).

b Map Scales.

(1) *Small Scale Maps.* 1:600,000 through 1:5,000,000 for strategical studies at high command echelons.

(2) *Medium Scale Maps.* 1:75,000 to 1:600,000 used for planning operations including road movements.

(3) *Large Scale Maps.* 1:1,000 to 1:75,000 used to meet the tactical, technical, and administrative needs of field units.

c. Map Colors.

(1) *Black.* Man-made features, marginal data, and grid.

(2) *Brown.* Terrain features and contour lines depicting elevations.

(3) *Green* Vegetation features.

(4) *Blue* Water features.

(5) *Red.* Main roads and built-up areas.

d Map Marginal Data Marginal data, in the form of diagrams, pictures, scales and text, are printed on the sheet outside the margin of the map. Provides the user with everything needed to fulfill his map reading requirements. Data of critical importance to the Combat Engineer are:

(1) *Grid Reference Box (usually located in the lower center margin).* Contains information for composing grid reference and provides a step by step example, using a sample point on the map. Includes Grid Zone Designation (Critical if area of operations includes more than one Grid Zone.)

(2) *Bar Scales (usually located in the lower center margin)* Graphical distance scales for determining ground distance.

(3) *Contour Interval (usually located in center lower margin below the Bar Scales).* Identifies the vertical distance between contour lines.

(4) *Legend (usually located in the lower left margin)* Illustrates and identifies topographic symbols used on the map.

(5) *Declination Diagram (usually located in the lower right margin)* Graphically illustrates the relationships between Grid North (symbolized by the letters GN), True North (symbolized by a star), and Magnetic North (symbolized by a half arrowhead). Typical Declination diagrams are shown in Fig. 16- 17. Of particular interest to the military user is the relationship of Grid North to Magnetic North, since this defines the relation of Azimuth directions on the map (grid) to an Azimuth obtained with a compass (magnetic). This relationship (the G-M angle), is expressed in degrees and minutes and accompanies the Declination Diagram. Most maps also contain a note for converting from Grid to Magnetic Azimuth and from Magnetic to Grid Azimuth as shown in Figure 16- 17. When the note is not given, conversion must be determined based on the Declination diagram.

NOTE: Declination Diagrams and G-M Angles vary from map to map. Users should exercise extreme care to insure that the proper conversions from Grid to Magnetic Azimuth or Magnetic to Grid Azimuth are used.

e. Map Orientation Before any map can be used it must be oriented with the ground; that is, when the map is horizontal, its north and south corresponds to north and south on the ground. Two principal methods of map orientation are:

(1) *Compass*

(a) Place the compass so that the index line on the dial parallels Grid North.

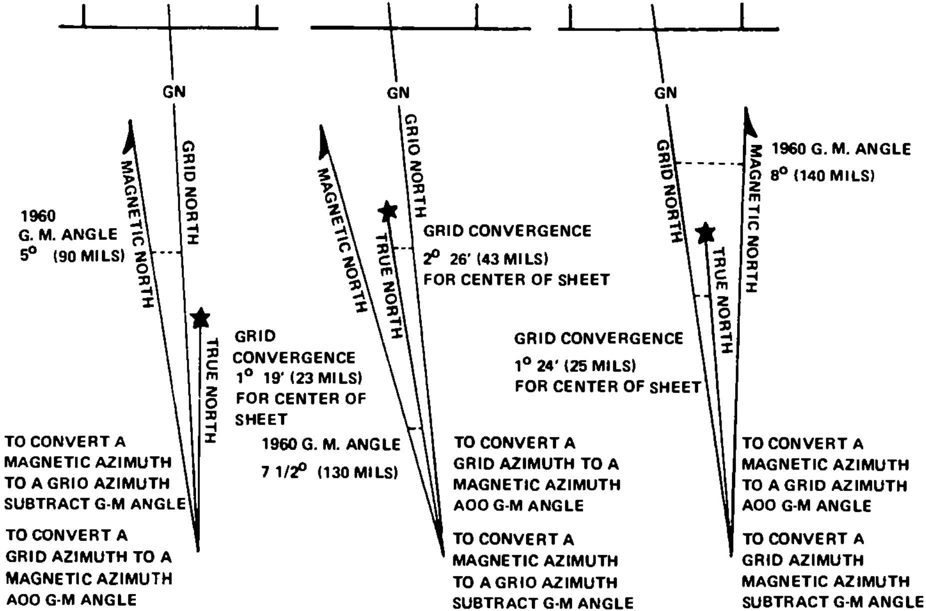


Figure 16–17. Declination diagrams.

(b) Rotate the map and compass until the directions of the black index line and the compass needle match the directions on the declination diagram.

(2) *Terrain Association.*

(a) Carefully examine both the map and the ground to find the linear features (roads, railroads, fences, power lines, etc.) or prominent objects which can be located on both.

(b) Align the feature on the map with the feature on the ground.

NOTE. Map Orientation by terrain association results in gross orientation which will usually be sufficiently accurate for land navigation but may not be sufficient for targeting. The use of more than one linear feature or prominent object for orientation will not only preclude reversal of direction but also refine the map-ground orientation.

f. Scale and Distance (Representative Fraction).

(1) 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: 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.

(2) 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 pints = 5 units (i.e. 5 in.).

b. The RF of the map is 1:50,000, therefore,

c. 5 x 50,000 = 250,000 units of ground distance (250,000 inches)

(3) Further data on finding unknown RF's, ground or map distances, is explained in FM 21–26 and table 16--17.

g. Contours. A contour line is a line representing an imaginary line on the ground along which all points are of the same elevation.

(1) Contour lines evenly spaced and wide apart indicate a uniform gentle slope.

(2) Contour lines evenly spaced and close together indicate a uniform steep slope. The closer the contour lines to each other the steeper the slope.

Table 16–17. 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	2,281	6.562	8,202	16,404	32,808
	YARDS	273	547	820	1,094	2.187	7,734	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

h 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.

(1) 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.

(2) 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 the slope angle. The slope angle can then be found in table 16–12. The approximate slope angle may be calculated by multiplying the value of $\frac{VD}{HD}$ by 57.3. This method should only be used for slope angles under 20°.

i. Aerial Photography As Supplements/Substitutes

(1) *General* Current aerial photography supplements printed maps by showing changes since the map was compiled. Vertical aerial photography (camera aimed straight down) is most often used for this purpose since scale, grid, and orientation are most easily correlated to a map (and therefore the ground). Only an approximate scale of most photographs can be determined, however, for most military applications, this approximate scale is sufficient. Methods of determining scale are:

(a) Photo-ground comparison method

$$\text{Scale (RF)} = \frac{\text{Photo Distance}}{\text{Ground Distance}}$$

(b) Photo-map comparison method.

$$\text{Scale (RF)} = \frac{\text{Photo Distance}}{\text{Map Distance}} \times \text{Map Scale (RF)}$$

(c) Focal length method

$$\text{Scale (RF)} = \frac{\text{F (Focal Length)}}{\text{H(Flight Altitude)} - \text{h(average ground elevation)}}$$

(2) *Point designation grid.* Grids are rarely printed on aerial photography. It is a user responsibility to construct a *world-wide standard* Point Designation Grid on each photo in the following manner (see fig. 16--18).

(a) Hold the photograph so that marginal information, regardless of where it is located, is in the normal reading position, draw straight lines across the photograph joining opposite reference marks (Fiducial marks).

(b) Space grid lines, starting at the center lines, 4 cm. apart, (a distance equal to 1,000 meters at a scale of 1:25,000).

(c) Number each centerline "50" and give numerical values to the remaining horizontal and vertical lines so that they increase to the right and up.

(3) *Photo grid coordinates* The Point Designated Grid (PDG) is used in the same manner as a map -READ RIGHT-UP. A Grid Coordinate using the Point Designation Grid consists of:

(a) The Letters "PDG".

(b) This mission and photo number (from the photo margin).

(c) The appropriate number of digits (READ RIGHT-UP) to locate the point on the photograph.

j Orientation (see para 16–14e). Photographs are normally oriented by construction of a Magnetic North arrow on the photo so that the photo can be quickly oriented with the ground using a compass.

(1) *Photo-ground.* Orientation with the ground can be accomplished by compass or terrain association methods as in paragraph 16–14e. Magnetic North is then constructed by aligning the compass with 0° or 360° and drawing a line along the graduated straight edge.

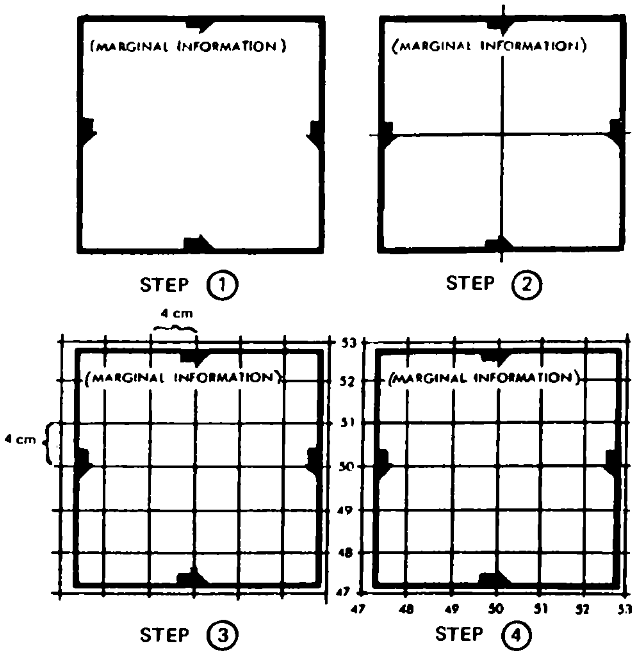


Figure 16–18. Construction of point designation grid.

(2) *Photo-map.*

(a) Carefully examine the photograph and the map to find two features (road junctions, bridges, water towers, etc.) which can be located on both the photo and the map.

(b) Connect the two features on both map and photograph with straight lines.

(c) Using the declination diagram, measure the grid azimuth of the line drawn *on the map* and determine the corresponding magnetic azimuth.

(d) Transfer this magnetic azimuth to the straight line *on the photo.*

(e) Based on this magnetic azimuth construct Magnetic North on the photo.

16–15. PROJECT MANAGEMENT

a. General. The following technique gives supervisors the ability to plan, schedule and control any engineer project and will point out which areas should be carefully controlled. Detailed references are found in TM 5–333.

b. Preliminary Planning.

(1) Receive job directive.

(2) Study directive and accompanying plans and specifications.

(3) Conduct site investigation to determine how the actual site conditions will affect the job. Typical factors are:

(a) Terrain
(b) Drainage
(c) Accessibility
(d) Soil Conditions
(e) Existing Facilities
(f) Natural Resources
(g) Weather
(h) Enemy

c. Task List.

(1) Break the assigned job into the separate operations or tasks necessary to successfully complete the job. The number and detail of these tasks will vary from job to job.

(2) Each separate task must be a time consuming part of a job which has a definable beginning and end.

(3) The tasks involved in building a timber trestle bridge could be as follows:

Task

A. Recon site
B. Secure and prepare site
C. Precut caps, sills, and scabs
D. Precut stringers, decking, and lateral braces
E. Place abutments
F. Bridge layout
G. Construct first trestle bent
H. Continue trestle bent const.
I. Place stringers first span
J. Continue placing stringers
K. Deck first span
L. Continue decking
M. Place curb and riser
N. Place treadway

d. Logic From the task list determine the essential relationships between the tasks. To accomplish this the following questions should be asked for each task:

(1) Is this task necessary to begin the project?
(2) What tasks must be finished before this one begins?
(3) What tasks may either start or finish at the same time as this one?
(4) What tasks cannot begin until this is finished?
(5) Does this tasks denote project completion?

e. Estimating (Detailed references in TM 5–302 and TM 5–333)

(1) Once the tasks are determined, each task requires an estimate of materials and equipment/manpower needs. Adjust data to reflect appropriate waste and efficiency factors.

(2) Man-hours, man-days, machine-hours or machine days are divided by the men or equipment in your crew to obtain the duration of the task.

16–16. CONVERSION FACTORS

See table 16–18.

Table 16–18. Conversion Factors

Multiply	by	to obtain
Acres	43,560	square feet.
acres	4,047	square meters.
acres	$1{,}562 \times 10^{-3}$	square miles.
acres	5645.38	square varas.
acres	4,840	square yards.
acre–feet	43,560	cubic--feet.
acres	100	square meters.
atmospheres	76.0	cms. of mercury.
atmospheres	29.92	inches of mercury.
atmospheres	33.90	feet of water.
atmospheres	14.70	pounds per sq. inch.
Board–feet	144 sq. in. x 1 in.	cubic inches.
British thermal units	0.2520	kilogram–calories.
British thermal units	777.5	foot–pounds.
British thermal units	2.928×10^{-4}	kilowatt- hours.
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.
bushels	1.244	cubic feet.
Centares	1	square meters.
centigrams	0.01	grams.
centiliters	0.01	liters.
centimeters	0.3937	inches.
centimeters	0.01	meters.
centimeters	393.7	mils.
centimeters	10	millimeters.
centimeters--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 mater.
centimeters of mercury	27.85	pounds per sq. foot.

Table 16–18. Conversion Factors (Con't)

Multiply	by	to obatin
centimeters of mercury	0.1934	pounds per sq. inch.
centimeters per second	0.6	meters per minute.
circular mils	0.7854	square mils.
cord–feet	4 ft. x 4 ft. x 1 ft.	cubic feet.
cords	8 ft. x 4 ft. x 4 ft.	cubic feet.
cubic centimeters	6.102×10^{-2}	cubic inches
cubic centimeters	10^{-6}	cubic meters.
cubic centimeters	2.642×10^{-4}	gallons.
cubic centimeters	10^{-3}	liters.
cubic feet	2.832×10^{4}	cubic cms.
cubic feet	1,728	cubic inches.
cubic feet	0.02832	cubic meters.
cubic feet	0.03704	cubic yards.
cubic feet	7.481	gallons.
cubic feet	28.32	liters.
cubic feet 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	0.01732	quarts (liq.).
cubic meters	10^{6}	cubic centimeters.
cubic meters	35.31	cubic feet.
cubic meters	1.308	cubic yards.
cubic meters	264.2	gallons.
cubic yards	27	cubic feet.
cubic yards	0.7646	cubic meters.
cubic yards	202.0	gallons.
cubic yards per minute	0.45	cubic feet per second.
cubic yards per minute	3.367	gallons per second.

Table 16–18. Conversion Factors (Con't)

Multiply	by	to obtain
Decigrams	0.1	grams.
deciliters	0.1	liters.
decimeters	0.1	meters.
degrees (angle)	60	minutes.
degrees (angle)	0.01745	radians.
degrees (angle)	3600	seconds.
dekagrams	10	grams.
dekaliters	10	liters.
dekameters	10	meters.
drams	1.772	grams.
drams	0.0625	ounces.
Ergs	9.486×10^{-11}	British thermal units.
Fathoms	6	feet.
feet	0.3048	meters.
feet	.36	varas.
feet	1/3	yards.
feet of water	0.4335	pounds per sq. inch.
feet per minute	0.5080	centimeters per sec.
feet per minute	0.01667	feet per second.
feet per minute	0.01136	miles per hour.
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 100 feet	1	per cent grade.
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	3.241×10^{-4}	kilogram–calories.
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	3.030×10^{-5}	horse power.

Table 16–18. Conversion Factors (Con't)

Multiply	by	to obtain
foot–pounds per minute	3.241×10^{-4}	kg–calories per min.
foot–pounds per minute	2.260×10^{-5}	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 per minute	2.228×10^{-3}	cubic feet per second.
gills	0.1183	liters.
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	2.205×10^{-3}	pounds.
gram-calories	3.968×10^{-3}	British thermal units.
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.
Hectares	2.471	acres.
hectares	1.076×10^{5}	square feet.
hectograms	100	grams.
hectoliters	100	liters.
hectometers	100	meters.
hectowatts	100	watts.

Table 16–18. Conversion Factors (Con't)

Multiply	by	to obtain
horse– power	42.44	B.t. units per min.
horse–power	33,000	foot--pounds per min.
horse–power	550	foot--pounds per sec.
horse–power	1.014	horse–power (metric).
horse–power	10.70	kg.–calories per min.
horse–power	0.7457	kilowatts.
horse–power	745.7	watts.
inches	2.540	centimeters.
inches	10^3	mils.
inches	.03	varas.
inches	0.03342	atmospheres.
inches of mercury	1.133	feet of water.
inches of mercury	70.73	pounds per square ft.
inches of water	0.002458	atmospheres.
inches of water	0.07355	inches of mercury.
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	2.2046	pounds.
kilograms	1.102×10^{-3}	tons (short).
kilogram–calories	3.968	British thermal units.
kilogram–calories	3088	foot–pounds.
kilogram–calories	1.588×10^{-3}	horse–power–hours.

Table 16–18. Conversion Factors (Con't)

Multiply	by	to obtain
kilogram—calories	1.162×10^{-3}	kilowatt—hours.
kg.—calories per min	0.06972	kilowatts.
kilogram—meters	9.302×10^{-3}	British thermal units.
kilogram—meters	9.807×10^{7}	ergs.
kgs. per cubic meter	10^{-3}	grams per cubic cm.
kgs. per cubic meter	0.06243	pounds per cubic foot.
kgs. per square meter	9.678×10^{-5}	atmospheres.
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.
kiloliters	10^{3}	liters.
kilometers	10^{5}	centimeters.
kilometers	3281	feet.
kilometers	10^{3}	meters.
kilometers	0.6214	miles.
kilometers per hour	0.5396	knots per hour.
kilowatts	56.92	B.t. units per min.
kilowatts	4.425×10^{4}	foot—pounds per min.
kilowatts	1.341	horse-power.
kilowatts-hour	3415	British thermal units.
kilowatts—hours	2.655×10^{6}	foot—pounds.
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	0.2642	gallons.
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.

Table 16–18 Conversion Factors (Con't)

Multiply	by	to obtain
Meters	100	centimeters.
meters	3.2808	feet.
meters	39.37	inches.
meters	10^{-3}	kilometers.
meters	10^{3}	millimeters.
meters	1.0936	yards.
microns	10^{-6}	meters.
miles	5280	feet.
miles	1.6093	kilometers.
miles	1760	yards.
miles per hour	1.467	feet per second.
miles per hour	1.6093	kilometers per hour.
miles per hour	0.8684	knots 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.
minutes (angle)	2.909×10^{-4}	radians.
minutes (angle)	60	seconds (angle).
myriagrams	10	kilograms.
myriameters	10	kilometers.
myriawatts	10	kilowatts.
nautical miles	1.152	miles.
nautical miles	2027	yards.
Ounces	8	drams.
ounces	437.5	grains.
ounces	28.35	grams.
ounces	0.0625	pounds.

Table 16–18. Conversion Factors (Con't)

Multiply	by	to obtain
ounces (fluid)	1.805	cubic inches.
ounces (troy)	480	grains (troy).
ounces (troy)	31.10	grams.
ounces (troy)	20	pennyweights (troy)
ounces (troy)	0.08333	pounds (troy).
Perches (masonry)	24.75	cubic feet.
pints (dry)	33.60	cubic inches.
pints (liq.)	28.87	cubic inches.
pounds	444,823	dynes.
pounds	453.6	grams.
pounds	16	ounces.
pounds	32.17	poundals.
pound–feet	1.356×10^7	centimeter–dynes.
pound–feet	13,825	centimeter–grams.
pound–feet	0.1383	meter–kilograms.
pounds of water	0.01602	cubic feet.
pounds of water	27.68	cubic inches.
pounds of water	0.1198	gallons.
pounds per cubic foot	16.02	kgs. per cubic meter.
pounds per cubic inch	27.68	grams per cubic cm.
pounds per foot	1.488	kgs. per meter.
pounds per square foot	0.01602	feet of water.
pounds per square foot	4.882	kgs. per square meter.
pounds per square inch	0.06804	atmospheres.
pounds per square inch	2.307	feet of water.
pounds per square inch	2.036	inches of mercury.
pounds per square inch	703.1	kgs. per square meter.
pounds per square inch	144	pounds per sq. foot.
Quadrants (angle)	90	degrees.
quadrants (angle)	5400	minutes.
quadrants (angle)	1.571	radians.
quarts (dry)	67.20	cubic inches.
ouarts (liq.)	57.75	cubic inches.

Table 16-18 Conversion Factors (Con't)

Multiply	by	to obtain
Radians	57.30	degrees.
radians	3438	minutes.
radians	0637	quadrants.
reams	500	sheets.
revolutions	360	degrees.
revolutions	4	quadrants.
revolutions	6.283	radians.
revolutions per minute	6	degrees per second.
revolutions per minute	0.1047	radians per second.
revolutions per minute	0.01667	revolutions per sec.
revs. per min. per min	1.745×10^{-3}	rads. per sec. per sec.
revs. per min. per min	0.01667	revs. per min. per sec.
revs. per min. per min	2.778×10^{-4}	revs. per sec. per sec.
revolutions per second	360	degrees per second.
revolutions per second	6.283	radians per second.
rods	16.5	feet.
Seconds (angle)	4.848×10^{-6}	radians.
square centimeters	0.1550	square inches.
square centimeters	100	square millimeters.
square feet	2.296×10^{-5}	acres.
square feet	0.09290	square meters.
square feet	3.587×10^{-8}	square miles.
square feet	.1296	square yaras.
square feet	1/9	square yards.
square inches	6.452	square centimeters.
square inches	6.944×10^{-3}	square feet.
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.

Table 16–18 Conversion Factors (Con't)

Multiply	by	to obtain
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 yards	2.066×10^{-4}	acres.
square yards	9	square feet.
square yards	0.8361	square meters.
square yards	3.228×10^{-7}	square miles.
square yards	1.1664	square varas.
steradians	0.1592	hemispheres.
steres	10^{3}	liters.
Temp. (degs. C.) + 273	1	abs. temp. (degs. C.).
temp. (degs. C.) + 17.8	1.8	temp. (degs. Fahr.).
temp. (degs. F.) + 460	1	abs. temp. (degs. F.).
temp. (degs F.)−32	5/9	temp. (degs. Cent.).
tons (long)	1016	kilograms.
tons (long)	2240	pounds.
tons (metric)	10^{3}	kilograms.
tons (metric)	2205	pounds.
tons (short)	907.2	kilograms.
tons (short)	2000	pounds.
tons (short) per sq. ft	9765	kgs. per square meter.
tons (short) per sq. ft	13.89	pounds per sq. inch.
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.

Table 16–18. Conversion Factors (Con't)

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	1.341×10^{-3}	horse–power.
watts	10^2	kilowatts.
watt–hours	3.415	British thermal units.
weeks	168	hours.
Yards	91.44	centimeters.
yards	3	feet.
yards	36	inches.
yards	0.9144	meters.

NOTE See FM 5–35 for additional conversion factors.

16–17. CONVERSION – ENGLISH UNITS TO METRIC UNITS

See table 16–19.

16–18. TIME DISTANCE CONVERSION

See table 16–20.

Table 16–19 Conversion – English Metric System

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
20	12.43	32.19	21.87	18.29	65.62	6.10	7.87	50.80
30	18.64	48.28	32.81	27.43	98.42	9.14	11.81	76.20
40	24.85	64.37	43.74	36.58	131.23	12.19	15.75	101.60
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
80	49.71	128 75	87.49	73.15	262.47	24.38	31.50	203.20
90	55.92	144.84	98.42	82.30	295.28	27.43	35.43	228.60
100	62.14	160.94	109.36	91.44	328.08	30.48	39.37	254.00

Example: 2 inches = 5.08 cm

Table 16–19 Conversion–English Metric System (Con't)

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 16–19. Conversion–English Metric Systems (Con't)

WEIGHT

	short ton → metric ton / metric ton → short ton		kg → pounds	pounds → kilograms	grams → ounces	ounces → grams
	short ton	metric ton	pounds	kilograms	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	58.7
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
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: 28 pounds = 9.07 kg + 3.63 kg = 12.70 kg

Table 16–19 Conversion–English Metric Systems (Con't)

VOLUME

cu. ft →	cu. yd → cu. meters		cu. yd → cu. ft → cu. meters		cu. meters → cu. ft → cu. yd	
	cu. yd	cu. meters	cu. ft	cu. meters	cu. ft	cu. yd
1	0.037	0.028	27.0	0.76	35.3	1.31
2	0.074	0.057	54.0	1.53	70.6	2.62
3	0.111	0.085	81.0	2.29	105.9	3.92
4	0.148	0.113	108.0	3.06	141.3	5.23
5	0.185	0.142	135.0	3.82	176.6	6.54
6	0.212	0.170	162.0	4.59	211.9	7.85
7	0.259	0.198	189.0	5.35	247.2	9.16
8	0.296	0.227	216.0	6.12	282.5	10.46
9	0.333	0.255	243.0	6.88	317.8	11.77
10	0.370	0.283	270.0	7.65	353.1	13.07
20	0.741	0.566	540.0	15.29	706.3	26.16
30	1.111	0.850	810.0	22.94	1059.4	39.24
40	1.481	1.133	1080.0	30.58	1412.6	52.32
50	1.852	1.416	1350.0	38.23	1765.7	65.40
60	2.222	1.700	1620.0	45.87	2118.9	78.48
70	2.592	1.982	1890.0	53.52	2472.0	91.56
80	2.962	2.265	2160.0	61.16	2825.2	104.63
90	3.333	2.548	2430.0	68.81	3178.3	117.71
100	3.703	2.832	2700.0	76.46	3531.4	130.79

Example: 3 cu. yd = 81.0 cu ft

Table 16–20. 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
15	13.03	22.00	24.14	6.71
20	17.37	29.33	32.19	8.94
25	21.71	36.67	40.23	11.18
30	26.05	44.00	48.28	13.41
35	30.39	51.33	56.33	15.64
40	34.74	58.67	64.37	17.88
45	39.08	66.00	72.42	20.12
50	43.42	73.33	80.47	22.35
55	47.76	80.67	88.51	24.59
60	52.10	88.00	96.56	26.82
65	56.45	95.33	104.61	29.06
70	60.79	102.67	112.65	31.29
75	65.13	110.00	120.70	33.53
100	86.84	146.67	160.94	44.70

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)
DA Pam 350–19	Training, Signal Security Instructional Packet

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 2–25	Explosives and Demolitions
FM 5–30	Engineer Intelligence
FM 5–31	Boobytraps
FM 5–35	Engineer's Reference and Logistical Data
FM 5–36	Route Reconnaissance and Classification
FM 10–13	Supply and Service Reference Data
FM 20–22	Vehicle Recovery Operations
FM 20–32	Mine/Countermine Operations at the Company Level

FM 20–33	Combat Flame Operations
FM 21–5	Military Training Management
FM 21–6	Techniques of Military Instruction
FM 21–10	Field Hygiene and 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 30–10	Denial Operations and Barriers
FM 31–60	River-Crossing Operations
FM 31–70	Basic Cold Weather Manual
FM 32–5	Signal Security
FM 32–6	Signal Security Techniques
FM 55–15	Transportation Reference Data
FM 101–10–1	Staff Officers' Field Manual

A–4. TECHNICAL MANUALS

TM 3–220	CBR Decontamination
TM 3–366	Flame Fuels
TM 5–200	Camouflage Materials
TM 5–210	Military Floating Bridge Equipment
TM 5–216	Armored Floating Bridge Equipment
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 5–337	Paving and Surfacing Operations
TM 5–342	Logging and Sawmill Operation
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
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24 SEPTEMBER 1976

By Order of the Secretary of the Army:

FRED C. WEYAND
General, United States Army
Chief of Staff

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The Adjutant General

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